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India: Impact of Climate Change to 2030
A Commissioned Research Report

THE NATIONAL INTELLIGENCE COUNCIL SPONSORS WORKSHOPS AND RESEARCH WITH NONGOVERNMENTAL EXPERTS TO GAIN KNOWLEDGE AND INSIGHT AND TO SHARPEN DEBATE ON CRITICAL ISSUES. THE VIEWS EXPRESSED IN THIS REPORT DO NOT REFLECT OFFICIAL US GOVERNMENT POSITIONS.

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India: The Impact of Climate Change to 2030
A Commissioned Research Report

Prepared By
Joint Global Change Research Institute and
Battelle Memorial Institute, Pacific Northwest Division

The National Intelligence Council sponsors workshops and research with nongovernmental experts to gain knowledge and insight and to sharpen debate on critical issues. The views expressed in this report do not reflect official US Government positions.

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Scope Note

Following the publication in 2008 of the National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030, the National Intelligence Council (NIC) embarked on a research effort to explore in greater detail the national security implications of climate change in six countries/regions of the world: India, China, Russia, North Africa, Mexico and the Caribbean, and Southeast Asia and the Pacific Island States. For each country/region we are adopting a three-phase approach.

- In the first phase, contracted research—such as this publication —explores the latest scientific findings on the impact of climate change in the specific region/country.
- In the second phase, a workshop or conference composed of experts from outside the Intelligence Community (IC) will determine if anticipated changes from the effects of climate change will force inter- and intra-state migrations, cause economic hardship, or result in increased social tensions or state instability within the country/region.
- In the final phase, the NIC Long-Range Analysis Unit (LRAU) will lead an IC effort to identify and summarize for the policy community the anticipated impact on US national security.

The Joint Global Change Research Institute (JGCRI) and Battelle, Pacific Northwest Division (Battelle, PNWD), developed this assessment on the climate change impact on India through 2030 under a contract with SCITOR Corporation. The Central Intelligence Agency’s Office of the Chief Scientist, serving as the Executive Agent for the DNI, supported and funded the contract.

This assessment identifies and summarizes the latest peer-reviewed research related to the impact of climate change on India, drawing on both the literature summarized in the latest Intergovernmental Panel on Climate Change (IPCC) assessment reports and on other peer-reviewed research literature and relevant reporting. It includes such impact as sea level rise, water availability, agricultural shifts, ecological disruptions and species extinctions, infrastructure at risk from extreme weather events (severity and frequency), and disease patterns. This paper addresses the extent to which regions within India are vulnerable to climate change impact. The targeted time frame is to 2030, although various studies referenced in this report have diverse time frames. The research does not draw inferences about the potential for internal or interstate conflict arising out of changes, e.g., in water supply or in likely migration from Bangladesh; such analyses will be conducted in the subsequent efforts described above.

This assessment also identifies (Annex B) deficiencies in climate change data that would enhance the IC understanding of potential impact on India and other countries/regions.

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Executive Summary

India is both a major greenhouse gas emitter and one of the most vulnerable countries in the world to projected climate change. The country is already experiencing changes in climate and the impacts of climate change, including water stress, heat waves and drought, severe storms and flooding, and associated negative consequences on health and livelihoods. With a 1.2 billion but growing population and dependence on agriculture, India probably will be severely impacted by continuing climate change. Global climate projections, given inherent uncertainties, indicate several changes in India's future climate:

- ***Global observations of melting glaciers suggest that climate change is well under way in the region, with glaciers receding at an average rate of 10–15 meters per year.*** If the rate increases, flooding is likely in river valleys fed by these glaciers, followed by diminished flows, resulting in water scarcity for drinking and irrigation.
- All models show a trend of general warming in mean annual temperature as well as decreased range of diurnal temperature and enhanced precipitation over the Indian subcontinent. ***A warming of 0.5^{o}C is likely over all India by the year 2030 (approximately equal to the warming over the 20th century) and a warming of 2-4^{o}C by the end of this century, with the maximum increase over northern India.*** Increased warming is likely to lead to higher levels of tropospheric ozone pollution and other air pollution in the major cities.
- ***Increased precipitation—including monsoonal rains—is likely to come in the form of fewer rainy days but more days of extreme rainfall events, with increasing amounts of rain in each event, leading to significant flooding.*** Drizzle-type precipitation that replenishes soil moisture is likely to decrease. Most global models suggest that the Indian summer monsoons will intensify. The timing may also shift, causing a drying during the late summer growing season. Climate models also predict an earlier snowmelt, which could have a significant adverse effect on agricultural production. Growing emissions of aerosols from energy production and other sources may suppress rainfall, leading to drier conditions with more dust and smoke from the burning of drier vegetation, affecting both regional and global hydrological cycles and agricultural production.

Uncertainties about monsoonal changes will affect farmers' choices about which crops to plant and the timing of planting, reducing productivities. In addition, earlier seasonal snowmelt and depleting glaciers will reduce river flow needed for irrigation. ***The large segment of poor people (including smallholder farmers and landless agricultural workers) may be hardest hit, requiring government relief programs on a massive scale. Finally, migration, especially from Bangladesh, may strain resources and India-Bangladesh relations.***

The most important impacts of climate change will likely include the following:

- ***Agriculture.*** High-input, high-output agriculture will be negatively affected even as demands for food and other agricultural products rise because of an increasing population and expectations for an improved standard of living. Millions of subsistence and smallholder farmers will experience hardship and hunger through being less able to predict climate conditions.[1] To a certain extent, trade may compensate for these deficits.

- ***Water:*** Glacier melt may yield more runoff in the short term but less in the medium and long terms. More severe storms (especially cyclones) will cause more damage to infrastructure and livelihoods and exacerbate salt water intrusion in storm surges. Changes in the timing and amount of monsoon rains will make the production of food and other agricultural products more uncertain, so that, even in good-weather years, farmers will be more likely to make decisions leading to lower-productivity.

- ***Exacerbation of Inequality:*** The welfare of those who are affected by climate change and who have limited means to adapt may act as a force that can change governments, strain public budgets, and foster unrest. About one-third of Indians are extremely poor, and 60 percent depend upon agriculture for their livelihoods.

- ***Energy:*** As India searches for additional sources of energy to meet rising demand, climate change mitigation efforts may constrain its use of indigenous and imported coal, oil, and gas, while development of nuclear energy will be slow at best and likely to encounter opposition. Other non-emitting technologies will require technology transfer and capacity-building.

- ***Migration:*** India receives immigrants from a number of countries. Under climate change conditions, it may be flooded with many more, particularly from Bangladesh. Such migration may exacerbate tension between the two countries as well as putting a strain on Indian central and state governments.

Adaptive capacity in India varies by state, geographical region, and socioeconomic status. Studies point to influential factors such as water availability, food security, human and social capital, and the ability of government (state and national levels) to buffer its people during tough times. ***Where adaptive capacity is low, the potential is greater for impacts to result in displaced people; deaths and damage from heat, floods, and storms; and conflicts over natural resources and assets.***

[1] The current accuracy of even current forecasts is in doubt. For example, the Indian Medium Range Weather Forecasting Center is not allowed to issue such forecasts in public media–that is the responsibility of the Indian Meteorological Department.

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Introduction and Background

Global climate projections, given inherent uncertainties, indicate several changes in India's future climate:

- Global observations of melting glaciers suggest that climate change is well under way in the region, with glaciers receding at an average rate of 10–15 meters per year.[i]
- If the rate of glacial melt increases, flooding is likely in the river valleys fed by these glaciers, followed by a diminished flow, resulting in a scarcity of water for drinking and agricultural irrigation.
- All models show a trend of general warming in mean annual temperature as well as decreased range of diurnal temperature and enhanced precipitation over the Indian subcontinent.[ii]
- A warming of 0.5^{o}C is likely over all India by the year 2030 (approximately equal to the warming over the 20th century) and a warming of 2-4^{o}C by the end of this century, with the maximum increase over northern India.[iii]
- Increased precipitation is likely to come in the form of fewer rainy days but more days of extreme rainfall events, with increasing amounts of rain in each event, leading to significant flooding.[iv] Fine precipitation (drizzle-type) that replenishes soil moisture is likely to decrease.
- Increased warming is likely to lead to higher levels of tropospheric ozone pollution and other air pollution in India's major cities.[v]
- Most global models suggest that the Indian summer monsoons will intensify with a warming climate. The timing may also shift, causing a drying during the late summer growing season.[vi]
- Climate models also predict an earlier snowmelt, which could have significant adverse effects on agricultural production, both irrigated and non-irrigated.[vii]
- Growing emissions of aerosols from energy production and other sources may suppress rainfall, leading to drier conditions with more dust and smoke from the burning of drier vegetation, affecting both regional and global hydrological cycles and agricultural production.[viii]

In both its greenhouse gas emissions and its vulnerability to climate change, India is one of the most significant countries in the world. With a large and growing population, India's emissions of greenhouse gases are increasing. Moreover, potential climate impacts in India are severe: sea level rise, changes in the monsoon, increased severe storms and flooding, more drought, and severe water stress. Recently, climate variability in the form of floods and cyclones has resulted in destruction of crops, property and infrastructure, as well as in negative impacts on human health and well-being. All of these impacts set back general socio-economic development. Rural dwellers' continuing dependence upon agriculture for food and livelihood (17.5 percent of gross domestic product (GDP) and more than 60 percent of the labor force)[ix] makes the Indian people particularly vulnerable to climate variability and change. Nowhere is this more evident than in the linkage of the annual monsoon cycle and agricultural production, commonly referred to as, "Indian agriculture gambles with monsoon."

The diversity and extremes of India's climate and geography are characteristic of its society as well. Religious and cultural diversity is a major feature of Indian life. The strong Hindu traditions have been synthesized with and challenged by other religions, notably Islam, Christianity, and Sikhism. India has at least 300 known languages, 24 of which have at least one million speakers each. There are differences, sometimes amounting to estrangement, between the North, with its history of grand-scale invasions, and the relatively stable South. Religious divisions became geographical divides when Muslim Pakistan (1947), then Bangladesh (1971), were created, and ethnic and caste-related strife continues among groups. However, the connectedness of the extended family is a core feature of Indian life. Together with a sense of civil society's claims on individuals and families, the extended family knits the society together and emphasizes interdependence.[x]

Diversity and extremes are evident in India's patterns of economic development as well. In this sphere, two themes stand in contrast: modernist, democratic, and technical development, intensified by the economic liberalization beginning in the early 1990s; and persistent poverty, subsistence agriculture, and caste-based discrimination. Various models of development have been advanced. Das[xi] characterizes the country-level model thus: "Rather than adopting the classic Asian strategy—exporting labor-intensive, low-priced manufactured goods to the West—India has relied on its domestic market more than exports, consumption more than investment, services more than industry, and high-tech more than low-skilled manufacturing." Kerala's model of human development emphasizes education, health services, and equality; however, slow economic development has somewhat tarnished this model, as incomes remain low and the contributions of Keralans working abroad continue to be very much needed.[xii] The Karnataka model focuses on technology, centered in Bangalore, and historically participatory local governance by *Panchayat.* Yet Karnataka also has "enduring gender inequity and regional disparities, and a visibly increasing gap between urban and rural areas."[xiii]

Despite substantial economic and general development progress, poverty, malnutrition, illiteracy, and inequality[xiv] continue to plague India, as well as serious environmental issues. India has not only several Silicon Valleys but also several Nigerias.[xv] In addition, the ongoing dispute with Pakistan over Kashmir and ethnic strife (e.g., in Assam) claim national attention. Conflict with Pakistan has lessened by confidence-building measures since 2002, when nuclear war was hinted at, but such hints arose again after the recent terrorist attack in Mumbai, although the response so far has been relatively temperate.

India's broad spectrum of highly articulated national policies includes inclusive growth goals in the areas of economic development, human development, and environmental protection. National goals are, of course, differentially implemented in each of India's states, which exhibit widely varying degrees of social and economic development. Limited growth has occurred in the areas of fiscal policy, privatization, small-scale industry, agriculture, and labor law.[xvi]

At the national level, India's climate change policies are subsumed in its economic-industrial and human development policies, which come first. Local policies have had some success in limiting significant urban air pollution problems. Substantial improvements in local air quality in Delhi, for example, have resulted from recent government programs to improve the quality of petrol and diesel fuels, introduction of emissions standards for vehicles, and conversion of buses and three-wheelers to compressed natural gas (CNG) fuel—but Kolkata and other metropolitan centers experience worsening air quality, with increasing combustion of fossil fuels contributing to carbon dioxide emissions. Generally speaking, climate change policy has been reactive rather than proactive and focused largely on the energy sector. According to reports from the Organization for Economic Cooperation and Development (OECD) and the Pew Center,[xvii] India, through normal policy developments, is "making significant progress in limiting greenhouse emissions" (i.e., from what emissions might have been) through energy efficiency improvements and environmentally friendly energy development. Also, India is participating in the Clean Development Mechanism of the United Nations Framework Convention on Climate Change (UNFCCC) and actively participating in the development of a proposed UNFCCC mechanism called Reducing Emissions from Deforestation and forest Degradation (REDD). The National Clean Development Mechanism Authority (NCDMA) is housed in the Ministry of Environment and Forests (MoEF); CDM India has operated since December 2003 as the Designated National Authority (DNA). More aggressive measures, India feels, should be financed by developed nations as they lead by reducing their own emissions and engaging in clean technology transfer, in accordance with the 1992 UNFCCC (ratified by 192 countries).

Internationally, India has played a key role in climate negotiations at several points. India broke the impasse at the first Conference of the Parties by leading the development of a common statement that became the basis for the Berlin Mandate. More recently, India hosted the eighth Conference of the Parties to the Framework Convention on Climate Change in 2002. India, bolstered by nongovernmental organizations such as the Tata Energy Research Institute (TERI) and the Centre for Science and Environment (CSE), focuses on per capita emissions (low in India and high in most developed countries) and on cumulative emissions (also low in developing countries and high in developed countries), as the indicators that developed countries should undertake mitigation first. Government officials press developed nations to establish and conform to emissions reduction goals and to engage in technology transfer to developing countries.

CSE rebutted the second World Resources Report,[xviii] making the distinction between "subsistence emissions" of the poor (mostly in developing countries) and the "luxury emissions" of the rich (mostly in developed countries). CSE has also characterized "green" policies dictated by the North (e.g., debt-for-nature swaps) as unwarranted interference in other nations, as exacerbating inequality among nations, and as likely to foster unsustainable management.

Projected Regional Climate Change

The current climate of India is highly diverse, ranging from the subfreezing Himalayan winters to the tropical climate of the south. The states of Assam and West Bengal experience extremely damp, rainy, and humid conditions, while the regions of Rajasthan and Gujarat make up part of the arid Great Indian Desert. Based on precipitation and temperature, India can be divided into six climatic regions: the Himalayas, Assam and West Bengal, the Indo-Gangetic Plain, the Western Ghats and coast, the Deccan (the interior of the Peninsula south of the Narmada River), and the Eastern Ghats and coast.[xix]

The Indian Meteorological Service divides the year into four seasons, two of which are characterized by monsoon conditions. Winter occurs from December through February, when conditions are generally relatively dry and cool. March through May is considered to be summer, as the conditions are usually hot and dry. During this period temperatures throughout non-Himalayan India reach the upper 30s°C and can reach as high as 48°C during the day in the pre-monsoon months.

The southwest monsoon season occurs from June through September, when the predominating southwest maritime winds bring rains to most of the country. One branch of the southwest monsoon, known as the Arabian Sea monsoon, generally breaks on the west coast early in the season and spreads across South Asia by early July. The other, known as the Bay of Bengal monsoon, spreads over Assam during June and travels along the Indo-Gangetic Plain toward New Delhi, merging with the Arabian branch to bring rains farther north. The southwest monsoon provides almost 80 percent of the annual rainfall to most of the country. It is critically important to agricultural production; predictions of its timing are used by agronomists and farmers to determine optimal dates for plantings.

The northeast monsoon occurs in October and November as the southwest monsoon retreats. The states of Tamil Nadu, Karnataka, and Kerala receive most of their rainfall from the northeast monsoon during November and December. (See Figure 1 for a map of Indian states and http://en.wikipedia.org/wiki/File:India_climatic_zone_map_en.svg for climate regions.)

Interannual climate variability is linked to a global-scale, naturally occurring phenomenon known as the El Niño/Southern Oscillation (ENSO) cycle.[2] ENSO can explain some of the inter-annual rainfall variability over the subcontinent of India and can affect the location and activity of tropical storms. Analysis of observational data shows a significant correlation between ENSO and tropical circulation and precipitation such that there is a tendency for less Indian summer monsoon rainfall in El Niño years and above-normal rainfall in La Niña years. However, the effect is not linear. The ability to accurately predict the timing and occurrence of the ENSO phenomenon is extremely important to agricultural production.

[2] The terms El Niño and La Niña represent opposite extremes of the ENSO cycle. El Niño refers to the above-average sea-surface temperatures that periodically develop across the east-central equatorial Pacific. It represents the warm phase of the ENSO cycle and is sometimes referred to as a Pacific warm episode. La Niña refers to the periodic cooling of sea-surface temperatures across the east-central equatorial Pacific. It represents the cold phase of the ENSO cycle, and is sometimes referred to as a Pacific cold episode.

Figure 1. Indian States.

Climate Observations

Global observations suggest that climate change is well under way. At continental, regional, and ocean basin scales, numerous long-term changes in climate have been observed, including widespread changes in precipitation amounts; ocean salinity; wind patterns; and aspects of extreme weather including droughts, heavy precipitation, heat waves, and the intensity of tropical cyclones. Studies of the tropical Indo-Pacific region show unusual warmth in the 20th century, and many isotope records show a trend toward warmer conditions in the tropical Indian Ocean. In most multi-centennial coral series, the late 20th century is shown to be warmer than any time in the past 100 to 300 years.

Some studies have suggested that the South Asian (Indian) monsoon, in the drier areas of its influence (northwest India), has recently reversed its millennia-long orbitally driven, low-frequency trend toward less rainfall. This recent reversal in monsoon rainfall also appears to coincide with a synchronous increase in inferred monsoon winds over the western Arabian Sea, a change that could be related to increased summer heating over and around the Tibetan Plateau.

Globally, estimates of the potential destructiveness of tropical storms and hurricanes show a substantial upward trend since the mid-1970s, with a trend toward longer storm duration and greater storm intensity. Storm activity is generally correlated with tropical sea surface temperature.

The distributions of global minimum and maximum temperatures have shifted to higher values, consistent with overall warming.[xx] More warm extremes imply an increased frequency of heat waves. However, cold extremes have warmed more than the warm extremes over the past 50 years. Further indications include the observed trend toward fewer frost days associated with the average warming in most mid-latitude regions. A prominent indication of a change in extremes is the evidence of increases in heavy precipitation events over the mid-latitudes in the past 50 years, even in places where mean precipitation amounts are not increasing. For very heavy precipitation events, increases are reported as well, but results are available for only a few areas.

Recent warming in sea surface temperatures (SSTs) is strongly evident at all latitudes, although there are inter-hemispheric differences. Much of the surface of the Indian Ocean has warmed since 1955, with the major exception of the 5°S to 20°S latitude belt. The Southern Ocean (south of 35°S) in the Atlantic, Indian, and Pacific sectors has generally warmed. The regions that exhibit cooling are mainly in the shallow equatorial areas and in some high-latitude regions. In the Indian Ocean, cooling occurs at subsurface depths centered on 12°S (South Equatorial Current) at 150 m depth and in the Pacific centered on the equator and 150 m depth. In the tropical and eastern subtropical Indian Ocean (north of 10°S), warming in the upper 100 m is consistent with the significant warming of the sea surface from 1900 to 1999. The surface warming trend during the 1900 to 1970 period was relatively weak but increased significantly in the 1970 to 1999 period, with some regions exceeding 0.2°C per decade. Models suggest that upper-ocean warming in the South Indian Ocean can be attributed to a reduction in the strength of the southeast trade winds and associated decrease in the southward transport of heat from the tropics to the subtropics.

Local and regional changes in the character of precipitation also depend a great deal on atmospheric circulation patterns determined by El Niño, the North Atlantic Oscillation (NAO),[xxi] and other patterns of variability. India's rainfall features show strong variability but little in the way of a century-scale trend, even as the linear trends of rainfall decreases for 1900 to 2005 were 7.5 percent in western Africa and a similar decrease was observed when averaged over the broader southern Asia region as a whole. Over much of northwestern India, the 1901 to 2005 period shows precipitation increases of more than 20 percent per century, but the same area shows a strong decrease in annual precipitation in the 1979 to 2005 period.

Very dry land areas across the globe have more than doubled in area since the 1970s, an observation that has been associated with precipitation decreases related to ENSO and with subsequent increases primarily due to surface warming. The tendency of the warming to be more pronounced in winter is a conspicuous feature of the observed temperature trends over India, one that is likely to continue.

Climate Predictions (Modeling)

While Global Circulation (or Climate) Models (GCMs) can be used to infer climate changes in specific regions, it is far preferable to develop models that have a high resolution sufficient to resolve local and regional scale changes. There are many challenges in reliably simulating and attributing observed temperature changes at regional and local scales. At these scales, natural climate variability can be relatively greater, making it harder to distinguish long-term changes expected due to external radiative forcings.[3]

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[3] Radiative forcings are changes in the net irradiance at the tropopause resulting from a change in an external driver of climate change, such as carbon dioxide or the output of the Sun. These changes in net irradiance are expressed as watts per meter squared (Wm^2).

The procedure of estimating the response at local scales based on results predicted at larger scales is known as "downscaling." The two main methods for deriving information about the local climate are (1) dynamical downscaling (also referred to as "nested modeling" using "regional climate models" or "limited area models") and (2) statistical downscaling (also referred to as "empirical" or "statistical-empirical" downscaling).[xxii] Chemical composition models include the emission of gases and particles as inputs and the simulation of their chemical interactions; global transport by the winds; and removal by rain, snow and deposition to the earth's surface.

Downscaled regional scale climate models rely on global models to provide boundary conditions for the region to be modeled. There are three primary approaches to numerical downscaling: (1) limited-area models, (2) stretched-grid models, and (3) uniformly high resolution atmospheric GCMs (AGCMs).

Regional Climate Model (RCM) projections for climate change in India were compared for eight models using several different IPCC scenarios at time intervals of 20 years. All models show positive trends of widespread warming (Figure 2), with warming more pronounced during winter and post-monsoon months compared to the rest of the year (i.e., seasonal changes) consistent with recent observations.

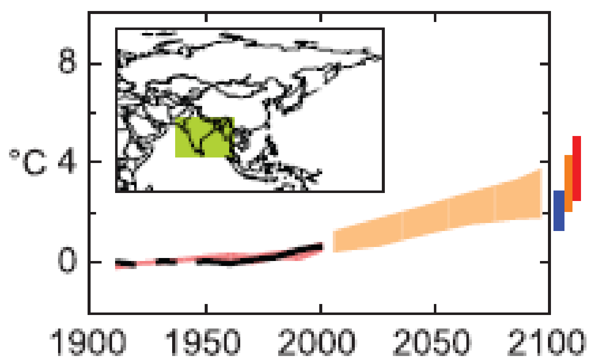

Figure 2. Temperature anomalies with respect to 1901-1950 for six Asian land regions 1906-2005 (black line) and as simulated (red envelope) by multi-model dataset (MMD) models. *Source:* Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: the Physical Science Basis*, eds. S. Solomon, D. Qin, M. Manning, M. Marquis, K. Averyt, M.M.B. Tignor, H.L. Miller Jr. and Z. Chen (Cambridge: Cambridge University Press 2007): 882.

Although some models show a slight decrease in precipitation over all India during the first few decades of the study, all models show increased precipitation during the monsoon season by the year 2100, especially over the northwestern parts of India, an area that is currently very dry. One model projects that by 2050 there will be an overall decrease in the number of rainy days over all India but an increase in the number of one-day extreme rainfall events. The magnitudes and patterns of the projected rainfall changes differ significantly between models, probably due to their coarse resolution.

The Atlantic and Pacific Oceans are strongly influenced by natural variability occurring on decadal scales, but the Indian Ocean appears to be exhibiting a steady warming. Natural variability (from ENSO, for example) in ocean-atmosphere dynamics can lead to important differences in regional rates of surface-ocean warming that affect the atmospheric circulation and hence warming over land surfaces. New modeling efforts have shown improvements in climate forecasts in the southern hemisphere when the incidence of the Indian Ocean Dipole (IOD) is included.[xxiii] The IOD occurs periodically when there is a cold water upwelling in the eastern Indian Ocean, during which the eastern half of the ocean becomes much cooler than the western half.

The recent IPCC assessment report suggests that, in the future, circulation associated with the monsoon may slow down, but the moisture in the air may increase. However, the representation of the observed monsoon maximum rainfall along the west coast of India, northern parts of Bay of Bengal, and north India is poor in many models.

A comparison of four different GCM models applied to the Indian subcontinent[xxiv] found a significant spread in the summer monsoon precipitation anomalies. Soil moisture was determined to be an important parameter in model projections. Most models project increased precipitation during the monsoon season, particularly over the northwestern parts of India, with differences in the magnitudes of the increase from one model to the other. West central India shows maximum overall increase in rainfall. Extremes in both temperature and precipitation events are likely to increase out to 2030.

Including sulfate aerosols in the models reduces the regional climate sensitivity, but the greenhouse warming still dominates the changes at the larger scale and longer time scale. Models that include emissions of short-lived radiatively active gases and particles suggest that future climate changes could significantly increase maximum ozone levels in already polluted regions. Projected growth of emissions of radiatively active gases and particles in the models suggest that they may significantly influence the climate, even out to year 2100.[xxv] Atmospheric brown clouds, plumes of polluted air moving from the Asian continent out over the Pacific and Indian Ocean, may cause changes in the monsoon circulation and reduce summer monsoon precipitation in parts of South and East Asia.

Global models that are unable to include small-scale spatial geographical features and distortions of albedo feedbacks are also unable to project precipitation over the Himalayas. It is expected that the net effect of a warming climate will be an increase in the rainfall associated with the monsoon. Several models suggest that throughout Asia there will be an overall decrease in the December-February precipitation, an increase in the remaining months, and more intense rainfall over larger areas in the future.

Stabilization emissions scenarios assume future emissions based on an internally consistent set of assumptions about driving forces (such as population, socioeconomic development, and technological change) and their key relationships. These emissions are constrained so that the resulting atmospheric concentrations of the substance level off at a predetermined value in the future. For example, if one assumes the global CO_2 concentrations are stabilized at 450 parts per million (ppm) (the current value is about 380 ppm), the climate models can simulate the climate consistent with the emissions of greenhouse gases and short-lived species of this scenario. The climate model predictions can be used to assess specific regional impacts at this stabilization level.

A recent study of models from the Coupled Model Intercomparison Project showed that the models' response to a +1 percent/yr increase in CO_2 includes a substantial warming of tropical storm basin SSTs, enhanced upper-tropospheric warming relative to the surface warming, and little change in lower-tropospheric relative humidity. The study included climate change scenarios from nine different global coupled climate models as inputs to an idealized hurricane model. The results demonstrate that there is a significant sensitivity in the models to the choice of climate model and convective parameterization.

A more detailed discussion of the ability of the models to project regional climate changes can be found in Annex A.[xxvi]

Projections of Future Temperature and Precipitation

Current projections of climate change from the latest IPCC Assessment[xxvii] suggest increases in temperatures, precipitation rates, and the intensity of tropical storms over the Indian Ocean.

Most models either assume a doubling of CO_2 and their results can be compared using this assumption, or the models are run to the year 2100 and the results of the climate projections are assessed for that date. The IPCC has not included numerical model results specifically for the year 2030. Kumar et al.[xxviii] have modeled climate changes on the Indian subcontinent for intermediate scenarios at 2020 and 2050; however, only the results for the final scenario for 2080 have been published. An earlier study[xxix] used eight global models to project temperature and precipitation changes over all India per decade for three different emission scenarios. Although the tables presented in this reference are useful, the uncertainties, especially in the prediction of precipitation changes, are great.

Most AGCMS predict general warming and enhanced rainfall over India, with these changes becoming particularly significant by 2040.[xxx] Kumar et al. use the model Providing Regional Climates for Impacts Studies (PRECIS), developed by the Hadley Centre for Climate Prediction and Research, to yield projections for climate change during intermediate time scales (every 10 years until 2100); these projections can be averaged over model results to estimate climate change in 2030.[xxxi] The models project an average temperature increase over all India by the year 2030 of around 0.5^{o}C, an increase comparable with that that has occurred over the globe during the 20th century. The maximum temperature increase (i.e., annual mean temperature change) is expected to occur over northern India, with a secondary maximum over the eastern peninsula. By the year 2100, the temperature increase could be on the order of 2-4^{o}C, with a maximum increase in the northern region of 4^{o}C.

A regional model recently developed at the Indian Institute of Tropical Meteorology (IITM) projected that, averaged over the country, India could face a temperature increase of 4°C by 2100. However, the model predicts that, because of the longer time scales for system-wide changes in atmosphere-ocean interactions, a delay in the increase in monsoon rainfall will occur,[xxxii] resulting in drought in some areas.

Seasonal Weather Patterns (Monsoons)

Monsoon rains account for most of India's annual rainfall. Monsoons are generally defined as tropical and subtropical seasonal reversals in both the surface winds and associated precipitation. The strongest monsoons occur over the tropics of southern and eastern Asia and northern Australia as well as parts of western and central Africa. Rainfall is the most important monsoon variable because the associated latent heat release drives atmospheric circulations and because

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rainfall plays a critical role in the global hydrological cycle and is vital to socioeconomic impacts.

Most global models suggest that the Indian monsoons will intensify with a warming climate.[xxxiii] Since the continental-scale land-sea thermal contrast is expected to become larger in summer and smaller in winter, one would expect that in the future the summer monsoon will be stronger and the winter monsoon will be weaker than they are presently. However, some models predict that a pronounced warming over the tropics will result in a weakening of the Asian summer monsoon circulations due to a reduction in the meridional thermal gradients between the Asian continent and adjacent oceans.

The global monsoon system embraces an overturning circulation that is intimately associated with the seasonal variation of monsoon precipitation over all major continents and adjacent oceans. The Asian monsoon can be divided into the East Asian and the South Asian or Indian monsoon systems. Although the Indian monsoons recur each year, their irregularity at a range of time scales from weeks to years depends on feedback from the ocean in ways that are not fully understood. Intra-seasonal variability is associated with the Monsoon Intra-Seasonal Oscillation (MISO) and the Madden-Julian Oscillation (MJO), which are long-lasting weather patterns that evolve in a systematic way for periods of four to eight weeks. On an interannual and decadal scale, statistical methods have shown that, while there are periods of high correlation between ENSO and monsoon variation, there are decades in which little or no association is apparent. The influence of ENSO on the position and strength of the subtropical high in the North Pacific influences both typhoons and other damaging heavy rainfall events and has been implicated in observed inter-decadal variations in typhoon tracks. This suggests that the spatial structure of warming in the Pacific will be relevant for changes.

For South Asia, the monsoon depressions and tropical cyclones generated over the Indian seas modulate the monsoon anomalies. For East Asia, the monsoonal circulations are strengthened by extratropical cyclones energized in the lee of the Tibetan Plateau and by the strong temperature gradient along the East Coast.

Although attention is often focused on the frequency or number of storms, the intensity, size, and duration are much more important. From an observational perspective, then, key issues are the tropical storm formation regions; the frequency, intensity, duration, and tracks of tropical storms; and associated precipitation. All of these can be influenced by climate teleconnections,[xxxiv] especially those such as the Indian dipole oscillation (IOD) and the Southern Annular Mode (SAM) Index. Annular modes are hemispheric scale patterns of climate variability.[xxxv] SAM is linked to variations in temperatures over Antarctica, sea-surface temperatures throughout the Southern Ocean, and the distribution of sea-ice around the perimeter of Antarctica.

New evidence indicates that increased aerosol loading[4] in the atmosphere may also have strong impacts on monsoon evolution through changes in local heating of the atmosphere and land surface. Polluted air can also have an effect on local circulation patterns. Heating of a lofted dust layer in the Tibetan Plateau could act as an elevated heat pump to strengthen the Asian summer monsoon circulation and cause a local increase in precipitation, despite the global reduction of evaporation that accompanies the aerosol-induced reduction in shortwave radiation

[4] Aerosols are very small particles that influence the climate in several ways. They are both emitted (e.g., via dust storms or from smokestacks) and form in the atmosphere.

at the surface. The dust-induced thermal contrast changes between the Eurasian continent and the surrounding oceans are postulated to trigger or modulate a rapidly varying or unstable Asian winter monsoon circulation, with a feedback to reduce the dust emission from its sources.

Sea Level Changes

A significant fraction of sea level rise is due to thermal expansion of a warmed ocean (as much as 0.3 to 0.8 m over the past century, according to the 2007 IPCC report). Geographic patterns of sea level rise are due mainly to changes in the distribution of heat and salinity in the ocean, resulting in changes in ocean circulation. Precise satellite measurements since 1993 show that the largest sea level rise since 1992 has taken place in the western Pacific and eastern Indian Oceans, with the potential for significant impacts on the east coast of India. The 2004 Indian National Communication to the UNFCCC states that sea level rise is highest in the Gulf of Kutch (Gujarat) and on the coast of West Bengal.[xxxvi] There is a large interannual variability in sea level rise associated with patterns of coupled ocean-atmosphere variability, including ENSO and the NAO.

Projected patterns of sea level rise display more similarity across models than in past assessments. Common features include a narrow band of pronounced sea level rise stretching across the southern Atlantic and Indian Oceans. Sea level is projected to rise between the present (1980-1999) and the end of this century (2090-2099) by 0.35 m (0.23 to 0.47 m). Due to ocean density and circulation changes, the distribution will not be uniform.

Agricultural Growing Periods

Many regions of India already face water scarcity. Productive agricultural regions in the North depend on the spring snowmelt to replenish regional water supplies. Climate models predict an earlier snowmelt, which could have a significant effect on agricultural production, especially if the levels of moisture in the soils are reduced during the growing season.

The retreat of snow and ice cover in and around the Himalayas is already having a drying effect on these regions. A recent study of the melting Naimona'ny glacier in the Himalayas, which provides water to the Indus, and Brahmaputra Rivers shows that the glacier has melted so much that the exposed surface of the glacier dated to 1944.[xxxvii]

A study of glaciers in the region shows that they are now receding at an average rate of 10-15 meters per year.[xxxviii] Himalayan glaciers collect water during the monsoon season and release it during the dry season, providing irrigation water for crops. If the rate of glacial melt increases, flooding is likely to occur in the river valleys fed by the glaciers. Later, as the river flows decrease to below previous rates, many people may be left without sufficient drinking water or water for irrigating crops.

Decreasing trends in evapotranspiration during recent decades are evident in records, even though such records are sparse. This is likely due to decreased sunshine duration related to increases in air pollution, atmospheric aerosols, and increases in cloud cover. An accelerating trend in sulfate deposition has been observed in Himalayan glaciers and is probably due to increased sulfur dioxide emissions from the increasing energy demand throughout Asia. The concentration of sulfate deposited in the glaciers in the past 50 years exceeded that for any prior 50-year period in the last millennium.[xxxix]

A model to predict changes in river flows due to future glacial melt from climate change was developed by the Centre for Ecology and Hydrology in the United Kingdom. Under different climate scenarios, the model predicts that in the upper Indus there will be an initial increase of between +14 percent and +90 percent in mean flows (compared to baseline) over the first few decades of the 100-year incremental scenario runs. By decade 10, river flows will decrease between –30 percent and –90 percent of baseline.[xl]

During the Indian Ocean Experiment[xli] that focused on emissions of human-generated aerosols from the Indian sub-continent, local forcing at the surface was observed to be significantly stronger than that at the top of the atmosphere. These results indicate that absorption of solar radiation by aerosols, primarily black carbon in the atmospheric column, is of great significance. It has been suggested that absorbing aerosols may have masked up to 50 percent of the surface warming in South Asia from the global increase in greenhouse gases. In cases where aerosols act to suppress rainfall (the second aerosol indirect effect), drier conditions tend to induce more dust and smoke due to the burning of drier vegetation, affecting both regional and global hydrological cycles and agricultural production. However, more research is needed to understand the combined effects of aerosols and dusts, which may influence the monsoon circulation and hydrological cycle in different ways.

Climatic Events

Extremes are the infrequent events at the high and low end of the range of values of a particular variable. The probability of occurrence of values in this range is called a probability distribution function (PDF) that for some variables is shaped similarly to a "Normal" or "Gaussian" curve (the familiar bell-shaped curve).

People affected by an extreme weather event (e.g., the heavy rainfall in Mumbai in July 2005) wonder whether climate changes due to human influences are responsible. It is difficult to attribute any individual event to a change in the climate. In most regions, instrumental records of variability typically extend only over about 150 years, so there is limited information to characterize how extreme rare climatic events could be. Further, several factors usually need to combine to produce an extreme event, so linking a particular extreme event to a single, specific cause is problematic. In some cases, it may be possible to estimate the anthropogenic contribution to such changes in the probability of occurrence of extremes.

As the climate changes and SSTs continue to increase, the conditions that cause tropical storms to form are no longer the same. Higher SSTs are generally accompanied by increased water vapor in the lower troposphere; thus, the moist static energy that fuels convection and thunderstorms is also increased. Hurricanes and typhoons currently form from pre-existing disturbances only where SSTs exceed about 26°C; so, as SSTs have increased, the areas over which such storms can form are potentially expanded. However, many other environmental factors also influence the generation and tracks of disturbances.

The 2007 IPCC assessment concluded that there was a risk of increased temperature extremes in India, with more extreme heat episodes in a future climate. This result has been confirmed and expanded in more recent studies. Future increases in temperature extremes are projected to follow increases in mean temperature over most of the world except where surface properties (e.g., snow cover or soil moisture) change. There is still much debate over whether there is likely to be an increase in tropical cyclone intensity.

Changes in tropical storm and hurricane frequency and intensity are often masked by large natural variability. ENSO greatly affects the location and activity of tropical storms around the world. Globally, estimates of the potential destructiveness of hurricanes show a substantial upward trend since the mid-1970s, with a trend toward longer storm duration and greater storm intensity, and this activity is strongly correlated with tropical SSTs. One study found a large increase in numbers and proportion of hurricanes reaching categories four and five globally since 1970, even as the total number of cyclones and cyclone days decreased slightly in most basins. The largest increase was in the North Pacific, Indian and Southwest Pacific Oceans.

Improved models, ones that prescribed convection constraints based on the relative humidity, were able to simulate the variability and extremes of rainfall quite well over most of India when compared to satellite-derived rainfall but had a tendency to overestimate heavy rainfall events in central India.

Several recent studies have addressed possible future changes in heat waves and found that in a future climate, heat waves are expected to be more intense, longer-lasting and more frequent. Based on an eight-member multi-model ensemble, heat waves are simulated to have increased for the latter part of the 20th century and are projected to increase globally and over most regions.

Impacts of Climate Change on Natural Ecosystems

Observed Changes

An analysis of seasonal and annual surface air temperatures for India, using data for 1881–2001 for 25 or more stations, shows a significant annual mean warming of 0.68°C per hundred years. Most of the warming occurs in the post-monsoon and winter seasons. The monsoon temperatures do not show a significant trend in most parts of the country except for a significant negative trend over northwest India. Maximum daytime temperatures show more of a trend than minimum nighttime temperatures,[xlii] in contrast to general expectation.

Water supply is changing. Almost 67 percent of the glaciers in the Himalayan mountain ranges, the source of major rivers in India, have retreated in the past decade.[xliii]

For India, the IPCC[xliv] reports increased frequency of hot days and multiple-day heat waves in the past century, with more deaths attributable to heat stress in recent years. Consecutive droughts in 1999 and 2000 led to a sharp decline in water tables in the northwest, and 2000-2002 droughts caused crop failures, leading to mass starvation and impacts on ~11 million people in Orissa.

Management decisions about natural hazards can cause conflicts. In 2002, under drought conditions in Andhra Pradesh, the state released dam water for electricity generation but not for irrigation. Poor farmers responded to such policies by smashing the pumps of their richer neighbors. Quarrels over water rights between states can be bitter, too. Tamil Nadu claimed that its neighboring state, Karnataka, violated agreements about sharing water from the Cauvery River.[xlv] Bangalore is facing acute water scarcity as it attempts to meet the drinking water needs of 7 million people in the city.[xlvi]

Public health is affected by currently experienced climate variability and change in the forms of heat and flooding. Between 1980 and 1998, 18 heat waves were reported in India; one in 1988 affected ten states and caused 1,300 deaths. Heat waves in Orissa, in the 1998-2000 period caused an estimated 2,120 deaths, and heat waves in 2003 in Andhra Pradesh caused more than 3,000 deaths.[xlvii] Flood-related increases in diarrheal disease have also been reported in India.[xlviii]

Observed trends in the mean sea level along the Indian coast indicate a rising trend of about 1 cm per decade, which is close to that recorded in other parts of the globe. Today, coastal regions in India and Bangladesh are subjected to stronger wind and flood damage than in the past because of stronger storm surges associated with tropical storms.[xlix]

Projected Changes: The Example of Forests

Based on the IPCC's *Special Report on Emission Scenarios*, a study by Ravindranath et al. (2006)[l] investigated the impacts of climate change on Indian forests into the year 2085 under two emission scenarios: A2 (740 ppm CO_2) and B2 (575 ppm CO_2). Globally, A2 is the more extreme scenario, representing a growing human population and slower and inequitable economic development whereby atmospheric CO_2 concentration is projected to double by 2050 and is likely to increase to 740 ppm by 2085. B2 represents moderate population growth, intermediate levels of economic development, adoption of environmentally sound technologies, and greater social equity.

Using the B2 scenario projections and Forest Service of India's categories of forests, a pattern emerges: colder forests are subject to a larger increase of about 3°C, while the Western Ghat evergreen forests become warmer by only about 2.4°C on average—compared to the national average of 2.9°C. For the A2 scenario, the magnitudes of the impacts are larger. Most of the forests show an increase of about 4°C with the northern temperate forests undergoing a temperature increase of around 4.6°C. Western Ghats evergreen, semi-evergreen, and mangrove forest types show the least impacts under both A2 and B2 scenarios.

Even with a conservative temperature increase of 1–2°C, most ecosystems and landscapes will be impacted through changes in species composition, productivity and biodiversity. Impacts to nearly 200,000 forest villages—naturally heavily dependant on forest resources—will be innumerable. Impacts to the country as a whole are also projected by way of economically important forest types, such as *Tectona grandis*, *Shorea robusta*, bamboo, upland hardwoods and pine. A clear possibility of a large-scale shift in forest types in India is projected for the period 2070 to 2100, with adverse implications for biodiversity and a nearly 70 percent increase in net primary productivity of forest types, with implications for biomass production and timber markets.

India's forests are already changing because of socioeconomic pressures; virgin forest areas are less dense and monocultures and plantations are preferred to native species. These conditions will be greatly exacerbated by climate change. Specifically, biodiversity is likely to be reduced under the projected climate scenarios representing changes or shifts in forest or vegetation types, forest dieback during the transient phase, and different response changes of species to climate changes even when there is no change in forest type.[li]

Impacts of Climate Change on Human Systems

Energy System

Primary energy demand in 2005 was roughly equivalent to that of Japan—but of course with many more people, India's per capita demand remains at about one-tenth of the OECD average. However, Indian demand is growing at a fast pace, 3.2 percent per year (2000-2005).[lii] The International Energy Agency (IEA)[liii] projects India's primary energy demand to more than double by 2030 in a reference scenario (i.e., no policies to slow demand); this projection is attributable largely to a projected annual growth rate for GDP of 6.3 percent. The primary energy demand growth areas will be industrial (mostly steel) and transport (although two- and three-wheelers will still be over half of vehicle stock). In this scenario, India will become the world's third-largest carbon dioxide emitter by 2030, although per-capita emissions will still be comparatively low.

Inequality is such an issue in the energy sector that the IEA devoted a chapter to it, "Focus on Energy Poverty." [liv] Approximately 412 million people are still without access to electricity in India. The use of fuelwood and dung for cooking and heating causes more than 400,000 premature deaths annually, mostly of women and children. Income disparities account for most of the energy access disparities, but other barriers include "unreliable energy service delivery, ineffective and regressive subsidies, gender discrimination in policy planning, inadequate information about the health impacts of current fuels and technologies, and administrative hurdles in getting connections." [lv] "Energy poverty" is one aspect of a concern in India that its booming economic conditions have benefited the "haves" but not the "have-nots."

India's current electrical system runs mostly on domestic coal: 82.7 percent fossil fuel, 14.5 percent hydropower, and 3.4 percent nuclear.[lvi] The transportation sector runs mostly on imported oil; domestic production is 785,000 bbl/day against a demand of 2.45 million bbl/day (2004 estimate).[lvii] OECD/IEA characterized the overall energy system as fueled "largely by coal and combined renewables and waste, with much smaller but growing shares of oil, gas, nuclear, and hydro."[lviii] Future increases in energy production will likely include the following:

- Domestic coal—although deposits are located at some distance from population centers and the coal is of low quality. (Higher quality coal is imported for steel making; India is the seventh-largest steel producer in the world.[lix]) Coal gasification could also be used to make diesel fuel.[lx] However, the use of coal contributes to anthropogenic climate change and bad air quality, so pressures to reduce greenhouse gas and other emissions could limit both options for coal use in India, unless carbon dioxide capture and storage technologies could be implemented.[lxi]

- Imported oil and gas—with associated issues of investing in oil fields, exploitation rights, and refineries in Myanmar, Sudan, Iraq, Russia, Vietnam, Venezuela, and Libya,[lxii] as well as raising the problematic prospect of a gas pipeline running through either Iran and Pakistan or Turkmenistan, Afghanistan, and Pakistan.

- Nuclear power—in part as a fruit of the 2005 "strategic partnership" with the United States, raising concerns about nuclear nonproliferation.

- Renewable sources—such as biomass fuels (waste and purpose-grown crops) and hydropower. Residential use of biomass (fuelwood, dung, and agricultural waste) is projected to change from a current 54 percent share to 12 percent in urban households, but a smaller 92-to-79 percent decline in rural households still means that the absolute amount of biomass used will increase. Biofuel crops, like other crops, will be affected by climate change;[lxiii] hydropower, like other water uses, will be subject to changes in precipitation under climate change.

- Domestic gas reserves—with 2002 and subsequent discoveries in the Krishna-Godavari basin (in Andhra Pradesh on the east coast) and more discoveries expected.[lxiv]

In all of these areas, advanced technologies will be essential to increasing production and meeting environmental regulations, including those related to climate change mitigation and adaptation. The Indian Government has introduced clean coal technologies like coal washing and the use of cleaner and less carbon-intensive fuels, e.g., liquefied petroleum gas (LPG) for automobiles and motor spirit-ethanol blending projects in selected states.[lxv]

Economic Growth and Development

Since 1990, India as a country has moved aggressively from a centrally planned economy to private ownership of businesses and trade liberalization. It has "developed a diversified industrial base and sophisticated financial sector. Its software subsector—one of the most dynamic in the world—has experienced a sustained and rapid growth."[lxvi] Over the past 25 years, the annual growth rate has been 6 percent, accelerating to a five-year annual average of 8.8 percent,[lxvii] investment at 30 percent of GDP, and booming foreign direct investment. India has made substantial strides in fostering human capital by reducing infant mortality, increasing life expectancy, and improving literacy. The central, democratic government provides stability and some curbs to unbridled free market-ism (or barriers to growth in an alternative characterization), and hordes of entrepreneurs provide the impetus for growth.

On the positive side, India's democracy results in equity slightly higher than the global average. The dependency ratio (the percentage of the population dependent on the percentage of the population in the work force) is relatively high, indicating that many people are available for the work force, supporting relatively few people other than themselves.

However, the poor condition of people engaged in agriculture and/or born into lower castes reduces the robustness of the overall economy. Climate change, adding to existing problems of the agricultural system, may worsen conditions for the large poor segment of the population enough to severely tax the economic and industrial resources of the central and state governments.

Thus, the impacts of climate change are likely to be felt first and foremost in the agricultural sector and associated water availability, with many people affected by lower food productivity (e.g., hunger, malnutrition, and its consequences for education and productive economic life) and burdens on the central and state governments in dealing with smallholders and landless workers who will require assistance. Educational and employment inequalities will exacerbate these conditions. Some (or many) of these workers will migrate to urban areas, placing stress on cities. The need to add to or replace infrastructure affected by climate change (e.g., in the energy and transportation sectors, as well as irrigation systems) will present additional economic costs. Finally, migrants, particularly from Bangladesh, will affect India's economy by providing competition for low cost labor.

Food Production and Drinking Water Supply

Agriculture and water are inseparable issues, as almost all the water use in India is for irrigation to support high productivity in agriculture. Thus, both the monsoon onset and active/break phase mean a great deal to the agriculture sector. Research indicates that the monsoon active/break phase is related to a tropical phenomenon called the Madden Julian Oscillation (MJO), which has a periodicity of 30-70 days, with a predictability of 20-30 days. Predicting the MJO has important implications to predicting subseasonal[5] rainfall variability. If farmers sow too early and the crop needs water when the monsoon break phase occurs, the whole crop is lost.

At the national level, India has abundant water resources for agriculture and drinking, as well as for cooking and sanitation uses. India withdraws 34 percent of its available water annually.[lxviii] However, at state and local levels, there are wide-ranging differences; overexploitation is already problematic and will likely become worse under climate change conditions.

Increasing temperatures and increased seasonal variability will likely cause Himalayan glaciers to melt more and more quickly, also leading to increasing danger from floods as glacial lakes burst out of their natural bounds. Changes over decades will include less flow in rivers fed today by snow and ice, with impacts on hydropower, urban water supply, and agriculture.[lxix] Although there is clear evidence of de-glaciation across the Himalayas, the effect on river flows is likely to be substantially different in different areas. The extent of the changes is very uncertain because, as Sengupta puts it, "River flow data is so scant and recent that it is impossible for scientists to predict how the current rates of glacial retreat will affect river volume."[lxx]

There are major regions, including many of the most highly productive agricultural and industrial regions of India, where water scarcity is already felt in day-to-day life. The retreats of snow and ice cover are important for several local climates, especially those near the Himalayas. The drying effect of an earlier spring snowmelt and, more generally, the earlier reduction in soil moisture is a continuing concern. Already 15 percent of aquifers are in critical condition, a figure that is projected to increase to a "frightening" 60 percent by the year 2030.[lxxi]

Especially in important agricultural areas that have benefited from the Green Revolution, irrigation has led to exploitation of groundwater resources—e.g., 94 percent in Punjab, 84 percent in Haryana, 60 percent in Tamil Nadu, and 51 percent in Rajasthan.[lxxii] Farmers who borrow to dig bore wells for crop irrigation may find that when groundwater tables decline, they cannot repay their loans; some probably will commit suicide. Groundwater depletion has been accelerated by the provision of free or subsidized electricity for agriculture: subsidized rates on irrigation pumps, some state-level free power policies, and supports for agricultural consumers.[lxxiii] In many places (northwest India as well as Pakistan) irrigation has resulted in not only overexploitation of water resources, but also increased soil salinity, waterlogging, and siltation of river basins. These problems have been intensified by declining soil fertility, increasing pest damage, and decreasing genetic diversity in crops.[lxxiv]

Environmental and economic leaders[lxxv] have called for a second Green Revolution as rates of growth in agricultural production have slowed. This would place more pressure on water resources for irrigation. To partially compensate for increased water demand, the efficiency of irrigation systems can be improved. And in recent years, Water Users Associations (WUAs) have formed to conduct participatory irrigation management; [lxxvi] these may promote conservation and water use efficiency.

Rainfed agriculture (65 percent of cropped land)[lxxvii] will experience climate change impacts, too. Without irrigation, smallholder farmers and landless agricultural workers will likely face household food shortages and loss of livelihoods, requiring government assistance or even international aid, as well as pressures on cities to accommodate migrants from rural areas.

[5] "Subseasonal" refers to any timescale shorter than a season.

Cultural Willingness to Change

Even if scientists knew unequivocally how climate change will manifest itself, traditional knowledge and practices would need to be accounted for and integrated into responses. Change is never as simple as providing information that immediately alters people's worldviews and ways of doing things. Selvaraju et al. (2004) explored approaches to help smallholder farmers to benefit from seasonal forecasting. Traditional knowledge in Avinashi (southern India) includes such rules of thumb as, "If it rains on the 10th of Adi (July) … the rainfall in the succeeding season will be good" and, "If the breeze is towards the east during July, the winter monsoon will be good; if towards south, the summer monsoon will be successful."[lxxviii]

Researchers found that farmers could use their knowledge about on-farm conditions in combination with probabilistic forecasts of rainfall (derived from Southern Oscillation Index data) to better meet their production objectives. The most important, and potentially largest-yielding decisions involve crop choice, sowing season, and planting density. However, these decisions can be the riskiest, coming at the beginning of the growth cycle, and "communicating the risk and opportunities of alternative management options is a major challenge." [lxxix] The final decisions always rest with the farmers, so participatory approaches are essential for this kind of cultural shift.

The Indo-Gangetic Plain, the "bread basket" of the region, comprises both highly modernized and traditional agriculture. The western region (the Punjab in Pakistan and India) is characterized by high productivity, high investment in infrastructure, and widespread use of fertilizers and groundwater irrigation. The eastern region (northeastern India and Bangladesh) exhibits low productivity, with poor infrastructure and low inputs of fertilizer and water, high risk of flooding, and chronic poverty. Rising population and climate change will have acombined impact in each of these regions.[lxxx] Changes and uncertainties in water supply (especially monsoonal changes) will affect irrigated and rainfed crops alike.

During the "wheat panic" of 2007, India purchased nearly 800,000 tonnes of wheat to buffer its reserves of this essential grain.[lxxxi] India sees keeping a buffer stock as a necessity in a country that, although theoretically food sufficient, has historically experienced shortages. Climate is one of the key components influencing agricultural production in small Indian farming systems, accounting for two-thirds of the variation in production. ENSO can explain some of the inter-annual rainfall variability that affects overall production. ENSO-based climate forecasts may be used to aid vulnerable smallholder agriculture production systems in India (see box above). However, unless projections of future climate change are able to account for how ENSO may change in a warming climate, these forecasts may not be able to prevent the significant agricultural losses that are possible.

Over the longer term, most studies project decreased yields in non-irrigated wheat and in rice and a loss in farm-level net revenue between 9 and 25 percent for a temperature increase of 2.0–3.5°C.[lxxxii] Considering a range of equilibrium climate change scenarios which project a temperature rise of 2.5°C to 4.9°C for India, Kumar and Parikh (2001) estimated that the impacts of climate change on Indian agriculture would be significant across the scenarios.[lxxxiii] They estimated that, with a temperature change of +2°C and an accompanying precipitation change of

+7 percent, farm-level total net revenue would fall by 9 percent, whereas with a temperature increase of +3.5°C and precipitation change of +15 percent, the fall in farm-level total net revenue would be nearly 25 percent. Aggarwal et al. explored agricultural adaptations to global environmental change in the Indo-Gangetic Plan, concluding that "new information and tools are needed to analyze the trade-offs between the joint socioeconomic and environmental goals, and possible adaptation strategies."[lxxxiv]

Livestock, too, will be affected by climate change. India has the largest livestock population in the world,[lxxxv] with animals used as milk producers (especially cattle and buffalo), draft animals, nutrient recycling (manure) and seeding, and as household capital, particularly in landless households. Heat stress lowers production and reproduction, reduces feed and fodder, and increases conditions favorable to disease. For example, outbreaks of foot and mouth disease in cattle are explained 52 percent (in Andhra) and 84 percent (in Maharashtra) by temperature, humidity, and rainfall; mastitis increases in dairy animals during hot and humid weather, which also is associated with increases in flies and cattle ticks.[lxxxvi]

Water availability will be a crucial factor in the continued viability of both crops and livestock, but management is diffuse. Under the Indian constitution, water is the responsibility of the states, not the central government. Thus, water management institutions at the state level have the biggest say in planning and allocation.[lxxxvii] At the national level, at least five ministries (Water Resources, Environment and Forests, Rural Development, Power, and Urban Development and Poverty Alleviation) are concerned with water, but no organizational mechanism exists to coordinate water management among these ministries. Moreover, efforts to adapt to more variability in water flows by constructing dams and catchments may increase tensions with Bangladesh and Pakistan.

While freshwater resources will be affected, the marine environment is and will be changing too. Fisheries stocks may collapse or move in the already-contested waters of the Indian Ocean, potentially affecting livelihoods and food supply for millions of people. The international ocean management regimes will require renegotiation.[lxxxviii]

Human Health

Currently, India's public health care system produces relatively poor health outcomes.[lxxxix] For India, Healthy Life Expectancy (HALE), which includes adjustment for time spent in poor health, is 53 years for children born in 2003.[xc] Despite perceived strengths of the national-level public health system (good expertise, written guidelines and standards, and network of research and training institutions), implementation and monitoring of services are weak.[xci] Funding for control of communicable diseases has been deemphasized since the 1980s; several infectious diseases, such a tuberculosis and malaria, have reemerged as public health care concerns.[xcii] In India, unplanned urbanization has contributed to the spread of *Plasmodium vivax* malaria and dengue.[xciii]

Climate change impacts on health include an expected increase in communicable diseases, such as malaria. Malaria is projected to move to higher latitudes and altitudes in India.[xciv] An assessment in India projected shifts in the geographical range and duration of the transmission window for *Plasmodium falciparum* and *Pvivax* malaria.[xcv]

Coping Capabilities in Facing Natural Disasters

India is highly vulnerable to natural disasters, and people live on marginal lands or in coastal and delataic cities where they are at greater risk. Floods, regional droughts, cyclones, and earthquakes affect millions of Indians.[xcvi]

In the area of disaster mitigation, much has been done to document conditions leading to vulnerability. For example, a *Flood Atlas of India* and a *Vulnerability Atlas of India* (1997, revised 2006) have been produced; the latter assesses the vulnerability of housing and infrastructure to earthquakes, cyclones and floods to improve zoning and construction.

In India, as in the United States, the primary responsibility for responding to disasters lies at the state level. The Disaster Management Act of 2005 set up the Natural Disaster Management Division in the Ministry of Home Affairs and proclaimed a new emphasis on disaster prevention. The United Nations Development Program[xcvii] has developed a plan for disaster preparedness and response that attempts to integrate government and other activities.

Many Indian states have limited resources and lack their own disaster management plans. Because of these factors, India's disaster response record has been mixed, with delayed response, lack of early warning systems and resources to undertake measures like mass evacuation, inadequate coordination among various government departments, failure to keep essential stores (e.g., sandbags, medicines, and life-saving equipment) on hand, and inadequate coordination with the Army and other service organizations, as well as donors.

As an example of disaster response, in 2007 the *New York Times* reported[xcviii] a United Nations official as saying that about 2,800 people in India, Bangladesh, Nepal, and Pakistan had died in monsoonal floods (“the worst in living memory”), from drowning, waterborne illnesses, snakebites or hunger. For survivors, the land damage meant there would be no near-term agricultural work for millions of landless laborers, leaving them to rely on the sporadic support of aid agencies and government relief organizations. The condition of the 31 million people affected in India was covered internationally but was not featured either in New Delhi newspapers or on national news channels.

Infrastructure is affected by climate hazards as well. For instance, 14 percent of the annual repair and maintenance budget of the newly built 760 km Konkan Railway in India is spent repairing damage to track, bridges, and cuttings due to extreme weather events such as rain-induced landslides. In spite of preventive targeting of vulnerable stretches of the line, operations must be suspended for an average of seven days each rainy season because of such damage.[xcix]

Systematic disaster preparedness at the community level has helped reduce death tolls; for instance, new warning systems and evacuation procedures in Andhra Pradesh after 1977 reduced deaths from coastal tropical cyclones to 10 percent of the 1977 total by 1997.[c]

Climate Change in the Neighborhood

The most obvious regional climate change impacts will likely concern water. The Indo-Gangetic Plain stretches from Pakistan’s coast across northern India to almost the whole of Bangladesh. The Indus River drains in Pakistan, the Ganges in India, and Bangladesh. Rivers fed by Himalayan snow and ice provide irrigation water for this important agricultural area. India has water agreements with both neighboring countries, and alleged violations of these agreements have caused international disputes.

Bangladesh, in particular, depends upon India to allow sufficient fresh water to flow into Bangladesh for every water use and for preventing salt water intrusion. Sea level rise and management decisions have reduced freshwater flows and increased salt-water intrusion in the Indus delta and Bangladesh. This adversely affects the Sundarbans, the largest mangrove forest in the world, which is shared by India and Bangladesh. In addition, flooding has displaced thousands to millions of Bangladeshis, who are subject to outbreaks of xenophobic violence if they resettle in India.

Also potentially important are changes in Arabian Sea (e.g., loss of fresh water input due to channeling of Indus river water to agriculture in Pakistan, leading to biogeochemical changes in the Western Arabian Sea); the impacts of aerosols (the "Atmospheric Brown Cloud"), which may diminish winter precipitation in western India and in Pakistan); and changes in the carbon cycle in the Bay of Bengal.

Adaptive Capacity

The impacts of climate change will be felt differentially, depending upon how well a society can cope with or adapt to climate change, that is, its adaptive capacity. Adaptive capacity is defined by the IPCC as, "The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences."[ci] Thus, adaptive capacity is distinguished from both climate change impacts and the degree to which those impacts affect the systems that are in place (as discussed in the previous sections).

Although the specific determinants (or "drivers") of adaptive capacity are a matter of debate among researchers, there is broad agreement that economic, human, and environmental resources are essential elements. Some components of this adaptive capacity are near term, such as the ability to deliver aid swiftly to those affected by, e.g., flooding or droughts. Other components include a high enough level of education so that people can change livelihoods, a quantity of unmanaged land that can be brought into food production, and institutions that provide knowledge and assistance in times of change. For instance, Yohe and Tol[cii] identified eight qualitative "determinants of adaptive capacity," many of which are societal in character, although the scientists draw on an economic vocabulary and framing:

1. The range of available technological options for adaptation.
2. The availability of resources and their distribution across the population.
3. The structure of critical institutions, the derivative allocation of decision-making. authority, and the decision criteria that would be employed.
4. The stock of human capital, including education and personal security.
5. The stock of social capital, including the definition of property rights.
6. The system's access to risk-spreading processes.
7. The ability of decisionmakers to manage information, the processes by which these decisionmakers determine which information is credible, and the credibility of the decisionmakers themselves.
8. The public's perceived attribution of the source of stress and the significance of exposure to its local manifestations.

Researchers have only recently taken on the challenge of assessing adaptive capacity in a comparative, quantitative framework. A global comparative study[ciii] of resilience to climate change (including adaptive capacity) was conducted using the Vulnerability-Resilience Indicators Model (VRIM—see box below).

Adaptive capacity, as assessed in this study, consists of seven variables (in three sectors), chosen to represent societal characteristics important to a country's ability to cope with and adapt to climate change:

Methodological Description of the Vulnerability-Resilience Indicator Model (VRIM)

The VRIM is a hierarchical model with four levels. The vulnerability index (level 1) is derived from two indicators (level 2): sensitivity (how systems could be negatively affected by climate change) and adaptive capacity (the capability of a society to maintain, minimize loss of, or maximize gains in welfare). Sensitivity and adaptive capacity, in turn, are composed of sectors (level 3). For adaptive capacity these sectors are human resources, economic capacity, and environmental capacity. For sensitivity, the sectors are settlement/infrastructure, food security, ecosystems, human health, and water resources. Each of these sectors is composed of one to three proxies (level 4). The proxies under adaptive capacity are as follows: human resource proxies are the dependency ratio and literacy rate; economic capacity proxies are GDP (market) per capita and income equity; and environmental capacity proxies are population density, sulfur dioxide divided by state area, and percent of unmanaged land. Proxies in the sensitivity sectors are water availability, fertilizer use per agricultural land area, percent of managed land, life expectancy, birthrate, protein demand, cereal production per agricultural land area, sanitation access, access to safe drinking water, and population at risk due to sea level rise.

Each of the hierarchical level values is comprised of the geometric means of participating values. Proxy values are indexed by determining their location within the range of proxy values over all countries or states. The final calculation of resilience is the geometric mean of the adaptive capacity and sensitivity.

- Human and Civic Resources
  - — *Dependency ratio:* proxy for social and economic resources available for adaptation after meeting basic needs.
  - — *Literacy:* proxy for human capital generally, especially the ability to adapt by changing employment.
- Economic Capacity
  - — *GDP (market) per capita:* proxy for economic well-being in general, especially access to markets, technology, and other resources useful for adaptation.
  - — *Income equity:* proxy for the potential of all people in a country or state to participate in the economic benefits available.
- Environmental Capacity

— *Percent of land that is unmanaged:* proxy for potential for economic use or increased crop productivity and for ecosystem health (e.g., ability of plants and animals to migrate under climate change).

— *Sulfur dioxide per unit land area:* proxy for air quality and, through sulfur deposition, other stresses on ecosystems.

— *Population density:* proxy for population pressures on ecosystems (e.g., adequate food production for a given population).

Adaptive capacity for a sample of 11 countries from the 160-country study is shown in Figure 3 (base year of 2005). There is a wide range of adaptive capacity represented by these countries; India ranks low, both in the sample and overall:

- Russia ranks 32nd and Libya 34th (in the highest quartile).
- Indonesia ranks 45th, Belize 48th, Mexico 59th, and China 75th (in the second quartile).
- The Philippines ranks 91st and India 119th (in the third quartile).
- Morocco ranks 136th and Haiti 156th (in the lowest quartile).

Any country-level analysis must take into account the comparative ranking of the country.

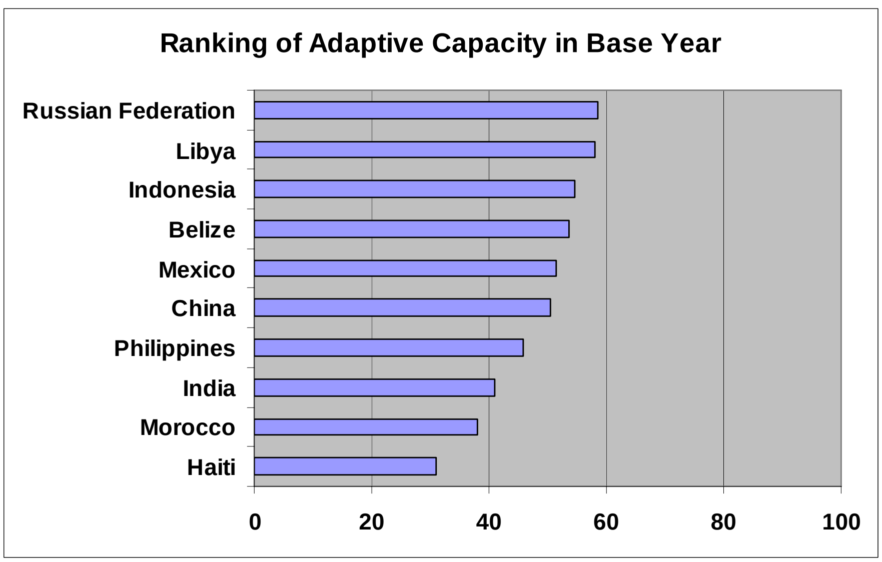

Figure 3. Sample of 11 countries' rankings of adaptive capacity (2005).

Figure 4 shows the contribution of each variable to the overall ranking (slight differences occurring because of the methodology (see box on page 25). India ranks low in comparison with Russia and China because of lower human resources (dependency ratio and literacy levels) than China, and both lower human resources and environmental capacity (non-managed land, emissions per total land area, and population density) than Russia.

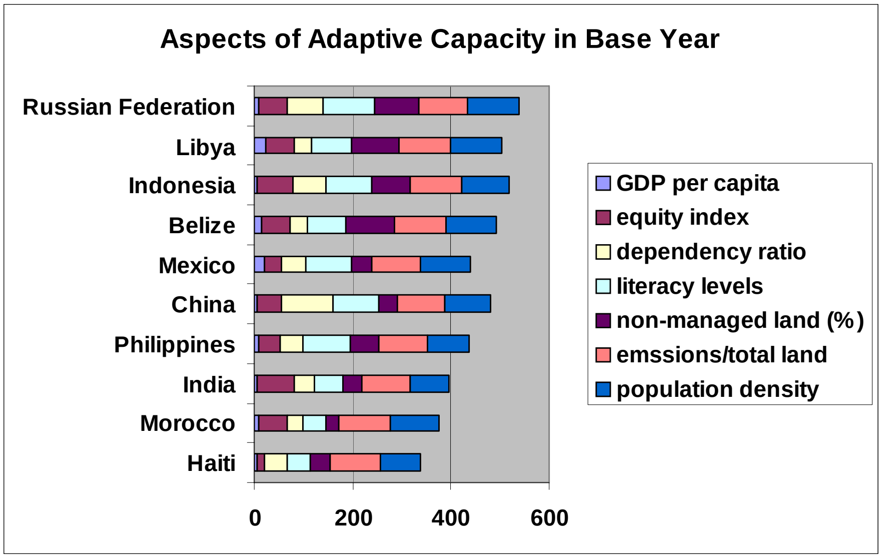

Figure 4. Variables' contributions to adaptive capacity rankings.

Figure 5 shows projected adaptive capacity growth over time for the 11-country sample. Projections are made for two scenarios; rates of growth are based on the IPCC's A1 scenario in its *Special Report on Emissions Scenarios*[civ]. Both scenarios feature moderate population growth and a tendency toward convergence in affluence (with market-based solutions, rapid technological progress, and improving human welfare). The scenarios used in this study differ in the rate of economic growth, one modeling high-and-fast economic growth, the other delayed growth. In the high-growth scenario, China overtakes Russia in adaptive capacity, but India retains its relatively low position throughout the entire period in both scenarios.

Strengths/Weaknesses in Adaptive Capacity Assessments

Even comparative measures of adaptive capacity only allow analysts to ask improved, more focused questions about area or local conditions that contribute to or reduce resilience. It is likely, for instance, that for particular places (e.g., states in India) important variables or domains are not included. For agricultural regions, this might include the extent of irrigation; for urban areas, better measures of education could be important. The measure of unmanaged land does not account for the potential usefulness of that land.

However, comparative measures such as these can be an important first step toward determining where to direct resources—for further analysis or additional factors.

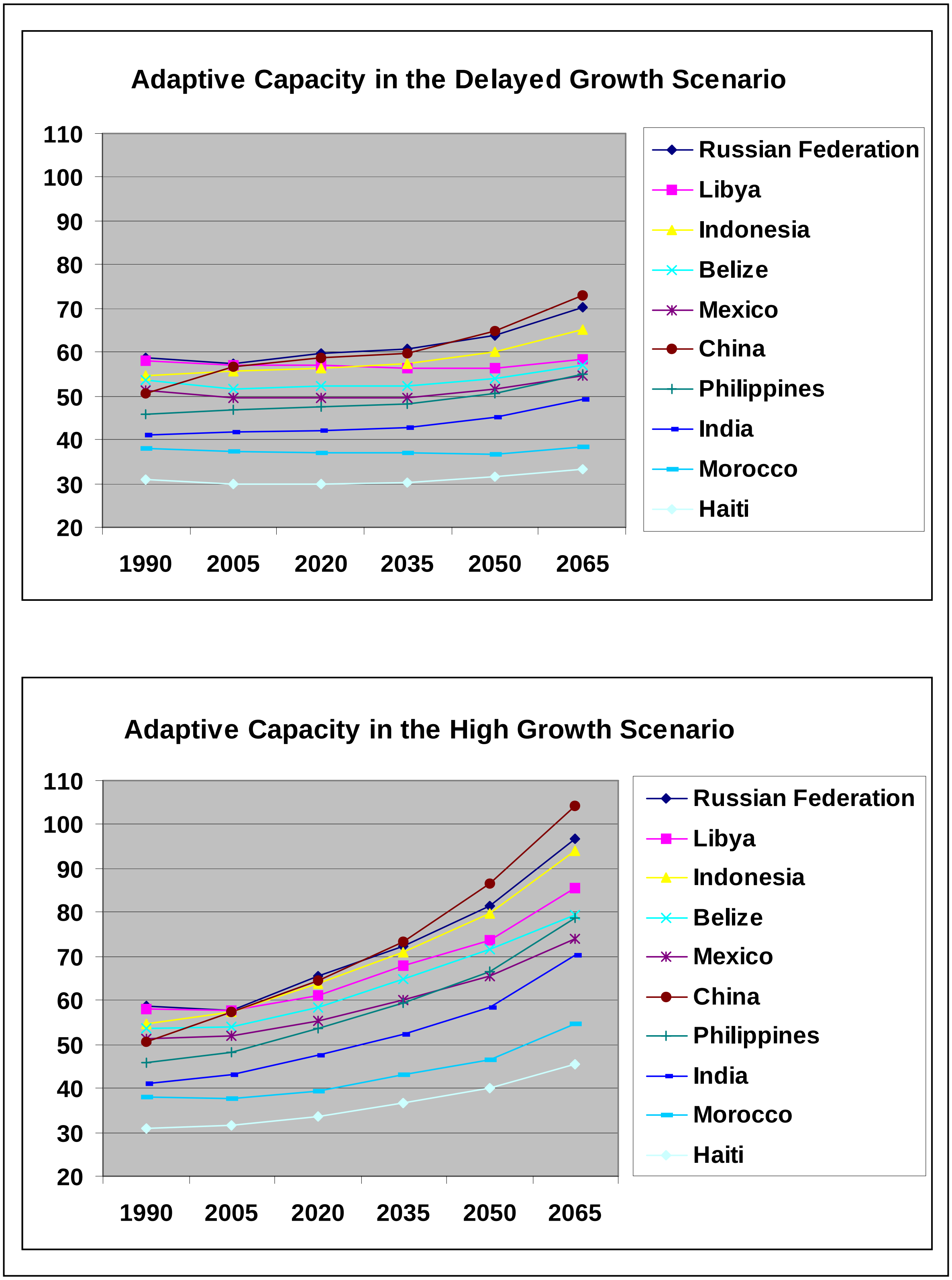

Figure 5. Projections of adaptive capacity for 11 countries.

Conclusions: High Risk Impacts

Agriculture

There are impacts to high-input, high-output agriculture as a result of various changes in the Indian climate, which will affect productivities negatively even as demand for food and other agricultural products rises because of both rising population and standard of living. On the other hand, millions of subsistence and smallholder farmers will experience immediate hardship and hunger because they will be less able to predict climate well enough to make adequate decisions about when to sow, what to grow, and how to time inputs.

Water

Glacier melt may yield more runoff in the short term but less in the medium and long terms. More severe storms (especially cyclones) will cause more damage to infrastructure and livelihoods and exacerbate saltwater intrusion[6] in storm surges. Changes in the timing and amount of monsoon rain will make the production of food and other agricultural products more uncertain, so that, even in good-weather years, farmers will be more likely to make decisions resulting in lower-productivity outcomes.

Energy

As India searches for additional sources of energy to meet rising demand, climate change mitigation efforts may constrain its use of indigenous and imported coal, oil, and gas, while development of nuclear energy will be slow at best and likely to encounter opposition. Other non-emitting technologies will require technology transfer and capacity-building.

Exacerbation of Inequality

In a country so prone to natural hazards, the welfare of those who are affected and who have limited means to recover will loom large under climate change, as a force that can change governments, strain public budgets, and foster unrest. The proportions are significant: about a quarter of the population lives on less than $1 a day; at least one-third face poverty, discrimination (often scheduled castes or tribes and Muslims), and lack of educational opportunities; and 60 percent are dependent upon agriculture for their livelihoods. Those who lack financial resources and adequate education and who depend on agriculture for sustenance and livelihood will be disadvantaged under climate change because they have few choices but continued dependence on shrinking or uncertain resources. India is attempting to reduce inequality by using quotas in government jobs and educational institutions;[cv] the National Rural Employment Guarantee Act (2005) also guarantees that at least one member of a rural household will have 200 days of work per year; and India's 11th five-year plan adopts the policy of sectoral, spatial, and socioeconomic growth that includes all people.

Migration

India receives immigrants from a number of countries. For instance, since 1960 the government has hosted approximately 110,000 de facto refugees from Tibet. The government considers Tibetans and Sri Lankans to be refugees and provides assistance to them. However, the government regards most other groups, especially Bangladeshis, as economic migrants and does not provide them with aid.[cvi]

[6] Saltwater intrusion is the process in which saltwater flows inland into fresh water because saltwater is denser.

Annex A:

Accuracy of Regional Models

This is an excerpt from IPCC (2007), Chapter 11, Regional models; see IPCC 2007 for references. [7]

11.4.2 Skill of Models in Simulating Present Climate

Regional mean temperature and precipitation in the multi-model dataset (MMD) models show biases when compared with observed climate (Table 1). The multi-model mean shows a cold and wet bias in all regions and in most seasons, and the bias of the annual average temperature ranges from –2.5°C over the Tibetan Plateau (TIB) to –1.4°C over South Asia (SAS). For most regions, there is a 6°C to 7°C range in the biases from individual models with a reduced bias range in Southeast Asia (SEA) of 3.6°C. The median bias in precipitation is small (less than 10 percent) in Southeast Asia, South Asia, and Central Asia (CAS), larger in northern Asia and East Asia (NAS and EAS, around +23 percent), and very large in the Tibetan Plateau (+110 percent). Annual biases in individual models are in the range of –50 to +60 percent across all regions except the Tibetan Plateau, where some models simulate annual precipitation 2.5 times that observed and even larger seasonal biases occur in winter and spring. These global models clearly have significant problems over Tibet, due to the difficulty in simulating the effects of the dramatic topographic relief, as well as the distorted albedo feedbacks due to extensive snow cover. However, with only limited observations available, predominantly in valleys, large errors in temperature and significant underestimates of precipitation are likely.

South Asia

Over South Asia, the summer is dominated by the southwest monsoon, which spans the four months from June to September and dominates the seasonal cycles of the climatic parameters. While most models simulate the general migration of seasonal tropical rain, the observed maximum rainfall during the monsoon season along the west coast of India, the north Bay of Bengal, and adjoining northeast India is poorly simulated by many models (Lal and Harasawa, 2001; Rupa Kumar and Ashrit, 2001; Rupa Kumar et al., 2002, 2003). This is likely linked to the coarse resolution of the models, as the heavy rainfall over these regions is generally associated with the steep orography. However, the simulated annual cycles in South Asian mean precipitation and surface air temperature are reasonably close to the observed. The MMD models capture the general regional features of the monsoon, such as the low rainfall amounts coupled with high variability over northwest India. However, there has not yet been sufficient analysis of whether finer details of regional significance are simulated more adequately in the MMD models.

Recent work indicates that time-slice experiments using an AGCM with prescribed SSTs, as opposed to a fully coupled system, are not able to accurately capture the South Asian monsoon response (Douville, 2005). Thus, neglecting the short-term SST feedback and variability seems to have a significant impact on the projected monsoon response to global warming, complicating the regional downscaling problem. However, May (2004a) notes that the high-resolution (about

[7] Some references in this section have been changed to be internally consistent with this document and other references have been removed to avoid confusion.

1.5 degrees) European Centre-Hamburg (ECHAM4) GCM simulates the variability and extremes of daily rainfall (intensity as well as frequency of wet days) in good agreement with the observations (Global Precipitation Climatology Project, Huffman et al., 2001).

Three-member ensembles of baseline simulations (1961–1990) from an RCM (PRECIS) at 50 km resolution have confirmed that significant improvements in the representation of regional processes over South Asia can be achieved (Kumar, 2006). For example, the steep gradients in monsoon precipitation with a maximum along the western coast of India are well represented in PRECIS.

East Asia

Simulated temperatures in most MMD models are too low in all seasons over East Asia; the mean cold bias is largest in winter and smallest in summer. Zhou and Yu (2006) show that over China, the models perform reasonably in simulating the dominant variations of the mean temperature over China but not the spatial distributions. The annual precipitation over East Asia exceeds the observed estimates in almost all models and the rain band in the mid-latitudes is shifted northward in seasons other than summer. This bias in the placement of the rains in central China also occurred in earlier models (e.g., Zhou and Li, 2002; Gao et al., 2004). In winter, the area-mean precipitation is overestimated by more than 50 percent on average due to strengthening of the rain band associated with extratropical systems over South China. The bias and inter-model differences in precipitation are smallest in summer, but the northward shift of this rain band results in large discrepancies in summer rainfall distribution over Korea, Japan, and adjacent seas.

Kusunoki et al. (2006) find that the simulation of the Meiyu-Changma-Baiu rains in the East Asian monsoon is improved substantially with increasing horizontal resolution. Confirming the importance of resolution, RCMs simulate more realistic climatic characteristics over East Asia than AOGCMs, whether driven by re-analyses or by AOGCMs (e.g., Ding et al., 2003; Oh et al., 2004; Fu et al., 2005; Zhang et al., 2005a, Ding et al., 2006; Sasaki et al., 2006b). Several studies reproduce the fine-scale climatology of small areas using a multiply nested RCM (Im et al., 2006) and a very-high resolution (5 km) RCM (Yasunaga et al., 2006). Gao et al. (2006b) report that simulated East Asia large-scale precipitation patterns are significantly affected by resolution, particularly during the mid- to late-monsoon months, when smaller-scale convective processes dominate.

Southeast Asia

The broad-scale spatial distribution of temperature and precipitation in December, January, February (DJF) and June, July August (JJA) averaged across the MMD models compares well with observations. Rajendran et al. (2004) examine the simulation of current climate in the MRI coupled model. Large-scale features were well simulated, but errors in the timing of peak rainfall over Indochina were considered a major shortcoming. Collier et al. (2004) assess the performance of the CCSM3 model in simulating tropical precipitation forced by observed SST. Simulation was good over the maritime continent compared to the simulation for other tropical regions. Wang et al. (2004) assess the ability of 11 AGCMs in the Asian-Australian monsoon region simulation forced with observed SST variations. They found that the models' ability to simulate observed interannual rainfall variations was poorest in the Southeast Asian portion of the domain. Since current AOGCMs continue to have some significant shortcomings in representing ENSO variability, the difficulty of projecting changes in ENSO-related rainfall in this region is compounded.

Rainfall simulation across the region at finer scales has been examined in some studies. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) stretched-grid Conformal-Cubic Atmospheric Model (CCAM) at 80-km resolution shows reasonable precipitation simulation in JJA, although Indochina tended to be drier than in the observations (McGregor and Nguyen, 2003). Aldrian et al. (2004a) conducted a number of simulations with the Max-Planck Institute (MPI) regional model for an Indonesian domain, forced by reanalyses and by the ECHAM4 GCM. The model was able to represent the spatial pattern of seasonal rainfall. It was found that a resolution of at least 50 km was required to simulate rainfall seasonality correctly over Sulawesi. The formulation of a coupled regional model improves regional rainfall simulation over the oceans (Aldrian et al., 2004b). Arakawa and Kitoh (2005) demonstrate an accurate simulation of the diurnal cycle of rainfall over Indonesia with an AGCM of 20-km horizontal resolution.

Central Asia and Tibet

Due to the complex topography and the associated mesoscale weather systems of the high-altitude and arid areas, GCMs typically perform poorly over the region. Importantly, the GCMs, and to a lesser extent RCMs, tend to overestimate the precipitation over arid and semi-arid areas in the north (e.g., Small et al., 1999; Gao et al., 2001; Elguindi and Giorgi, 2006).

Over Tibet, the few available RCM simulations generally exhibit improved performance in the simulation of present-day climate compared to GCMs (e.g., Gao et al., 2003a,b; Zhang et al., 2005b). For example, the GCM simulation of Gao et al. (2003a) overestimated the precipitation over the northwestern Tibetan Plateau by a factor of five to six, while in an RCM nested in this model, the overestimate was less than a factor of two.

This paper does not represent US Government views.

		temperature BIAS					% precipitation BIAS				
REGION	SEASON	MIN	25	50	75	MAX	MIN	25	50	75	MAX
Asia											
NAS	DJF	-9.3	-2.9	-1.3	0.0	2.9	-18	5	12	19	93
	MAM	-6.0	-4.3	-2.7	-0.5	0.6	-4	39	45	74	110
	JJA	-4.8	-2.0	-0.5	0.4	2.2	-38	-2	19	32	62
	SON	-6.2	-2.6	-2.1	-0.5	1.9	-14	12	23	30	49
	ANN	-5.2	-2.6	-1.4	-0.6	1.3	-11	15	24	35	55
CAS	DJF	-4.4	-2.6	-1.2	0.2	3.3	-33	-2	18	43	77
	MAM	-4.3	-3.0	-1.4	0.2	2.0	-36	22	25	34	83
	JJA	-4.9	-1.6	0.3	1.4	5.7	-71	-37	-25	14	60
	SON	-4.5	-3.2	-1.9	-0.4	1.6	49	-12	-4	15	47
	ANN	-3.9	-2.3	-1.4	0.6	2.2	-44	4	12	21	53
TIB	DJF	-9.3	-3.8	-2.2	-1.4	2.2	15	131	177	255	685
	MAM	-7.0	-4.3	-3.8	-1.3	0.6	130	160	209	261	486
	JJA	-6.7	-2.5	-1.0	-0.2	1.6	4	30	37	53	148
	SON	-5.9	-3.6	-2.5	-1.7	0.0	66	93	150	180	330
	ANN	-5.3	-3.3	-2.5	-1.6	0.6	51	88	110	142	244
EAS	DJF	-6.5	-4.5	-3.7	-1.3	1.8	-20	26	60	79	142
	MAM	-5.2	-2.9	-2.0	-1.0	0.5	1	32	45	60	105
	JJA	-3.9	-2.0	-1.1	-0.4	1.4	-15	0	3	15	27
	SON	-5.9	-3.4	-2.7	-1.6	-0.3	-17	1	14	34	75
	ANN	-5.4	-3.2	-2.5	-1.2	0.2	-6	12	22	31	60
SAS	DJF	-7.4	-4.0	-2.6	-1.6	1.9	-27	0	30	59	127
	MAM	-5.6	-1.9	-0.7	-0.4	2.5	-44	-26	-1	13	72
	JJA	-2.9	-1.3	-0.1	0.6	1.9	-70	-25	-14	5	29
	SON	-5.2	-3.2	-2.1	-0.9	2.6	-26	-12	-2	14	42
	ANN	-4.8	-2.4	-1.4	-0.8	2.2	-49	-16	-10	5	33
SEA	DJF	-3.6	-2.6	-1.8	-1.2	0.4	-37	-10	-2	26	49
	MAM	-2.6	-1.6	-0.5	-0.1	1.1	-32	-9	11	25	59
	JJA	-2.5	-1.8	-0.7	-0.4	1.0	-28	-10	4	16	46
	SON	-3.0	-1.9	-1.2	-0.8	1.0	-37	-12	-4	18	51
	ANN	-2.8	-1.9	-1.0	-0.5	0.8	-28	-13	0	23	43

Table 1. Biases in present-day (1980-1999) surface air temperature and precipitation in the MMD simulations. The simulated temperatures are compared with the HadCRUT2v (Jones, et al., 2001) data set and precipitation with the CMAP (update of Xie and Arkin, 1997) data set. Temperature biases are in °C and precipitation biases in percent. Shown are the minimum, median (50 percent) and maximum biases among the models, as well as the first (25 percent) and third (75 percent) quartile values. Colors indicate regions/seasons for which at least 75 percent of the models have the same sign of bias, with orange indicating positive and light violet negative temperature biases and light blue positive and light brown negative precipitation biases.

Annex B:

Knowledge Gaps That Preclude a Full Evaluation of Climate Change Impacts Affecting India and India's Adaptive Capacities

To increase the likelihood that this evaluation represents a reasonable assessment of India's projected climate changes and their impacts, and the country's adaptive capacity, the following gaps would need to be addressed:

- In physical science research, regional analyses will continue to be limited by the inability to model regional climates satisfactorily, including complexities arising from the interaction of global, regional, and local processes. One gap of particular interest is the lack of medium-term (20-30 years) projections that could be relied upon for planning purposes. Similarly, scientific projections of water supply and agricultural productivity are limited by inadequate understanding of various climate and physical factors affecting both areas. Research agendas in these areas can be found in, for instance, the synthesis and assessment reports of the US Climate Change Science Program (http://www.climatescience.gov) and the National Academy of Sciences (e.g., http://books.nap.edu/catalog.php?record_id=11175#toc). Similar types of issues exist for the biological and ecological systems that are affected.
- In social science research, scientists and analysts have only partial understandings of the important factors in vulnerability, resilience, and adaptive capacity – much less their interactions and evolution. Again, research agendas on vulnerability, adaptation, and decision-making abound (e.g., (http://books.nap.edu/ catalog.php?record_id=12545).
- Important factors are unaccounted for in research; scientists know what some of them are, but there are likely factors whose influence will be surprising. An example from earlier research on the carbon cycle illustrates this situation. The first carbon cycle models did not include carbon exchanges involving the terrestrial domain. Modelers assumed that the exchange was about equal, and the only factor modeled was deforestation. This assumption, of course, made the models inadequate for their purposes. In another example, ecosystems research models are only beginning to account for changes in pests, e.g., the pine bark beetle.
- Social models or parts of models in climate research have been developed to simulate consumption (with the assumption of well-functioning markets and rational actor behavior) and mitigation/adaptation policies (but without attention to the social feasibility of enacting or implementing such policies). As anthropogenic climate change is the result of human decisions, the lack of knowledge about motivation, intent, and behavior is a serious gap. Moreover, the long time scale of climate-related research introduces uncertainties about social behavior in the future as well as weaknesses in scientists' ability to predict the social conditions under which mitigation and adaptation will be undertaken.

Overall, research about climate change impacts on India has been undertaken piecemeal: discipline by discipline, sector by sector, with political implications considered separately from physical effects. This knowledge gap can be remedied by integrated research into energy-economic-environmental-political conditions and possibilities.

Annex C:

State/District Vulnerability and Adaptive Capacity in India

Note: The original source data used for derivation of state and district adaptive capacity was from 1990-1991 sources and may not reflect current circumstances.

Results from the Vulnerability-Resilience Indicators Model (VRIM)
The vulnerability of India and Indian states to climate change was assessed using the Vulnerability-Resilience Indicators Model (VRIM) (see box on page 25 for description).[cvii] Vulnerability here includes both adaptive capacity and climate sensitivity (i.e., potential negative impacts of climate change).

As in other quantitative rankings, India is ranked as more vulnerable than most countries to climate change; in a VRIM-assisted study of 160 countries,[cviii] India ranks low in the third quartile. The largest contributions to current vulnerability of India in the VRIM analysis are food security (as represented by total protein intake in the sensitivity aspect) and water availability (also in the sensitivity aspect). Rapid expansion in the use of groundwater, primarily for irrigation, has contributed significantly to agricultural and overall economic development in India, but in many arid and hard-rock zones, increases in overdraft areas and associated water-quality problems are emerging.

Specific comparative levels of adaptive capacity are shown in Figure 6. Adaptive capacity is lowest along the Indo-Gangetic Plain, higher in the northwest and south.

When sensitivity and adaptive capacity are combined into an overall comparative measure of vulnerability, small mountainous northern inland states tend to be ranked higher than coastal states, and only five states are ranked higher than the world average.

Interestingly, most of the variability in state-level sensitivity proxies (i.e., proxies that represent how large climate impacts are) results from variability in settlement and food sensitivity, i.e., social and economic factors. On the other hand, most of the variability in state-level proxies for coping and adaptive capacity results from environmental rather than economic or human resource factors. These results imply that social policies would be more likely to be effective in reducing sensitivity, while environmental protection policies would likely be more effective in increasing coping and adaptive capacity.

Many analyses attempt to measure these kinds of differences by using GDP per capita or some income measure as a summary proxy. However, this study shows no meaningful correlation between net domestic product (NDP) per capita in states and vulnerability of a state to climate impacts. Differences other than economic ones are of great importance. For example, literacy rates in the states range from 44 to 91 percent, life expectancy from 58 to 70 years. There are great disparities in natural resources and climate hazards among Indian states.

Figure 6. Coping and adaptive capacity comparative levels of India's states (average of four periods, 1990-2035). *Source:* based on Antoinette L. Brenkert and Elizabeth L. Malone, "Modeling vulnerability and resilience to climate change: a case study of India and Indian states," *Climatic Change* 72 (2005): 57-102.

Adaptive Capacity of Indian Districts

O'Brien et al.[cix] performed a detailed analysis of adaptive capacity at the district level in India; likely because of the focus on agriculture and the difference in variables measured, the results differ from the VRIM analysis. To measure adaptive capacity, the researchers used the following indicators:

- Biophysical indicators: soil conditions (the depth of the soil cover and severity of soil degradation) and groundwater availability (based on estimates of the total amount of replenishable groundwater available annually).
- Human and social capital: adult literacy rates, degree of gender equity in a district, and the presence of alternative economic activities (an indicator of the ability of farmers in a district to shift to other economic activities).
- Infrastructure: irrigation rates and quality of infrastructure (measured using the Infrastructure Development Index of the Center for Monitoring of Indian Economy).

The capacity index map shows higher degrees of adaptive capacity in districts located along the Indo-Gangetic Plains (except Bihar) and lower adaptive capacity in the interior portions of the country, particularly in the states of Bihar, Rajasthan, Madhya Pradesh, Maharashtra, Andhra Pradesh, and Karnataka.

O'Brien et al. measured sensitivity under exposure to climate change. They found the areas with high to very high climate sensitivity for agriculture to be located in the semi-arid regions of the country, including major parts of the states of Rajasthan, Gujarat, Punjab, Haryana, Madhya Pradesh, and Uttar Pradesh. Under the HadRM2 (the Hadley Centre's Regional Model) scenario, district climate sensitivity noticeably increased in Uttar Pradesh, Madhya Pradesh, and Maharashtra.

Vulnerability in India was assessed by summing a district-level index of adaptive capacity with an index of climate sensitivity under exposure. The districts with the highest/lowest sensitivity were not necessarily the most/least vulnerable. For example, most districts in southern Bihar exhibited only medium sensitivity to climate change, yet were still highly vulnerable as the result of low adaptive capacity. By contrast, most districts in northern Punjab showed very high sensitivity to climate change, yet were found to be only moderately vulnerable as the result of high adaptive capacity.

Last, the research team added factors representing exposure to globalization. Liberalization of agricultural trade may provide new opportunities for some Indian farmers to engage in production for export market, but also may expose many other farmers to competition from imported agricultural products. One example is the liberalization of trade in edible oils and oilseeds which led to a crash in domestic oilseed prices in the late 1990s due to imports of inexpensive Malaysian palm oil. For farmers in southern India, particularly in the state of Andhra Pradesh, this price crash, perhaps exacerbated by such factors as the inability to afford imported hybrid seeds, proved devastating and is associated with the beginning of a long wave of suicides by bankrupt farmers.

O'Brien et al. focused on exposure to import competition, with the result that high vulnerability was shown in most of Rajasthan and Karnataka, as well as in substantial portions of Bihar, Madhya Pradesh, Maharashtra, Gujarat, and Assam. Notable areas of low vulnerability occurred along the Indo-Gangetic plains. Districts, mostly concentrated in Rajasthan, Gujarat, Madhya Pradesh, as well as in southern Bihar and western Maharashtra, may be interpreted as areas of "double exposure," where globalization and climate change are likely to pose simultaneous challenges to the agricultural sector.

Several short case studies complement the broader-scale research. The case studies showed the effect that institutional barriers or support systems have on local-level vulnerability; this is not visible in the district-national profiles. In the cases of Jhalawar (Rajasthan) and Anatapur (Andhra Pradesh), institutional barriers leave farmers who are "double exposed" poorly equipped to adapt to either of the stressors, let alone both simultaneously. In Chitradurga (Karnataka), on the other hand, institutional support appears to facilitate adaptation to both climatic change and globalization. However, these supports tend to disproportionately benefit the district's larger farmers.

This paper does not represent US Government views.

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A COMMISSIONED RESEARCH REPORT

SPECIAL REPORT

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China: Impact of Climate Change to 2030
A Commissioned Research Report

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A Commissioned Research Report

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Scope Note

Following the publication in 2008 of the National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030, the National Intelligence Council (NIC) embarked on a research effort to explore in greater detail the national security implications of climate change in six countries/regions of the world: India, China, Russia, North Africa, Mexico and the Caribbean, and Southeast Asia and the Pacific Island States. For each country/region we are adopting a three-phase approach.

- In the first phase, contracted research—such as this publication —explores the latest scientific findings on the impact of climate change in the specific region/country.
- In the second phase, a workshop or conference composed of experts from outside the Intelligence Community (IC) will determine if anticipated changes from the effects of climate change will force inter- and intra-state migrations, cause economic hardship, or result in increased social tensions or state instability within the country/region.
- In the final phase, the NIC Long-Range Analysis Unit (LRAU) will lead an IC effort to identify and summarize for the policy community the anticipated impact on US national security.

The Joint Global Change Research Institute (JGCRI) and Battelle, Pacific Northwest Division (Battelle, PNWD), developed this assessment on the climate change impact on China through 2030 under a contract with SCITOR Corporation. The Central Intelligence Agency's Office of the Chief Scientist, serving as the Executive Agent for the DNI, supported and funded the contract.

This assessment identifies and summarizes the latest peer-reviewed research related to the impact of climate change on China, drawing on both the literature summarized in the latest Intergovernmental Panel on Climate Change (IPCC) assessment reports and on other peer-reviewed research literature and relevant reporting. It includes such impact as sea level rise, water availability, agricultural shifts, ecological disruptions and species extinctions, infrastructure at risk from extreme weather events (severity and frequency), and disease patterns. This paper addresses the extent to which regions within China are vulnerable to climate change impact. The targeted time frame is to 2030, although various studies referenced in this report have diverse time frames.

This assessment also identifies (Annex B) deficiencies in climate change data that would enhance the IC understanding of potential impact on China and other countries/regions.

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Executive Summary

China is well known for its size: it has the world's largest population, the third largest land area, the fourth (nominal) or second (purchase power parity) largest economy and is the second largest primary energy producer and consumer and the largest carbon dioxide emitter.[1]

As a major global player in human-caused climate change, China is vulnerable to the adverse impacts of climate change:

- Over the past century (1908 to 2007), the average temperature in China has risen by 1.1 degree Celsius.
- Although no significant trend was observed in nationally averaged precipitation amounts over the past 50 years, a drying trend was observed in the Yellow River Basin and North China Plain.
- Over the past 30 years, the sea level and sea surface temperature have increased 90 millimeters (mm) and 0.9^{o}C, respectively.
- ***China has experienced more extreme events (floods, droughts, storms) in recent years than ever before.*** The extreme weather events have caused direct economic losses of $25 to 37.5 billion in China per year.

One regional climate model projects a country-averaged annual mean temperature increase of 1.3-2.1°C by 2020 (2.3-3.3°C by 2050); another regional climate model projects a 1-1.6°C temperature increment and a 3.3-3.7 percent precipitation increase between 2011 and 2020, depending on the emissions scenario.

By 2030, sea level rise along coastal areas could be 0.01-0.16 meters, increasing the possibility of flooding and intensified storm surges, leading to degradation of wetlands, mangroves, and coral reefs. ***Agricultural growing seasons will lengthen and the risk of extreme heat episodes will increase. Storms may intensify, but warming temperatures are likely to enhance drying in already-dry areas, so both droughts and floods may increase.***

Compared to other countries, China ranks lower in resilience to climate change than Brazil, Turkey, and Mexico, but higher than India. China ranks high in food security, human health, and human resources. ***Projections of resilience show China gaining capacity quickly and outranking Brazil, Turkey, and Mexico by 2020.***

In recent years, the Chinese Government has paid increasing attention to the negative consequences of climate change. In 2007, China laid out its roadmap to battle climate change in *China's National Climate Change Program*, which was followed by a white paper in 2008 titled *China's Actions and Policies on Climate Change*. Both documents reviewed China's past achievements and presented its future plans in the following areas:

[1] Office of Energy Markets and End Use of the Energy Information Administration, "World Carbon Dioxide Emissions from the Consumption and Flaring of Fossil Fuels, 1980-2006," International Energy Annual 2006 Table H.1co2, December 8, 2008, http://www.eia.doe.gov/pub/international/iealf/tableh1co2.xls (accessed January 15, 2009).

- Strengthening government management in vulnerable sectors such as water resources, agriculture, forestry, and coastal regions.
- Building early-warning and monitoring networks.
- Raising public awareness.
- Enhancing R&D investment.
- Employing international resources.

China is thus demonstrating its determination to tackle climate change issues as an important domestic affair. However, some prominent climate impacts have seemingly not caught the government's attention, such as the underrated and underpublicized water crisis, as well as the underdeveloped social protection system. In addition, China must demonstrate an ability to implement its ambitious plans.

The negative consequences of climate change may expose the following sectors to high risk:

- **Water.** ***Scarcity of natural water resources, fast-growing urbanization and industrialization, severe water pollution, cheap water prices, and the adverse impacts of climate change on water sources may lead to a water crisis in China.*** The drought regions in northern China may be prone to social unrest caused by conflicts about water rights and distribution between social groups and between sectors. The expected South-to-North Water Diversion Project may alleviate the water stress of some northern regions, but it will not provide a full solution (and has in any case been delayed).[2] ***The forthcoming water crisis may impact China's social, economic, and political stability to a great extent.***
- **Coastal Regions.** ***Due to their flat and low landscape, China's coastal regions, the engine of China's economic achievement, are highly vulnerable to storm, flood, and sea-level rise.*** The increasing frequency and intensity of extreme weather events such as typhoons has threatened economic development at local, regional, and national levels. China has been actively developing early warning systems and related monitoring systems and improving the design standards of sea dikes and port docks. These efforts may help buffer some risk of natural weather extreme events.
- **Social and Political Uncertainties.** Facing a large unemployed population, China's underdeveloped social protection system is less and less able to protect those who need it. Rising expenses in health care, education and housing have been financial burdens for the average Chinese family. The export-oriented economy is vulnerable to a global financial crisis. The increasing dependence on foreign oil exposes China to an unstable world oil market. ***The adverse impacts of climate change will add extra pressure to existing social and resource (such as energy) stresses.*** Establishing an effective social protection system should be ranked high on the Chinese Government's long to-do list.

[2] E.L. Malone and A.L. Brenkert, "Vulnerability, sensitivity, and coping/adaptive capacity worldwide," *The Distributional Effects of Climate Change: Social and Economic Implications*, M. Ruth and M. Ibarraran, eds., Elsevier Science, Dordrecht (in press).

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Introduction and Background

China is the world's third largest country in terms of land area, after Russia and Canada. Its land sprawls from the plateaus and mountains in the west to the lower lands in the east. The Yellow River (or Huang He) and the Long River (or Chang Jiang) are the two main rivers running from west to east, flowing into the Pacific Ocean.

With soaring economic growth over the past two decades, China has successfully transformed itself into a global economic giant. In 2007, China's GDP reached $3.25 trillion (nominal) and $7.10 trillion (purchasing power parity, PPP), ranked as the fourth and second place in the world, respectively.[i] Meanwhile, China's thriving economy has placed the country as one of the top two carbon emitters for years. In 2006, China finally surpassed the United States and became the largest carbon emitter.[ii]

Mitigation of greenhouse gas emissions (GHG), along with energy conservation, has long been regarded as the key strategy for China to battle climate change. With the increasing number of extreme weather events, China has started to focus on adaptation and adaptive capacity building.

Since 1949, mainland China has been governed by the Chinese Communist Party (CCP). In 1978, CCP undertook an unprecedented economic reform, aiming to transfer China from a Soviet-style central planning economy to a system: "Socialism with Chinese characteristics." In the 30-year-long period of impressive economic growth, private sector and joint-venture companies have dominated China's manufacturing output. Meanwhile, the Chinese Government maintains firm control over such key sectors as banking, telecommunications, and energy.[iii] Media is a mixed story: the government sets boundaries for political coverage but grants the media more freedom to report social news. With 300 million Internet users,[iv] public opinions expressed on the Internet may play a role in directly or indirectly influencing China's social and political progress.

Although widely admired for achieving fast-paced economic growth, the most populous country (1.3 billion by the end of 2007), scores low for some of the economic indicators on a per capita basis. For example, China's GDP per capita ranked 109th (nominal) or 106th (PPP) among 181 countries, according to the World Bank in 2007. The Gini coefficient[3], a key indicator of income equity, reached an alarming .469[v] (UN 2008). In the late 1990s, nearly 30 million workers were unemployed due to the reform of state-owned enterprises. Millions of workers were left in a dire situation and found it difficult to support their families.[vi] The 2008 global financial crisis has hit coastal regions—where the export-oriented economy is dominating—hard.

Given the unbalanced regional economic development between the western and eastern regions of China, an underdeveloped social protection system for the poor, a new annual labor force of 10 million in a nearly saturated job market, as well as spotty terrorist activities led by Islamic extreme groups and the unrest from Tibetan anti-government organizations, social stability is China's top governance priority.

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[3] The Gini coefficient is a measure of statistical dispersion most prominently used as a measure of inequality of income distribution or inequality of wealth distribution. It is defined as a ratio with values between 0 and 1. A low Gini coefficient indicates more equal income or wealth distribution, while a high Gini coefficient indicates more unequal distribution.

Since 2005, CCP has advocated "building a harmonious society,"[vii] a political doctrine formally endorsed by the party in 2006. As *The Washington Post* suggests, it is "a move that further signaled a shift in the party's focus from promoting all-out economic growth to solving worsening social tensions."[viii]

In the midst of social and economic development, China has been distressed by its acute energy and environmental pressures. China's economy is mainly fueled by coal, which accounted for 76 percent of its primary energy production and 70 percent of primary energy consumption in 2005. Although coal is its cheapest and largest domestic fossil resource, China faces a daunting challenge for closing its energy gap and mitigating greenhouse gas emissions in a coal-based fast-growing economy. As the second largest oil importer after the United States, China's economy is vulnerable to the unstable international oil market. China has been known for its serious environmental problems as well: Two-thirds of the 338 Chinese cities for which air-quality data are available are considered polluted.[ix] Industrial sources have polluted more than 70 percent of Chinese rivers and lakes, while underground water in 90 percent of Chinese cities is also affected.[x]

The concept of a "harmonious society" has now extended to an environmental dimension – the government has urged society to have a harmonious relationship between nature and economic development.

China is a proven, tough negotiator in international discussions on mandatory mitigation targets. Mr. MA Kai, head of China's powerful National Development and Reform Commission (NDRC), stated clearly at the release of China's first national policy on climate change in 2007, "China will not commit to any quantified emissions reduction targets." Then, Mr. MA added, "…that does not mean [China] will not assume responsibilities in responding to climate change."[xi] Thus, China's current stance may be subject to change.

China has been actively developing national strategies and policies to deal with climate change. After the Earth Summit in 1992, China, being among one of the first participating countries, published *China's Agenda 21* in 1994—a white paper on China's strategies for sustainable development. In 1996, China for the first time addressed sustainable development as its key guideline and strategic goal for national social and economic development. In 2003, China established the National Coordination Committee on Climate Change, headed by the NDRC, and joined by 14 other Chinese Ministries and Administrations.[xii] In 2007, China released *China's National Climate Change Programme* (CNCCP), the first-ever roadmap outlining specific policy objectives, key areas of actions, and mitigation and adaptation policies to address climate change. China also formed the National Leading Group on Climate Change, headed by Premier Wen Jiabao the same year. In 2008, the State Council published an important white paper on *China's Policies and Actions for Addressing Climate Change* (CPAACC), which systematically introduced specific policies and measures on China's adaptive strategies since the release of CNCCP.[xiii]

China's stance on climate change, according to CNCCP, can be summarized as follows: [xiv]

(1) To address climate change within the framework of sustainable development.

(2) To follow the principle of "common but differentiated responsibilities" of the UNFCCC.

(3) To place equal emphasis on both mitigation and adaptation.

(4) To integrate climate change policy with other interrelated policies, and to promote climate change policies in a coordinated manner.

(5) To rely on the advancement and innovation of science and technology.

(6) To participate in international cooperation actively and extensively.

For the first time, the Chinese Government sought to place "equal emphasis on both mitigation and adaptation," although mitigation has long attracted investment and been the key strategy to battle climate change in China. The new stance signaled that China will enhance its investment in R&D, policy and regulatory support, and project development for building adaptive capabilities.

Regarding rising international pressures to reduce its soaring carbon emissions, President Hu, who spoke at the G-8 meeting held in summer 2008 in Japan, advanced three arguments to be considered: "(1) China is a developing country in the process of industrialization and modernization…, (2) China's per capita emissions are relatively low, and are even lower if calculated in accumulative terms..., and (3) as a result of changes in international division of labor and manufacturing relocation, China faces mounting pressure of international transferred emissions."[xv]

China and India, the two largest developing countries, are strong advocates of "common but differentiated responsibilities." The two countries urged developed countries to take the lead in reducing greenhouse gas emissions and called for developing countries to focus on poverty reduction and sustainable development. However, China has received much praise during recent climate forums for its impressive and hard mitigation efforts pushed by the central government,[xvi] while India was criticized for not yet "putting its shoulder to the wheel."[xvii]

China consists of 22 provinces, five autonomous regions (Tibet, Xinjiang Uyghur, Ningxia Hui, Inner Mongolia, and Guangxi Zhuang), four municipalities (Beijing, Tianjin, Shanghai, and Chongqing), and two special administrative regions (Hong Kong and Macau) (see http://en.wikipedia.org/wiki/File:China_administrative.gif#filehistory).

Projected Regional Climate Change

Current Climatology of China[xviii]

China extends from 53° to 18° N and from 73° to 134° E and has a wide range of complex topography (see http://www.askasia.org/images/teachers/media/43.gif) and climates. China's climate varies from tropical to cold temperate and from high mountain to desert. The most productive and populated part of the country is found in the coastal regions fronting the Pacific and the valleys of the three great rivers: Huang He, Chiang Jiang, and Xi Jiang. In addition, the outer territories of China consist of Manchuria in the northeast, Inner Mongolia in the north, Xinjiang Uygur in the west, and Tibet in the southwest. The southern borders with Pakistan, India, and Nepal consist of some of the most mountainous territory in the world.

The climate of central China and Manchuria is dominated by the great seasonal wind reversal called the Asiatic monsoon. From October until April winds tend to blow out from China and the heart of Asia under the influence of the great high-pressure system which develops in Siberia and central Asia at that time. From May until September or October, as the continent of Asia heats up, this area becomes one of low atmospheric pressure and winds are drawn into much of China, both from the Indian Ocean and the Pacific. These warm, moist winds bring most of the annual rainfall to Manchuria and China proper at that time. Tibet, Xinjiang Uygur, and Inner Mongolia, furthest removed from the influence of the sea, receive much less rain. China proper at that time. Tibet, Xinjiang Uygur, and Inner Mongolia, furthest removed from the influence of the sea, receive much less rain.

North China, including Manchuria, has extremely cold winters of almost Siberian severity; Inner Mongolia and Xinjiang Uygur share in this winter cold. Tibet, a great upland plateau rimmed by some of the highest mountains in the world, has cool summers and very cold winters. In the northwest, Turphan sits in a depression 150m below sea level and is referred to as the "hottest place in China" with maximums of around 47^{o}C.

South and central China have a tropical or subtropical climate with no real winter cold. Eastern China has abundant summer rain while the northern and western regions contain much desert and semi-desert.

The coastal regions occasionally receive very heavy rainfall from typhoons, or tropical cyclones, which intensify in the South China Sea and move northeastward along the coast. The very strong winds associated with these disturbances are most severe in the coastal belt. Typhoons are most frequent from July to October.

South China is partly within the tropics and is the warmest and wettest part of the country in summer. Rainfall is very heavy between May and September along the coast and abundant inland. Winters are mild and frost almost unknown.

Maps showing average annual temperature, precipitation, and vegetation cover are available at http://www.chinamaps.org/china/china-temperature-map.html; http://www.chinamaps.org/china/china-map-of-precipitation.html; http://www.chinamaps.org/china/china-land-cover-map-large-2.html).[xix]

Vast arid and semi-arid desert regions in northwestern China and along the boundary area of China and Mongolia produce dust storms that can occur in any season including in summer and fall. The largest storms mainly occur in spring. These storms affect not only China and Mongolia but also areas downwind including Korea, Japan, and even the Pacific, Hawaii and the west coast of North America. Understanding and quantifying the climatic effect of the aeolian dust, mostly consisting of mineral aerosols, from these storms is important for predicting climate change in China.

China has two of the Earth's major natural dust sources: the Taklamakan Desert in the west China and the Gobi Desert in Mongolia and northwest China.

Estimates of the amount of dust produced annually from China's desert vary greatly. One study (Zhang et al)[xx] derived an annual dust production of 800 megatons (ranging from 500–1100 megatons) from China deserts, which included Taklamakan Desert and Gobi Desert in Inner Mongolia. In another study[xxi] a detailed analysis was conducted on one major dust event (April 2001) and it was found that the total dust production for all particles (diameters less than 36 mm) was about 643 megatons over a ten day period the period. The estimated emissions from this one event are almost equal to the estimated total annual emissions from Zhang et al.

A number of factors influence the annual production of dust, including meteorological conditions, climatic cycles such as El Niño–Southern Oscillation and North Atlantic Oscillation, and changes in land-use and land-cover, including the increasing desertification noted in some regions of China. Using a dust emission model, the relative contribution to the annual dust emissions from Mongolia, Taklimakan and Badain Jaran were 29 percent, 21 percent and 22 percent of the Asian dust, respectively.[xxii] (For a map of global worldwide emissions of dust, see T.D. Jickells, R.A. Duce, K.A. Hunter, et al. "Global Iron Connections Between Desert Dust, Ocean Biogeochemistry, and Climate." *Science* 308 (April 1, 2005): 67)

The direct and indirect atmospheric radiative forcing by dust has implications for global climate change and presently is one of the largest unknowns in climate models. Development of a better parameterization of the effects of dust on climate change is important to building a better climate model.

China has about 50,000 rivers located mostly in the southern and eastern areas of the country. More than 1,500 of these rivers lie in basins of at least 1,000 km^2. Major rivers include theYangtze, Yellow, Soughua, Liaohe, Haihe, Huaihe and Pearl Rivers. These river basins, inhabited by 50 percent of China's population and contributing to over 2/3 of China's agricultural and industrial production, frequently experience significant flooding. The climate in these regions is dominated by the East Asia monsoon in the summer and by continental air currents in winter.

China's history is filled with reports of the frequent flooding of major rivers. Natural disasters such as floods destroy (on average) a reported 4,182,000 houses per year with some four million people per year needing to be urgently resettled or transferred from their homes.[xxiii] Because of the high population density in the river basins, floods in China generally affect large numbers of victims. The Yangtze Basin is home to 400 million people, with an average density of 214 people/km^2, making it the most densely populated basin in the world. The Yangtze River floods in China in 1991 and 1998 affected a total of 210 million and 238 million people respectively. The latter disaster forced China to request international aid for the first time.

Climate Observations

China's Assessment Report on Climate Change[xxiv] includes an evaluation of mean temperature, precipitation, and other climate data from 740 stations across Mainland China. Annual mean surface air temperature in Mainland China as a whole rose by about 1.1 ^{o}C for the last 50 years, with a warming rate of about 0.22 ^{o}C per 10 years. This rate of warming is significantly higher than the 100-year linear warming trend (1906-2005) of 0.74 ^{o}C observed at the global scale.[xxv] The largest warming occurred in winter and spring and in Northeast China, North China and Northwest China. A cooling trend was observed in Southwest China, as reported in earlier studies. Summer mean temperature in the middle and lower reaches of the Yangtze River also decreased in the last 50 years.

No significant trend was observed in nationally averaged precipitation amounts over the past 50 years. However, a drying trend was observed in the Yellow River Basin and North China Plain, with the largest drop in precipitation amounts occurring in Shandong Province. A small increase in annual precipitation was observed in the Yangtze River Basin, resulting primarily from increased summer rainfall.

Since 1956, the country-averaged pan-evaporation rate (a measure that corrects for temperature, humidity, solar radiation etc.) has decreased a small amount, although this could be due to a reduction in solar radiation at the surface. In parts of the North China Plain, annual sunshine duration in the recent years is almost 500 hours fewer than that of 50 years ago. Some studies have suggested that there are changes in the frequency and magnitude of extreme weather and climate events over the past 50 years;[xxvi] however, this is not universally accepted.

There has been a significant increase in aerosol pollution throughout China, especially in the urban areas. Menon[xxvii] has suggested that the observed trend toward increased summer floods in south China and drought in north China, thought to be the largest change in precipitation trends since 950 A.D.,[xxviii] may have an alternative explanation: human-made absorbing aerosols in remote populous industrial regions that alter the regional atmospheric circulation and contribute to regional climate change. Menon's research also suggests that the spatially varying atmospheric heating caused by black carbon (BC) alters the Asian summer monsoonal circulation causing the change in precipitation patterns over China.

Regions at higher latitudes are experiencing a faster rate of warming than the more temperate regions. Mongolia, particularly around Lake Hovsgol, has been warming more than twice as fast as the global average. Winter temperatures in Mongolia have increased a staggering 3.6°C on average during the past 60 years.[xxix]

Climate Predictions (Modeling)

Although Global Circulation (or Climate) Models (GCMs) can be used to infer climate changes in specific regions, it is far preferable to develop models that have a high resolution sufficient to resolve local and regional scale changes. There are many challenges in reliably simulating and attributing observed temperature changes at regional and local scales. At these scales, natural climate variability can be relatively larger, making it harder to distinguish long-term changes expected due to external forcings.

The procedure of estimating the response at local scales based on results predicted at larger scales is known as "downscaling." The two main methods for deriving information about the local climate are (1) dynamical downscaling (also referred to as "nested modeling" using "regional climate models" or "limited area models") and (2) statistical downscaling (also referred to as "empirical" or "statistical-empirical" downscaling).[xxx] Chemical composition models include the emission of gases and particles as inputs and simulate their chemical interactions; global transport by the winds; and removal by rain, snow, and deposition to the earth's surface.

Downscaled regional- scale climate models rely on global models to provide boundary conditions and the radiative effect of well-mixed greenhouse gases for the region to be modeled. There are three primary approaches to numerical downscaling: (1) limited-area models, (2) stretched-grid models, and (3) uniformly high resolution atmospheric GCMs (AGCMs) or coupled atmosphere-ocean (-sea ice) GCMs (AOGCMs).

The magnitudes and patterns of the projected rainfall changes differ significantly among models, probably due to their coarse resolution. The Atlantic and Pacific Oceans are strongly influenced by natural variability occurring on decadal scales, but the Indian Ocean appears to be exhibiting a steady warming. Natural variability (from El Niño- Southern Oscillation [ENSO], for example) in ocean-atmosphere dynamics can lead to important differences in regional rates of surface-ocean warming that affect the atmospheric circulation and hence warming over land surfaces.

Including sulfate aerosols in the models damps the regional climate sensitivity, but greenhouse warming still dominates the changes. Models that include emissions of short-lived radiatively active gases and particles suggest that future climate changes could significantly increase maximum ozone levels in already polluted regions. Projected growth of emissions of radiatively active gases and particles in the models suggest that they may significantly influence the climate, even out to year 2100.[xxxi] Atmospheric brown clouds, plumes of polluted air moving from the Asian continent out over the Pacific Ocean, may cause precipitation to increase over the Indian Ocean in winter and decrease in the surrounding Indonesia region and the western Pacific Ocean, causing a reduction in summer monsoon precipitation in South and East Asia.

Stabilization emissions scenarios assume future emissions based on an internally consistent set of assumptions about driving forces (such as population, socioeconomic development, and technological change) and their key relationships. These emissions are constrained so that the resulting atmospheric concentrations of the substance level off at a predetermined value in the future. For example, if one assumes the global CO_2 concentrations are stabilized at 450 parts per million (ppm) (the current value is about 380 ppm), the climate models can be tuned to produce this result. The tuned model predictions for regional climate changes can be used to assess specific impacts at this stabilization level. A more detailed discussion of the ability of the models to project regional climate changes can be found in Appendix A.

Climate Projections of Future Temperature and Precipitation

Climate changes in temperature and precipitation over China have been projected based on a regional climate model developed by the National Climate Center/China Meteorological Administration (NCC/CMA) and the Institute of Atmospheric Physics/Chinese Academy of Sciences (IAP/CAS).[xxxii]

Gao et al.[xxxiii] worked with a regional climate model (named RegCM/China), a modified version of the NCAR/RegCM2 model, to make climate projections up to the year 2100. The model results indicate that a significant warming will occur in the 21st century in China, with the largest warming occurring in winter and in the northern portions of China. Under varied emission scenarios of greenhouse gases, the country-averaged annual mean temperature is projected to increase by 1.3-2.1°C by 2020, 2.3-3.3°C by 2050, and 3.9-6.0°C by 2100. The model also projected a 10 percent-12 percent increase in annual precipitation in China by the year 2100, with the increases particularly evident in Northeast China, Northwest China and the Tibetan Plateau. Central China was projected to undergo a drying trend. The model indicated that anthropogenic climate change probably will lead to a weaker winter monsoon and a stronger summer monsoon across East Asia.

Yinlong et al.[xxxiv] worked with PRECIS, (Providing Regional Climates for Impacts Studies), a regional climate model, to obtain high-resolution projections of future climate over China. PRECIS was used to analyze the climate change in the 21st century over China under the A2 and B2 GHGs emissions assumptions constructed in the 2000 *Special Report on Emissions Scenarios* (SRES).[xxxv] PRECIS is a Regional Climate Model (RCM) developed at the UK Met Office Hadley Centre for Climate Prediction and Research with a high horizontal resolution of 50 km-50 km and 19 vertical layers. The model is capable of running at a resolution of 1.875^{o} in longitude and 1.25^{o} in latitude.

The model projected changes of surface air temperature and precipitation for three time-slices of the 21st century. By the third time slice, 2071-2100, the temperatures in Northeast China, North China, and Northwest China are projected to increase, while the precipitation amounts are projected to decrease under the SRES B2 scenario. The climate would become warmer and drier over these three regions in the northern part of China; and the precipitation over Central China,

Table 1 Average changes of surface air temperature and precipitation under SRES A2 and B2 scenarios over China from PRECIS simulation relative to baseline (1961–1990), plus corresponding CO_2 concentrations

Time-slice	A2			B2		
	Temperature increment /℃	Precipitation increase /%	CO_2 / (mL/m³)	Temperature increment /℃	Precipitation increase /%	CO_2 / (mL/m³)
2011–2020	1.00	3.3	440	1.16	3.7	429
2041–2050	2.11	7.0	559	2.20	7.0	492
2071–2080	3.89	12.9	721	3.20	10.2	561

Table 2 2071–2100 average changes of mean temperature and precipitation under SRES B2 scenario over seven regions from PRECIS relative to 1961–1990

Regions	Temperature change / ℃					Preciptation change / %				
	Annual	Spring	Summer	Autumn	Winter	Annual	Spring	Summer	Autumn	Winter
Northeast China	3.8	3.1	4.7	3.6	3.9	4	2	1	0	43
North China	3.5	2.9	4.1	3.2	3.8	14	28	2	9	63
Central China	3.0	2.6	3.5	2.9	3.0	11	17	8	4	2
East China	2.7	2.4	2.9	3.0	2.8	9	12	11	−8	2
South China	2.8	3.1	3.0	2.4	2.9	8	13	15	2	−36
Southwest China	2.9	2.6	3.1	2.7	3.1	9	8	7	6	8
Northwest China	3.7	3.0	4.2	3.8	3.7	13	22	4	−2	38
Whole China	3.3	2.9	3.8	3.3	3.5	10	13	6	3	9

East China, and South China would increase largely in summer (not as much in winter); the precipitation in South China in winter would obviously decrease. This means that both the flooding in summer and drought in winter would be enhanced over these three regions in the southern part of China.

Tables 1 and 2 show the results of the analysis. The PRECIS model runs project that average temperature increments at the end of the 21st century over China will be over 3°C, while the percentage of precipitation is projected to increase by 10 percent under SRES A2 and B2 scenarios. The ratio of maximum/minimum surface air temperature during the 2080s under the B2 scenario is projected to increase; changes in extreme events are discussed below.

Projections of Sea Level Changes

A significant fraction of sea level rise is due to thermal expansion of a warmed ocean (as much as 0.3 to 0.8 meters over the last century, according to the Intergovernmental Panel on Climate Change (IPCC)[xxxvi]). Geographic patterns of sea level rise are due mainly to changes in the distribution of heat and salinity in the ocean, resulting in changes in ocean circulation. Precise satellite measurements since 1993 show that the largest sea level rise since 1992 has taken place in the western Pacific and eastern Indian Oceans. There is a large interannual variability in sea level rise associated with patterns of coupled ocean-atmosphere variability, including El Niño-Southern Oscillation (ENSO) and the North Atlantic Oscillation (NAO).

Much of China's coastline is vulnerable to sea level rise. Storm surges, droughts, and other extreme climate events are the main cause of coastal disasters. The Yellow River Delta, the Yangtze River Delta, and the Pearl River Delta are the most vulnerable coastal regions in China. By 2030, the sea levels along China's coastal areas could rise by 0.01-.16 meters,[xxxvii] increasing the possibility of flooding and intensified storm surges. These disasters could increase coastal erosion, degrade coastal ecosystems such as wetlands, mangroves, and coral reefs, and exacerbate saltwater intrusion. In particular, sea level rise would cause significant degradation of wetland, and submergence/erosion of tidal flat land in the Yangtze River Delta. The South China region is also especially susceptible to sea level rise, estimated to be between 0.60-0.74 meters by 2100. This would adversely affect low-lying and damp areas in the Pearl River Delta more than other places. In this case, the border lines of mangrove areas are likely to move northward and the scope of coral bleaching is likely to expand.

Projections of Changes in Agricultural Growing Seasons
The following describes a simulation of the present and future climate using the Regional Integrated Environment Modeling System (RIEMS) and the SRES A2 emissions scenario:[xxxviii]

- The simulated climatic belts, climatic seasons, and Yellow River ice phenology in China are compared between the present climate during 1975–1984 and the future climate during 2035–2044.[xxxix] Compared to 1975-1984, most of the climatic belts in China will shift northward in 2035-2044, by a maximum of 1.5-2° of latitude. The southern boundary of the Northern Sub-tropical Belt (NSB) will shift northward significantly, in spite of the little change in its northern boundary. The entire Southern Sub-tropical Belt (SSB) and the Middle Sub-tropical Belt (MSB), as well as the northern boundary of the Warm Extra-tropical Belt (WEB), will also shift northward by 1-2°of latitude. The starting dates of spring and summer will mostly advance, opposite to the delays in the starting dates of autumn and winter. As a whole, the summer in China will grow longer by 26.1 days, while spring, autumn, and winter will become shorter by 6.8, 7.9, and 11.4 days, respectively. In the upper reach of the Yellow River (URYR), the date for enduring sub-zero temperatures will be delayed by eight days and the date for enduring above-zero temperatures will advance by five days. In the lower reach of the river, the date for enduring sub-zero temperatures will be delayed by four days and the date for enduring above-zero temperatures will advance by four days.

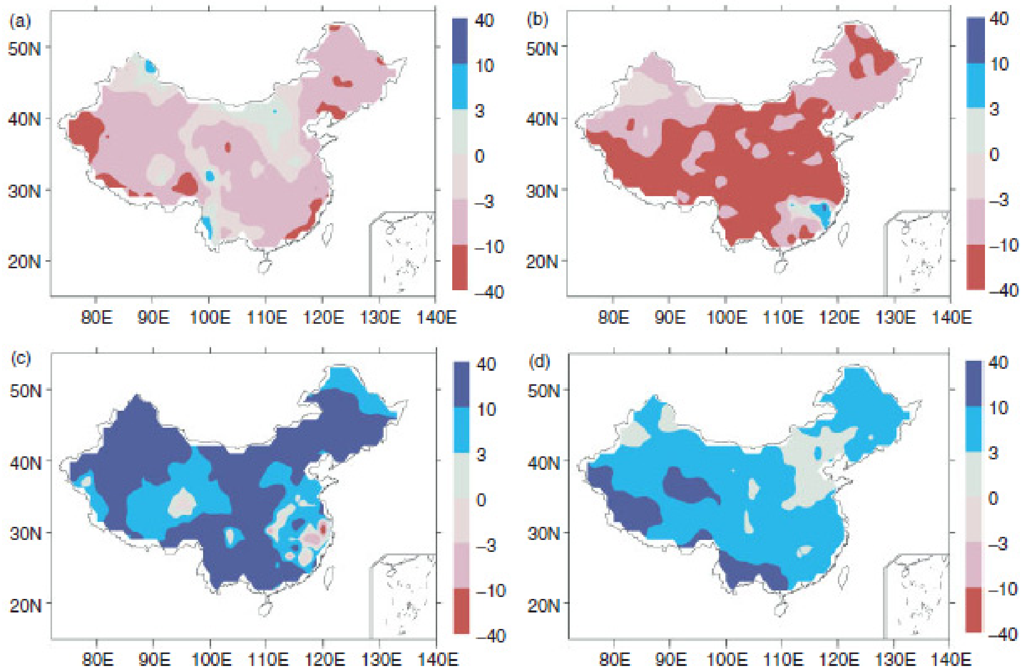


Figure 1. Differences in the starting dates of spring (a), summer (b), autumn (c), and winter (d), between 1975-1984 and 2035-2044. Positive (negative) values represent postponed (advanced) days. Units are in days.

Figure 1 (above) shows the changes in the starting dates of various seasons from 1975-1984 to 2035-2044 when the CO_2 concentration increases by 0.77 times that of the former period. In the spring (a), the starting dates change little in part of southwestern and northwestern China and central-western inner Mongolia, but they are moved forward in the rest of China by more than 10 days in part of Xinjiang and between three and 10 days in a large part of the country including the northeastern and western and central-southeastern areas of China. The biggest advance in the starting dates of seasons occurs in summer (b). Except for part of Fujian province in the southeast, the starting dates of summer move forward by more than three days in most of China. In a large portion of the country, the summer season advances by more than 10 days. Delays in the starting dates of seasons are most pronounced in autumn (c). These delays are generally more than three days, except in part of southeastern China. In northwestern, southern-southwestern China, and central-northern China, the starting dates of autumn are delayed by more than 10 days. The starting dates of winter are postponed by more than three days in a major portion of the country (d). In parts of western and southwestern China, the delays are more than 10 days.

It has been suggested that absorbing aerosols may have masked up to 50 percent of the surface warming in South Asia from the global increase in greenhouse gases. In cases where aerosols act to suppress rainfall (the second aerosol indirect effect), drier conditions tend to induce more dust and smoke due to the burning of drier vegetation, affecting both regional and global hydrological cycles and agricultural production.

Changes in the Frequency or Strength of Extreme Climatic Events

Extremes are the infrequent events at the high and low end of the range of values of a particular variable. The probability of occurrence of values in this range is called a probability distribution function (PDF) that for some variables is shaped similarly to a "Normal" or "Gaussian" curve (the familiar bell-shaped curve).

People affected by an extreme weather event wonder whether climate changes due to human influences are responsible. It is difficult to attribute any individual event to a change in the climate. In most regions, instrumental records of variability typically extend only over about 150 years, so there is limited information to characterize how extreme rare climatic events could be. Further, several factors usually need to combine to produce an extreme event, so linking a particular extreme event to a single, specific cause is problematic. In some cases, it may be possible to estimate the anthropogenic contribution to such changes in the probability of occurrence of extremes.

As the climate changes and sea surface temperatures (SSTs) continue to increase, the conditions that cause tropical storms to form are no longer the same. Higher SSTs are generally accompanied by increased water vapor in the lower troposphere; thus, the moist static energy that fuels convection and thunderstorms is also increased. Hurricanes and typhoons currently form from pre-existing disturbances only where SSTs exceed about 26°C; so, as SSTs have increased, the areas over which such storms can form are potentially expanded. However, many other environmental factors also influence the generation and tracks of disturbances.

The 2007 IPCC assessment concluded that there was a risk of increased temperature extremes, with more extreme heat episodes in a future climate in China. This result has been confirmed and expanded in more recent studies. Future increases in temperature extremes are projected to follow increases in mean temperature over most of the world except where surface properties (e.g., snow cover or soil moisture) change. There is still much debate over whether there is likely to be an increase in tropical cyclone intensity.

Changes in tropical storm and hurricane frequency and intensity are often masked by large natural variability. The El Niño-Southern Oscillation greatly affects the location and activity of tropical storms around the world. Globally, estimates of the potential destructiveness of hurricanes show a substantial upward trend since the mid-1970s, with a trend toward longer storm duration and greater storm intensity, and the activity is strongly correlated with tropical SSTs. One study[xl] found a large increase in numbers and proportion of hurricanes reaching categories 4 and 5 globally since 1970, even as the total number of cyclones and cyclone days decreased slightly in most basins. The largest increase is in the North Pacific, Indian and Southwest Pacific Oceans.

The geography and climatology of China enables the frequent occurrence of extreme events. Summer storms move eastward along the river systems, dumping large amounts of rainfall that can cause severe flooding. As a harbinger of the projected intensification of extreme events in southern and eastern China, Chongqing and Sichuan in the upper Yangtze Basin generally experience a once-every-100-years drought, but was subject to rare flooding in 2007.[xli]

Half of the country's land area is arid or semiarid. Water shortages in northern China over the past three decades have been severe and led to the ongoing construction of the South-North Water Diversion Project, a gigantic project that will divert water from three points of the

Yangtze River basin to the north. Global warming is likely to enhance such drying. China's agricultural output could be reduced by 5-10 percent by 2030, adding stress to a country that has 20 percent of the world's population and only 7 percent of the arable land. Major ecosystem impacts can be expected with the loss of tundra and mountain forests and the intensification of wildfires.

Gao[xlii] recently studied the possible changes of extreme events due to climate change (in a 2x CO_2 scenario) over East Asia, with a focus on the China region as simulated by a regional climate model (RegCM2). His results show a measurable increase in both daily maximum and daily minimum temperatures. The overall diurnal temperature range decreased. The number of days with extreme heat increased, while the number of extreme cold decreased. There was an increase in the number of rainy days and heavy rain days over some sub-regions of China. There was also a change in the frequency of tropical storms affecting the coastlines.

Application of the PRECIS regional model[xliii] to study extreme events showed that the occurrence frequency of extremely high-temperature and extreme precipitation events is expected to increase, while extremely low temperature events are projected to decrease. Drought with high temperature events may become more common in the northern part of China, while flooding in summer in the part of China is expected to increase. The models that have been applied to analyze extreme events in China show some differences, but overall they indicate a general trend of an increasing frequency of daily high temperature extremes, a decrease in the frequency of daily minimum temperature extremes, an increase in both the intensity of precipitation events and the frequency of extreme precipitation events, and an increase in the occurrence of droughts or dry spells. The biggest problem in performing analyses of extreme events for most of the globe is a lack of access to high-quality, long-term climate data with the appropriate time resolution.

China is located in the East Asian monsoon region, where arid and semiarid climate dominates in the northern parts of the country. In this region, the strength of monsoon circulation can cause not only drought/flood and cold/warm events, but also windy conditions and air pollution. Some of the early records of dust storm activity in the world are recorded in ancient Chinese literature referring to dust falls in northern China as ‘‘yellow wind’’ or ‘‘black wind,’’ as well as ‘‘dust rain’ or ‘‘dust fog.’’ Dust storms usually occur in the spring and early summer.

Dust storm frequency in the region has increased in the past decade. Although increasing desertification has likely contributed to the increases in dust storms, the increase over the past three years is more logically explained by changes in weather and climate than desertification because the land area affected by desertification changes relatively little over a few years.

China is subject to extensive damage from flooding of its river basins. The Yangtze River flood of 1998 in China submerged more than 21 million hectares of farmland, an area about seven times the size of Belgium. The flood produced an estimated 238 million victims and the cleanup cost was an estimated $30 billion. Clearly, increasing flooding of the river valleys due to climate change will have a significant impact on the country.

Impacts of Climate Change on Natural Ecosystems

Clearly a wide range of environmental observations support the fact that rapid climate change is under way in China.

Since the 1960s, forest cover on Mount Qilian has decreased by 16.5 percent, and its forest belt moved up 400 meters. In Sichuan Province, grass production and quality have decreased. In southwest China, the Sanjiang (Three-River) Plain, and Qinghai Province wetlands have shrunk and their functions declined. Since the 1950s, mountain disasters in Southwest China are more frequent and the losses they have caused have increased. Climate change has raised the potential for disease incidence and transmission, particularly of vector-borne infectious diseases.[xliv]

China's natural systems have witnessed evident impacts of climate change on water resources, sea level rise, forestry, permafrost and glaciers, and deserts.

Water Resources

Besides human development, climate change has been revealed as a key factor in the changes of water resources in China.[xlv] Drought has hit wider areas in northern China and flooding has increased in southern China. Instability in agricultural production has been rising since the 1980s. As plants bud and flower earlier, they are more subject to crop damage from spring frost, which has increased. Also over the past two decades, optimum areas for growing winter wheat in Northeast China have moved northward and extended westward. Production of certain varieties of maize that have a relatively long growth period and high yield have increased overall productivity.

Since the 1950s,[xlvi] water runoffs to six large rivers in China have all been decreasing, with the largest decrease along the Haihe River. Some rivers in northern China face intermittent flow. Large flooding events occurred along the Yangtze, Pearl, Songhua, Huaihe, and Yellow Rivers as well as the Taihu Lake in the 1990s, resulting in increasingly heavy losses. Climate change and sea level rise have already affected China's coastal areas, where the economic losses from storm surges, flooding, heavy rains, drought and other serious climatic events are significant. The Yellow River Delta, Yangtze River Delta, and Pearl River Delta are more vulnerable to storm surge, coastal flooding, shoreline erosion, and losses of wetlands than other coastal places.

Due to the decrease in annual mean runoff, the Ningxia Hui Autonomous Region and the Gansu Province, two neighboring arid provinces in northwestern China, are in danger of facing serious water shortages in the next 50 to 100 years. The Inner Mongolia Autonomous Region and the Xinjiang Autonomous Region, two adjacent provinces of the Ningxia Hui Autonomous Region, may also experience an increasing gap between water supply and demand during the same period. Meanwhile, Hubei and Hunan provinces, two bordering provinces located in the Yangtze River, will face more flooding in the near future.[xlvii]

Sea Level Rise

Over the past 30 years, along the Chinese coast, the sea level and sea surface temperature have increased by 90 millimeters (mm) and 0.9^{o}C, respectively.[xlviii] Sea level rise has not only resulted in seawater intrusion, soil salinization and coastal erosion, but also threatened coastal and marine ecosystems such as mangrove swamps and coral reefs. The rising sea temperature has also degraded marine fishing resources.[xlix]

Liu et al.[l] report that since the 1950s the rates of sea level rise along China's coastline have been between 1.4-3.2 mm per year; marine ice condition on the surface of Bohai Sea and Yellow Sea has decreased; glacier areas in Northwest China have decreased by 21 percent over the past 50 years; the permafrost in Tibet has gotten thinner by up to 4-5 meters; the water levels of some high plateau inland lakes have risen; and grassland production in Sichuan, Qinghai, and southern

Gansu Provinces have decreased. In recent years, coral bleaching has been observed in the coastal of Hainan and Guangxi Provinces.

Forest

The observed impacts of climate change on forestry and other natural ecosystems may be reflected by the northward shift of the northern boundaries of eastern subtropical and temperature zones, the upward move of vertical spectrum of forest belts, increasing frequency of plant diseases and insect pests (such as the American white moth and the pinewood nematode[li]), and increasing forest fires.[lii]

However, as many studies reveal, climate change may bring some positive impacts on China's forestry productivity and output.[liii,liv,lv] Data show that the growing season has been extended by 1.4 to 3.6 days per year in the northern regions and by 1.4 day per year across the country between 1982 and 1993.[lvi] According to a Chinese study published in 2007, net primary productivity grew by 11.5 percent between 1982 and 1999 due to climate change.[lvii]

Permafrost and Glaciers

The Qinghai-Tibet Plateau has the most extensive high-altitude permafrost on earth—one of the most sensitive regions to climate change.[lviii] The Plateau, taking up 25 percent of China's land area, is sometimes called the "water tower of Asia."[lix]

The more pronounced temperature changes in the western and northern parts of China may lead to shrinking permafrost and reduced glacier areas in the Qinghai-Tibet Plateau. The permafrost thickness there decreased a maximum of 4-5 meters, and the glacier areas in northwestern China decreased by 21 percent in the past 50 years.[lx] It is estimated that by 2050 glacier areas in western China will decrease by 27.7 percent, and the spatial distribution of permafrost will face significant change in the Qinghai-Tibet Plateau.[lxi]

Higher average temperatures in summer are thawing permafrost in Mongolia as well and disturbing the soil structure around the shallow tree roots. Scientists working in Mongolia have noted that the mountains are losing their snowcaps, and the glaciers on the northern shore are shrinking.

In the past decade, Mongolia has experienced four of the worst drought years on record. And during the same period, intense storms have grown more frequent, according to a recent IPCC Assessment Report on the impacts of climate change.[lxii] As permafrost retreats deeper or disappears, the ground becomes a giant sponge that removes water away from plant roots. As the taiga forest grows thinner and with the loss of the insulating tree cover, the soil warming accelerates. The drying soil and dying vegetation create a flashpoint, raising the risk of wildfires in an area without firefighting equipment or teams. Wildfires are growing more frequent and fiercer. If the topsoil eroding into Hovsgol's tributaries spurs algal growth in the lake, it could ruin the region's best source of drinking water.

A study of glaciers in the Himalayas show that they are now receding at an average rate of 10-15 meters per year.[lxiii] These glaciers collect water during the monsoon season and release it during the dry season, providing irrigation water for crops. If the rate of glacial melt increases, flooding is likely to occur in the river valleys fed by the glaciers. Later, as the river flows decrease to below previous rates, many people may be left without sufficient drinking water or water for irrigating crops. The rapid shrinking of No 1 Glacier on Tianshan Mountain in Northwest China's Xinjiang Uygur Autonomous Region is a clear warning of the reality of climate change.

The shrinkage is taking place at the rate of 3.5 meters a year on the eastern part of the glacier and 5.9 meters a year on the western part. The glacier has been in a state of retreat since the 1950s. The continuous shrinking split the glacier into two independent glaciers in 1993. From 1958 to 2004, the average thickness of the glacier decreased by 12 meters and the volume of ice loss reached more than 20 million cubic meters. Long-term observations from 1962 to 2006 showed that the glacier's area decreased by 270,000 square meters at an accelerating rate.

Deserts

Desert expansion has accelerated with each successive decade since 1950. China's Environmental Protection Agency reports that the Gobi Desert expanded by 52,400 square kilometers (20,240 square miles) from 1994 to 1999, an area half the size of Pennsylvania. With the advancing Gobi now within 150 miles of Beijing, China's leaders are beginning to sense the gravity of the situation. The dust bowl currently forming in China is much larger than the one that formed in the Great Plains of the United States during the 1930s when the US population was only 150 million—compared with 1.3 billion in China today.

The increase of dust storms may also lead to severe air pollution episodes, destruction of vegetation, erosion of surfaces, and change in soil pH values, affecting agricultural production, downwind of their source.

Impacts of Climate Change on Human Systems

Climate change has substantially stressed China's economic and social development, especially evident in agriculture and along coastal regions, as well as the energy sector. The increasing frequency and intensity of extreme weather events have brought significant damage to local economies and infrastructure but also attracted national attention to the adverse impacts of climate change.

Agriculture

Agriculture is highly dependent on temperature, precipitation, and water resources, which are greatly affected by climate change. According to CPAACC,[lxiv]

- Climate change has already produced visible adverse effects on China's agriculture and livestock sectors, manifested by increased instability in agricultural production, severe damages to crops and livestock caused by droughts and high temperatures, aggravated spring freeze, and decline in the output and quality of grasslands.
- China expects that the adverse impacts on agriculture and livestock will reduce crop production, such as wheat, paddy rice and corn; change the agricultural production structure; accelerate the decomposition of organic elements in the soil; expand the affected areas suffered from crop diseases and insect pests; degrade grasslands; increase natural fire disasters; reduce livestock production; and increase the risk of livestock epidemics.

Due to the impact of climate change, spring phenophase, a key indicator of crop response to recent regional climate change,[lxv] has advanced two-to-four days since the 1980s.[lxvi] A study conducted by Du et al. (2004) shows observed increases in animal production in Tibet related to the rise of annual temperature, especially during the summer season.[lxvii]

Recent studies[lxviii] show that climate change is likely to significantly influence China's agricultural output. By 2030, overall crop productivity in China could decrease by as much as 5-10 percent if no action is taken. By the second half of the 21st century, climate change could cause reductions in yields of rice, maize and wheat of up to 37 percent. In the next 20-50 years, agricultural production may be seriously affected, compromising long-term food security in China. The North China Plain is the largest agricultural production area in China. The extensive use of groundwater for irrigation agriculture under variable climatic conditions has resulted in the rapid decline of the groundwater table, especially in areas north of the Yellow River, leading to hydrological imbalance and unsustainable agricultural production. Future climate change is likely to exacerbate the problem.

If the negative impacts of climate change are not effectively controlled, Chinese experts warn that the production of wheat, rice, and corn will be reduced by 37 percent in the late 21st century. From 2010 to 2030, western China would suffer a water shortage of 20 billion cubic meters.[lxix]

Coastal Regions
China's coastal regions consist of eight provinces, two municipalities (Shanghai and Tianjin) and two special administrative regions (Hong Kong and Macao). The regions account for 16.8 percent of China's total land areas, 41.9 percent of its population, and 72.5 percent of China's GDP (including Hong Kong and Macao).[lxx]

With about 144 million square meters, China's low coastal lands, with an elevation less than 5 meters, are the major areas vulnerable to sea level rise and extreme climate events such as storm surges and typhoons. Since the 1960s, these areas have observed increasing frequency and intensity of tropical storms, while the frequency of both the Northwest Pacific tropical cyclones and the related landfall events over China has been decreasing, on average, during the same period.[lxxi]

Energy
According to a recent estimate by the International Energy Agency, China will overtake the United States to become the world's largest energy consumer after 2010.lxxii Energy for the heating and cooling of buildings is expected to grow as a result of improved living standards and hotter summers.

Significantly longer periods of heat waves have been observed in many Chinese cities, especially in eastern and southern China. These two regions are China's most active economic zones, fueled mainly by energy imported from other regions. The frequent heat waves caused a wide use of air conditioning and pushed the local power supply to the edge. The impacted areas suffered power shortages and cutoffs to deal with the shortage.[lxxiii]

Disasters and Hazards
Recent disasters and hazards caused by extreme events have caused significant damage to the local and regional economy, infrastructure, energy transmission, and transportation, as well as the daily life of the affected areas. Nevertheless, extreme weather events—especially floods and storms—have often led to intensive national media coverage, including newspaper, TV and Internet, which have effectively raised public concerns over the adverse impacts of climate change.

A list of major extreme weather events in the past five years includes the following:

- In January and February 2008, 19 provinces in central, eastern, and southern China witnessed unusual snowfall, persistent low temperatures, and icing. The three-week-long extreme weather caused disruptions in transportation and electric power transition, rising food prices, and damage to agriculture and livestock.[lxxiv,lxxv] At least 100 million people were affected and 60 died.[lxxvi]

- In 2007, Guangdong Province in southern China experienced record rainfall. In Zhanjiang, a coastal province in eastern China, many houses and factories were destroyed by a tornado. In north and west China, the Inner Mongolia Autonomous Region, Shaanxi and Gansu provinces, and Chongqing municipality suffered from record droughts. Some areas of Shaanxi and Chongqing are still experiencing shortages of drinking water.[lxxvii]
- In August 2004, Typhoon Rananim hit the wealthy Zhejiang Province. Rananim killed at least 164 people and 55,000 livestock, injuring more than 1,800 people, destroying 64,300 houses, and affecting 13 million people. The worst typhoon since 1956 resulted in a direct economic loss of $2.2 billion.[lxxviii]

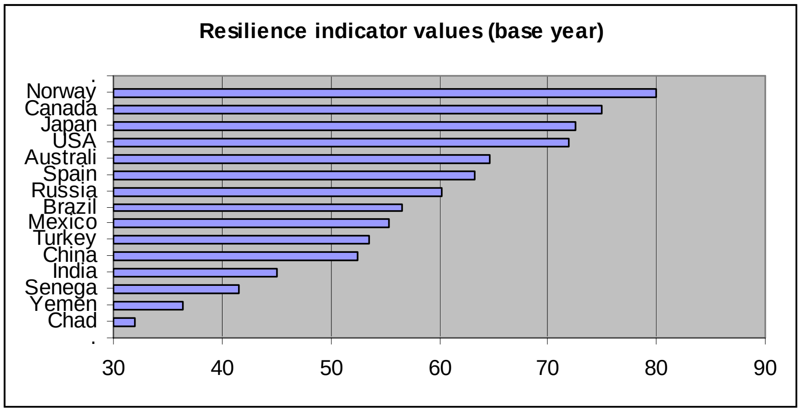
Adaptive Capacity

A global comparative study[lxxix] of resilience to climate change (including adaptive capacity) was conducted using the Vulnerability-Resilience Indicators Model (VRIM—see box below). A sample of 15 countries, including China, spans a wide range of values (Figure 2). A closer look at these countries provides insight into the *sources* of the rankings (see box on page 24).

Methodological Description of the Vulnerability-Resilience Indicator Model (VRIM)

The VRIM is a hierarchical model with four levels. The resilience index (level 1) is derived from two indicators (level 2): sensitivity (how systems could be negatively affected by climate change) and adaptive capacity (the capability of a society to maintain, minimize loss of, or maximize gains in welfare). Sensitivity and adaptive capacity, in turn, are composed of sectors (level 3). For adaptive capacity these sectors are human resources, economic capacity, and environmental capacity. For sensitivity, the sectors are settlement/infrastructure, food security, ecosystems, human health, and water resources. Each of these sectors is made up of 1-3 proxies (level 4). The proxies under adaptive capacity are as follows: human resource proxies are the dependency ratio and literacy rate; economic capacity proxies are GDP (market) per capita and income equity; and environmental capacity proxies are population density, sulfur dioxide divided by state area, and percent of unmanaged land. Proxies in the sensitivity sectors are water availability, fertilizer use per agricultural land area, percent of managed land, life expectancy, birth rate, protein demand, cereal production per agricultural land area, sanitation access, access to safe drinking water, and population at risk from sea level rise.

Each of the hierarchical level values is composed of the geometric means of lower level values. Proxy values are indexed by determining their location within the range of proxy values over all countries or states. The final calculation of resilience is the geometric mean of the adaptive capacity and sensitivity.



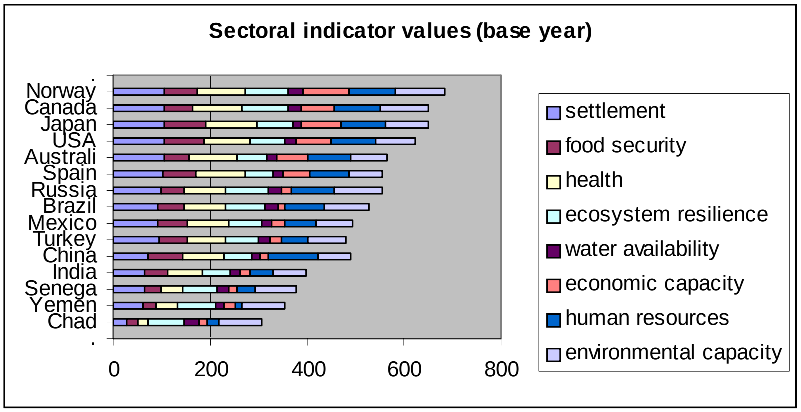


Figure 2. VRIM Base year results: resilience rankings and the element indicator values for example countries.

Impact of Sources on State Vulnerability-Reliance Indicators

- Norway's GDP per capita in combination with the equity index provides the highest resilience ranking among these countries.
- Spain has high scores in economic capacity, settlement security, and food security and human health compared to the other countries, partially offset by the lowest scores in ecosystem resilience and environmental response capacity to climate.
- China scores highest in food security (due to cereal production) and human health and has among the highest scores in human resources.
- Yemen scores lowest in people in the workforce and is low in economic capacity due to inequity. This country also scores low in water availability and cereal production and has a high birth rate.
- Chad scores lowest in settlement security due to lack of access to clean water and sanitation.
- Senegal also scores low in settlement security, but for a different reason: many people live in sea-surge prone areas.

Projections of resilience are based on different rates of change in the proxy values. If the same change rates were used to project the baseline values, countries would travel parallel pathways into the future. A change in ranking can only result from responses that are unique to countries and/or from alternative scenarios. Figure 3 shows projections for the 15-country sample, for the high-growth and delayed-growth scenarios of the future into 2065. The relative rankings of the four lowest-ranked countries do not change in either scenario, although the pathways differ. In the high-growth scenario, countries tend to converge more than in the delayed growth scenario.

The high-growth scenario shows a greater increase in resilience for developing countries than for the developed countries (Figure 4). In the high-growth scenario, China has the largest increase in resilience. It changes ranks from 5th from the bottom among the 15 countries around the turn of the century to "developed country" resilience by 2050. This ranking is equivalent to Spain and even outranks Australia. In the delayed-growth scenario China's resilience increases only a fraction faster than other developing countries, ranking 8th by 2050. Russia also shows potential increase in resilience, especially in the high-growth scenario, by maintaining ecosystem resilience.

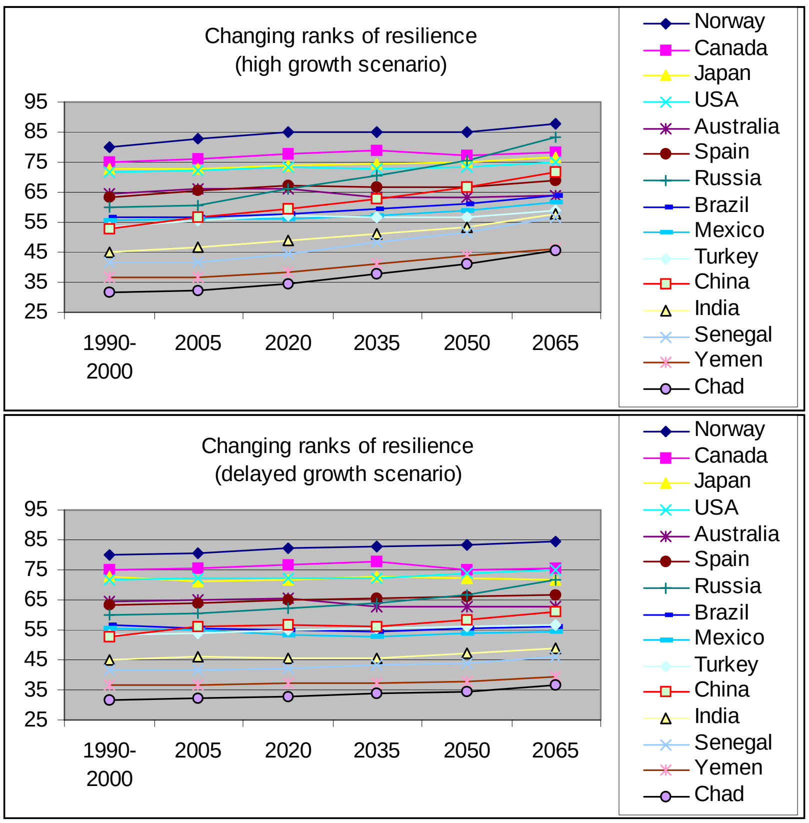


Figure 3. Projections of the resilience indicator value for the example countries.

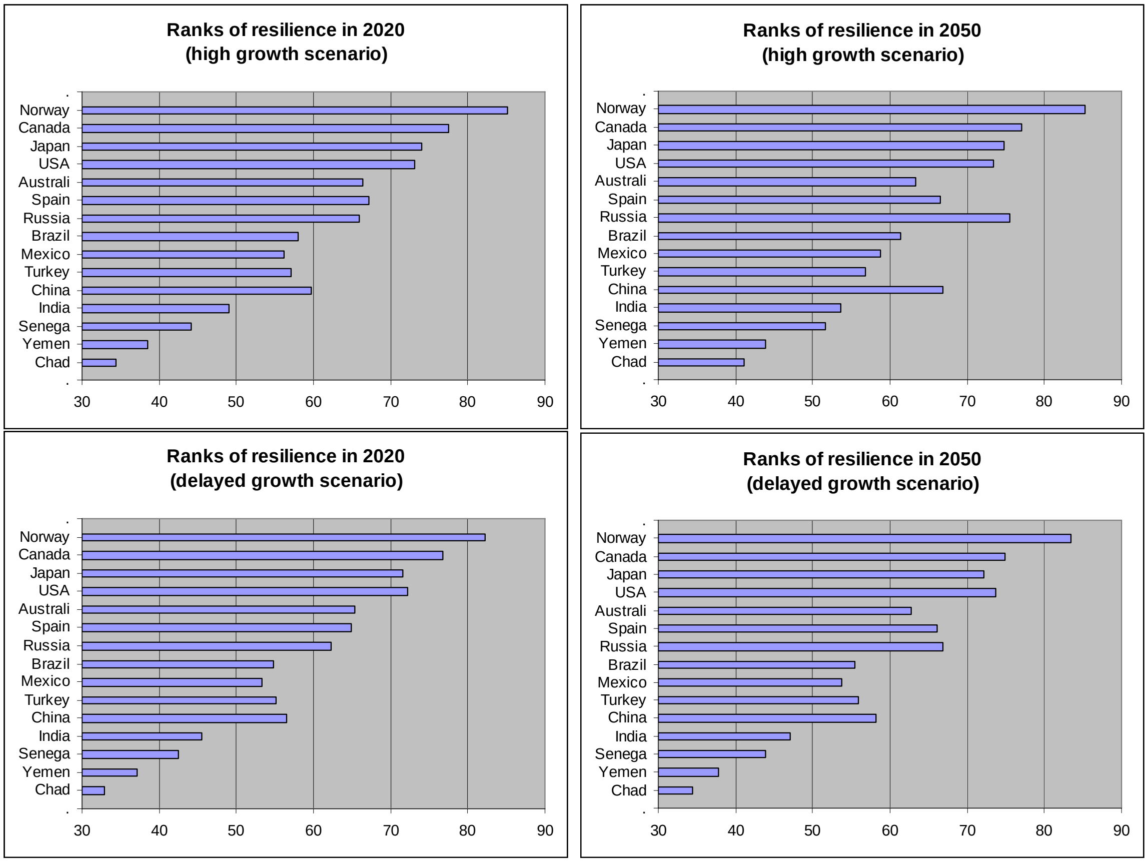


Figure 4. Changes in ranking by 2020 and 2050 for the example countries.

Figure 5 shows the contributing element indicator values to help examine the contributing factors in these phenomena. For example, on the one hand, China's investment in infrastructure alleviates the settlement sensitivity and leads to China becoming considerably more resilient in the high-growth scenario. On the other hand, for the currently highest ranking resilient countries, reduced resilience in ecosystem sensitivity and water availability over time (due to increasing population and land-use changes) is compensated less by economic growth and infrastructure investment than in China.

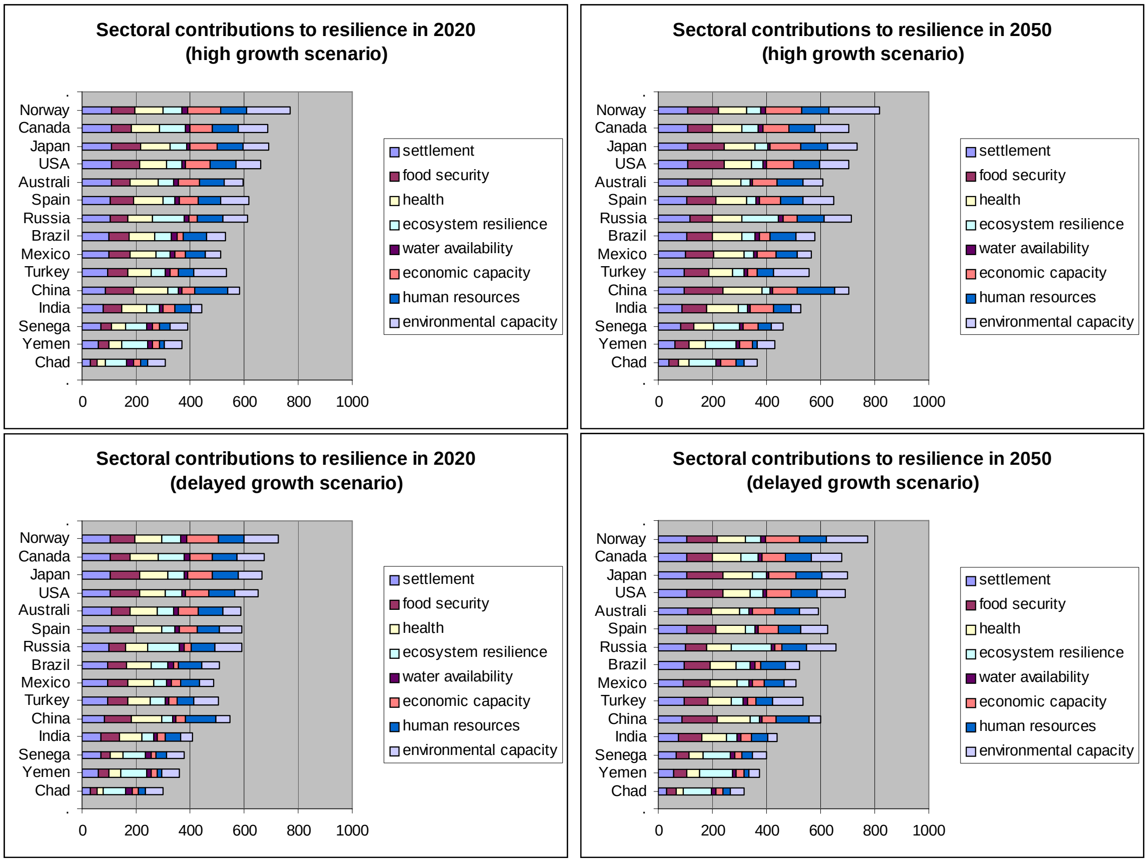


Figure 5. Element indicator values for the example countries.

Current Chinese plans reflect a determination to increase adaptive capacity. The Chinese Government has been promoting mitigation and energy conservation, which had long been regarded as the key strategy for China to battle climate change. With the new stance of "equal emphasis on both mitigation and adaptation," addressed in *China's National Climate Change Program* (CNCCP), the government will devote its resources to adaptive capacity-building to buffer the adverse impacts of climate change in China.

According to CNCCP and *China's Actions and Policies on Climate Change* (CPAACC), China's past achievements and future actions are reflected in its governmental management of such vulnerable sectors as water, coastal management, agriculture, and forestry. China is also active in building and improving its early warning and monitoring network to reduce avoidable social and economic damages caused by extreme weather events. In addition, the central government has been supporting policy and pouring financial investments into the development of science and technology related to climate change. China continues its national and local public information campaign to raise public awareness and keeps an open and active attitude toward using international available resources for improving its adaptive capacity.

Water Resources

Past Achievements: China has issued a series of laws and regulations to enhance the sustainable use of water resources, including the Law of the Prevention and Control of Water Pollution (1984, 1996), Law of Water and Soil Conservation (1991), Flood Control Law (1997), and Water Law (2002). China also set up programs of flood control and disaster alleviation for major rivers, as well as water conservation programs. By the end of 2007, China has successfully controlled soil erosion over one million square kilometers.[lxxx]

Future Actions: According to the CNCCP and the CPAACC, China will take the following strategies to enhance adaptive capacity of water resources to climate change:[lxxxi]

(1) China will establish a national system of water right allocation and water right transfer and develop market-oriented financing and a management system for key water conservation projects.

(2) China will construct projects to control floods on major rivers and floods caused by mountain torrents. To alleviate the trend of droughts in the north and floods in the south, China plans to speed the construction of the Project of South-to-North Water Diversion, which aims to help optimize the allocation of water resources from the Yangtze River, Yellow River, Huaihe River, and Haihe River. In addition, China will continue the construction of regional water storage and water diversion projects.

(3) China will promote technology development for water conservation, sea water use, wastewater and rainfall utilization, artificial rainfall enhancement, industrial water recycling, and water efficiency irrigation, etc.

China's near-term goals by 2010 are to complete anti-flood systems in major rivers, raise the drought relief standard in farmland, and effectively reduce the vulnerability of water resources to climate change.[lxxxii]

Coastal Management

Past Achievements: China's coastal regions are the country's most economically developed regions. Since the 1980s, China has launched a series of laws to protect coastal regions and marine resources, such as the Marine Environment Protection Law (1983 and 1999), China's Marine Programs (1998), and Law of Administration of Sea Areas (2002).[lxxxiii]

Future Actions: Due to their low and flat landscape, the lack of monitoring and emergency response network, as well as less stringent standards of anti-tide construction, China's coastal regions are vulnerable to sea level rise, coastal erosion, and soil salinization. According to the CNCCP and CPAACC,[lxxxiv] China will take the following strategies to improve the adaptive capacity of its coastal areas:

(1) China will build up regional management regulations in accordance with the related laws, establish an integrated coastal zone management system and coordination mechanism, develop demonstration sites for integrated management, and improve design standards for sea dike and port docks. China will also speed up the process of setting up natural reserves for coral reefs and mangroves.

(2) China will invest R&D focused on protection and restoration of marine ecosystems, including the cultivation, transplant, and recovery of coastal mangroves, protection and restoration of coral reefs, as well as the protection of coastal wetlands and ecosystems.

(3) China will build more observation sites in coastal areas and on islands, improve the capability of aerial remote sensing and telemetering of marine environments, and build early-warning and response systems for tidal disasters.

China's near-term goals are to construct and expand mangroves, to effectively raise the adaptive capacity of coastal regions by establishing a monitoring network and related regulations, and to construct a coastal shelterbelt system by 2010.[lxxxv]

Agriculture

Past Achievements: Agriculture is one of the most important economic sectors in China, employing over 300 million laborers[lxxxvi] (the largest labor-intensive sector) and contributing to 11.3 percent of GDP in 2007 (the third largest, after the industry and service sectors).[lxxxvii] China has issued a series of laws and regulations related to agriculture, such as the Grassland Law (1985), Fisheries Law (1986), Law on Land Management (1986, 1998), Regulations of Responses to Major Emergent Animal Epidemics, Agriculture Law (2002), and Livestock Epidemics (2003). The government has invested heavily in agricultural infrastructure, improved irrigation and drainage efficiency and capability, and promoted dry farming and water-efficient technologies. China also has been actively promoting the cultivation of stress-resistant crop seeds.[lxxxviii]

Future Actions: According to the CNCCP, China's strategies for improving adaptive capacity of the agricultural sector can be summarized as follows:[lxxxix]

(1) China will promote production clusters using advantageous crop varieties. The government will continue to expand the demonstration projects on water efficiency irrigation and on dryland farming in arid areas. China will protect and improve the grassland ecosystem by converting grazing areas back to grassland; constructing meadow enclosures, artificial grasslands and grassland fire-prevention facilities; and carrying out projects to protect aquatic ecosystems.

(2) China will accelerate the construction of supporting facilities for large-scale, water-saving irrigation areas; upgrade aging mechanical and electronic equipment; improve irrigation and drainage systems; and conduct small-scale hydraulic projects focused on field irrigation and drainage. China will accelerate the construction of water collection and utilization projects in mountain areas and other arid areas.

(3) China will develop varieties of crops and livestock resistant to drought, waterlogging, high temperature, diseases, and pests. Technology development will be focused on photosynthesis, biological nitrogen fixation, bio-technology, prevention of diseases and pests, stress resistance, and precision agriculture.

By 2010, China's near-term goals are to increase improved grassland by 24 million hectares, restore 52 million hectares of grassland affected by degradation, desertification, and salinity, and strive to increase the efficient utilization agricultural irrigation water.[xc]

Forestry

Past Achievements: To protect forest and other ecosystems, China has issued and enforced relevant laws and regulations, including the Forest Law (1984, 1998), Law on the Protection of Wildlife, Law on Water and Soil Conservation (1989), Management Regulations on National Forest Diseases and Insect Pests Central Monitoring Stations (2001), Law on Prevention and Control of Desertification (2002), Regulations on Conversion of Farmland to Forests, and Forest Fire Prevention Regulations (2003).[xci] The government has established a comprehensive monitoring system for forest resources and ecosystem conditions; improved an evaluation system and emergency-response system for forest fires, pests and diseases; implemented a national medium- and long-term program for the prevention of forest fires, pests and diseases; enhanced the protection of endangered species and their habitat ecosystems; and restored the functions of eco-fragile areas and ecosystems.

Future Actions: According to the CNCCP, China's strategies to improve adaptive capacity for the forestry sector can be summarized as follows:[xcii]

(1) China will amend the Forest Law and Law on the Protection of Wildlife, draft a Law of Nature Reserve and Regulations on Wetland Protection, and address climate change adaptation in existing laws by adding new articles or contents.

(2) The government will strengthen the protection of existing forest resources and other natural ecosystems, restore degraded natural forest ecosystems progressively, protect wetland conservation, expand the total area of nature reserves, and develop bio-corridors among reserves. China also will strengthen controls on forest fire, insect and disease, and integrate existing forestry monitoring systems into a comprehensive monitoring system for forest resources and other ecosystems.

(3) The focus areas include forest fire control; forest insect and disease control; and development of tree species with a high resistance to cold, drought, pests, and disease. China also will focus on biodiversity conservation and restoration; and monitoring technologies for forest resources and forest ecosystems, such as desertification, wild animals and plants, wetlands, forest fires, forest pests and diseases.

By 2010, China's near-term goals are to increase the forest coverage rate to 20 percent and to increase the carbon sink by 50 million tons over 2005's level. China also will aim to protect 90 percent of forest ecosystems and national key wildlife, increase nature reserve areas to 16 percent of the total territory, and control 22 million hectares of desertificated lands during the same time.[xciii]

Early Warning System and Monitoring Network

In the face of increasing extreme meteorological emergencies, China has improved its early warning system and monitoring network to enhance adaptive capacity in vulnerable sectors such as coastal management, agriculture, and forestry.

In early 2009, the China Meteorological Administration issued a circular urging its branches at all levels to provide accurate extreme weather forecasts (such as for snow, frost, rain, and storms) to "local governments, relevant organizations and the public via phone, text messages, e-mail and other methods." The circular especially stressed that the grain production bases located in north China and Yellow River and Huai Rivers should be provided with updated drought information.[xciv]

To counter flood and storms, local governments have been required to develop city flood control and water drainage plans. The state will further establish its monitoring and control network to deal with epidemic-infected area caused by climate change.[xcv]

The People's Liberation Army (PLA) has often been deployed by the government as an emergency rescue team to the affected areas when facing extreme weather events like floods and storms. PLA, called the People's Army, has been highly praised for self-sacrifice and efficiency.

Raising Public Awareness
Past Achievements: With the purpose of fostering a social atmosphere to build a resources-conserving and environmentally friendly society, China has been conducting intensive social marketing to raise public awareness on energy conservation and climate change. Since 1992, China has launched 18 National Energy Conservation Weeks. The government issued the Public Action Plan on Energy Conservation and Emission Reduction, and coordinated relevant national and local activities with communities, enterprises, schools, governmental agencies, and the mass media. The Chinese Government requires governmental agencies to take leadership to reduce their own energy consumption in building and transportation. China also encourages citizens to change their lifestyles and consumption patterns for energy conservation and emission reduction. In recent years, nongovernmental organizations and many social groups have been actively playing a role in promoting energy conservation and emission reduction.[xcvi]

Future Actions: According to the CNCCP, China's strategies to raise public awareness can be summarized as follows:[xcvii]

(1) All level of governmental officials and decision-makers of enterprises and institutions should be exposed to climate change information and work toward raising public awareness.

(2) China will fully employ the power of the mass media to disseminate information about climate change through books, newspapers, periodicals, audio and video products, and the Internet. China will integrate knowledge about climate change into its education system.

(3) China will establish an incentive mechanism to encourage public and enterprise participation, increase the transparency of decision-making processes related to climate change issues, promote public supervision, and encourage social groups and NGOs to play active roles.

(4) China will strengthen international cooperation on public awareness related to climate change issues, especially good practices on climate change information dissemination and education. China will actively promote information exchanges in the form of publications, movies, television, audio and video tapes and other literature, building a database on climate change and providing information retrieval services for domestic agencies, research institutions, and schools.

By 2010, China's near-term goals are to raise awareness of all Chinese society on climate change and to establish a high-efficient institutional and management framework to address climate change.[xcviii]

Enhancing R&D Investment
Past Achievements: In 2006, China invested $38.5 billion on R&D, 1.4 percent of its GDP that year, up 22 percent from 2005. The government also announced 16 national key projects and 10 national laboratories to be completed by 2020.[xcix] In 2007, the Chinese Government earmarked $556 million (20 percent higher than in 2006) for the National Natural Science Foundation, an organization similar to the US National Science Foundation.[c] Energy and environment are two important R&D areas attracting government funding.

Future Actions: According to the CNCCP, China's strategies to enhance climate change-related R&D are summarized as follows:[ci]

(1) China will support climate change-related R&D under the framework of the National Program for Medium-to-Long-Term Scientific and Technological Development (2006-2020), strengthen the macro management and policy guidance for scientific and technological research related to climate change, improve regional and sectoral research, and encourage innovation of climate change science and technology.

(2) China will promote scientific research and technological development in the following key areas: scientific facts and uncertainty, impacts of climate change on the social economy, analysis of the effectiveness of socioeconomic benefits and costs in response to climate change, and technology for mitigation and adaptation. China will pay special attention to the development of large-scale and precise climate change monitoring technology, energy efficiency and clean energy technology, emission control and utilization technology for carbon dioxide, methane and other greenhouse gas emissions in key sectors, biological carbon-capture technology, and carbon sequestration technology.

(3) China will establish effective incentive and competition mechanisms and a favorable academic environment for researchers, foster academic leaders and eminent candidates with international vision and the ability to lead climate change studies, and encourage junior research. China will strengthen the disciplinary development of climate change science, promote research teams, establish the "open, free, competitive, and cooperative" operation mechanism for climate change research institutes, and make full use of various channels and approaches to enhance the research ability and independent-innovation capacity of China's scientists and research institutions. China will build up climate change science and technology management teams and R&D teams in the context of China's national circumstances, encouraging Chinese scientists to participate in international R&D programs on global climate change and pursue positions in international research institutions.

(4) China will establish relatively stable governmental-funded channels as the main financing sources to support climate change-related scientific and technological research, taking measures to ensure the full allocation and efficient use of governmental investment; raise funds through various channels and by various means from all sectors of the society; introduce venture capital investment in the area of climate change research; guide business and enterprises to increase their investment in R&D on climate change science and technology and encourage them to take a leading role for technology innovation; and use the bilateral and multilateral funds from foreign governments and international organizations to assist China's R&D on climate change science and technology.

Using International Resources

Since the late 1980s, China has been actively using international resources, such as foreign governments, international organizations and research institutes, to promote its science and technology development related to energy efficiency and climate change.

The international collaboration not only improves China's research capacity but also influences China's climate-related policies, such as policies adopted by China's farming and forestry departments, China's water resources management, China's comprehensive management of coastal zone and marine ecosystems, and China's laws and regulations related to climate change. In addition, China enhances information exchanges and resource sharing with international organizations and institutes.[cii]

For bilateral exchanges related to climate change issues, China has established a dialogue and cooperation mechanism with the European Union, Japan, the United States, Canada, the United Kingdom, Australia, India, Brazil, and South Africa.

China actively participates in international scientific and technological cooperation programs, including the Intergovernmental Panel on Climate Change, the World Climate Research Programme under the framework of the Earth System Science Partnership, the International Geosphere-Biosphere Programme, the International Human Dimensions Programme on Global Environmental Change, the Intergovernmental Group on Earth Observations, the Global Climate Observation System, the Global Ocean Observation System, the Array for Real-Time Geostrophic Oceanography, and the International Polar Year.

Through international cooperation, China has conducted systematic research under the clean development mechanism (CDM). By July 2008, China had implemented 244 CDM cooperation projects, which were registered with the United Nations. It is expected that the reduction of carbon dioxide emissions through CDM projects will reach 113 million tons per year.[ciii]

Conclusions: High-Risk Impacts

China has demonstrated its determination to tackle the climate change issues as an important domestic affair. However, the government has not seriously addressed some prominent climate impact issues, such as the underrated and underpublicized water crisis, the climate security of coastal regions, and the underdeveloped social protection system. In addition, China must demonstrate an ability to implement its ambitious plans.

Water

With 20 percent of the world's population but only 7 percent of global water resources, China is suffering an underrated water crisis. According to Chinese studies, China's water supply is likely to reach its limit by 2030 when its population hits 1.6 billion with an urbanization rate of 60 percent. China's water supply will fall 11 billion cubic meters annually in spite of the improved supply capacity.[civ] Beijing is among the most affected cities.

A scarcity of natural water resources, fast-growing urbanization and industrialization, severe water pollution, and cheap water prices are among the main factors leading to China's water crisis. The adverse impacts of climate change on water sources, especially with frequent droughts in the north, will push the crisis even further.

The drought regions may be prone to social unrest caused by water shortages. Conflicts over water rights and distribution between social groups and between sectors may occur. The serious middle- and long-term droughts may lead environmental refugees to flee to water-rich regions. The expected South-to-North Water Diversion Project may alleviate the water stress of some northern regions, but it will not be sufficient enough to provide a full solution.[cv]

Frequent and prolonged droughts and floods will not only affect livelihoods, but also damage the local, regional, and national economy. With 300 million workers, agriculture, which is highly water-dependent, may be at greater risk than all other sectors. The negative impacts on agriculture will bring high risk for China's food security but also lead to an influx of immigrants to urban areas for jobs, transferring resource and social stress to Chinese cities.

Coastal Regions

China has an 18,000-km coastline, and one third of China's border faces the sea. With 16.8 percent of China's total land area, 41.9 percent of the population, and 72.5 percent of China's GDP, the coastal regions are the engine of China's sustainable economic growth.

However, due to their flat and low landscape, most of China's coastal regions are highly vulnerable to sea level rise, including Shanghai—China's business and financial hub. The increasing frequency and intensity of extreme weather events such as typhoons has threatened the economic development at local, regional, and national levels.

China has been actively developing early warning systems and related monitoring systems and improving the design standards of sea dike and port docks. Improved management, including increased effectiveness of early-warning and monitoring systems, better enforcement of design standards, and increase in trained emergency responses teams could lower the risk of damage from extreme weather events.

Social and Political Uncertainties

China's actual unemployment rate in the past three years is widely believed to be much higher than the official 9.6 percent.[cvi] Facing a large unemployed population, China's underdeveloped social protection system is less and less able to protect those who need it. Rising expenses on healthcare, education and housing have been financial burdens for the average Chinese family. The export-oriented economy is vulnerable to the present global financial crisis. Chinese experts believe that 2009 will be a difficult year for China's economy.[cvii] As the second largest oil importer, China has exposed itself to an unstable international oil market.

The adverse impacts of climate change will add extra pressure to the existing social and resource (such as energy) stresses. Establishing an effective social protection system will be ranked high in the Chinese Government's long to-do list.

Policy Implementation

There is little doubt that China has taken climate change issues seriously, although China's seriousness has often been overlooked due to its more-publicized, non-negotiable, "you-take-the-first-step" attitudes in international negotiations. Evidence of China's seriousness is apparent in its fast growing array of national laws, regulations, and policies that focus on mitigation, energy efficiency, resource protections, and adaptive capacities. The Chinese Government has successfully used its power to promote and implement some of its national programs and policies, such as energy efficiency standards for appliances, top 1,000 industrial energy conservation program,[cviii] and an efficient light bulb subsidy program.[cix]

In the context of a mixed economy, conflicted interests and different priorities between national and local governments, and complicated stakeholder relations, implementation is China's big hurdle for the success of mitigation and adaptation. For example, compliance with the building energy code is mandated under Chinese law. However, the actual enforcement rate is very low in mid- and small-sized cities.[cx] Building adaptive capacities will face the same challenge. Smart employment of a set of policy instruments, such as regulations, incentive and voluntary programs, and well-designed local action plans could improve implementation. Other countries could help China by sharing their experiences on implementation.

Annex A: Accuracy of Regional Models

This is an excerpt from IPCC (2007), Chapter 11, Regional models; see IPCC 2007 for references. [4]

11.4.2 Skill of Models in Simulating Present Climate

Regional mean temperature and precipitation in the MMD models show biases when compared with observed climate (Table 3). The multi-model mean shows a cold and wet bias in all regions and in most seasons, and the bias of the annual average temperature ranges from –2.5°C over the Tibetan Plateau (TIB) to –1.4°C over South Asia (SAS). For most regions, there is a 6°C to 7°C range in the biases from individual models with a reduced bias range in Southeast Asia (SEA) of 3.6°C. The median bias in precipitation is small (less than 10 percent) in Southeast Asia, South Asia, and Central Asia (CAS), larger in northern Asia and East Asia (NAS and EAS, around +23 percent), and very large in the Tibetan Plateau (+110 percent). Annual biases in individual models are in the range of –50 to +60 percent across all regions except the Tibetan Plateau, where some models simulate annual precipitation 2.5 times that observed and even larger seasonal biases occur in winter and spring. These global models clearly have significant problems over Tibet, due to the difficulty in simulating the effects of the dramatic topographic relief, as well as the distorted albedo feedbacks due to extensive snow cover. However, with only limited observations available, predominantly in valleys, large errors in temperature and significant underestimates of precipitation are likely.

South Asia

Over South Asia, the summer is dominated by the southwest monsoon, which spans the four months from June to September and dominates the seasonal cycles of the climatic parameters. While most models simulate the general migration of seasonal tropical rain, the observed maximum rainfall during the monsoon season along the west coast of India, the north Bay of Bengal and adjoining northeast India is poorly simulated by many models (Lal and Harasawa, 2001; Rupa Kumar and Ashrit, 2001; Rupa Kumar et al., 2002, 2003). This is likely linked to the coarse resolution of the models, as the heavy rainfall over these regions is generally associated with the steep physical geography of local mountains. However, the simulated annual cycles in South Asian mean precipitation and surface air temperature are reasonably close to the observed. The multi-model data set (MMD) models capture the general regional features of the monsoon, such as the low rainfall amounts coupled with high variability over northwest India. However, there has not yet been sufficient analysis of whether finer details of regional significance are simulated more adequately in the MMD models.

Recent work indicates that time-frame experiments using an atmospheric general circulation model (AGCM) with prescribed sea surface temperatures (SSTs), as opposed to a fully coupled system, are not able to accurately capture the South Asian monsoon response (Douville, 2005). Thus, neglecting the short-term SST feedback and variability seems to have a significant impact on the projected monsoon response to global warming, complicating the regional downscaling problem. However, May (2004a) notes that the high-resolution (about 1.5 degrees) European Centre-Hamburg (ECHAM4) general circulation model (GCM) simulates the variability and extremes of daily rainfall (intensity as well as frequency of wet days) in good agreement with the observations (Global Precipitation Climatology Project, Huffman et al., 2001).

[4] Some references in this section have been changed to be internally consistent with this document and other references have been removed to avoid confusion.

Three-member ensembles of baseline simulations (1961–1990) from a regional climate model (RCM) (PRECIS) at 50 km resolution have confirmed that significant improvements in the representation of regional processes over South Asia can be achieved (Rupa Kumar et al., 2006). For example, the steep gradients in monsoon precipitation with a maximum along the western coast of India are well represented in PRECIS.

East Asia

Simulated temperatures in most MMD models are too low in all seasons over East Asia; the mean cold bias is largest in winter and smallest in summer. Zhou and Yu (2006) show that over China, the models perform reasonably well in simulating the dominant variations of the mean temperature over China, but not the spatial distributions. The annual precipitation over East Asia exceeds the observed estimates in almost all models and the rain band in the mid-latitudes is shifted northward in seasons other than summer. This bias in the placement of the rains in central China also occurred in earlier models (e.g., Zhou and Li, 2002; Gao et al., 2004). In winter, the area-mean precipitation is overestimated by more than 50 percent on average due to strengthening of the rain band associated with extratropical systems over South China. The bias and inter-model differences in precipitation are smallest in summer but the northward shift of this rain band results in large discrepancies in summer rainfall distribution over Korea, Japan and adjacent seas.

Kusunoki et al. (2006) find that the simulation of the Meiyu-Changma-Baiu rains in the East Asian monsoon is improved substantially with increasing horizontal resolution. Confirming the importance of resolution, regional climate models (RCMs) simulate more realistic climatic characteristics over East Asia than atmospheric-ocean general circulation models (AOGCMs), whether driven by re-analyses or by AOGCMs (e.g., Ding et al., 2003; Oh et al., 2004; Fu et al., 2005; Zhang et al., 2005a, Ding et al., 2006; Sasaki et al., 2006b). Several studies reproduce the fine-scale climatology of small areas using a multiply nested RCM (Im et al., 2006) and a very-high resolution (5 km) RCM (Yasunaga et al., 2006). Gao et al. (2006b) report that simulated East Asia large-scale precipitation patterns are significantly affected by resolution, particularly during the mid- to late-monsoon months, when smaller-scale convective processes dominate.

Southeast Asia

The broad-scale spatial distribution of temperature and precipitation in December-January-February (DJF) and June-July-August (JJA) averaged across the MMD models compares well with observations. Rajendran et al. (2004) examine the simulation of current climate in the MRI coupled model. Large-scale features were well simulated, but errors in the timing of peak rainfall over Indochina were considered a major shortcoming. Collier et al. (2004) assess the performance of the CCSM3 model in simulating tropical precipitation forced by observed SST. Simulation was good over the maritime continent compared to the simulation for other tropical regions. Wang et al. (2004) assess the ability of 11 AGCMs in the Asian-Australian monsoon region simulation forced with observed SST variations. They found that the models' ability to simulate observed interannual rainfall variations was poorest in the Southeast Asian portion of the domain. Since current AOGCMs continue to have some significant shortcomings in representing El Niño- Southern Oscillation (ENSO) variability, the difficulty of projecting changes in ENSO-related rainfall in this region is compounded.

Rainfall simulation across the region at finer scales has been examined in some studies. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) stretched-grid Conformal-Cubic Atmospheric Model (CCAM) at 80-km resolution shows reasonable precipitation simulation in JJA, although Indochina tended to be drier than in the observations (McGregor and Nguyen, 2003). Aldrian et al. (2004a) conducted a number of simulations with the Max-Planck Institute (MPI) regional model for an Indonesian domain, forced by reanalyses and by the ECHAM4 GCM. The model was able to represent the spatial pattern of seasonal rainfall. It was found that a resolution of at least 50 km was required to simulate rainfall seasonality correctly over Sulawesi. The formulation of a coupled regional model improves regional rainfall simulation over the oceans (Aldrian et al., 2004b). Arakawa and Kitoh (2005) demonstrate an accurate simulation of the diurnal cycle of rainfall over Indonesia with an AGCM of 20-km horizontal resolution.

Central Asia and Tibet

Due to the complex topography and the associated mesoscale weather systems of the high-altitude and arid areas, GCMs typically perform poorly over the region. Importantly, the GCMs, and to a lesser extent RCMs, tend to overestimate the precipitation over arid and semi-arid areas in the north (e.g., Small et al., 1999; Gao et al., 2001; Elguindi and Giorgi, 2006).

Over Tibet, the few available RCM simulations generally exhibit improved performance in the simulation of present-day climate compared to GCMs (e.g., Gao et al., 2003a,b; Zhang et al., 2005b). For example, the GCM simulation of Gao et al. (2003a) overestimated the precipitation over the north-western Tibetan Plateau by a factor of five to six, while in an RCM nested in this model, the overestimate was less than a factor of two.

		temperature BIAS					% precipitation BIAS				
REGION	SEASON	MIN	25	50	75	MAX	MIN	25	50	75	MAX
Asia											
NAS	DJF	-9.3	-2.9	-1.3	0.0	2.9	-18	5	12	19	93
	MAM	-6.0	-4.3	-2.7	-0.5	0.6	-4	39	45	74	110
	JJA	-4.8	-2.0	-0.5	0.4	2.2	-38	-2	19	32	62
	SON	-6.2	-2.6	-2.1	-0.5	1.9	-14	12	23	30	49
	ANN	-5.2	-2.6	-1.4	-0.6	1.3	-11	15	24	35	55
CAS	DJF	-4.4	-2.6	-1.2	0.2	3.3	-33	-2	18	43	77
	MAM	-4.3	-3.0	-1.4	0.2	2.0	-36	22	25	34	83
	JJA	-4.9	-1.6	0.3	1.4	5.7	-71	-37	-25	14	60
	SON	-4.5	-3.2	-1.9	-0.4	1.6	49	-12	-4	15	47
	ANN	-3.9	-2.3	-1.4	0.6	2.2	-44	4	12	21	53
TIB	DJF	-9.3	-3.8	-2.2	-1.4	2.2	15	131	177	255	685
	MAM	-7.0	-4.3	-3.8	-1.3	0.6	130	160	209	261	486
	JJA	-6.7	-2.5	-1.0	-0.2	1.6	4	30	37	53	148
	SON	-5.9	-3.6	-2.5	-1.7	0.0	66	93	150	180	330
	ANN	-5.3	-3.3	-2.5	-1.6	0.6	51	88	110	142	244
EAS	DJF	-6.5	-4.5	-3.7	-1.3	1.8	-20	26	60	79	142
	MAM	-5.2	-2.9	-2.0	-1.0	0.5	1	32	45	60	105
	JJA	-3.9	-2.0	-1.1	-0.4	1.4	-15	0	3	15	27
	SON	-5.9	-3.4	-2.7	-1.6	-0.3	-17	1	14	34	75
	ANN	-5.4	-3.2	-2.5	-1.2	0.2	-6	12	22	31	60
SAS	DJF	-7.4	-4.0	-2.6	-1.6	1.9	-27	0	30	59	127
	MAM	-5.6	-1.9	-0.7	-0.4	2.5	-44	-26	-1	13	72
	JJA	-2.9	-1.3	-0.1	0.6	1.9	-70	-25	-14	5	29
	SON	-5.2	-3.2	-2.1	-0.9	2.6	-26	-12	-2	14	42
	ANN	-4.8	-2.4	-1.4	-0.8	2.2	-49	-16	-10	5	33
SEA	DJF	-3.6	-2.6	-1.8	-1.2	0.4	-37	-10	-2	26	49
	MAM	-2.6	-1.6	-0.5	-0.1	1.1	-32	-9	11	25	59
	JJA	-2.5	-1.8	-0.7	-0.4	1.0	-28	-10	4	16	46
	SON	-3.0	-1.9	-1.2	-0.8	1.0	-37	-12	-4	18	51
	ANN	-2.8	-1.9	-1.0	-0.5	0.8	-28	-13	0	23	43

Table 3. Biases in present-day (1980-1999) surface air temperature and precipitation in the MMD simulations. The simulated temperatures are compared with the HadCRUT2v (Jones, et al., 2001) data set and precipitation with the CMAP (update of Xie and Arkin, 1997) data set. Temperature biases are in °C and precipitation biases in per cent. Shown are the minimum, median (50 percent) and maximum biases among the models, as well as the first (25 percent) and third (75 percent) quartile values. Colors indicate regions/seasons for which at least 75 percent of the models have the same sign of bias, with orange indicating positive and light violet negative temperature biases and light blue positive and light brown negative precipitation biases.

Annex B: Knowledge Deficiencies that Preclude a Full Evaluation of Climate Change Impacts on China and China's Adaptive Strategies

To increase the likelihood that this evaluation represents a reasonable assessment of China's projected climate changes and their impacts, as well as the country's adaptive capacity, the following gaps would need to be addressed:

- In physical science research, regional analyses will continue to be limited by the inability to model regional climates satisfactorily, including complexities arising from the interaction of global, regional, and local processes. Uncertainties in changing monsoonal activity, dust storms, and desertification leave important gaps in knowledge needed for climate projections. One gap of particular interest is the lack of medium-term (20-30 years) projections that could be relied upon for planning purposes. Similarly, scientific projections of water supply and agricultural productivity are limited by inadequate understanding of various climate and physical factors affecting both areas. Research agendas in these areas can be found in, for instance, the synthesis and assessment reports of the US Climate Change Science Program (http://www.climatescience.gov) and the National Academy of Sciences (e.g., http://books.nap.edu/catalog.php?record_id=11175#toc). Similar types of issues exist for the biological and ecological systems that are affected.
- In social science research, scientists and analysts have only partial understandings of the important factors in vulnerability, resilience, and adaptive capacity—much less their interactions and evolution. Again, research agendas on vulnerability, adaptation, and decision-making abound (e.g., (http://books.nap. edu/catalog.php?record_id=12545).
- Important factors are unaccounted for in research; scientists know what some of them are, but there are likely factors whose influence will be surprising. An example from earlier research on the carbon cycle illustrates this situation. The first carbon cycle models did not include carbon exchanges involving the terrestrial domain. Modelers assumed that the exchange was about equal, and the only factor modeled was deforestation. This assumption, of course, made the models inadequate for their purposes. In another example, ecosystems research models are only beginning to account for changes in pests, e.g., the pine bark beetle.
- Social models or parts of models in climate research have been developed to simulate consumption (with the assumption of well-functioning markets and rational actor behavior) and mitigation/adaptation policies (but without attention to the social feasibility of enacting or implementing such policies). As anthropogenic climate change is the result of human decisions, the lack of knowledge about motivation, intent, and behavior is a serious shortcoming.

Overall, research about climate change impacts on China has been undertaken piecemeal: discipline by discipline, sector by sector, with political implications separately considered from physical effects. This knowledge gap can be remedied by integrated research into energy-economic-environmental-political conditions and possibilities.

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SPECIAL REPORT

INDIA: IMPACT OF CLIMATE CHANGE TO 2030
A COMMISSIONED RESEARCH REPORT

SPECIAL REPORT

NIC 2009-04D April 2009

Russia: Impact of Climate Change to 2030
A Commissioned Research Report

THE NATIONAL INTELLIGENCE COUNCIL SPONSORS WORKSHOPS AND RESEARCH WITH NONGOVERNMENTAL EXPERTS TO GAIN KNOWLEDGE AND INSIGHT AND TO SHARPEN DEBATE ON CRITICAL ISSUES. THE VIEWS EXPRESSED IN THIS REPORT DO NOT REFLECT OFFICIAL US GOVERNMENT POSITIONS.

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NIC

Russia: The Impact of Climate Change to 2030
A Commissioned Research Report

Prepared By
Joint Global Change Research Institute and
Battelle Memorial Institute, Pacific Northwest Division

The National Intelligence Council sponsors workshops and research with nongovernmental experts to gain knowledge and insight and to sharpen debate on critical issues. The views expressed in this report do not reflect official US Government positions.

NIC 2009-04D
April 2009

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Scope Note

Following the publication in 2008 of the National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030, the National Intelligence Council (NIC) embarked on a research effort to explore in greater detail the national security implications of climate change in six countries/regions of the world: India, China, Russia, North Africa, Mexico and the Caribbean, and Southeast Asia and the Pacific Island States. For each country/region we are adopting a three-phase approach.

- In the first phase, contracted research—such as this publication—explores the latest scientific findings on the impact of climate change in the specific region/country.
- In the second phase, a workshop or conference composed of experts from outside the Intelligence Community (IC) will determine if anticipated changes from the effects of climate change will force inter- and intra-state migrations, cause economic hardship, or result in increased social tensions or state instability within the country/region.
- In the final phase, the NIC Long-Range Analysis Unit (LRAU) will lead an IC effort to identify and summarize for the policy community the anticipated impact on US national security.

EastLink Consulting, LLC, collaborating with the Joint Global Change Research Institute (JGCRI) and Battelle, Pacific Northwest Division (Battelle, PNWD), developed this assessment on the climate change impact on Russia through 2030 under a contract with SCITOR Corporation. The Central Intelligence Agency's Office of the Chief Scientist, serving as the Executive Agent for the DNI, supported and funded the contract.

This assessment identifies and summarizes the latest peer-reviewed research related to the impact of climate change on Russia, drawing on both the literature summarized in the latest Intergovernmental Panel on Climate Change (IPCC) assessment reports and on other peer-reviewed research literature and relevant reporting. It includes such impact as sea level rise, water availability, agricultural shifts, ecological disruptions and species extinctions, infrastructure at risk from extreme weather events (severity and frequency), and disease patterns. This paper addresses the extent to which regions within Russia are vulnerable to climate change impact. The targeted time frame is to 2030, although various studies referenced in this report have diverse time frames.

This assessment also identifies (Annex B) deficiencies in climate change data that would enhance the IC understanding of potential impact on Russia and other countries/regions.

This paper does not represent US Government views.

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Executive Summary

Russia is already experiencing the impacts of climate change in the form of milder winters; melting permafrost; changing precipitation patterns; the spread of disease; and increased incidence of drought, flooding, and other extreme weather events. Many of these observed climate impacts are having concrete, negative effects on Russians' quality of life. By 2030, Russia will start to feel the impacts of climate change in relation to both water and food supply. Nonetheless, a significant portion of the country's senior leaders continue to voice the view that a warming climate is a net benefit for Russia. Russia has a number of attributes that provide a greater capacity for resilience than some other industrialized countries and most developing countries. However, **as the impacts of climate change continue and intensify over the coming years, Russia's capacity to adapt and protect its people will be severely tested.**

The most important impacts of climate change in Russia will likely include the following:

- **Energy. A warming climate holds the possibility of milder and shorter heating seasons, which in turn may lead to reduced Russian energy demand. Increased water availability—particularly along those Siberian rivers that are used for hydroelectric power—should result in increased power production in certain parts of the country. However, existing and future energy infrastructure for the all-important petroleum industry will experience more pronounced challenges—structural subsidence, risks associated with river crossings, and construction difficulties as permafrost thaws earlier and deeper, impeding the construction of vital new production areas.** These latter challenges have the potential for a material, negative impact on the single-greatest source of revenue to the Russian state—the oil and gas industry.
- **Water.** Many parts of Russia's massive territory will experience increases in the availability of water, including much of Siberia, the Far North, and northwestern Russia. This change will bring certain positive impacts—including for hydroelectric generation (above). However, managing the increased flows will pose other problems, especially when these increased flows coincide with extreme weather events such as downpours, or springtime ice-clogged floods. In addition, increasing water shortages are predicted for southern parts of European Russia, areas that already experience significant socioeconomic and sociopolitical stresses. Moreover, a number of densely populated Russian regions that are already subject to water shortages are expected to face even more pronounced difficulties in decades to come.
- **Agriculture. As growing seasons become longer and precipitation patterns change, using lands for agricultural purposes that previously would have been too far north—too cold for too much of the year—will become possible.** Raising new crops and new varieties of crops that are currently grown in Russia also could become possible. However, a changing climate may not be hospitable to expanded agriculture. A key question is whether the longer growing seasons and the warmer Russian agricultural lands will result in increased yields. Yields of existing crops may fail and whether new crops will succeed remains to be seen. **Agriculture will become more reliant on irrigation (especially in the southern parts of European**

Russia), pesticides and herbicides, and more vulnerable to droughts and other extreme weather.

- **Migration. Russia, which is already the number two destination for immigrants (after the United States) is likely to experience greater migration pressure from Central Asia, the Caucasus countries, Mongolia, and northeastern China.** These latter areas are expected to experience increased water shortages and resulting economic stress. In addition, internal migration pressures may occur as residents in Russia's many northern cities face increasing economic and climate-related challenges.

- **Accentuation of existing socioeconomic and sociopolitical stresses. Russia is better equipped to deal with the impacts of climate change than many of its neighbors. Nonetheless, by 2030, climate change appears likely to accentuate some of the stresses that currently plague Russia.** Some of the most affected regions are areas where already socioeconomic and sociopolitical relations are attenuated and unsettled. Most of the impacts of climate change will manifest themselves in smaller cities and in the Russian countryside. For example, the long-turbulent North Caucasus region will be drier, hotter, and less prosperous than it is today. The Primorskiy Kray and the Russian Far East, which have long struggled to develop peacefully next to China, appear likely to experience even greater migration pressures, which could exacerbate longstanding cross-border tensions.

Contents

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Introduction and Background

Current Climatology of Russia[i]

Russia has the largest amount of land area of any country in the world. Most of this area is more than 400 kilometers from the sea, with the center of the country being almost 4,000 kilometers from the sea. The terrain ranges from grassy steppes in the south to frigid tundra in the polar north. The treeless, marshy tundra comprises almost 10 percent of the country. Russia's topography includes the world's deepest lake and Europe's highest mountain, and its landscape contains all the major vegetation zones of the world except a tropical rain forest. More than half of the country is above 60° north latitude and is covered with snow for almost half of the year.

Less than one percent of Russia's population lives in the northernmost part of the country, from the Finnish border to the Bering Strait. This area, shaped by glaciation in the last ice age, continues to be subject to erosion by frost weathering. Rivers here flow north to the Arctic Ocean, often hampering drainage of lakes and ponds across the tundra. Summer nights, called "white" nights, are so short that dawn comes shortly after dusk. Vegetation above the permafrost consists mostly of mosses, lichen, and dwarf trees and shrubs.

Russia's large forested region, called the taiga, comprises an area about the size of the United States and contains primarily coniferous trees such as spruce, cedar, larch, and fir. The region includes most of European Russia, and about one-third of Russia's people live there. The annual average temperature of this region is below freezing; the northern part of this region is one of the coldest inhabited areas on Earth.

The steppes, often imaged as typical Russian landscape, are treeless, grassy plains occasionally interrupted by mountain ranges. Located from south of Moscow to the Black and Caspian seas, this is the only region that has a relatively temperate climate and is suited to agriculture. However, the region occasionally experiences catastrophic droughts and short, intense periods of precipitation. At the southernmost part of the region, a narrow subtropical climate warms the edges of the Black Sea and provides Russia's only warm resort area.

Most of Russia receives little precipitation. In the south and east, mountain ranges prevent Indian and Pacific Ocean winds from bringing precipitation and warmer temperatures inland. The highest levels of precipitation are in the northwest region of the country, with levels decreasing toward southeast and European Russia. The wettest areas are along the Pacific coast and near the Caucasus. A monsoonal climate along Russia's Pacific coast brings seasonally high amounts of precipitation, reversing the direction of winds in summer and winter.

In winter, steady winds tend to blow from the south and southwest across most of the country. In summer, winds come from the north and northwest. This reversal of the winds causes less temperature variation than might be expected between winter and summer. For January, the average temperatures are -8 degrees Celsius (°C) in St. Petersburg, -27°C in the West Siberian Plain, and -43°C at Yakutsk (east-central Siberia, at about the same latitude as St. Petersburg). In the summer, the Arctic islands average 4°C, and the southernmost regions of Russia average 20°C.

This paper does not represent US Government views.

Projected Regional Climate Change

Climate Observations

Temperature trends over most of the Arctic and northern Russia before about 1920 were likely dominated by natural variability.[ii] It is difficult to explain increasing temperatures since 1920 without including the impacts of human emissions of greenhouse gases. Average temperatures over the past decade are the warmest ever measured in the documented history of climate records in Russia. Studies by Roshydromet,[iii] the Federal Service for Hydrometeorology and Environmental Monitoring, show that annual average temperatures over Russia have increased significantly during the past 10 years; the models suggest a continuation of this trend over the next five to 10 years. Such conclusions are supported by the findings of other Russian agencies, the Russian Academy of Sciences in particular, and by most foreign scientists (Figure 1).

Data collected by the Roshydromet surface network of hydrometeorological observations show that during 1990-2000 the mean annual surface air temperature increased by 0.4°C. (During the previous hundred years, the increase was only about 1.0°C.) Warming is more evident in winter and spring and more intensive east of the Urals.[iv]

Temperatures in the Arctic are rising at almost double the rate of the global average. In many inland Arctic regions, surface air temperatures have warmed 0.2°C per decade over the past 30 years. Sea ice in the Arctic has decreased by 3 percent per decade between 1978 and 1996, and summer sea ice thickness has decreased by 40 percent since the 1950s.[v] Precipitation at high latitudes has increased by 15 percent over the past decade, with most of this increase occurring over the past 40 years.[vi] Arctic summers are now warmer than at any time in at least the past 400 years.

The fourth Intergovernmental Panel on Climate Change (IPCC) climate change assessment (AR4)[vii] reported that in areas of the boreal north, the liquid precipitation season has become longer by up to three weeks over the past 50 years. Increasing winter temperatures in the northern regions has considerably changed the ice regime[1] of the region's water bodies. Comparing the years 2010-2015 with 1950-1979, the assessment predicts that, in the later period, ice cover duration on the rivers in Siberia is expected to be 15-27 days shorter and maximum ice cover thinner by 20-40 percent. Also, an annual increase of 5 percent was observed in river flow, with a winter increase of 25-90 percent over the base flow due to increased melt and thawing permafrost.

Winter snowfall and snow depth in the Northern Hemisphere's high latitude regions have increased during the past few decades; this trend is likely to be associated with increasing precipitation related to surface air warming. This trend is supported by significant positive trends in winter temperatures across much of the former Soviet Union in the past 50 years.[viii]

Most recent research shows that Siberian permafrost temperatures rose considerably during the latter half of the 20th century, although the extent to which this can be attributed entirely to climate warming is currently unknown. Recent research revealed positive warming trends for all permafrost regions in response to positive trends in air temperature, with the strongest warming trend in regions of continuous permafrost. A slight cooling trend is found only for the topmost soil layers in regions of seasonally frozen ground at the southern margins of the region draining into the Arctic.

[1] An ice regime is a region of generally consistent ice conditions. Ice types are measured in a range from grey ice (0-.15 m) to permanent ice (>3 m). See ftp://ftp2.chc.nrc.ca/CRTreports/ISOPE_98_IRS_database.pdf.

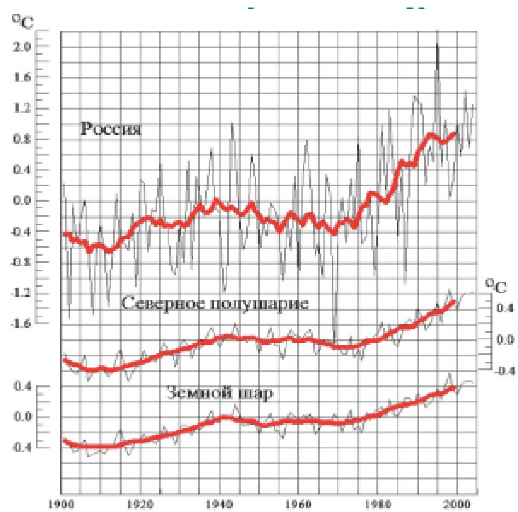

Figure 1. Surface air temperature increase in Russia, the Northern Hemisphere, and the world, 1900-2004. Source: Dobrolyubova, Julia, *Climate Change Effects and Assessment of Adaptation Potential in the Russian Federation* (Moscow: Russian Regional Environmental Centre, November 19-20, 2007), slides.

Melting permafrost serves as another revealing indicator of climate change. Significant areas of the Russian permafrost zone, which covers 60 percent of the country (the largest such region in the world falling under a single nation's jurisdiction), clearly show a trend of temperature increase in the top layers of frozen ground from the 1970s to the 1990s, corresponding with the warming of the atmosphere. Although climate change in European Russia is less severe than in Siberia, the change in the condition of frozen terrain is no less substantial. In the past 20-30 years, temperatures in the frozen ground of Russia's European Arctic and Subarctic have increased between 0.22 and 1.56°C, matching increases in the number and thickness of taliks (thawed underground pockets). These observations suggest a progressive increase in seasonally thawing soil, as well as a 14-80 percent increase in thawed pockets of soil in individual regions of the Russian Arctic.[ix]

Areas of seasonal frost have also shifted noticeably northward, and the area of isolated and sporadic pockets of frozen soil has decreased.[x] Although deeper layers of frozen soil are insulated against thawing by icy strata and organic soil and vegetation, models suggest that deeper seasonal thawing may change the composition of plant and animal communities.[xi] Natural tundra will likely grow smaller disappear entirely as a result.[2] [xii]

Satellite-derived measurements of snowfall show a spring and summertime decrease, likely due to increased temperatures. Snow accumulation over Russia accounts for about 5 percent of fresh water discharge to the Arctic Ocean. Significant changes in fresh water discharge have affected the salinity, sea ice distribution and circulation of the Arctic and nearby oceans. North of 50° N

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[2] The source does not provide an exact date of when natural tundra depletion may occur, other than mentioning that the change in composition of plant and animal communities is already occurring: "Although deeper layers of frozen soil are insulated against thawing by intermediate icy strata and a layer of organic soil and vegetation, models demonstrate that further deepening of seasonal thawing as a result of rising air temperatures may upset that balance. Should this happen, it will change (and this is already occurring) the composition of plant and animal communities, and existing natural complexes of the tundra may severely dwindle, or disappear entirely." http://assets.panda.org/downloads/wwf_arctica_eng_1.pdf

latitude, annual precipitation has increased by about 4 percent over the past 50 years, especially over Russia's permafrost-free zone and the entire Great Russian Plain. Over northern Russia, snow is providing a declining fraction of total annual precipitation.

The 20th century saw a trend of increased river output from the six largest Eurasian rivers flowing into the Arctic Ocean.[xiii] A similar trend is found in the climate simulation for the same period by the Hadley Centre's coupled climate model when the effects of manmade greenhouse gases are included. This finding is in line with predictions that global warming will cause changes in the water cycle.

Studies have shown that runoff in the Lena River increases in winter, spring, and (especially) the summer; and discharges decrease in autumn. These changes in seasonal streamflow characteristics indicate a hydrologic regime shift toward early snowmelt and higher summer streamflow, perhaps due to regional climate warming and permafrost degradation in the southern parts of Siberia. Winter snow accumulation is a major influence on summer and autumn discharge of the Ob and Yenisey Rivers and can affect winter and spring discharges of the Lena River, suggesting the importance of topography and permafrost conditions to river discharges in high-latitude regions.

Climate Predictions (Modeling)

Although Global Circulation (or Climate) Models (GCMs) can be used to infer climate changes in specific regions, developing models that have a high resolution sufficient to resolve local and regional scale changes is preferable. There are many challenges in reliably simulating and attributing observed temperature changes at regional and local scales. At these scales, natural climate variability can be relatively larger, making it harder to distinguish long-term changes expected due to external forcings.

The procedure of estimating the response at local scales based on results predicted at larger scales is known as "downscaling." The two main methods for deriving information about the local climate are (1) dynamical downscaling (also referred to as "nested modeling" using "regional climate models" or "limited area models"), and (2) statistical downscaling (also referred to as "empirical" or "statistical-empirical" downscaling). Chemical composition models include the emission of gases and particles as inputs and simulate their chemical interactions; global transport by winds; and removal by rain, snow, and deposition to the earth's surface.

Downscaled regional climate models rely on global models to provide boundary conditions and the radiative effect of well-mixed greenhouse gases for the region to be modeled. There are three primary approaches to numerical downscaling: (1) limited-area models, (2) stretched-grid models, and (3) uniformly high resolution atmospheric GCMs (AGCMs) or coupled atmosphere-ocean (-sea ice) GCMs (AOGCMs).

The magnitudes and patterns of the projected rainfall changes differ significantly among models, probably due to their coarse resolution. The Atlantic and Pacific Oceans are strongly influenced by natural variability occurring on decadal scales, but the Indian Ocean appears to be exhibiting a steady warming. Natural variability (from ENSO, for example) in ocean-atmosphere dynamics can lead to important differences in regional rates of surface-ocean warming that affect the atmospheric circulation and hence warming over land surfaces. Including sulfate aerosols in the models damps the regional climate sensitivity, but greenhouse warming still dominates the changes. Models that include emissions of short-lived radiatively active gases and particles suggest that future climate changes could significantly increase maximum ozone levels in already polluted regions. Projected growth of emissions of radiatively active gases and particles in the models suggest that they may significantly influence the climate, even out to year 2100.

Stabilization emissions scenarios assume future emissions based on an internally consistent set of assumptions about driving forces (such as population, socioeconomic development, and technological change) and their key relationships. These emissions are constrained so that the resulting atmospheric concentrations of the substance level off at a predetermined value in the future. For example, if one assumes the global CO_2 concentrations are stabilized at 450 parts per million (ppm) (the current value is about 380 ppm), the climate models can be tuned to produce this result. The tuned model predictions for regional climate changes can be used to assess specific impacts at this stabilization level. A more detailed discussion of the ability of the models to project regional climate changes can be found in Annex A.

Climate Projections of Future Temperature and Precipitation

The IPCC AR4 does not include predictions specifically focused on Russia. Most of the country is included within a modeling region referred to as Northern Asia (NAS). Warming in this region is expected to be well above the global mean—consistent with the more general result that high latitudes will (and are) warming more than low latitudes (see Figure 2). This warming is particularly great in autumn and early winter when sea ice is thinnest and the snow depth is insufficient to blur the relationship between surface air temperature and sea ice thickness. Precipitation is also very likely to increase (Annex A).[xiv]

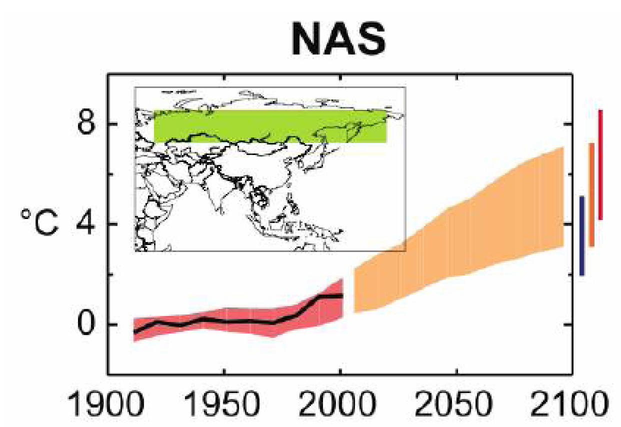

Figure 2. IPCC projected temperature increases for Northern Asia (NAS) (including Russia). Temperature anomalies with respect to 1901-1950 for the NAS land region for 1906-2005 (black line) and as simulated (red envelope) by multi-model datasets incorporating known forcings; and as projected for 2001-2100 for the A1B scenario (orange envelope). The bars at right represent the range of projected changes for 2091-2100 for the B1 (blue), the A1B (orange) and the A2 (red) scenarios. Source: Climate Change Risk Management Ltd, "Climate Change in Russia: research and impacts" (May 2008), hyperlink (accessed February 17, 2009): http://www.uk-russia-ccproject.info/documents/Impacts_in_Russia_Report_2008.pdf

The Arctic is extremely vulnerable to climate change.[xv] The region is warming much more rapidly than the global average. The IPCC report states that the winter warming of northern high latitude regions by the end of the century will be at least 40 percent greater than the global mean, based on a number of models and emissions scenarios. Temperature increases for the central Arctic are projected to be about 3-4°C during the next 50 years. Even an optimistic scenario for projecting future greenhouse gas emissions yields a result of a 4°C increase in autumn and winter average temperatures in the Arctic by the end of this century. Recent satellite data show that the area covered with perennial ice in the Arctic Ocean has receded significantly in recent years, falling to nearly half the area observed in 2005.

During the 21st century, the thaw depth will increase substantially, summer soil moisture will eventually be reduced, and a poleward movement of the permafrost extent is expected. Based on three global climate models (Canadian Climate Center scenario, GFDL scenario and ECHAM scenario), a 30-40 percent increase in active layer thickness for most of the permafrost area is projected, with the largest relative increases concentrated in the northernmost locations.[xvi]

Regionally, the changes are a response to both increased temperature and increased precipitation (changes in circulation patterns). In a few regions, Siberia for example, the amount of snow is projected to increase because of the increase in precipitation (snowfall) from autumn to winter. Consistent results from the majority of the current generation of models show, for a future warmer climate, that a poleward shift of storm tracks occurs with greater storm activity at higher latitudes.[xvii]

Most models ignore the effect of land cover change in future projections. Past and future changes in land cover may affect the climate in several ways, causing changes in albedo, in the ratio of latent to sensible heat, and therefore in surface temperature, and in CO_2 fluxes to and from the land. No coupled AOGCM has included all the effects of land cover changes. The general consensus is that land cover changes may be very important at the regional level, where these changes occur.

At the regional level, the Russian Federation has considerable experience in climate modeling, with three centers of research: St.Petersburg V.A. Fock Institute of Physics; Institute for Numerical Mathematics (INM) in Moscow, and the Oboukhov Institute of Atmospheric Physics in the Russian Academy of Sciences (IAP-RAS) in Moscow. Both the INM and the IAP-RAS have their own climate models, although only the former submitted simulation data as part of the IPCC fourth assessment process.

Table 1 shows the 2080-2099 temperature and precipitation projections from a set of 21 global models. The numbers represent average (mean) changes from the period 1980-1999 over the 21 models. For each season, the minimum, 25 percent, 50 percent, 75 percent, and maximum changes are shown. For example, for the winter (DJF, or December, January and February), the average minimum temperature increase is 2.9°C, and the average precipitation change is +12 percent.

The five-to-10-year projections of the Russian hydro-dynamical climate models[xviii] match very well with the model projections of the IPCC AR4[xix], when the same scenarios and assumptions are used.[xx] These projections suggest that the mean annual surface air temperature over Russia will increase over the next five to 10 years by $0.60^{o}C \pm 0.2$ from the annual mean temperature in the year 2000. The increase in temperature will vary by region, but by 2015 the average winter temperatures will have increased by an additional 1°C. In summer, the increase is only expected to be 0.40°C. During this same period, annual averaged precipitation is projected to increase by 4-6 percent, with the increase being as much as 7-9 percent north of Eastern Siberia.[xxi]

	Temperature Response					Precipitation Response				
Season	**Min**	**25**	**50**	**75**	**Max**	**Min**	**25**	**50**	**75**	**Max**
DJF	2.9	4.8	6.0	6.6	8.7	12	20	26	37	55
MAM	2.0	2.9	3.7	5.0	6.8	2	16	18	24	26
JJA	2.0	2.7	3.0	4.9	5.6	-1	6	9	12	16
SON	2.8	3.6	4.8	5.8	6.9	7	15	17	19	29
Annual	2.7	3.4	4.3	5.3	6.4	10	12	15	19	25

This table is **UNCLASSIFIED.**

Table 1: Regional averages of temperature and precipitation projections from a set of 21 global models in the MMD for the A1B scenario for the region of Northern Asia (NAS: 50°N, 40°E: 70°N, 180°E). The table shows the minimum, maximum, median (50 percent), and 25 and 75 percent quartile values among the 21 models, for temperature (°C) and precipitation (percent) change. The changes are calculated as the 2080-2099 mean with respect to the 1980-1999 mean. DJF=December January February, MAM= March April May, JJA=June July August, SON=September October November. Source: Table 11.1 in IPCC [Intergovernmental Panel on Climate Change]. *Climate Change 2007: the Physical Science Basis*, ed. S. Solomon, D. Qin, M. Manning, M. Marquis, K. Averyt, M.M.B. Tignor, H.L. Jr. Miller, and Z. Chen (Cambridge: Cambridge University Press, 2007).

Maximum temperature increases are expected to occur in the winter in the Arctic.[xxii] By the middle of the 21st century, temperatures are projected to rise as much as 4-5°C in the Arkhangelsk region, the Komi Republic, the Yamalo-Nenets Autonomous Area, and over Taimyr.[xxiii] Temperature increases in the summer in these regions are small. However, in the southern regions, such as in the Northern Caucasus, the Volga region, and in the south of Western Siberia, an increase of 2–3°C is projected.

According to an assessment done by the World Wildlife Fund (2008),[xxiv] an appreciable increase in winter precipitation totals is expected by 2050—notably, a 30 percent increase on the Taymyr Peninsula and a 15-20 percent increase in Chukotka and the Barents Sea region. This increase in precipitation is expected to continue throughout the second half of the century. Total precipitation will more than double current values in the eastern Russian Arctic, consequently forming a deep layer of snow and reducing the period of soil freeze in winter. Alternatively, summer precipitation totals will increase only 5-10 percent by 2050, and 10-20 percent by the end of the 21st century, with the increase being slightly larger in the eastern part of the Arctic. An increase in the frequency of heavy rainfall is forecasted for the same region, effectively accelerating coastline erosion. Throughout the Arctic, there will be more rainfall than evaporation, despite predicted increases in evaporation due to warming.[xxv] The result is the formation of bogs[3], more likely prominent along the central and eastern Arctic coast.

Trends of wintertime snow mass accumulation vary over the country. In European Russia (that is, Russia east of the Urals) and south of Western Siberia snow mass is expected to decrease compared with long-term mean values. By 2015 a 10-15 percent decrease is expected. In most of the rest of Russia, snow accumulation is expected to increase by 2-4 percent.[xxvi]

[3] According to the US Environmental Protection Agency, bogs are "characterized by spongy peat deposits, acidic waters, and a floor covered by a thick carpet of sphagnum moss. Bogs receive all or most of their water from precipitation rather than from runoff, groundwater or streams. As a result, bogs are low in the nutrients needed for plant growth, a condition that is enhanced by acid forming peat mosses." See http://www.epa.gov/owow/wetlands/types/bog.html.

Projected changes in annual river runoff vary across the country. Winter runoff is projected to increase from 60-90 percent in the Central and Volga Federal Districts, and from 5-40 percent in other Federal Districts. In the Black Earth area and in the south of the Siberia Federal District, springtime river runoff is projected to decrease by 10-20 percent.[xxvii]

Permafrost and Arctic Ice Projections

According to a collaborative report led by Climate Change Risk Management (CCRM),[xxviii] seasonal thaw depths are predicted to increase around 2050 by more than 50 percent in the northernmost permafrost regions, and 30-50 percent elsewhere. By 2100, it is predicted that almost 60 percent of current permafrost regions will thaw and freeze on a seasonal basis.[xxix] Increased precipitation contributes to the thawing of frozen soils and is projected to lead to a 14 percent increase in freshwater discharge into the Arctic Ocean. Modelers warn that there are significant uncertainties in model projections of changes to the permafrost.[xxx]

A coupled climate-permafrost model was used by Anisimov and Renava (2006)[xxxi] to calculate changes in permafrost extent and thickness for three timeslices. Model results predict a reduction of near-surface permafrost area by 11 percent, 18 percent, and 23 percent by 2030, 2050, and 2080, respectively. Contractions of near-surface permafrost over these same periods are 18 percent, 29 percent, and 41 percent, respectively.

Despite the uncertainties, most modelers agree that seasonal thaw depths will increase by more than 50 percent in the northern Russia, including much of Siberia and the Far East; and by 30 percent to 50 percent in most other permafrost regions.[xxxii] Figure 3 shows the projected changes in active-layer permafrost thickness in northern Eurasia by 2050. Increased methane emissions from the melting permafrost will be a significant feedback on radiative forcing and climate change. Projected changes in the permafrost to the year 2050 are shown in Figure 3.

Most models project that summer ice will decline much more rapidly than winter ice.[xxxiii] Arctic sea ice is projected to decrease more rapidly than other sea ice.[xxxiv] Some scientists suggest that the Arctic Ocean could be ice free in summer in the next 10-20 years.[xxxv]

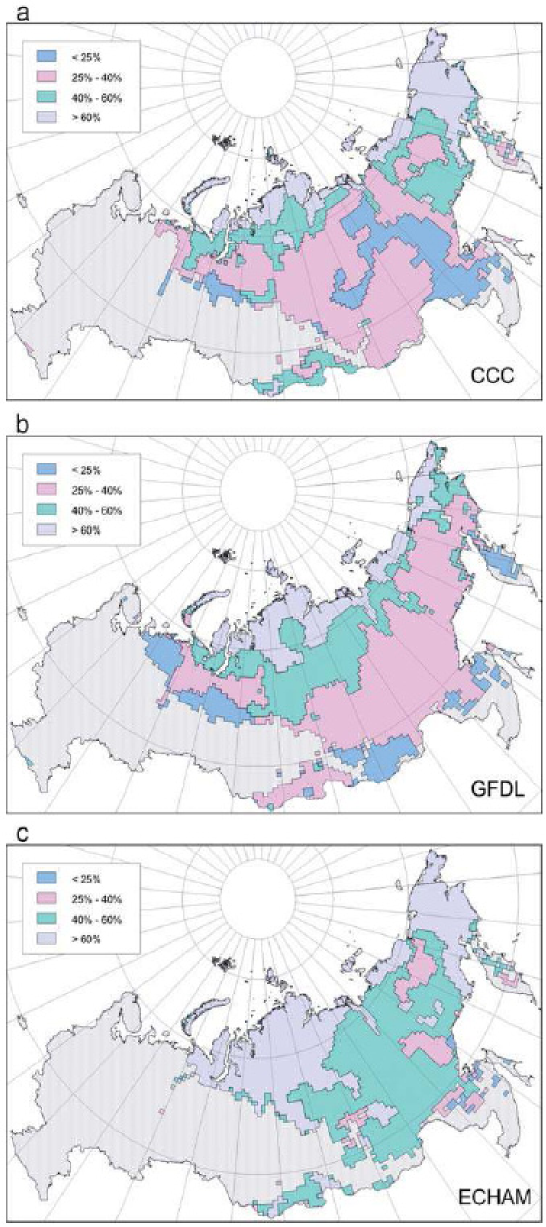

Figure 3. Projected 2050 changes of the active-layer permafrost thickness in northern Eurasia, relative to present-day simulations, based on forcing from three different global climate models: (a) CCC (Canadian Climate Center) scenario; (b) GFDL scenario; (c) ECHAM scenario (From Anisimov and Reneva 2006). Source: Climate Change Risk Management Ltd, "Climate Change in Russia: research and impacts" (May 2008), http://www.uk-russia-ccproject.info/documents/Impacts_in_Russia_Report_2008.pdf (accessed February 17, 2009).

Projections of Changes in Agricultural Growing Seasons

The decline in the number of very cold winters in many regions across Russia has led to better conditions for growing winter crops. In the Central Black-Earth and Volga regions, the frequency of very cold winters has decreased from an average of 18-22 percent in the period up to 1990 to 8-10 percent in the past several years.[xxxvi] In Northern Caucasia, this frequency has been reduced from 10 percent to 4 percent.

Conditions for growing corn have improved in many areas of European Russia. In the Stavropol Territory, "climate-related"[xxxvii] corn yield has increased 30 percent over the past 20 years, but in parts of Asian Russia (e.g., the Baikal), corn yield has decreased.

From 1970 to 2000, the growing season (with air temperatures above +5^{o}C) lengthened by an average of approximately 5-10 days over much of the agricultural region in European Russia. However, frost-free periods did not lengthen.[xxxviii]

If this trend continues, agricultural production may increase significantly by 2015. The growing season is likely to be significantly lengthened. Both the growing season and duration of frost-free days may be increased on the order of 10-20 days per year.[xxxix] Many plant species may experience a northward migration of growing boundaries. On the Siberian rivers and in the Kama River basin, a reduction of the freeze period of as many as 15-27 days is expected by 2010-2015.

Changes in the Frequency or Strength of Extreme Climatic Events

Changes in the frequency of extreme events may be one of the most damaging consequences of climate change. Climate change over the past 10-20 years in Russia has been linked to extreme events, including heat waves, floods, and fires. The IPCC assessment[xl] reports a substantial increase in the number of days with more than 10 millimeters of rain in Siberia, causing a 50-70 percent increase in surface runoff. There were also a significant increase in the number of fires in Siberian peatlands and more frequent flooding in Russian Arctic rivers due to heavy rain and earlier breakup of river ice.[xli] Satellite measurements show that vegetation fires, mostly forest fires, occurred over about 10 million hectares during 1997-2003. Outbreaks of disease-carrying insects also occurred in the northern part of the country, where outbreaks have never been observed in the past.[xlii]

Observations suggest that large floods are already more frequent.[xliii] By 2015, there is likely to be more flooding in river basins in the Archangelsk Region, the Komi Republic, the Ural area, and in the basins of Enisei and Lena.[xliv] In the Arctic, increased water discharges occurring earlier in the spring may be blocked by ice jams, causing the duration of inundated flood plains to increase from the current 12 days to 24 days. In the past five years, the Lena, one of the world's 10 largest rivers, has experienced two floods more severe that any previous recorded flood.[xlv]

Ice-jam-induced floods in the Lena River Basin are expected to double by 2015. Flooding in the Far East and the Maritime areas is expected to double or triple. In the mountain and submountain regions of Northern Caucasia (Republics of North Caucasia, Stavropol Region) and in the Western and Eastern Sayan Mountains, more mudflow and landslide hazards are expected.[xlvi] In St. Petersburg, the probability of a disastrous flood is expected to increase in the next 5-10 years.[xlvii]

The average annual discharge of fresh water from the six largest Eurasian rivers to the Arctic Ocean increased by 7 percent between 1936 and 1999.[xlviii] Peterson et al. (2002), Wu et al. (2005) and Shiklomanov et al. (2006)[xlix] project Russian river discharges will continue to increase at an accelerated rate. The average projected change in annual discharge in large Russian rivers is around 15 percent (range: -12 to 45 percent).[l] Annual discharge in the Yenisey, Ob, Lena and Kolyma rivers are projected to change by 6-45 percent, -12-45 percent, 12-45 percent, and 10-45 percent, respectively.[li] All experienced significantly larger increases in winter discharges—as much as 325 percent in a high-sensitivity scenario (4ºC).[lii]

Over this century, increases in the frequency and intensity of heat waves are expected in western and central Europe, possibly including parts of Russia. A record-breaking heat wave occurred in central Europe in summer 2003. This event was the hottest since instrumental records began around 1780 (1.4°C above the previous warmest in 1807) and is very likely to have been the hottest since at least 1500.[liii]

Hazardous events due to the changes in permafrost are expected to increase by 2015.[liv] Melting of permafrost islands will lead to increases in landslides, mudflows, and other dramatic and abrupt changes in the landscape.[lv] When a glacier recedes, unstable glacial lakes are formed that increase the likelihood of glacier-related outbursts and debris slides. Glacier retreat between 1985 and 2000 has resulted in a 3-6 percent increase in the proportion of glaciers covered by debris, increasing the melt rate and the likelihood of glacier-related significant events such as rock and mud slides.[lvi]

On both the Baltic and Pacific coasts, a rise in sea level may result in the coastline being more vulnerable to tsunamis. Studies of the Baltic region have stressed the possibility that tsunami activity could profoundly affect the coastline. Some of the largest tsunamis ever observed have occurred along the Pacific coast, which is prone to tsunamis. The IPCC 2007 assessment identifies the Baltic and White seas as areas of probable increased flooding and erosion.[lvii]

Over large areas of Russia, the number of both high-intensity and mid-intensity fire-hazard days is expected to increase. By 2015 the number of fire-hazard days may increase by more than five days in a season on most of the territory. The areas most likely to experience an increased duration of fire-hazard days (more than 7 days in a season) include areas south of the Khanty-Mansi Autonomous Area; and in Kurgan, Omsk, Novosibirsk, Kemerovo and Tomsk Regions, Krasnoyarsk and Altai Territories, Sakha-Yakutia Republic.[lviii]

Impacts of Climate Change on Human-Natural Systems

In Russia, the socioeconomic impact of climate change has long been controversial. Some of Russia's most prominent climate scientists have argued persistently that a warming climate will bring net positive benefits for a cold, massive country whose territory includes vast expanses of permafrost and undeveloped forests, while others posit some unmitigated negatives. While the debate continues among Russian observers, the weight of scientific evidence points to a more complicated picture—some significant benefits, as well as profound problems for human systems that have the potential to challenge Russia's ability to respond.

Economic Growth and Development

The Russia that will face the unfolding impacts of climate change between now and 2030 is a Russia newly grown accustomed to relative wealth. No longer is it the economic basket case that it was in the 1980s and 1990s. In fact, until the global financial crisis began to bite in Russia in late 2008, the country had ridden a decade-long wave of economic good fortune following the crash of the Russian ruble in August 1998.

Russia is extraordinarily dependent on its extractive industries and commodity production. In addition, the country's development has been highly uneven, with most wealth concentrated in the capital, Moscow. Only a modest trickle-down effect has occurred in smaller cities, and virtually none has occurred in rural areas. Most of the impacts of climate change will manifest themselves in smaller cities and in the Russian countryside.

Another consideration that relates to the advance of climate change impacts is the role of the government in people's everyday lives. During Soviet times, government was highly intrusive but simultaneously was the source of considerable private skepticism. ("We pretend to work; they pretend to pay us," was one of the core folk wisdoms.) Government did, however, provide services that ensured a minimum standard of living for nearly all citizens. In today's Russia, many people have arguably even less expectation that the government will provide for their minimum requirements. But if climate change begins to wreak serious humanitarian impacts, such as recurrent massive flooding or the collapse of aging infrastructure, and if the government is not in a position to respond in a commensurate way, one of the key questions will be whether climate change prompts political unrest. For the time being, we judge this to be a significant, but unresolvable open question.

Energy Systems

The stable operation of energy systems is a major technological challenge for a country as massive as Russia. It is also a matter of vital importance to everyday Russians, whose day-to-day survival depends on the timely availability of heat and power in the face of Russia's severe climate. Energy systems are no less of a matter of survival for the Russian economy, which stays afloat largely due to petroleum exports. For these reasons, the impacts of climate change on Russian energy systems are of exceptionally great importance.

The seasonality and geographical scope of climate change across Russia have significant implications for Russian changing energy demand between now and 2030. As is mentioned above, mean temperature increase in Russia by 2030 is projected to be significant nationwide, although more pronounced in the north and east of the country than in the south and west, and more pronounced in winter and spring than in the summer or fall.[lix]

As shown in Figure 4, the projected climate warming is expected to lead to a reduction in the length and intensity of the heating season, which has the potential to result in reduced energy consumption for heating. Roshydromet projects that on average, by 2015, the heating season will be three to five days shorter across the entire country.[lx] In the eastern regions of Primorskiy Kray, Sakhalin, and Kamchatka, the heating season may be more than five days shorter by 2015. Some regions may experience little if any reduction in the length of the heating season. These trends are projected to extend and intensify by 2030 and beyond.

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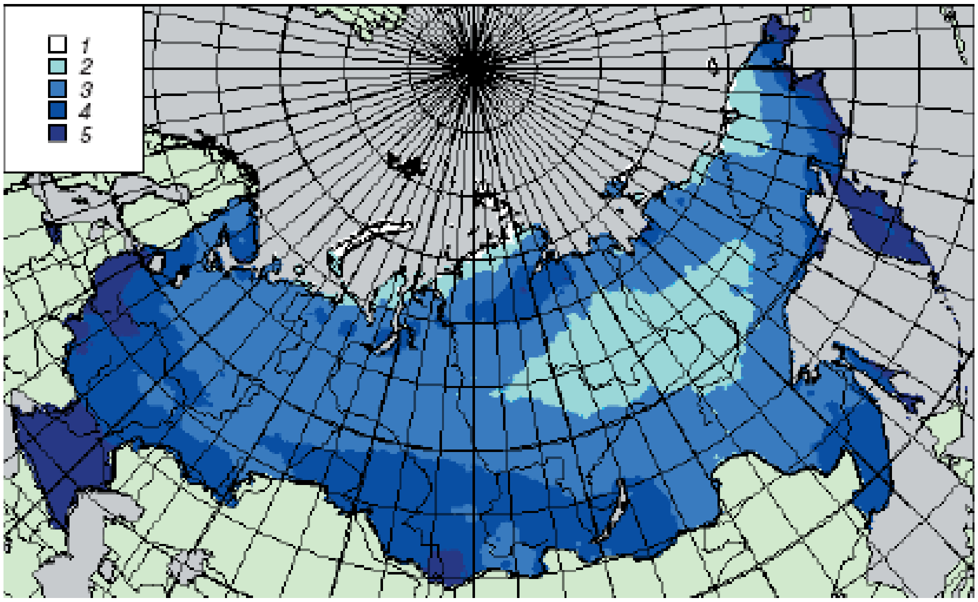

Figure 4. Reduction in duration of the heating season. Legend: Zone 1 shows ***reduction*** of the length of the heating season by 0.0-1.9 percent, Zone 2 -- 2.0-3.9 percent, Zone 3 -- 4.0-5.9 percent, Zone 4 -- 6.0-7.9 percent, Zone 5 -- 8.0-10.0 percent. Source: Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet), "Assessment Report on Climate Change and its Consequences in Russian Federation" (Moscow, 2008).

In areas that experience this change, residents and workers may experience greater indoor comfort, as heating systems and building envelopes will be better able to cope with the heating load.

For those regions that do experience a reduction, the extent of the related energy savings is a matter of some debate, even in official Russian government projections. According to analysis presented in 2005 and 2008 by the Russian Federal Service on Hydrometeorology (Roshydromet), the reduction in heating days resulting from a warmer climate may not translate into saved fuel. Even if there are fewer total heating days, they may stretch out over the same period of the year—or even longer[lxi] —because of increased temperature variability.[lxii]

This Roshydromet analysis contrasts with the Russian Federation's Fourth National Communication under the UN Framework Convention on Climate Change, which was submitted in 2006. According to the Fourth National Communication, the reduction in heating requirements by 2025 will result in a net fuel savings of 5-10 percent nationwide (and greenhouse gas emissions reduction of 2 percent).[lxiii] If the latter projection proves accurate, the saved fuel could provide a significant economic benefit, and potentially a significant balance-of-payments benefit, provided that the saved fuel was exported instead of being consumed domestically.

Just as a changing climate is expected to affect energy demand in Russia, so too will it affect energy supply. On the supply side of the ledger, the changing climate may affect hydroelectric power production, electricity transmission and distribution systems, and petroleum production and transportation systems.

Hydroelectric power production will realize some benefit, and some negative impacts, associated with the increase in flows of rivers that are used for hydroelectric production. As is true with the question of the length of the heating season, the net benefit or cost in 2020 remains ambiguous.

Many of the major Russian rivers will experience increased water flows due to glacial melt and selective regional precipitation changes. For the most part, this change will offer opportunities for increased power production. According to Roshydromet, the Volga-Kamsk Cascade will experience a net increase of 10-20 percent in water flows. The reservoirs throughout the Northwest Federal District will experience a 5-10 percent increase, and the massive Siberian power dams along the Angarsk-Yenisey, Vilyu, Kolyma, and Zeya will experience increases ranging as high as 15 percent. In addition, certain hydro-electric reservoirs in the southern part of the country will experience reductions in productivity due to reduced water flow. Nonetheless, operating regimes for all power dams will require review in light of anticipated climate change, according to Roshydromet. In addition, there will be increased challenges related to managing head and tail waters in the face of increased flows, and particularly in relation to increased incidence of extreme downpours.[lxiv]

Another energy supply-related impact from climate change to 2030 will relate to electricity transmission systems. One form of the heightened risk to power transmission will come from permafrost melt and the resulting creation of thermokarst and other unstable soil conditions. High-voltage power lines will be one of the many kinds of structures that will be susceptible to damage as upper soil layers thaw and re-freeze. One particularly vulnerable transmission system will be the lines serving the Bilibino nuclear power plant on the Arctic coast and running from the town of Chersk to Pevek.

Another heightened risk for power transmission systems will be increased wind load on power stanchions, as on other large structures. Power lines in the North Caucasus, as well as in the regions of Murmansk, Arkhangelsk, Leningrad, portions of Sakha (Yakutia), Irkutsk, Magadan, Khantiy-Mansiysk, and Evenkia will be exposed to 20 percent increases in wind force and may need to be reconstructed or reinforced as a consequence.[lxv]

Climate change by 2030 appears unlikely to sufficiently affect the Russian electric power sector as to lead to significant national security implications for the Russians. However, major power system failures could lead to serious human hardship and could therefore conceivably fuel political dissatisfaction in Russia. If a major portion of one of Russia's regional power grids were destabilized by the failure of a major power dam, or if power supply lines failed due to unusually abrupt winds in the North Caucasus, for example, one could envision the potential for localized instability.

If the hydropower and power transmission industries face challenges as climate change intensifies, even greater challenges face the petroleum industry, with likely greater significance for the Russian economy and state. In today's Russia, oil and gas are the predominant components of economic performance. Together they represent on the order of 60 percent of total exports and one-third or more of state revenues.[lxvi] Russia learned, starting in late 2008, that its economy was therefore at risk of significant volatility in case of a downturn in global energy prices, and diversifying the economy away from extractive industries is a stated goal of the Russian government. However, for the foreseeable future, the core of Russia's economy will remain oil and gas.[lxvii]

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This in turn means that Russia's economy is highly vulnerable to climate change impacts that affect the current or future operations of the petroleum sector. Many areas that are currently the focus of exploration and production activity will be more difficult to exploit. Pipeline and rail transportation systems that cross major rivers and permafrost will be subjected to unprecedented stresses and strains, many of which were not anticipated when initial design parameters were established. Critical new upstream development areas, such as the Yamal Peninsula, will be more complicated to reach by land and harder to develop in the face of thawing permafrost and shorter winter seasons.

The Russian petroleum industry has traditionally centered in West Siberia and the Volga region, with transportation links extending to European portions of Russia and then to western and central European markets. The Russian gas industry has centered on three super-giant fields in the Nadym-Pur-Taz region—the Urengoy, Yamburg, and Medvezh'ye fields. At present, in addition to thousands of producing oil and gas wells, Russia has roughly 50,000 kilometers of oil pipelines and roughly 150,000 kilometers of gas pipelines, most of which were constructed in the 1980s under Soviet rule. There are also scores of processing plants and refineries distributed across Russia's massive territory.[lxviii] (See Figure 5 for a map of existing and planned pipelines and gas production regions.)

The core climate-related vulnerability facing oil and gas pipeline systems is that these systems were designed and built with the presumption of a stable climate. The thousands of river crossings did not provide margins of error to accommodate the increased water flow that will result from climate change by 2030. They were not constructed using horizontal directional drilling techniques that allow deeper and more secure passage under riverbeds. Underwater river crossings in several key producing and transit regions are thought to be particularly at risk—the upper and lower Volga and its tributaries in the regions of Nizhegorodskaya, Orenburg, Perm, Samara, Saratov, Ulyanovsk, Bashkortostan, Tatarstan, Tyumen, Novosibirsk, and Sakhalin among others.[lxix]

In addition to climate-related risks for river crossings, oil and gas pipelines and other facilities are at risk in permafrost regions. In these areas, pipelines and other structures are typically constructed above ground to allow thermal insulation to avoid thawing the soil. In the period to 2030, however, these regions will experience deeper seasonal thawing, resulting in structural subsidence and weakened integrity of pipelines and other petroleum-industry installations.

The permafrost zones are also exceptionally important for the future development of oil and especially gas production. Russian gas production has been the basis of not only Russian export earnings but also Russia's controversial, growing politico-economic power vis-à-vis central and western European neighbors, as was demonstrated again in early 2009 during the Russian-Ukrainian gas crisis.

Maintaining Russian gas exports is therefore a matter of highest national priority. There has been a dramatic decline of production at the Urengoy, Yamburg, and Medvezh'ye fields that have been the core of Russian gas production since the end of the Soviet period.[lxx] New production is crucial for Gazprom to realize its production targets and satisfy both domestic requirements and export consumers in coming years.[lxxi]

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Three of the key areas that the Russians expect to produce new gas will keenly feel the effects of a changing climate by 2030. First, the Yamal peninsula is an Arctic region that is a vast wealth of untapped gas prospects. According to some Gazprom projections, it could account for as much as 200 billion cubic meters (bcm) of gas production per year by 2020, and 360 bcm per year by 2030.[lxxii] However, developing Yamal will be significantly complicated by a changing climate. Supplies that will need to be brought in by land will require the construction of new roads and rail links, which will be tricky with the growth of thermokarst. Previous techniques, like the use of seasonal ice roads will be more problematic due to the shorter cold season. New above-ground pipelines and other elevated installations will have to be constructed using deeper foundations to avoid structural damage from subsidence.

A second key area for new Russian gas production is the Barents Sea. Here, one massive new field called Shtokman is to be developed some 550 kilometers north of the Kola Peninsula, with a projected annual production of around 90 bcm of gas.[lxxiii] This hugely challenging technical undertaking, which will require the construction of ice-capable production platforms in more than 300 meters of water, is especially difficult because it is so far offshore that it is beyond the range of helicopters, yet it is vulnerable to seasonal pack ice and vicious storms. In the face of a rapidly changing Arctic climate, vessels traveling to Shtokman will have to navigate increasingly severe waters and endure bitter winter storms.

A third key projected area for the Russian gas industry is Eastern Siberia and the Russian Far East. Here too, climate change in the period to 2030 will pose increasing complications—melting permafrost, swollen rivers, more frequent and severe storms and more prevalent incidence of traditionally atypical forms of disease. As mentioned above, the Russian gas industry has traditionally been oriented toward customers within Russia and in neighboring European countries. However, in the past decade, Gazprom and the Russian government have identified the goal of moving to the East and developing gas resources that can feed to the Pacific Rim. The official Eastern Gas Program released in August 2007 projects total extraction of 100 bcm/year by 2030.[lxxiv] New fields are being developed in the Sea of Okhotsk, near Sakhalin Island. Other prospects are being pursued as far west as the area to the north of Lake Baikal (e.g., the Kovykta field) and in the Sakha Republic (Yakutia). All of these projects will require major new construction with countless major and minor river crossings and a significant number of permafrost operations. This development will therefore be vulnerable to the same kinds of challenges from climate impacts as have been discussed above.

Food Production and Drinking Water Supply

Russia will experience a mix of positive and negative impacts on food and water supply in the period to 2030. The net impacts in these important areas will depend heavily on the extent to which adaptation measures can be implemented in an affordable and timely manner, but doing so will be difficult.

Experts project that Russia will experience an increase in total water supply in the period to 2030. According to Roshydromet, in the aggregate Russia will experience an 8-10 percent increase in water volume by 2015—the equivalent of a 12-14 percent increase per capita—with these trends expected to continue in the years that follow.

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That said, different regions will experience significantly different changes in their respective water supply. The northern and northwestern portions of European Russia, as well as the central Volga, many of the non-Chernozem lands, the Urals, and the Russian Far East will experience increasing water availability. In the dams along the Volga-Kamsk Cascade, water flows are projected to increase by 10-20 percent by 2015, as mentioned above. In the Northwest federal district, dams will see a 5-10 percent increase over the same period. And some of the key Siberian rivers systems—the Angarsk-Yenisey, the Vilyu, the Kolyma, and the Zeya—will experience flow increases by up to 15 percent.[lxxv]

On the other hand, many other parts of Russia will experience worsening water shortages, including densely populated industrial regions that are projected to experience increases in water demand of 5-25 percent.[lxxvi] In the Chernozem lands, these water-poor areas will include the Belgorod, Voronezh, Kursk, Lipetsk, Orel, and Tambov regions. In the south, Kalmykia, Krasnodar, Stavropol, and Rostov regions will face increasingly challenging water situations, with reductions in water supply on the order of 5-15 percent.[lxxvii] In southwestern Siberia, the list will include Altay, Kemerovo, Novosibirsk, Omsk, and Tomsk. Across a key southern belt, a whole host of Russian regions will face mounting, and serious, water problems. Included in this list will be both certain key agricultural lands (more on food supply below), and also a number of key industrial regions. Even the capital and the Moscow Oblast' will face "particularly acute" water supply problems.[lxxviii]

Regarding food supply, the longstanding popular presumption in Russia has been that a warmer global climate would translate into a significantly more hospitable Russian environment for agricultural production. Indeed, there are several respects in which climate change by 2030 will reduce longstanding challenges for Russian agriculture. First and foremost, growing seasons have already become longer and are predicted to become longer still.[lxxix]

Accompanying this change will be a reduction in the frequency of winter temperatures that are sufficiently bitter to damage winter plantings. More sensitive varieties of winter plantings will be possible in much of Russia by 2030, and it will be possible to plant existing varieties farther north than would have been the case in the past.[lxxx] For example, it will be possible to plant longer-ripening grains and late-ripening sugar beets as far north as Moscow.[lxxxi] Interestingly, the longer growing seasons will not be accompanied by an increased frost-free period except in the Northwestern, Central, and Volga federal districts.[lxxxii]

Based on temperature ranges expected by 2030, it will also be possible to introduce entirely new crops that are not widely grown in Russia today. For example, the projected temperature of the north Caucasus and the lower Volga will be well suited to intensive agriculture for crops that are typically found in Central Asia and the south Caucasus at present—crops such as cotton, grapes, tea, citrus, and other fruits and vegetables.[lxxxiii]

A key question, however, is whether the longer growing seasons and the warmer Russian agricultural lands will result in increased yields. In fact, this does not appear to be assured—at least not based on the crops that are currently raised. Many of the current "bread basket" areas of Russia—including the Black Earth or Chernozem lands, the lower Volga region, and the southern part of Siberia—will experience reductions in grain yields resulting from reduced precipitation—reductions in yields of more than 22 percent by 2020. Warmer average temperatures will produce better grain yields in some parts of the country that have not traditionally served as the heartland for grain production. Regions such as the Northwest and Central federal districts and the Volga-Vyatsk region are expected to see a 10-15 percent increment in grain yields. Nationwide, according to Roshydromet, grain yields could shrink by more than 11 percent by 2020.[lxxxiv]

Plant diseases and pests will become a more serious challenge in many parts of Russia. In the southern part of European Russia and in western Siberia, locusts are expected to be increasingly common. Already they are found more frequently than was the case two or three decades ago, and they are expected to be even more prevalent in the future in the Stavropol, Kalmykia, Volgograd, Astrakhan, Saratov, and Rostov regions, and in some parts of southern Siberia.[lxxxv] In northwestern Russia, farmers are experiencing an infestation of Colorado potato beetles, which are now found in Karelia. In coming years, as mild winters become increasingly common, they are expected to spread into southern parts of the Arkhangelsk region and the Komi Republic.[lxxxvi]

A third question that arises about future agriculture is whether human management and distribution systems, and rural society itself, will be able to adapt in a timely manner to manage new crops, new supply chains, and requirements. Indeed, rural Russia has typically been resistant to change. In addition, supply, distribution, and management issues have historically posed great hurdles for Russian agriculture. A key question will be whether a true national market for food and agricultural products develops, or whether Russian regions persist in semi-national, semi-intra-region forms of agricultural trade.[lxxxvii]

Additional challenges for agriculture by 2030 will come from the increased frequency of severe weather events. Periods of drought in key agricultural regions are expected to be 50-100 percent more frequent by 2015, with the trend line continuing thereafter.[lxxxviii]

By 2030, Russia will start to feel the impacts of climate change in relation to both water and food supply. To maintain stable food supply, significant changes will be required in terms of varieties that are planted, the lands that are used for agriculture, and the extent and intensity of pesticide and irrigation use. All of these solutions are theoretically possible, but none will come easily or inexpensively. All will test the ability of Russian authorities and Russian agriculture to adapt quickly as climate change impacts are felt.

Transportation Systems

Transportation systems are another aspect of Russia's socioeconomic life that will experience major impacts from climate change by 2030. For the most part, these impacts will entail the need for significant adaptations, which will imply significant capital requirements. This will be true for Russia's extensive rail networks as well as its more limited road networks. However, in relation to river transportation and especially Far North maritime transport, a changing climate will open new and likely beneficial possibilities.

Russia's railways are the backbone of its goods and passenger transportation system, with over 87,000 kilometers of railroads stretching across most of the country.[lxxxix] The system is a state-owned monopoly that moves 1.3 billion passengers and 1.3 billion tons of freight annually, which represents 83 percent of all freight in Russia (not counting petroleum pipeline operations).[xc] The rail system is most highly developed in the European part of Russia and along the southern reaches of Siberia. Nonetheless, a significant portion of the rail system—such as the Baikal-Amur Mainline (BAM)—cross permafrost zones, so they will be subject to the same risks of subsidence and structural weakening from permafrost melt as well as increased vulnerability at river crossings from increased Siberian river flows, as discussed above.

Russia's road transport systems are much less significant for cross-country transportation, but they too will be affected by climate change. Some of the impacts may be positive, in that reduced winter snowpack in European Russia (where the road system is much more developed and much more used than in the Arctic or the Far East) may reduce road hazards and wear and tear on existing roads. Other impacts will be negative, however. The increase in weather variability, with elevated risks of severe storms and downpours, may lead to elevated dangers for road transportation and risks of mudslides and erosion in mountainous areas and near rivers and floodplains. In the Far North and Far East, where wintertime ice roads have been a means of wintertime survival, shorter cold seasons will result in significantly reduced road transport capacity.[xci]

River transport, which is another key element of Russia's total transportation system, will experience both new problems and benefits from climate change to 2030, varying by region. In areas such as the Don River Basin in Russia's southwest, where there will be a reduction in total water flow, river navigation may encounter serious challenges. Extensive, and expensive, dredging may be required to allow continued barge and river freighter traffic.

In other areas, where river flows will significantly increase, such as along the major Siberian river systems and in the northwest of the country, river transport may be enhanced and facilitated. The exception to this rule may occur in areas where the earlier arrival of spring weather and the more pronounced melt-off of winter snow and ice lead to river ice jams and flooding.[xcii]

Another potentially significant transportation impact from climate change is the increased possibility of sea passage through Arctic waters. The so-called Northern Sea Route (NSR) that runs from near the island of Novaya Zemlya to the Bering Strait offers the prospect of up to a 40 percent savings in sea distance for journeys between northern Europe and Pacific Rim ports in either North America or northeastern Asia.[xciii] By 2020, the navigation season along the NSR will increase from around 36 days at present to around 40 days per summer.[xciv] Furthermore, the reduction in the extent of Arctic ice will allow vessels to travel in deeper waters farther from shore. Nonetheless, Arctic Sea shipping will not be without its share of challenges. Icebergs will continue to pose hazards to navigation, and bitter storms may produce significant wave action.

Human Health

Climate change may present Russia with a host of new and unwelcome challenges by 2030—both in the form of dangers related directly to climate and in the form of pest-borne disease.

In the case of direct effects, the combination of more frequent droughts and heat waves has had an impact on vulnerable populations in Russia already.[xcv] By 2030, as extreme weather events become more prevalent, this kind of increased risk to human health will rise further, particularly affecting the aged and infirm, especially for those unable to afford residential air conditioning.

Historically, Russia's bitter winters served as a check on the populations of many disease-carrying pests. Rodent populations, mosquitoes, and ticks were limited by the rigor of the seasons.

In recent years, however, these historical factors have receded. For example, according to one report, Russia's current rodent population is ten times higher than historical norms. Worse yet, one-third of the rodent population is estimated to carry one of the viruses that cause hemorrhagic fever with renal syndrome (or HFRS), which is a deadly illness if not caught early in its course.[xcvi] Incidences of HFRS spike after each occurrence of an unusually mild Russian winter.

As in other northern countries, mosquitoes have always been a summertime challenge in Russia. (Due to the poor quality of the housing stock, mosquitoes were often an unexpected wintertime challenge too; they would live through the winter in standing water in Russian basements, as many Western students and diplomats experienced.) But by 2030, they are expected to pose an increasing public health threat. As may as 250,000 Russians suffer from latent, local forms of malaria. West Nile and Denge Fever are reported to be spreading across the country as well.[xcvii]

Ticks are another disease vector that will grow worse by 2030. Tick encephalitis, Lyme disease, and tick rickettsiosis (Rocky Mountain Spotted Fever) are three of the diseases that are spreading increasingly aggressively across Russia.

Intestinal diseases are also a risk for Russia in the period to 2030. This risk will be especially significant in southern European Russia and the northern Caucasus region, where fresh water supply and water quality are expected to deteriorate as a result of climate change.[xcviii] However, even in distant Yakutia, in 2002, early spring flooding, which will also be increasingly common in Siberia by 2030, triggered a massive outbreak of enteric fever.[xcix]

Coping Capabilities in Facing Natural Disasters

Russia is better equipped than many other countries to respond to disasters resulting from climate change, certainly much better equipped than most of its regional neighbors. The central entity involved in governmental response to natural and manmade disasters is the Russian Federation Ministry of Civil Defense, Emergency Situations, and Disaster Response (known in Russia by the shorthand "Ministry of Emergency Situations," and often referred to in the West as "Emercom"). This organization brings together many of the functions that fall under the US Department of Homeland Security, including the Federal Emergency Management Agency (FEMA) and the Coast Guard, as well as local fire departments all across the country.[c] It is a proud, well-recognized organization that has earned public respect for its involvement in responding to a number of tragic occurrences in recent years.

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Of particular significance for response to climate change impacts will be the Ministry's units with responsibility for forest fire prevention and response, maritime emergencies, flood protection and response, and search and rescue. The Ministry is Moscow-based but has regional centers across Russia, including several in southern Siberia that could be especially important in ensuring timely response to climate change-related disasters.

Another important component of Russia's coping capacity comes from the Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet or Hydromet). Hydromet is the rough equivalent of the US National Oceanic and Atmospheric Administration (NOAA) and is active in monitoring, assessment, analysis, and prediction of weather and climate. Hydromet operates the Russian weather service, including over 1,600 meteorological stations across Russia,[ci] as well as serving as the leading scientific organization and the lead Russian representative for international negotiations and scientific undertakings related to climate change. Its research institutes work in close collaboration with institutes under the Russian Academy of Sciences, as well as leading Russian participation in the IPCC and other scientific assessment and forecasting activities.

Despite the considerable capabilities of both of these governmental organizations to analyze and respond to natural disasters, Russia will face a number of challenges in this context. Effective adaptation to climate change will require the application of huge resources and, more difficult, careful policy reforms. For example, policymakers will have to decide what to do with the residents of Russia's outsized northern urban centers. These Arctic cities are a monument to the sensibilities of Soviet planners—and an economic disaster.[cii] Thawing permafrost will pose more problems for these cities, and many of these cities sit on or near the banks of the Siberian rivers that will experience significant increases in flows and increased risks of flooding. Yet mass relocation would be both costly and politically challenging.

Other Urban Infrastructure

In the period to 2030, climate change could have a variety of impacts on urban infrastructure in Russia. Some of these impacts have already been discussed above, such as the potential for a reduction in heating requirements and heating loads that could accompany an increase in wintertime temperatures.

Another broad category of impact—but a negative one—is projected sea-level rise. This impact has the potential to bring significant challenges to a host of Russian cities and port complexes. Particularly vulnerable is Russia's second city, St. Petersburg, which is already regularly at risk of flooding when strong winds blow to the east from the Gulf of Finland. This vulnerability will only rise as sea level rises and storm surges grow more intense.[ciii] The risks of catastrophic flooding in St. Petersburg before 2030, and of consequent damage to both the economy and to unique historical buildings, is great.

St. Petersburg is not the only city at risk. The level of the Black Sea has been rising since the 1920s, and the rate of rise has increased significantly since the 1980s (currently about 2 centimeters per year).[civ] This will affect Russia's main warm water port complex at Novorossiysk, where dry cargoes, crude oil, and refined petroleum products are all exported. It will also affect Russia's main Black Sea military base, which is at Sevastopol, in neighboring Ukraine. Outside the Black Sea area, Russia's vital deepwater Atlantic basin port at Murmansk, which comprises both military and civilian capacity, will also be at risk to rising sea levels, as will the Pacific Rim ports, including Vladivostok and others.

As a general matter, Russia's population is projected to experience significant risks in the period to 2030 and beyond from extreme weather events—floods, torrential rains, severe winds, tornados, hurricanes, and the like. Officially designated dangerous hydrometeorological events across all of Russia have been growing markedly more common for the past decade-plus.[cv] This trend is expected to continue to 2030 and afterward. Russia's major urban centers may experience periods of drought combined with heat waves. In such circumstances, the risks of heat-related or disease-related illness could rise significantly.

International Issues

The international treatment of the Arctic over the next 20 or so years and questions of immigration related to climate change will affect Russia.

Greenhouse warming may bring greater changes in the Arctic than anywhere else on the planet. As has been discussed above, pronounced warming is already eroding the polar ice cap, and the thermal qualities of open water are contributing in turn to further warming and further melt-off.

This all translates into the Arctic being a much less imposing and more hospitable place than it has been in the past. Summers will bring increasingly extensive open seas that will facilitate speedy sea transportation of goods between northern Europe and the Pacific coasts of North America and northeastern Asia.[cvi] (See transportation discussion above.) New ports are being built along the Russian Arctic coast.

In addition, the warmer Arctic is engendering increased interest on the part of all of the littoral states in off-shore development. In 2007, the Russian polar scientist and politician Artur Chilingarov led an undersea expedition intended to bolster Russian claims that the Arctic is predominantly within the exclusive economic zone of Russia. One of Chilingarov's key arguments is that the undersea Lomonosov Ridge extends from Russian territory and therefore validates Russia's claim to half of Arctic Ocean. Complicating matters further, there is no clear agreement as to the legal regime that should govern competing claims in the Arctic.[cvii] Chilingarov's expedition culminated with the depositing of a Russian flag on the sea bottom, some 2.5 miles below the surface. "The Arctic has special geopolitical importance for Russia," Chilingarov later said.[cviii]

Given that Russia is not alone in its strong economic and security interests in the Arctic, climate changes that affect the Arctic could prompt the development of new military bases and activity. In late January 2009, military and political leaders from NATO met in Reykjavik, Iceland, to discuss how to manage the opportunities and challenges posed by a warming Arctic. The Secretary-General of NATO, Jaap de Hoop Scheffer, told the assembled audience, "Climate change is not a fanciful idea. It is already a reality, a reality that brings with it certain new challenges, including for NATO. Several Arctic rim countries are strengthening their capabilities, and military activity in the High North region has been steadily increasing."[cix] It is thus possible to imagine a significant increase in military presence in the Arctic, beyond what has been the case since the end of the Cold War.

Another international issue facing Russia is climate-related migration. Already today, Russia is the world's second biggest destination for migration (after the United States), attracting an estimated seven million migrants in 2008, of whom only about four million were legal.[cx] At present, most migrants present in Russia are from the countries of Central Asia and the Caucasus, and they seek economic opportunity to help support families in their countries of origin. Many migrants are involved in construction, other manual labor, and trading, especially in foodstuffs. In the Russian Far East and Primorskiy Kray, there are also a significant number of temporary workers from northeastern China. In short, today's migration to Russia seems to be significantly motivated by the "pull" phenomenon of economic opportunity.

By 2030, migration may become more of a "push" phenomenon. Water availability is projected to become an increasingly serious challenge in Central Asia, Mongolia, and northeastern China, and simultaneously droughts are projected to become more frequent. Glacial-fed rivers are at risk of becoming more and more depleted by 2030.[cxi] The ability of the Central Asian states to adapt to a changing climate may well be more limited than is the case with Russia. In turn, migration may become a source of instability within Russia, especially in difficult economic times. Already today, nationalist and reactionary political and social groupings are committing increasing numbers of hate crimes in Russian cities and towns. A Moscow-based nongovernmental organization that monitors hate crimes recorded over 500 attacks against foreigners in 2008, a one-third increase over 2007.[cxii]

Adaptive Capacity

The impacts of climate change will be felt differentially, depending upon how well a society can cope with or adapt to climate change, that is, its adaptive capacity. Adaptive capacity is defined by the IPCC as "The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences."[cxiii] Although the specific determinants (or "drivers") of adaptive capacity are a matter of debate among researchers, there is good agreement that economic, human, and environmental resources are essential elements. Some components of this adaptive capacity are near term, such as the ability to deliver aid swiftly to those affected by, e.g., flooding or droughts. Other components include a high enough level of education so that people can change livelihoods, sufficient unmanaged land that can be brought into food production, and institutions that provide knowledge and assistance in times of change. For instance, Yohe and Tol[cxiv] identified eight qualitative "determinants of adaptive capacity," many of which are societal in character, although the scientists draw on an economic vocabulary and framing:

1. The range of available technological options for adaptation.
2. The availability of resources and their distribution across the population.
3. The structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be employed.

4. The stock of human capital, including education and personal security.
5. The stock of social capital, including the definition of property rights.
6. The system's access to risk-spreading processes.
7. The ability of decision-makers to manage information, the processes by which these decision-makers determine which information is credible, and the credibility of the decision-makers themselves.
8. The public's perceived attribution of the source of stress and the significance of exposure to its local manifestations.

Russian Adaptive Capacity in a Global Context

Researchers have only recently taken on the challenge of assessing adaptive capacity in a comparative, quantitative framework. A comprehensive global comparative study[cxv] of resilience to climate change (including adaptive capacity) was conducted using the Vulnerability-Resilience Indicators Model (VRIM—see box below).

Adaptive capacity, as assessed in this study, consists of seven variables (in three sectors), chosen to represent societal characteristics important to a country's ability to cope with and adapt to climate change:

Human and Civic Resources

- *Dependency ratio:* proxy for social and economic resources available for adaptation after meeting basic needs.
- *Literacy:* proxy for human capital generally, especially the ability to adapt by changing employment.

Economic Capacity

- *GDP (market) per capita:* proxy for economic well-being in general, especially access to markets, technology, and other resources useful for adaptation.
- *Income equity:* proxy for the potential of all people in a country or state to participate in the economic benefits available.

Environmental Capacity

- *Percent of land that is unmanaged:* proxy for potential for economic use or increased crop productivity and for ecosystem health (e.g., ability of plants and animals to migrate under climate change).
- *Sulfur dioxide per unit land area:* proxy for air quality and, through sulfur deposition, other stresses on ecosystems.
- *Population density:* proxy for population pressures on ecosystems (e.g., adequate food production for a given population).

Adaptive capacity for a sample of 10 countries from the 160-country study is shown in Figure 6 (base year of 2005). There is a wide range of adaptive capacity represented by these countries. Russia ranks high, both in the sample and overall:

- Russia ranks 32nd and Libya 34th (in the highest quartile).

- Indonesia ranks 45th, Belize 48th, Mexico 59th, and China 75th (in the second quartile).
- The Philippines ranks 91st and India 119th (in the third quartile).
- Morocco ranks 136th and Haiti 156th (in the lowest quartile).

Any country-level analysis must take into account the comparative ranking of the country.

Methodological Description of the Vulnerability-Resilience Indicator Model (VRIM)

The VRIM is a hierarchical model with four levels. The vulnerability index (level 1) is derived from two indicators (level 2): sensitivity (how systems could be negatively affected by climate change) and adaptive capacity (the capability of a society to maintain, minimize loss of, or maximize gains in welfare). Sensitivity and adaptive capacity, in turn, are composed of sectors (level 3). For adaptive capacity these sectors are human resources, economic capacity, and environmental capacity. For sensitivity, the sectors are settlement/infrastructure, food security, ecosystems, human health, and water resources. Each of these sectors is composed of one to three proxies (level 4). The proxies under adaptive capacity are as follows: human resource proxies are the dependency ratio and literacy rate; economic capacity proxies are GDP (market) per capita and income equity; and environmental capacity proxies are population density, sulfur dioxide divided by state area, and percent of unmanaged land. Proxies in the sensitivity sectors are water availability, fertilizer use per agricultural land area, percent of managed land, life expectancy, birth rate, protein demand, cereal production per agricultural land area, sanitation access, access to safe drinking water, and population at risk due to sea level rise.

Each of the hierarchical level values is composed of the geometric means of participating values. Proxy values are indexed by determining their location within the range of proxy values over all countries or states. The final calculation of resilience is the geometric mean of the adaptive capacity and sensitivity.

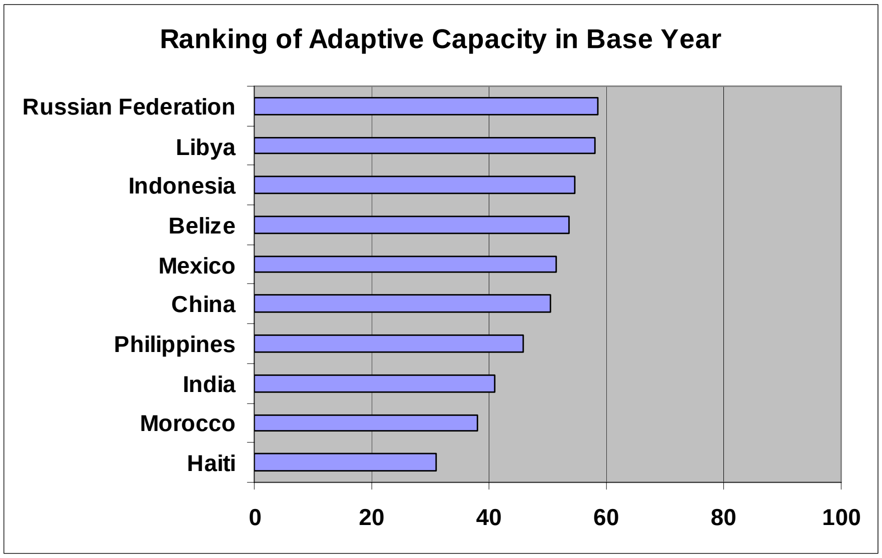


Figure 6. Sample of 10 countries' rankings of adaptive capacity (2005).

Figure 7 shows the contribution of each variable to the overall ranking (slight differences occurring because of the methodology [see box]). In current adaptive capacity, Russia ranks first among the 10 countries shown in Figure 6. Russia's comparatively high literacy levels (indicating higher human capital), low greenhouse gas emissions, and low population density (indicating a less of a burden on the environment) more than compensate for low GDP per capita. This corresponds roughly with the pattern that one

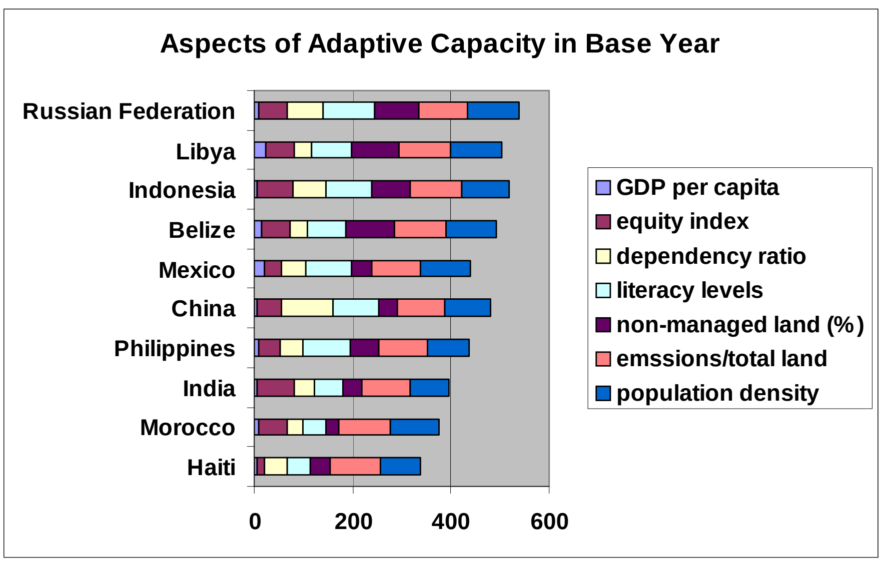


Figure 7. Variables' contributions to adaptive capacity rankings.

would expect for Russia. Russia has some significant areas of vulnerability, but it also stands to see some beneficial impacts from climate change. It has a well-educated populace, an economy that has some diversification but not a great deal, and a socioeconomic picture in which there is a small middle class, a small cluster of people with great wealth, and many who have only limited means.

Figure 8 shows projected adaptive capacity growth over time for the 10-country sample. Projections are made for two scenarios; rates of growth are based on the IPCC's A1 scenario in its *Special Report on Emissions Scenarios*.[cxvi] VRIM simulates two different hypothetical development tracks out to the year 2065 (well beyond the timescale of the present study) with intermediate results at 15-year time steps. These alternative development tracks are not intended to be predictive; they are scenarios.

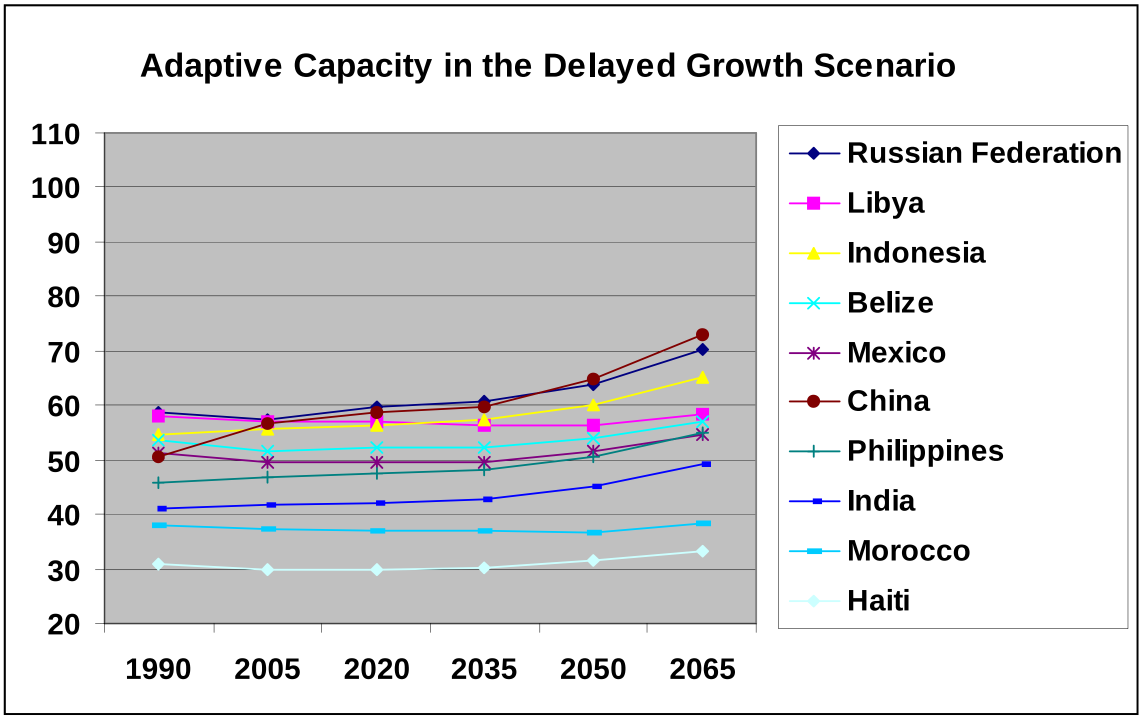
Both scenarios feature moderate population growth and a tendency toward convergence in affluence (with market-based solutions, rapid technological progress, and improving human welfare). The scenarios used in this study differ in the rate of economic growth, one modeling high-and-fast economic growth, the other delayed growth.

Over time, a low-growth scenario widens the gap among the 10 countries—and the high-growth scenario widens the gap even more (Figure 8). In both scenarios, China's high economic growth (indicated by GDP per capita), favorable dependency ratio, and literacy rate allow that country to overtake Russia by 2050. In both scenarios, the strengths and weaknesses of current Russian adaptive capacity persist, with slow economic growth being a notable weakness.

Looking forward, Russia's ability to cope with climate change impacts to 2030 and beyond will obviously depend on both the nature and extent of the impacts and the extent to which Russia's adaptive capacities develop over time. This in turn depends on the nature and extent of Russia's socioeconomic and sociopolitical development over the coming years.

In the delayed-growth scenario, Russia's position is much less influenced by wealth accumulation (adaptive capacity) and much more heavily influenced by water availability, the production of cereal grains, and the use of fertilizer (included in impacts/sensitivity rather than in adaptive capacity). In this scenario, Russia's adaptive capacity still improves over time, but its progress, like that of other countries, is much more modest than in the high-growth scenario.

The high-growth scenario could, in the case of Russia, be consistent with robust early-period revenues from hydrocarbons and other commodity production, leading to significant wealth accumulation in the country and, over time, greater economic diversification of the sort that has been advocated in the last year by President Dmitriy Medvedev. (The elements and implications of this high-growth scenario are outwardly consistent with the track that Russia appeared to be on until the collapse of energy prices in the past six months.) In this scenario, Russia's adaptive capacity grows significantly over time, with Russia ending the period second only to China.



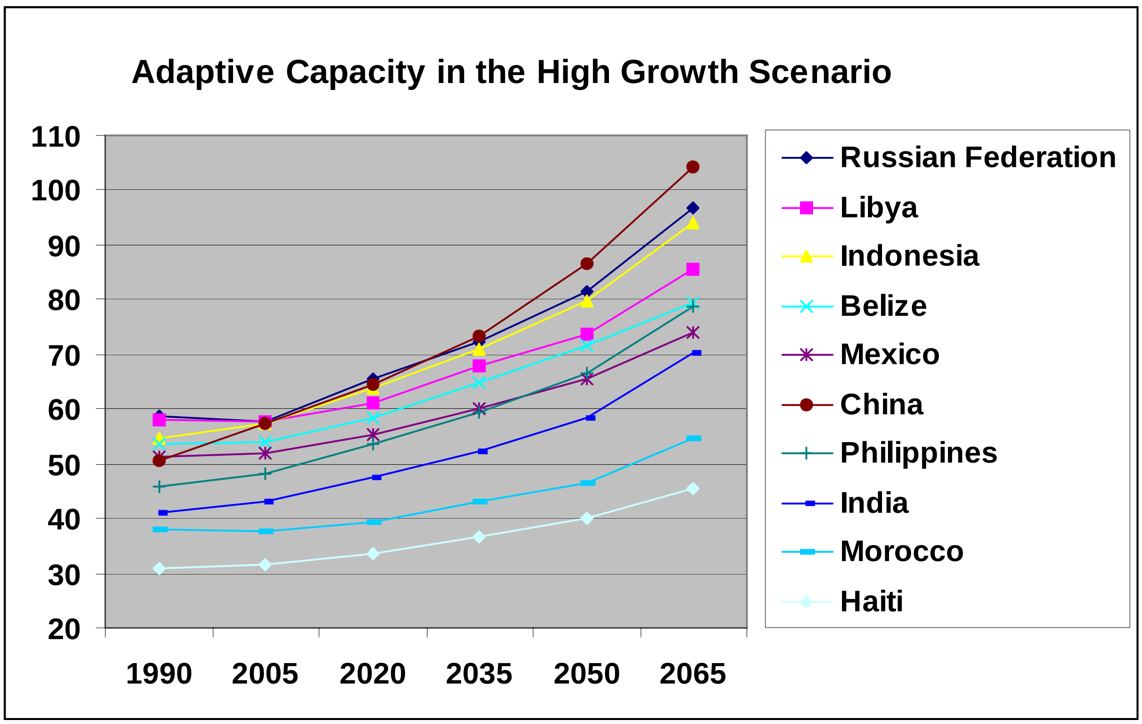


Figure 8. Projections of adaptive capacity for 10 countries.

In the real world, a variety of factors will play into the overall calculus of Russia's adaptive capacity. Evolving socioeconomic conditions will be one key factor. To highlight this fact, one can compare the adaptation of the Russian oil industry to the adaption of its gas industry in the period since the breakup of the USSR. In the late 1990s and the first years of the current decade, the Russian oil industry experienced rapid innovation that reflected new ownership forms, new managerial techniques, and the introduction of international technology. Production skyrocketed, especially after the 1998 financial crash, while environmental impacts for the oil industry as a whole (spills, emissions, and accidents) dropped. By comparison, the relatively traditionalist Russian gas industry, where there was substantially less commercial, managerial, and technological change, evolved less dramatically.

In the area of Russian agriculture, socioeconomic forms and institutions most likely will be significant in determining the efficacy of the sector's adaptation to climate change.[cxvii] One particular shortcoming will be the relative weakness of agricultural education and training, akin to the extension service programs operated by the US Department of Agriculture. Russia's rural population is generally the country's most conservative social grouping; adapting to changing climatic conditions will require innovation that has historically been alien to much of rural Russian society.

Strengths/Weaknesses in Adaptive Capacity Assessments

Even comparative measures of adaptive capacity only allow analysts to ask better focused questions about area or local conditions that contribute to or reduce resilience. It is likely, for instance, that for particular places in Russia important variables or domains are not included. For agricultural regions, this might include the extent of irrigation; for urban areas, better measures of education could be important. The measure of unmanaged land does not account for the potential usefulness of that land.

However, comparative measures such as these can be an important first step toward determining where to direct resources—for further analysis or additional factors.

Conclusions: High Risk Impacts

Energy. Russia's current and foreseeable future economic health depends extremely heavily on Russia's ability to produce and export oil and natural gas. The oil and gas infrastructure that exists today was not designed with an eye to vulnerability stemming from a changing climate—such as structural subsidence, pipeline crossings at surging rivers, and sea-level rise. Therefore, current production will be increasingly at risk in the coming years. Moreover, as production from traditional Russian gas supply provinces declines, Russia must develop replacement sources. The Yamal Peninsula and Barents Sea (including the Shtokman field) are absolute priorities, and the Russian Far East is a secondary priority. The impacts of a changing climate may delay significantly (or significantly raise the cost of) efforts to bring these new production areas on-line, which could affect Russia's fiscal position and balance of payments.

Agriculture. By 2030, Russia will begin to experience significant changes in agriculture. The critical question will be whether the positive impacts – longer growing season, new land that can be put under the plow, and the possibility of introducing new varieties and new crops—will outweigh the significant negative impacts. In this latter regard, the reduction in precipitation in parts of Russia's traditional agricultural belts and the projected reduction in yields for traditional grain crops are significant considerations. Also significant is the projected increasing reliance on irrigation and chemical additives to deter pests and enrich soils. Rural Russia historically has been a very traditionalist part of the country, and to date Russia has not developed widespread systems to educate farmers, particularly to help them anticipate and adapt to changes in their growing conditions stemming from climate change. There are risks that rural Russia simply will not adapt itself in a timely manner to the agricultural realities of a changing climate. Russia's food supply could be under stress.

Migration. Many of Russia's southern neighbors face a drier, hotter future in which economic prospects may become increasingly dire. If these neighbors are unable to adapt themselves in a timely manner and provide for their populations, Russia may experience significant new migration pressures, which could plausibly be associated with greater instability and ethnic strife in affected Russian cities and towns.

Accentuated Socio-Economic and Socio-Political Stresses. Russia is a massive country with a pronounced continental climate, thus extreme weather is not entirely unfamiliar. Nor is hardship unfamiliar to the people of Russia. Nonetheless, the significant increase in dangerous weather events over the last two decades, and the prospect of a continuing trend in this regard, make clear that extreme weather may be the sword of Damocles hanging over Russia's future. Heat waves, wind storms, droughts, and severe flooding may result in considerable damage to infrastructure, impacts on livelihoods, and even significant loss of life. These threats, in turn, may place even greater socio-economic and socio-political stress on parts of the country where the relationship between the government and governed is already tense. Areas such as the North Caucasus have already seen political tensions and instability that are unrelated to climate change. By 2030, however, climate change could significantly exacerbate such areas of stress.

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Annex A: Accuracy of Regional Models

This is an excerpt from IPCC (2007), Chapter 11, Regional models; see IPCC 2007 for references.[4]

11.4.2 Skill of Models in Simulating Present Climate

Regional mean temperature and precipitation in the MMD models show biases when compared with observed climate (Table 2). The multi-model mean shows a cold and wet bias in all regions and in most seasons, and the bias of the annual average temperature ranges from –2.5°C over the Tibetan Plateau (TIB) to –1.4°C over South Asia (SAS). For most regions, there is a 6°C to 7°C range in the biases from individual models with a reduced bias range in Southeast Asia (SEA) of 3.6°C. The median bias in precipitation is small (less than 10 percent) in Southeast Asia, South Asia, and Central Asia (CAS), larger in northern Asia and East Asia (NAS and EAS, around +23 percent), and very large in the Tibetan Plateau (+110 percent). Annual biases in individual models are in the range of –50 to +60 percent across all regions except the Tibetan Plateau, where some models simulate annual precipitation 2.5 times that observed and even larger seasonal biases occur in winter and spring. These global models clearly have significant problems over Tibet, due to the difficulty in simulating the effects of the dramatic topographic relief, as well as the distorted albedo feedbacks due to extensive snow cover. However, with only limited observations available, predominantly in valleys, large errors in temperature and significant underestimates of precipitation are likely.

South Asia

Over South Asia, the summer is dominated by the southwest monsoon, which spans the four months from June to September and dominates the seasonal cycles of the climatic parameters. While most models simulate the general migration of seasonal tropical rain, the observed maximum rainfall during the monsoon season along the west coast of India, the north Bay of Bengal and adjoining northeast India is poorly simulated by many models (Lal and Harasawa, 2001; Rupa Kumar and Ashrit, 2001; Rupa Kumar et al., 2002, 2003). This is likely linked to the coarse resolution of the models, as the heavy rainfall over these regions is generally associated with the steep orography. However, the simulated annual cycles in South Asian mean precipitation and surface air temperature are reasonably close to the observed. The MMD models capture the general regional features of the monsoon, such as the low rainfall amounts coupled with high variability over northwest India. However, there has not yet been sufficient analysis of whether finer details of regional significance are simulated more adequately in the MMD models.

Recent work indicates that time-slice experiments using an AGCM with prescribed SSTs, as opposed to a fully coupled system, are not able to accurately capture the South Asian monsoon response (Douville, 2005). Thus, neglecting the short-term SST feedback and variability seems to have a significant impact on the projected monsoon response to global warming, complicating the regional downscaling problem. However, May (2004a) notes that the high-resolution (about 1.5 degrees) European Centre-Hamburg (ECHAM4) GCM simulates the variability and extremes of daily rainfall (intensity as

[4] Some references in this section have been changed to be internally consistent with this document and other references have been removed to avoid confusion.

well as frequency of wet days) in good agreement with the observations (Global Precipitation Climatology Project, Huffman et al., 2001).

Three-member ensembles of baseline simulations (1961–1990) from an RCM (PRECIS) at 50-kilometer resolution have confirmed that significant improvements in the representation of regional processes over South Asia can be achieved (Rupa Kumar et al., 2006). For example, the steep gradients in monsoon precipitation with a maximum along the western coast of India are well represented in PRECIS.

East Asia

Simulated temperatures in most MMD models are too low in all seasons over East Asia; the mean cold bias is largest in winter and smallest in summer. Zhou and Yu (2006) show that over China, the models perform reasonably in simulating the dominant variations of the mean temperature over China, but not the spatial distributions. The annual precipitation over East Asia exceeds the observed estimates in almost all models and the rain band in the mid-latitudes is shifted northward in seasons other than summer. This bias in the placement of the rains in central China also occurred in earlier models (e.g., Zhou and Li, 2002; Gao et al., 2004). In winter, the area-mean precipitation is overestimated by more than 50 percent on average due to strengthening of the rain band associated with extratropical systems over South China. The bias and inter-model differences in precipitation are smallest in summer but the northward shift of this rain band results in large discrepancies in summer rainfall distribution over Korea, Japan and adjacent seas.

Kusunoki et al. (2006) find that the simulation of the Meiyu-Changma-Baiu rains in the East Asian monsoon is improved substantially with increasing horizontal resolution. Confirming the importance of resolution, RCMs simulate more realistic climatic characteristics over East Asia than AOGCMs, whether driven by re-analyses or by AOGCMs (e.g., Ding et al., 2003; Oh et al., 2004; Fu et al., 2005; Zhang et al., 2005a, Ding et al., 2006; Sasaki et al., 2006b). Several studies reproduce the fine-scale climatology of small areas using a multiply nested RCM (Im et al., 2006) and a very-high resolution (5 kilometers) RCM (Yasunaga et al., 2006). Gao et al. (2006b) report that simulated East Asia large-scale precipitation patterns are significantly affected by resolution, particularly during the mid- to late-monsoon months, when smaller-scale convective processes dominate.

Southeast Asia

The broad-scale spatial distribution of temperature and precipitation in DJF and JJA averaged across the MMD models compares well with observations. Rajendran et al. (2004) examine the simulation of current climate in the MRI coupled model. Large-scale features were well simulated, but errors in the timing of peak rainfall over Indochina were considered a major shortcoming. Collier et al. (2004) assess the performance of the CCSM3 model in simulating tropical precipitation forced by observed SST. Simulation was good over the Maritime continent compared to the simulation for other tropical regions. B. Wang et al. (2004) assess the ability of 11 AGCMs in the Asian-Australian monsoon region simulation forced with observed SST variations. They found that the models' ability to simulate observed interannual rainfall variations was poorest in the Southeast Asian portion of the domain. Since current AOGCMs continue to have some significant shortcomings in representing ENSO variability, the difficulty of projecting changes in ENSO-related rainfall in this region is compounded.

Rainfall simulation across the region at finer scales has been examined in some studies. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) stretched-grid Conformal-Cubic Atmospheric Model (CCAM) at 80-kilometer resolution shows reasonable precipitation simulation in JJA, although Indochina tended to be drier than in the observations (McGregor and Nguyen, 2003). Aldrian et al. (2004a) conducted a number of simulations with the Max-Planck Institute (MPI) regional model for an Indonesian domain, forced by reanalyses and by the ECHAM4 GCM. The model was able to represent the spatial pattern of seasonal rainfall. It was found that a resolution of at least 50 kilometers was required to simulate rainfall seasonality correctly over Sulawesi. The formulation of a coupled regional model improves regional rainfall simulation over the oceans (Aldrian et al., 2004b). Arakawa and Kitoh (2005) demonstrate an accurate simulation of the diurnal cycle of rainfall over Indonesia with an AGCM of 20-kilometer horizontal resolution.

Central Asia and Tibet

Due to the complex topography and the associated mesoscale weather systems of the high-altitude and arid areas, GCMs typically perform poorly over the region. Importantly, the GCMs, and to a lesser extent RCMs, tend to overestimate the precipitation over arid and semi-arid areas in the north (e.g., Small et al., 1999; Gao et al., 2001; Elguindi and Giorgi, 2006).

Over Tibet, the few available RCM simulations generally exhibit improved performance in the simulation of present-day climate compared to GCMs (e.g., Gao et al., 2003a,b; Zhang et al., 2005b). For example, the GCM simulation of Gao et al. (2003a) overestimated the precipitation over the north-western Tibetan Plateau by a factor of five to six, while in an RCM nested in this model, the overestimate was less than a factor of two.

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		temperature BIAS					% precipitation BIAS				
REGION	SEASON	MIN	25	50	75	MAX	MIN	25	50	75	MAX
Asia											
NAS	DJF	-9.3	-2.9	-1.3	0.0	2.9	-18	5	12	19	93
	MAM	-6.0	-4.3	-2.7	-0.5	0.6	-4	39	45	74	110
	JJA	-4.8	-2.0	-0.5	0.4	2.2	-38	-2	19	32	62
	SON	-6.2	-2.6	-2.1	-0.5	1.9	-14	12	23	30	49
	ANN	-5.2	-2.6	-1.4	-0.6	1.3	-11	15	24	35	55
CAS	DJF	-4.4	-2.6	-1.2	0.2	3.3	-33	-2	18	43	77
	MAM	-4.3	-3.0	-1.4	0.2	2.0	-36	22	25	34	83
	JJA	-4.9	-1.6	0.3	1.4	5.7	-71	-37	-25	14	60
	SON	-4.5	-3.2	-1.9	-0.4	1.6	49	-12	-4	15	47
	ANN	-3.9	-2.3	-1.4	0.6	2.2	-44	4	12	21	53
TIB	DJF	-9.3	-3.8	-2.2	-1.4	2.2	15	131	177	255	685
	MAM	-7.0	-4.3	-3.8	-1.3	0.6	130	160	209	261	486
	JJA	-6.7	-2.5	-1.0	-0.2	1.6	4	30	37	53	148
	SON	-5.9	-3.6	-2.5	-1.7	0.0	66	93	150	180	330
	ANN	-5.3	-3.3	-2.5	-1.6	0.6	51	88	110	142	244
EAS	DJF	-6.5	-4.5	-3.7	-1.3	1.8	-20	26	60	79	142
	MAM	-5.2	-2.9	-2.0	-1.0	0.5	1	32	45	60	105
	JJA	-3.9	-2.0	-1.1	-0.4	1.4	-15	0	3	15	27
	SON	-5.9	-3.4	-2.7	-1.6	-0.3	-17	1	14	34	75
	ANN	-5.4	-3.2	-2.5	-1.2	0.2	-6	12	22	31	60
SAS	DJF	-7.4	-4.0	-2.6	-1.6	1.9	-27	0	30	59	127
	MAM	-5.6	-1.9	-0.7	-0.4	2.5	-44	-26	-1	13	72
	JJA	-2.9	-1.3	-0.1	0.6	1.9	-70	-25	-14	5	29
	SON	-5.2	-3.2	-2.1	-0.9	2.6	-26	-12	-2	14	42
	ANN	-4.8	-2.4	-1.4	-0.8	2.2	-49	-16	-10	5	33
SEA	DJF	-3.6	-2.6	-1.8	-1.2	0.4	-37	-10	-2	26	49
	MAM	-2.6	-1.6	-0.5	-0.1	1.1	-32	-9	11	25	59
	JJA	-2.5	-1.8	-0.7	-0.4	1.0	-28	-10	4	16	46
	SON	-3.0	-1.9	-1.2	-0.8	1.0	-37	-12	-4	18	51
	ANN	-2.8	-1.9	-1.0	-0.5	0.8	-28	-13	0	23	43

Table 2. Biases in present-day (1980-1999) surface air temperature and precipitation in the MMD simulations. The simulated temperatures are compared with the HadCRUT2v (Jones, et al., 2001) data set and precipitation with the CMAP (update of Xie and Arkin, 1997) data set. Temperature biases are in °C and precipitation biases in per cent. Shown are the minimum, median (50%) and maximum biases among the models, as well as the first (25%) and third (75%) quartile values. Colors indicate regions/seasons for which at least 75% of the models have the same sign of bias, with orange indicating positive and light violet negative temperature biases and light blue positive and light brown negative precipitation biases.

This paper does not represent US Government views.

Annex B: Knowledge Deficiencies that Preclude a Full Evaluation of Climate Change Impacts on Russia and Russia's Adaptive Capacity

In order to increase the likelihood that this evaluation represents a reasonable assessment of Russia's projected climate changes and their impacts, and the country's adaptive capacity, the following gaps would need to be addressed:

- In physical science research, regional analyses will continue to be limited by the inability to model regional climates satisfactorily, including complexities arising from the interaction of global, regional, and local processes. One gap of particular interest is the lack of medium-term (20-30 years) projections that could be relied upon for planning purposes. Similarly, scientific projections of water supply and agricultural productivity are limited by inadequate understanding of various climate and physical factors affecting both areas. Research agendas in these areas can be found in, for instance, the synthesis and assessment reports of the US Climate Change Science Program (http://www.climatescience.gov) and the National Academy of Sciences (e.g., http://books.nap.edu/catalog.php?record_id=11175#toc). Similar types of issues exist for the biological and ecological systems that are affected.
- In social science research, scientists and analysts have only partial understandings of the important factors in vulnerability, resilience, and adaptive capacity—much less their interactions and evolution. Again, research agendas on vulnerability, adaptation, and decision-making abound (e.g., (http://books.nap.edu/catalog.php?record_id=12545).
- Important factors are unaccounted for in research; scientists know what some of them are, but there are likely factors whose influence will be surprising. An example from earlier research on the carbon cycle illustrates this situation. The first carbon cycle models did not include carbon exchanges involving the terrestrial domain. Modelers assumed that the exchange was about equal, and the only factor modeled was deforestation. This assumption, of course, made the models inadequate for their purposes. In another example, ecosystems research models are only beginning to account for changes in pests, e.g., the pine bark beetle.
- Social models or parts of models in climate research have been developed to simulate consumption (with the assumption of well-functioning markets and rational actor behavior) and mitigation/adaptation policies (but without attention to the social feasibility of enacting or implementing such policies). As anthropogenic climate change is the result of human decisions, the lack of knowledge about motivation, intent, and behavior is a serious lack.

Overall, research about climate change impacts on Russia has been undertaken piecemeal: discipline by discipline, sector by sector, with political implications separately considered from physical effects. This knowledge gap can be remedied by integrated research into energy-economic-environmental-political conditions and possibilities.

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SPECIAL REPORT

RUSSIA: IMPACT OF CLIMATE CHANGE TO 2030
A COMMISSIONED RESEARCH REPORT

NATIONAL INTELLIGENCE COUNCIL

SPECIAL REPORT

NIC 2009-07D August 2009

North Africa: The Impact of Climate Change to 2030 (Selected Countries)

A Commissioned Research Report

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North Africa: The Impact of Climate Change to 2030 (Selected Countries)

A Commissioned Research Report

The National Intelligence Council sponsors workshops and research with nongovernmental experts to gain knowledge and insight and to sharpen debate on critical issues. The views expressed in this report do not reflect official US Government positions.

NIC 2009-007D
August 2009

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Scope Note

Following the publication in 2008 of the National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030, the National Intelligence Council (NIC) embarked on a research effort to explore in greater detail the national security implications of climate change in six countries/regions of the world: India, China, Russia, North Africa, Mexico and the Caribbean, and Southeast Asia and the Pacific Island states. For each country/region, we are adopting a three-phase approach.

- In the first phase, contracted research—such as this publication—explores the latest scientific findings on the impact of climate change in the specific region/country.
- In the second phase, a workshop or conference composed of experts from outside the Intelligence Community (IC) will determine whether anticipated changes from the effects of climate change will force inter- and intra-state migrations, cause economic hardship, or result in increased social tensions or state instability within the country/region.
- In the final phase, the NIC's Long-Range Analysis Unit (LRAU) will lead an IC effort to identify and summarize for the policy community the anticipated impact on US national security.

To support research by the National Intelligence Council on the national security impacts of global climate change, this assessment of the impact of climate change on North Africa through 2030 is being delivered under the Global Climate Change Research Program contract with the Central Intelligence Agency's Office of the Chief Scientist.

This assessment identifies and summarizes the latest peer-reviewed research related to the effects of climate change on selected countries in North Africa, drawing on the literature summarized in the latest Intergovernmental Panel on Climate Change (IPCC) assessment reports, National Communications to the United Nations Framework (UNFCCC) on Climate Change, and on other peer-reviewed research literature and relevant reporting. It includes such impacts as sea-level rise, water availability, agricultural shifts, ecological disruptions and species extinctions, infrastructure at risk from extreme weather events (severity and frequency), and disease patterns. This paper addresses the extent to which the countries in the region are vulnerable to climate change impact. The targeted time frame is to 2030, although various studies referenced in this report have diverse time frames.

This assessment also identifies (Annex B) deficiencies in climate change data that would enhance the IC's understanding of potential impacts on North Africa and other countries/regions.

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Executive Summary

Model projections available for North Africa indicate a clear increase in temperature over the next 20 years that is expected to continue throughout the 21st century, probably at a rate higher than the estimated global average. Model simulations also suggest a drying trend in the region, particularly along the Mediterranean coast, driven by large decreases expected in summertime precipitation. Because coastal areas historically receive by far the largest amount of rainfall in North Africa, future decreases will likely have a significant and noticeable impact. Precipitation trends in the interior semiarid and arid regions of North Africa are more difficult to predict due to the very small amount of natural precipitation that characterizes these areas. Climate change will induce some variations in precipitation patterns, but the trend is not clear, as some models predict slight increases and others predict slight decreases in annual precipitation amounts.

The Regional Climate Change Index (RCCI)[1] identifies the Mediterranean as a very responsive region to climate change ("Hot-Spot"). Given the ecological and socioeconomic characteristics of the southern Mediterranean countries, the impact of climate change may be more marked than in other regions of the world. Still, most of the predicted impacts in the region are already occurring regardless of climate change (e.g., water stress and desertification). Climate change is expected to exacerbate these trends.

Based on global climate projections and given inherent uncertainties, the most significant impacts of climate change in North Africa (Morocco, Algeria, Tunisia, Libya, and Egypt) will likely include the following:

- ***Water Resources Stress.***[2] All countries of North Africa are presently experiencing water stress. Model simulations show a general decrease in rainfall across North Africa, with median decreases in average annual precipitation of 12 percent and 6 percent projected for the Mediterranean and Saharan regions, respectively. This general drying trend for North Africa is punctuated by seasonal variations in projected precipitation that differ by region. Predicted decreases in average annual rainfall, accompanied by projected increases in the population of the region, may impede access to water for millions of inhabitants. In addition, with decreasing water levels, other ecological effects such as salinity in coastal areas and deterioration of water quality may increase.
- ***Agriculture.*** Model results are inconsistent regarding future changes in crop yields and agricultural growing seasons in North Africa, and we do not know whether variations in temperature, precipitation, or atmospheric CO_2 will be the dominant factor. One modeling study suggests that future increases in atmospheric CO_2 concentrations will increase maize yields in Morocco, while other modeling studies suggest that future increases in air temperature will have a negative effect on growing seasons and crop yields in Egypt. Relatively heat-tolerant species, such as maize, are expected to suffer the smallest losses in yield and growing area, while heat-intolerant crops, such as wheat, are expected to suffer the largest losses. In addition, intensive irrigation practices in the region may result in further

[1] The RCCI is calculated for 26 land regions from projections of 20 global climate models using the Intergovernmental Panel on Climate Change (IPCC) emission scenarios.

[2] Water Stress, as used by the IPCC, refers to a per capita water availability of below 1,000 cubic meters per person per year; sometimes IPCC referenced sources also use a ratio of withdrawals to long-term average runoff of 0.4. The IPCC formally defines a country as water stressed when withdrawals exceed 20% of renewable water supply.

salinity, which may lead to desertification. Adaptation strategies, including modifications in sowing dates to match climate changes and development of heat-tolerant crop varieties, will likely mitigate some of the expected negative effects on North African agriculture. Development of regional and local climate models in the coming years that include projections of Mediterranean Sea level rise and decreases in the Nile River flow are expected to provide more accurate estimates of future changes in North African agricultural regions.

- ***Migration.*** In recent years, North Africa has experienced vast migration pressures from both migrants that settle in the region from the south or that use North African countries as a transit area to reach Europe. Thus far, experts have not cited climate change as a driving force for migration in the region; nevertheless, a warmer climate and changing precipitation patterns, which will likely reduce viable cropland and reduce access to water, will increase urbanization and make accommodating the needs of a growing population more difficult. Besides food and water necessities, climate change-related migration may also imply greater demands on infrastructure along the coasts as well as ethnic, racial, or religious clashes.
- ***Natural Disasters.*** Because of the lack of historical data from tide gauges in the region, the wide range of future estimates in sea level, and the paucity of regional climate model projections for the Mediterranean Sea, a definitive estimate of sea level rise along the coastline of North Africa in the next 20 years is not possible. However, the intensity and frequency of floods along the Mediterranean coast are expected to increase by the middle of the 21st century. Compared to other regions, the impacts of sea level rise in North Africa are expected to be stronger in terms of social, economic, and ecological factors. Highly populated and agriculturally important coastal cities are the most vulnerable.

In addition, two more potentially serious impacts are the following:

- ***Tourism.*** Tourism is an important source of income for most countries of North Africa. Of concern, however, are the large quantities of water this sector demands and the little attention that governments of this region have given to water provision in the past. Thus, increased water scarcity, sea level rise, and increasing temperatures will likely have a negative impact on this sector and consequently the economy of most North African countries.
- ***Energy.*** The economies of Algeria, Libya and (to a lesser extent) Egypt are dependent on the hydrocarbon industry. Because of the revenues they receive from exporting fossil fuels—mostly to Europe—they are to some degree more resilient to the deleterious impacts of climate change. Any shift in the interest of other regions in importing natural gas and oil from North Africa, conversely, may make these North African countries considerably more vulnerable. However, there is no indication now that Europe and other importing regions will stop importing from North Africa in the next few decades.

Based on a comprehensive global comparative study of resilience to climate change (including adaptive capacity) using the Vulnerability-Resilience Indicators Model, a wide range of adaptive capacity is represented in this group of countries from Libya (ranking 34th in a 160-country study) to Morocco (ranking 136th in the same study). Under a high-growth scenario of the future, all countries gain adaptive capacity, especially Libya. However, under a delayed-growth scenario, all of these North African countries lose adaptive capacity.

Contents

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Introduction and Background

North Africa is vulnerable to climate change impacts, both direct and indirectly, e.g., as a result of any actions to reduce greenhouse gas emissions and thus consumption of fossil fuels. This report summarizes peer-reviewed and other relevant research about this region, including projected climate changes, impacts on human and natural systems, and the adaptive capacities of countries in the region. Literature sources include the 2007 Intergovernmental Panel on Climate Change (IPCC) Assessment Report, peer-reviewed journal articles, and reports generated by governments and scientific organizations.

The report focuses on the five northernmost countries in Africa: Morocco, Algeria, Tunisia, Libya, and Egypt. Collectively, the report refers to these countries as "North Africa," although we recognize that other groups of countries are given this same label.[3] All five countries are coastal, with northern borders on the Mediterranean Sea. A brief description of each country is given below.

Morocco
The Kingdom of Morocco borders the Mediterranean Sea to the north, the North Atlantic Ocean to the west (the two bodies of water separated by the Straits of Gibraltar), Western Sahara to the south, and Algeria to the south and east. Morocco's area totals 446,550 sq km, including 250 sq km of water. Its northern coast and interior are mountainous, but it also has plateaus, valleys, and rich coastal plains. The northern mountains are subject to earthquakes, and the country experiences periodic droughts. Current environmental issues include soil erosion from degradation-causing land management, water polluted by raw sewage, siltation of reservoirs, and oil pollution of coastal waters. Its population is about 35 million (2009 estimate). Life expectancy at birth is 72 years. Its people are 99 percent Muslim, with the rest Christian or Jewish. Gross Domestic Product (GDP) per capita in 2008 was estimated by the CIA at $4,000 United States dollars (USD) equivalent, with an unemployment rate of 10 percent (2008 estimate).

Algeria
The People's Democratic Republic of Algeria is bordered on the west by Morocco, Western Sahara, and Mauritania; on the southwest by Mali; on the southeast by Niger; and on the east by Libya and Tunisia. Its area totals 2,381,740 sq km, with no areas of water. Algeria's terrain is mostly high plateau and desert, with some mountains and a narrow, discontinuous coastal plain. Its mountainous areas experience severe earthquakes, and the country is subject to mudslides and floods in rainy seasons. Algerian population totals about 34 million (2009 CIA estimate). Life expectancy at birth is 74 years. The population is 99 percent Sunni Muslim (the state religion), with Christians and Jews composing the remainder. Oil and gas account for approximately 60 percent of budget revenues, 30 percent of GDP, and more than 95 percent of export earnings. GDP per capita was estimated for 2008 at $7,000 USD equivalent, with an unemployment rate of 13 percent (2008 estimate).

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[3] For a map of North Africa, demarcated by the red line, see: Welt-atlas.de: Atlas of the World, s.v. "Map of Africa, North," http://www.welt-atlas.de/datenbank/karten/karte-0-9008.gif (accessed May 11, 2009).

Tunisia

The Tunisian Republic is located between Algeria and Libya. Its area totals 163,610 sq km, including 8,250 sq km of water. Tunisia has mountains in the north; a hot, dry central plain; and semiarid regions in the south (merging into the Sahara Desert). Current environmental issues include ineffective toxic and hazardous waste disposal, water polluted by raw sewage, limited natural fresh water resources, deforestation, overgrazing, and soil erosion. Tunisia's population totals about 10.5 million (2009 estimate). Life expectancy at birth is 76 years. Tunisians are 98 percent Muslim, 1 percent Christian, and 1 percent Jewish and other religions. GDP per capita in 2008 was estimated by the CIA at $7,900 USD equivalent, with a 14 percent unemployment rate (2008 estimate).

Libya

The Great Socialist People's Libyan Arab Jamahiriya lies between Egypt and Tunisia, also bordering Sudan to the southeast, Niger and Chad to the south, and Algeria to the west. Libya's area totals 1,759,540 sq km, including no areas of water. Its terrain is flat to undulating plains, plateaus, and depressions; its landscape is mostly barren. The country is subject to dust and sand storms; the ghibli, a southern wind that lasts one to four days, occurs in spring and fall. Current environmental issues include desertification and extremely limited fresh natural water. Total population is approximately 6.3 million (2009 CIA estimate). Life expectancy at birth is 77 years. Citizens are 97 percent Sunni Muslim. Revenues from oil contribute about 95 percent of export earnings, about one-quarter of GDP, and 60 percent of public sector wages; Libya imports about three-quarters of its food. GDP per capita in 2008 was estimated by the CIA at $14,400 USD equivalent; the unemployment rate for 2004 was estimated at 30 percent.[i]

Egypt

The Arab Republic of Egypt is located between Libya to the west and the Gaza Strip and the Red Sea to the east; Egypt includes the Asian Sinai Peninsula and the Suez Canal. Egypt's area totals 1,001,450 sq km, including 6,000 sq km of water. Except for the Nile River valley and delta, Egypt is a desert plateau. It is subject to periodic droughts, earthquakes, flash floods, landslides, dust and sand storms, and a driving windstorm called khamsin in the spring. Current environmental issues encompass loss of agricultural land to urbanization, soil salination below the Aswan High Dam; oil and water pollution, and limited natural fresh water that is increasingly stressed by population growth. Current population is about 83 million (2009 estimate). Life expectancy at birth is 72 years. Citizens are 90 percent Muslim (mostly Sunni), 9 percent Coptic, and 1 percent Christian and other religions. GDP per capita in 2008 was estimated by the CIA to be $5,400 USD equivalent, with an unemployment rate of 8.7 percent.

Projected Regional Climate Change

Current Climatology of North Africa

The climate of North Africa varies substantially between coastal and inland areas of the region. Along the coast, North Africa has a Mediterranean climate, which is characterized by mild, wet winters and warm, dry summers, with ample rainfall of approximately 400 to 600 mm per year. Inland, the countries of North Africa have semiarid and arid desert climates, which are marked by extremes in daily high and low temperatures, with hot summers and cold winters, and little rainfall—approximately 200 to 400 mm per year for semiarid regions and less than 100 mm per year for desert regions.[ii] Figure 1, a plot of average daily rainfall in North Africa for the period

1983-2005, illustrates the demarcation between the coastal and inland climate zones. The Mediterranean climate zone, indicated by the blue-green and turquoise-colored shading, runs along a relatively thin strip of land bordering the coasts of Morocco, Algeria, Tunisia, and parts of Libya and Egypt. The semiarid climate zone, indicated by the blue shading, is a transition zone between the Mediterranean zone and the arid desert climate zone, which is indicated by the dark blue shading. As Figure 1 shows, the semiarid and desert climate zones dominate, and most of North Africa is very dry. Along the coast, the rainy season typically runs from October to March or April. Torrential downpours during the rainy season can cause devastating flooding, and droughts occur frequently in the dry inland regions, sometimes lasting for years at a time.[iii] Figures 2 through 4 show the monthly average daily minimum temperatures, daily maximum temperatures, and total rainfall amounts for the capital cities in North Africa, all of which are situated on the Mediterranean coast and thus have ample rainfall, except for Cairo, Egypt.

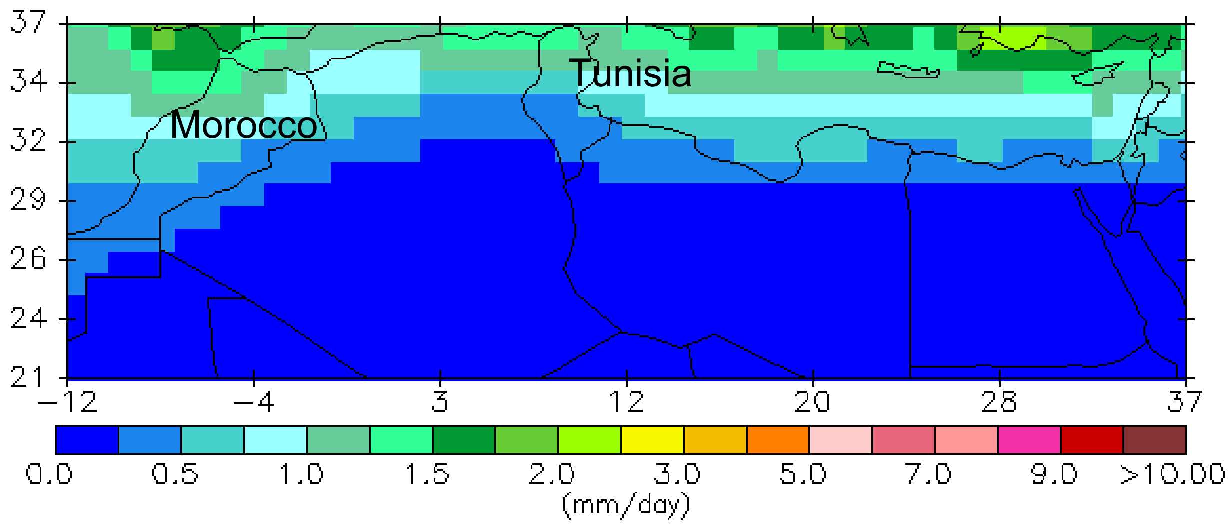

Figure 1. Daily average precipitation rates for North Africa during the period 1983-2005. Latitude (°N) is listed on the y-axis and longitude is listed on the x-axis (negative values are °W and positive values are °E). Precipitation values were measured by satellite; daily values were derived by dividing the total monthly averaged amount of precipitation for a given month by the number of days in the month for the 22-year climatology period. Source: NASA Atmospheric Science Data Center, *NASA Surface Meteorology and Solar Energy: Global/Regional Data*, http://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?na+s01#s01 (accessed May 18, 2009).

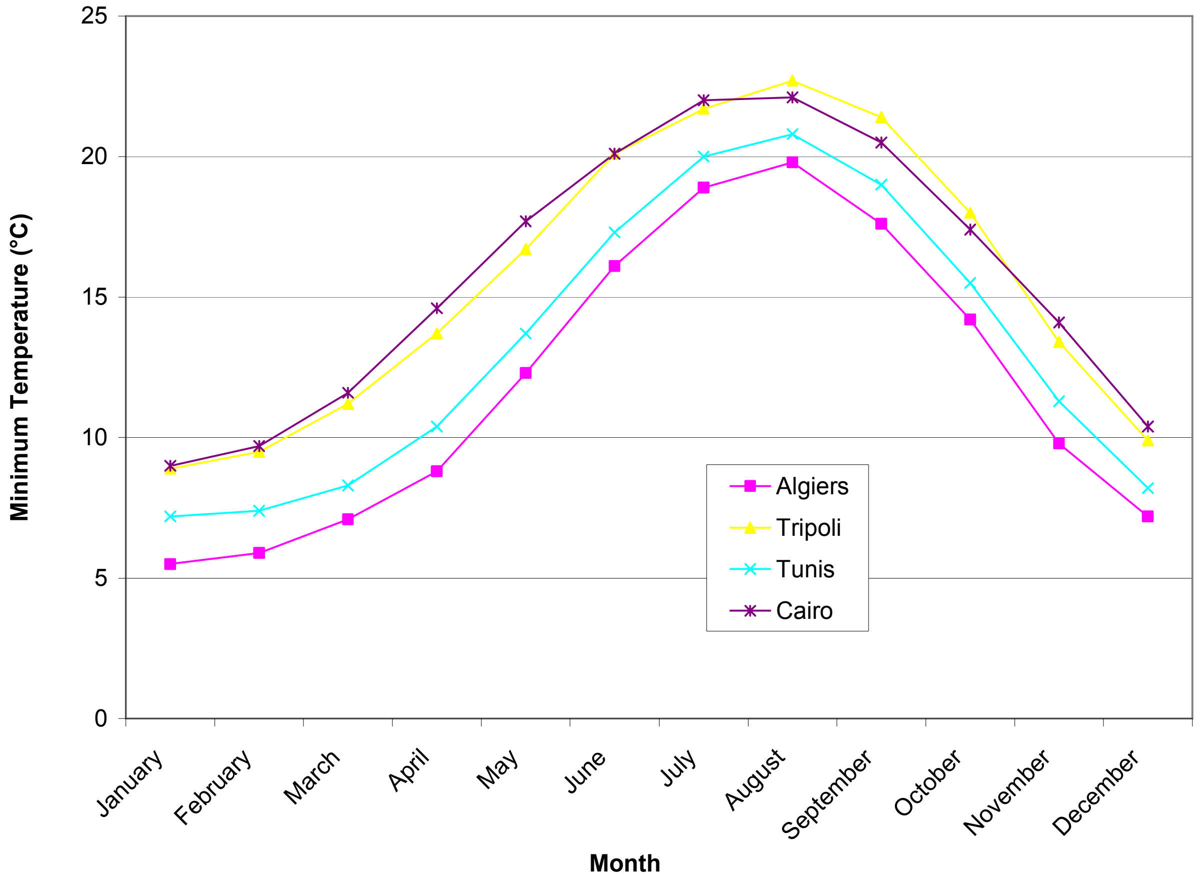

Figure 2. Monthly averaged daily minimum temperatures for capital cities in North Africa. Climatology values for Algiers, Algeria are averaged over the period 1976-2005; values for Tunis, Tunisia are averaged over the period 1961-1990; values for Tripoli, Libya are averaged over the period 1961-1990; and values for Cairo, Egypt are averaged over the period 1971-2000; values for Rabat, Morocco are not available. *Source*: World Meteorological Organization, *World Weather Information Service*, http://www.worldweather.org/ (accessed May 15, 2009).

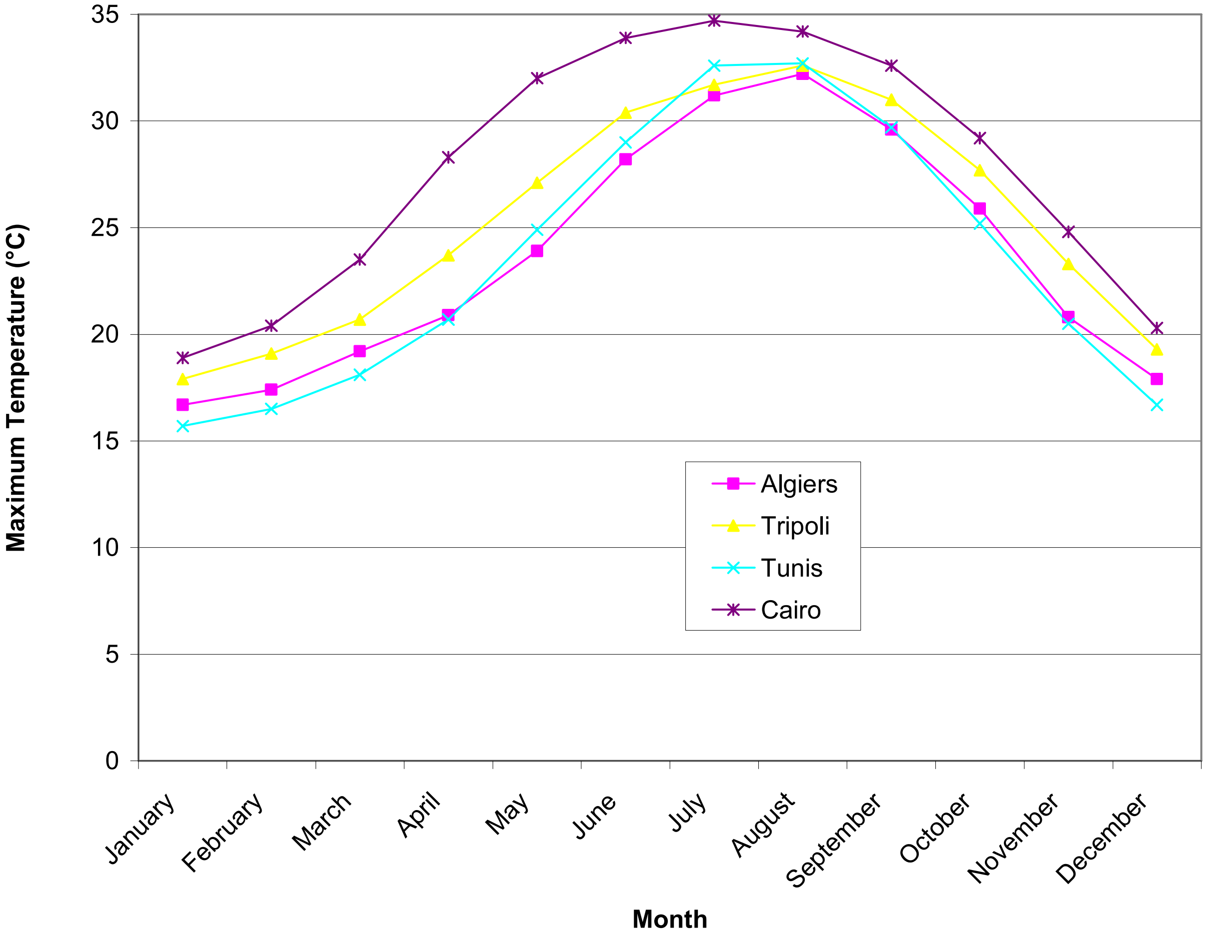

Figure 3. Monthly averaged daily maximum temperatures for capital cities in North Africa. Climatology values for Algiers, Algeria are averaged over the period 1976-2005; values for Tunis, Tunisia are averaged over the period 1961-1990; values for Tripoli, Libya are averaged over the period 1961-1990; and values for Cairo, Egypt are averaged over the period 1971-2000; values for Rabat, Morocco are not available. Source: World Meteorological Organization, *World Weather Information Service*, http://www.worldweather.org/ (accessed May 15, 2009).

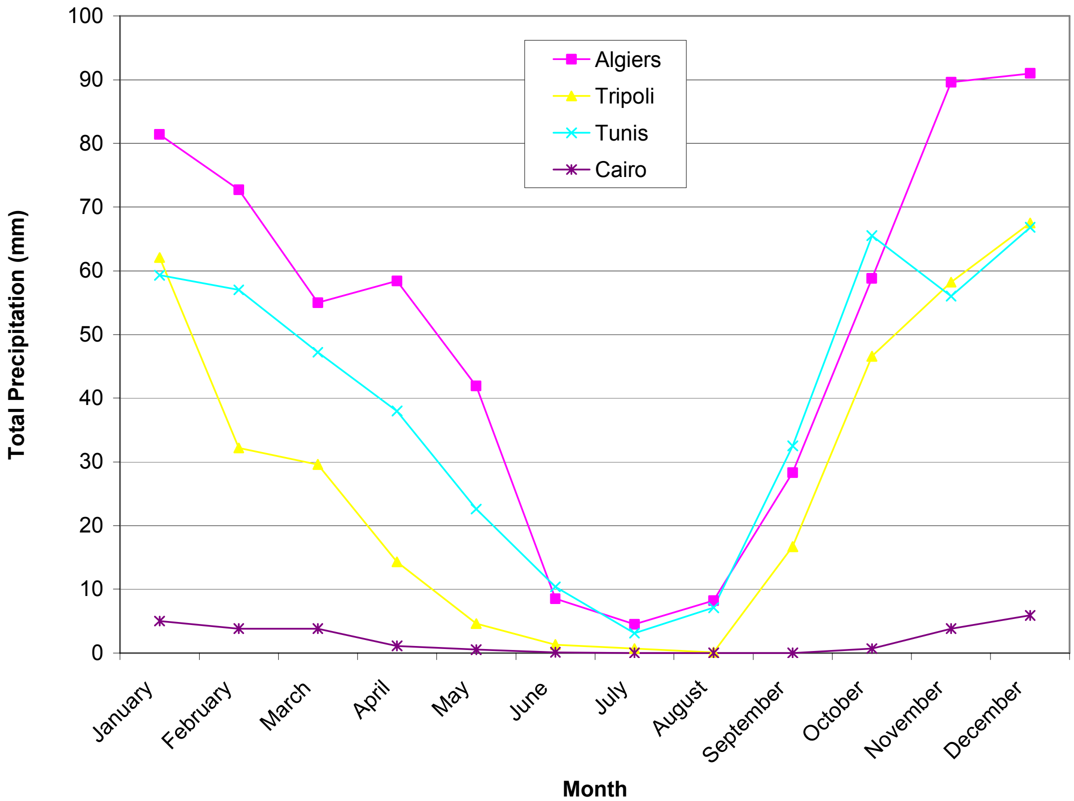

Figure 4. Monthly averaged total precipitation values for capital cities in North Africa. Climatology values for Algiers, Algeria are averaged over the period 1976-2005; values for Tunis, Tunisia are averaged over the period 1961-1990; values for Tripoli, Libya are averaged over the period 1961-1990; and values for Cairo, Egypt are averaged over the period 1971-2000; values for Rabat, Morocco are not available. Source: World Meteorological Organization, *World Weather Information Service*, http://www.worldweather.org/ (accessed May 15, 2009).

An important distinctive climatic feature of North Africa is the *sirocco*, a hot, dry, southerly wind that occurs year round. Siroccos are typically strongest in the spring, when they can reach gale force strength (defined as sustained wind speeds of 34 to 47 knots). Wind events generally last 10 to 12 hours, but events as long as 36 hours have been observed. The winds originate over the Sahara Desert and blow north across North Africa, over the Mediterranean Sea, and into southern Europe. Because siroccos flow from the desert, they typically contain large amounts of sand and dust that limit visibility and can damage machinery. Siroccos are caused by the west-to-east progression of extratropical cyclones (low pressure systems) across the Mediterranean.[4]

[4] Sirocco winds are caused by the eastward progression of extratropical cyclones across the Mediterranean Sea where a low pressure center entrains southerly winds in a warm sector and thereby generates the sirocco winds. See: Weather Online, *Wind of the World: Sorocco*, http://www.weatheronline.co.uk/reports/wind/The-Sirocco.htm (accessed May 15, 2009).

The sirocco is called by different names across the North African region, including *chili* in Tunisia, *ghibli* in Libya, and *khamsin* in Egypt.[iv]

Climate Predictions (Modeling)
General circulation models (GCMs) are the main tool used by scientists to project future climate change. These models simulate atmospheric and oceanic circulations, as well as processes that occur on land. As a result, GCMs are very complex models, and they tend to have rather low spatial resolutions, on the order of 400 to 125 km. To obtain model information on the local and regional scales, such as for North Africa, at higher resolutions than native GCM grid sizes, "downscaling" is used. There are two main downscaling methods, dynamical and statistical. Dynamical downscaling involves the use of high-resolution climate models with observed or simulated data as boundary conditions. This approach has high credibility, but it is computationally expensive. In contrast, statistical downscaling, which involves application of established relationships between observed data and modeled data, is computationally inexpensive, and it can replicate finer scales than dynamical downscaling. Statistical downscaling methods do not accurately simulate regional feedback effects, however.[v]

In general, GCM predictions of temperature changes for a given region are consistent, but predictions of precipitation changes can vary widely due to the difficulty in simulating the myriad factors that influence precipitation frequency, duration, and intensity. An additional complication for North Africa is the fact that most of the region has an arid or semiarid climate and thus receives little rainfall annually, as shown in Figure 1. Given the very low level of annual rainfall that occurs in the region, it is inherently difficult to predict changes in precipitation associated with future climate change. A more detailed discussion of the ability of GCMs to project regional climate changes is given in Annex A.

GCMs simulate changes in climate under scenarios of future greenhouse gas and aerosol emissions. The 2000 IPCC *Special Report on Emission Scenarios* (SRES)[vi] laid out the four basic scenario families used by IPCC scientists to predict future climate change; they are summarized in Table 1. This set of scenarios is designed to represent the range of possible future global conditions that will influence greenhouse gas emissions. The scenarios are based on consistent and reproducible assumptions about global forces that impact greenhouse gas emissions, including economic development, population, and technological change.

Climate researchers frequently use GCMs from the UK Met Office Hadley Centre for Climate Prediction and Research to investigate future changes in temperature and precipitation. These models are representative of many GCMs used to simulate the effects of climate change. The HadCM2 model has four different integrations that represent the climate effects of greenhouse gases and sulfate aerosols. Greenhouse gases, such as carbon dioxide, water vapor, ozone, methane, and nitrous oxide, absorb infrared radiation emitted from the Earth and subsequently emit it back into the atmosphere, which results in a net warming of the Earth's surface. HadCM2 includes the combined forcing of all greenhouse gases as an equivalent CO_2 concentration of 0.5 percent or 1 percent, depending on the integration. HadCM2 can also incorporate the negative direct forcing of sulfate aerosols by means of an increase in clear-sky albedo; sulfate forcing is 0.5 percent or 1 percent, depending on the model integration. The influence of sulfate aerosols is important because they reflect incoming solar radiation; thus less energy reaches the surface of the Earth, which results in a net cooling of the Earth's surface. Each integration of HadCM2 has four ensembles, from which an ensemble mean can be calculated.[vii] Ensembles are used to represent the range in uncertainty of model predictions. In this case, the same model, HadCM2, is run four times using different initial conditions. The average of a series of ensembles is always more accurate than any single model run. HadCM2 has a spatial resolution of 2.5° latitude by 3.75° longitude. In general, this resolution is sufficient to resolve climate changes on a country-level scale in North Africa, without the need for downscaling or temporal smoothing.[viii] To simulate local climate changes, however, downscaling is required.

Emission Scenario	Economic Development	Global Population	Technology Changes	Theme
A1	Very rapid	Peaks around mid-21st century and declines thereafter	Rapid introduction of new and more efficient technologies	Convergence among regions; increased cultural and social interactions
A2	Regionally-oriented	Continuously increasing	Slower and more fragmented than A1, B1, and B2	Self-reliance and preservation of local identities
B1	Rapid change toward service and information economy	Same as A1	Introduction of clean and resource-efficient technologies	Global solutions to economic, social, and environmental sustainability
B2	Intermediate levels of economic development	Continuously increasing, but not as fast as A2	Less rapid and more diverse changes than A1 and B1	Local solutions to economic, social, and environmental sustainability

Table 1. Summary of IPCC emissions scenarios. Source: Intergovernmental Panel on Climate Change (IPCC), *Special Report on Emissions Scenarios (SRES)*, eds. Nebojsa Nakicenovic and Rob Swart (Cambridge: Cambridge University Press, 2000), http://www.ipcc.ch/ipccreports/sres/emission/index.htm.

In contrast to the most recent GCMs, which are run under conditions matching the various IPCC emissions scenarios, many GCMs prior to approximately 2000 were run under more simplistic conditions. The most common method of simulating climate change in the older models was with an equivalent doubling of atmospheric CO_2 concentrations ($2\times CO_2$), which represented the net radiative effect of increases in CO_2 and other greenhouse gases since pre-industrial times (typically equivalent to 560 ppm of CO_2). Models established a baseline using "current" CO_2 concentrations ($1\times CO_2$), and the change between $1\times CO_2$ and $2\times CO_2$ in model output was considered representative of future climate change. Under this type of scenario, researchers often neglected to frame the model results in terms of specific decadal changes, so the exact timeframe for projected climate changes was not specified.

Additional information on the GCMs mentioned in this report is available from the IPCC Data Distribution Centre (http://www.ipcc-data.org/).

Projections of Future Changes in Temperature and Precipitation

According to M Humle et al. average annual surface temperatures and, to a lesser degree, total precipitation amounts have changed in North Africa during the 20th century.[ix] Surface temperatures have risen across the region, especially in Tunisia and northern Algeria, which experienced an approximately 2 to 3°C increase in temperature. The trend in precipitation is less certain, likely due to the relatively small amounts of rainfall historically observed across much of

North Africa. There was a slight increase of 0 to 10 percent in total rainfall observed in the semiarid and arid regions and a slight decrease of 0 to 10 percent observed along the coastal regions during the 20th century.

We do not know the degree to which these observed trends in temperature and precipitation are due to the influence of climate change versus other anthropogenic effects, particularly changes in land cover and land use. Several researchers[x] have suggested that soil degradation, vegetation loss, and deforestation in Africa associated with changes in agricultural and grazing practices, urbanization, and construction of transportation infrastructure over the past 50 years have been major drivers for regional temperature and precipitation variability, and that increases in greenhouse gas and aerosol concentrations have played a lesser role.

Rising concentrations of greenhouse gases in the global atmosphere during the 21st century are expected to cause a net warming of the Earth's surface, and the relative influence of changes in land use and cover in Africa may contribute to this trend as well. A recent modeling study[xi] that simulated future changes in temperature and precipitation in Africa due to greenhouse forcing and land use changes found that the effect of land cover on total climate change appeared to be limited to tropical Africa and did not influence adjacent regions, such as the Sahara Desert or Mediterranean Basin. As a result, changes in land use and cover are likely to have a limited effect on future changes in temperature and precipitation in North Africa; the largest influence probably will be due to forcing from greenhouse gases and aerosols.

To quantify regional future changes in temperature and precipitation associated with climate change, the IPCC uses a coordinated set of climate model simulations archived at the Program for Climate Model Diagnosis and Intercomparison (called the multi-model dataset, or MMD). Although the MMD models have significant systematic errors in prediction of some major observed climatic events in Africa, such as rainfall in southern Africa, placement of the Atlantic Inter-Tropical Convergence Zone (ITCZ), and ocean upwelling off the West Africa coast, they have predicted robust regional trends in temperature and precipitation for North Africa.[xii] Figure 5 shows the projected increases in temperature for the Southern European and Mediterranean (SEM) and Saharan Africa (SAH) regions for the 21st century. As defined by the IPCC and shown by the green highlighted areas in Figure 5, the Southern European and Mediterranean region encompasses 30°N to 48°N latitude and 10°W to 40°E longitude, and the Saharan Africa region encompasses 18°N to 30°N latitude and 20°E to 65°E longitude. Taken together, the southernmost portion of the SEM region combined with the western two-thirds of the SAH region comprise the North African area that is the focus of this report. The SEM region corresponds to the coastal areas of North Africa that have a Mediterranean climate, while the SAH region corresponds to the inland areas of North Africa that have semiarid and arid desert climates.

To obtain the temperature information shown in Figure 5, a subset of 58 simulations from 14 models of the MMD was used for the observed period and 47 simulations from 18 models for the future projections; the future projections were calculated for the A1B emissions scenario. The width of the shading and the bars in Figure 5 represent the 5 to 95 percent range of the model output. Model simulations are presented in the context of observed warming during the 20th century, which is important because if GCMs cannot accurately reproduce observed climatic data, they cannot be relied upon to simulate future climate changes. Numerical results from simulations of 21 MMD models are summarized in Table 2 and show that by the end of the 21st century, annual mean temperatures in the Mediterranean and Saharan regions of North Africa are expected to increase by median values of 3.5 and 3.6°C, respectively, for the A1B scenario, with the largest increases expected during the summer months of June, July, and August. These temperature increases are larger than the global annual mean warming of 2.8°C predicted by the MMD models for the same period.[xiii]

The IPCC also used the MMD models to estimate precipitation changes for the 21st century under the A1B scenario. As shown in Table 2, the model simulations show a general decrease in rainfall across North Africa, with median decreases in average annual precipitation of 12 percent and 6 percent projected for the Mediterranean and Saharan regions, respectively. This general drying trend for North Africa is punctuated by seasonal variations in projected precipitation that differ by region. All of the MMD models show a clear decrease in future precipitation in the SEM region, with the largest decrease of 24 percent expected during the months of June, July, and August. This drying trend is likely driven by increased moisture divergence and a systematic northward shift of the storm tracks affecting winter precipitation in the region, as well as losses in soil moisture during the summer.[xiv] Results are less definitive for the SAH region; all of the MMD models predict a clear decrease in future precipitation of 18 percent for the period December to May, but the predicted decrease is much smaller for the months of June, July, and August. Furthermore, the models predict a slight increase in future precipitation of 6 percent for the months of September, October, and November in the SAH region. Some of these variations in predictions of future precipitation trends are likely related to uncertainty in the ability of climate models to successfully downscale precipitation over Africa.[xv]

Season	**Temperature Change (°C)**		**Precipitation Change (%)**	
	SEM	**SAH**	**SEM**	**SAH**
Annual	+3.5	+3.6	-12	-6
Dec/Jan/Feb	+2.6	+3.2	-6	-18
Mar/Apr/May	+3.2	+3.6	-16	-18
Jun/Jul/Aug	+4.1	+4.1	-24	-4
Sep/Oct/Nov	+3.3	+3.7	-12	+6

Table 2. Median changes in temperature and precipitation predicted by a set of 21 IPCC MMD models under the A1B emissions scenario for the Southern Europe and Mediterranean (SEM) and Saharan Africa (SAH) regions. Source: Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: the Physical Science Basis*, eds. S. Solomon, D. Qin, M. Manning, M. Marquis, K. Averyt, M.M.B. Tignor, H.L. Jr. Miller, and Z. Chen (Cambridge: Cambridge University Press, 2007), http://www.ipcc.ch/ipccreports/ar4-wg1.htm.

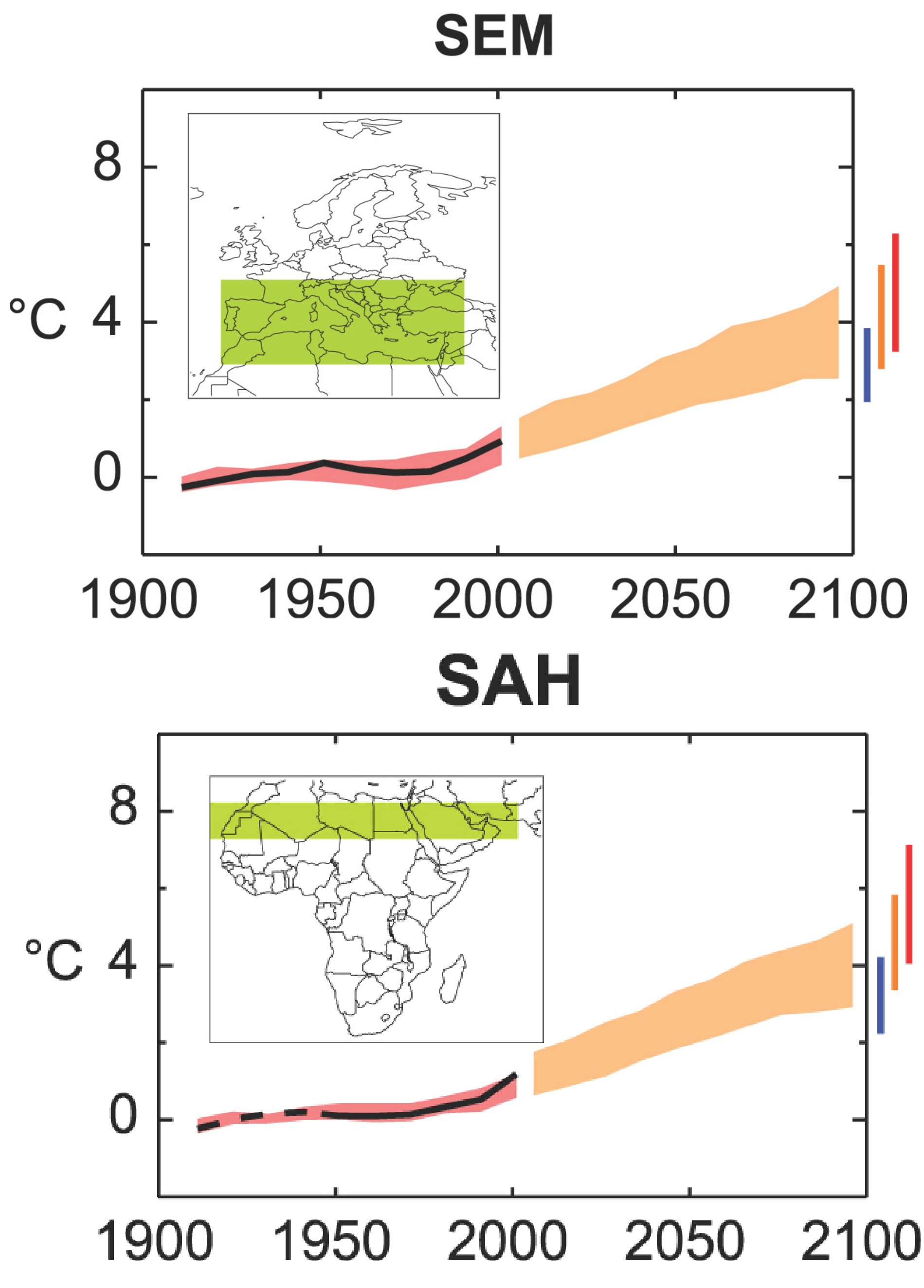

Figure 5. Temperature changes in °C predicted by the IPCC MMD models for the Southern Europe and Mediterranean (SEM) and Saharan Africa (SAH) regions. Temperature anomalies for the region with respect to 1901-1950 are shown for 1906-2005 (black line), as simulated by the MMD models using known forcings (red envelope), and as projected for 2001-2100 by the MMD models for the A1B scenario (orange envelope). The colored horizontal bars on the right side of the figure represent the range of projected changes for 2091-2100 for the B1 scenario (blue), the A1B scenario (orange), and the A2 scenario (red). The width of the shading and the bars represent the 5 to 95 percent range of the model results.[xvi]

The same trends in future temperature and precipitation changes predicted by the IPCC MMD models also have been simulated by several North African regional and country-specific studies. In an analysis of climate change in Africa through 2100, Hulme et al[xvii] used seven GCMs run under the A1, A2, B1, and B2 emissions scenarios to project temperature and precipitation changes for the "2020s" and "2050s" relative to 1961-1990. For the North Africa region, the models predicted temperature increases of 0.9 to 1°C and 1.8 to 2.2°C for the B1 and A2 scenarios, respectively, for the "2020s"; and increases of 1.2 to 1.5°C and 3.1 to 4.4°C for the B1 and A2 scenarios, respectively, for the "2050s." Precipitation projections were less definitive but involved a drying trend for the region, especially along the Mediterranean coast of North Africa, that is expected to become more pronounced with time.

The future drying trend was also observed in a study of anthropogenic climate change in the Mediterranean region for the end of the 21st century.[xviii] Results from a global variable-resolution climate model run under the B2 emissions scenario projected a decrease of 0.065 mm/day in annual average precipitation for the period 2070-2099 relative to 1960-1989. The authors predicted that evaporation in the Mediterranean basin would increase in winter and spring but decrease in summer and fall, despite projected increases in surface temperature, leading to the net decrease in regional precipitation. Giorgi[xix] found similar results in his development of a Regional Climate Change Index (RCCI) from the output of 20 GCMs run under the A1B, A2, and B1 emissions scenarios. Giorgi determined that the Mediterranean region was one of the two most vulnerable areas in the world to climate change due to the large decrease in mean precipitation predicted by the GCMs for the period 2080-2099.

Most recently, Paeth et al[xx] used the regional REMO GCM run under the A1B emissions scenario to estimate annual mean temperature and precipitation changes in tropical and North Africa through 2050. REMO is a synoptic scale model for Africa that has a spatial resolution of 5°. Paeth et al results confirm those of the IPCC and previous researchers, who predict a warming and drying trend in the region over the next century. Paeth et al estimate that by 2050, surface temperatures in North Africa will increase by approximately 1.5 to 2°C and precipitation will decrease by 10 to 30 percent across many of the desert areas of the region, with larger precipitation decreases of up to 200 percent along the coasts of Morocco, Algeria, and Tunisia.

These regional trends in temperature and precipitation are supported by a recent country-scale model analysis for Morocco.[xxi] Results from a statistical analysis of output from a series of GCMs suggest that mean annual surface temperatures in Morocco will increase by 0.6 to 1.1°C and annual precipitation will decrease by 4 percent for the period 2000-2020.

Projections of Future Changes in Sea Level

As the global ocean warms due to climate change, its volume will increase, and as a result, sea level will rise. The rate of sea level rise differs on a regional scale, principally due to local variations in the balance between the density and circulation of the oceans. Recent changes in Mediterranean Sea level along the North African coast are difficult to quantify due to lack of observational data. An analysis[xxii] of tide gauge data from the Permanent Service for Mean Sea Level (PSMSL) data set indicates that Mediterranean Sea level rose at a rate of approximately 1 mm per year during the 20th century. This value is based on data from stations situated along the southern European coast, however, and therefore may not be completely representative of recent changes in sea level along the coast of North Africa. Only a few tide gauge stations are located along the North African coast – near the Strait of Gibraltar and the Nile River Delta – and these stations do not have a long enough record to reliably estimate changes in sea level during the 20th century.

The sparseness of tide gauge records is a global problem, and researchers have attempted to overcome this issue by combining the tide gauge observations with satellite altimeter data. Recent analysis of tide gauge records and data from the TOPEX/Poseidon satellite altimeter indicate that Mediterranean Sea level rose approximately 0.5 to 1 mm per year during the period 1950-2000.[xxiii] Thus, although definitive assessment of recent changes in Mediterranean Sea level is not possible, it seems likely that sea level rose along the coast of North Africa by approximately 0.5 to 1 mm per year for at least the second half of the 20th century. This increase is less than the global average sea level rise of 1.8 ± 0.5 mm per year for 1961 to 2003 and 1.7 ± 0.5 mm per year for the 20th century estimated by IPCC using PSMSL tide gauge records.[xxiv]

Using the ensemble mean of a subset of 16 models from the MMD, the IPCC has estimated future regional changes in sea level due to thermal expansion, including ocean density and circulation changes. The majority of future sea level rise is expected to be caused by the thermal expansion of oceans, and the rest will be due to melting ice sheets and glaciers, with minor contributions from land subsidence and changes in atmospheric pressure.[xxv] Results for the projected sea level rise due to thermal expansion for North Africa for the period 2080-2099 relative to 1980-1999 for the A1B emissions scenario are shown in Figure 6. These sea level projections are given in relation to the average global sea level increase of 13 to 32 cm due to thermal expansion that has been predicted by the IPCC MMD models for the same period under the A1B scenario. The global MMD climate models do not have sufficient spatial resolution to capture future changes in the Mediterranean Sea; therefore the only relevant projected changes in sea level indicated by Figure 6 for this report are for the Atlantic coast of Morocco. Figure 6 indicates that sea level along the Atlantic coast of Morocco will rise approximately 0 to 5 cm above the global average value at the end of the 21st century, for a net increase of 18 to 37 cm under the A1B scenario.

Since the global MMD climate models are not able to simulate future climate changes in the Mediterranean Sea region, downscaling and use of regional climate models are required. Only one climate model is currently available at the regional scale for accurately simulating future changes in the climate of the Mediterranean Sea region: the Sea-Atmosphere Mediterranean Model (SAAM). Developed by the Centre National de Recherches Météorologiques (CNRM) in France, SAAM is an ocean-atmosphere regional climate model with a horizontal resolution of 9 to 12 km.[xxvi]

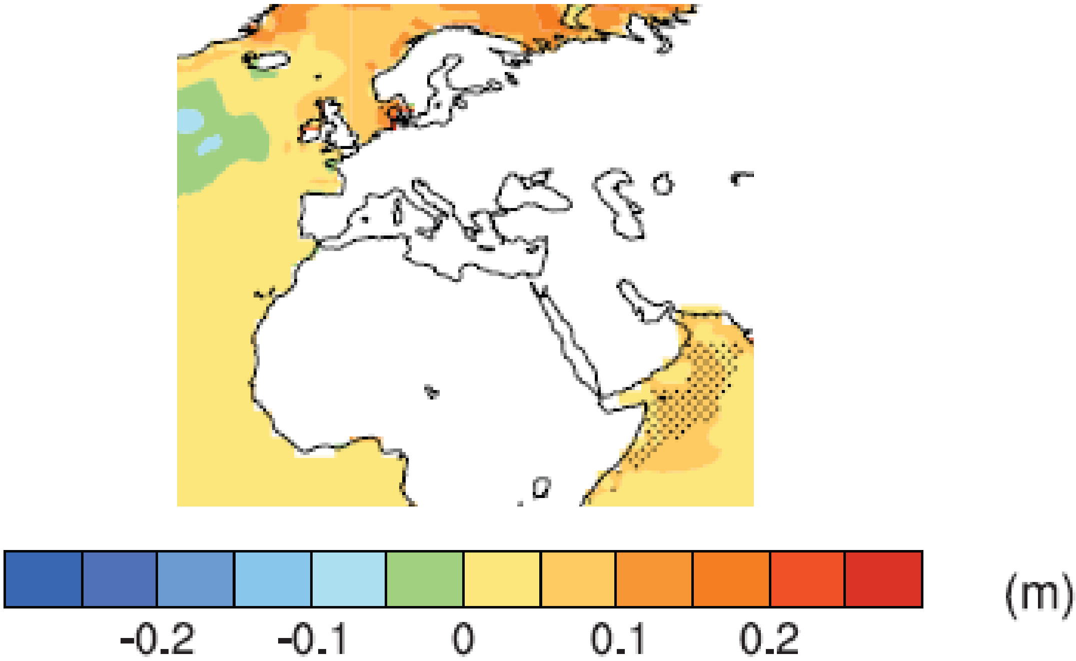

Figure 6. Projected changes in local sea level due to thermal expansion for the period 2080-2099 relative to the period 1980-1999. Sea level change was calculated as the difference between averages of projections for 2080-2099 and 1980-1999 from the ensemble mean of 16 GCMs run under the A1B emissions scenario. The local sea level changes shown are above/below the global average sea level rise of 13 to 32 cm due to thermal expansion that is expected by the end of the 21st century under the A1B emissions scenario. Changes in sea level associated with thermal expansion include changes in ocean density and circulation.[xxvii]

To predict future changes in Mediterranean Sea level rise, SAAM was run for the period 1960-2099 under the A2 emissions scenario.[xxviii] The model simulated changes in Mediterranean Sea level associated with thermal expansion of the oceans and did not include contributions from melting ice sheets and glaciers. Results show that projected sea level rise associated with changes in water density (on the order of 5 to 20 cm) is significantly larger than that associated with changes in circulation (on the order of 0 to 3 cm). The largest increase in sea level on the North African coast is expected to be approximately 15 to 20 cm (5 to 6.5 mm per year) along the Algerian coast. Mediterranean Sea level rise along the rest of the North African coast is expected to be approximately 5 cm (1.7 mm per year) or less. These regional Mediterranean Sea level projections are roughly comparable to the average global sea level increase of 3.8 ±01.3 mm per year due to thermal expansion that has been predicted by the IPCC MMD models for the period 2080-2100 under the A2 emissions scenario.[xxix] It is important to note that the regional Mediterranean Sea level projections are derived from a single model run; thus their results are significantly more uncertain than would analogous results from an ensemble of models, but they represent the most current estimates of sea level rise along the North African coast.

Older model projections provide a more pessimistic view of sea level increases in the North African region. A recent analysis[xxx] of the impacts of sea level rise on the Mediterranean coast of Morocco used model simulations from a 1996 modeling study[xxxi] that predicted sea level increases of 20 to 86 cm along the Moroccan coast by 2100 under the old IS92a emissions scenario. The IS92a scenario assumed a worldwide rate of greenhouse gas emissions that would cause a doubling of atmospheric CO_2 concentrations over pre-industrial levels by the end of the 21st century, which is too aggressive by about 50 years, according to recent estimates,[xxxii] thus making the accuracy of 1996 model study uncertain. In addition, an unspecified Tunisian model study, cited in the Initial Communication of Tunisia to the United Nations Framework Convention on Climate Change, projected a sea level increase of 38 to 55 cm along the Tunisian coast by 2100.[xxxiii]

Projections of Future Changes in the Frequency and Intensity of Extreme Climatic Events

Little research has been conducted on changes in the frequency and intensity of extreme climatic events in Africa, either in analysis of past observations or future model predictions. North Africa is not subject to tropical cyclones (hurricanes) or directly impacted by the El Niño – Southern Oscillation (ENSO) phenomenon. The most common extreme events in the region are droughts and floods. There is some evidence that the intensity and frequency of floods and droughts have been increasing in recent years, although we do not know to what extent these increases are due to the influence of climate change versus other anthropogenic effects, such as changes in land cover or irrigation practices. Catastrophic floods in Algeria and Morocco in 2001-2002 caused extensive destruction of property and loss of life.[xxxiv] The worst flooding event in Algerian history occurred in Algiers on November 10-14, 2001, when the equivalent of an entire month of rainfall fell in a matter of several hours. 751 people died and property losses were estimated at $300 million USD equivalent. In Morocco, 63 people died and hundreds of hectares of agricultural land were damaged from a devastating flood on November 20-27, 2002. In addition, climatic data from Morocco, Algeria, and Tunisia indicate that the frequency of droughts increased from approximately one per decade to 5-6 per decade during the course of the 20th century.[xxxv]

The IPCC[xxxvi] reports that in regions where mean drying is expected, such as North Africa in the 21st century, there will be a proportionally larger decrease in the number of rainy days expected to occur. This result suggests that although there will be less net rainfall in the region in the future, rain will be more intense on days that it does fall, indicating a compensation between intensity and frequency of precipitation that may lead to enhanced flooding.

In its First National Communication to the United Nations Framework Convention on Climate Change,[xxxvii] Morocco outlined several likely changes in extreme events, based on climate scenarios developed according to IPCC guidelines. In the 21st century, the frequency and intensity of frontal and convective thunderstorms in the regions north and west of the Atlas Mountains[5] are expected to increase, the frequency and intensity of droughts in the southern and eastern portions of the country are expected to increase, and the length of the rainy season is expected to decrease.

Sea level rise associated with climate change is expected to increase flooding along the coast from storm surges.[xxxviii] For example, a recent analysis of the potential increase in flooding along the eastern Mediterranean coast of Morocco[xxxix] predicts that for a sea level rise of 20 to 86 cm, 24 to 59 percent of the coastal area will be lost due to flooding in 2050-2100. Residential, recreational, and agricultural lands are expected to be most impacted.

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[5] The Atlas Mountains extend across northern Africa from Morocco to Tunisia, separating the coastal areas from the Sahara Desert. Separate ranges in Morocco, running from southwest to northeast, include the Anti-Atlas, the High Atlas, and the Middle Atlas Ranges.

Due to lack of research, it is not possible to predict any definitive future trends in the frequency or intensity of extreme climatic events in North Africa. Droughts and floods are the most common extreme climatic events that occur in North Africa, and there is observational evidence that their frequency and intensity have increased in the past 10 to 20 years, especially in Morocco, Algeria, and Tunisia. Likely future changes across the region include periods of more intense rainfall and increases in coastal flooding from storm surges associated with sea level rise.

Impacts of Climate Change on Human-Natural Systems

According to Claudia Ringler (2009),[xl] a senior research fellow at the International Food Policy Research Institute, “While population, diet patterns, and urbanization currently have a greater impact on water security, by 2025, climate change will account for more of the threat.” As pointed out by a number of studies reviewed in this report, the general drying trend predicted for North Africa may in turn translate to sizable impacts on the region’s agriculture.

In 2005 the agricultural area of the three largest countries in North Africa—Algeria, Libya and Egypt—was estimated at about 60.3 million hectares (11.7 percent)[xli]. The size of agricultural area in Morocco and Tunisia is considerably larger—62.9 percent and 68.1 percent of land, respectively (2005 estimate). Almost all of Libya and Egypt’s land is desert (94-96 percent).[xlii] The geography of land use and demographic patterns of both countries reveal that rainfall (water resources) is the dominant factor in Libya, and the Nile River the dominant factor (source of water) in Egypt.

One-quarter of northern Algeria is unproductive; only 3 percent of its land is cultivated, despite having 25 percent of the population involved in agriculture.[xliii] Similar to Algeria, only a small percentage of Egypt’s land is arable, but, unlike Algeria, its land is largely productive and can be cropped two to three times annually. In Libya, almost all crops are grown for domestic consumption. Cereals are produced in the northwestern (Tripolitania) and eastern (Cyrenaica) regions of the country, while agriculture in the southwestern region (Fezzan) of the country is concentrated in the oases. Morocco is relatively self-sufficient in food production, but due to recent occurrences of drought, it has been forced to import grains during some years. In Tunisia, fertile land is usually limited to the north, where cereals, olives, fruits, grapes and vegetables are harvested. Currently, Tunisia’s growing season provides the country an advantage by allowing it to profit from exporting fresh produce to Europe before European crops ripen.

Table 3 summarizes agricultural production, major exports and imports, and the total size of agriculture as part of each North African country’s GDP.

Water resources and agriculture, being intertwined impacts, are discussed first, followed by a discussion of climate change impacts on migration, coastal areas, tourism and energy.

	Agricultural Production	**Major Exports**	**Major Imports**	**Agricultural GDP as share of total GDP Percent, 2004**
Algeria	Wheat Cow milk (fresh) Indigenous sheep meat	Dates, Oil of maize, Cocoa butter	Wheat, Dry whole cow milk, Dry skim cow milk	9.8
Egypt	Tomatoes Rice, paddy Buffalo milk	Cotton lint Rice, milled Oranges	Wheat Maize Cake of soybeans	15.1
Libya	Indigenous chicken meat Olives Indigenous sheep meat	Skins, dry salted (sheep) Crude organic materials, NES Skins with wool, sheep	Flour of wheat Oil of maize Wheat	---
Morocco	Wheat Cow milk, whole (fresh) Indigenous chicken meat	Tangerines, mandarins, clementines, satsumas Crude organic materials, NES Oranges	Wheat Maize Oil of soybeans	15.9
Tunisia	Olives Wheat Tomatoes	Oil of olive, virgin Dates Crude organic materials, NES	Wheat Cake of soybeans Maize	12.6

Table 3. 2006 Agricultural Outlook in North Africa. Information not available. *Source*: FAO (Food and Agricultural Organization of the United Nations), s.v. "Agricultural sector," FAO Country Profiles, 2006, http://www.fao.org/countryprofiles/.

Water Resources Stress

Observed trends pointing to a drier North Africa will have severe implications on the region's water availability, accessibility, and demand. Already, North Africa is experiencing high water stress. According to Ashton (2002),[xliv] even without climate change, North African countries will surpass their maximum economically usable land-based water resources before 2025. Population increases accompanied by growing water demands are causing significant water deficits in these arid countries. For the period 1990-2002, the average annual population growth in North Africa was the highest in the world at 2.9 percent.[xlv] At the same time, the Water Exploitation Index (i.e., total water extraction per year as a percentage of long-term freshwater resources) is high for most countries of the region: more than 50 percent for Tunisia, Algeria, and Morocco, and more than 90 percent for Egypt and Libya.[xlvi] Physical water scarcity[6] becomes apparent when withdrawals surpass 40 percent of the annually renewable resource.[xlvii]

Given an expected population growth in the region of approximately 50 million between 2025 and 2050,[xlviii] climate change-induced droughts are likely to place further stress on North Africa's freshwater resources. With an increase of 3°C, for example, an estimated 155-600 million North Africans will experience water stress.[xlix]

In preparation for Morocco's Initial Communication to the United Nations Framework Convention on Climate Change (UNFCCC), a partial study of vulnerability to climate change

[6] Physical water scarcity is water availability of less than 1,000 cubic meters per person per year.

impacts was conducted.[l] Based on this study, it is expected that, by 2020, climate change-related disruptions in rainfall will reduce dam capacity (i.e., concentrated rainfall and rapid sludge accumulation exacerbated by erosions); upset river flow rates; and decrease water levels, thereby effectively decreasing natural outlets for water tables and increasing salinity in coastline areas; and deteriorate water quality. The study estimated the result will be a 10-15 percent reduction of Morocco's water resources. This same reduction is estimated for Algeria.

The IPCC Assessment[li] further reports that projected temperature increases of 1-4°C and declines in precipitation of up to 10 percent are likely to result in annual reductions in runoff in Morocco's Ouergha watershed.[7] For example, holding precipitation levels constant, a 1°C rise in temperature could lead to a 10 percent reduction in runoff.[lii] Assuming annual runoff reductions in other watersheds, the aggregate decline is equivalent to the loss of one large dam per year in the region.

According to GTZ (2007),[liii] a private international enterprise that collaborated with various Tunisian ministries and authorities as well as several nongovernmental organizations to develop an adaptation strategy to climate change in the country's agricultural sector, Tunisia's water resources are estimated to decline 28 percent by 2030. Of particular risk will be the loss of groundwater reserves.

Yet a graver situation may be experienced in Egypt, where it is predicted that 74.8 percent of Egyptians will have less than adequate fresh water supply by 2030.[liv]

With climate change comes a looming potential for conflict over water resources. Over extraction of water together with the impacts of climate change may lead governments to divert major river dams, construct large dams, or tap underground aquifers that traverse beneath the territory of neighboring countries.[lv] Such may prove to be the case with the large fossil-water aquifers beneath the Sahara desert—namely, the Eastern Erg artesian aquifer, which extends from Algeria into Tunisia, and the Nubian Sandstone underlying Libya, Egypt, and Sudan.[lvi] There are already concerns that the latter is generating international conflict. Libya is tapping the Nubian aquifer on a massive scale as part of its "Great Manmade River" project.[lvii] This in turn is creating fear that pumping water beneath Libyan territory is draining groundwater reserves in Egypt and Sudan.

Similarly, with increased heat and aridity, conflicts over the Nile River may surface between Egypt and its neighboring countries. Egypt's dependence on the Nile River is appreciable; more than 95 percent of its water needs are satisfied from the Nile.[lviii] The Nile waters, which originate outside Egypt, traverse nine countries to the South: Sudan, Eritrea, Ethiopia, Uganda, Kenya, Tanzania, Rwanda, Burundi, and Zaire. Although the Nile River is governed by International Law (the Nile Agreement of 1959, signed by Egypt and Sudan), and despite relatively consistent cordial relations between Egypt and Sudan, disputes over water between the two countries have occurred. In 1995, in the wake of the assassination attempt on President Hosni Mubarak, accusations began flying back and forth between Cairo and Khartoum, and Sudan threatened to "cut off Egypt's water."[lix] The fact that Sudan lacks the engineering capacity to carry out such a threat did little to soften the frenzy in the Cairo press, and the current Arab League's Secretary-General, Amr Moussa, then former Egyptian Foreign Minister, warned Islamic leader Hassan al-Turabi not "to play with fire."[lx]

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[7] The Ouergha River is a tributary of the Sebou River (the largest by volume in Morocco) in northern Morocco and the source of water for the Al Wahda Dam, the second-largest dam in Africa.

As less water becomes available, the demand for water grows higher and, with higher demand, the need to rely on costly water treatment and extraction methods increases. Wastewater treatment and re-use has become prevalent in Tunisia, Egypt and Morocco; the use of desalinated water has become prevalent in Egypt and Libya.[lxi] In addition, North Africa is increasingly investing in water infrastructure, accounting for more than 20 percent of public sector investment in Morocco and Tunisia, and 12 percent in Algeria.[lxii] In 2002, Ragab and Prudhomme[lxiii] reported that:

- By 2010, Algeria estimates it will need another 5.5 km^3 of water annually: 50 percent for irrigation and 50 percent for domestic and industrial uses. It plans to build 50 more dams and 10 diverting canals and will tap non-renewable fossil water beneath the Sahara.
- In 2000, Tunisia expected to use 90 percent of its surface water in the north and all of its groundwater. Part of the country's agenda is to build new large dams and develop a network of pipes and canals for water transportation between river basins. As a result of these efforts, Tunisia will be able to transport more than half of the water captured behind dams in the northern regions.
- Morocco plans to double the proportion of its river flow that is controlled by dams and extract more groundwater. It will construct 60 large dams, 100 km-long sink boreholes and construct 280 km of water-transportation structures.
- Libya intends to tap more underground water and transport it to the coastal aquifers, which have been excessively depleted due to overextraction. Libya's annual water withdrawal is larger than the volume of its renewable resources.

According to Egypt's Initial National Communication on Climate Change to the United Nations Framework Convention on Climate Change (UNFCCC), Egypt also is undergoing massive projects to divert some of the Nile waters to Northern Sinai and to the Toshka depression in the extreme southern part of the country.[lxiv] In addition, 70 percent of cultivated areas rely on low-efficiency surface irrigation systems, which result in high water losses, a decline in land productivity, saturation of the ground with water, and salinity problems.[lxv]

As the true costs of pollution and water scarcity become increasingly apparent, however, governments and policymakers are also becoming increasingly willing to address water problems.[lxvi] In 2007, Algeria, Egypt and Morocco spent 20 and 30 percent of their budgets on water. Bucknall's, *Making the Most of Scarcity: Accountability for Better Water Management in the Middle East and North Africa* (2007),[lxvii] assesses that by 2050, MENA governments will most likely begin to employ water for enterprises that generate the highest amount of money and employment and begin to import more hydro-intensive crops such as wheat. The report estimates that the cost of water-related environmental problems is between 0.5 and 2.5 percent of GDP for most countries.

Given that the volume of water available for food production has not been sufficient to satisfy increasing demand, Wichelns (2000)[lxviii] describes the role of virtual water (i.e., the volume of water embodied in food crops that are traded internationally) as a method by which North African countries have coped with water scarcity in the past. Such was the case during the boom of the 1970s, when higher incomes and increasing populations created a greater demand for food that could only be generated by increasing food imports.

Agriculture
Irrigation plays the most crucial role in the arid regions, which are characterized by low rainfall or evapotranspiration exceeding precipitation most of the year and high interannual rainfall variability. Accordingly, water scarcity related to climate change is expected to have negative consequences on North Africa's agriculture. Water and land resources in North Africa are primarily used for agriculture.[lxix] North Africa accounts for more than 41 percent (about 6 million hectares) of total irrigated lands in Africa.[lxx] Consequently, the Northern region represents more than half of the agricultural water withdrawal of the continent.[lxxi]

In North Africa, rising temperatures associated with climate change are expected to decrease the land areas suitable for agriculture, shorten the length of growing seasons, and reduce crop yields.[lxxii] The decrease in annual precipitation that is predicted for Northern Africa in the 21st century will exacerbate these effects, particularly in semiarid and arid regions that rely on irrigation for crop growth. Rising atmospheric CO_2 levels are expected to stimulate plant photosynthesis, however, which might result in higher crop yields and could offset some of the negative effects of higher temperatures and less rainfall in the region.

Only a few systematic modeling studies of the effects of climate change on agriculture in North Africa are available, possibly due to the relatively small areas of arable land in the region combined with the lack of suitable regional or downscaled climate model information. For example, only about 3 percent of the total land area of Egypt can be used for farming, almost all of it in the Nile River Delta and Valley.[lxxiii] GCMs cannot accurately resolve temperature and precipitation variations on such a small spatial scale, which makes evaluation of future agricultural changes difficult.

Already, however, the areas suitable for agriculture are heavily exploited.[lxxiv] Arable land availability, food price shocks, and population growth are current problems.[lxxv] In addition, policymakers in the region tend to adopt agricultural policies that favor perimeter irrigation, construction of dams, and the development of tourism sectors, which are water-intensive, over more traditional agricultural cultivation, which requires less water (e.g., wheat) and the development of fruits and vegetables for export.[lxxvi]

Based on observations, experiments, and model analyses made by the National Institute for Agricultural Research in Morocco, several potential changes to agricultural growing seasons in Morocco were outlined in Morocco's First National Communication to the United Nations Framework Convention on Climate Change.[lxxvii] Likely changes in the 21st century include a reduction in the growth period of regional crops, a reduction in the duration of crop cycles, and an increase in the risk of dry periods during the course of crop cycles.

Several researchers have used GCM climate simulations in conjunction with crop models in an attempt to quantify the effects of climate change on crop yields, particularly in Morocco and Egypt. Jones and Thornton (2003)[lxxviii] investigated the potential changes in maize production associated with climate change in Africa and Latin America, including Morocco, using the HadCM2 model. The authors focused on maize because it is an important crop for smallholder farmers in those regions. HadCM2 simulated changes in temperature and precipitation for the period 2040-2069 ("2055"), and these climate projections were used by the CERES-Maize crop model to simulate the growth, development, and yield of maize crops. Model results predicted a substantial increase in maize crop yield in Morocco in 2055 due to the effects of climate change, from a baseline value of 317 kg/ha to a value of 550 kg/ha, which represents an approximately

175 percent increase. These model simulations suggest that the positive effects of increased atmospheric CO_2 concentrations may be the dominant influence on future maize crop yield in Morocco. Maize is a member of a group of plant species that have a relatively high optimum temperature range for photosynthesis,[lxxix] which makes maize tolerant of high air temperatures and may explain why higher crop yields were projected for a hotter future climate.

Egypt, where agriculture is not feasible without irrigation (99.8 percent of its cropland is irrigated), depends on other countries for over 90 percent of its renewable water resources.[lxxx] Almost all of Egypt, 96 percent of its land, is covered by desert, and 97 percent of the population is concentrated on only 4 percent of irrigated land.[lxxxi]

In 2006, Egypt's cultivated area was estimated at approximately 8 million acres or about 3.5 percent of the country's total land area.[lxxxii] Meanwhile, 30 percent of Egypt's labor force works in the agricultural sector; contributing 14.8 percent of the nation's GDP (2006 estimate).[lxxxiii] Arable land in Egypt is restricted to the Nile valley from Aswan to Cairo and the Nile Delta north of Cairo.[lxxxiv] The Nile Delta, a region characterized by high production, high irrigation, and smallholder agriculture, is also a region with severe urban water and land-use challenges and projections of high population increase (see Natural Disasters discussion below).[lxxxv]

In recent years, the country has undergone several major agricultural developments, including expanding production of two of its major exporting crops as shown in Table 4: rice (40 percent of agricultural exports) and cotton (20 percent). However, these crops are also two of the most hydro-intensive crops. A changing climate, together with the expansion of cultivated areas in Egypt given the country's policy to add more agricultural lands, implies additional stress on the country's water resources and all the negative ramifications on agriculture and its economy.

Produce	Unit	Productivity Feddan (Acres)			Realized Percentage %
		2001/02 Base year	2006/07 Targeted	2006/07 Achieved	
Wheat	Ardeb	18.8 (19.5)	20.0 (20.8)	19.25 (19.98)	96.3
Maize	Ardeb	24.75 (25.69)	27.5 (28.5)	25.5 (26.5)	92.7
Rice	Ton	3.9 (4.0)	4.2 (4.4)	4.2 (4.4)	100.0
Beans	Ardeb	8.6 (8.9)	10.5 (10.9)	9.2 (9.5)	87.6
Cotton	Cantar	7.2 (7.5)	8.0 (8.3)	7.6 (7.9)	95.0
Sugar Cane	Ton	50.0 (51.9)	51.5 (53.5)	51.4 (53.3)	99.8

Table 4. "Development in Agricultural Productivity during the 5-year-plan (2002-2007)"
Source*:* Egypt State Information Service: Your Gateway to Egypt, s.v. "Agriculture," http://www.sis.gov.eg/En/Economy/Sectors/Agriculture/050301000000000001.htm (accessed April 6, 2009).

In an early analysis of the effects of climate change on Egyptian agriculture, El-Shaer et al (1997)[lxxxvi] used the GFDL (Geophysical Fluid Dynamics Laboratory), UKMO (United Kingdom Meteorology Office), and GISS (Goddard Institute for Space Studies) GCMs, under unspecified conditions of $2\times CO_2$, in conjunction with CERES crop models to simulate changes in wheat and maize yields and growing season length. Analysis focused on four important agricultural regions in Egypt: the northern Nile Delta, the Mid-Delta, the northern Mediterranean coast, and Upper (southern) Egypt. The models projected a decrease in wheat yield of 10 to 50 percent for all regions except the northern coast, where an increase of approximately 80 percent was predicted.

Wheat grows under natural precipitation in the northern coastal zone, in contrast to the other regions, where crops are irrigated, and the increases in wheat yield simulated by the models for the northern coast were tied to increases in precipitation projected for the region. The models also predicted a decrease in maize yields for all regions, with the largest losses of approximately 60 percent in Upper Egypt. These results for maize yields in Egypt are in contrast to those of Jones and Thornton[lxxxvii] for Morocco, which suggests that, in Egypt, the negative effects of future temperature increases may outweigh the positive effects of future atmospheric CO_2 concentration increases. The model results of El-Shaer et al (1997)[lxxxviii] also showed a decrease in growing season length in all regions for wheat and maize; the largest decreases were approximately 20 to 25 days in the northern Delta and northern coastal regions for wheat and in the Mid-Delta and Upper Egypt regions for maize. The authors found that simulation of adaptation strategies, such as shifting planting dates and changing crop varieties, made no significant impact on projected crop yields or season lengths.

In a follow-up study, Yates and Strzepek (1998)[lxxxix] examined the potential effects of climate change on crop yields in the Nile Basin in 2060 using the GFDL, UKMO, and GISS GCMs. Temperature and precipitation projections from the GCMs were used in conjunction with an unspecified crop model to estimate the changes in yield for wheat, rice, grains, protein feed, other food, non-food, and fruit yields in 2060 relative to 1990. All models indicated a decrease in crop yield, with the largest losses, up to 20 to 50 percent, in yields of wheat and grains. Climate change in the GCMs was represented by $2\times CO_2$ equivalent to 600 to 640 ppm, which is a high projection relative to current estimates.[xc] Therefore, these model results should be interpreted with caution. The authors found that simulated adaptation measures, including increased fertilizer application and development of new crop varieties, substantially mitigated the projected decreases in crop yields expected in the mid-21st century, which is in contrast to the earlier findings of El-Shaer et al[xci] for the same region.

Most recently, Hegazy et al (2008)[xcii] investigated the influence of increased air temperatures associated with future climate change on the spatial and temporal distribution of four crops in Egypt through 2100. Analysis focused on cotton, wheat, rice, and maize because they are some of the most economically important crops currently grown in Egypt. Air temperature patterns in Egypt for 2025, 2050, 2075, and 2100 were simulated using a database of information compiled from multiple GCMs run under the B2 emissions scenario. Subsequently, these temperature projections were used to create seasonal and spatial crop distribution maps in a geographic information system (GIS) program. Crop distribution simulations were based on the optimum air temperatures for maximum growth of cotton, wheat, rice, and maize throughout the agricultural season, which are 23.0°C, 16.8°C, 25.8°C, and 26.0°C, respectively. Crop distributions were projected for three areas of the country: Upper (southern), Middle, and Lower (northern) Egypt. Currently, all four crops are grown in Lower Egypt; wheat, rice, and maize are grown in Middle Egypt; and only rice and maize are grown in Upper Egypt. Results from the model study indicate that higher temperatures in Egypt associated with climate change in the 21st century will likely necessitate a shift in crop sowing dates to earlier in the season, to prevent crop losses due to excessively warm growing conditions. Compared to the reference sowing year of 2005, the model study predicts future sowing dates will shift one to eight weeks earlier, depending on the crop type, region, and year. The exception is rice sowing in Upper Egypt, which is expected to shift one week later in 2025 and remain unchanged in 2050 and 2075. Wheat is the most heat-sensitive of the four analyzed crops, and the models estimate that by 2100, air temperatures will be high enough that growing wheat in Egypt will be impossible. During the 21st century, increases in air temperature are also predicted to cause a decrease in the land area suitable for growing wheat, from approximately 106,000 ha of land in Lower Egypt in 2005 to 6,500 ha in 2075. Cotton, rice, and maize are expected to be more tolerant of potential higher temperatures in Egypt and are not predicted to lose such a dramatic amount of viable growing area, assuming appropriate adaption measures are taken, such as shifting to earlier sowing times.

Using the MAGICC/SCENGEN and GCMs climate change scenarios, Eid et al (2007)[xciii] measured the economic impacts of climate change on farm net revenue in Egypt by 2050. The study was based on the Ricardian approach, which carries the advantage of accounting for a variety of adaptations (e.g., adoption of new crops and farming systems) that farmers apply in the face of a changing economy and environment.[xciv] The study found that if no adaptation measures are taken, temperature increases of 1.5°C (as predicted by the MAGICC/SCENGEN scenario) and 3.6°C (GCM scenario) will considerably reduce the farm net revenue per hectare. Accordingly, the study predicts that by 2050, climate change could reduce agricultural yields of several Egyptian crops—from an 11 percent reduction in rice to 28 percent for soybeans when compared to production under current climate conditions.

However, the same study suggests that reductions of farm net revenue could be less severe if farmers opt to use heavy machinery on farms, and revenue could even increase if farmers use irrigation.[xcv] Still, the study only takes into account changes in net farm revenue due to temperature changes and does not consider the effects of warming on water resources. Hence, predicted increases in farm net revenue due to irrigation could be offset by the impacts of climate change on the country's water resources.

Plans to increase agricultural productivity through intensive irrigation may not only imply further water scarcity, but also soil salination and associated desertification. Salination is a soil threat (inland) arising from a high evaporation rate under increasing temperature and reduced rainfall.[xcvi] Salination also represents a water threat due to over abstraction by a growing population, which can lead to sea water intrusion in coastal areas and the transformation of fresh groundwater into brackish water. The use of fossil groundwater to irrigate agricultural land can lead to salination, and is not a sustainable agricultural practice.[xcvii]

Soil salination already has been observed in several Mediterranean regions, including parts of Spain, Italy, and Greece. This trend, however, is particularly pronounced in countries south of the Mediterranean, such as in large parts of Algeria, Libya, and Egypt and a few regions in Morocco and Tunisia. For example, in Tunisia water quality is often a concern, as more than 30 percent of available water contains more than 3g per liter of salt.[xcviii]

In North Africa, salination is widespread and at risk of increasing. The impact on North African economy, compared to the impact on the region's European neighbors, is greater. Countries such as Morocco and Egypt have a considerably larger portion of their population employed in agriculture (44 percent and 28 percent respectively).[xcix] In addition, the contribution of agriculture to GDP in 2007 is also higher in North Africa—at 16, 14 and 11 percent in Morocco, Egypt and Tunisia, compared to 3 and 2 percent in Spain and Italy, respectively.[c]

Present Climate Change Coping Practices in Agriculture of Egyptian Farmers

A survey conducted by Eid et al (2007)[ci] of 900 Egyptian households from 20 governorates, revealed that Egyptian farmers have noticed a change in temperature and rainfall patterns—either from their own experience and/or with the help from agricultural extension teams. Overall, 85 percent of the households noticed a change in temperature in the form of heat waves during the summer and an increase in winter minimum temperatures. In addition, 65 percent of the households cited shortages in the amount of rainfall each season.

In response to the observed changes in temperature, many farmers adapted by increasing the frequency of irrigation, increasing the quantity, or avoiding irrigating in the afternoon when the temperature is at its highest. Some farmers reported changing their crop sowing dates to evade expected high temperatures, while others started using heat-tolerant varieties. Other reported changes included increased management of pesticide and fertilizer applications, planting trees as fences around the farm, use of intercropping between crop plants of varying heights, and fruit mulching for vegetables.

Regarding decreased rainfall, farmers recognized the use of high-water-efficient varieties and/or early maturing varieties as effective ways to cope with rainfall shortage, while others mentioned underground or drainage water for irrigation and improved drainage as alternative methods for coping with observed changes in rainfall.

Additional anthropogenic disturbances such as deforestation, overgrazing in rangelands, non-sustainable irrigation practices, and extractive farming practices, which produce fertility reductions and depletion of carbon stored in the soil, may be contributing to desertification in North Africa.[cii] According to Zafer Adeel, Director of the United Nations University's (UNU's) Canadian-based International Network on Water, Environment and Health and co-chair of the team that developed a global assessment of desertification as part of the 2005 Millennium Ecosystem Assessment, efforts in the past to forestall desertification have been consistently under-funded, and policies in the region that promote agricultural intensification in dry areas and the settlement of nomadic populations are exacerbating soil salination.[ciii]

According to Arnell (2004),[civ] the IPCC SRES scenarios indicate that by 2050, average annual runoff in North Africa will decrease considerably, effectively accelerating soil degradation in the region. If the trend toward soil salination persists, vegetation in the region will be compromised and desertification, where land is completely lost for agricultural use, is likely to expand. Desertification, would in turn imply increased emissions of carbon dioxide (as vegetation is lost) and other greenhouse gases, reductions in agronomic productivity, contamination of water resources, and reductions in biodiversity.[cv]

Since the beginning of the 20th century, Morocco has experienced droughts with a mean cyclic temporal frequency of 11 years.[cvi] However, the Moroccan Meteorological Office has observed a rise in the frequency, intensity, and duration of drought in the past three decades—an occurrence that is particularly pronounced in the spring.

In 2007, a drought caused a significant decline in Morocco's grain crop production: from 9.3 million tons in 2006 to 2.0 million tons in 2007.[cvii] According to the IPCC Chairman, Rajendra

Pachauri, the rise in the frequency and persistence of droughts due to rising world temperatures will likely increase the dependence on large-scale and costly food imports of countries such as Morocco.

Tunisia is also experiencing persistent droughts. Rain-fed agriculture represents 90 percent of the country's agricultural area, exposing this sector to climate variability.[cviii] Of particular importance to Tunisia's economy are cereals, which are primarily (97 percent) cultivated under rain-fed conditions. In the late 1990s, water reserves did not satisfy the water needs of both Tunisia and Morocco, which resulted in several irrigation-dependent agricultural systems to cease production.

Migration

Experts agree that the poorest countries will be the most affected by climate change.[cix] In particular, climate change poses a unique challenge for Sub-Saharan Africa, which comprises the poorest countries in the world. On one side, much of Sub-Saharan Africa is experiencing *economic* water scarcity, a condition in which a country cannot afford to make use of its water resources.[cx] On the other side, desertification is shifting the desert's limit further south in the Sahelian zone, particularly in Burkina Faso and Mali, as indicated by de Wit and Stankiewicz (2006).[cxi] As the effects of climate change further exacerbate these trends, North Africa undoubtedly will experience greater migration from Sub-Saharan Africa in the next few decades. However, there is little literature that deals with climate as a motivating factor for migration, and what references there are consider environment-migration relations at a very general level.[cxii]

Forced migration is a lingering problem in several countries of Africa, predominantly in Sub-Saharan Africa. Migrants residing in refugee camps or settlements for more than five years (known as protracted refugees) are common.[cxiii] In general, different estimates indicate that in any given year, between 65,000 and 120,000 Sub-Saharan Africans enter into Morocco, Tunisia, Algeria, Libya, or Mauritania, of which 70 to 80 percent are thought to migrate through Libya, and 20 to 30 percent through Algeria and Morocco.[cxiv] Specifically, more than 100,000 Sub-Saharan Africans currently live in Algeria (primarily Sahwari refugees), 1-1.5 million Sub-Saharan immigrants settle in Libya, and between 2.2 and 4 million in Egypt (primarily Sudanese).[cxv] In Tunisia and Morocco, the number of Sub-Saharan communities is smaller, but immigration from Sub-Saharan Africa into these two countries is also growing—on a magnitude of several tens of thousands of immigrants annually.[cxvi]

In addition, North African countries are in a special position with respect to migration in that they are both migration destinations and transit areas for refugees from Sub-Saharan countries and Asia trying to reach Europe (see http://www.migrationinformation.org/pdf/).[cxvii] In the context of North Africa as a transit region, several tens of thousands of Sub-Saharan Africans attempt to cross the Mediterranean every year.[cxviii] A growing number of Egyptians cross the Mediterranean to Italy by way of Libya. In addition, since Libya's pan-African policies connecting East African migration systems with the Euro-Mediterranean migration system, migrant workers and refugees from Sudan, Somalia, Eritrea, and Ethiopia, who used to settle in Cairo, now increasingly migrate to Libya by way of Sudan, Chad, or Egypt. There is also an increasing trend of Chinese, Indian, Pakistani, and Bangladeshi migrants who are flying to Morocco using Saharan routes through Niger and Algeria.

Besides cross-border migration, another issue exists in the increased urbanization of North African countries. There are two aspects. First, North African countries experience vast internal migration. The most common scenario involves migration from rural areas to the city. With an expected population increase of 50 million in North Africa (including, in this study, the five countries covered here plus Sudan) between 2025 and 2050, internal migration from rural areas to cities can be expected to increase in the first half of the 21st century.[cxix] Predicted sea-level rise in the coasts and reduced precipitation in many rural agricultural parts of North Africa will likely cause an exodus from rural areas to cities. Second, migrants who consider North Africa as their final destination or those who fail to enter Europe sometimes remain in North Africa. Presently, North African cities, such as Nouakchott, Rabat, Oran, Algiers, Tunis, Tripoli, Benghazi, and Cairo, are homes to large communities of Sub-Saharan migrants.[cxx]

There are two types of migration patterns identified by the IPCC assessment that may emerge as a result of climate change: (1) "repetitive migrants," representing ongoing adaptation to climate change, and (2) "short-term shock migrants," who respond to a particular climate event.[cxxi] Migration due to climate change may have the following implications:

- ***Greater Demands on Infrastructure Along the Mediterranean Coasts***.[cxxii]
- ***Violence Against Migrants***. Social unrest, including attacks against migrants stemming from ethnic and racial clashes as well as human trafficking, is already a reality for some North African countries.[cxxiii]
- ***Radical Fundamentalist Religious Movements***. Presently, for example, al-Qa'ida has bases in North Africa, including Algeria, and kidnappings of foreigners have occurred as recent as 2009.[cxxiv] The number of terrorist events perpetrated by radical fundamentalist groups may rise as a result of socio-economic factors related to climate change.[cxxv]

One of the few studies examining climate as a driving force for migration, Meze-Hausken (2000),[cxxvi] investigated the empirical consequences of climate perturbations on human adaptation and migration in dryland Africa. The study's objective was to investigate whether experience from past drought behavior during the previous three decades served as an analogy for impacts under future climate change. Vulnerability to climate events was assessed by analyzing migrants' behavior and living conditions before and after the onset of past droughts; specifically, 104 subsistence farmers in mixed agricultural systems in Tigray, Ethiopia were visited. The farmers were former drought migrants living in arid regions with high interannual rainfall variability. The results showed that although differentiation in farming yield is little during times of drought (i.e., at first, all farmers cultivate in a similar ecological setting, with little irrigation and similar technology), a combination of different socio-economic and environmental indicators such as animal holdings, non-agricultural income, and remittances determined how soon problems of shortage began after a drought. It was found, however, that after a certain number of months among critical food- and water-deficiency, the primary difference in vulnerability between households diminished. After a threshold is surpassed, farmers have no options to cope with the crisis, leaving farmers equally affected despite their socio-economic point of departure; many are forced to migrate. Failures of the response mechanisms of households and the relief mechanism of the state were the main drivers behind migration.

Natural Disasters Along Coastal Zones
According to Nicholls et al (1999) and Nicholls and Tol (2006), based on HadCM2 and HadCM3 models, the southern Mediterranean (Turkey-Algeria) is one of the regions with the largest risk of increased flooding in absolute terms for the 21st century.[cxxvii] The other regions of risk are West Africa (includes Morocco), East Africa, South Asia and Southeast Asia. Coastal cities will be especially vulnerable due to the concentration of poor populations in potentially hazardous areas, such as Alexandria—the second largest city in Egypt.[cxxviii]

Specifically, studies on the vulnerability of several sectors of Alexandria suggest that with a 30cm sea level rise by 2025, Alexandria will incur land and property losses of tens of billions of dollars, more than half a million inhabitants may be displaced, and 70,000 jobs will be lost.[cxxix]

Similarly, examining global model predictions of sea level rise by 2050 for 84 developing countries, a study by Dasgupta et al (2007)[cxxx] found that although sea level rise impacts on the land areas of the Middle East and North Africa (MENA) region are lower than the average of developing countries (0.25 percent vs. 0.31 percent with a 1m sea level rise), impacts on MENA are comparatively higher when measured in social, economic and ecological terms. Low-lying coastal areas in Tunisia, Libya, and particularly Egypt, were identified as having the greatest risk in North Africa.

According to Dasgupta et al, given a 1m sea level rise, an estimated 10 percent of Egypt's population would be impacted, with most of the impact being felt in the Nile Delta.[cxxxi] Thus, the impact of sea level rise will have subsequent effects on Egypt's agriculture and GDP (Figures 15).

To a lesser extent, approximately 5, 3, and 2 percent of the population of Tunisia, Libya, and Morocco will be impacted by a 1m sea level rise, respectively.[cxxxii] Based on Dasgupta et al's 2007 study, an assessment led by the World Bank (2007)[cxxxiii] estimated that for an increase in temperature of 1-3ºC, between 6 and 25 million people will be exposed to coastal flooding in North Africa's urban areas.

However, given the lack of tide gauge observational data in the region, the wide range of future estimates in sea level, and the paucity of regional climate model projections for the Mediterranean Sea, a definitive estimate of sea level rise along the coastline of North Africa in the next 20 years is not possible.

Tourism
Tourism development is a major priority for North African governments, and the sector is expected to continue to increase in the next decade for most countries of the region (Table 5).[cxxxiv] In Tunisia and Morocco, coastal tourism is an important source of income, as is reef ecotourism in Egypt.[cxxxv] Most of the development, however, has been carried out without much regard for environmental protection, sewage treatment, water provision, and energy inputs.[cxxxvi] Particularly in light of the region's water scarcity, tourism development is of concern.

In Tunisia, for example, where "mass-beach" tourism is advertised, tourist zones per person consume approximately 8-10 percent times per day the quantity of water of the rest of the country.[cxxxvii] In Morocco, tourism development has resulted in large stretches of its coastlines turning into concrete.[cxxxviii] Declining water availability, sea level rise, and increasing temperatures could reduce not only the attractiveness, but also the livability of these ecosystems.

	2009 (%)	2019 (%)
Egypt	15.0	14.6
Libya	8.6	10.1
Tunisia	16.7	16.3
Algeria	4.3	5.0
Morocco	16.2	16.7

Table 5. Outlook of the contribution of the tourism sector to Gross Domestic Product in North Africa. Source: World Travel and Tourism Council, s.v.v. "Egypt," "Libya," "Tunisia," "Algeria," and "Morocco" http://www.wttc.org/eng/Tourism_Research/Tourism_Economic_Research/Country_Reports/ (accessed April 26, 2009).

Energy

Because of their high natural gas and oil revenues, Libya and Algeria's economies (and to a lesser extent that of Egypt's), are likely to be less impacted by climate change in the short term (see Adaptive Capacity section for Libya). Morocco's dependence on agricultural production has slowed down its economic growth—a trend which may be exacerbated by climate change by the middle of the 21st century, unless significant policy changes are made.[cxxxix] For example, in 2005, Morocco's government spent more than twice the amount it had planned on food subsidies. By contrast, Tunisia has a more diversified economy. Hence, despite higher energy costs, Tunisia's economy has grown in recent years.

Algeria, Egypt, Libya, and Nigeria are the largest natural gas producers in Africa and the largest African consumers of natural gas.[cxl] The latter can be explained by the limited infrastructure there is on the continent for intraregional trade of natural gas. According to the Energy Information Administration (EIA)'s *International Energy Outlook 2008*, from 2005 to 2030, natural gas consumption will grow by 3.5 percent in Africa.

Libya has the largest proven reserves in Africa (41.5 billion barrels in 2007), followed by Nigeria (36.2) and Algeria (12.3)—all three are members of the Organization of Petroleum Exporting Countries (OPEC).[cxli] Libya's economic growth is contingent on the hydrocarbon industry, both because of the revenues from exports, and because the country relies on oil and natural gas to satisfy national demand. The World Bank estimates that in 2004 Libya's hydrocarbon exports contributed over 95 percent of total merchandise exports and revenues from the oil and natural gas sectors.[cxlii] In addition, revenues from these sectors equated to more than half of the country's GDP.

Similarly, in Algeria, oil and natural gas exports, which represented 98 percent of all exports in 2006, are the main driving force behind the country's significant economic growth in recent years.[cxliii] In 2006, Algeria's real GDP growth rate was 4 percent. Producing 2.8 trillion cubic feet of natural gas in 2004, Algeria ranks as the eighth largest natural gas producer in the world and the second largest producer among OPEC member countries after Iran. Like Libya, Algeria depends on fossil fuels to satisfy domestic demand. In 2004, natural gas comprised 62 percent of total energy consumption. The rest was exported primarily to Europe, although some was exported to the United States.

In the 1990s Brauch[cxliv] predicted that Libya and Algeria's fossil reserves would be depleted considerably in the 21st century; in particular, their oil reserves were estimated to be exhausted by 2014 and 2037, respectively. According to *Wood Mackenzie* reports,[cxlv] however, Libya remains highly unexplored and only 25 percent of the country is covered by exploration agreements with oil companies. In addition, since the 1990s, Libya's natural gas production has augmented considerably over the past few years (39 billion cubic feet in 2005). The country plans to free up more oil for export, particularly to Europe.[cxlvi] Although Algeria has produced oil since 1965, it, too, is considered to be underexplored.[cxlvii]

However, Algeria and Libya's economies are highly dependent on Europe. For example, in 2006, the vast majority of Libyan oil exports were sold to European countries, such as Italy (495,000 barrels/day), Germany (253,000), Spain (113,000), and France (87,000).[cxlviii] The United States, too, has increased its oil imports from Libya since lifting sanctions against Libya in 2004. In 2006, the United States imported an average of 85,500 barrels/day of total Libyan exports, compared to 56,000 barrels/day in 2005.

Research by Hans Günter Brauch indicates industrialized countries need to reduce their carbon dioxide emissions by 80 percent by 2050 in order to limit climate change.[cxlix] This might imply a shift in Europe's energy demand and a shift from fossil fuels to non-fossil energy sources. Accordingly, it will become critical that North African countries develop their comparative advantage in high solar energy or other industries for possible export in the future. As of yet, however, there has not been any indication that Europe will considerably reduce its natural gas and oil imports from North Africa.

In terms of emissions from North Africa, the 2007 Observatoir Méditerranean de l'Energie (OME) trend scenario, based on estimates provided by Mediterranean countries and their major energy companies, reveal that primary energy demand in the Mediterranean Basin will be 1.5 times higher in 2025 than in 2006.[cl] Emissions from energy use in southern and eastern Mediterranean countries in 2004 were estimated at 663 million metric tons of CO_2—an increase of 58 percent from 1990. This growth rate surpasses the global rate by 20 points. Throughout the Mediterranean, emissions from electricity and heating emit more CO_2 emissions from energy use than any other sector (e.g., transportation, construction, and other fuel combustion), especially in the southern and eastern Mediterranean countries. The 21 Mediterranean countries studied by OME only contributed 7.4 percent of total global emissions of CO_2 related to energy use between 1850 and 2005. Yet OME predicts that if investment and development decisions made on energy over the past 30 years remain the same, and in light of the demographic and economic trends of southern and eastern Mediterranean countries, an appreciable high growth in emissions could be expected south of the Mediterranean.

Adaptive Capacity

The impacts of climate change will be felt differentially, depending upon how well a society can cope with or adapt to climate change, that is, its adaptive capacity. Adaptive capacity is defined by the IPCC as "The ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences."[cli] Although the specific determinants (or "drivers") of adaptive capacity are debated among researchers, there is good agreement that economic, human, and environmental resources are essential elements. Some components of this adaptive capacity are near term, such as the ability to deliver aid swiftly to those affected by, e.g., flooding or droughts. Other components include a high enough level of education to enable workers to change the means of earning their livelihoods, sufficient unmanaged land that can be brought into food production, and institutions that provide knowledge and assistance in times of change. For instance, Yohe and Tol[clii] identified eight qualitative "determinants of adaptive capacity," many of which are societal in character, although the scientists draw on an economic vocabulary and framing:

1. The range of available technological options for adaptation.
2. The availability of resources and their distribution across the population.
3. The structure of critical institutions, the derivative allocation of decisionmaking authority, and the decision criteria that would be employed.
4. The stock of human capital, including education and personal security.
5. The stock of social capital, including the definition of property rights.
6. The system's access to risk-spreading processes.
7. The ability of decisionmakers to manage information, the processes by which these decisionmakers determine which information is credible, and the credibility of the decisionmakers themselves.
8. The public's perceived attribution of the source of stress and the significance of exposure to its local manifestations.

North African Adaptive Capacity in a Global Context

Researchers have only recently taken on the challenge of assessing adaptive capacity in a comparative, quantitative framework. A comprehensive global comparative study[cliii] of resilience to climate change (including adaptive capacity) was conducted using the Vulnerability-Resilience Indicators Model (VRIM—see box below).

Adaptive capacity, as assessed in this study, consists of seven variables (in three sectors), chosen to represent societal characteristics important to a country's ability to cope with and adapt to climate change:

Human and Civic Resources

- ***Dependency Ratio:*** proxy for social and economic resources available for adaptation after meeting basic needs.
- ***Literacy:*** proxy for human capital generally, especially the ability to adapt by changing employment.

Economic Capacity

- ***GDP (market) Per Capita:*** proxy for economic well-being in general, especially access to markets, technology, and other resources useful for adaptation.
- ***Income Equity:*** proxy for the potential of all people in a country or state to participate in the economic benefits available.

Environmental Capacity

- ***Percent of Land that is Unmanaged:*** proxy for potential for economic use or increased crop productivity and for ecosystem health (e.g., ability of plants and animals to migrate under climate change).
- ***Sulfur Dioxide Per Unit Land Area:*** proxy for air quality and, through sulfur deposition, other stresses on ecosystems.
- ***Population Density:*** proxy for population pressures on ecosystems (e.g., adequate food production for a given population).

Methodological Description of the Vulnerability-Resilience Indicator Model (VRIM)

The VRIM is a hierarchical model with four levels. The resilience index (level 1) is derived from two indicators (level 2): sensitivity (how systems could be negatively affected by climate change) and adaptive capacity (the capability of a society to maintain, minimize loss of, or maximize gains in welfare). Sensitivity and adaptive capacity, in turn, are composed of sectors (level 3). For adaptive capacity these sectors are human resources, economic capacity, and environmental capacity. For sensitivity, the sectors are settlement/infrastructure, food security, ecosystems, human health, and water resources. Each of these sectors is made up of one to three proxies (level 4). The proxies under adaptive capacity are as follows: human resource proxies are the dependency ratio and literacy rate; economic capacity proxies are GDP (market) per capita and income equity; and environmental capacity proxies are population density, sulfur dioxide divided by state area, and percent of unmanaged land. Proxies in the sensitivity sectors are water availability, fertilizer use per agricultural land area, percent of managed land, life expectancy, birth rate, protein demand, cereal production per agricultural land area, sanitation access, access to safe drinking water, and population at risk from sea level rise.

Each of the hierarchical level values is composed of the geometric means of lower level values. Proxy values are indexed by determining their location within the range of proxy values over all countries or states. The final calculation of resilience is the geometric mean of the adaptive capacity and sensitivity.

Adaptive capacity for a sample of 10 countries from the 160-country study is shown in Figure 7 (base year of 2000). There is a wide range of adaptive capacity represented by these countries. Libya ranks high and Morocco ranks low, both in the sample and overall:

- Russia ranks 32nd and Libya 34th (in the highest quartile).
- Indonesia ranks 45th, Belize 48th, Mexico 59th, and China 75th (in the second quartile).
- The Philippines ranks 91st and India 119th (in the third quartile).
- Morocco ranks 136th and Haiti 156th (in the lowest quartile).

Any country-level analysis must take into account the comparative ranking of the country.

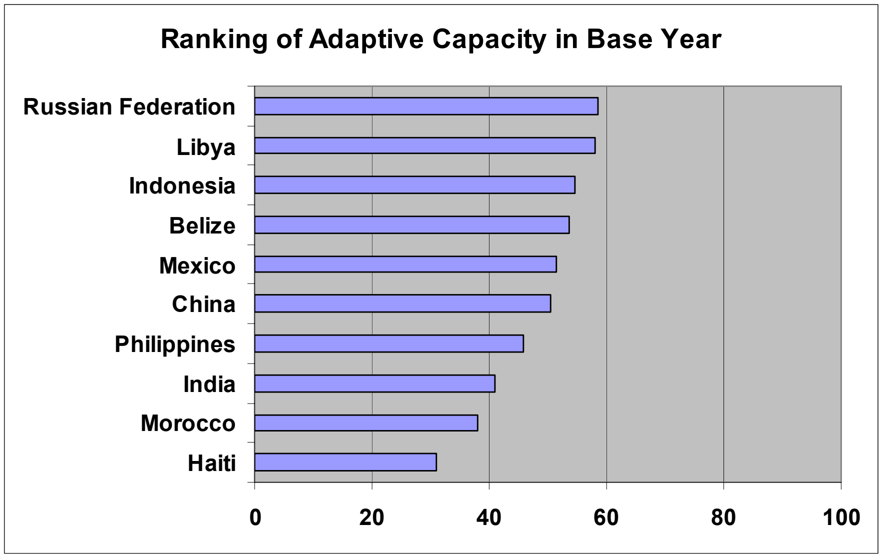


Figure 7. Sample of 10 countries' rankings of adaptive capacity (2000).

Figure 8 shows the contribution of each variable to the overall ranking (slight differences occurring because of the methodology (see box)). In current adaptive capacity, Libya ranks second and Morocco second-to-last among the 10 countries shown in Figure 7. Although Libya has a comparatively unfavorable dependency ratio, it shows comparatively high adaptive capacity in all the environment-related variables. Morocco, on the other hand, ranks poorly on almost all adaptive capacity variables, with the exceptions of emissions and population density.

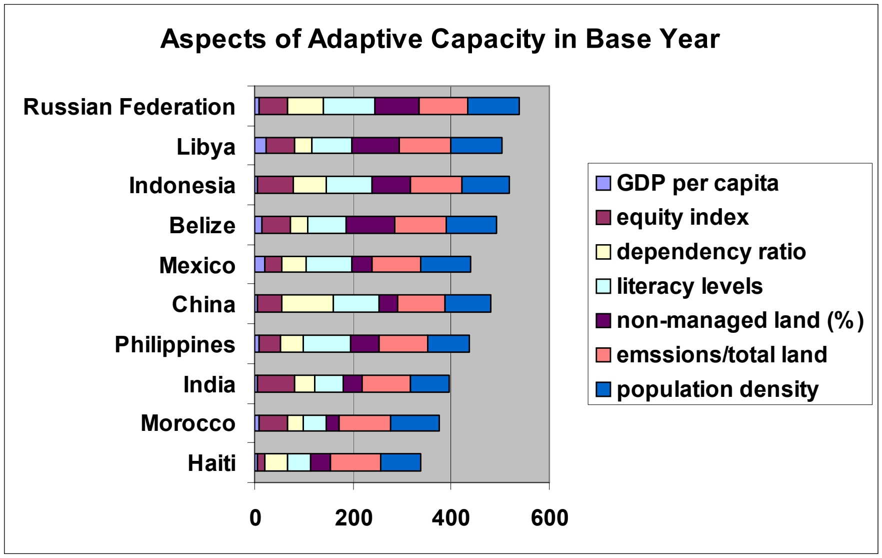


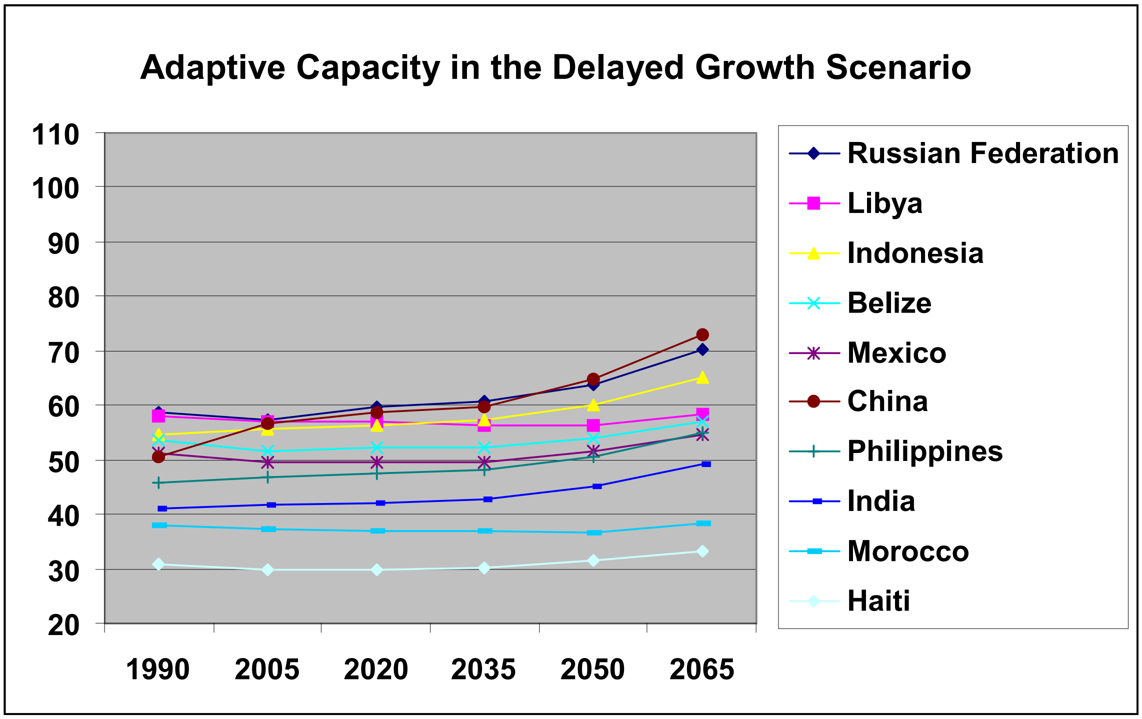
Figure 8. Variables' contributions to adaptive capacity rankings.

Figure 9 shows projected adaptive capacity growth over time for the 10-country sample. Projections are made for two scenarios; rates of growth are based on the IPCC's A1 scenario in its *Special Report on Emissions Scenarios*.[cliv] VRIM simulates two different hypothetical development tracks out to the year 2065 (well beyond the timescale of the present study) with intermediate results at 15-year time steps. These alternative development tracks are not intended to be predictive; they are scenarios.

Both scenarios feature moderate population growth and a tendency toward convergence in affluence (with market-based solutions, rapid technological progress, and improving human welfare). The scenarios used in this study differ in the rate of economic growth, one modeling high-and-fast economic growth, the other delayed growth.

Over time, a low-growth scenario widens the gap among the 10 countries—and the high-growth scenario widens the gap even more. Libya's adaptive capacity over time is almost static in the delayed-growth scenario and increases only slowly in the high-growth scenario. In both scenarios, China and Indonesia outstrip Libya by 2035. Morocco holds its second-to-last place among the ten countries in the sample, but the gap between India and Morocco grows as India is projected to build adaptive capacity at a faster rate.

Figure 10 shows the three categories of adaptive capacity and their contributions to individual countries rankings in North Africa. All countries have relatively low economic capacity and relatively higher environmental capacity. Libya ranks highest in all three aspects among the five countries.



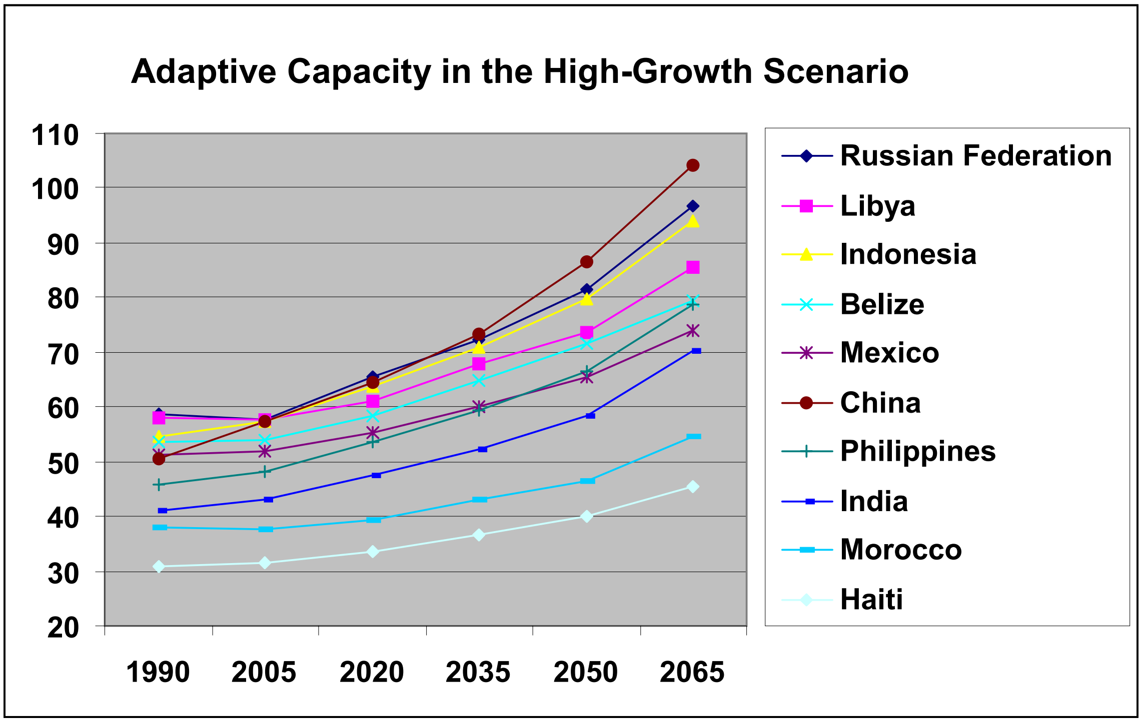


Figure 9. Projections of adaptive capacity for 10 countries.

By 2050 (Figure 11) large differences appear between scenarios, although the relative rankings of the five countries remain the same. Libya makes large gains and the other countries modest gains in adaptive capacity under the high-growth scenario, but all five countries actually lose adaptive capacity by 2050 under the delayed growth scenario.

Thus, assumptions about how conditions unfold in the world and in the region determine rates of (dis)improvement in North Africa's adaptive capacity.

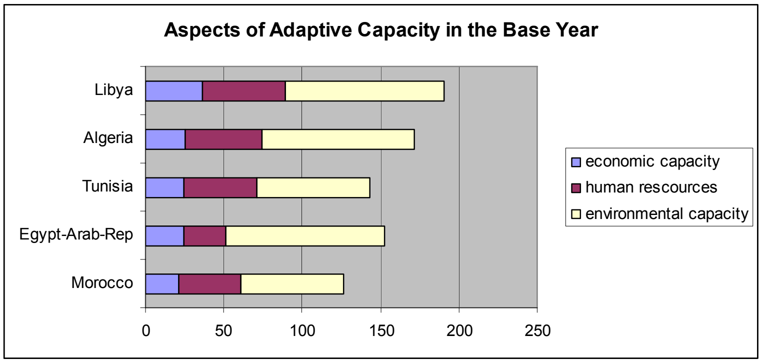


Figure 10. Base year (2000) adaptive capacity of North African countries.

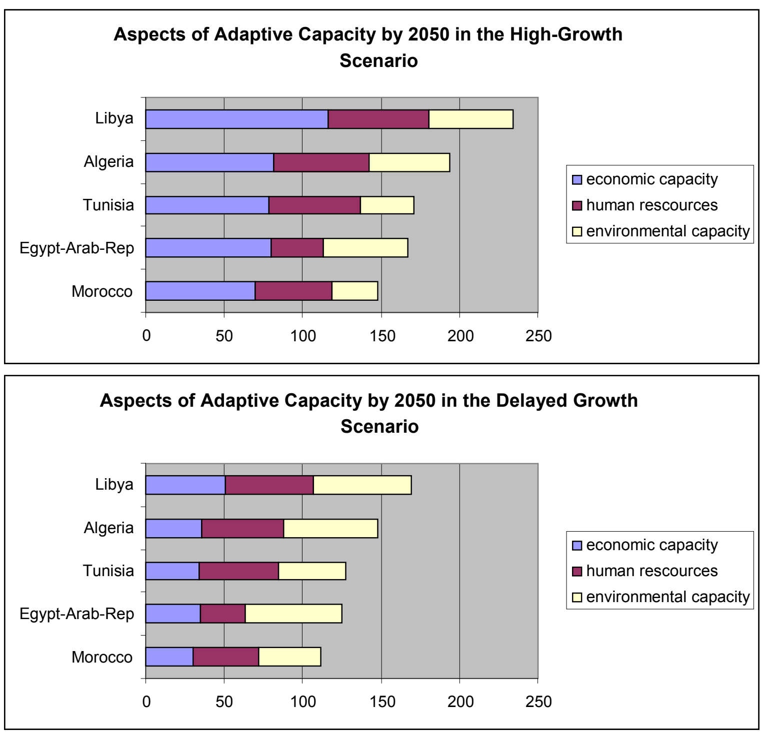


Figure 11. Snapshots of North African adaptive capacity in 2050 under two scenarios

Conclusions: High-Risk Impacts

The sectors in North Africa that are most vulnerable to predicted climate change are the water sector, the agricultural sector, and the coastal zone. Other less studied factors, but clearly existing ones, such as migration, may exacerbate conditions in North Africa in the 21st century.

- ***Water Resource Stress.*** Water scarcity, even in the absence of climate change, will be one of the most critical problems facing North African countries in the next few decades. It is estimated that Morocco and Algeria's water resources will be reduced by 10-15 percent by 2020, Tunisia's water resources will decline by 28 percent by 2030, and 74.8 percent of Egyptians will have less than adequate fresh water by the same year. Conflicts over water, as have been observed in the past, are likely to surface between African countries. In addition, low-efficiency surface irrigation practices may produce higher water losses, decreases in land productivity, and increased salination.
- ***Agriculture.*** Reduced annual rainfall and increased persistence and frequency of droughts related to climate change may have negative consequences on the region. Morocco and Tunisia's agricultural sector has already been largely impacted by increasingly frequent droughts. Egypt, where agriculture is impossible without irrigation, is at risk of being largely impacted. However, model results are inconsistent regarding future changes in crop yields and agricultural growing seasons in North Africa. One modeling study suggests that future increases in atmospheric CO_2 concentrations will increase maize yields in Morocco. Nevertheless, as the price of water becomes apparent, North African countries will likely rely more on food imports.
- ***Migration.*** Increased migration from Sub-Saharan Africa and increased internal migration to urban areas will place further pressures on water resources, food availability, infrastructure and the ecosystem.
- ***Natural Disasters.*** North Africa is one of the regions with the largest predicted impacts from flooding given its close proximity to the Mediterranean Sea and the highly concentrated and poor populations along the coasts.

Annex A:

Accuracy of Regional Models

Below is an excerpt from IPCC (2007), Chapter 11, Regional models; see IPCC 2007 for references. [8]

11.2.2 Skill of Models in Simulating Present and Past Climates

There are biases in the simulations of African climate that are systematic across the multi-model dataset (MMD) models, with 90% of models overestimating precipitation in southern Africa, by more than 20% on average (and in some cases by as much as 80%) over a wide area often extending into equatorial Africa. The temperature biases over land are not considered large enough to directly affect the credibility of the model projections.

The Inter-Tropical Convergence Zone (ITCZ) in the Atlantic is displaced equatorward in nearly all of these AOGCM [Atmosphere-Ocean General Circulation Model] simulations. Ocean temperatures are too warm by an average of 1°C to 2°C in the Gulf of Guinea and typically by 3°C off the southwest coast in the region of intense upwelling, which is clearly too weak in many models. In several of the models there is no West African monsoon as the summer rains fail to move from the Gulf onto land, but most of the models do have a monsoonal climate albeit with some distortion. Moderately realistic interannual variability of sea surface temperatures (SSTs) in the Gulf of Guinea and the associated dipolar rainfall variations in the Sahel and the Guinean Coast are, by the criteria of Cook and Vizy (2006), only present in 4 of the 18 models examined. Tennant (2003) describes biases in several AGCMs [Atmospheric General Circulation Models], such as the equatorward displacement of the mid-latitude jet in austral summer, a deficiency that persists in the most recent simulations.

Despite these deficiencies, AGCMs can simulate the basic pattern of rainfall trends in the second half of the 20th century if given the observed SST evolution as boundary conditions, as described in the multi-model analysis of Hoerling et al (2006) and the growing literature on the interannual variability and trends in individual models (e.g., Rowell et al, 1995; Bader and Latif, 2003; Giannini et al, 2003; Haarsma et al, 2005; Kamga et al, 2005; Lu and Delworth, 2005). However, there is less confidence in the ability of AOGCMs to generate interannual variability in the SSTs of the type known to affect African rainfall, as evidenced by the fact that very few AOGCMs produce droughts comparable in magnitude to the Sahel drought of the 1970s and 1980s (Hoerling et al, 2006). There are exceptions, but what distinguishes these from the bulk of the models is not understood.

The very wet Sahara 6 to 8 ka is thought to have been a response to the increased summer insolation due to changes in the Earth's orbital configuration. Modelling studies of this response provide background information on the quality of a model's African monsoon, but the processes controlling the response to changing seasonal insolation may be different from those controlling the response to increasing greenhouse gases. The fact that GCMs have difficulty in simulating the full magnitude of the mid-Holocene wet period, especially in the absence of vegetation feedbacks, may indicate a lack of sensitivity to other kinds of forcing (Jolly et al, 1996; Kutzbach et al, 1996).

[8] Some references in this section have been changed to be internally consistent with this document and other references have been removed to avoid confusion.

Regional climate modelling has mostly focused on southern Africa, where the models generally improve on the climate simulated by global models but also share some of the biases in the global models. For example, Engelbrecht et al (2002) and Arnell et al (2003) both simulate excessive rainfall in parts of southern Africa, reminiscent of the bias in the MMD. Hewitson et al (2004) and Tadross et al (2006) note strong sensitivity to the choice of convective parametrization, and to changes in soil moisture and vegetative cover (New et al, 2003; Tadross et al, 2005a), reinforcing the view (Rowell et al, 1995) that land surface feedbacks enhance regional climate sensitivity over Africa's semi-arid regions. Over West Africa, the number of Regional Climate Model (RCM) investigations is even more limited (Jenkins et al, 2002; Vizy and Cook, 2002). The quality of the 25-year simulation undertaken by Paeth et al (2005) is encouraging, emphasizing the role of regional SSTs and changes in the land surface in forcing West African rainfall anomalies. Several recent AGCM time-slice simulations focusing on tropical Africa show good simulation of the rainy season (Coppola and Giorgi, 2005; Caminade et al, 2006; Oouchi et al, 2006).

Hewitson and Crane (2005) developed empirical downscaling for point-scale precipitation at sites spanning the continent, as well as a 0.1° resolution grid over South Africa. The downscaled precipitation forced by reanalysis data provides a close match to the historical climate record, including regions such as the eastern escarpment of the sub-continent that have proven difficult for RCMs.

Annex B:

Knowledge Deficiencies that Preclude a Full Evaluation of Climate Change Impacts on North Africa and North Africa's Adaptive Strategies

To increase the likelihood that this evaluation represents a reasonable assessment of North Africa's projected climate changes and their impacts, as well as the region's adaptive capacity, the following gaps would need to be addressed:

- In physical science research, regional analyses will continue to be limited by the inability to model regional climates satisfactorily, including complexities arising from the interaction of global, regional, and local processes. Uncertainties in changing precipitation, dust storms, and desertification leave important gaps in knowledge needed for climate projections. One gap of particular interest is the lack of medium-term (20 to 30 year) projections that could be relied upon for planning purposes. Similarly, scientific projections of water supply and agricultural productivity are limited by inadequate understanding of various climate and physical factors affecting both areas. Similar types of issues exist for the biological and ecological systems that are affected. These gaps are particularly acute for North Africa, where regional models are poor and relatively few impacts studies have been conducted.
- In social science research, scientists and analysts have only a partial understanding of the important factors in vulnerability, resilience, and adaptive capacity—much less their interactions and evolution. Again, research agendas on vulnerability, adaptation, and decisionmaking abound (e.g., (http://books.nap. edu/catalog.php?record_id=12545).
- Important factors are unaccounted for in research; scientists know what some of them are, but there are likely factors whose influence will be surprising. An example from earlier research on the carbon cycle illustrates this situation. The first carbon cycle models did not include carbon exchanges involving the terrestrial domain. Modelers assumed that the exchange was about equal and the only factor modeled was deforestation. This assumption, of course, made the models inadequate for their purposes. In another example, ecosystems research models are only beginning to account for changes in pests, e.g., the pine bark beetle.
- Social models or parts of models in climate research have been developed to simulate consumption (with the assumption of well-functioning markets and rational actor behavior) and mitigation/adaptation policies (but without attention to the social feasibility of enacting or implementing such policies). As anthropogenic climate change is the result of human decisions, the lack of knowledge about motivation, intent, and behavior is a serious shortcoming.

Overall, research about climate change impacts on North Africa has been undertaken piecemeal: discipline by discipline, sector by sector, with political implications separately considered from physical effects. This knowledge gap can be remedied by integrated research into energy-economic-environmental-political conditions and possibilities.

[i] According to the *Encyclopedia of Nations*, the high unemployment rate, also estimated for 2000, is linked with the country's years of sanctions, which have affected Libya's oil and gas exports, in addition to Mu'ammar al-Qadhafi's efforts at preventing the emergence of the growing private sector. Source: *Encyclopedia of the Nations*, s.v. "Libya Working Conditions," http://www.nationsencyclopedia.com/economies/Africa/Libya-WORKING-CONDITIONS.html (accessed May 28, 2009).

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NATIONAL INTELLIGENCE COUNCIL

SPECIAL REPORT

NORTH AFRICA: THE IMPACT OF CLIMATE CHANGE TO 2030 (SELECTED COUNTRIES)

A COMMISSIONED RESEARCH REPORT

SPECIAL REPORT

NIC 2009-06D August 2009

Southeast Asia and Pacific Islands: The Impact of Climate Change to 2030

A Commissioned Research Report

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Southeast Asia and Pacific Islands: The Impact of Climate Change to 2030

A Commissioned Research Report

Jointly prepared by:
Joint Global Change Research Institute
Battelle Memorial Institute, Pacific Northwest Division
Scitor Corporation

NIC 2009-006D
August 2009

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Scope Note

Following the publication in 2008 of the National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030, the National Intelligence Council (NIC) embarked on a research effort to explore in greater detail the national security implications of climate change in six countries/regions of the world: India, China, Russia, North Africa, Mexico and the Caribbean, and Southeast Asia and the Pacific Island states. For each country/region, we are adopting a three-phase approach.

- In the first phase, contracted research—such as this publication—explores the latest scientific findings on the impact of climate change in the specific region/country.
- In the second phase, experts from outside the Intelligence Community (IC) will meet at a workshop or conference to determine if anticipated changes from the effects of climate change will force inter- and intra-state migrations, cause economic hardship, or result in increased social tensions or state instability within the country/region.
- In the final phase, the NIC Long-Range Analysis Unit (LRAU) will lead an IC effort to identify and summarize for the policy community the anticipated impact on U.S. national security.

To support research by the National Intelligence Council (NIC) on the National Security Impacts of Global Climate Change, this assessment of the impact of Climate Change on Southeast Asia and Pacific Islands through 2030 is being delivered under the Global Climate Change Research Program contract with the Central Intelligence Agency's Office of the Chief Scientist.

This research identifies and summarizes the latest peer-reviewed research related to the effects of climate change on Southeast Asia and Pacific Islands, drawing on both the literature summarized in the latest Intergovernmental Panel on Climate Change (IPCC) assessment reports and on other peer-reviewed research literature. It includes such impacts as sea-level rise, water supply and demand, agricultural shifts, ecological disruptions and species extinctions, infrastructure at risk from extreme weather events (severity and frequency), and disease patterns. The research addresses the extent to which Southeast Asia and Pacific Islands are vulnerable to climate change impacts. The timeframe of this analysis extends through 2030, although various studies referenced in this report have diverse timeframes and extend through the 21st century.

The research also identifies (Annex B) deficiencies in climate change data that would enhance the IC understanding of potential impacts on Southeast Asia and Pacific Islands and other countries/regions of interest.

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Executive Summary

Southeast Asia and Pacific Islands are at risk from the impact of climate change in the next 20 years due to the region's large and growing population, long coastlines, abundant low-lying areas, reliance on the agricultural sector, and dependence upon natural resources. This report focuses on the nations of Thailand, Cambodia, Laos, Vietnam, the Philippines, Malaysia, Singapore, and Indonesia. These countries have a diverse range of governments, populations, religions, economic growth, development, and allocation of natural resources, but they all have a similar tropical maritime climate and face similar threats from climate change.

The effects of climate change have already begun in the Southeast Asia and Pacific Islands region:

- Average annual surface temperatures in the region increased by 0.5-1.1 °C during the period 1901-2005.[i]
- Precipitation patterns are changing regionally, with increases in some locations and decreases in others. For example, annual rainfall decreased across most of the southern regions of Indonesia (Java, Lampung, South Sumatra, South Sulawesi, and Nusa Tenggara) and increased across most of the northern regions of the country (Kalimantan and North Sulawesi) during the period 1931-1990.[ii]
- Sea level is rising, and the magnitude varies regionally. During the period 1993-2001, the largest increases in sea level (15-25 mm per year) in the region occurred near Indonesia and the Philippines, while only moderate changes (0-10 mm per year) occurred along the coasts of Thailand, Cambodia, and Vietnam.[iii]

Global circulation model projections indicate that climate change will continue to occur in the region over the course of the 21st century:

- Climate model simulations clearly indicate that average annual temperatures are likely to increase across the region by approximately 1°C through 2030, and they will keep increasing through the remainder of the 21st century.
- The magnitude, location, and trends of future precipitation changes are much less certain due to the inherent difficulty of modeling such changes. Furthermore, future precipitation changes due solely to climate change are difficult to resolve because they are superimposed on significant interannual variations that occur naturally in the region. Climate model simulations suggest that net precipitation rates will increase across the region in the next 20 years, but there will likely be local decreases that will vary geographically and temporally.
- It is difficult to project future changes in monsoon patterns and the effects of El Niño-Southern Oscillation (ENSO) on precipitation in the region, due to the difficulty of modeling these phenomena. Climate model results suggest that the onset of the monsoon in Thailand, Laos, Cambodia, and Vietnam may be delayed by 10-15 days for the period 2030-2070, but the duration of the monsoon will not change.[iv] There is no evidence from climate model simulations that ENSO events will become more frequent due to climate change, but it is possible that their intensity may increase.[v]

- Sea level will continue to rise, although rates will vary across the region. By the end of the 21st century, sea level is projected to have risen by approximately 30-40 cm.[vi]

There is overwhelming evidence that climate change will impact a variety of sectors in Southeast Asia and Pacific Islands through 2030. All of the major effects of climate change on the region are interrelated, so it is impossible to assess one impact independently of the others. The most high-risk impacts of climate change in the region are related to fresh water and ocean water resources, and include the following:

Sea Level Rise. Throughout the region, rising sea level causes a number of devastating effects in the region, including saltwater intrusion into estuaries and aquifers, coastal erosion, displacement of wetlands and lowlands, degradation of coastal agricultural areas, and increased susceptibility to coastal storms. These effects are interrelated with impacts on agriculture, natural disasters, river deltas, water resources, coastal ecosystems, human livelihoods and infrastructure, and national security. Sea level rise has overarching socioeconomic impacts as well, due to loss in income associated with degradation of agricultural areas and loss of housing associated with coastal inundation, for example.

Water Resources. Future changes in regional water resources are closely tied to changes in precipitation. Individual areas under severe water stress in the region are projected to increase dramatically in the next few decades, although model results suggest that the region as a whole will not be at risk for water shortages. Fresh water resources on all island nations in the region are especially vulnerable to any variability in precipitation because many rely on rainwater collection for their supply of fresh water. The management of water issues is one of the most challenging climate-related issues in the region, as it is central to health and sustainable development. The impacts of climate change on water resources are interrelated with impacts on agriculture, river deltas, forests, coastal ecosystems, diseases and human health, and national security.

Agriculture. Assessment of the specific impacts of climate change on agriculture is challenging because it is difficult to reliably simulate the complicated effects of future variations in temperatures, precipitation, and atmospheric CO_2 concentrations on crop growth. Temperature increases associated with climate change could result in a northward expansion of growing areas and a lengthening of the growing season. Rising atmospheric CO_2 levels are expected to stimulate plant photosynthesis, which would result in higher crop yields. Studies show that the beneficial effects of CO_2 on plants may be offset by average temperature increases of more than 2°C, however. Overall, it is likely that future crop yields will vary by region and by crop, with yield increases in some locations but decreases in others. Management of the agricultural sector by regional nations is critical to their economic growth and national security. The impacts of climate change on agriculture are interrelated with impacts on sea level, river deltas, natural disasters, water resources, and national security.

Coastal Regions. Coastal regions are some of the most at-risk areas for the impacts of climate change in the region due to their prevalence and high population density.

Mangroves and coral reefs across the region are two key coastal ecosystems that are expected to be significantly impacted by climate change. Many coastal areas are already degraded by pollution, sediment-laden runoff, and destructive fishing practices. Climate change-related destruction and degradation of mangroves and coral reefs will only exacerbate these effects, and result in long-term economic repercussions, since these ecosystems are central to the tourism, agriculture, fishing, and aquaculture industries. The area's coastal regions are also susceptible to inundation associated with sea level rise and destruction of infrastructure from flooding and storm surges, which are likely to increase as a result of future climate change. Careful management and safeguarding of coastal regions by regional governments is therefore essential in the next 20 years, as the effects of climate change manifest themselves. Impacts on coastal regions are interrelated with sea level, river deltas, natural disasters, water resources, agriculture, forests, and human livelihoods and infrastructure.

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Contents

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Introduction and Background

The Southeast Asia and Pacific Islands region is one of the most vulnerable areas in the world to climate change, due to its large and growing population, its long coastlines and low-lying areas, the economic importance of its agricultural sector, and its high dependence upon natural resources for development.[vii] This report summarizes the latest peer-reviewed research on projected climate change in Southeast Asia and Pacific Islands and the associated impacts on human and ecological systems across the region. Literature sources include the latest Intergovernmental Panel on Climate Change (IPCC) assessments, peer-reviewed journal articles, and reports generated by governments and scientific organizations.

The nations that constitute the focus of this assessment are Thailand, Cambodia, Laos, Vietnam, the Philippines, Malaysia, Singapore, and Indonesia. For convenience, these countries are referred to as "Southeast Asia" in this report, unless otherwise noted. The geographic scope of this report includes the region of approximately 23.5 °N to 10 °S latitude and 97 °E to 141 °E longitude. A map of the region, including the countries and their capitals, is given in Figure 1.

Specific information about the geography, economy, and society of the countries of interest is summarized below.[viii]

Thailand: Thailand is a coastal nation that borders Burma, Cambodia, Laos, Malaysia, the Andaman Sea, and the Gulf of Thailand. The total area of Thailand is 514,000 km^2, composed of 511,770 km^2 of land and 2,230 km^2 of water, and it has 3,219 km of coastline. The topography of Thailand includes a central plain, the Khorat Plateau in the east, and mountainous regions. It is subject to droughts nationwide and land subsidence in the Bangkok area resulting from depletion of the water table. Environmental issues in Thailand include air pollution from vehicle emissions, water pollution from organic and factory wastes, deforestation, soil erosion, and wildlife populations threatened by illegal hunting. The estimated population in 2009 is approximately 66 million, with an annual growth rate of 0.6 percent. The urban population constitutes 33 percent of the total population. Life expectancy is approximately 73 years. The Thai population is overwhelmingly Buddhist, with approximately 5 percent Muslims.

Thailand has a well-developed infrastructure, a free-enterprise economy, and generally pro-investment policies, which permitted annual real Gross Domestic Product (GDP) growth of more than 6 percent for the period 2002-04. Overall economic growth fell sharply in 2005-2007, however, because persistent political crises stalled infrastructure mega-projects, eroded investor and consumer confidence, and damaged the country's international image. The GDP (purchasing power parity) for 2008 was $553 billion. The labor force includes 43 percent in agriculture, 20 percent in industry, and 37 percent in services.

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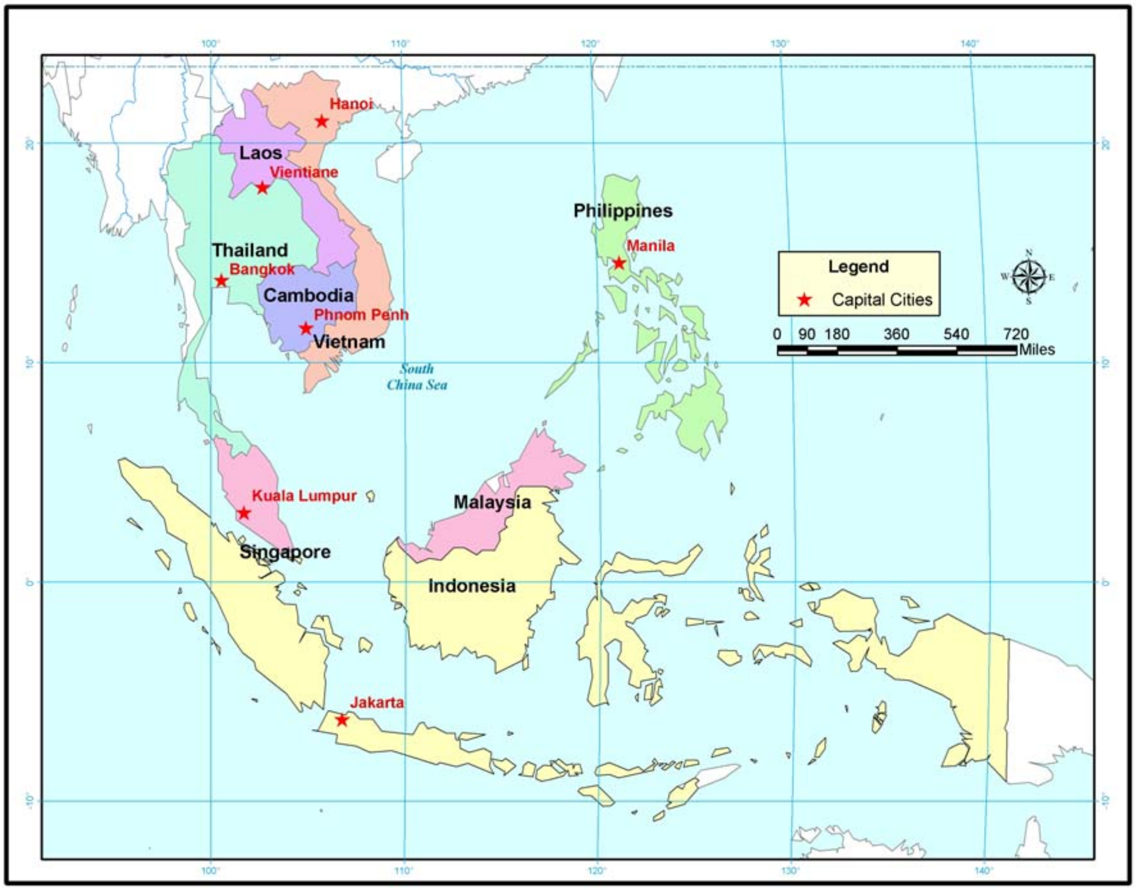

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Figure 1. Map of the geographic region of interest for this report. Colored areas indicate the eight nations of focus.

Laos: Laos is a landlocked nation that borders Burma, Cambodia, Thailand, China, and Vietnam. Laos' total area is 236,800 km^2, composed of 230,800 km^2 of land and 6,000 km^2 of water. Laos is subject to droughts and floods. Current environmental issues include deforestation and soil erosion; most of the population does not have easy access to potable water. Laos' estimated 2009 population is about 6.8 million, with a 2.3 percent annual growth rate. The urban population makes up 31 percent of the total population. Life expectancy is approximately 57 years. The religious make-up of the population is approximately 67 percent Buddhist, 1.5 percent Christian, and other unspecified religions.

Laos is one of the few remaining one-party Communist states. It has an underdeveloped infrastructure, particularly in rural areas: the nation has no railroads, a rudimentary road system, and limited external and internal telecommunications. Subsistence agriculture, dominated by rice, accounts for about 40 percent of GDP and provides 80 percent of total employment. The GDP (purchasing power parity) for 2008 was $14 billion. The labor force includes 80 percent in agriculture and 20 percent in industry and services.

Cambodia: Cambodia is a coastal nation that borders Thailand, Laos, Vietnam, and the Gulf of Thailand. Cambodia's total area is 181,040 km^2, composed of 176,520 km^2 of land and 4,520 km^2 of water. Its terrain is mostly low, flat plains, with mountains in the southwest and north. Cambodia is subject to flooding and occasional droughts. Current environmental issues include soil erosion, lack of potable water in rural areas, and declining fish stocks due to illegal fishing and overfishing. In addition, illegal logging activities throughout the country and strip mining for gems in the western region along the border with Thailand have resulted in habitat loss and declining biodiversity. In addition, destruction of mangrove swamps threatens natural fisheries. Cambodia's 2009 population is estimated at 14.5 million, with a 1.8 percent annual growth rate. The urban population makes up 22 percent of the total population. Life expectancy is approximately 62 years, and 95 percent of the population is Theravada Buddhist.

Cambodia's economy grew about 10 percent per year during 2004-2008, driven mainly by construction, agriculture, tourism, and an expanding garment industry. As of 2008, the garment industry employed more than 320,000 people and accounted for more than 85 percent of Cambodia's exports. The global financial crisis is weakening demand for Cambodian exports, however. Tourism has grown rapidly in recent years, with more than 2 million foreign visitors per year during 2007-2008. The GDP (purchasing power parity) for 2008 was approximately $28 billion. The labor force includes 75 percent in agriculture, with the remaining 25 percent in unspecified areas.

Vietnam: Vietnam is a coastal nation that borders China, Laos, Cambodia, the Gulf of Thailand, the Gulf of Tonkin, and the South China Sea. Vietnam's total area is 329,560 km^2, composed of 325,360 km^2 of land and 4,200 km^2 of water. Vietnam is subject to occasional typhoons from May to January that can cause extensive flooding, especially in the Mekong River delta. Current environmental issues include deforestation and soil degradation due to logging and slash-and-burn agricultural practices, water pollution, over-fishing, limited potable water supply due to groundwater contamination, growing urban industrialization, and increasing population migration to Hanoi and Ho Chi Minh City. Vietnam's estimated 2009 population is about 87 million, with a 0.9 percent annual growth rate. The urban population makes up 28 percent of the total population. Life expectancy is approximately 72 years. The distribution of religions includes 9.3 percent Buddhist, 6.7 percent Catholic, 1.5 percent Hoa Hao, 1.1 percent Cao Dai, 0.5 percent Protestant, and 0.1 percent Muslim, with 80 percent reporting no religion.

Vietnam has an export-oriented economy, with 68 percent of GDP in 2007 coming from exports. The agriculture sector has shrunk from 25 percent of the nation's economic output in 2000 to less than 20 percent in 2008. The global financial crisis will constrain Vietnam's ability to reduce poverty and create jobs in coming years. The nation's GDP (purchasing power parity) for 2008 was $242 billion. The labor force includes 56 percent in agriculture, 19 percent in industry, and 26 percent in services.

Philippines: The Philippines is an archipelago of 7,107 islands located east of Vietnam, between the Philippine Sea and the South China Sea. The total area of the Philippines is 300,000 km^2, composed of 298,170 km^2 of land and 1,830 km^2 of water. The Philippines is mostly mountains with narrow to extensive coastal lowlands. It is subject to typhoons, landslides, active volcanoes, destructive earthquakes, and tsunamis. Environmental issues in the Philippines include uncontrolled deforestation (especially in watershed areas), soil erosion, air and water pollution in major urban centers, coral reef degradation, and increasing pollution of coastal mangrove swamps that are important fish breeding grounds. The estimated 2009 population is approximately 98 million, with an annual growth rate of 2 percent. The urban population constitutes 65 percent of the total population. Life expectancy is approximately 71 years. The Philippine population is overwhelmingly Catholic, with approximately 5 percent Muslims.

Economic growth in the Philippines has averaged 5 percent since 2001. The economy faces several long-term challenges, such as improving employment opportunities and alleviating poverty. In the coming years, the Philippines will need sustained economic growth to make progress in alleviating poverty, given the nation's high population growth and unequal distribution of income. The Philippine economy grew at its fastest pace in three decades in 2007 with real GDP growth exceeding 7 percent, but growth slowed to 4.5 percent in 2008 as a result of the world financial crisis. The GDP (purchasing power parity) for 2008 was $320.6 billion. The labor force includes 35 percent in agriculture, 15 percent in industry, and 50 percent in services.

Malaysia: Malaysia occupies the southern portion of the Malay Peninsula and the northern one-third of the island of Borneo. Malaysia borders Indonesia, Brunei, and Thailand. Malaysia's total area is 329,750 km^2, composed of 328,550 km^2 of land and 1,200 km^2 of water. Malaysia is subject to flooding, landslides, and forest fires. Current environmental issues include air pollution from industrial and vehicular emissions, water pollution from raw sewage, deforestation, and smoke and haze from Indonesian forest fires. Malaysia's estimated 2009 population is about 26 million, with a 1.8 percent annual growth rate. The urban population makes up 70 percent of the total population. Life expectancy is approximately 73 years. The religious make-up of the population is approximately 60 percent Muslim, 19 percent Buddhist, 9 percent Christian, 9 percent Hindu, and other less populous religions.

Malaysia is a middle-income country that has transformed from a producer of raw materials into an emerging multi-sector economy. It has recently attracted investments in high technology industries, medical technology, and pharmaceuticals. As an oil and gas exporter, Malaysia has profited from higher world energy prices, although the rising cost of domestic gasoline and diesel fuel forced Kuala Lumpur to reduce government subsidies. Real GDP growth has averaged about 6 percent per year over the past few years, although regions outside of Kuala Lumpur and the manufacturing hub of Penang are growing less robustly. Decreasing worldwide demand for consumer goods is expected to hurt economic growth. The GDP (purchasing power parity) for 2008 was $387 billion. The labor force includes 10 percent in agriculture, 45 percent in industry, and 45 percent in services.

Singapore: Singapore is a small city-state that borders Malaysia on the southern tip of the Malay Peninsula. Singapore's total area is 692.7 km^2, composed of 682.7 km^2 of land and 10 km^2 of water. Singapore's terrain includes lowlands and a gently undulating central plateau that contains a nature preserve. Current environmental issues include industrial pollution, limited natural fresh water resources, limited land availability that causes waste disposal problems, and seasonal smoke and haze from forest fires in Indonesia. Singapore's estimated 2009 population is about 4.7 million, with a 1 percent annual growth rate. The population is 100 percent urban. Life expectancy is approximately 82 years. The distribution of religions includes 42.5 percent Buddhist, 14.9 percent Muslim, 8.5 percent Taoist, 4 percent Hindu, and 4.8 percent Catholic.

Singapore has a free-market economy that features a per capita GDP equal to that of the four largest West European countries. Singapore's economy depends primarily on exports, particularly consumer electronics, information technology products, pharmaceuticals, and a growing service sector. Real GDP growth for the period 2004-2007 averaged 7 percent, but it dropped to 1.2 percent in 2008 due to the global financial crisis. The nation's GDP (purchasing power parity) for 2008 was $240 billion. The labor force includes 33 percent in industry and 67 percent in services.

Indonesia: Indonesia is an archipelago between the Indian Ocean and the Pacific Ocean. Indonesia's total area is 1,919,440 km^2, composed of 1,826,440 km^2 of land and 93,000 km^2 of water. Its terrain is mostly coastal lowlands, although larger islands have interior mountains. Indonesia is subject to occasional floods, severe droughts, tsunamis, earthquakes, volcanoes, and forest fires. Current environmental issues include deforestation, water pollution from industrial wastes and sewage, air pollution in urban areas, and smoke and haze from forest and agricultural fires. Indonesia's estimated 2009 population is about 240 million, with a 1.1 percent annual growth rate. The urban population makes up 52 percent of the total population. Life expectancy is approximately 71 years. About 86 percent of the population is Muslim, with smaller Christian and Hindu populations.

Indonesia has made significant economic advances in recent years, but the nation faces challenges stemming from the global financial crisis and world economic downturn. Indonesia's debt-to-GDP ratio in recent years has declined steadily because of increasingly robust GDP growth and sound fiscal stewardship. Indonesia still struggles with poverty and unemployment, inadequate infrastructure, corruption, a complex regulatory environment, and unequal resource distribution among regions. As global demand slows and prices for Indonesia's commodity exports fall, Indonesia faces the prospect of growth significantly below the 6-plus percent recorded in 2007 and 2008. The GDP (purchasing power parity) for 2008 was $916 billion. The labor force includes 42 percent in agriculture, 19 percent in industry, and 39 percent in services.

Projected Regional Climate Change

Current Climatology of Southeast Asia

Southeast Asia has a tropical maritime climate featuring relatively high temperatures, high relative humidity, and abundant precipitation. Figures 2-4 shows the monthly average daily minimum temperatures, monthly average daily maximum temperatures, and rainfall amounts for the capital cities of the Southeast Asian countries that are the focus of this report. There are three basic seasons in Southeast Asia: the rainy season, winter, and summer, although the characteristics, duration, and timing of the seasons vary widely based on latitude and geography.

Thailand has a rainy, warm, and cloudy southwest monsoon season from mid-May to September, a dry, cool winter northeast monsoon season from October to mid-March, and a warm and relatively dry summer season from mid-March to mid-May; Thailand's southern isthmus on the Malay Peninsula is generally hot and humid year-round.[ix]

Laos and ***Cambodia*** both have two main seasons: the rainy season from May to November and the dry season from December to April.[x]

Vietnam has a hot, rainy season under the influence of the monsoon from May to September and a warm, dry season from October to March.[xi]

The Philippines has a northeast monsoon season from November to April and a southwest monsoon season from May to October.[xii]

Malaysia has a southwest monsoon season from April to October and a more rainy northeast monsoon season from October to February.[xiii]

Singapore has a southwest monsoon season from June to September and a more rainy northeast monsoon from December to March; during the inter-monsoon period, afternoon and early evening thunderstorms are common.[xiv]

Indonesia's climate is hot and humid year-round, although it is more moderate in the highlands.[xv]

The general pattern of rainy, winter, and summer seasons is typical except during El Niño-Southern Oscillation (ENSO) events. ENSO is a global climate phenomenon that recurs irregularly every 2-7 years and is associated with changes in sea surface temperature and prevailing winds. During a period of El Niño, the Northeast Trade Winds slacken, which increases the length of the dry season and creates drought conditions. La Niña is the complementary phenomenon; La Niña events are marked by a strengthening of the Northeast Trade Winds and a concomitant increase in the length of the rainy season. La Niña years are characterized by widespread flooding, landslides, and surface runoff from higher than average rainfall.

There is a great deal of natural climate variability in Southeast Asia. The regular pattern of seasonal monsoons can cause extreme weather events, such as floods and droughts. Overlaid on the monsoon variability is the periodic shift in global climate caused by ENSO, which can create or intensify existing floods and droughts.

Drought in El Niño years can have wide-reaching impacts on countries in Southeast Asia. For example, during the 1992 El Niño episode, total inflow to the Angat Reservoir in the Philippines, a major source of domestic and irrigation water supplies, was 69 percent less than average for the first six months of the year. As a result, there was a 20 percent reduction in the domestic water supply for the Manila metropolitan region, which necessitated water rationing in many areas. The cropping season was also delayed due to water shortages in June and July, and there were negative impacts on the national rice yield due to lack of irrigation water.[xvi]

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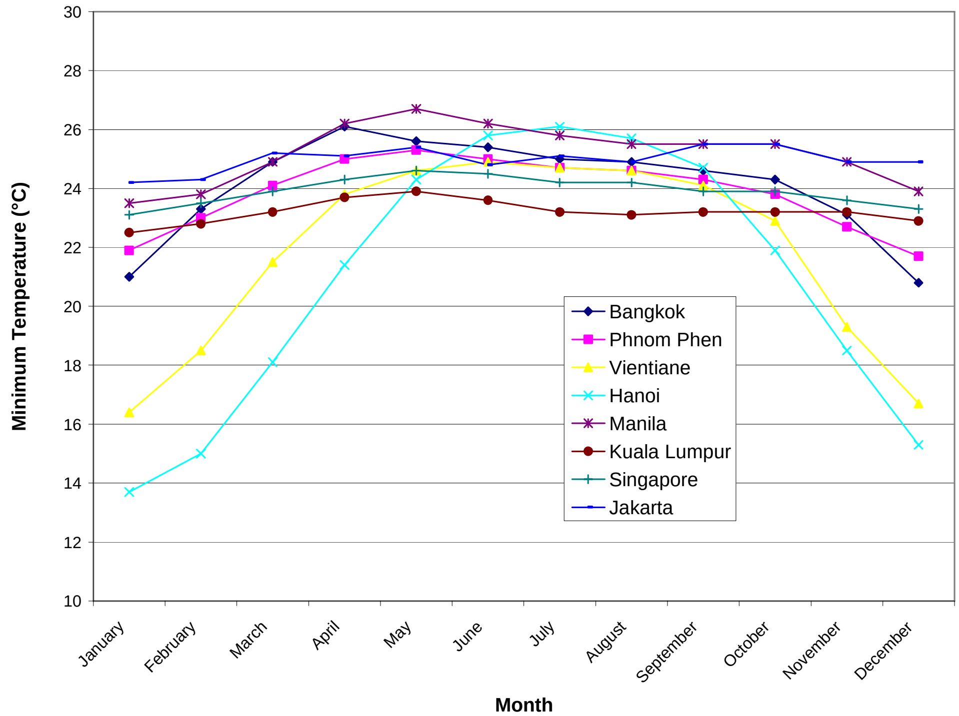

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Figure 2. Monthly averaged daily minimum temperatures for the capital cities of the Southeast Asian countries that are the focus of this report. Climatology values for Bangkok, Thailand are averaged over the period 1961-1990; values for Phnom Penh, Cambodia are averaged over the period 1997-2001; values for Vientiane, Laos are averaged over the period 1951-2000; values for Hanoi, Vietnam are averaged over the period 1898-1990; values for Manila, Philippines are averaged over the period 1971-2000; values for Kuala Lumpur, Malaysia are averaged values over the period 1971-2000; values for Singapore are averaged values over the period 1961-1990; and values for Jakarta, Indonesia are averaged over the period 1994-1990. Source: World Meteorological Organization, *World Weather Information Service*, http://www.worldweather.org/ (accessed April 15, 2009).

Tropical cyclones, called typhoons in the Pacific, also bring a great deal of precipitation to regions of Southeast Asia north of approximately 10° latitude. Tropical cyclones do not occur near the equator because Coriolis force is required to impart rotation to developing systems; thus Indonesia, Malaysia, Singapore, and southern portions of the Philippines are generally spared from their devastating effects. Typhoons usually form in the Central Pacific and move in a westerly direction across Southeast Asia. The typhoon season typically runs from April to December, with the peak number of typhoons generally occurring in September and October.

Climate Predictions (Modeling)

General circulation models (GCMs) are the main tool used by scientists to project future climate change. These models simulate atmospheric and oceanic circulations, as well as processes that occur on land. As a result, GCMs are very complex models, and they tend to have rather low

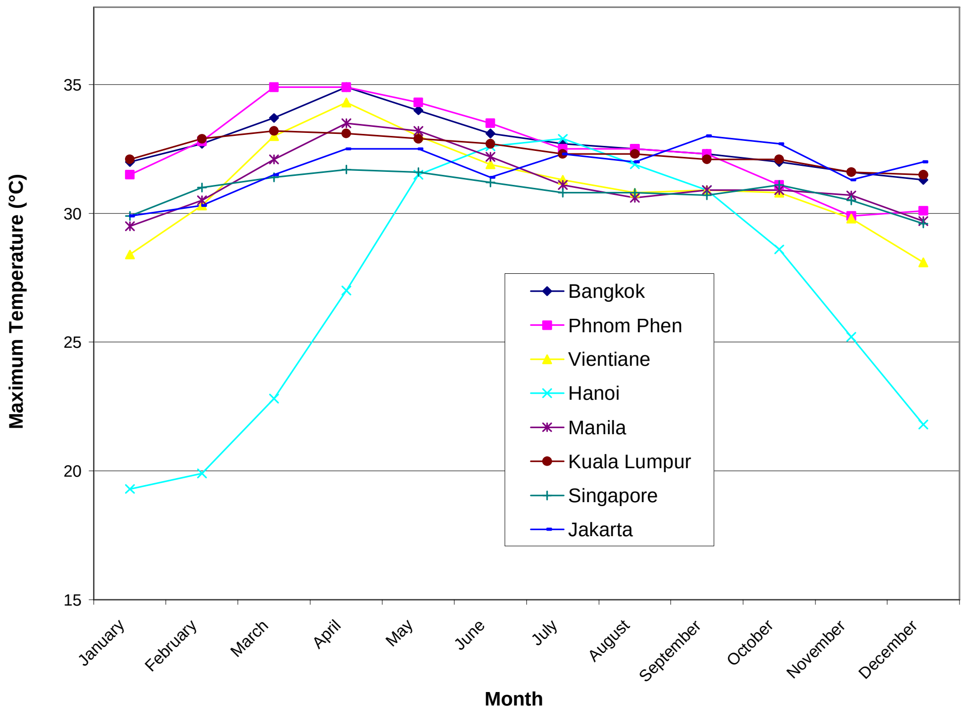

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Figure 3. Monthly averaged daily maximum temperatures for the capital cities of the Southeast Asian countries that are the focus of this report. Climatology values for Bangkok, Thailand are averaged over the period 1961-1990; values for Phnom Penh, Cambodia are averaged over the period 1997-2001; values for Vientiane, Laos are averaged over the period 1951-2000; values for Hanoi, Vietnam are averaged over the period 1898-1990; values for Manila, Philippines are averaged over the period 1971-2000; values for Kuala Lumpur, Malaysia are averaged values over the period 1971-2000; values for Singapore are averaged values over the period 1961-1990; and values for Jakarta, Indonesia are averaged over the period 1994-1990. Source: World Meteorological Organization, *World Weather Information Service*, http://www.worldweather.org/ (accessed April 15, 2009).

spatial resolutions, on the order of 400 to 125 km. To obtain model information on the local and regional scales, such as for Southeast Asia, at higher resolutions than native GCM grid sizes, "downscaling" is used. There are two main downscaling methods, dynamical and statistical. Dynamical downscaling involves the use of high-resolution climate models with observed or simulated data as boundary conditions. This approach has high credibility, but it is computationally expensive. In contrast, statistical downscaling, which involves application of established relationships between observed data to modeled data, is computationally inexpensive, and it can replicate finer scales than dynamical downscaling. Statistical downscaling methods do not accurately simulate regional feedback effects, however.[xvii]

In general, GCM predictions of temperature changes for a given region are consistent, but predictions of precipitation changes can vary widely due to the difficulty in simulating the myriad of factors that influence precipitation frequency, duration, and intensity. An additional

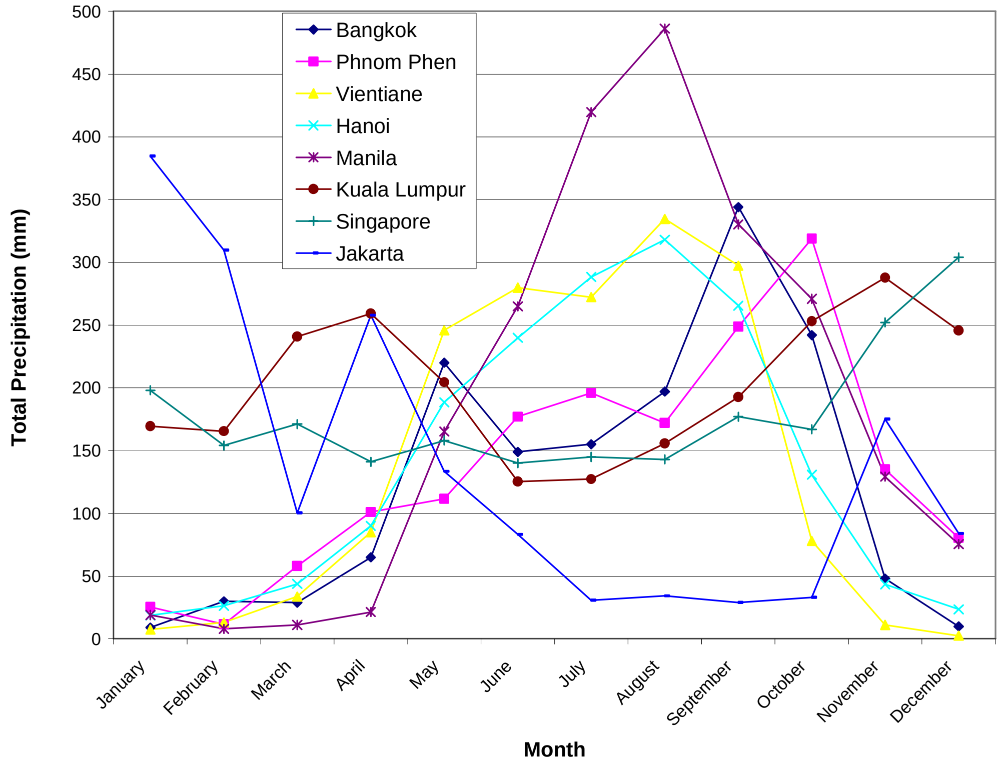

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Figure 4. Monthly averaged total precipitation values for the capital cities of the Southeast Asian countries that are the focus of this report. Climatology values for Bangkok, Thailand are averaged over the period 1961-1990; values for Phnom Penh, Cambodia are averaged over the period 1997-2001; values for Vientiane, Laos are averaged over the period 1951-2000; values for Hanoi, Vietnam are averaged over the period 1898-1990; values for Manila, Philippines are averaged over the period 1971-2000; values for Kuala Lumpur, Malaysia are averaged values over the period 1971-2000; values for Singapore are averaged values over the period 1961-1990; and values for Jakarta, Indonesia are averaged over the period 1994-1990. Source: World Meteorological Organization, *World Weather Information Service*, http://www.worldweather.org/ (accessed April 15, 2009).

complication for Southeast Asia is the fact that precipitation varies naturally on an interannual time scale due to ENSO and other natural variability. Any precipitation changes associated with future climate change in model simulations are overlaid on this natural variability, and it can be very difficult for GCMs to resolve the natural and anthropogenic contributions. A more detailed discussion of the ability of GCMs to project regional climate changes is given in Annex A.

GCMs simulate changes in climate under scenarios of future greenhouse gas and aerosol emissions. The 2000 IPCC Special Report on Emission Scenarios (SRES)[xviii] laid out the four basic scenario families used by IPCC scientists to predict future climate change; they are summarized in Table 1. This set of scenarios is designed to represent the range of possible future global conditions that will influence greenhouse gas emissions. The scenarios are based on consistent and reproducible assumptions about global forces that impact greenhouse gas emissions, including economic development, population, and technological change.

The following excerpt from the 2000 IPCC Special Report on Emission Scenarios (SRES) describes the emissions scenarios in more detail:

- **A1.** The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in the mid-21st century and declines thereafter, and the rapid introduction of new and more efficient technologies. Major underlying themes are convergence among regions, capacity building and increased cultural and social interactions, with a substantial reduction in regional differences in per capita income. The A1 scenario family develops into three groups that describe alternative directions of technological change in the energy system. The three A1 groups are distinguished by their technological emphasis: fossil-intensive (A1FI), non-fossil energy sources (A1T) or a balance across all sources (A1B), where balance is defined as not relying too heavily on one particular energy source, on the assumption that similar improvement rates apply to all energy supply and end use technologies.
- **A2.** The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than other storylines.
- **B1.** The B1 storyline and scenario family describes a convergent world with the same global population, that peaks in the mid-21st century and declines thereafter, as in the A1 storyline, but with rapid change in economic structures toward a service and information economy, with reductions in material intensity and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.
- **B2.** The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social and environmental sustainability. It is a world with continuously increasing global population, at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

Climate researchers frequently use GCMs from the UK Met Office Hadley Centre for Climate Prediction and Research to investigate future changes in temperature and precipitation. These models are representative of many GCMs used to simulate the effects of climate change. The HadCM2 model has four different integrations that represent the climate effects of greenhouse gases and sulfate aerosols. Greenhouse gases, such as carbon dioxide, water vapor, ozone, methane, and nitrous oxide, absorb infrared radiation emitted from the Earth and subsequently emit it back into the atmosphere, which results in a net warming of the Earth's surface. HadCM2 includes the combined forcing of all greenhouse gases as an equivalent CO_2 concentration of 0.5 percent or 1 percent, depending on the integration. HadCM2 can also incorporate the negative direct forcing of sulfate aerosols by means of an increase in clear-sky albedo; sulfate forcing is 0.5 percent or 1 percent, depending on the model integration. The influence of sulfate aerosols is

Emission Scenario	Economic Development	Global Population	Technology Changes	Theme
A1	Very rapid	Peaks around mid-21st century and declines thereafter	Rapid introduction of new and more efficient technologies	Convergence among regions; increased cultural and social interactions
A2	Regionally-oriented	Continuously increasing	Slower and more fragmented than A1, B1, and B2	Self-reliance and preservation of local identities
B1	Rapid change toward service and information economy	Same as A1	Introduction of clean and resource-efficient technologies	Global solutions to economic, social, and environmental sustainability
B2	Intermediate levels of economic development	Continuously increasing, but not as fast as A2	Less rapid and more diverse changes than A1 and B1	Local solutions to economic, social, and environmental sustainability

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Table 1. Summary of IPCC emissions scenarios. Source: Intergovernmental Panel on Climate Change (IPCC), *Special Report on Emissions Scenarios (SRES)*, eds. Nebojsa Nakicenovic and Rob Swart (Cambridge: Cambridge University Press, 2000), http://www.ipcc.ch/ipccreports/sres/emission/index.htm.

important because they reflect incoming solar radiation; thus less reaches the surface of the Earth, which results in a net cooling of the Earth's surface. Each integration of HadCM2 has four ensembles, from which an ensemble mean can be calculated.[xix] Ensembles are used to represent the range in uncertainty of model predictions. In this case, the same model, HadCM2, is run four times using different initial conditions. The average of a series of ensembles is always more accurate than any single model run.

HadCM3 is the successor to HadCM2. Its integrations are run under six different climatology scenarios of population growth, greenhouse gas emissions, and technology development through the 21st century. Both HadCM2 and HadCM3 have spatial resolutions of 2.5° latitude by 3.75° longitude. In general, this resolution is sufficient to resolve climate changes on a country-level scale in Southeast Asia, without the need for downscaling or temporal smoothing.[xx] To simulate local climate changes, however, downscaling is required.

In contrast to the most recent GCMs, which are run under conditions matching the various IPCC emissions scenarios, many GCMs prior to approximately 2000 were run under more simplistic conditions. The most common method of simulating climate change in the older models was with an equivalent doubling of atmospheric CO_2 concentrations ($2\times CO_2$), which represented the net radiative effect of increases in CO_2 and other greenhouse gases since pre-industrial times (typically equivalent to 560 ppm of CO_2). Models established a baseline using "current" CO_2 concentrations ($1\times CO_2$), and the change between $1\times CO_2$ and $2\times CO_2$" in model output was considered representative of future climate change. Under this type of scenario, researchers often neglected to frame the model results in terms of specific decadal changes, so the exact timeframe for projected climate changes was not specified.

Additional information on the GCMs mentioned in this report is available from the IPCC Data Distribution Centre (http://www.ipcc-data.org/).

This paper does not represent US Government views.

Projections of Future Changes in Temperature and Precipitation

Rising concentrations of greenhouse gases in the global atmosphere during the 21st century are expected to cause a net warming of the Earth's surface. Higher surface temperatures will likely increase surface evaporation and thus global precipitation. To quantify regional future changes in temperature and precipitation, the IPCC uses a coordinated set of climate model simulations archived at the Program for Climate Model Diagnosis and Intercomparison (called the multi-model dataset, or MMD). Figure 5 shows the projected increase in temperature for Southeast Asia for the 21st century in the context of observed warming during the 20th century. This distinction is important because if GCMs cannot accurately reproduce observed climatic data, then they cannot be relied upon to simulate future climate changes. To obtain the temperature information shown in Figure 5, a subset of 58 simulations from 14 models of the MMD was used for the observed period and 47 simulations from 18 models for the future projections; the future projections were calculated for the A1B emissions scenario. The width of the shading and the bars in Figure 5 represent the 5-95 percent range of the model output. Results show that by the end of the 21st century, the annual mean temperature across Southeast Asia is expected to increase by a median value of 2.5°C, with little seasonal variation. This increase compares to a historical warming of 0.5-1.1°C in Southeast Asia for the period 1901-2005. The future temperature increase is expected to vary by location, with stronger warming in the interior of countries on the Asian mainland and less warming along coastal regions and in island nations.[xxi]

IPCC also used the MMD models to estimate precipitation changes for the 21st century under the A1B scenario. In contrast to the temperature projections, which are consistent in predicting a temperature increase across Southeast Asia, future precipitation changes are less straightforward to quantify. Results from the MMD simulations show a net increase in precipitation across the region, with a median increase in average annual precipitation of 7 percent; these increases generally follow the location of the Intertropical Convergence Zone (ITCZ).[xxii] The ITCZ is a region of low pressure and thus rising air near the equator that occurs where the Northeast Trade Winds meet the Southeast Trade Winds. As air rises, it cools and moisture condenses out, causing clouds and precipitation to form. Consequently, the ITCZ is marked by a band of heavy precipitation that moves northward and southward seasonally, following the warmest surface temperatures. The MMD models predict that the strongest and most consistent future increases in precipitation will follow the movement of the ITCZ, and thus will occur over Thailand, Cambodia, Laos, Thailand, the Philippines, Malaysia, Singapore, and northern Indonesia in June, July, and August; and will occur over southern Indonesia and Papua New Guinea in December, January, and February. During the times when these regions are not under the influence of the ITCZ, the models predict that concomitant decreases in precipitation will occur. The overall trend forecasted by the MMD models is for precipitation to increase during the rainy season and decrease during the dry season.[xxiii]

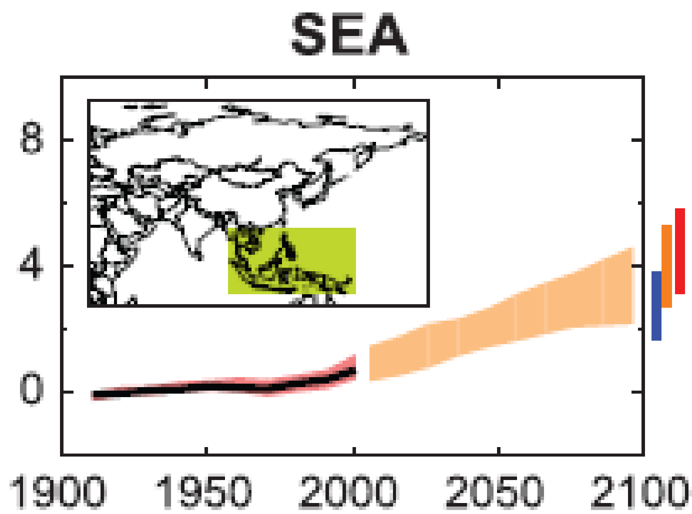

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Figure 5. Temperature changes in °C predicted by the IPCC MMD models for Southeast Asia (SEA). Temperature anomalies for the region with respect to 1901-1950 are shown for 1906-2005 (black line), as simulated by the MMD models using known forcings (red envelope), and as projected for 2001-2100 by the MMD models for the A1B scenario (orange envelope). The colored horizontal bars on the right side of the figure represent the range of projected changes for 2091-2100 for the B1 scenario (blue), the A1B scenario (orange), and the A2 scenario (red). The width of the shading and the bars represent the 5-95 percent range of the model results. Source: Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: the Physical Science Basis*, eds. S. Solomon, D. Qin, M. Manning, M. Marquis, K. Averyt, M.M.B. Tignor, H.L. Jr. Miller, and Z. Chen (Cambridge: Cambridge University Press, 2007), http://www.ipcc.ch/ipccreports/ar4-wg1.htm.

Variations in future regional precipitation are expected. Although a net increase in future precipitation is expected globally in a warmer world, regional precipitation rates in Southeast Asia will vary due to a variety of reasons, including shifts in the ITCZ, changes in the monsoons, variations in ENSO, local hydrological feedbacks, and alterations in atmospheric stability.[xxiv] Future climate change-induced variations of regional precipitation will be superimposed on the natural interannual variations that occur in Southeast Asia. For example, analysis of monthly rainfall from 210 stations across Indonesia for the periods 1931-1960 and 1961-1990 showed that annual rainfall has decreased across most of the southern regions of Indonesia (Java, Lampung, South Sumatra, South Sulawesi, and Nusa Tenggara) and increased across most of the northern regions of the country (Kalimantan and North Sulawesi).[xxv]

In addition to the global simulations of future temperature and precipitation changes executed by the IPCC, several other researchers have conducted localized simulations for the Southeast Asian region. Lal and Harasawa[xxvi] used four GCMs to estimate the effect of climate change on temperature and precipitation in Asia for the periods 2049-2069 and 2070-2099. Their analysis of Southeast Asia included the region of 10°S – 20°N latitude and 95°E – 155°E longitude, which encompasses the countries that are the focus of this report, except for the northern-most sections of Laos and Vietnam. The authors ran the Japanese CCSR/NIES model, the Australian CSIRO model, the German ECHAM4 model, and HadCM2 under conditions of greenhouse gas forcing only and combined greenhouse gas and sulfate aerosol forcings. Ensemble results for the four GCMs showed a consistent increase in both temperature and precipitation across Southeast

Asia for both time periods. Due to increases in greenhouse gases only, the annual average temperature was predicted to increase by 2.15°C, the average "winter" season (December, January, and February) temperature was predicted to increase by 2.28°C, and the average "summer" season (June, July, and August) temperature was predicted to increase by 2.01°C for the 2049-2069 period. The inclusion of sulfate aerosol forcing in the GCMs caused a slight reduction in the magnitude of the expected temperature increases, to 1.72°C, 1.73°C, and 1.6°C for annual, winter, and summer average temperatures, respectively. In addition, the models predicted a uniform increase of 4.6 percent, 3.5 percent, and 3.4 percent in annual, winter, and summer average precipitation, respectively, for the period 2049-2069 due to increases in greenhouse gases. As with the temperature predictions, inclusion of sulfate aerosol forcing in the four GCMs resulted in a moderate reduction in the expected precipitation increase, to 1.0 percent, 2.9 percent, and 2.6 percent for annual, winter, and summer average precipitation, respectively. The temperature results of Lal and Harasawa are consistent with those of the IPCC MMD models, which also predicted little seasonal variation in the expected temperature increases across Southeast Asia. The seasonally uniform precipitation results of Lal and Harasawa are in contrast to those of the IPCC MMD models, however, which showed a variation in future precipitation changes for the rainy and dry seasons. The inconsistency of the precipitation estimates from these two studies underscores the difficulty in obtaining consistent precipitation forecasts from GCMs under conditions of future climate change.

Lal et al[xxvii] continued their earlier work by simulating the temperature and precipitation effects resulting from climate change over small island states, including those of the Pacific Ocean, for the periods 2010-2029, 2049-2069, and 2070-2099. The authors ran the CCSR/NIES, CSIRO, ECHAM4, CCCma, and HadCM2 models under conditions of greenhouse gas forcing only and combined greenhouse gas and sulfate aerosol forcings. See M. Lal, H. Harasawa, and K. Takahashi, "Future climate change and its impacts over small island states," *Clim. Res.*, 19 (2002):179–192 for results from the ensemble of five models for the Pacific Ocean Islands (the region 23°S – 23°N latitude and 120°E – 145°W longitude, which includes the Philippines and eastern Indonesia). Model results projected annual mean temperature increases of 0.93±0.12°C and 0.79±0.05°C due to increases in greenhouse gases and greenhouse gases plus sulfate aerosol, respectively, by 2010-2029. The models also predicted annual mean precipitation increases of 2.9±1.0 percent and 1.9±0.8 percent due to increases in greenhouse gases and greenhouse gases plus sulfate aerosol, respectively, by 2010-2029. Similar to the authors' earlier work in the Asia region,[xxviii] model results for the Pacific Ocean Islands showed a mostly uniform increase in both temperature and precipitation for the three simulated time periods of 2010-2029, 2049-2069, and 2070-2099 with little seasonal variation. The exception was slightly larger increases in precipitation during the summer season for the periods 2049-2069 and 2070-2099. The authors noted that regional precipitation is strongly dependent on local topography, particularly elevated terrain, which is typically not well represented in GCMs, and consequently there is significant uncertainty in their model projections of regional precipitation due to future climate change.

Although the IPCC MMD model results[xxix] and the ensemble mean results of Lal and Harasawa[xxx] and Lal et al[xxxi] differed slightly from each other regarding the magnitude of projected seasonal precipitation in Southeast Asia, the models were generally internally consistent in the sense that they all predicted precipitation increases. Other researchers who have used a series of GCMs to estimate the future effects of climate change on precipitation in specific countries in Southeast Asia have obtained conflicting results.

For example, Boer and Faqih[xxxii] examined the potential changes in future temperature and precipitation in Indonesia through 2080 using the CCSR, CSIRO, ECJAM4, CGCM1, and HadCM3 GCMs under the A2 and B2 emissions scenarios. Results showed an expected uniform increase in average temperature across the country of approximately 0.0344°C per year for the A2 scenario and approximately 0.0211°C per year for the B2 scenario. Precipitation changes varied by model and emissions scenario, however, as CCSR and CSIRO predicted rainfall increases, ECHAM4 and CGCM1 predicted rainfall decreases, and HadCM3 varied depending on the emissions scenario. Based on these results, the authors concluded that it was not possible to determine the specific effects of climate change on precipitation across Indonesia.

Variations in the intensity and occurrence of tropical cyclones (typhoons) due to climate change will also impact precipitation changes in regions of Southeast Asia north of approximately 10 °N latitude. There is significant uncertainty in future changes in tropical cyclone occurrence and intensity, however, due to the fact that few GCMs have the spatial resolution necessary to simulate synoptic scale patterns. The IPCC reports that in general, higher-resolution models that can simulate tropical cyclone characteristics predict that mean and peak precipitation intensities will increase in future tropical cyclones.

Projections of Future Changes in Monsoons and ENSO

Regional precipitation in Southeast Asia will be affected by future variations in monsoons due to climate change. Giorgi et al[xxxiii] analyzed the global effects of climate change for the period 2071-2100 relative to 1961-1990 using nine GCMs run under the A2 and B2 emissions scenarios. The model results predicted a consistent increase in summer monsoon precipitation across Southeast Asia relative to the global mean average precipitation. Overall precipitation across the region was not expected to change, however, which suggests that rainfall will decrease in some areas and/or during seasons that are not impacted by the monsoon.

Bhaskaran and Mitchell[xxxiv] examined the changes in Southeast Asian monsoon precipitation due to climate change for the period 1990 to 2100 using the Hadley Centre HadCM2 global climate model. Two scenarios of HadCM2 were used: forcing only from greenhouse gases represented by a 1 percent per year increase in CO_2 concentration, and with the addition of sulfate aerosol forcing. Overall, the model simulations indicated that monsoon-related precipitation will increase as CO_2 concentration increases, and monsoon genesis and intensity are sensitive to sulfate aerosol forcing. Specific results for the region between 5 °N and 25 °N latitude and 90 °E and 105 °E (roughly including Thailand, Cambodia, Laos, and Vietnam) indicated an expected 10-15 day delay in the monsoon onset date, but with no extension of the monsoon season for the period 2030 to 2070. The model simulations also predicted an increase of approximately 3-6 mm day^{-1} in total daily precipitation and a substantial increase in frequency of intensity of areal mean precipitation for the same period, which, if realized, could lead to an increase in monsoon-related flooding across the region.

As previously noted, natural variations in monsoon frequency and intensity are tied to ENSO, so any future enhancement of ENSO associated with climate change will likely affect monsoon characteristics. Future changes in ENSO are very uncertain, however, because GCMs cannot accurately simulate past observed ENSO variations and thus simulations of future changes are suspect.[xxxv] Paeth et al[xxxvi] studied potential variations in ENSO and monsoons in the 21st century using a suite of 12 GCMs under six IPCC emissions scenarios. Model results projected a substantial warming of the eastern tropical Pacific Ocean of more than 5°C, which represented a change in the background state of ENSO. There was no compelling evidence in the model simulations for wholesale changes in the frequency of El Niño and La Niña events in the 21st century, although results suggested that the intensity of ENSO events may increase. The authors concluded that the intensity of summer monsoons in South Asia may increase as a result of changes in ENSO due to future climate change, with the caveat that model uncertainty in simulating ENSO makes it impossible to draw any definitive conclusions.

Projections of Future Changes in Water Resources

Changes in temperature and precipitation in Southeast Asia will affect water resources. Tao et al[xxxvii] studied the impact of climate change on global water resources for the period 2021-2030 using two Hadley Centre models. HadCM2 was run with forcing from greenhouse gases represented by a 1 percent per year increase in CO_2 concentration and sulfate aerosols, and HadCM3 was run under the same conditions as HadCM2 but with the addition of ozone changes and the indirect forcing of sulfate aerosols. The model results projected that annual mean temperatures will increase uniformly by 0.5-1.5°C across Southeast Asia by 2021-2030. Precipitation projections across the region for the same period were not consistent due to variations between the models. The HadCM2 ensemble mean predicted that annual mean precipitation will increase by 0-100 mm in southern Philippines, western Malaysia, Singapore, and western Indonesia; increase by 0-50 mm in northern Vietnam, Thailand, and Laos; decrease by 0-50 mm in Cambodia; decrease by 0-100 mm in southern Vietnam and eastern Malaysia; and decrease by 100-150 mm in northern Philippines and eastern Indonesia. HadCM3 results were similar, with the exception of a projected increase in annual mean precipitation of greater than 150 mm for most of Indonesia. The models were consistent in predicting an increase in annual mean potential evapotranspiration[1] of 0-100 mm across Southeast Asia by 2021-2030, which suggests that climate change may cause a net decrease in ecosystem water demand across the region. Furthermore, model projections showed little change in annual soil moisture deficit across Southeast Asia by 2021-2030, indicating that the region as a whole may not be susceptible to water shortages or water stress on local vegetation due to climate change. The models indicated that net increases in precipitation across parts of Southeast Asia due to climate change are likely to lead to increased surface runoff, however, which in turn may cause increased erosion, flooding, and water pollution. Surface runoff occurs when soil moisture exceeds soil's water-holding capacity. Changes in annual surface runoff predicted by the GCMs mirrored the precipitation predictions, with variations across Southeast Asia and among the models. Areas with the largest predicted increases in surface runoff included parts of Thailand, Philippines, Malaysia, Vietnam, Laos, and Indonesia.

Arnell[xxxviii] estimated the global effects of climate change on water resources using the Hadley Centre HadCM2 and HadCM3 global climate models. All simulations included forcing from greenhouse gases represented as a 1 percent per year increase in CO_2 concentration from 1990 to 2100, with no sulfate aerosol forcing. Analysis focused on surface runoff, and model projections showed that by 2040, annual surface runoff will increase by greater than 150 mm per year in Thailand, Malaysia, Singapore, and the Philippines and decrease by 50 to 150 mm per year in Laos, Cambodia, Vietnam, and Indonesia. See Nigel W. Arnell, "Climate change and global water resources," *Global Environmental Change* 9 (1999): S31-S49 for a graphic representation of the change in monthly average runoff for Thailand as predicted by the HadCM2 ensemble mean (thick black line) compared to baseline conditions (shaded region). The increases in runoff

[1] The combined process of water *evaporation* from the Earth's surface and *transpiration* from vegetation.

were predicted to occur during the rainy season, from June through October. The magnitude of the predicted changes in surface runoff generated in this study is consistent with that of Tao et al,[xxxix] although the specific locations where increases and decreases in surface runoff were predicted varied among the two studies.

On a regional scale, Jose et al[xl] investigated the effects of climate change on water resources in the Philippines using the CCCM, UKMO, and GFDL GCMs run under conditions of 2×CO_2. Analysis focused on two major reservoirs, Lake Angat and Lake Lanao, which provide water for domestic use, irrigation, and hydroelectric power in the Philippines. The models predicted a uniform increase in average annual temperature of approximately 2-3°C at both reservoir locations. Predictions of precipitation change were not consistent, however; CCCM estimated a slight decrease in annual average rainfall while the UKMO and GFDL models predicted a slight increase at both reservoirs. The authors used the temperature and precipitation simulations in conjunction with a hydrological model to estimate the changes in future rainfall runoff to the two reservoirs. For Lake Angat, the predicted changes in runoff were -12 percent, 5 percent, and 32 percent for the CCCM, UKMO, and GFDL models, respectively. Predicted changes at Lake Lanao were -2 percent, -12 percent, and 7 percent for the CCCM, UKMO, and GFDL models, respectively. As might be expected, projected changes in runoff roughly correlated with projected changes in precipitation. The variations in the model projections underscore the difficulty GCMs have in simulating precipitation changes, particularly on a local scale. Any areas that see an increase in runoff could experience an increase in flooding, while decreased runoff could lead to water shortages. These results are comparable to an earlier study by the same authors that focused only on the effect of climate change on water resources at Lake Angat.[xli]

A study published as part of the Assessments of Impacts and Adaptations to Climate Change[xlii] used the HadCM3, CCC, and CSIRO GCMs with downscaling to determine the effect of climate change in 2020, 2050, and 2080 for the Pantabangan-Carranglan Watershed (PCW) on the island of Luzon in the Philippines. Model results showed that by 2020, mean daily precipitation is expected to increase by an average of 6.7 percent and mean daily maximum temperature is expected to increase by an average of 1.6 percent, compared to observed daily values for the period 1960-1990. These changes are expected to result in an increase in stream flow during the rainy season and a decrease during the dry season. The authors concluded that there will be a higher likelihood of floods during the rainy season and water shortages during the dry season in the PCW Watershed associated with future climate change.

Projections of Future Changes in Sea Level

As the global ocean warms, its volume will increase, and as a result, sea level will increase. Net global sea level rose by approximately 17 cm in the 20th century.[xliii] The rate of sea level rise varies regionally, however, principally due to local variations in the balance between the density and circulation of the oceans. Changes in local ocean momentum flux are also important in the tropical Pacific.[xliv] Patterns of coupled ocean-atmosphere variability, such as ENSO, also influence local sea level rise. Recent analysis of tide gauge records and data from the TOPEX/Poseidon satellite altimeter indicate that changes in sea level have varied across the tropical Pacific for the period 1950-2001.[xlv] See J.A. Church, N.J. White, and J.R. Hunter, "Sea level rise at tropical Pacific and Indian Ocean islands," *Global Planet. Change*, 53, no. 3 (2006): 155–168 for trends in sea level for 1993-2001 using a blend of the tide gauge and satellite data. The largest recent increases in sea level in Southeast Asia have been observed near Indonesia and the Philippines, while only moderate changes have been observed along the coasts of Thailand, Cambodia, and Vietnam. These recent rates of change in sea level are characteristic of natural interannual climate variability and are consistent with the trend toward more frequent and intense ENSO events that have been observed in the past 20 years.

The IPCC[xlvi] has estimated regional future changes in sea level due to ocean density and circulation changes for the 21st century using the ensemble mean of a subset of 14 models from the MMD. Results for the projected sea level change in Southeast Asia for the period 2080-2099 relative to 1980-1999 for the A1B emissions scenario are shown in Figure 6. The regional sea level projections are given in relation to the average global sea level increase of 35 cm expected over the same period by IPCC for the A1B emissions scenario. Thus, Figure 6 shows that most of the seas around Southeast Asia are expected to rise approximately 0-5 cm above the global average value by the end of the 21st century, for a net increase of 35-40 cm. A few areas, such as the Southern Philippines and parts of Indonesia, are expected to observe decreases in sea level of 0-5 cm below the global average value, for a net increase of 30-35 cm. Any increase in sea level represents a significant change for Southeast Asia, which is comprised of low-lying coastal and island nations that will be severely impacted by rising ocean waters.

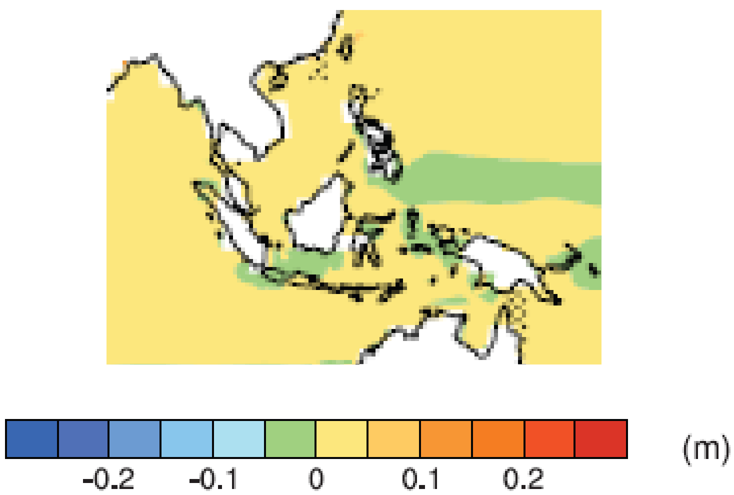

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Figure 6. Projected local sea level changes in meters during the 21st century relative to the global average. Sea level change is calculated as the difference between averages for 2080-2099 and 1980-1999 from the ensemble mean of 16 GCMs using the A1B emissions scenario. The local seal level changes shown are above/below the global average sea level rise of 35 cm expected in the 21st century under the A1B emissions scenario. Regional sea level changes are attributed to changes in ocean density and circulation. Source: Intergovernmental Panel on Climate Change (IPCC), *Climate Change 2007: the Physical Science Basis*, eds. S. Solomon, D. Qin, M. Manning, M. Marquis, K. Averyt, M.M.B. Tignor, H.L. Jr. Miller, and Z. Chen (Cambridge: Cambridge University Press, 2007), http://www.ipcc.ch/ipccreports/ar4-wg1.htm.

Projections of Future Changes in River Delta Flooding and Salinity Intrusion

Sea level rise resulting from climate change will affect flooding and salinity intrusion of major rivers and deltas across Southeast Asia. Several researchers have examined these effects on the Mekong River Delta in southern Vietnam. The health of the Mekong Delta is important because it supports agriculture, particularly rice production, in Vietnam and Cambodia. Since 1997, 50 percent of rice production in Vietnam has been supported by the Mekong Delta.[xlvii] Flooding of the Mekong Delta can be devastating on rice crops, while salinity intrusion reduces the amount of fresh water available for crop irrigation.

Khang et al[xlviii] studied the effect of sea level rise on salinity intrusion in the Mekong River Delta during the dry season (December to June) using a coupled hydro-dynamic and advection dispersion model. Salinity intrusion during the dry season is a problem because fresh water from the Delta permits a dry season rice crop via irrigation, and this contribution is essential to Vietnam's rice production and export. The authors ran the model under conditions of the B2 emissions scenario, specifically considering the effects of a 20 cm increase in sea level and a 15 percent decrease in Mekong River flow by the mid-2030s. The authors measured salinity intrusion by identifying the extent of water with a salinity concentration of 2.5 g/L, which is the threshold value for reduction in rice yield by approximately 25 percent. Results from the model showed that by the mid-2030s, the 2.5 g/L saline front is likely to shift upstream by 10 km in the main Mekong River and by 20 km in the rice paddy fields during the dry season. Consequently, due to the associated loss in fresh water from the river for irrigation, the total reduction in land area for dry season rice cropping was estimated at approximately 71,000 ha.

Wassmann et al[xlix] investigated the effect of sea level rise on flooding of the Mekong Delta during the flood season (August to November) using a hydraulic model. Similar to the work of Khang et al,[l] the authors ran the model under a scenario of 20 cm increase in sea level by 2030. Results showed that in October, at the peak of the flood season, high water discharge into the Mekong River is expected to increase water levels in the Mekong Delta by 11.9 cm, leading to substantial aggravation of annual flooding in the Delta region. The authors concluded that increases in sea level due to climate change will cause excessive flooding in tidally inundated areas of the Mekong Delta and longer periods of flooding in the central portion of the Mekong Delta, both of which will negatively impact rice production.

Impacts of Climate Change on Human and Natural Systems

Southeast Asia is susceptible to climate change for a variety of reasons. It has major populations concentrated along low-lying coastal areas, including the poor who subsist as smallholder farmers and fishermen,[li] and it contains fragile and unique ecosystems. The economy of much of the region is dependent on vulnerable industries, such as agriculture, aquaculture, fishing, and tourism. In addition, many nations in Southeast Asia are undergoing rapid economic development, which will likely exacerbate the effects of climate change on human and natural systems.

Although the precise extent and magnitude of future climate change in Southeast Asia is uncertain, it has already begun to impact the following human and natural systems:

- Sea level
- River deltas
- Natural disasters
- Water resources
- Agriculture
- Forests and biodiversity

- Coastal ecosystems
- Coral reefs
- Diseases and human health
- Electricity demand in urban areas
- Human livelihoods and infrastructure

Nearly all of these systems are interrelated. For example, rising sea level causes saltwater intrusion into river deltas, which limits available fresh water and in turn impacts agricultural irrigation, drinking water availability, and population patterns. Climate change impacts on natural and human systems also have socioeconomic consequences on both micro and macro scales, which will affect the economic vitality of individual countries and the region as a whole.

Impacts of Sea Level Rise

As documented in the Model Projections section, sea level rose in the Southeast Asia region at rates of up to 3 cm per year for the period 1993-2001,[lii] and sea level is projected to rise up to 40 cm in the 21st century.[liii] Increases in sea level associated with climate change are particularly problematic for Southeast Asia, which is comprised of low-lying coastal and island nations. In fact, approximately 20 percent of the world's population of low-lying coastal regions is in Southeast Asia.[liv] The effects of rising sea level on island nations, including the Philippines, Malaysia, Singapore, and Indonesia, whose borders are mostly or entirely coastline, will be most pronounced.[lv] Although limited studies exist, recent estimates indicate that Indonesia could lose 2,000 small islands to sea level rise by 2030.[lvi] The primary impacts of sea level rise are saltwater intrusion into estuaries and aquifers, coastal erosion, displacement of wetlands and lowlands, degradation of coastal agricultural areas, and increased susceptibility to coastal storms.

Climate change-induced sea level rise in Southeast Asia will likely have significant economic effects as well. A recent study estimates that rising ocean waters could cause the loss of 40,000 km^2 of land in Vietnam, particularly rice paddies, and necessitate re-engineering of port facilities and transportation systems. Taken together, these impacts could result in economic losses of up to 80 percent of the yearly Vietnamese GDP.[lvii] In addition, coastal inundation of Indonesian cities associated with potential sea level rise in the 21st century is estimated to cause total economic losses of 1.8-2.3 billion.[lviii] Sea level rise is expected to inundate 38 km^2 of the total land area of Jakarta, Indonesia, by 2030, resulting in economic losses of US$1 billion.[lix]

Impacts on River Deltas

Increases in sea level due to climate change will impact river deltas in a variety of ways, particularly by increasing flooding, coastal erosion, and salinity intrusion. The Red River and Mekong River Deltas in Vietnam appear to be particularly vulnerable to the impacts of climate change. Saltwater intrusion into the Red River Delta is already occurring, and as outlined in the Model Projections section, saltwater intrusion is expected to move farther inland as a result of climate change. Saltwater intrusion is a serious problem for agricultural regions, particularly rice paddies, since fresh water from river deltas is a primary source of irrigation water in Vietnam. Saltwater intrusion also damages coastal ecosystems and modifies fish and wildlife habitats.[lx]

A recent study[lxi] of the impacts of sea level change on global river deltas found that by 2050 there will be serious challenges to human occupancy of delta regions in Vietnam and Indonesia. Table 2 shows that almost 2 million people will be at risk from the impacts of sea level rise on the Mekong River Delta in Vietnam, which will constitute approximately 6.5 percent of the total population dependent on the delta. Furthermore, the Vietnam coast is an area of active economic development that is experiencing a rapid increase in population density, which will exacerbate future effects of climate change on the health of the Mekong and Red River Deltas.[lxii]

River Delta	Country	Population at Risk	% of Delta Population at Risk	% Delta Area Potentially Lost
Chao Phraya	Thailand	12,300	0.01	0.34
Mahakam	Indonesia	64,800	7.06	6.29
Mekong	Vietnam	1,910,000	6.51	5.82
Red (Hong)	Vietnam	70,500	0.85	0.95

This table is **UNCLASSIFIED**

Table 2. Impacts associated with climate change on Southeast Asian river deltas in 2050. Source: Jason P. Ericson, Charles J. Vorosmarty, S. Lawrence Dingman, Larry G. Ward, and Michel Meybeck, "Effective sea-level rise and deltas: Causes of change and human dimension implications." *Global and Planetary Change* 50 (2006): 63-82.

Impacts of Natural Disasters

Natural disasters, such as floods, droughts, and typhoons, can have far-reaching impacts on a variety of sectors in Southeast Asia, including agriculture, water resources, coastal ecosystems, and infrastructure. The Philippines appears to be particularly susceptible to impacts associated with climate change-induced increases in natural disasters. The nation experiences a wide range of climate-related hazards, including tropical cyclones, floods, droughts, and landslides.[lxiii] As a result, flood-prone settlements, agricultural lands susceptible to drought, highly erodible and unstable areas on steep slopes, and grasslands and forests near settlements that are susceptible to fire have been identified as regions in the Philippines that are at risk from climate-change enhanced natural disasters.[lxiv]

Incidents of flooding have grown worse recently in the Philippine capital of Manila. Flooding in Manila is caused by a combination of climate-change induced sea level rise (1 to 3 mm per year), land subsidence (3 to >10 mm per year) associated with over-extraction of groundwater, and natural deltaic subsidence. Currently, even moderate rains can cause flooding in the Manila area, and some locations are left inundated for weeks or months at a time.[lxv]

Impacts on Water Resources

Climate change is expected to impact the supply and quality of fresh water in Southeast Asia, which in turn will have far-reaching impacts on agriculture, coastal ecosystems, and population growth. Heavy seasonal monsoon rainfall in Southeast Asia provides abundant fresh water, but increases in agricultural use, inadequate planning and misuse, and deforestation have led to water shortages in recent years, particularly in dry seasons.[lxvi] Climate change will likely exacerbate these effects. Recent observed increases in temperature have already contributed to increased evapotranspiration in water bodies, which results in decreased fresh water availability.

Much of Southeast Asia's water supply and water quality are sensitive to small changes in the frequency and distribution of precipitation. Recent changes in precipitation patterns have already been linked with increases in runoff, erosion, flooding, and associated impacts on surface water and groundwater in Southeast Asia.[lxvii] Climate change-induced variations in precipitation patterns, such as delays in the onset of the monsoon or a shift toward heavier, less frequent precipitation events, are therefore expected to have significant impacts on water resources in the region.[xxxiv] Falling water levels in many constructed reservoirs, associated with changes in precipitation patterns and droughts in ENSO years, have already led to decreased water availability and decreased hydroelectric power production.[lxviii]

Fresh water resources on island nations of Southeast Asia are especially vulnerable to any variability in precipitation because many island populations rely on rainwater collection for their supply of fresh water. Droughts that are associated with periodic ENSO events disrupt fresh water supplies, and any increase in frequency or intensity of droughts associated with future climate change could have severe impacts on water resources.[lxix] Watersheds on the island of Java are more vulnerable to the effects of climate change than other islands in Indonesia.[lxx] Although not an island, Singapore is also vulnerable to variability in precipitation patterns, because its water supply is based upon reservoirs which are significantly impacted by short-term decreases in precipitation.[lxxi]

Impacts on Agriculture

Agriculture is a major component of the economy in many nations of Southeast Asia. Recent increases in population and incomes have changed demands for agricultural products, which has led to increases in production of domestic consumption crops, such as grains and animal feed, and industrial crops, such as palm oil and natural rubber. These changes have been accompanied by the conversion of huge areas of land for agricultural purposes.

Future climate change will have a significant impact on agriculture in the region, particularly rice and corn production. Rice is the most important food crop across Southeast Asia and accounts for more than 80 percent of total grain production in nearly every country in the region;[lxxii] corn is also grown in some key locations, such as the Philippines. Rice and corn crops are very susceptible to climate variability, particularly due to flooding, tropical cyclones, El Niño-induced droughts, and the salinization of coastal waters.[lxxiii] For example, for the period 1968-1990, 48 percent of the losses in rice and corn production in the Philippines were caused by tropical cyclones and floods, 33 percent were caused by drought, and 18 percent were caused by weather-related incidents of pests and diseases.[lxxiv]

In theory, temperature increases associated with climate change should cause a northward expansion of growing areas and a lengthening of the growing season. Rising atmospheric CO_2 levels are expected to stimulate plant photosynthesis, which would result in higher crop yields. However, increased heat stress on plants in a warmer climate may negate the effects of higher CO_2 levels, since plants are very sensitive to air temperature. Many crops in the tropics are already grown in conditions near the maximum temperatures they can endure, and even small changes in temperature will decrease their productivity.[lxxv] For example, Peng et al[lxxvi] found that during the period 1979-2003, a 1°C increase in growing season minimum temperature during the dry cropping season (January – April) decreased rice yield by 10 percent at Laguna, Philippines. Higher minimum temperatures may benefit some crops, however, particularly those in upland regions and higher latitudes. Any increases in coastal or river delta flooding and salinity intrusion due to climate change will likely reduce future crop yields.

In an attempt to quantify the effects of climate change on crop yield in Southeast Asia, several researchers have used GCM climate simulations in conjunction with crop models. Matthews et al[lxxvii] investigated the possible changes on rice production in Asia caused by increases in atmospheric CO_2 and temperature due to climate change using the GFDL, GISS, and UKMO GCMs. The models were run using 300 ppm (GFDL, GISS) and 323 ppm (UKMO) of CO_2 as a baseline concentration (1×CO_2), and future climate change was simulated as 2×CO_2. Changes in rice crop production were estimated using two rice crop simulation models in conjunction with the GCMs. The crop models were calibrated for the *indica* rice ecotype that is prevalent in Indonesia, Malaysia, the Philippines, and Thailand. Overall, results indicated that rice yields across Asia are directly correlated with atmospheric CO_2 concentrations but indirectly correlated with temperature. In Southeast Asia, the models predicted clear increases in total rice production of up to 25 percent for Indonesia and Malaysia, compared to 1993 production levels. Model predictions were split for the Philippines and Thailand, however, with a modest increase in rice production of approximately 6-14 percent predicted by the GFDL model and a decrease in rice production of approximately 1-12 percent predicted by the GISS and UKMO models. These results suggest that the enhancing effect of increasing atmospheric CO_2 concentrations on rice growth is likely to be more important in Indonesia and Malaysia, while the negative effect of increasing temperatures on rice growth is likely to dominate in the Philippines and Thailand.

Buan et al[lxxviii] studied the potential effects of climate change on rice and corn crops in the Philippines using the CCCM, GFDL, GISS, and UKMO GCMs in conjunction with rice and corn crop models. The GCMs simulated changes in total rainfall, solar radiation, and maximum and minimum temperature for the first and second cropping seasons at six locations in the Philippines based on 2×CO_2. The six sites used in the study represented the major rice and corn growing areas in the Philippines, with a range in elevation of 22-302 meters above sea level. The GCMs predicted an increase in temperature at all six sites for both cropping seasons, but estimations of rainfall and solar radiation varied by model, location, and cropping season. Model results projected consistent decreases in corn yield of approximately 11-15 percent at all locations for both cropping seasons, but the predictions of changes in rice production were very inconsistent, with increases at some locations and decreases at others.

Amien et al[lxxix] studied the effects of climate change on rice yields in Java, Indonesia, through 2050 using the GISS GCM in conjunction with a rice crop growth simulation model. Rice is a staple food in Indonesia, and approximately 60 percent of rice grown in the country comes from the fertile volcanic ash soils on Java.[lxxx] Analysis focused on Ngawi in East Java, an inland location on the flood plain of the Bengawan Solo River, and Sukamandi in West Java, a lowland coastal location. These sites are two principal rice production areas in Indonesia. Climate change was represented in the GCM by 2×CO_2 equal to 555 ppm. The GISS simulations predict that in the 2030s decade, monthly rainfall at Sukamandi and Ngawi will increase by 10.3 percent and 6.2 percent, respectively; maximum temperature will increase by 7.2 percent and 6.9 percent, respectively; and solar radiation will increase by 1.1 percent at both locations. Based on these projected changes in meteorological conditions, rice yield at Sukamandi is expected to decrease by 18 percent in normal years and remain unchanged in El Niño years; at Ngawi, rice yield is expected to decrease by 17 percent and 11 percent in normal years and El Niño years, respectively.

In a follow-up study, Amien et al[lxxxi] continued their analysis of rice yields in Java, Indonesia, using the GFDL and UKMO GCMs in addition to the GISS GCM. Analysis shifted to Mojosari in East Java, an inland site on the flood plain of the Brantas River, and Pusakanegara in West Java, a lowland coastal site. As in their previous study, climate change was represented in the GCMs by 2×CO_2 equal to 555 ppm. Climate projections from the GCMs were incorporated into a crop growth simulation model to determine the effects on crop yield. Rice yield results were similar to the earlier study, with reductions in yield predicted in both East and West Java due to climate change, although higher yield reductions were projected due to natural interannual climate variability, such as that associated with ENSO. The authors concluded that adoption of heat-tolerant rice varieties by farmers in Indonesia could compensate for expected yield losses due to climate change.

Most recently, Naylor et al[lxxxii] investigated the potential effect of climate change on rice agriculture in Indonesia through 2050 using a suite of GCMs and a risk assessment model. Analysis focused on the regions of West/Central Java and East Java/Bali, which account for approximately 55 percent of Indonesia's annual rice production. The authors examined the impact of climate change on natural climate variability, particularly ENSO. El Niño events typically cause a delay of up to 2 months in the onset of the monsoon in Indonesia, which delays planting of the rice crop. As a result, a 30-day delay in monsoon onset was selected as a critical threshold in the study.

Analysis of observed data for 1983-2004 showed that the probability of a 30-day delay in monsoon onset was 18.2 percent for West/Central Java and 9.1 percent for East Java/Bali, which corresponded to 11 percent and 6.5 percent reductions in rice production, respectively. The authors used a set of 20 empirically downscaled CCMs from the IPCC MMD to simulate future changes in precipitation under the A2 and B2 emissions scenarios through 2050. Results showed that, in most cases, a delay in monsoon onset is likely to occur more frequently in 2050 than it has for the past 30 years. For example, under the A2 scenario, the probability of a 30-day delay in monsoon onset in 2050 is expected to be 23-33 percent for West/Central Java and 19.8-40 percent for East Java/Bali. Model projections also suggested that there will be about a 10 percent increase in precipitation later in the crop year (April – June) and a large decrease of up to 75 percent in precipitation later in the dry season (July – September), which could have serious negative consequences for rice agriculture in Indonesia.

As these modeling studies demonstrate, crops in Southeast Asia are very susceptible to drought, flooding, and storms associated with natural interannual climate variability caused by ENSO. In recent years, delayed onset of the rainy season, by up to a month in ENSO years, has been observed to cut rice yields by up to 11 percent in parts of Indonesia.[lxxxiii] Potential increases in the frequency and severity of climate extremes under future climate change are expected to cause greater losses, which will be exacerbated if extremes occur during critical stages of crop growth. In order to address these issues, Lansigan et al[lxxxiv] investigated the potential impacts of climate extremes on agriculture by comparing crop-sowing yields for El Niño and non-El Niño years in the Philippines. Results indicated that during El Niño years, the variability in weather patterns moved the sowing date for rice (normally near Julian day 173) to as early as Julian day 137 (mid-May) or as late as Julian date 229 (mid-August), representing a major change in the cycle of planting and harvest. Results also showed that the variability of precipitation in El Niño years reduced crop yield. Typically, an El Niño year was marked by a shorter, more intense wet season, which decreased crop growing time, subjected crops to stress from excess water, and consequently caused a crop loss of 52-81 percent. High temperatures also significantly decreased rice production, particularly if they occurred during early phases of development.

Crop water requirements were significantly altered under El Niño regimes, because changes in temperature and precipitation altered rates of plant evapotranspiration. In the Philippines, results showed that El Niño was associated with a 20-50 percent reduction in rainfall, requiring increased crop irrigation. These results are consistent with the modeling simulations of Amien et al[lxxxv] that projected similar changes on rice yields in Java, Indonesia due to ENSO-related climate variability. Thus, it is likely that natural climate variability will continue to cause significant impacts on Southeast Asian agriculture in coming decades, and any increases in the frequency or severity of climate variability due to climate change will serve to aggravate these natural effects.

On a more local scale, a recent study[lxxxvi] found that water availability is the key parameter affecting mangosteen growth in Thailand. Higher mangosteen yields are associated with increased water available to plants during fruiting, which suggests that impacts on precipitation associated with future climate change will be important for the mangosteen industry.

Increases in temperature have also been related to increased outbreaks of agricultural pests and diseases, such as rice stem borers and twisting disease. Climate change is expected to exacerbate these outbreaks and necessitate the more frequent use of stronger pesticides to protect crops.[lxxxvii]

Impacts on Forests and Biodiversity

In 2005, the biologically diverse forests of Southeast Asia represented 5.1 percent of the total forest area in the world, and they were a major source of global forest products, accounting for 50 percent of total forestry exports from Asia and the Pacific.[lxxxviii] Degradation and unsustainable practices, such as illegal logging and conversion of native forests to palm oil plantations or agricultural lands, have made many Southeast Asian forests particularly vulnerable to climate change. Burning and clearing of forests has increased the likelihood that they will not be able to adapt to projected changes in temperature and precipitation. The combination of human stresses and climate change is expected to increase the incidence of forest fires and make recovery from fires more difficult.[lxxxix] In addition, habitat destruction in Asian boundary forests is increasing. Individual plant and animal species are often located in narrow bands of suitable environmental conditions, and their ability to tolerate new conditions associated with climate change will determine their future survival.[xc]

Teak wood is an important economic product in Indonesia and the Philippines, and the teak tree is known to be especially sensitive to increases in temperature and changes in precipitation. Such dependence of individual species on existing climate conditions is a major threat to forest health, as flora, fauna, and pests are expected to adapt at different rates, and with varying levels of success.[xci] Overall, climate change is expected to transform the types and species of forest vegetation in Indonesia.[xcii]

Although variations in temperature and precipitation due to future climate change will impact forests across Southeast Asia, only a few limited studies are available that project the potential effects on specific species and regions. Boonpragob and Santisirisomboon[xciii] investigated the potential changes in forest type and distribution in Thailand due to climate change using the UK89, UKMO, and GISS GCMs. The models were run using 320 ppm of CO_2 as a baseline concentration ($1\times CO_2$), and future climate change was simulated as $2\times CO_2$. Model projections indicated that increases in temperature and variations in precipitation in Thailand due to climate change will reduce areas of subtropical forest and subtropical wet forest, and increase the areas of tropical dry forest, tropical moist forest, and tropical wet forest. Overall, the model simulations suggested that climate change will likely cause the expansion of tropical dry forest into subtropical moist forest in the northern part of the country, and the cause replacement of subtropical forests with tropical forests in the southern part of the country.

Koskela[xciv] examined the effects of predicted climate change on the growth rate of Merkus pine trees in Thailand. Merkus pines grow across Southeast Asia at elevations less than 1200 meters, including parts of Thailand, Laos, Cambodia, Vietnam, and the Philippines. Koskela used a gas-exchange model to estimate changes in trees' gross photosynthesis, transpiration, and stomatal conductance, and a carbon- and nitrogen-balance model to simulate the growth of young trees. The models were run under several climate change scenarios involving variations in temperature, precipitation, and atmospheric CO_2. The models were used to simulate Merkus pine growth rate changes at two representative locations in Thailand: Ban Wat Chan, a high-altitude site in the northern highlands and Surin, a low-altitude site on the northeastern Khorat Plateau. Results showed that rising temperature and atmospheric CO_2 levels associated with climate change are expected to increase annual photosynthesis and transpiration rates in pine seedlings, and cause concurrent large increases in total tree biomass and height. These results suggest that future climate change could enhance growth of Merkus pine trees and shorten the seedling stage. The author noted that actual tree growth in the future will be dependent on rainfall variability, since prolonged periods of drought could offset any enhancement in tree growth due to higher atmospheric CO_2 levels.

Booth et al[xcv] assessed the possible effects of climate change through 2050 on two tree species in Vietnam using a climatic mapping program model, a simple plant growth simulation model, and a process-based tree growth simulation model. Each model was run under a range of climate change scenarios involving variations in temperature, precipitation, evapotranspiration, and atmospheric CO_2. The authors analyzed two tree species that they considered to be representative of those important for forestry in Vietnam: *Styrax tonkinensis*, a native species used for pulp and perfume ingredients, and *Acacia mangium*, an introduced species used for pulp and fuel. Results from the climatic mapping program indicated that areas in Vietnam which are climatically suitable for growing *S. tonkinensis* will likely decrease as a result of future climate change. The simulation models projected that increases of 1-2°C in mean annual temperature in the vicinity of Hanoi will decrease *S. tonkinensis* growth rate by approximately 5-22 percent, since the species is not well adapted to warmer growing conditions. The authors noted that it was not possible to identify which of the four variables modeled in their study—temperature, precipitation, evapotranspiration, or atmospheric CO_2—had the most dominant effect on plant growth under future climate change conditions. They concluded that climate change is likely to cause significant alterations in the Vietnamese forestry industry, and these effects will be related to shifts in suitable growing regions rather than variations in tree yield.

Changes in forestry and vegetation due to climate change will likely impact species biodiversity in Southeast Asia. To investigate the possible future changes in global biodiversity, Malcolm et al[xcvi] calculated changes in habitat areas and associated extinctions of endemic plant and vertebrate species in 25 biodiversity "hotspots," including the Philippines. The authors used a suite of 14 GCMs run under conditions of $2\times CO_2$ in conjunction with two global vegetation models. Biodiversity hotspots were defined as regions that are home to a large number of the world's species per unit land area and have suffered significant natural habitat loss. Biomes (vegetation types) were used as proxies for natural habitats in the study. Modeled habitat loss for the Philippines was 3-32 percent and associated mean required migration rate was 59-736 meters per year, depending on the vegetation model and biome type. Although these changes in habitat area and migration rate are from one limited study for a specific area in Southeast Asia, the results suggest that climate change likely poses a threat to biodiversity in the region.

Impacts on Coastal Ecosystems

Rapid development of coastal megacities has led to highly concentrated population surges and economic activity in recent years, with roughly 80 percent of the population of Southeast Asia living within 100 km of the coasts in 2005. Coastal regions are major contributors to the regional economy because they are central to tourism, fishing, and aquaculture.[xcvii]

Mangroves are a key component of Southeast Asian coastal ecosystems that will be affected by future climate change. Mangroves are critical to the region because they provide habitats for fish, help maintain coastal water quality, protect shorelines from erosion and storm surges, and provide products and services for human communities. Because of their importance, mangroves are very valuable. For example, the value of Malaysian mangroves for storm protection and flood control is estimated at US$300,000 per kilometer of coastline, based on the cost of replacing the mangroves with rock walls.[xcviii]

There are several climate change-related effects that are expected to impact mangroves, both positively and negatively. Sea level rise will impact mangroves to some degree, depending on the rate of mangroves' ability to migrate landward to maintain their preferred hydroperiod. Increases in intensity and frequency of storms related to climate change may intensify damage to mangrove forests through defoliation, stress, and soil impacts. Increased precipitation in tropical areas due to climate change may increase mangrove range and biodiversity. In addition, mangroves are likely to experience increased growth rates in response to increased atmospheric CO_2 levels.[xcix]

On Olango Island in the Philippines, climate change is expected to cause destruction of mangroves, deaths of coral reefs, and loss of feeding grounds for migratory birds.[c] Other ecosystem impacts in the Philippines associated with future climate change include coral bleaching, seaweed and sea grass impacts, shoreline erosion, and aggravation of marine diseases. Ecosystem effects will be driven by changes in ocean circulation, marine biogeochemistry, and increasing sea surface temperatures.[ci]

Along the Vietnam coast, climate change is expected to result in loss of habitats for many rare and endemic species; destruction of coral reefs, mangroves, and sea grass beds; and a resulting decrease in living resources for residents.[cii]

Increases in temperature are also projected to negatively impact fishing and aquaculture, with decreased abundance of large predator fish and significant decreases in the viability of fish larvae in warmer waters.[ciii]

Impacts on Coral Reefs

Sustainable fisheries and coral reef systems are critical to the livelihoods of millions of people across Southeast Asia. The region has more coral reefs than any other part of the world, with a total of over 100,000 km^2, equivalent to 34 percent of the world's total. The reefs have substantial economic importance—the value of the region's sustainable coral reef fisheries alone is estimated at US$2.4 billion per year. Coral reefs are also important for food security, employment, tourism, pharmaceutical research, and shoreline protection.[civ]

Increases in atmospheric CO_2 concentration associated with climate change affect ocean water chemistry and have a direct impact on the growth of corals. Silverman et al[cv] studied these effects using a coupled climate/carbon cycle model. Coral reefs grow by precipitating calcium carbonate ($CaCO_3$) from ocean water, but the chemistry of the oceans is being changed by rising atmospheric CO_2 levels that are causing the oceans to become more acidic. Results from the model study show that most coral reefs are currently precipitating 20-40 percent less $CaCO_3$

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compared to pre-industrial times, and reefs located in the warm water pool of the Western Pacific show the strongest response to changes in water chemistry and temperature associated with climate change. When atmospheric CO_2 concentrations reach 560 ppm, which represents a doubling of CO_2 levels since pre-industrial times, all coral reefs are expected to stop growing and begin to dissolve. Present atmospheric CO_2 concentrations are approximately 380 ppm, and if emissions continue at the current rate, atmospheric levels will reach 560 ppm by the mid-22nd century.[cvi] The potential widespread reduction in the number and extent of coral communities due to the climate change-induced decline in coral skeleton growth rates will have devastating impacts on coastal marine ecosystems and the various industries that are dependent on coral reefs.

Increasing sea surface temperatures associated with climate change are also a significant threat to the health of coral reefs in Southeast Asia. Elevated sea surface temperatures cause coral bleaching, which is the loss of color due to stress-induced expulsion of algae or loss of pigmentation of algae within the corals. The 1997-1998 ENSO caused the largest worldwide coral bleaching event ever recorded, damaging or destroying an estimated 18 percent of Southeast Asia's coral reefs. An increase in ocean water temperatures of only 1-2°C above the normal threshold temperature for a few weeks can cause a bleaching event, and extreme or prolonged temperature anomalies, such as those expected from future climate change, can cause significant coral mortality.[cvii] Increased temperatures in recent years have significantly increased coral reef bleaching in the region, notably in the vast and diverse reefs of Indonesia, the Philippines, and Thailand.[cviii]

Mass bleaching and mortality of corals has been widespread since the 1980s, but the magnitude varies significantly and is correlated with "hot spots" of sea surface temperature. Corals in accelerated warming regions will likely be impacted sooner than predicted by global climate change models. Impacts will be less severe and occur more slowly for corals in waters that are anomalously cooler than the global average, such as those around Indonesia.[cix]

The reefs of Southeast Asia, particularly near Indonesia and the Philippines, are already degraded by pollution, sediment-laden runoff, destructive fishing practices, and other human impacts;[cx] all of these effects will be compounded by climate change. Southeast Asian reefs do have several characteristics that make them more favorable for recovery compared to other ocean reefs, however, such as high levels of biodiversity, large-scale through-flow of Pacific Ocean water, and nearby reef systems to aid in reproduction. Impacts on humans as a result of coral damage and destruction due to climate change include lost or reduced tourism and fishery activities, and more difficult to quantify aspects such as shoreline damage.[cxi]

Guinotte et al[cxii] studied "marginal" coral reefs in the Pacific basin, which are those reefs considered to be living at the extremes of tolerable environmental limits. Results showed that corals in Southeast Asia that are most likely to become marginal due to increasing sea surface temperatures by 2069 are those in the Philippines, Gulf of Thailand, and Andaman Sea.

Recent country-specific impacts on coral reefs include the following:[cxiii]

- Thailand has an estimated 1,800 km^2 of coral reefs in the Gulf of Thailand and the Andaman Sea. Sea surface temperature increases along Thailand's coasts have been particularly pronounced, such as near Phuket, where the sea surface temperature increased at a rate of more than 0.02°C per year between 1981 and 1999. As a result of the warming waters, coral reefs along Thailand's coasts have experienced significant bleaching episodes, especially in the Gulf of Thailand. Existing pressures due to economic development, such as sedimentation and wastewater pollution associated with tourism, are expected to compound climate change pressures on reefs. Some coral reefs around small islands are currently under only minimal threat from existing pressures.

- The coral reefs of Cambodia and Vietnam are some of the most threatened in Southeast Asia; over 95 percent are threatened by existing pressures such as overfishing, land use changes, and high population density.
- There are over 350 species of coral in Malaysia. Over 85 percent of Malaysia's reefs are currently threatened by existing pressures such as shipping lanes, harmful fishing practices, and land use changes.
- Singapore has many fringing and patch reefs around both its main island and small offshore islands. Singapore's total coral reef area is estimated to be about 54 km^2 and includes more than 197 hard coral species. These reefs are also some of the most threatened in Southeast Asia, with over 95 percent threatened by existing pressures, including land reclamation and development.
- Indonesia has approximately 51,000 km^2 of coral reefs, and over 85 percent are currently threatened by existing pressures such as overfishing and land use changes. Indonesia's coral reefs provide annual economic benefits estimated at US$1.6 billion per year. The greatest diversity of coral reef fish in the world is found in Indonesia, with more than 1,650 species in eastern Indonesia. Monitoring shows that the nation's reef conditions are currently declining. The 1997-1998 El Niño killed up to 95 percent of coral around certain Indonesian islands. Some areas have rebounded remarkably, possibly due to anomalously cooler waters in the area around Indonesia.
- The Philippines' coral reefs are severely threatened by existing pressures including overfishing, destructive fishing practices, agriculture, and aquaculture. The Philippines' approximately 26,000 km^2 of coral reefs contain extremely diverse species, and they provide annual economic benefits estimated at US$1.1 billion per year. The first ever mass-bleaching event in the Philippines was reported in 1998-1999; it proceeded nearly clockwise around the Philippines and was correlated with anomalously high sea-surface temperatures.

Impacts on Diseases and Human Health

Climate-related health risks in Southeast Asia include increases in vector-borne disease, heat stress, food stress, and air pollution. Studies suggest that disease outbreaks in the region, including malaria, dengue, diarrhea, and cholera, are linked with climate events such as droughts and floods, which are in turn strongly related to ENSO events. Changes in temperature and precipitation patterns have already been linked to increases in dengue fever and malaria in Indonesia, Thailand, and Vietnam.[cxiv]

Mosquito populations will be affected by variations in temperature and precipitation associated with future climate change, and thus the incidence of mosquito-borne diseases such as dengue fever and malaria are likely to be affected as well. Environmental conditions strongly influence the growth and survival of mosquitoes. The optimum temperature range for mosquito survival is 20-25°C, and rainfall is critical for mosquito reproduction because standing water is necessary for several of their life stages. Flooding due to excessive precipitation however, can disrupt mosquito larvae development.[cxv]

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Hopp and Foley[cxvi] modeled the response of *Ae. aegypti*, the principal mosquito carrier of dengue fever, to observed climate variations for the period 1958-1995 in order to determine how future climate change may impact the incidence of worldwide dengue fever cases. They found that there was a strong relationship between mosquito larvae density and temperature, precipitation, and relative humidity. Results showed that for countries in Southeast Asia, cases of dengue fever are strongly dependent on climate-induced variations in mosquito densities. As a result, it is likely that increases in temperature and precipitation expected from future climate change in Southeast Asia will cause increased incidence of dengue fever across the region, in the absence of preventive measures to control the spread of the disease.

Martens et al[cxvii] conducted a similar study that investigated the potential impact of global climate change on malaria risk. The authors predicted changes in malaria epidemic potential for the 21st century by using temperature and precipitation output from the UKMO GCM run under two emissions scenarios in conjunction with an integrated linked-system model. Analysis focused on the *P. vivax* and *P. falciparum* mosquito species. The authors concluded that temperature and precipitation are the main climate variables that affect malaria transmission. Model results indicated that the incidence of malaria infection is sensitive to future climate change in Southeast Asia, and as a result, an increased rate of malaria infection is likely across the region in the 21st century.

Projected increases in flooding due to changes in precipitation patterns and sea level rise are expected to increase the risk of water-borne disease such as dermatosis, amoebiasis, cholera, giardia, shigellosis, and typhoid. Residents of Southeast Asia already have higher risks of mortality and morbidity from water-borne diseases than in many other parts of the world, and climate change is expected to exacerbate these risks.[cxviii]

Heat is also a public health threat, especially among the elderly and very young. Chronic exposure to excessive heat has been linked to increased incidence of cardiovascular and respiratory diseases. Researchers have noted that humans may be capable of adapting to heat associated with climate change, but the response time cannot be predicted.[cxix]

A recent study[cxx] found that human health impacts from climate change in the Philippines include blooms of toxic marine micro-organisms which can lead to dietary constraints and even poisoning, increases in heat stroke and vector-borne diseases, and population dislocation. Although this study was focused on the Philippines, the impacts are applicable across the Southeast Asian region.

Impacts on Electricity Demand in Urban Areas

Future increases in temperature and relative humidity associated with climate change will impact electricity demand across Southeast Asia, particularly in urban areas where air conditioning is more common. In order to determine the effect of climate change on temperature and associated electricity demand in Thailand through 2080, Parkpoom and Harrison[cxxi] ran the HadCM3 general circulation model under four integrations that corresponded to the A1, A2, B1, and B2 emissions scenarios. These four scenarios were selected in order to represent the range of future socioeconomic developments in Thailand. Model analysis focused on the Bangkok metropolitan area, since 70 percent of Thailand's electricity demand is concentrated there. An initial linear regression analysis found that temperature is the most significant weather variable that affects electricity demand in Thailand. The model simulations were run to predict temperature increases due to climate change, and that information was fed into an electricity demand sensitivity model in order to estimate the concomitant increases in electricity demand. Results showed that annual mean temperature is expected to increase by approximately 0.46-0.67°C in the 2020s (2011-2040) and 1.1-1.9°C in the 2050s (2041-2070) in Thailand under the four climatology scenarios. These temperature increases translate into an expected increase in peak electricity demand of 1.0-3.1 percent in the 2020s and 2.8-8.5 percent in the 2050s, with the highest demand during the summer season. Variations among model output corresponding to the four climatology scenarios became more pronounced as time increased. The authors concluded that the potential changes in electricity demand predicted by the model runs are significant and likely necessitate substantial investment in electrical power plant capacity to meet future demand. Nevertheless, these projected increases may only be a small portion of what is expected to occur over the next few decades due to economic development. For example, electricity consumption in Malaysia has been increasing on the order of 4-8 percent per year since 2001, and this rate is expected to continue.[cxxii] Thus, a 1-8 percent increase in electricity demand in Thailand over the next 60 years associated with climate change may be only a small fraction of the total increase in demand due to general economic development, urbanization, and increases in manufacturing.

Impacts on Human Livelihoods and Infrastructure

Livelihoods in many parts of Southeast Asia, particularly in less urban areas, are heavily dependent on natural resources. Whether derived from fisheries, coral reefs, forests, agriculture, or tourism, residents are sensitive to impacts on these natural resources from climate change.[cxxiii]

In the Philippines, climate change will heavily impact coastal-dwelling Filipinos, who are highly dependent on coastal resource related livelihoods, such as fishing, seaweed cultivation, aquaculture, shell collecting, and tourism.[cxxiv] Population resettlement options in Manila are hindered by residents' strong cultural connections to lifelong homelands, particularly among impoverished populations.[cxxv]

Climate-related increases in sea level and ecological perturbations related to extreme weather events will compound anthropogenic and climate change-related pressures, such as shortages in drinking water on small islands. These pressures could increase human migration to the mainland or larger islands.[cxxvi]

Coastal erosion and inundation of coastal zones has increased across the region in recent years, damaging infrastructure and natural resources. Thailand's coastline is already observed to be eroding at a rate of 15-25 meters per year in some places.[cxxvii] In Indonesia, adaptation to new livelihoods and resettlement as a result of increased coastal inundation associated with sea level rise will be particularly difficult for very low-income households with little social safety net and other cultural constraints. Impacts from inundation include physical damage to houses, and social damage such as interruption of school and commerce. In the city of Makassar, for example, the estimated damage to 4,000 houses from sea level rise in 2000-2002 was approximately US$11 million. Entire sections of communities in coastal Indonesia are already being abandoned because of frequent inundation, often within "unplanned" housing communities containing highly impoverished residents. Climate change is expected to exacerbate these problems.[cxxviii]

Adaptive Capacity

The impacts of climate change will be felt differentially, depending upon how well a society can cope with or adapt to climate change. Adaptive capacity is defined by the IPCC[cxxix] as "the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences." Thus, adaptive capacity is distinguished from both climate change impacts and the degree to which those impacts affect the systems that are in place, as discussed in the previous sections.

Although the specific determinants (or "drivers") of adaptive capacity are a matter of debate among researchers, there is broad agreement that economic, human, and environmental resources are essential elements. Some components of this adaptive capacity are near-term, such as the ability to deliver aid swiftly to those affected by, for example, floods or droughts. Other components include a level of education sufficient for people to change livelihoods, a quantity of unmanaged land that can be brought into food production, and institutions that provide knowledge and assistance in times of change. For instance, Yohe and Tol[cxxx] identified eight qualitative "determinants of adaptive capacity," many of which are societal in character, although the scientists draw on an economic vocabulary and framing:

1. The range of available technological options for adaptation.
2. The availability of resources and their distribution across the population.
3. The structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be employed.
4. The stock of human capital, including education and personal security.
5. The stock of social capital, including the definition of property rights.
6. The system's access to risk-spreading processes.
7. The ability of decisionmakers to manage information, the processes by which these decisionmakers determine which information is credible, and the credibility of the decisionmakers themselves.
8. The public's perceived attribution of the source of stress and the significance of exposure to its local manifestations.

The Adaptive Capacity of Southeast Asia in a Global Context

Researchers have only recently taken on the challenge of assessing adaptive capacity in a comparative, quantitative framework. A global comparative study[cxxxi] of resilience to climate change (including adaptive capacity) was conducted using the Vulnerability-Resilience Indicators Model (VRIM – see box on page 44).

Adaptive capacity, as assessed in this study, consists of seven variables (in three sectors), chosen to represent societal characteristics important to a country's ability to cope with and adapt to climate change:

Human and Civic Resources

- **Dependency ratio:** proxy for social and economic resources available for adaptation after meeting basic needs.
- **Literacy:** proxy for human capital generally, especially the ability to adapt by changing employment.

Economic Capacity

- **GDP (market) per capita:** proxy for economic well-being in general, especially access to markets, technology, and other resources useful for adaptation.
- **Income equity:** proxy for the potential of all people in a country or state to participate in the economic benefits available.

Environmental Capacity

- **Percent of land that is unmanaged:** proxy for potential for economic use or increased crop productivity and for ecosystem health (e.g., ability of plants and animals to migrate under climate change).
- **Sulfur dioxide per unit land area:** proxy for air quality and, through sulfur deposition, other stresses on ecosystems.
- **Population density:** proxy for population pressures on ecosystems (e.g., adequate food production for a given population).

Methodological Description of the Vulnerability-Resilience Indicator Model (VRIM)

The VRIM is a hierarchical model with four levels. The vulnerability index (level 1) is derived from two indicators (level 2): sensitivity (how systems could be negatively affected by climate change) and adaptive capacity (the capability of a society to maintain, minimize loss of, or maximize gains in welfare). Sensitivity and adaptive capacity, in turn, are composed of sectors (level 3). For adaptive capacity these sectors are human resources, economic capacity, and environmental capacity. For sensitivity, the sectors are settlement/infrastructure, food security, ecosystems, human health, and water resources. Each of these sectors is composed of one to three proxies (level 4). The proxies under adaptive capacity are as follows: human resource proxies are the dependency ratio and literacy rate; economic capacity proxies are GDP (market) per capita and income equity; and environmental capacity proxies are population density, sulfur dioxide divided by state area, and percent of unmanaged land. Proxies in the sensitivity sectors are water availability, fertilizer use per agricultural land area, percent of managed land, life expectancy, birthrate, protein demand, cereal production per agricultural land area, sanitation access, access to safe drinking water, and population at risk due to sea level rise.

Each of the hierarchical level values is comprised of the geometric means of participating values. Proxy values are indexed by determining their location within the range of proxy values over all countries or states. The final calculation of resilience is the geometric mean of the adaptive capacity and sensitivity.

The adaptive capacities for a sample of 10 countries from the 160-country study are shown in Figure 7 for the base year of 2005. These countries represent a wide range of adaptive capacity; of note for the Southeast Asian region, Indonesia ranks 45th (high in the second quartile) and the Philippines ranks 91st (high in the third quartile). Any country-level analysis must take into account the comparative ranking of the country in the 160-country group.

Figure 8 shows the contribution of each variable in the model to the overall ranking of adaptive capacity. Slight differences occur in the contribution of the variables among the countries due to the overall methodology, as described in the box below. Indonesia ranks third because of its relatively high rankings in most areas; the exceptions are a very low ranking in GDP per capita and a moderately low ranking in non-managed land. The lower overall rank of the Philippines stems principally from low rankings in the equity index and dependency ratio.

Figure 9 shows projected adaptive capacity growth over time for the 10-country sample. Projections are made for two scenarios, with rates of growth based on the A1 emissions scenario. Both modeled scenarios feature moderate population growth and a tendency toward convergence in affluence, featuring market-based solutions, rapid technological progress, and improving human welfare. The scenarios used in this study differ in the rate of economic growth: one models high-and-fast economic growth and the other models delayed growth. In the delayed-growth scenario, Indonesia showed strong growth in adaptive capacity and is projected to

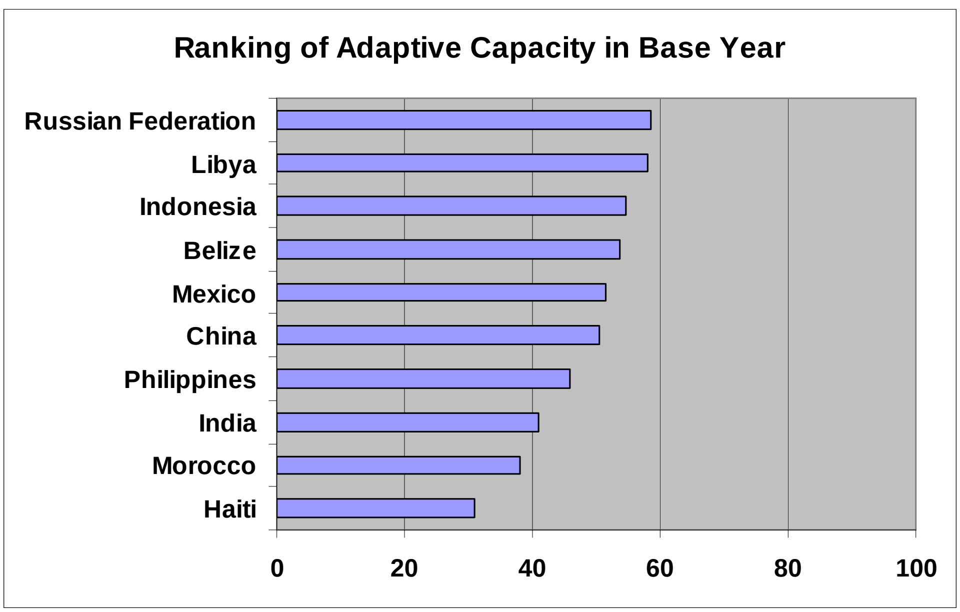

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Figure 7. Adaptive capacity for a sample of 10 countries for the base year of 2005. Source: Based on E.L. Malone and A.L. Brenkert, "Vulnerability, sensitivity, and coping/adaptive capacity worldwide," *The Distributional Effects of Climate Change: Social and Economic Implications*, M. Ruth and M. Ibarraran, eds., Elsevier Science, Dordrecht (in press).

overtake Libya by 2035. The Philippines showed good growth in adaptive capacity and is projected to catch up with Mexico by 2065. In the high-growth scenario, Indonesia ranks in the top three countries; however, China is predicted to move past Indonesia by 2020. By 2065, the model projects that the Philippines will have moved past Mexico and caught up to Belize.

Strengths and Weaknesses in Adaptive Capacity Assessments

Comparative measures of adaptive capacity, such as the model results outlined in the previous section, only allow analysts to ask improved, more focused questions about area or local conditions that can contribute to or reduce resilience. It is likely, for instance, that important variables or domains for particular sub-national areas are not included. For agricultural regions, a key domain might be the extent of irrigation; for urban areas, it might be better measures of education. In addition, the measure of unmanaged land does not account for the potential usefulness of that land. Comparative measures are an important first step toward determining the allocation of resources, either for further analysis or to address additional factors.

Specific Adaptive Capacity Considerations for Southeast Asia

Climate change is expected to exacerbate the effects of natural disasters, such as floods, droughts, and typhoons. Community-based disaster preparedness focuses on building adaptive and coping capacities at the local level, such as construction of flood control infrastructure and emergency shelters, and providing community training. A community-based disaster preparedness pilot project in the Philippines in 1998-1999 demonstrated the promise of this approach to overcoming impacts associated with climate change, while also highlighting the need to simultaneously increase local capacity and responsibility.[cxxxii] Expansion of this type of disaster preparedness program to other nations in Southeast Asia could help mitigate the expected impacts of climate change on the region.

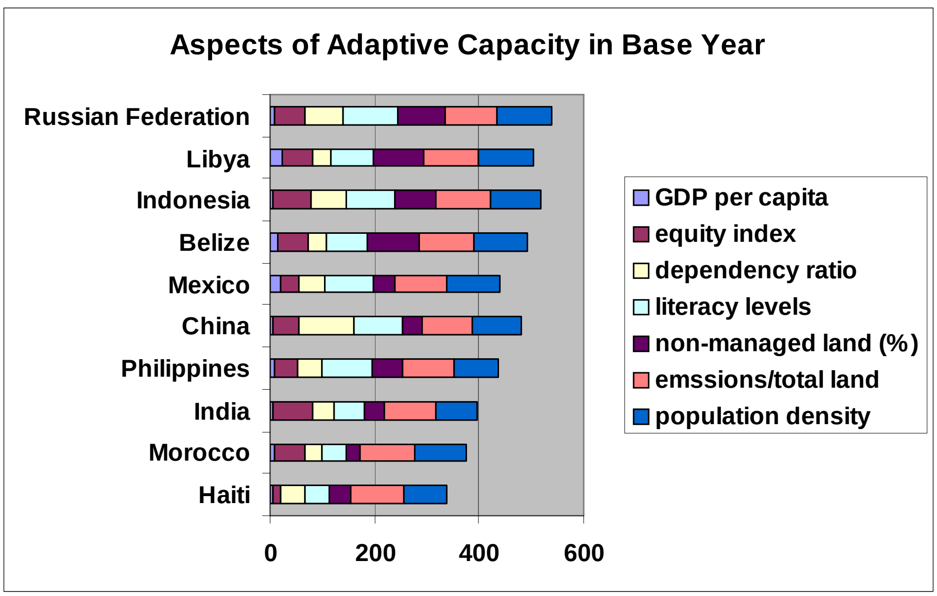

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Figure 8. The contributions of several variables to adaptive capacity rankings. Source: Based on E.L. Malone and A.L. Brenkert, "Vulnerability, sensitivity, and coping/adaptive capacity worldwide," *The Distributional Effects of Climate Change: Social and Economic Implications*, M. Ruth and M. Ibarraran, eds., Elsevier Science, Dordrecht (in press).

Many Southeast Asian countries are facing a water crisis due more to poor management than to water scarcity. Rapid industrialization and increases in population and wealth have led to dramatic increases in demands for water and energy in many Southeast Asian nations. With the additional stresses expected from climate change, Asian countries will need to consider new methods for water management to ensure sustainability of water resources for human and ecological requirements.[cxxxiii]

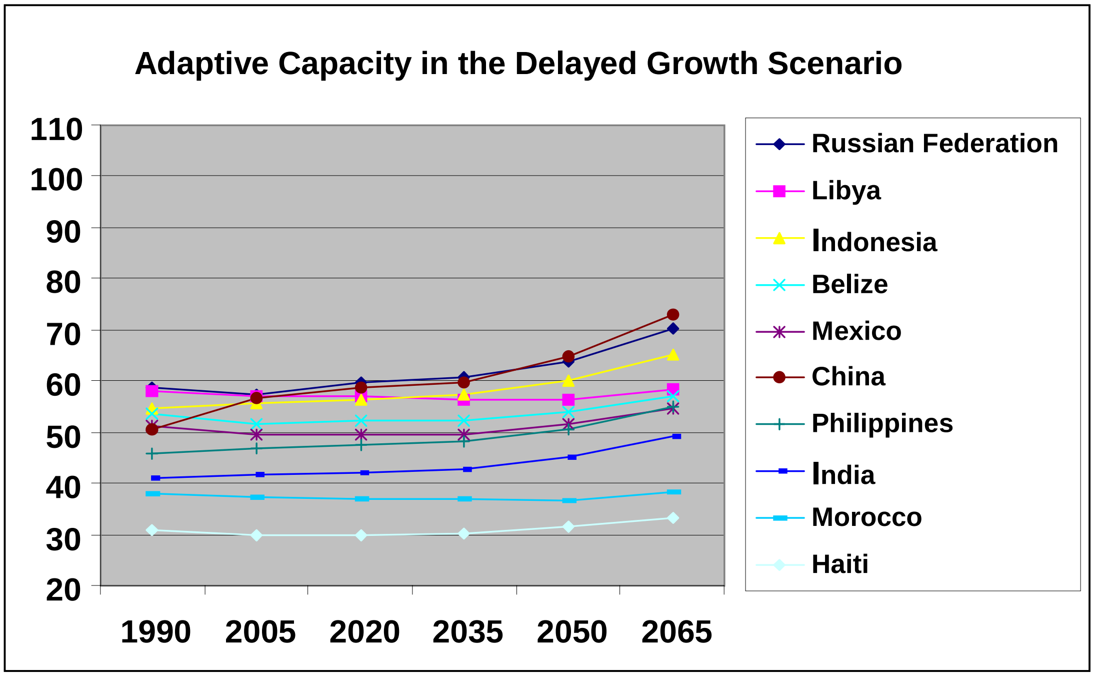
- The recent sustained regional economic growth of Southeast Asian countries is energy-intensive and has relied heavily on consumption of fossil fuels. International policy responses to global climate change in the next several decades may restrict use of fossil fuels,[cxxxiv] which will necessitate that Southeast Asian governments invest in development of alternative energy sources, such as solar and wind power.
- Improvement in the coordination of policy and planning to address adaptive capacity in Southeast Asia is vital because climate change will have impacts far beyond the purview of a single governmental ministry or organization. To improve adaptive capacity, inter-agency and inter-ministry coordination is required and must include integration with national disaster risk management.[cxxxv]
- A holistic approach to building adaptive capacity, which will include the needs of vulnerable groups and vulnerable locations, is recommended for Southeast Asia. Part of this holistic approach is the consideration of the potential impacts of adaptation measures. For example, a dam and reservoir may increase the adaptive capacity of one region, but it may negatively influence the adaptive capacity of downstream communities.[cxxxvi]

Summary of Possible Adaptive Strategies for Climate Change in Southeast Asia

The following adaptive strategies were recently summarized in a review report on climate change in the Asia/Pacific region.[cxxxvii] The effectiveness and suitability of these strategies will vary for the different countries in Southeast Asia, depending on national priorities and specific susceptibilities to the impacts of climate change, but all of these strategies are potentially relevant for the region.

Disasters and Emergency Management

- Diversify economic activity to reduce reliance upon climate-sensitive sectors
- Develop emergency management plans for climate hazards
- Develop early warning systems for extreme weather events (e.g., flood, cyclones, heat waves)
- Expand availability and use of risk-spreading institutions (e.g., insurance, government assistance)
- Identify critical activities and infrastructure for protection (e.g., health services, energy, transport, communication)



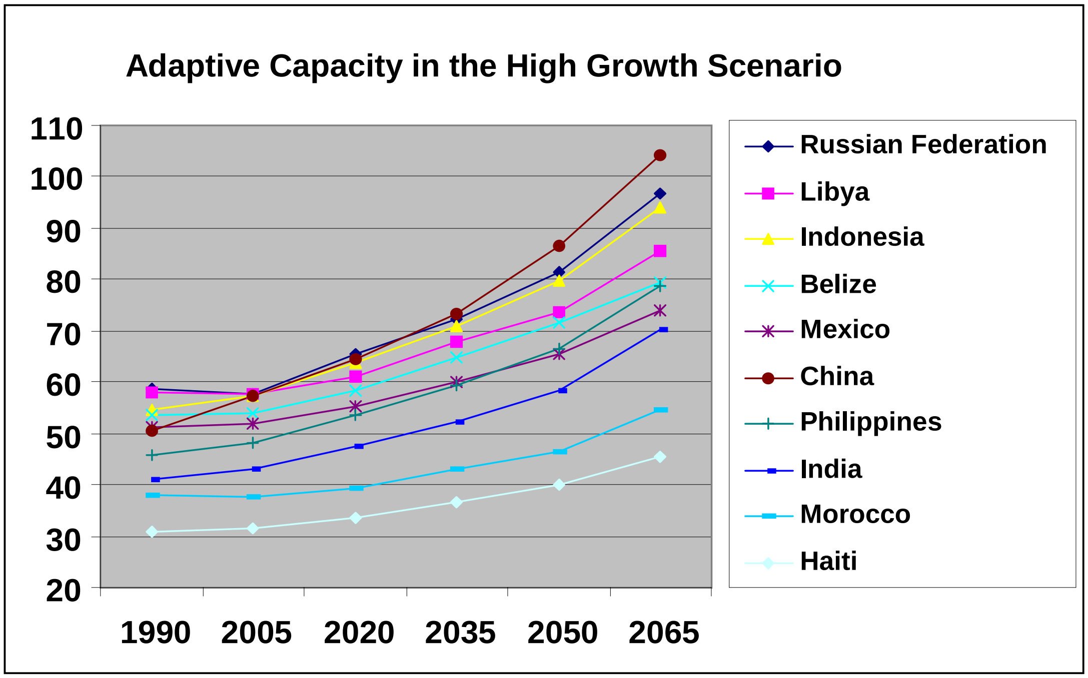


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Figure 9. Projections of adaptive capacity for 10 countries under a delayed growth scenario and a high growth scenario. Source: Based on E.L. Malone and A.L. Brenkert, "Vulnerability, sensitivity, and coping/adaptive capacity worldwide," *The Distributional Effects of Climate Change: Social and Economic Implications*, M. Ruth and M. Ibarraran, eds., Elsevier Science, Dordrecht (in press).

Water Resources

- Develop new water resources and storages (where possible)
- Invest in climate and catchment monitoring and research
- Rehabilitate existing water supply and transport systems
- Implement water management measures
- Increase recycling and reuse of waste water
- Invest in water saving technologies/methods

Agriculture

- Change farming practices
- Change timing of farm operations
- Use different crop varieties (i.e., heat resistant)
- Review governmental and institutional policies and programs
- Research new practices and technologies (e.g., land-use planning, biotechnology)
- Develop drought management and relief protocols

Forests and Biodiversity

- Establish conservation areas and networks
- Invest in natural resource management plans
- Manage land use to reduce environmental harm
- Identify at-risk ecosystems and species
- Develop aquaculture and plantation forestry instead of exploiting native resources

Coastal Communities

- Identify vulnerable areas, communities, and infrastructure
- Channel future development around "high," "moderate," and "low growth" areas
- Develop coastal zone management plans
- Construct new, or modify existing, coastal defenses
- Design infrastructure to accommodate sea-level rise
- Manage progressive retreat from the coastline

Public Health

- Develop early warning systems for extreme weather events (e.g., flood, cyclones, heat waves)
- Establish or bolster public health institutions

- Engage in research and development regarding disease transmission and prevention
- Improve access of individuals and communities to medical and public health agencies
- Provide education in disease prevention

Conclusions: High-Risk Impacts

There is overwhelming evidence that climate change will impact a variety of Southeast Asian sectors through 2030. The timing and magnitude of climate change impacts are difficult to quantify due to limitations in projections of future trends in temperature and precipitation in Southeast Asia. Studies using GCMs indicate that average annual temperatures across the region will rise by approximately 1°C through 2030, and they will keep rising through the remainder of the 21st century. The magnitude, location, and trends of future precipitation changes are much less certain, however, due to the inherent difficulty in modeling such changes. Future alterations in precipitation patterns associated with climate change are complicated by a strong natural variability in local climate, associated with ENSO, that routinely causes flooding and droughts across the region. Model simulations suggest that net precipitation rates will increase across Southeast Asia in the next 20 years, but there will likely be local decreases.

A recent study[cxxxviii] found that the areas in Southeast Asia that are most vulnerable to climate change are:

- All regions of the Philippines
- The Mekong River Delta in Vietnam
- Most regions of Cambodia
- North and East Laos
- The Bangkok region of Thailand
- West Sumatra, South Sumatra, West Java, and East Java in Indonesia.

The most high-risk impacts of climate change in Southeast Asia are related to fresh water and ocean water resources, due to the region’s heavy dependence on precipitation for supplies of fresh water and its close proximity to the ocean. All of the major effects of climate change on Southeast Asia are interrelated, so it is impossible to assess one impact independently of the others.

Sea Level Rise

- Sea level rose in the Southeast Asia region at rates up to 3 cm per year during 1993-2001, and GCM projections indicate that it will continue to rise up to 40 cm by the end of the 21st century.
- Since Southeast Asia is composed entirely of low-lying coastal and island nations, rising sea level causes a number of devastating effects, including saltwater intrusion into estuaries and aquifers, coastal erosion, displacement of wetlands and lowlands, degradation of coastal agricultural areas, and increased susceptibility to coastal storms.

- Impacts from sea level rise are interrelated with impacts on agriculture, natural disasters, river deltas, water resources, coastal ecosystems, human livelihoods and infrastructure, and national security.
- Sea level rise also has overarching socioeconomic impacts, due to loss in income associated with degradation of agricultural areas and loss of housing associated with coastal inundation, for example.

Water Resources

- Future changes in Southeast Asian water resources are closely tied to changes in precipitation.
- GCM results suggest that there will be a net increase in surface runoff across the region, but local trends will vary, with increases in some areas and decreases in others. Any areas that see an increase in runoff could experience an increase in erosion, flooding, and water pollution, while decreased runoff could lead to water shortages.
- Individual areas under severe water stress in Southeast Asia are projected to increase dramatically in the next few decades, although model results suggest that the region as a whole will not be at risk for water shortages.
- Fresh water resources on island nations of Southeast Asia are especially vulnerable to any variability in precipitation because many island populations rely on rainwater collection for their supply of fresh water.
- The management of water issues is one of the most challenging climate-related issues in Southeast Asia, as it is central to health and sustainable development.
- Water resource impacts are interrelated with impacts on agriculture, river deltas, forests, coastal ecosystems, diseases and human health, and national security.

Agriculture

- Agriculture is a major component of the economy in many nations of Southeast Asia, and there is no question that it will be significantly affected by climate change in the next 20 years.
- Assessment of specific agriculture impacts is challenging, because it is difficult for GCMs and crop models to reliably simulate the complicated effects of future variations in temperatures, precipitation, and atmospheric CO_2 concentrations on crop growth.
- Overall, it is likely that future crop yields will vary by region and by crop, with yield increases in some locations but decreases in others.
- Climate change-induced impacts on agriculture will be augmented by natural climate variability, especially due to ENSO, which is responsible for serious impacts on agriculture associated with droughts, floods, and severe storms.
- Management of the agricultural sector by Southeast Asian nations is critical to their economic growth and national security. Food shortages in the region, clearly associated with ENSO years in the past and projected to increase with changing climate, will stress poor populations across the region who are already susceptible to malnutrition.

- Agriculture impacts are interrelated with impacts on sea level, river deltas, natural disasters, and water resources.

Coastal Regions

- Coastal regions are some of the most at-risk areas for the impacts of climate change in Southeast Asia due to their prevalence and high population density.
- Many coastal areas in Southeast Asia are already degraded by pollution, sediment-laden runoff, and destructive fishing practices.
- Mangroves and coral reefs are two key coastal ecosystems that are expected to be significantly impacted by climate change. Destruction and degradation of mangroves and coral reefs will result in long-term economic repercussions for Southeast Asia, since these ecosystems are central to the tourism, agriculture, fishing, and aquaculture industries.
- Coastal regions obviously are susceptible to inundation associated with sea level rise and destruction of infrastructure from flooding and storm surges, which are likely to increase as a result of future climate change.
- Careful management and safeguarding of coastal regions by Southeast Asian governments is essential in the next 20 years, as the effects of climate change manifest themselves.
- Impacts on coastal regions are interrelated with impacts on sea level, river deltas, natural disasters, water resources, agriculture, forests, and human livelihoods and infrastructure.

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Annex A: Accuracy of Regional Models

This is an excerpt from IPCC Fourth Assessment Report, Working Group 1 Report, Chapter 11: Regional Climate Projections; see original text for references.[2]

11.4.2 Skill of Models in Simulating Present Climate

Regional mean temperature and precipitation in the MMD models show biases when compared with observed climate. The multi-model mean shows a cold and wet bias in all regions and in most seasons, and the bias of the annual average temperature ranges from –2.5°C over the Tibetan Plateau (TIB) to –1.4°C over South Asia (SAS). For most regions, there is a 6°C to 7°C range in the biases from individual models with a reduced bias range in Southeast Asia (SEA) of 3.6°C. The median bias in precipitation is small (less than 10 percent) in Southeast Asia, South Asia, and Central Asia (CAS), larger in northern Asia and East Asia (NAS and EAS, around +23 percent), and very large in the Tibetan Plateau (+110 percent). Annual biases in individual models are in the range of –50 to +60 percent across all regions except the Tibetan Plateau, where some models simulate annual precipitation 2.5 times that observed and even larger seasonal biases occur in winter and spring. These global models clearly have significant problems over Tibet, due to the difficulty in simulating the effects of the dramatic topographic relief, as well as the distorted albedo feedbacks due to extensive snow cover. However, with only limited observations available, predominantly in valleys, large errors in temperature and significant underestimates of precipitation are likely.

Southeast Asia

The broad-scale spatial distribution of temperature and precipitation in December-January-February (DJF) and June-July-August (JJA) averaged across the MMD models compares well with observations. Rajendran et al (2004) examine the simulation of current climate in the MRI coupled model. Large-scale features were well simulated, but errors in the timing of peak rainfall over Indochina were considered a major shortcoming. Collier et al (2004) assess the performance of the CCSM3 model in simulating tropical precipitation forced by observed sea surface temperature (SST). Simulation was good over the maritime continent compared to the simulation for other tropical regions. B. Wang et al (2004) assess the ability of 11 atmospheric general circulation models (AGCMs) in the Asian-Australian monsoon region simulation forced with observed SST variations. They found that the models' ability to simulate observed interannual rainfall variations was poorest in the Southeast Asian portion of the domain. Since current atmosphere-ocean general circulation models (AOGCMs) continue to have some significant shortcomings in representing El Niño- Southern Oscillation (ENSO) variability, the difficulty of projecting changes in ENSO-related rainfall in this region is compounded.

Rainfall simulation across the region at finer scales has been examined in some studies. The Commonwealth Scientific and Industrial Research Organisation (CSIRO) stretched-grid Conformal-Cubic Atmospheric Model (CCAM) at 80-km resolution shows reasonable precipitation simulation in JJA, although Indochina tended to be drier than in the observations (McGregor and Nguyen, 2003). Aldrian et al (2004) conducted a number of simulations with the Max-Planck Institute (MPI) regional model for an Indonesian domain, forced by reanalyses and

[2] Some references have been removed to avoid confusion.

by the ECHAM4 GCM. The model was able to represent the spatial pattern of seasonal rainfall. It was found that a resolution of at least 50 km was required to simulate rainfall seasonality correctly over Sulawesi. The formulation of a coupled regional model improves regional rainfall simulation over the oceans (Aldrian et al, 2004b). Arakawa and Kitoh (2005) demonstrate an accurate simulation of the diurnal cycle of rainfall over Indonesia with an AGCM of 20-km horizontal resolution.

Annex B: Knowledge Deficiencies that Preclude a Full Evaluation of Climate Change Impacts in Southeast Asia and Southeast Asia's Adaptive Strategies

To increase the likelihood that this report represents a reasonable assessment of the projections and impacts of future climate change in Southeast Asia, as well as the region's adaptive capacity, the following general data gaps must be addressed:

- In physical science research, regional analyses of climate change are limited by the inability of GCMs to model regional climates satisfactorily, including complexities arising from the interaction of global, regional, and local processes. For example, uncertainties in changing monsoonal activity and ENSO due to natural variations and anthropogenic emissions are important information gaps needed for accurate climate projections. A particularly critical modeling gap for Southeast Asia is the fact that GCMs cannot consistently project the magnitude and location of future precipitation on a country-specific scale. Another important data gap is the lack of reliable medium-term climate projections that can be used for planning adaptive strategies for the next 20-30 years. Similarly, scientific projections of water supply and agricultural productivity are limited by inadequate knowledge of various climate and physical factors. Research agendas in these areas can be found in, for instance, the synthesis and assessment reports of the US Climate Change Science Program (http://www.climatescience.gov) and the National Academy of Sciences (e.g., http://books.nap.edu/catalog.php?record_id=11175#toc). Similar issues exist for the biological and ecological systems that will be affected by future climate change.
- In social science research, scientists and analysts have only partial understandings of the important factors affecting vulnerability, resilience, and adaptive capacity. As with the physical science data gaps, research agendas on vulnerability, adaptation, and decision-making abound (e.g., http://books.nap.edu/catalog.php?record_id=12545).
- Important research factors are still unaccounted for given the current available data. The early approach to carbon cycle modeling is a good example of this type of information gap. The first carbon cycle models did not include carbon exchanges involving the terrestrial domain because modelers assumed that the exchange was about equal. As a result, the only factor modeled was deforestation; the omission of terrestrial carbon exchange rendered the models inadequate. Ecosystems research models are another example—they are only beginning to account for changes in pests populations, such as the pine bark beetle.
- Social models have been developed to simulate consumption, with the assumption of well-functioning markets and rational actor behavior, and mitigation/adaptation policies, but without attention to the social feasibility of enacting or implementing such policies. Since anthropogenic climate change is the result of human decisions, the lack of knowledge about human motivation, intent, and behavior is a serious shortcoming in these social models.

Overall, research about climate change impacts on Southeast Asia has been undertaken in a piecemeal fashion: discipline by discipline, sector by sector, with political implications considered separately from physical effects. This knowledge gap can be remedied by integrated research into energy-economic-environmental-political conditions and possibilities.

Specific research and data gaps regarding climate change and adaptive capacity in Southeast Asia include the following:

- Wang et al[cxxxix] found that a suite of 11 GCMs used to simulate observed interannual rainfall variations had the poorest skill over the Southeast Asian portion of the domain. The authors concluded that current GCM shortcomings in representing natural ENSO variability make it difficult to project changes in ENSO-related rainfall in Southeast Asia.
- Murdiyarso[cxl] summarized many of the difficulties of using GCMs and crop models to accurately simulate the impacts of climate change on agriculture in Southeast Asia. He noted that GCMs cannot reliably predict changes in drought and storm frequencies, which makes it impossible to model future crop yield changes.
- Luo and Lin[cxli] noted that continued refinement of dynamic crop simulation models that can utilize GCM scenarios is needed. The simulation models must be able to synthesize the range of possible crop impacts, including CO_2 fertilization, temperature, disease, and changes in soil and water. Four specific high-priority research needs were identified, including assessment of the crop- and region-specific benefit of CO_2 fertilization, development of more integrated agricultural models which account for biophysical and socioeconomic factors, inclusion of socioeconomic factors in the models, and evaluation of the relative importance of climate variability versus changes in mean climate parameters.
- Sivakumar et al[cxlii] noted that it is necessary to understand potential crop responses to the range of possible climate scenarios. Evaluation of future changes in crop yield associated with variations in the frequency and intensity of extreme climate events, such as floods, storms, and droughts, is particularly important. Assessment of sustainability practices, agricultural productivity, changes in erosion, degradation of soil quality, and ecosystem health also need careful consideration.
- Rosensweig et al[cxliii] noted that improved observation networks are urgently needed in Southeast Asia in order to document the sensitivity of physical and biological systems to warming in the region.
- Burke et al[cxliv] noted a need for better information about the location of coral reefs and the threats to their survival.
- Kobayashi[cxlv] noted that there is a need for detailed studies of the magnitude and extent of climate change impacts on urban settlements, particularly in developing countries.
- Sia Su[cxlvi] noted that future climate change research must incorporate important weather factors, such as relative humidity, pressure, and wind speed/direction, which can influence the effects of climate on disease outbreaks and associated morbidity and mortality rates.
- Penny[cxlvii] identified the need for comprehensive modeling that reflects increased snowmelt and monsoon rainfall to assess the implications for food security, wetlands management, and biodiversity in Southeast Asia.
- Preston et al[cxlviii] identified the need to include the potential for irreversible loss of large ice sheets in the Arctic and Antarctic in projections of global sea level rise. Contributions from large ice sheets could rapidly increase global sea level, with devastating impacts on the coastal and island nations of Southeast Asia.

This paper does not represent US Government views.

- Thanh et al[cxlix] identified research gaps with regard to land-ocean interactions and coastal impacts in Vietnam and upland countries. Research needs include synchronization of research and applied scale data and greater public availability of data. More detailed, integrated and comprehensive investigations are required to obtain information on coastal nutrients, pollutants, material fluxes and coastal interaction processes that have been impacted by both human activities and climate change.
- Hanh and Furukawa[cl] identified information gaps on sea level rise and coastal zone vulnerability in Vietnam.
- Mapalo[cli] identified research gaps for evaluating climate change and sea level rise at Olango Island in the central Philippines. Research needs include information on storm surge, quantification of coral and sand extraction, natural disaster impact data, groundwater salinity and transmissibility data, endangered species information, assessment of the impacts of mangroves on sea grass beds, and a detailed topographic map of the region.

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NATIONAL INTELLIGENCE COUNCIL

SPECIAL REPORT

SOUTHEAST ASIA AND PACIFIC ISLANDS: IMPACT OF CLIMATE CHANGE TO 2030

A COMMISSIONED RESEARCH REPORT

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SPECIAL REPORT

NIC 2009-11D December 2009

Mexico, The Caribbean, and Central America: The Impact of Climate Change to 2030:

A Commissioned Research Report

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Mexico, the Caribbean, and Central America: The Impact of Climate Change to 2030

A Commissioned Research Report

Prepared By
Joint Global Change Research Institute and
Battelle Memorial Institute, Pacific Northwest Division

The National Intelligence Council sponsors workshops and research with nongovernmental experts to gain knowledge and insight and to sharpen debate on critical issues. The views expressed in this report do not reflect official US Government positions.

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December 2009

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Scope Note

Following the publication in 2008 of the National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030, the National Intelligence Council (NIC) embarked on a research effort to explore in greater detail the national security implications of climate change in six countries/regions of the world: India, China, Russia, North Africa, Mexico and the Caribbean, and Southeast Asia and the Pacific Island states. For each country/region, we are adopting a three-phase approach.

- In the first phase, contracted research—such as this publication—explores the latest scientific findings on the impact of climate change in the specific region/country.
- In the second phase, a workshop or conference composed of experts from outside the Intelligence Community (IC) will determine if anticipated changes from the effects of climate change will force inter- and intra-state migrations, cause economic hardship, or result in increased social tensions or state instability within the country/region.
- In the final phase, the NIC Long-Range Analysis Unit (LRAU) will lead an IC effort to identify and summarize for the policy community the anticipated impact on US national security.

This assessment on the impact of Climate Change on Central America and the Caribbean through 2030 is part of the Global Climate Change Research Program contract with the Central Intelligence Agency's Office of the Chief Scientist.

This assessment identifies and summarizes the latest peer-reviewed research related to the impact of climate change on selected countries in Central America and the Caribbean. It draws on the literature summarized in the latest Intergovernmental Panel on Climate Change (IPCC) assessment reports, National Communications to the United Nations Framework (UNFCCC) on Climate Change, statistical data from the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) and on other peer-reviewed research literature and relevant reporting. It includes such impacts as sea level rise, water availability, agricultural shifts, ecological disruptions and species extinctions, infrastructure at risk from extreme weather events (severity and frequency), and disease patterns. This paper addresses the extent to which the countries in the region are vulnerable to impact of climate change. The targeted time frame is to 2030, although various studies referenced in this report have diverse time frames.

This assessment also identifies (Annex B) deficiencies in climate change data that would enhance the IC understanding of potential impacts on Central America and the Caribbean and other countries/regions.

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Executive Summary

Mexico, the countries of the Caribbean, and Central America examined in this report are at risk from the impacts of climate change in the next 20 years because they will be exposed to a greater range of climate changes and have a relatively weak adaptive capacity when compared to the world at large. Within the region, climate change is evident in increased temperatures, changes in precipitation, and sea level rise—and perhaps in weather variability and natural disaster events. Countries in this report include Belize, Cuba, the Dominican Republic, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama; Puerto Rico is also discussed.

Steady increases within the region in the number of extreme weather events—hurricanes, storms, and droughts—and their effect on infrastructure, public health, loss of human life and agriculture may be attributable to climate change. The countries reviewed do not yet have a full understanding of the potential impacts of future climatic changes and are not prepared to prevent or reduce those impacts.

Regional leaders are aware of these challenges and have begun to make commitments and agreements that will enhance their understanding of future climate change, their own adaptive capacity, and where critical changes and investments need to be made. Leaders have not addressed the problem from a preventive perspective through policy changes or infrastructure investments because of a lack of systematic analysis that quantifies and qualifies the potential impact to the region, allowing the development of relevant and economically viable options. At present the region is still responding to climate change in a reactive manner.

- Regional leaders realize that leaving the situation "as is" will exacerbate their fragile economies, resources, and adaptive capacity but lack strategic plans to address the issue.
- Most countries in the region are signatories to many multilateral environmental agreements (See Annex C) but are only now beginning to implement such agreements.
- There are significant gaps in the ability to fully understand in a systemic way all the dimensions of climate change impacts at the economic, social, and/or environmental level in the region. There are gaps and deficiencies in data, systematic methodologies/analysis, and tools to monitor, share, and track information and events at the local, national, and regional levels.

Efforts are starting to reduce systemic knowledge gaps. There is insufficient funding by regional governments to undertake detailed modeling that would result in information to rank and evaluate the financial viability of potential climate change adaptation projects. Several entities at the national and regional levels are working to develop improved analytical methods and information sharing as well as better data and data availability.

- In September 2008, the Economic Commission for Latin America and the Caribbean (ECLAC) announced that it would undertake multiple studies to review how climate change is affecting regional economies. Currently, the consensus is that climate change is likely to impose serious economic consequences for the Central American and Caribbean regions, making it increasingly difficult to respond to the challenges of poverty reduction, higher human development, and environmental sustainability linked to the attainment of the United Nations Millennium Development Goals.

- Upcoming studies by the ECLAC are expected to contribute to a better understanding of the economic impact of climate change in the region and will outline the costs and benefits of needed related policy responses, both in terms of mitigation and adaptation.

In this report, information available for a selected set of Mexico, Caribbean, and Central American countries has been reviewed to start understanding the projected climate change variability, given certain scenarios to 2030, as well as to start an initial assessment of these countries' current adaptive capacity to reduce such effects.

Very limited modeling and analysis are available for the countries of interest. Because of that, this initial analysis draws heavily on the respective Governments First National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC). These reports offer the most comprehensive and comparable information available today. In the case of Mexico, the Third Communication was used to review summary impacts. This review, however, was primarily focused on improving inventories of greenhouse gases across all types and production of energy as well as the greenhouse gases generated by major economic activity.

This review identifies the following high-priority risks:

- *Energy*. Energy resources, production, and use vary widely across the countries under review. As all the countries experience population growth, economic growth, and industrialization, they will increase their need and demand for energy. All the countries under review rely on imported fossil fuels, with the exception of Mexico, which is a net exporter of energy resources. In most of the countries, the largest generator of greenhouse gases is the energy sector. Although they are very small contributors to global emissions, most of the countries will benefit from increasing use of renewable energy. Most have begun efforts to evaluate and implement small renewable energy projects, such as solar energy in rural areas of El Salvador, wind energy in Nicaragua and Costa Rica, and an intensive effort in Dominican Republic to evaluate hydro-generated electricity.

- *Agriculture*. The agricultural sector climate related research for most of the countries in this review is limited. Where research is available, productivity losses are projected for optimist, moderate, and pessimist scenarios for some key food crops with estimates that vary from 10 percent to more than 50 percent degradation by the year 2030.

- *Water Resources*. The majority of the population in most of the countries reviewed lives in coastal areas, which are highly vulnerable to severe climate changes. As populations continue to grow in the same areas, increasing water extraction and rising sea levels are expected to have severe impacts on the quantity and quality of water available. Many of these countries' aquifers are open to ocean waters and are already experiencing increased salinity. Rising sea levels will accelerate the deterioration of aquifers and available water resources.

- *Migration.* In Central America, an increase in intra-regional migration during the 1980s and 1990s as well as extra-regional migration was the result of social unrest and economic contraction. Future patterns of migration are not expected to change significantly. Moreover, the inability of countries in the region to adapt and recover from severe climate events with major impacts on their economies will continue to promote migration outside the region, in particular, to the United States and Canada. The large number of immigrants coming to the United States in the past 20-25 years will facilitate this movement.

Most of the countries under review have submitted their First Communication to the UNFCCC; Mexico has submitted its third. Significant work and analysis needs to be done to fully capture the impact on socio-economic systems and their current ability to recover, adapt, and reduce the effects of climate change.

The great variation of information available for each country reduces the ability to compare the full set of key indicators across all countries in a consistent manner.

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Contents

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Introduction and Background

Current State of the Region

Mexico, islands in the Caribbean, and the countries of Central America are vulnerable to climate change. Principal components of this vulnerability include their extensive coastlines, current economic dependence on agriculture, the potential for storm damage, scarcity of fresh water, and limited capacity to adapt. This report examines changes in the climate that can be expected, the impacts of those changes on the region and on individual countries, and the resources they can call upon to mitigate or adapt to those impacts. The focus is on ten islands and countries:[1] Belize, Cuba, the Dominican Republic, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, and Puerto Rico.[i] Figure 1 shows the area with the selected countries' names in red.

Figure 1. The Central American and Caribbean region with study countries' names in red.

Belize

Belize borders the Caribbean Sea to the east, Mexico to the north, and Guatemala to the west and south. Its total area is 22,966 km^2, including 160 km^2 of water. The country is mostly a flat, swampy coastal plain, with low mountains in the southern portion. It is subject to frequent

[1] Other countries in this region, such as Costa Rica, El Salvador, and Jamaica, as well as Bermuda and other islands, are mentioned in the report but not discussed in detail.

hurricanes and coastal flooding. Current environmental issues include deforestation, water pollution, and solid and sewage waste disposal. Belize's 2009 population is estimated at 308,000, growing at 2 percent annually (2009 estimate). Life expectancy at birth is 68 years. Fifty percent of the population are Roman Catholic, 27 percent Protestant, 14 percent other religions, and 9 percent claim no religion. Gross Domestic Product (GDP) per capita is $8,600 [US dollar (USD) equivalent; 2008 estimate].

Cuba

The Republic of Cuba is an island between the Caribbean Sea and the North Atlantic Ocean. Its total area is 110,860 km^2 (no areas of water). Cuba's terrain is mostly flat or rolling plains, with hills and mountains in the southeast of the island. It is subject to both hurricanes and droughts. Current environmental issues are air and water pollution, biodiversity loss, and deforestation. The 2009 population is estimated at 11.5 million, with a growth rate of 0.2 percent annually. Life expectancy at birth is 77 years. Religions include Roman Catholicism, Protestantism, Jehovah's Witnesses, Judaism, and Santeria. GDP per capita in 2008 was estimated at $9,500 USD.

Dominican Republic

The Dominican Republic occupies the eastern two-thirds of the island Hispaniola, between the Caribbean Sea and the North Atlantic Ocean. Its area totals 48,730 km^2, including 350 km^2 of water. In the Dominican Republic, highlands and mountains are interspersed with fertile valleys. The country experiences severe storms and hurricanes, occasional flooding, earthquakes, and periodic droughts. Current environmental issues include water shortages, soil erosion and consequent coral reef damage, and deforestation. The 2009 population is estimated at 9.6 million, with a growth rate of 1.5 percent annually (2009 estimate). Life expectancy at birth is 74 years. Citizens are 95 percent Roman Catholic. GDP per capita in 2008 was estimated at $8,100 USD.

Guatemala

The Republic of Guatemala has two coasts: on the Gulf of Honduras to the east and on the North Pacific Ocean to the south. Guatemala borders Mexico and Belize to the north and Honduras and El Salvador to the south. Its area totals 108,890 km^2, including 460 km^2 of water. Its Caribbean coast is susceptible to hurricanes and severe storms. The country is also subject to volcanic activity and earthquakes. Current environmental issues include deforestation in the Peten rainforest, soil erosion, and water pollution. Guatemala's population in 2009 was estimated at about 13 million, growing at a 2 percent per annum rate. Life expectancy at birth is 70 years. Religions include Roman Catholicism, Protestantism, and indigenous Mayan beliefs. GDP per capita for 2008 was estimated at $5,200 USD.

Haiti

The Republic of Haiti is located on the western third of the island Hispaniola, east of the Dominican Republic and bordered by both the North Atlantic Ocean and the Caribbean Sea. Its area totals 27,750 km^2, including 190 km^2 of water. The country is mostly rough and mountainous. Haiti experiences hurricanes, severe storms, occasional flooding and earthquakes, and periodic droughts. Current environmental issues include radical deforestation, soil erosion, and inadequate potable water; although coral reefs exist, little is known about their condition.[ii] Haiti's population in 2009 was estimated at 9 million, with an annual growth rate of 1.8 percent. Life expectancy at birth is 61 years. Citizens are 80 percent Roman Catholic, 16 percent Protestant, 3 percent other religions, and 1 percent no religion. Roughly half the population is reported to practice voodoo. GDP per capita was estimated for 2008 at $1,300 USD.

Honduras

The Republic of Honduras is bordered by the Caribbean Sea to the north, Guatemala and El Salvador to the west, the North Pacific Ocean to the southwest, and Nicaragua to the south. Its area totals 112,090 km^2, including 200 km^2 of water. Honduras is mountainous in the interior, with narrow coastal plains. It experiences frequent but generally mild earthquakes, as well as hurricanes and floods along its Caribbean coast. Current environmental issues include deforestation, land degradation, soil erosion, and water pollution by mining activities. Honduras' population was estimated at almost 8 million in 2009, with a growth rate of 2 percent (2009 estimate). Life expectancy at birth is 69 years. The population is 97 percent Roman Catholic and 3 percent Protestant. GDP per capita was estimated at $4,400 USD for 2008 with extremely high inequality.

Mexico

The United Mexican States constitute the southernmost country in North America, bordered on the north by the United States, to the east by the Gulf of Mexico and the Caribbean Sea, to the south by Belize and Guatemala, and to the west and south by the North Pacific Ocean. Mexico's area totals 1,972,550 km^2, including 49,510 km^2 of water. Its terrain is diverse: high mountains, low coastal plains, high plateaus, and desert. It experiences tsunamis along the Pacific coast, and hurricanes on all coasts, as well as volcanic activity and earthquakes in the center and south. Current environmental issues include inadequate waste disposal, scarce natural fresh water resources and pollution in existing resources, deforestation, erosion, desertification, land degradation, air pollution, and land subsidence from groundwater depletion. Mexico's estimated population for 2009 is 111 million, growing at an annual rate of 1 percent. Life expectancy at birth is 76 years. The population is 77 percent Roman Catholic, 6 percent Protestant, and 17 percent unspecified. GDP per capita was estimated at $14,200 USD for 2008.

Nicaragua

The Republic of Nicaragua is situated between Honduras and Costa Rica to the north and south, respectively, and between the North Pacific Ocean and the Caribbean Sea to the west and east, respectively. Its area totals 129,494 km^2, including 9,240 km^2 of water area. Extensive Atlantic coastal plains rise to central interior mountains; the narrow Pacific coastal plain has volcanoes. Nicaragua experiences earthquakes, volcanic activity, landslides, and hurricanes. Current environmental issues include deforestation, soil erosion, and water pollution. The population estimate for 2009 was about 6 million, growing at an annual rate of 1.8 percent. Life expectancy at birth is 69 years. Citizens are 59 percent Roman Catholic, 22 percent Evangelical, 1.6 percent Moravian, 1 percent Jehovah's Witnesses, and 16 percent no religion. GDP per capita was estimated for 2008 at $2,900 USD.

Panama

The Republic of Panama is located on the isthmus between North America and South America, bordered by the Caribbean Sea and the Pacific Ocean. The southernmost country of Central America, Panama sits between Costa Rica and Columbia. Its total area is 78,200 km^2, of which 2,210 km^2 are water. In its center is a line of mountains, with plains and rolling hills in the coastal areas. Toward Columbia is dense jungle, which, combined with forest protections, causes a break in the Pan American Highway; this area is subject to occasional severe storms and forest fires. In its center is the Panama Canal. Current environmental issues include agricultural runoff that pollutes water and threatens fisheries; deforestation; land degradation and soil erosion (with resulting siltation of the Panama Canal); urban air pollution; and environmental degradation caused by extensive mining. The 2009 estimated population is 3.3 million, growing at 1.5 percent annually. Life expectancy at birth is approximately 77 years. The population is 85 percent Roman Catholic, 15 percent Protestant. The service sector is 80 percent of Panama's economy; per capita GDP is $11,600 USD (2008 estimate). The country's growth rate has been above 8 percent in recent years, but both the unemployment rate and inequality in per capita GDP are high.

Puerto Rico

The Commonwealth of Puerto Rico, a self-governing territory of the United States, consists of several islands situated east of the Dominican Republic and west of the Virgin Islands. Its area is 13,790 km^2, including 4,900 km^2 of water. The main island, Puerto Rico, is mostly mountainous but has large coastal areas both in the north and in the south. As all the countries covered in this report, Puerto Rico is subject to hurricanes. Current environmental issues include erosion and occasional droughts with accompanying water shortages. Its population numbers about 4 million (2009 estimate), with a growth rate of 0.3 percent. Life expectancy is 79 years. Roman Catholicism dominates (85 percent), but Protestant, Jewish, indigenous, and African religions are also espoused. Puerto Rico's per capita GDP is $17,800 USD (2008 estimate), and economic activities are largely services and industry.

Emissions

Latin America (the Caribbean, Central, and South America) is responsible for only a small fraction of global carbon emissions (Figure 2). Within the Latin American and Caribbean region, Meso-America—typically thought of as covering some of Mexico south to Honduras and Nicaragua—represents half of the carbon dioxide emissions of Latin America and the Caribbean accounts for less than 15 percent (Figure 3). This figure illustrates the wide variation of carbon dioxide (CO_2) emissions in the region. The highest and most quickly increasing—40 percent between 1990 and 2000—amount comes from South America, while the lowest and relatively more slowly rising amount comes from the Caribbean.

Although the region is a very small contributor to total worldwide carbon dioxide emissions, the impacts of climate change in this region are already being felt. Temperature increases in the atmosphere and sea, instability in rainfall, and rising sea levels are affecting food production, infrastructure, livelihood, and the health of populations. Extreme weather events (droughts, hurricanes, floods, etc.) have added more stress on an already weakened environment and further eroded the ability of the environment to mitigate their harmful effects.

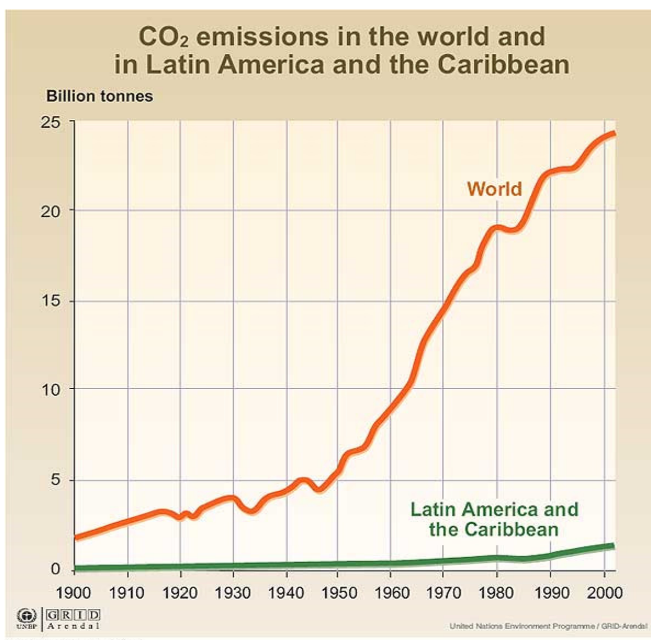

Figure 2. Relative CO_2 emissions in Latin America and the Caribbean. Source: United Nations Environment Program, "Vital Climate Graphics for Latin America and the Caribbean," (UNEP 2003) http://www.grida.no/publications/vg/lac/.

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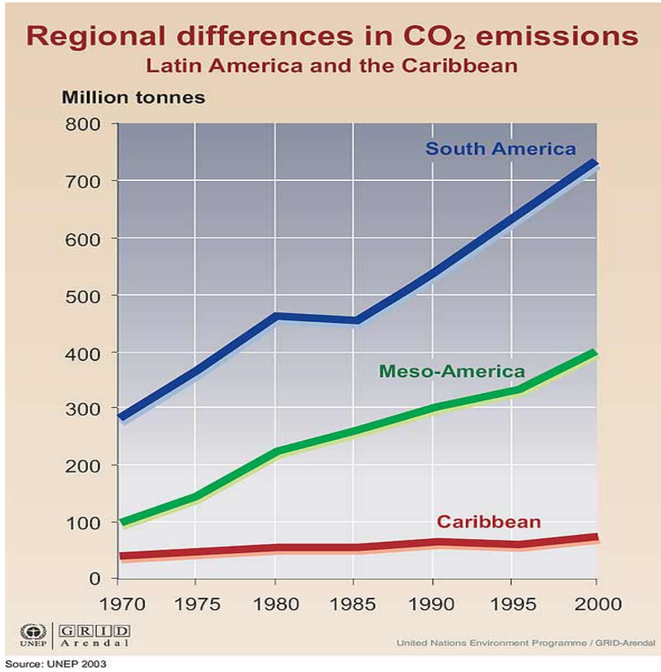


Figure 3. Regional differences in CO_2 emissions. Source: United Nations Environment Program (UNEP), "Vital Climate Graphics for Latin America and the Caribbean," (2003) http://www.grida.no/publications/vg/lac/.

Economic growth and emissions have moved roughly in the same direction. As developing economies continue urbanization and industrialization, the risk of growing emissions increases because of energy use mix and the inability of economies to become more energy efficient. In the region under evaluation, there has been a wide variety of energy intensity of GDP over the past 37 years. Most of the countries have become more energy efficient, with the exception of Haiti and Nicaragua, two of the lowest-performing countries by many measures. These two countries have gone through many years of political unrest, resulting in economic contraction, capital flight, migration of the best human capital, and inefficiencies at every level of economic activity (see Table 1).

Country	1970	1980	1990	2000	2007
Costa Rica	1.61	1.36	1.33	1.06	1.17
Cuba	...	...	2.64	1.99	1.86
Guatemala	2.83	2.38	2.71	2.68	2.32
Haití	3.75	3.13	2.42	3.43	4.58
Honduras	3.85	3.18	3.24	2.78	2.64
Mexico	1.14	1.20	1.31	1.13	1.08
Nicaragua	2.38	2.99	3.76	3.88	4.31
Dominican Republic	2.41	1.65	1.47	1.66	1.17
Panama	1.40	1.29	1.21	1.17	1.42
Latin America and the Caribbean	**1.59**	**1.47**	**1.60**	**1.53**	**1.46**

Table 1. Energy Intensity of Gross Domestic Product (2000 Prices =100) (in thousands of barrels of oil equivalent for US $1 M of GDP). Source: CEPAL/ECLAC [Comisión Económica para América Latina y el Caribe/Economic Commission for Latin America and the Caribbean], *Anuario Estadístico de América Latina y el Caribe: 2008* (United Nations 2009).

Economic Growth and Development

Central America, Mexico, and the Caribbean countries all continue to experience population growth, albeit at different rates, leading to an increase in food demand. Most of the countries in these regions depend greatly on agricultural production. Variations in crop yields, food crops, and cash crops present major food security challenges.

Since 1990, the countries in the region have experienced large disparities GDP. Some have suffered from economic contraction due to political unrest, capital flight, migration of the better-educated segment of the population, and the loss of foreign investments. Examples include Guatemala, El Salvador, Nicaragua, and Haiti from the late 1970s through the 1990s. The socio-political challenges of the 1980s and increases in extreme weather events in the 1990s hurt the fragile economies of the region. The absence of a strong legal foundation has also greatly reduced the opportunity for recovery. El Salvador, Guatemala, and Nicaragua were directly affected by insurgencies and increased weather-related natural disasters. At the same time, neighboring countries had to cope with an increase in refugees because of the difficulties associated with war and natural disasters. All these countries have been severely affected by hurricanes, floods, and tropical storms in the past two decades. Regional GDP has shown the effects of all these events through wide fluctuations from one year to the next (see Figure 4).

This paper does not represent US Government views.

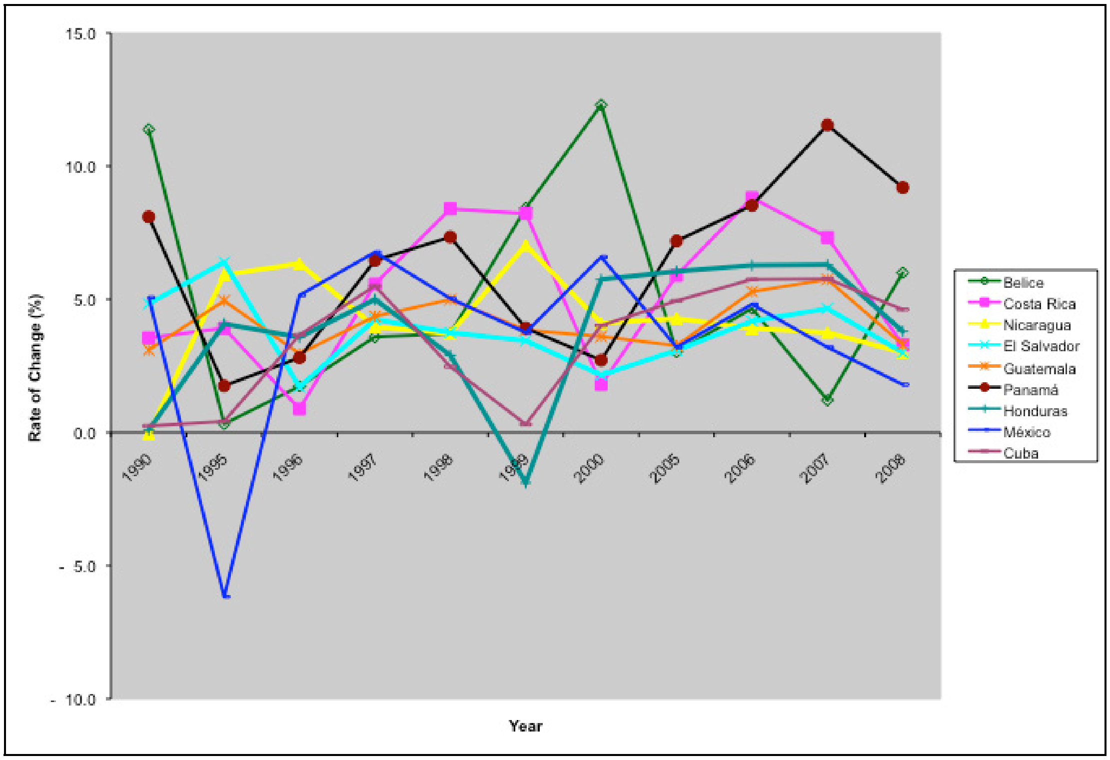
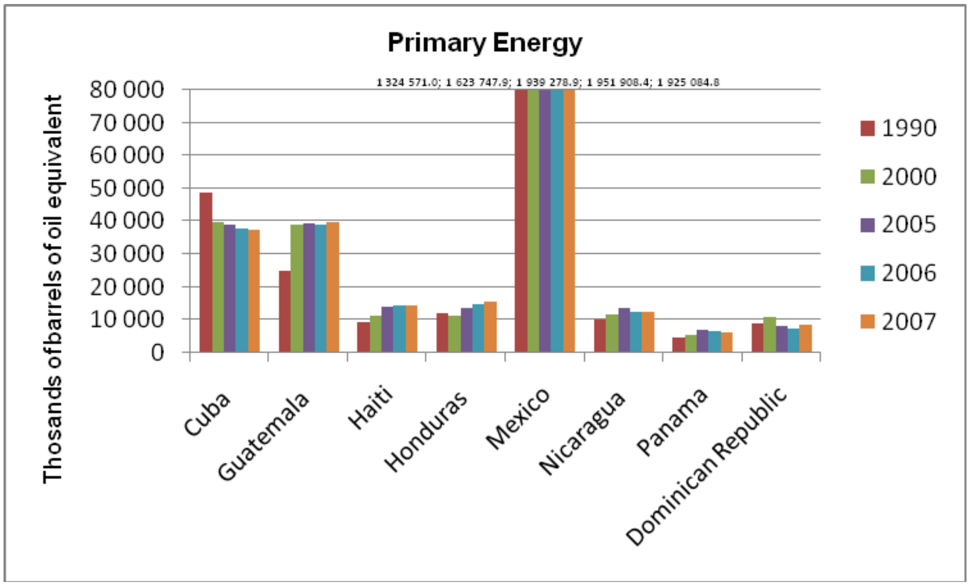


Figure 4. Rate of Change in Gross Domestic Product (GDP) (1990-2008). Data for Haiti and the Dominican Republic are not included. Source: CEPAL/ECLAC [Comisión Económica para América Latina y el Caribe/Economic Commission for Latin America and the Caribbean], *Anuario Estadístico de América Latina y el Caribe: 2008* (United Nations 2009).

Energy Systems

The countries in the region selected for evaluation, have mostly fossil fuel-based economies and are mostly net importers of energy. Since 1984 they have continued to increase their overall energy consumption. Except Mexico, primary and secondary energy production has remained below total annual consumption (Figure 5). Primary energy production is the production of energy found in its natural state—wood, natural gas, bagasse,[2] and hydroelectricity. It also includes the amount of fuel extracted and the energy consumed in the production process and the supply to energy producers and conversion. Secondary energy production is derived from the conversion of primary energy products. Petroleum, for example, is refined into kerosene and diesel.

[2] Sugarcane fiber left over after juice extraction.



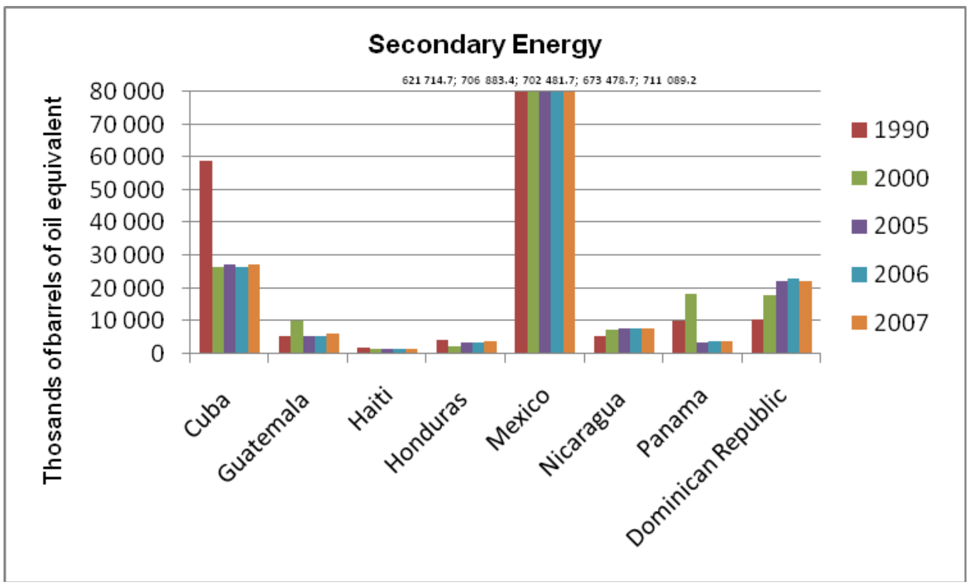


Figure 5. Primary and Secondary Energy Production by Country and Regions. Note: no data for Belize and Puerto Rico. Source: CEPAL/ECLAC [Comisión Económica para América Latina y el Caribe/Economic Commission for Latin America and the Caribbean], *Anuario Estadístico de América Latina y el Caribe: 2008* (United Nations 2009).

As economies industrialize, most countries in this review will remain highly vulnerable to the fluctuations in the cost of oil. Mexico is the only country in the group that is a net exporter of energy resources; all others in this study are net importers of petroleum-based products. During the 1990-2007 time period, regional energy consumption increased 158 percent; in Costa Rica, Nicaragua, and Dominican Republic it increased about 200 percent; and in Panama by 288 percent. Energy consumption is expected to increase as population and economies continue to grow. Figures 6 and 7 illustrate total energy consumption and total energy supply by country and type, respectively. Note that energy supply information is not available for the same time period as that for energy consumption.

Energy supply composition across the countries reviewed remains predominantly based on petroleum, except for Haiti, Nicaragua and Honduras. These three countries had the lowest annual GDP growth rates within the group from 1990 to 2007. On the other hand, Costa Rica, Cuba, Panama, and Dominican Republic have the largest shares of oil-based energy and experienced the largest annual GDP growth rates.

As noted earlier, all countries except Mexico are net importers of petroleum-based products. In the Dominican Republic oil-based energy supply remains significant and accounted for 74 percent of total energy in 2005 and 79 percent in 2002. The island nations of Cuba, Puerto Rico, Haiti, and the Dominican Republic remain particularly vulnerable to supply of petroleum-based energy products since they must be brought by ship to the islands for refining and processing. Hydroenergy plays a significant role only in Costa Rica, where it accounted for 18-24 percent of supply; for the other countries it ranged from 0.1 to 9.8 percent for Cuba and Panama respectively.

Food Production and Drinking Water Supply

Central America, the Caribbean, and Mexico have economies with significant agricultural sectors though agricultural land use as part of total land area varies widely. In Belize only six percent of the total land area was devoted to agriculture in 2005 reflecting the fact that over 50 percent of GDP comes from the services industry, particularly tourism. The comparable figure for the Dominican Republic was 70 percent, Costa Rica and Haiti 57 percent, Cuba 60 percent, and Mexico 55 percent (Figure 8). All the countries reviewed have maintained relatively stable ratios of agricultural land use to total land area for the past 27 years.

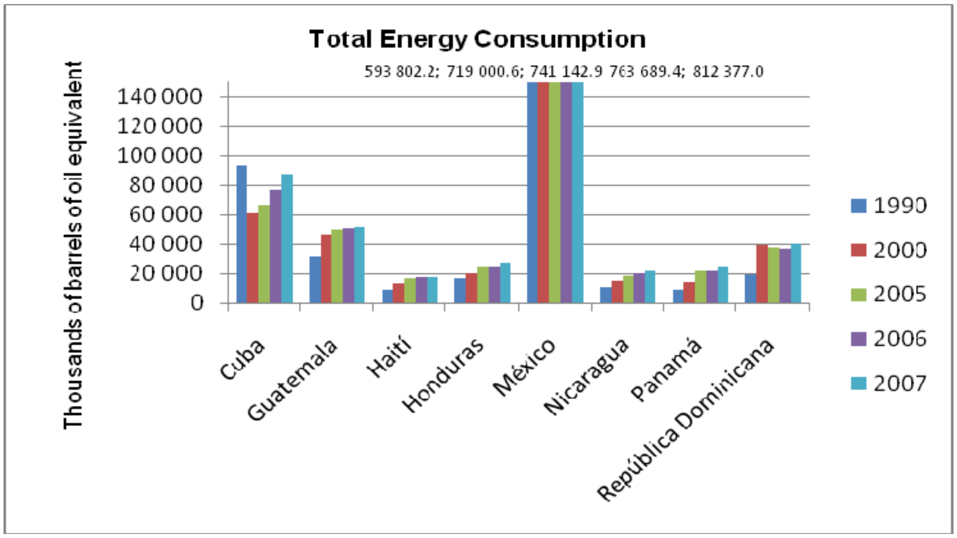


Figure 6. Consumption by country. Note: no data for Belize and Puerto Rico. Source: CEPAL/ECLAC [Comisión Económica para América Latina y el Caribe/Economic Commission for Latin America and the Caribbean], *Anuario Estadístico de América Latina y el Caribe: 2008* (United Nations 2009).

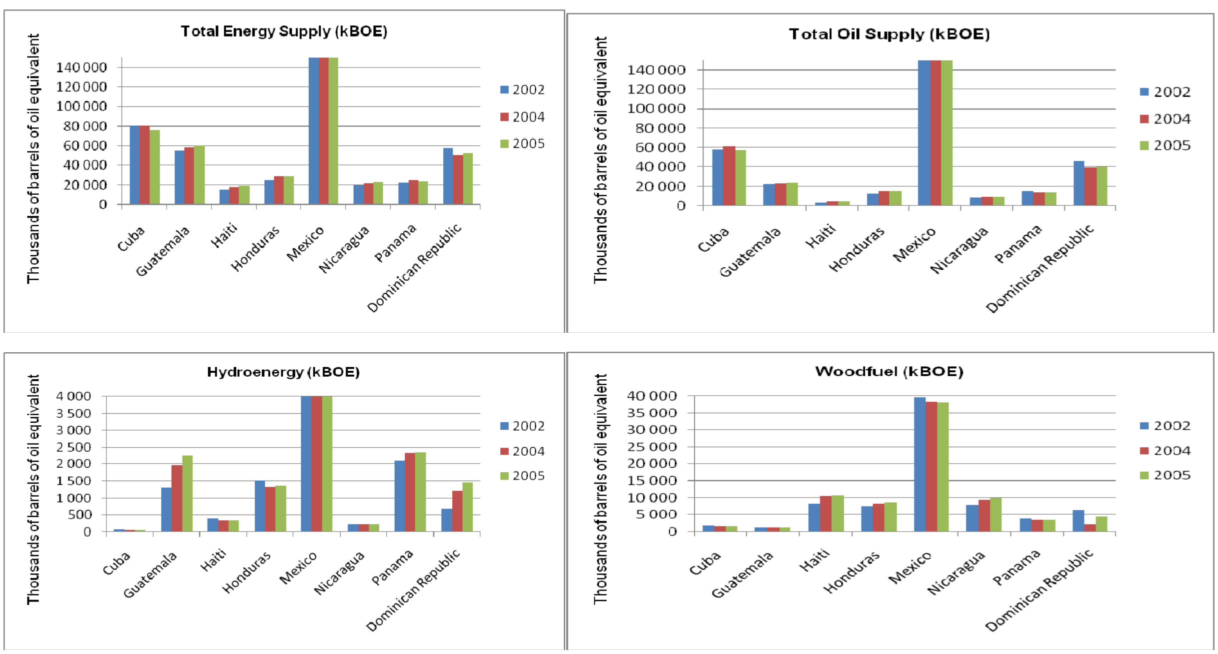


Figure 7. Energy supply by type (2002-2005). Note: no data for Belize and Puerto Rico. Source: CEPAL/ECLAC [Comisión Económica para América Latina y el Caribe/Economic Commission for Latin America and the Caribbean], *Anuario Estadístico de América Latina y el Caribe: 2008* (United Nations 2009).

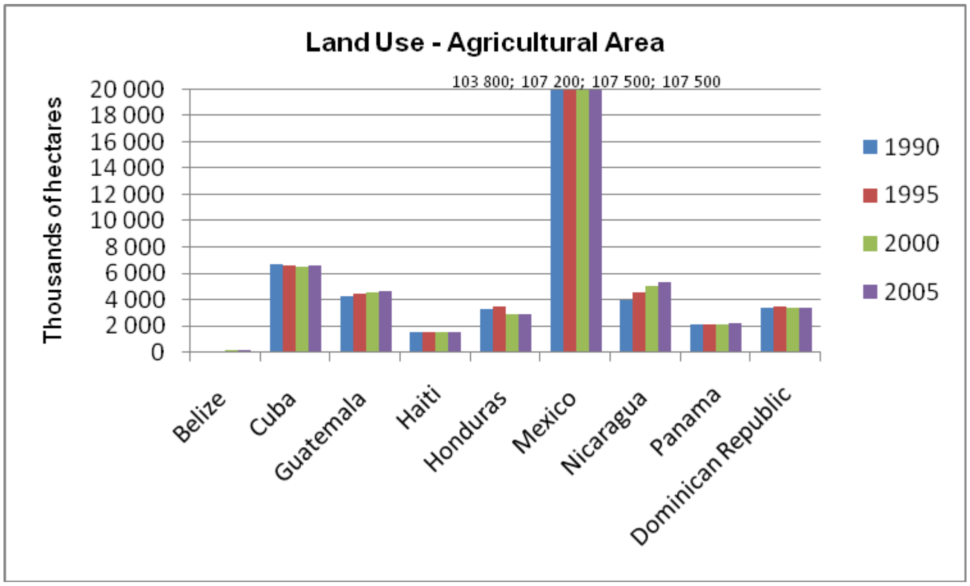


Figure 8. Agricultural area and total land area by country in hectares. Source: CEPAL/ECLAC [Comisión Económica para América Latina y el Caribe/Economic Commission for Latin America and the Caribbean], *Anuario Estadístico de América Latina y el Caribe: 2008* (United Nations 2009).

Although the areas dedicated to agricultural activity and food production are significant in almost all the countries studied, a large portion of the population lives in poverty and struggles to survive. Table 2 shows the percentage of the population living in poverty and extreme poverty. Those with income amounting to less than twice the cost of a basic food basket[3] are considered to be living in poverty. Those with income amounting to less than the cost of a basic food basket are considered to be living in extreme poverty. Costa Rica and Panama are the only two countries of those for which we have information that have less than 20 percent in poverty and no more than 5 percent in extreme poverty. Figure 9 shows the Consumer Price Index (CPI)—the change in the cost of the food basket—with the base year of 2000.

[3] The food basket is a concept used in poverty measurement; it differs in components by country or region according to local diets and availability but must provide adequate calories and protein. Traditionally, a food basket has represented the minimum food items required for a family over a one-month period.

POOR AND INDIGENT POPULATION, URBAN AND RURAL AREAS
(Percentage of total population)

		Poverty				Extreme poverty			
Country	**Years**	**Total**	**Urban**	**Rest**	**Rural**	**Total**	**Urban**	**Rest**	**Rural**
Guatemala	1998	49.1	...	...	69.0	16.0	...	...	41.8
	2002	45.3	...	...	68.0	18.1	...	...	37.6
	2006	42.0	...	...	66.5	14.8	...	...	42.2
Honduras	1994	74.5	68.7	80.4	80.5	46.0	38.3	53.7	59.8
	1999	71.7	64.4	78.8	86.3	42.9	33.7	51.9	68.0
	2007	59.9	47.8	64.0	78.8	26.2	18.0	32.5	61.7
Mexico	1994	36.8	...	...	56.5	9.0	...	...	27.5
	2000	32.3	...	...	54.7	6.6	...	...	28.5
	2006	26.8	...	...	40.1	4.4	...	...	16.1
Nicaragua	1993	66.3	58.3	73.0	82.7	36.8	29.5	43.0	62.8
	2001	63.8	50.8	72.1	77.0	33.4	24.5	39.1	55.1
	2005	54.4	48.7	58.1	71.5	20.8	16.4	23.7	46.1
Panama	1994	25.3	...	...	...	7.8	...	...	...
	1999	20.8	...	...	...	5.9	...	...	...
	2007	18.7	...	...	46.6	5.0	...	...	24.1
Dominican Republic	2002	42.4	...	...	55.9	16.5	...	...	28.6
	2006	41.8	...	...	49.5	18.5	...	...	28.5
	2007	43.0	...	...	47.3	19.0	...	...	24.6
Latin America	**1994**	**38.7**	**...**	**...**	**65.1**	**13.6**	**...**	**...**	**40.8**
	2000	**35.9**	**...**	**...**	**62.5**	**11.7**	**...**	**...**	**37.8**
	2007	**28.9**	**...**	**...**	**52.1**	**8.1**	**...**	**...**	**28.1**

Data not available for Cuba, Belize, Haiti, and Puerto Rico

Table 2. Percentage of total population living in poverty by country. Note: no data for Belize, Cuba, Haiti, and Puerto Rico. Source: CEPAL/ECLAC [Comisión Económica para América Latina y el Caribe/Economic Commission for Latin America and the Caribbean], *Anuario Estadístico de América Latina y el Caribe: 2008* (United Nations 2009).

The countries under review have experienced a steady increase in CPI that has translated into reduced access to the basic food basket. By 2008, Haiti had the highest Index (350) followed by the Dominican Republic (290), Nicaragua (202) and Honduras (188). These countries also have been affected by severe climate variations since the 1990s and highly variable inflation rates. Although food production indexes have remained positive (Figure 10), in Nicaragua, Honduras, and Guatemala a significant portion of the population has experienced a steady decline in access to food because of reduced purchasing power.

This paper does not represent US Government views.

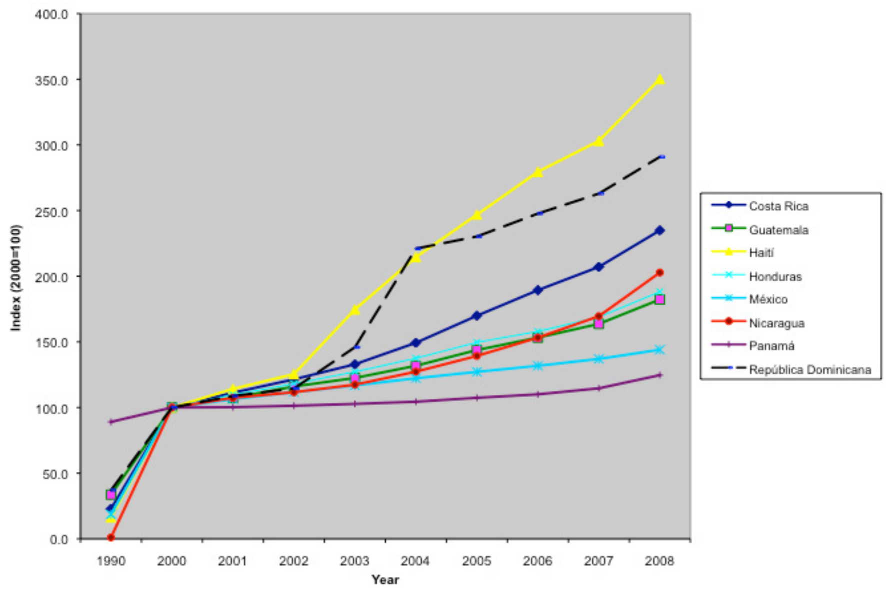


Figure 9. Consumer Price Index by Country. (2000=100). Source: CEPAL/ECLAC [Comisión Económica para América Latina y el Caribe/Economic Commission for Latin America and the Caribbean], *Anuario Estadístico de América Latina y el Caribe: 2008* (United Nations 2009).

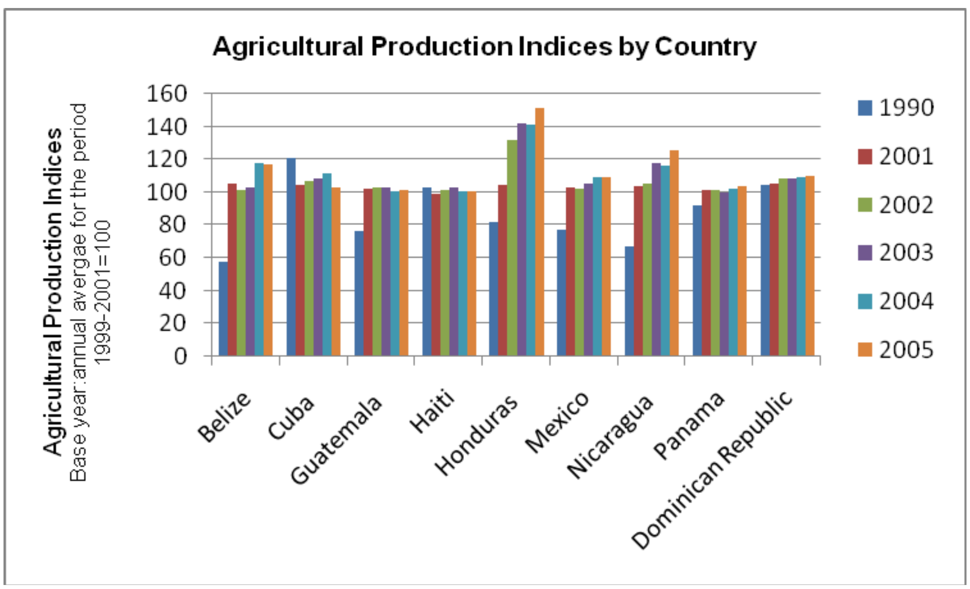


Figure 10. Food Production Indexes by Country. Source: CEPAL/ECLAC [Comisión Económica para América Latina y el Caribe/Economic Commission for Latin America and the Caribbean], *Anuario Estadístico de América Latina y el Caribe: 2008* (United Nations 2009).

Table 3 shows the extent to which six countries provided their citizens with basic services, such as drinking water, sanitation, and electricity. Drinking water across the selected countries varies significantly between urban areas and rural areas. In 2007, Costa Rica had drinking water supply services available for 99.2 percent of total urban dwellings and 88.5 percent of total rural dwellings. The respective figures in Guatemala were 90 percent and 60 percent, and in the Dominican Republic 80.6 and 55.4 percent. Among the countries that provided information, Nicaragua has the lowest percentage of population with available basic services.

Human Health

Since 1990 the region has experienced a series of re-emerging diseases following such severe climatic events as floods, hurricanes, and droughts. Evidence points to increases in several communicable diseases, such as dengue, malaria, Hantavirus pulmonary syndrome, and the reemergence of a large host of infectious diseases following years in which there were El Niño/Southern Oscillation (ENSO) events.

		Piped water		*Excreta disposal system*		*Electric lighting*	
Country	Area	1995 c/	2007 c/	1995 c/	2007 c/	1995 c/	2007 c/
Costa Rica	Total	...	95.2	...	25.6	...	99.1
	Urban	...	99.6	...	39.3	...	99.8
	Rural	...	88.5	...	5.0	...	98.0
Guatemala	Total	63.6	76.3	32.6	40.3	64.1	81.8
	Urban	89.6	90.0	73.3	68.4	91.2	93.7
	Rural	43.6	60.6	1.4	7.6	43.4	68.0
Honduras	Total	70.7	82.5	26.8	33.0	55.3	73.9
	Urban	80.6	93.6	51.5	62.9	86.1	97.9
	Rural	62.1	71.8	5.6	4.1	28.9	50.7
Mexico	Total	84.3	...	60.8	73.5	95.9	98.5
	Urban	94.1	...	81.7	90.0	99.3	99.7
	Rural	67.9	...	25.8	42.1	90.5	96.1
Nicaragua	Total	61.0	...	61.1	26.4	69.3	73.9
	Urban	86.0	...	56.7	21.1	90.8	95.5
	Rural	27.0	...	67.0	33.9	40.6	43.7
Dominican Republic	Total	70.1	71.9	19.8	23.2	88.5	...
	Urban	82.8	80.6	30.5	32.3		100.0
	Rural	48.1	55.4	1.2	5.8		68.6

Table 3. Basic services supplied in six countries. Note: no data for Belize, Haiti, Panama, and Puerto Rico. Source: CEPAL/ECLAC [Comisión Económica para América Latina y el Caribe/Economic Commission for Latin America and the Caribbean], *Anuario Estadístico de América Latina y el Caribe: 2008* (United Nations 2009).

Projected Regional Climate Change

Central American and Caribbean countries span the tropics and the subtropics and include continental land masses, island chains, and mountain ranges of varying orientations and elevations.[iii] The general climate of the region is described as dry winter/wet summer. The temperature range within the region is small due to its maritime tropical characteristics except for the mountainous areas where temperatures are modulated by changes in altitude.

Rainfall intensity and timing determines the climate classification and the meteorological features of the climate in the region. The topography of countries with significant mountains can influence variations in annual rainfall, the timing of peak rainfall, and the length of the rainy season. Windward slopes of the larger mountainous islands tend to have the highest amounts of rainfall.

The continental landmass of Central America lies between two oceans and contains some of the most diverse coastal and marine ecosystems in the world. Tropical forests, particularly in Costa Rica, are a significant sink for greenhouse gases and are of great value to countries interested in gaining credits under trading mechanisms such as those specified in the Kyoto protocol to the UNFCCC.[4]

The Caribbean experiences a wet season from May through October and a dry season from November through April. During late July or early August, a short-lived dry period may occur. In the winter and early summer, the occasional intrusion of a mid-latitude polar front can influence weather patterns by bringing cool, moist air to the region.

Tropical storms and hurricanes are a perennial feature of the Caribbean. The official hurricane season lasts from June 1 to November 30. The phase of the ENSO influences the likelihood of hurricane formation in the Atlantic. During El Niño, (the ENSO warm phase), the formation of tropical hurricanes in the Atlantic is inhibited. Alternately, during La Niña (the ENSO cold phase) the formation of hurricanes is enhanced.

The Atlantic Multidecadal Oscillation (AMO) is another important natural influence on air temperatures, precipitation levels, and storm activity in the Caribbean. The AMO has cool and warm phases, each lasting several decades. The phase of the AMO also plays a role in suppressing tropical storm formation. The AMO and ENSO are several features of the Caribbean climate that can complicate the observations of temperature and precipitation trends.

Climate Observations

Evidence of intensified climate variability can be seen in multiple key economic, social, and environmental indicators. A review of regional natural disasters that are weather-related demonstrates that the frequency and impact of severe events has steadily increased in both number and affected population.

Since 1990 the Central American and Caribbean region has experienced a steady rise in the number of people affected by severe events - floods, hurricanes, and storms (Table 4). The increase has occurred because most urban centers are located in the coastal areas.

In 1998 Hurricane Mitch was one of six hurricanes that caused significant damage in the region. The countries affected still have not fully recovered from the disaster. In Honduras, at least 90

[4] For more information on trading mechanisms specified in the Kyoto protocol, please see http://unfccc.int/kyoto_protocol/items/2830.php.

percent of the population was without water; in Nicaragua, 32 percent of the water infrastructure was damaged; and in Guatemala, the water and sewage systems in 396 communities were damaged and 20,000 latrines destroyed.

The Central American and Caribbean regions have followed the global trend of warming surface temperatures that the rest of the world has experienced. Some experts believe a warming climate may contribute to an increase in frequency and intensity of the ENSO phenomenon.

Warmer-than-average temperatures in the Pacific around the equator reduce the normal difference in the sea surface temperature between the Pacific's eastern and western sides, affecting wind patterns. At the same time, the warmer waters move toward the east along the equator, while the weakened trade winds reduce the equatorial Pacific's capacity to absorb cold water, thus consolidating the temperature anomaly. This affects the patterns that warm the atmosphere. It also affects wind direction, sea currents, and storm patterns.[iv]

In Central America ENSO leads to excessive rainfall along the coast of the Atlantic Ocean, while the Pacific coast remains dry. The effects of ENSO have caused large increases in rainfall in some areas and extended droughts in others. There was a high incidence of hurricanes and tropical storms in 1998, which was a key year for ENSO effects in the warming of ocean surface water. Figure 11 shows climate impacts and the areas affected by above-normal surface ocean temperature in Mexico, Central America, and South America during 1998.

		1990	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Floods														
Caribbean c/														
	Number of Events	3	2	6	1	0	1	3	1	4	6	2	5	6
	People Afected	5,000	35,780	39,066	35,000	0	0	675	5,070	100,085	216,060	39,040	290,302	91,190
	Deaths (Human)	4	0	6	0	0	13	18	26	43	72	3,353	54	17
Latin America d/														
	Number of Events	15	13	6	11	8	20	28	22	31	27	16	21	14
	People Afected	207,236	326,185	310,000	970,207	436,300	1,904,352	307,866	711,782	731,969	409,955	587,016	703,735	643,555
	Deaths (Human)	173	298	40	700	464	30,852	469	225	307	452	249	434	244
Latin America & Caribbean e/														
	Number of Events	18	15	12	12	8	21	31	23	35	33	18	26	20
	People Afected	212,236	361,965	349,066	1,005,207	436,300	1,904,352	308,541	716,852	832,054	626,015	626,056	994,037	734,745
	Deaths (Human)	177	298	46	700	464	30,865	487	251	350	524	3,602	488	261
Landslides														
Caribbean c/														
	Number of Events	0	0	1	0	0	0	1	0	0	0	1	0	0
	People Afected	0	0	175	0	0	0	0	0	0	0	1,200	0	0
	Deaths (Human)	0	0	0	0	0	0	10	0	0	0	2	0	0
Latin America d/														
	Number of Events	1	4	5	2	6	4	5	3	5	4	2	2	2
	People Afected	0	0	7,000	30,000	2,600	200	350	0	0	1,810	5,751	2,500	0
	Deaths (Human)	33	165	216	312	272	112	122	114	285	136	40	70	21
Latin America & Caribbean e/														
	Number of Events	1	4	6	2	6	4	6	3	5	4	3	2	2
	People Afected	0	0	7,175	30,000	2,600	200	350	0	0	1,810	6,951	2,500	0
	Deaths (Human)	33	165	216	312	272	112	132	114	285	136	42	70	21
Droughts														
Caribbean c/														
	Number of Events	0	0	0	1	1	0	2	0	0	1	1	0	0
	People Afected	0	0	0	607,200	820,000	0	0	0	0	35,000	0	0	0
	Deaths (Human)	0	0	0	0	0	0	0	0	0	0	0	0	0
Latin America d/														
	Number of Events	2	1	1	3	4	3	3	5	4	1	4	2	1
	People Afected	2,483,160	0	0	324,000	10,100,000	105,000	21,125	1,896,596	103,500	0	192,500	52,990	0
	Deaths (Human)	0	0	0	0	0	12	0	41	0	0	0	0	0
Latin America & Caribbean e/														
	Number of Events	2	1	1	4	5	3	5	5	4	2	5	2	1
	People Afected	2,483,160	0	0	931,200	10,920,000	105,000	21,125	1,896,596	103,500	35,000	192,500	52,990	0
	Deaths (Human)	0	0	0	0	0	12	0	41	0	0	0	0	0
Hurricanes/Tornados/Tropical Storms														
Caribbean c/														
	Number of Events	6	7	4	0	6	9	1	8	8	2	17	17	2
	People Afected	2,000	70,260	294,995	0	1,084,000	251,857	62,000	5,920,175	327,720	10,000	943,601	2,642,816	15,260
	Deaths (Human)	0	16	63	0	550	6	14	42	15	34	2,836	111	5
Latin America d/														
	Number of Events	1	8	7	9	10	2	8	14	11	3	4	19	3
	People Afected	0	30,062	727,724	757,405	3,189,660	2,000	32,910	100,452	616,667	9,900	151,845	3,332,649	270,700
	Deaths (Human)	38	194	122	287	19,045	10	35	90	104	16	29	1,755	15
Latin America & Caribbean c/														
	Number of Events	7	15	11	9	16	11	9	22	19	5	21	36	5
	People Afected	2,000	100,322	1,022,719	757,405	4,273,660	253,857	94,910	6,020,627	944,387	19,900	1,095,446	5,975,465	285,960
	Deaths (Human)	38	210	185	287	19,595	16	49	132	119	50	2,865	1,866	20

Table 4. Climate-related natural disasters in Latin America and Caribbean Region (1990–2006). Note: Latin American includes South America as well as Central America. Source: CEPAL/ECLAC [Comisión Económica para América Latina y el Caribe/Economic Commission for Latin America and the Caribbean], *Anuario Estadístico de América Latina y el Caribe: 2008* (United Nations 2009).

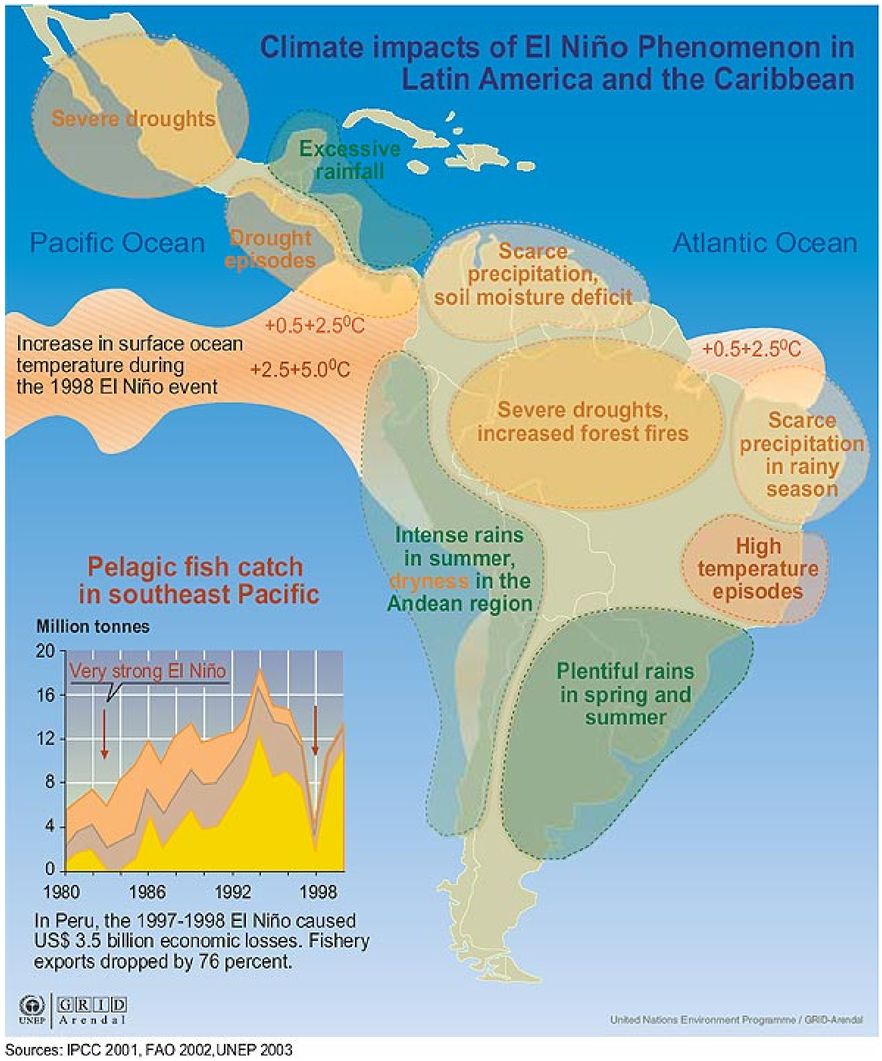


Figure 11. Impact of El Niño in Latin America and the Caribbean. Source: United Nations Environment Program, "Vital Climate Graphics for Latin America and the Caribbean," (UNEP 2003) http://www.grida.no/publications/vg/lac/page/2753.aspx.

Shortcomings in the frequency and quality of past climate data in the region present a problem in accurately assessing trends. In 2001, a workshop was held to develop climate indices for the Caribbean region.[v] At that time the region had significant problems in digitizing and developing quality assurance methods for daily weather data. Jamaica was the only country in the region to have developed a digital archive, and that was lost in a fire in 1992. Data from 30 stations were used during the 2001 exercise, primarily stations in the Caribbean islands, with one coastal Florida station, and 4 stations from Belize. The results showed that over the last few decades the number of very warm days and nights has dramatically *increased* and the number of very cool days and nights has *decreased*. The maximum number of consecutive dry days has also decreased, but the number of heavy rainfall events has increased.

The 1998 IPCC[vi] assessment reported that on average the Caribbean islands experienced an increase in temperature exceeding 0.5°C from the year 1900 until the time of the report. Over the same period there had been a significant increase in rainfall variability, with mean annual total rainfall declining by approximately 250 mm. However the decreasing rainfall trend was not significant.

The most recent IPCC assessment[vii] reports that air temperatures in the Caribbean have been increasing by as much as 0.1°C per decade and sea levels have been increasing by approximately 2 mm per year over the last few decades.

Data show that there is currently a significant drying trend in the Caribbean and Central-American.[viii] These include a satellite estimate since 1979 and several land-based observational data sets. A multi-model ensemble mean prediction of precipitation change in the region suggests this drying trend is likely to continue. Intermodel agreement on the amplitude of the drying trend yields median amplitude of between 0.5 and 1 mm per day, per 100 years over most of the region.

In the Commonwealth of the Bahamas the data show that mean daily maximum temperatures for July have increased at the rate of 3.6ºF (2°C) per 100 years and more recently at the rate of 4.8ºF (2.6°C) per 100 years.[ix] Sea level rise is expected to occur at a rate of 0.06 inches (1.5 mm) per year, with a sea level rise of about 8 inches (20 cm) by 2060. Observations taken in neighboring islands suggest that rises of 6 to 10 inches (15.2 to 25.4 cm) per 100 years can be expected.[x]

Ecological changes in Central American have substantiated the influence of climate change. For example, vegetation changes have been observed in the tropical montane cloud forests of Costa Rica. The changes suggest that atmospheric warming has raised the average altitude of the base of the orographic cloud bank during the dry season.[xi] Changes in populations of birds, lizards, and anurans[5] all reflect a broad response to regional climate change that includes widespread amphibian extinctions in remote highland forests.

Climate Predictions (Modeling)

Although Global Circulation (or Climate) Models (GCMs) can be used to infer climate changes in specific regions, it is far preferable to develop models that have a resolution sufficient to resolve local and regional scale changes. There are many challenges in reliably simulating and attributing observed temperature changes at regional and local scales. At these scales, it is hard to identify long-term changes expected from external forcings because of the large natural climate variability.

The procedure of estimating the response at local scales based on results predicted at larger scales is known as "downscaling." The two main methods for deriving information about the local climate are (1) dynamical downscaling (also referred to as "nested modeling" using

[5] An order of animals in the class Amphibia that includes frogs and toads.

"regional climate models" or "limited area models") and (2) statistical downscaling (also referred to as "empirical" or "statistical-empirical" downscaling). Chemical composition models include the emission of gases and particles as inputs and simulate their chemical interactions; global transport by winds; and removal by rain, snow, and deposition to the earth's surface.

Downscaled regional climate models rely on global models to provide boundary conditions and the radiative effect of well-mixed greenhouse gases for the region to be modeled. There are three primary approaches to numerical downscaling: (1) limited-area models, (2) stretched-grid models, and (3) uniformly high resolution atmospheric GCMs (AGCMs) or coupled atmosphere-ocean (-sea ice) GCMs (AOGCMs).

GCMs simulate changes in climate under scenarios of future greenhouse gas and aerosol emissions. The 2000 IPCC *Special Report on Emission Scenarios* (SRES)[xii] laid out the four basic scenario families used by IPCC scientists to predict future climate change; they are summarized in Table 5. This set of scenarios is designed to represent the range of possible future global conditions that will influence greenhouse gas emissions. The scenarios are based on consistent and reproducible assumptions about global forces that affect greenhouse gas emissions, including economic development, population, and technological change.

Emission Scenario	Economic Development	Global Population	Technology Changes	Theme
A1	Very rapid	Peaks around mid-21st century and declines thereafter	Rapid introduction of new and more efficient technologies	Convergence among regions; increased cultural and social interactions
A2	Regionally oriented	Continuously increasing	Slower and more fragmented than A1, B1, and B2	Self-reliance and preservation of local identities
B1	Rapid change toward service and information economy	Same as A1	Introduction of clean and resource-efficient technologies	Global solutions to economic, social, and environmental sustainability
B2	Intermediate levels of economic development	Continuously increasing, but not as fast as A2	Less rapid and more diverse changes than A1 and B1	Local solutions to economic, social, and environmental sustainability

Table 5. Summary of IPCC emissions scenarios. Source: Intergovernmental Panel on Climate Change (IPCC), *Special Report on Emissions Scenarios (SRES)*, eds. Nebojsa Nakicenovic and Rob Swart (Cambridge: Cambridge University Press, 2000), http://www.ipcc.ch/ipccreports/sres/emission/index.htm.

The magnitudes and patterns of the projected rainfall changes differ significantly among models, probably due to their coarse resolution. The Atlantic and Pacific Oceans are strongly influenced by natural variability occurring at 10-year intervals, but the Indian Ocean appears to be exhibiting a steady warming. Natural variability (from ENSO, for example) in ocean-atmosphere dynamics can lead to important differences in regional rates of surface-ocean warming that affect the atmospheric circulation and hence warming over land surfaces. Including sulfate aerosols in the models dampens the regional climate sensitivity, but greenhouse warming still dominates the changes. Models that include emissions of short-lived radiatively active gases and particles suggest that future climate changes could significantly increase maximum ozone levels in already polluted regions. Projected growth of emissions of radiatively active gases and particles in the models suggest that they may significantly influence the climate, even to 2100.

Stabilization emissions scenarios assume future emissions based on an internally consistent set of assumptions about driving forces (such as population, socioeconomic development, and technological change) and their key relationships. These emissions are constrained so that the resulting atmospheric concentrations of the substance level off at a predetermined value in the future. For example, if one assumes global CO_2 concentrations are stabilized at 450 parts per million (ppm) (the current value is about 380 ppm), the climate models can be tuned to produce this result. The tuned model predictions for regional climate changes can be used to assess specific impacts at this stabilization level. A more detailed discussion of the ability of the models to project regional climate changes can be found in Annex A.

Climate Projections of Future Temperature and Precipitation

The most recent IPCC report[xiii] states that the small islands of the Caribbean will probably experience a warming over the next century that may be somewhat smaller than the global annual mean warming. Temperature increases in the Caribbean at the end of the 21st century are projected to range from 1.4°C to 3.2°C with a median of 2.0°C. This level of warming is still likely to lead to significant sea level rise, deterioration of coastal areas, erosion of beaches, and increased invasion of non-native species. Reduced water resources could lead to an inadequacy of fresh water to meet demand during low-rainfall periods. The amount of sea level rise is not expected to be uniform because of the geographical differences in the islands. Extensive geographical, topographical, ecological, sociological, and population density information gathered into a detailed geographic information system (GIS) would be required before any predictions could be made.

Figure 12a shows the monthly changes projected for temperature and precipitation on a monthly basis from 1980-1999 to 2080-2099 in the Caribbean as reported by the IPCC.[xiv] Temperatures appear to change very little by month, unlike changes in precipitation. Most models predict changes in annual precipitation varying from –39 to +11 percent, with a median of –12 percent.[xv] Some regions are projected to have a slight increase in precipitation in December, January, and February (Figures 13b and 14), while a decrease is projected in June, July, and August.

This paper does not represent US Government views.

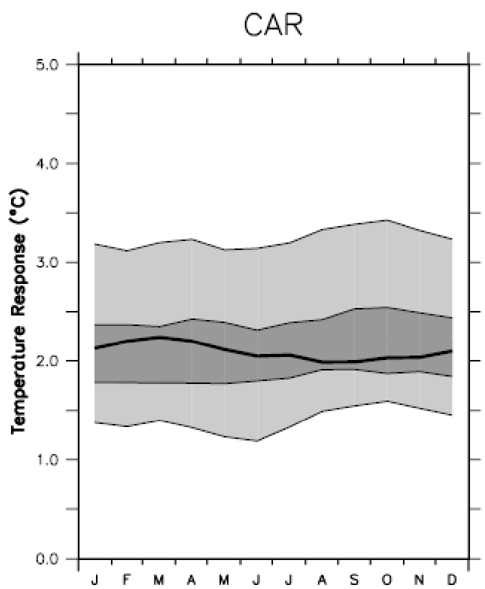


Figure 12a. Monthly temperature change (ºC) from 1980-1999 to 2080-2099 Caribbean (CAR). Thick lines represent the median of the 21 climate models used in the dataset. The dark grey area represents the 25 percent and 75 percent quartile values among the 21 models, while the light grey area shows the total range of the models. Source: J.C. and B. Hewitson, "Regional Climate Projections: Supplementary Material," in *Climate Change 2007: the Physical Science Basis*, eds. S. Solomon, D. Qin, M. Manning, M. Marquis, K. Averyt, M.M.B. Tignor, H.L. Miller Jr. and Z. Chen (Cambridge: Cambridge University Press 2007).

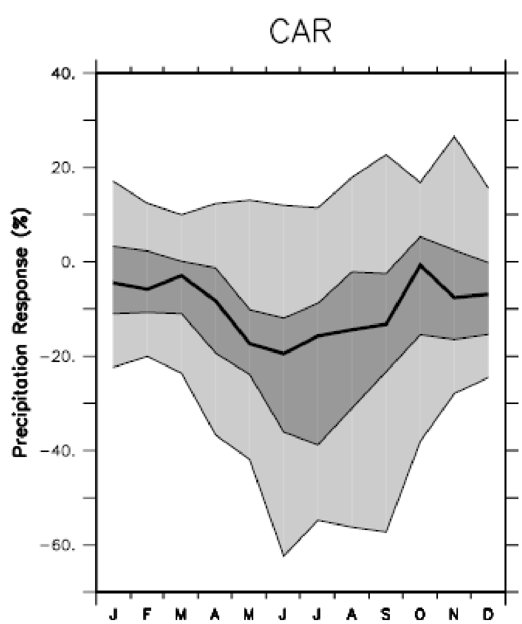


Figure 12b. As in 12a, but for precipitation change (%).

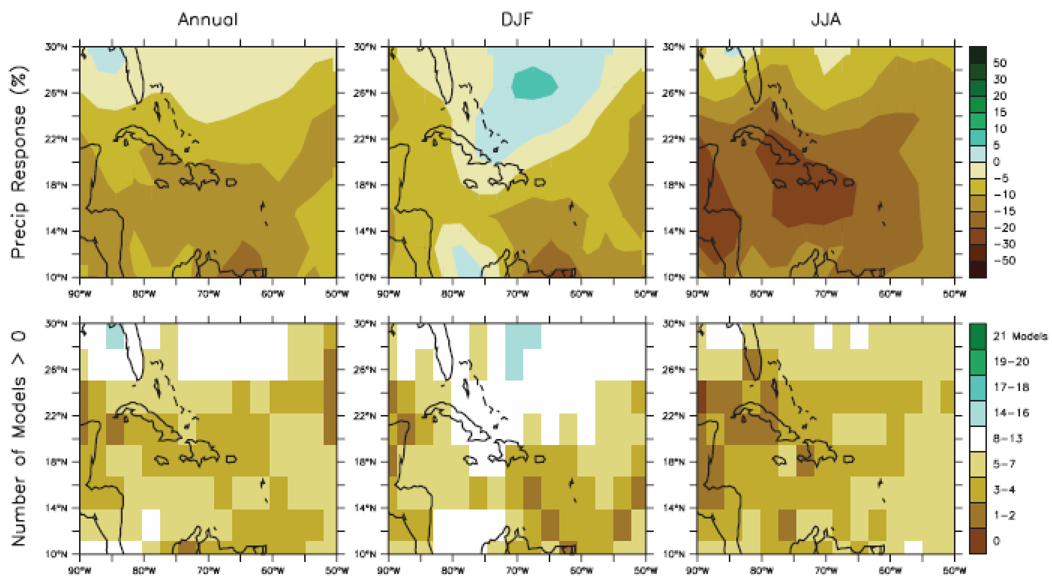


Figure 13. Projected precipitation changes over the Caribbean. Top row: Annual mean, December January February and June July August, fractional precipitation change between 1980 to 1999 and 2080 to 2099, averaged over the 21 climate models. Bottom row: number of models out of 21 that project increases in precipitation. Source: J.C. and B. Hewitson, "Regional Climate Projections," in *Climate Change 2007: the Physical Science Basis*, eds. S. Solomon, D. Qin, M. Manning, M. Marquis, K. Averyt, M.M.B. Tignor, H.L. Miller Jr. and Z. Chen (Cambridge: Cambridge University Press 2007).

Projections of decreasing precipitation in Central America and the Caribbean agree with projections of a general drying in the subtropical Atlantic associated with a phase shift to the positive phase of the North Atlantic Oscillation (NAO). Increases in sea surface temperatures (SSTs) are of primary concern because of the relationship of SSTs to storm intensities. A projected climatological analysis of the Caribbean from 2041 to 2058 using a Parallel Climate Model (PCM) and National Center for Environmental Prediction (NCEP) reanalysis data showed a future warming of around 1°C (SSTs) along with an increase in the rain production during the Caribbean wet seasons. Although the PCM appears to under-predict SSTs, projected changes in feedback processes of cloud formation and solar radiative interactions lead to changes in projected rainfall variability and conditions that may be favorable for increases in tropical storm frequency.[xvi]

The IPCC projects a mean warming in Central America between 1980-1999 and 2080-2099 to vary from 1.8°C to 5.0°C, with half of the models projecting a range of 2.6°C to 3.6°C and a median of 3.2°C (Figure 14). There is a seasonal difference of around 1°C in the median values between winter (December, January, and February) and spring (March, April, and May). As projected for the Caribbean, Central America is likely to experience a decrease in rainfall in the future. Precipitation changes for Central America are shown in Figure 15.

The UK Hadley Centre PRECIS (Providing Regional Climates for Impact Studies) regional model was used to study climate change in Central America.[xvii] The researchers found that interactions between regional atmospheric circulation patterns, trade winds, and the region's complex topography not only define different precipitation regimes for the Caribbean basin (windward) and the Pacific basin (leeward), but also modify the annual cycle of precipitation. Assuming a doubled CO_2 environment, preliminary findings revealed that precipitation change in the future is very different on the Atlantic and Pacific sides of Central America and is also a function of elevation. The Atlantic side not only experiences a reduction in precipitation throughout the year, but also sees a change in the shape of the annual cycle where the Mid-Summer Drought feature seems to disappear. High elevation regions were shown to have an even greater reduction in precipitation compared to lowlands. This variability in the rainy season is very important for planning in key sectors, such as agriculture and power generation that are at the heart of the region's economy.

The same model was applied to Costa Rica[xviii] where cloud formation at high elevations is a primary source of moisture. Research indicates rising temperatures can cause clouds to form at higher altitudes, having a drying effect on areas below. These changes are expected to degrade the viability of numerous biological species in the area.

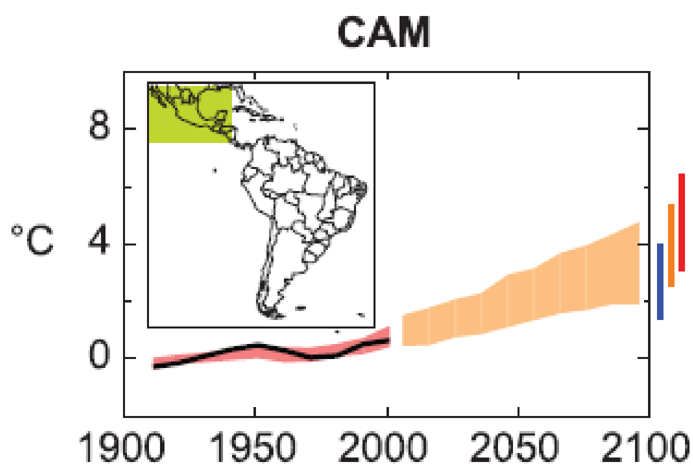


Figure 14. Temperature anomalies for Central America with respect to 1901 to 1950 for 1906 to 2005 (black line) and as simulated (red envelope) by models for 2001 to 2100. The bars at the end of the orange envelope represent the range of projected changes for 2091 to 2100 for various scenarios. Source: J.H. Christensen and B. Hewitson, "Regional Climate Projections," in *Climate Change 2007: the Physical Science Basis*, eds. S. Solomon, D. Qin, M. Manning, M. Marquis, K. Averyt, M.M.B. Tignor, H.L. Miller Jr. and Z. Chen (Cambridge: Cambridge University Press 2007).

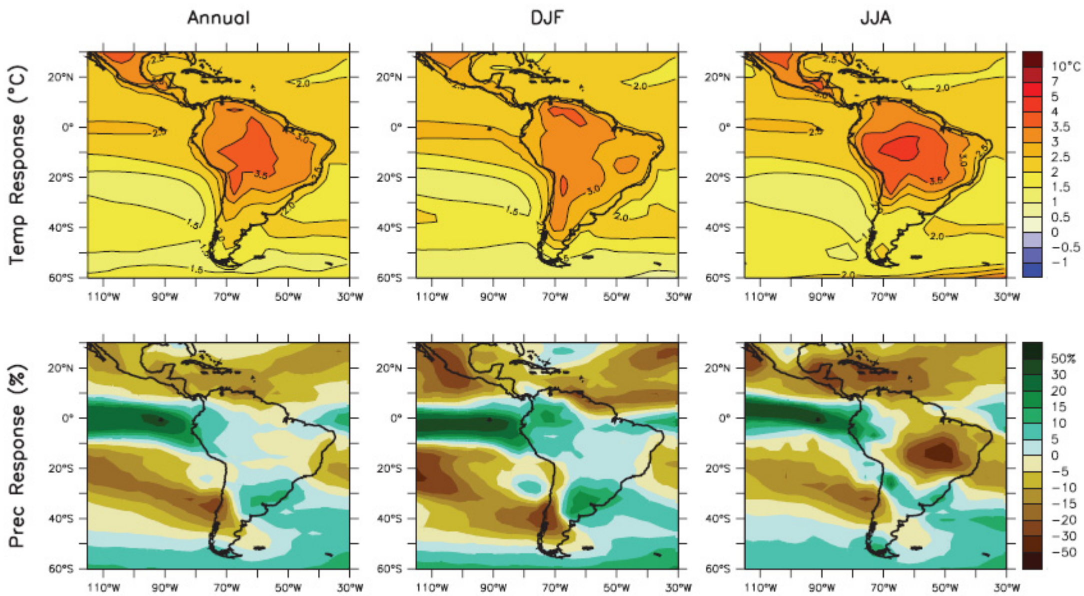


Figure 15. Temperature and precipitation changes over Central and South America. Top row: Annual mean, Dec, Jan Feb and Jun, Jul, Aug temperature change between 1980 to 1999 and 2080 to 2099, averaged over 21 models. Middle row: same as top, but for fractional change in precipitation. Source: J.C. and B. Hewitson, "Regional Climate Projections," in *Climate Change 2007: the Physical Science Basis*, eds. S. Solomon, D. Qin, M. Manning, M. Marquis, K. Averyt, M.M.B. Tignor, H.L. Miller Jr. and Z. Chen (Cambridge: Cambridge University Press 2007).

In 2003, the Hadley Center ran its climate change model using the scenarios from the IPCC Special Report on Emissions Scenarios (SRES).[xix] The Center concluded that the nominal warming predicted for all scenarios is similar over the next 40 years, even though each scenario represents a significant difference in level of emissions. This is explained by the long life of atmospheric CO_2 and the inertia of the climate system from emissions at the time of the study. The Center also concluded that the climate outcome for the second part of the 21st century will depend on the level of emissions in the next few decades. The model predicts precipitation changes in Central America and the Caribbean of up to -24 mm between present day and 2080s for the SRES A1B scenario. The important message from this modeling and analysis is that there is significant need to track, monitor, and mitigate the effects of rising temperatures and climate change at a country-by-country level.

Projections of Changes in Agricultural Growing Seasons

Central America is likely to continue converting forests for agricultural use. However, the general projected drying trend in the area is likely to limit the agricultural crops that can be grown. Projected temperature changes may not differ much by season, but changes in rainfall likely will. The result will be extended periods of drought and possible loss of soil fertility during the peak growing season in June, July, and August.

Also threatening agricultural productivity is the possible salinization of ground water supplies due to climate change and sea-level rise.

Many Central American and Caribbean countries have major fishing industries. Climate change is likely to lead to changes in migration patterns and depth of fish stocks thereby hurting the fishing industry.

Changes in the Frequency or Strength of Extreme Climatic Events

While increasing sea surface temperatures are linked to increasing storm intensities, natural variability in the coupled ocean-atmosphere system also plays a major role in hurricane variability. However, even considering the influence of natural variability, there has been a significant increase in Atlantic hurricane activity since 1970.[xx] During the 2005 hurricane season, SSTs across the tropical Atlantic were 0.9°C above the 1901-1970 average.[xxi] A recent study attempted to separate out the fraction of SST increase due to greenhouse-gas-driven climate change from that due to natural variations.[xxii] Results suggested that 0.45°C of the temperature increase in SST was due to global warming; El Niño accounted for about 0.2°C; the Atlantic Multidecadal Oscillation (AMO), explained less than 0.1°C, and year-to-year variability in temperatures explained the rest. This study contends that hurricane seasons will become more active as global temperatures rise. At the same time, however, there is still a great deal of debate in the scientific community regarding recent and future trends in hurricane frequency and intensity.

Impact by Country of Climate Change on Human-Natural Systems

This section examines the impact country-by-country, relying principally on insights provided in the submissions (National Communications) of the countries to the IPCC. Text boxes are included to highlight case studies and to include Puerto Rico in the discussion.

The submissions of countries to the UNFCCC provide national-level analyses driven by climate change scenarios. These submissions represent both high-quality scientific research and a degree of comparability not available in more local-level studies, which are few with the exception of Mexico.

Most of the impacts and vulnerability studies reviewed here use the IS92 scenarios.[xxiii] These scenarios (six alternatives, IS92a-f) were published in the 1992 Supplementary Report to the IPCC Assessment. The scenarios showed the evolution of greenhouse gas emissions over time, given assumptions about population and affluence. All of them assumed that no special policies to respond to climate change had been adopted. The resulting range of possible greenhouse gas futures spans almost an order of magnitude. Data came mostly from the published forecasts of major international organizations or from published expert analyses. IS92a has been widely used in impact assessments and assumes global population rises to 11.3 billion by 2100 and annual economic growth averages 2.3 percent between 1990 and 2100. Both conventional and renewable energy sources are used. The IS92e scenario has the highest greenhouse gas emissions, with moderate population growth, high economic growth, high fossil fuel availability and eventual phase-out of nuclear power. The IS92c scenario, on the other hand, has CO_2

emissions eventually falling below their 1990 starting level, with population first growing and then declining, low economic growth, and severe constraints on fossil fuel supply.

Belize

The Government of Belize completed its First National Communication to the Conference of the Parties of the UNFCCC[xxiv] in July 2002. The overarching conclusion of this first assessment is that the country's economy is highly dependent on a stable climate for successful agriculture, fishery, timber, and tourism industries. More than 50 percent of the country's GDP comes from the services industries where tourism plays a critical role. The country considers this assessment to be an initial effort to understand the role that Belize plays in the generation of greenhouse gas emissions, its adaptive capacity, the impact climate change variability will have on all economic sectors, and its human development goals. The government concedes much work is needed to understand the full impact and adaptability options.

The Minister of Natural Resources, Environment, Commerce and Industry stated the following: "Belize is prepared to continue working with the international community to negotiate responsibly for strong, achievable and enforceable mechanisms that will control the emissions of greenhouse gases. We are also prepared to utilize the nation's natural resources to assist in the global effort to mitigate the emissions as long as the measures can be accommodated within the nation's development strategy and ultimately contribute to the socio-economic development of our people."

The initial assessment was bounded by several key characteristics of the country: about 70 percent is still under natural vegetation cover, it has extensive low-lying coastal areas, and about 50 percent of its total population lives in urban centers along the coastal areas.

Belize is a net remover of greenhouse gases. In 1994, it was estimated that it absorbed six million metric tons (MMT) against three MMT of emissions. The Global Warming Potential (GWP), however, reveals a different picture. The GWP is a factor based on the relative radiative force for each gas and its respective life in the atmosphere. Using the GWP, Belize contributes to 9.5 MMT CO_2 equivalent while absorbing 3.5 MMT. Moreover, the UNFCCC recognizes that countries such as Belize, "Non-Annex I Parties," have a higher commitment to the alleviation of poverty and investing in sustainable development than to the mitigation of greenhouse gases.

Since signing and ratifying the UNFCCC, Belize has undertaken impact assessments on staple crops, coastal sensitivity to sea level rise, and water resources of the Belize River Valley. Climate change scenarios that project global mean surface temperature increases of 1°C to 3.5°C by 2100 are expected to contribute to a rise in sea level between 20 and 100 cm. Rising sea levels will have large effects on Belize's already low-lying coastline and its small islands with fragile ecosystems. Today, about 60 percent of the coastal areas experience flooding. Most residential areas around Belize City are built on drained/reclaimed wetlands vulnerable to sea level rise. A 1-meter rise in sea level would turn the wetlands into lakes, accelerating coastal erosion, exacerbating coastal flooding, raising water tables, and increasing the salinity of rivers and aquifers. This rise would also provide a higher level for coastal flooding, forcing storm surges further inland and facilitating greater damage from smaller surges.

In the past 20 years, Belize's rate of real estate development (hotels, restaurants, tourism services) in the coastal areas has accelerated sharply to accommodate the growing tourism industry and the expansion of coastal residential areas. The rapid growth has placed increased pressure on the available resources manifested by reduction in water quality, increased soil erosion, and an overextended waste disposal infrastructure. The study estimates that a 50 cm rise in sea level over the next 100 years would overtake more than 50 percent of the beaches; a 100 cm rise would destroy 90 percent of the beaches.

The outlying islands and the Placentia Peninsula are already threatened by a 20 cm rise in sea level. The conclusion at this time is that, to protect these urban areas, sea walls and dikes will need to be built.

When the simulation model that was used adds rising sea levels to increased precipitation as expected in rising temperatures, it reveals that the river areas of the country will remain in a permanent state of flooding throughout the year because of reduced drainage capacity.

Saltwater intrusion is another major concern throughout the coastal areas. Some of the outlying islands have already been equipped with desalination plants to reduce the impact of growing demand on drinkable water by development/population expansion. At this stage, it is clear that the projected sea level rise in the next 100 years, coupled with increases in the rate of water extraction, will result in higher events of saltwater intrusion. Belize gets its water upstream where the water is already salty during the dry season, making drinking water salinity a problem.

Aquaculture has been undertaken along the coastline in areas that are vulnerable to flooding and erosion. Together, these increase water turbidity, which in turn reduces the productivity of cage aquaculture and fish/shrimp farms along the coasts.

Belize's coral reefs are not expected to suffer from rising sea level, but from rising temperatures and rising storm surges. Its coral reefs are living near or at their upper temperature resilience today, so a small increase in temperature will cause them to "bleach," making the corals more susceptible to diseases/pathogens that would eventually kill them. Two bleaching events occurred in Belize in 1995 and 1998 (ENSO years), and elevated sea temperatures affected 52 percent of the reefs. The economic impact of losing coral reefs is twofold: aquaculture and tourism. Tourism today accounts for 15 percent of the GDP and is the largest source of foreign exchange and employment.

Cuba

The Government of Cuba submitted its First National Communication to the UNFCCC[xxv] in August of 2004. The study included the main island and all adjacent islands that form the Cuban Archipelago. Cuba's climate is tropical, with marine influence and average temperatures ranging from 24°C in the plains to 26°C and slightly higher in the eastern shores. The variability in climate stems mostly from the level of precipitation. The average annual rainfall is 130 cm/year between May and October, when 80 percent of total precipitation occurs. The dry period runs between November and April.

The most common and frequent weather events that occur in Cuba are tropical cyclones. This is the term used for the different levels of intensity from tropical depression to hurricane. From year to year, Cuba can experience 0-5 tropical depressions/storms and 0-4 hurricanes.

The Cuban economy suffered a severe contraction with the breakup of the Soviet Union. The contraction triggered a large reduction in funds and goods injection, eliminated the trading links to eastern European countries, and limited access to external credit. All of this caused Cuba's GDP to experience a freefall between 1989 and 1994. In 1995 the economy started to recover slowly and has continued with small but positive GDP changes.

In its National Communication, the IPCC main categories of greenhouse gases were used to calculate national inventories with the following activities as sources: energy, industrial process, solvents and other product use, agriculture, land-use change and forestry, and waste. Greenhouse gases were estimated at 41,314 gigagrams (Gg) in 1990 compared to 26,043 Gg in 1994. CO_2 was the greatest contributor to emissions (94 percent) from the energy sector in both years, though a net removal of gases was achieved by the changes in land use and forestry sectors. The 37 percent decrease in that timeframe resulted from the sharp economic contraction.

Initial estimates of future greenhouse gases, with annual GDP growth of 4-6 percent and carbon intensity levels equal to the ones in 1990 and no mitigation efforts, indicate that Cuba's gross level of emissions will reach 81.3 MMT by the year 2020. When the simulation model includes a reduction on the real energy intensity achieved since 1990, the gross emissions levels drop to around 70 MMT. This implies that there is potential for greenhouse gas reduction by the year 2030.

Cuba enjoys a robust network of surveillance systems focused on meteorology, climate, and atmospheric pollution with 75 meteorological stations and 11 rain and air quality monitoring stations. This surveillance network accounts for a significant contribution of information and data to the World Meteorological Surveillance System (WMS), the Global Atmosphere Surveillance (GAS), the Global Climate Observing Systems (GCOS) and the Global Ocean Observing System (GOOS).

Cuba has a well-structured system of research programs that covers a wide variety of problems focused on understanding the economic, technical, intellectual, and cultural development of the country. The following studies are underway:

- Global change and the evolution of the Cuban environment.
- Sustainable development of the mountains.
- Sustainable energy development.
- Production of foods for its population through sustainable ways.
- Production of animal food through sustainable ways.
- Agricultural biotechnology.

- Vegetable improvements and phytogenetic resources.
- Biodiversity.
- Agricultural ecosystems and soils.

Cuba conducted a study on national biodiversity in 1995 and learned that it has 6,700 plant species, 42 different ecosystems, and more than 19,600 animal species. About 10 percent of the animal species and 2 percent of plant species are at risk of extinction. Cuba classifies 30.8 percent of its agricultural land as "low productivity" and 46 percent as "very low productivity." This has resulted in a continued crop productivity loss with yield indexes below 70 percent.

Observations confirm that Cuba has experienced an annual average temperature increase of about 0.5°C during the period 1951-1996. This is attributable mainly to an increase of 1.4°C in average minimum temperatures, while the increase in average maximum temperature has been insignificant, i.e., there is a reduction in the daily variability of temperatures. Cuba at the same time has experienced an increase in the severity of events such as tornados, rain, hail, and drought since the mid-1070s. ENSO played a key role in the climate variability across the country during this period.

The study, initiated in 2000 to simulate future effects of climate change, used the MAGICC/SCENGEN climate models to generate three different scenarios—optimistic, moderate, and pessimistic. The scenarios combined increases in temperature, using 1990 as the base year, for the years 2010, 2030, 2050, and 2100, and their corresponding rise in sea level for both IS92a and KyotoA1 emissions scenarios. The variance in temperature increase from the three scenarios ranged from 0.34°C to 2.52°C. The variance in sea level rise from the three scenarios ranged from 2 to 55 centimeters. Since all models have limitations, the above scenarios were evaluated with two separate models.

Climate change in general tends to decrease the amount of surface water, even in the case where the model projects precipitation increases. Saltwater intrusion into aquifers is a serious concern and highly probable because most of Cuba's aquifers are open to the sea. A rise in sea level of 30 cm by 2100 will result in a rise in saltwater intrusion of no less than 10 miles inland.

The impact on coastal zones and marine resources based on the scenarios evaluated can be summarized as flooding and displacement in low-lying areas, coastal erosion and the retreat of the coast line, an increase in storm surges, an increase in the salinity in estuaries and aquifers, changes in sediment patterns, and the reduction of light in the marine ecosystem.

The study evaluated the impact in agriculture by focusing on food crop productivity, biomass, diseases and pathogens, and forests. For food production, a set of basic products such as beans, soybeans, corn, cassava, sugar cane, rice, potatoes, and sorghum was evaluated. Productivity losses for the year 2030 where there was no fertilizing effect from CO_2, was between 10-15 percent for rice, cassava and corn; 5-10 percent for sugar cane; and 40-45 percent for potatoes. If the model includes the fertilizing effect from CO_2 and crops, such as beans, soybeans and rice with shorter growing cycles, gains in productivity are possible. These results will depend on the sensitivity of the climate to changes in energy balance.

Mangroves and other forest areas (especially deciduous trees) will suffer. The National Communication estimates that by 2030 sea level rise will affect 7.1 percent of mangrove forest areas, with about 42.9 percent of the area not recoverable.

The evaluation of the impact of climate change on human health focused on the following diseases: acute lung diseases, bronchitis, viral hepatitis, chicken pox, meningitis, and acute diarrhea. Initial estimates revealed that all of the diseases would almost double by 2010 from the 1991-1998 base year with implications of similar impact on the cost of dealing with the increased number of disease events.

Dominican Republic

The Government of the Dominican Republic completed its First National Communication to the UNFCCC[xxvi] in March 2004. The Dominican Republic is an island nation whose variable climate is highly influenced by the surrounding water, easterly winds, pressure systems, topography, and recurrent hurricanes. Its average annual precipitation is 150 cm that varies from 35 cm to 274.3 cm (~ 108 in) in the island's interior mountain range. Emissions for 1990 and 1994 were estimated at 8,690 Gg and 15,003 Gg, respectively. More than 90 percent of the emissions were of CO_2, mostly from the use of fossil fuels to meet energy demands. Similar to the rest of the countries in the region, total gross emissions are very small, but the effects of climate variability can be significant.

The study to evaluate the impact of climate change was performed using different scenarios with adjustments for the Dominican Republic's climate patterns. The study evaluated the effects on water resources, coastal zones, agriculture, forestry, and health.

Three emission scenarios were chosen for this assessment, an optimistic one, IS92c; a moderate one, IS92a; and a pessimistic one, IS92f. The base period chosen was 1961-1991. Projections were made for temperature, precipitation, and rise in sea level. Under the moderate scenario temperature is expected to increase to 26.9°C, precipitation to decrease to 113.7 cm, and sea level to rise by 12.33 cm by 2030. These projections are compared to actual levels for 1990.

The evaluation on water resources used a methodology that included the current water balance adjusted with coefficients representing average monthly changes in temperature and rainfall. Three models were used—CSRT, ECH4 and HADCM2—for the IS92 emissions scenario (moderate) at different levels of sensitivity. The models were run against two regions of the country. The models were run for the years 2010, 2030, 2050, and 2100. A rise in sea level similar to the one used and observed in Cuba (2.9 mm/year) was used to evaluate the impact on aquifers. Rainfall is the only source of water replenishment in the Dominican Republic. Since moderate scenarios estimate a reduction of up to 25 percent in water resources, the Dominican Republic will need new policies to reduce water demand and will have to invest in infrastructure to increase its supply.

The most important aquifers in the country are open, which means they are in contact with ocean water. This is why saltwater intrusion will increase with rising sea levels, exacerbating the loss of water resources for urban, industrial, and agricultural use. The CSRT model estimates an increase in temperature of 0.7°C and a 4 percent increase in rainfall. The ECH4 model estimates an increase in temperature of 2.6°C and a 10 percent increase in rainfall in the next 100 years. As temperatures rise, so does evaporation, reducing water resources by 28 percent relative to the base period. The HADCM2 model estimates a rise in average temperature of 4.2°C and a decrease in rainfall of 60 percent, causing a loss of 95 percent of the water resources by the year 2100.

The Dominican Republic's coastal areas have a rich diversity in ecosystems and economic activities. The cities and towns located along the coastal areas contain 64 percent of the population. Based on the chosen scenarios of emissions and rising sea levels of 0.14 cm/year and 1.01 cm/year, a cumulative rise in sea level is projected to range from 3.77 cm to 26.73 cm by the year 2030. This will affect major coastal roads, housing, and bridges with all needing repairs and reconstruction more frequently.

The Dominican Republic enjoys an active and growing tourism industry. The majority of the activities are associated with beaches, coral reefs and clear water. Lack of information on soil erosion and coastal erosion did not allow for a complete evaluation of the potential impact of rising temperatures and rising sea levels on the tourism economy. At this time, rising temperatures and rising sea levels are not expected to have a large impact on the fishing industry.

Forest productivity in the Dominican Republic today is very high in areas of large rainfall and very low in areas of low rainfall. Under the scenario used for the HADCM2 model (including the fertilizing effects of CO_2), estimates of up to 21.2 percent increases in forest productivity are projected by the year 2050 in the regions where there is currently a high level of production. There is no significant change in productivity in the regions of low yields.

Evaluation of the impact on agricultural production was focused on potatoes, rice, and corn as initial examples since the current methodology could adjust for the variability across the country on growing cycles, rainfall, and products. The impact on potatoes under all scenarios is negative. The largest decrease is associated with the HADCM2 model that projects that in the latter part of the next century growing potatoes may be impossible. Productivity losses by the year 2030 are estimated at above 50 percent. Productivity losses for rice are less dramatic, ranging from 12 percent by the year 2030 to around 50 percent by the year 2100. There are no significant productivity losses for corn; however, productivity does gradually decrease in the same timeframe.

The impact on health in the Dominican Republic was focused on the patterns observed in the past 10 to 15 years. In some regions, 80 percent of malaria cases have been observed where only 10 to 15 percent of the population is located. Changes in temperature and rainfall as projected by the scenarios reveal that future adjustments would be in the frequency of cases (increasing from 16 to 20 percent), but that current patterns and geographical distribution would be maintained. In this analysis, there was no clear evidence or correlation between ENSO and increases in the number of malaria cases.

Guatemala

Guatemala submitted its first national communication to the UNFCC in December 2001.[xxvii] The communication, prepared by the Ministry of Environment and Natural Resources, identifies four major areas vulnerable to climate change: health, forests, production of basic grains, and hydrologic resources. The analysis of Guatemala's climate is based on data from the network of stations of the National Institute of Seismology, Volcanology, Meteorology and Hydrology (*Instituto Nacional de Sismología, Vulcanología, Meteorología e Hidrología*). The emissions scenarios chosen to estimate the changes in global mean temperature were IS92c, IS92a, and IS92d.

Three diseases among several analyzed were identified as the principal diseases associated with climatic variability in Guatemala: acute diarrhea, acute respiratory infection, and malaria. Acute diarrhea and malaria are highly prevalent in the warmest and rainiest months of the year (May-October).[xxviii] Acute respiratory infection is more prevalent during September-November and February-March (i.e., the transitioning periods from summer to winter and vice versa). The criteria used to assess the diseases with the largest possible impact from climate change are the following:

- Having a relation (direct or indirect) to climate and its variability.
- Being of high prevalence at a national level.
- Being within the ten major causes of morbidity and mortality.
- Having statistical data to develop the research.
- Not having been discarded in other studies at the international level.
- Having a profound understanding of its epidemiology.
- Obtaining results that are beneficial to health.

In addition to coinciding with the largest number of the aforementioned criteria, acute diarrhea and acute respiratory infection represent the studied diseases with the greatest potential impact on the country and are the principal causes of illness and deaths among Hondurans (363,679 and 962,827 deaths in 1999, respectively), particularly in children less than 5 years old. Malaria was selected because it is a vector disease and is predominantly present among adult males. The poor state of health in Guatemala results from the poor quality of life, little availability of health and sanitary programs, and the lack of adequate nutrition. The prevalence of infectious diseases in Guatemala reflects this poor state of health and is among the major causes of deaths in the country.

An assessment of the impact on health due to climate change was based on climatology baseline from 1961-1990, climate information for the period 1991-1999, and a pessimistic scenario on climate change. The Bultó Index was also used. This is a methodology developed in Cuba that is based on empirical statistical models for projecting future behaviors of diseases using climatic conditions as variables, such as maximum and minimum temperatures, thermal oscillation, precipitation, and the influence of ENSO. The analysis of the three diseases focused on the southwestern part of Guatemala, but according to the communication, the results could be similar for the rest of the country with the exception of malaria which shows a tendency to decline by 2030.

The results indicate that by 2030, acute respiratory infection has a tendency to increase in frequency, particularly at the beginning of the rainy season. By the same year, acute diarrhea also increases in frequency, with the greatest prevalence in June and July. However, the communication points out that the disease is not only influenced by climate and its variability, but also by such factors as poor sanitary infrastructure, especially in rural and marginal urban areas of the country, the lack of health education, and poor coverage of health care services. When analyzing the effects of climate variability in the behavior of malaria in the region, the result is a significant decline in malaria cases and abating of the seasonal patterns of the disease as a result of the effects of climatic variability.

For the assessment of climate change impacts on forest resources, vegetation cover is analyzed as a function of the IS92c, IS92a, and IS92d climate change scenarios and bioclimatic scenarios assigned to Guatemala that are based on the Holdridge Life Zone Model. Under the optimistic scenario, climatic conditions have an impact on very limited areas of the country; only 416 km^2 of forest cover (0.38 percent of the total surface area of the country), which is equivalent to 4.2 million cubic meters of lumber. Under the pessimistic scenario, close to 4,000 km^2 of coniferous and mixed forests (3.67 percent of the surface area of the country) would suffer, which is equivalent to 40 million cubic meters of lumber. Coniferous forests represent 80 percent of forest productivity, so the decline in forest cover would also have economic consequences. However, the authors caution that the analysis is based on climatic projections to 50 years (from 1999), which is a short period of time for forests to show significant changes.

The climate change scenarios for the vulnerability study on the production of basic grains is based on the changes for the year 2030 in the normal (ECCG_C), optimistic (ECCG_HA, extensive wetness), and pessimistic (ECCG_SA, extensive dryness) scenarios.[6] Corn, beans, and rice, with their cultural, socioeconomic, and nutritional significance in Guatemala, were the basic crops studied. Corn is the most important crop in the country and makes up the basic diet of a majority of Guatemalans, particularly in rural areas. In addition, most corn producers are subsistence farmers. Beans are the second most important food crop in Guatemala and one of the major sources of protein. Rice is a significant source of carbohydrates in the national diet and is also used in the production of domestic beverages.

The yield differences in the production of basic crops that were simulated according to the baseline (projections of environmental conditions in the absence of climate change), and the differences that were obtained under climate change, represent the potential size of the impact for 2030 (Table 6).

For each zone examined, yield variability (production) was determined between the production in the baseline and production under climate change, and for the normal, optimistic and pessimistic scenarios (Table 7).

[6] The scenarios were defined specifically for the National Communication; details can be found in that report.

The simulations show that variability in normal climate conditions implies the largest negative consequences on the studied crops. The results also indicate that in the areas where climatic conditions are expected to be more extreme, the extent of negative consequences on agricultural production of basic crops will be larger.

The hydrometeorological data used to evaluate the impact of climate change on hydrological resources are based on the results (precipitation and evapotranspiration) of the baseline of the climate scenarios, which was used to create a base scenario for precipitation (P), evapotranspiration (ETP) and runoff (R) and for each basin studied. The MOD-BAL model, developed by UNESCO, was used to estimate future runoff according to climatic parameters established in the climatic scenarios to the year 2030.

Under the optimistic scenario (ECCG_HA), an increase in runoff can be expected. River flows of 10 liters per second under this scenario would increase to up to 11.5 liters per second. Under the pessimistic scenario (ECCG_SA), a reduction in runoff can be expected. Runoff of major rivers of large departments and cities such as Guatemala, Escuintla, Mazatenango and Quetzaltenango may decrease by as much as 50 percent. Accordingly, basins of 10 liters per second could diminish by as much as 5 liters per second.

Station	Temperature increments (ºC)			Precipitation Variability (%)		
	HA	C	SA	HA	C	SA
Camantulul	1.5	1.0	2.2	+9	-1	-19
Panzós	1.6	1.0	2.1	-1	-2	-19
Asunción Mita	1.6	0.9	2.3	+9	-2	-22
Labor Ovalle	2.8	2.4	3.6	+7	-1	-19
San Jerónimo	1.4	1.1	2.3	+6	0	-10
INSIVUMEH	1.5	1.0	2.2	+7	-1	-18
S. Cruz Balanyá	1.5	1.0	2.2	+7	-1	-18
Promedio	1.7	1.2	2.4	+6	-1	-18
HA: Optimistic scenario (excess wetness); C: Normal scenario (central); SA: Pesimistic scenario (excess dyness)						

Table 6. The simulations were made for corn, beans and rice, for13 agricultural seasons (1980 to 1993), and in seven climatic observatory sites. Source: Herrera and Associates (2000)

Zone	Crop	Yield (Kg/ha)							
		Actual	Baseline	Optimistic	% Change	Normal	% Change	Pessimistic	% Change
1	Corn	2857	2738	3142	15	2957	8	3091	13
2	Corn	2025	1952	1744	-11	1828	-6	1630	-16
	Rice	2025	4136	3303	-20	3462	-16	3018	-27

3	Corn	2270	2263	2029	-10	2003	-11	1500	-34
	Beans	1281	1281	743	-42	918	-28	433	-66
4	Corn	2189	2163	2430	12	2280	5	2131	-1
5	Corn	1954	1954	2021	3	1918	-2	1876	-4
6	Corn	2237	2245	2156	-4	2169	-3	2120	-6
7	Corn	2384	2374	2412	2	2447	3	2339	-1
6	Beans	113	2104	2157	3	2163	3	2110	00

Table 7. Climate change impacts on the production of Basic Grains. Source: Herrera and Associates (2000).

Haiti

Haiti's Ministry of the Environment submitted the country's First National Communication to the UNFCCC in 2001.[xxix] Haiti has also submitted a National Adaptation Programme of Action (NAPA) to the UNFCCC.[xxx] NAPAs provide a process for Least Developed Countries (LDCs) to identify priority activities that respond to their urgent and immediate needs with regard to adaptation to climate change. The rationale for NAPAs rests on the limited ability of LDCs to adapt to the adverse effects of climate change. In Central America and the Caribbean, only Haiti has been designated as an LDC.[xxxi]

Similar to many of the Latin American reports, Haiti's National Communication first focuses on emissions sources, particularly energy emissions. Four sources are listed: wood (71 percent), oil (20 percent), hydropower (5 percent), and bagasse (4 percent). Most of the energy demand (69 percent) is for residential housing.

The vulnerability section focuses on agriculture and water. The method used is also the method specified for many of the other countries in this region, using the MAGICC and SCENGEN models to generate scenarios. There are three sensitivity scenarios (low, middle, and high). The results show temperature increases of ~0.6 to 1.2°C by 2020, ~1.1 to 2.3°C by 2050, and ~1.4 to 4.0° by 2100. By 2030, precipitation at a medium sensitivity decreases from 5.9 percent in February to 20 percent in July.

For agriculture, all three crops studied—potatoes, rice, and maize—show decreased yields, even with CO_2 fertilization. Forestry, too, is projected to experience detrimental effects. Less precipitation and higher temperatures are the sources of these negative consequences.

For water, the decline in precipitation has a devastating impact, combined with saltwater intrusion as sea level rises. Every variable shows marked changes; for instance, precipitation in 2030 is projected to decline by 187 mm annually and continue to decline to 477 mm annually by 2060.

Honduras

Honduras submitted its first national communication to the UNFCC on November 15, 2000.[xxxii] In considering possible effects of climate change, the communication draws partly on projections developed by the country's Climate Change Program of the Environment Ministry and partly on a 1995 US EPA-funded Central American Project on Climate Change (Proyecto Centro Americano de Cambio Climático). Under the Central American Project on Climate Change, Honduras participated in studies on the vulnerabilities of hydrologic resources and addressed the possible impact from climate change-related sea level rise.

Honduras is highly affected by extreme climatic events—in terms of both the frequency of climatic changes, as well as the intensity of occurrences. In 1995-96, the impact from drought in the driest regions of the country brought about famine, human losses, emergence of water-borne diseases, cardiovascular and respiratory diseases related to atmospheric pollution and extreme temperatures, loss of crops, and increased forest fires. Hurricane Mitch in 1999 and the historic amounts of rainfall that followed the next year cost the lives of many civilians, as well as causing appreciable losses and deterioration of infrastructure, crop failure and depletion of watersheds.

In response to this, Honduras' Climate Change Program of the Environment Ministry has developed sectoral vulnerability studies associated with medium-to-long-term occurrences such as climate change. Studies specific to climate change relate to future climate projections based on the IPCC scenarios. The table below shows projected future changes of average annual temperature, precipitation, and cloudiness for the pessimistic and moderate scenarios based on these studies:

Pessimistic Scenario

Year	Temperature ºC	Precipitation (%)	Cloudiness (%)
2010	0.6 to 0.9	-6.6 to -8.4	-2.5 to -4.0
2030	1.0 to 1.5	-11.2 to -14.5	-4.3 to -6.8

Moderate Scenario

Year	Temperature ºC	Precipitation (%)	Cloudiness (%)
2010	0.6 to 0.8	-2.4 to -6.4	-2.4 to -3.7
2030	0.9 to 1.3	-9.7 to -12.5	-3.8 to -5.9

Figures 18 and 19 identify what areas in Honduras are likely to experience the highest temperatures and the most precipitation for 2030, respectively.

Reduced precipitation as indicated by these projections may cause considerable sectoral damages, particularly if this reduction due to climate change is accompanied by precipitation reductions that arise from an El Niño event in areas near the Pacific slope.

Changes in the hydrologic cycle due to climate change will occur in the form of floods and droughts that year by year will affect considerably the agricultural zones of the country, such as the Valley of Comauagua, the Valley of Sula and the Valley of Choluteca. The rise in temperature and reduction in rainfall will likely have effects on the supply of water for drinking, irrigation, and the generation of electric energy. Given the high importance of agriculture to Honduras, it is highly likely the economy will suffer severely.

This paper does not represent US Government views.

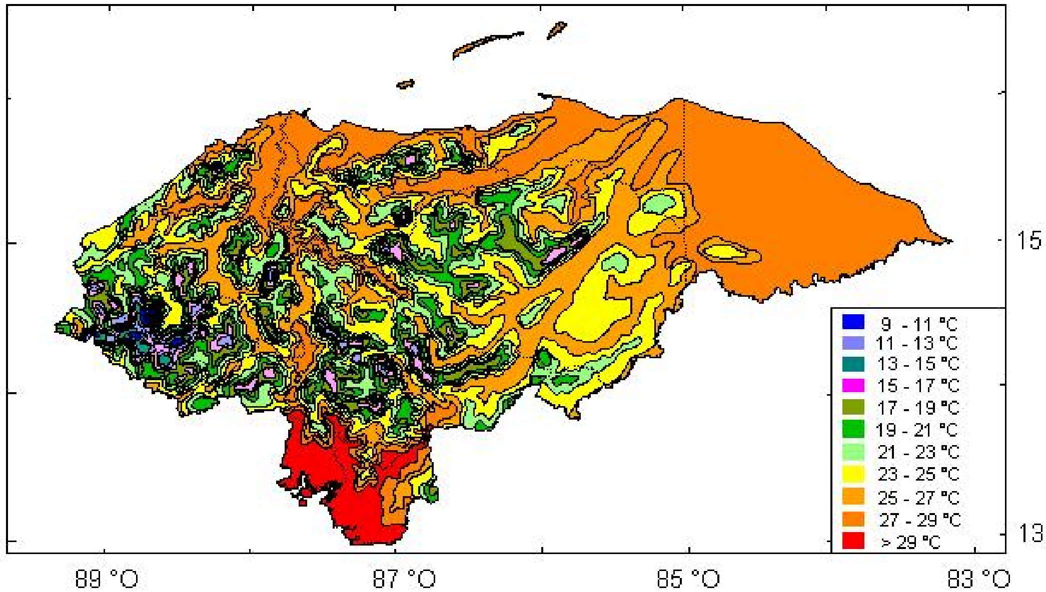


Figure 16. Spatial distribution of temperature in Honduras – Results for the year 2030 given the moderate scenario. Source: Honduras, "First National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change" (November 2000) http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php

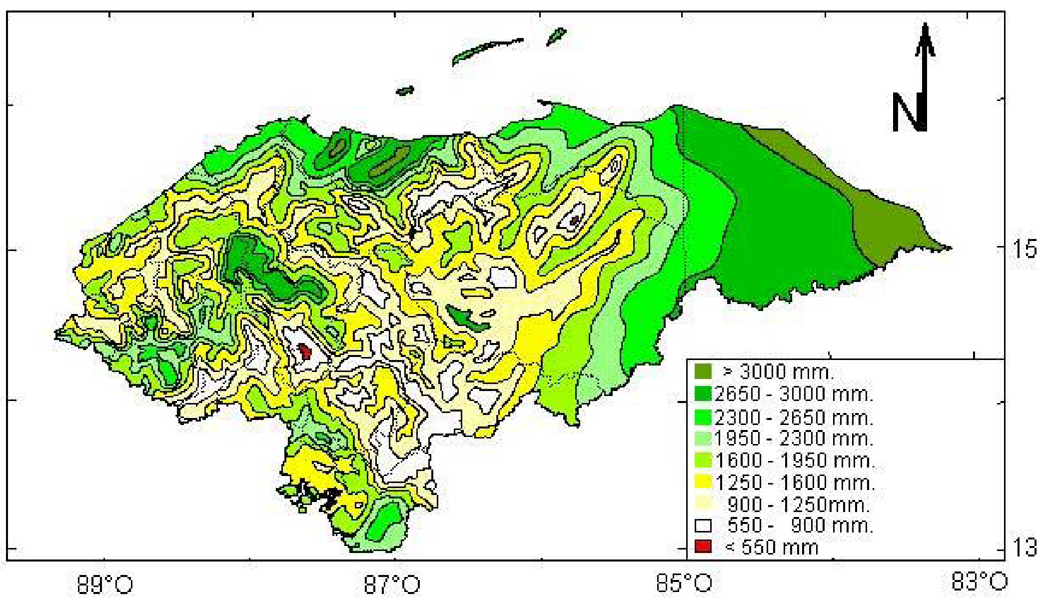


Figure 17. Spatial distribution of precipitation in Honduras – Results for the year 2030 given the moderate scenario. Source: Honduras, "First National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change" (November 2000) http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php

This paper does not represent US Government views.

Based on the 1995 Central American Project on Climate Change, preliminary estimates of the areas vulnerable to sea level rise by 2025 are shown below.

Affected Zone	**Loss by inundation estimates (km^2)**
Valle de Sula	885
Valle de Cuyamel	39
Punta Gorda	3
Omoa	2
Tulián	3
Puerto Cortés	20
Bahía de Tela	46
Valle de Río Leán	100
Llanura del Esparta a la Ceiba	175
Total	**1,276**

In addition to the economic damage from flooding associated with the rise in sea level, Honduras' first communication also points out possible socio-cultural implications that are difficult to quantify. Such may be the case with nationally treasured archeological sites and valuable tourist resources, such as mangroves, wetlands and reefs that are vulnerable to erosion and flooding.

Mexico

The Government of Mexico submitted its Third Communication to UNFCC as an update to its previous submission[xxxiii] in December 2007. This report includes an inventory of greenhouse gases in 2002. In contrast with the other countries in this review, Mexico is a net producer/supplier of fossil fuels and an increasingly important emitter of greenhouse gases.

Inventories of greenhouse gas emissions for the third report were calculated for the year 2002 in the energy sector, industrial processes, solvents, agriculture, land use/changes/forestry and waste. The energy sector generated 61 percent of all emissions, followed by land use/changes/forestry with 14 percent, waste 10 percent, industrial processes 8 percent and agriculture 7 percent. At that time emissions in terms of CO_2 equivalent represented an increase of 25 percent from the base year (1990).

The Long-Range Energy Alternatives Planning (LEAP) system was used to build the base emission scenarios for 2008, 2010 and 2030 to estimate future greenhouse gases. For these projections three scenarios were used: base or current, low economic growth and high economic growth. A key conclusion was that electricity generation is highly sensitive to GDP growth, resulting in 30 percent reduction of emissions in the low economic growth scenario and 24 percent increase in the high economic scenario. Another conclusion accepted in the report found that implementing automobile energy efficiency standards would help significantly in the reduction of greenhouse gases, in combination with the expansion of renewable and nuclear energy. This report focused extensively in quantifying all types of gases generated by the use and generation of energy/fuels across the major sectors of the economy. Currently, there are many programs, regulations and measures underway by the Secretaría de Energía (SENER) to increase the efficient use of energy as well as to save energy with the goal of reducing greenhouse gas emissions in the next 100 years. There are also programs to increase the role of renewable energy including wind and biomass. By the end of 2007 the plan was to have a total of 5,000 GW/year for incorporation into the electricity network with the goal of covering 8 percent of total electricity demand by the year 2012.

GCMs were used to estimate the impact of climate change under four SRES emission scenarios: A1B, A2, B2 and B1. The overarching results were that Mexico's climate is projected to be warmer by the years 2020, 2030 and 2080, especially in the northern part of the country with a temperature increase of 2-4°C. Rainfall was estimated to decrease by 15 percent in the central regions and by less than 5 percent on the regions around the Gulf of Mexico. The hydrological cycle will be more intense creating a larger number of storms during the rainy season and a prolonged period of drought during the dry season. These cycles indicate that 75 percent of precipitation will evaporate while only 5 percent will be able to replenish aquifers. IPCC estimates that Mexico could experience reductions in runoff ranging from 10-20 percent as a national average with over 40 percent in coastal areas of the Gulf. The projected increases in severe storms and prolonged droughts made by these models have already been observed across the country in the past five years.

Mexico's national average water availability is calculated at 4,000 cubic meters per capita per year. The national average availability varies significantly among the different regions of the country, particularly in the center and north, where the average is 2,500 cubic meters per capita per year.[7] The figures are somewhat misleading since 75 percent of the water is used by the agricultural sector, 14 percent by households and 11 percent by the industrial sector. According to the Comisión Nacional del Agua (CNA) the agricultural sector wastes 55 percent of water extracted while the urban sector wastes 43 percent due to leaks in the extraction and distribution process and through excessive use. Adding decreases in rainfall of 5-10 percent and increases in temperature of 1-3ºC will result in water availability losses between 5 and 15 percent by the year 2020 and 2050. Water resource loss will vary widely across the country. This will have a critical impact in the north and central regions, a severe impact in the Pacific-central region, and a strong-to-moderate impact in the south and Gulf coast regions. As a result, it is clear that significant changes will be required in the use and distribution of this resource.

Climate change projections were applied to three models for evaluating the efficiency of corn yields based on temperature, rainfall, topography, soil type and vegetative period. Moderate yield losses were found in the moderate yield areas, which would force increased use of marginal lands of up to 4 percent, resulting in further yield reductions. Several models were used with the same scenarios, providing different results with variations of productivity changes between slight increase and moderate losses depending on the region.

[7] 1,000 cubic meters per capita per year is an indicator of water scarcity.

Forestland coverage is a key factor in the mitigation of climate change. The risk of forest fires increases with rising temperature and reduction of rainfall. Loss of forestland will be exacerbated as agricultural activity moves into marginal lands and forest areas. Under the different models used for scenario A2 the estimated forestland affected ranges from 8 percent to 33 percent by 2020 and from 9 percent to 76 percent by 2050.

The report provides results of a specific study on water resources undertaken for the Hermosillo and Sonora regions. The study outlines options as solutions to the water availability challenges with some qualitative estimates of the type of action, time to implement, efficiency ratios, cost, viability, participants, and outcomes.

Other studies of Mexico generally echo the major concerns about impacts discussed in the National Communication, especially crop production, precipitation, and water availability. Conde et al.[xxxiv] focus on maize, the staple food of rural dwellers, especially subsistence farmers in Tlaxcala, Mexico. Mexican policy changed from self-sufficiency in food production during the 1990s to an emphasis on "guarantee[ing] people's capacity to acquire food."[xxxv] Imports became more important—but not to the poorest and subsistence farmers. Using the SRES A2 and B2 scenarios leads to projected yield increases because the threat of frost is reduced. Using the Ceres-maize model, however, leads to yield reductions. Wehbe et al.[xxxvi] explore coffee production in its climatic and economic context in Veracruz. Their model indicates that coffee production falls by 34 percent by 2020, making it not economically viable. Salinas-Zavala and Lluch-Cota[xxxvii] find that ENSO events are correlated to winter wheat yields in Sonora (El Niño with increases, La Niña with decreases); the ability to forecast ENSO events may thus reduce the impact of climate change on wheat yields. Luers et al.[xxxviii] also focus on wheat in the same region (the Yaqui Valley), specifying a quantitative measure of vulnerability and finding that "Valley farmers, without adaptations, are on average more vulnerable to a 20 percent decrease in wheat prices than a 1°C increase in average minimum temperature."[xxxix]

Drought has long plagued Mexico. Boyd and Ibarrarán[xl] explore the implications of projected increases in drought in northern Mexico (up to a 36 percent increase projected by the Canadian Climate Change model) on various economic sectors. As expected, agricultural production is highly affected. Electricity from hydropower constitutes another significant loss. A ripple effect then slows productivity in manufacturing, chemicals, and refining sectors, although these losses are not as great as in agriculture and electricity. Finally, consumption declines, with inequality increasing as the already-poor are more affected.

Nicaragua

A case study for evaluating impacts of climate change in Nicaragua[xli] revealed that temperature increases ranging from 1.3°C to 1.5°C by the year 2030 would result in a 12.4 percent to 14.5 percent drop in precipitation. In this study, Umaña and colleagues considered three main temperature change scenarios: optimist, moderate and pessimist for the years 2010, 2030, 2050 and 2100. The optimist scenario assumed temperature increases of 0.8°C for 2010, 1.3°C for 2030 and 2.1°C for 2100, resulting in 7.9, 12.4 and 21 percent decrease in precipitation.

For the moderate scenario with temperature changes of 0.8°C in 2010 and 1.3°C in 2030 (the same as for the optimist scenario), precipitation is estimated to decrease from 7.9 to12.4 percent. For the pessimist scenario, temperature change is projected to increase by 0.9°C in 2010 and 1.5°C in 2030, resulting in a decrease from 8.4 percent to 14.5 percent in precipitation.

The scenario changes in temperature and precipitation were used to simulate the impact on the three main food crops produced in the country: corn, beans and soybeans. While the impact is expected to vary across the country's different zones, the end results are expected to be greater evaporation and an increased need of water for irrigation of crops, a longer duration of the vegetative cycle, and reduced plant productivity. In the moderate temperature change scenario, the estimated fall for corn production is 5 percent to 30 percent, for beans 5 percent to 32 percent, and for soybeans 2.5 percent to 18 percent by the 2030.

Panama

Espinosa et al.[xlii] evaluated the impact of climate change on water resources in the La Villa, Chiriqui and Chagres river basins of Panama. The goal of the research was to develop different scenarios of water resource availability under given climate changes experienced by the doubling of global CO_2 concentration in the next 100 years.

For simulating impact, they used the model CLIRUN3 in combination with 20-year records of precipitation, potential evapotranspiration and water flow to simulate monthly river runoff in the Chagres (Panama Canal) river basin. This basin is critical because it supplies water to 25 percent of the country's population and is crucial to international navigation. The Chiriqui river basin is the main national source of hydropower and the La Villa river basin is highly important to agricultural activity. The Chagres river basin is part of the Atlantic watershed; the other two belong to the Pacific watershed.

The authors ran the model for the watersheds under scenarios with temperature increases of l^{o}C and 2^{o}C, with precipitation changes of plus or minus 15 percent for the Pacific and plus or minus 20 percent for the Atlantic watershed. Although the model and information had limitations, the simulated results had a high correlation, 0.9, with the observed data. The simulation study showed "A clear indication that basins located in the Pacific region would be the most affected under the conditions of the incremental scenarios used." During November-December, when water demand is higher, water flow is projected to lessen as temperature increases, whether or not precipitation increases. This suggests that the basins are highly sensitive to temperature changes, particularly during the dry season.

Under a scenario of increased temperature and decreased precipitation, the mean monthly flow tends to decrease by 3 to 42 percent, both in the Atlantic and Pacific basins.

If simultaneous increases in temperature and precipitation took place, the flow in the Pacific basins would be reduced by 5 percent to 35 percent from November to March. During the remaining months the mean flow would increase by 4 percent to 40 percent. However, in the basin of the Atlantic watershed all the simulated values would be 3 percent to 50 percent higher than the mean value.

Espinosa et al. point out that there is great uncertainty in the assessment of changes in climatic conditions for different time periods because GCMs are not highly reliable tools for studies in the Central American region. However, the use of incremental scenarios allowed evaluation of how sensitive water resource availability is under different temperature increments and precipitation changes. (U

Puerto Rico—Climate Change Impacts on Water Availability for a Bioenergy Project in the Lajas Valley

Puerto Rico is looking at the feasibility of finding green energy alternatives. Researchers Guindin, Weiss and Pérez-Alegría[xliii] evaluated a bioenergy project based on sugarcane ethanol to use over 24,281 ha (60,000 ac) of prime farmland in the Lajas Valley.

Predicting sugarcane water needs under current conditions and for the future was considered a critical issue for the sustainability of any agricultural enterprise in the proposed region. In this research, the authors noted that there is intense competition for a finite amount of water among agricultural, residential, and commercial users. The objective of their effort was to study the impact of irrigation requirements for sugarcane using different climate change scenarios. The authors used the climate scenarios for 2010-2039 (2010s), 2040-2069 (2040s), and 2070-2099 (2070s) periods from the HadCM3 A21 model developed at the UK Hadley Climate Research Center and the CGM2 A21 model developed by the Canadian Climate Centre. Climate change scenarios were generated based on projections from these models. The relative changes in precipitation, maximum and minimum temperature were calculated for the three periods (2010s, 2040s, and 2070s) using the climate change scenarios from the HadCM3 and CGM2 models. Sugarcane water requirements were calculated with CropWat 4 using generated monthly temperature and precipitation for the three periods.

The authors state their conclusions as follows:

"Both climate change scenarios project a decrease in total annual precipitation for 2010s, 2040s and 2070s. The HadCM3 model projected a 43 mm decrease in total annual precipitation for 2010s while the CGM2 model projected a decrease of 400 mm for the same period. For 2070s, the HadCM3 model projected a 422 mm decrease in total annual precipitation. Under the current climate conditions, simulation results indicate that the irrigation system does not have the capacity to supply the irrigation water requirements for 60,000 acres of sugarcane in the Lajas Valley. Future irrigation water requirements for sugarcane show an increase over 90 percent under climate change scenarios for the periods 2010s, 2040s and 2070s, based on the actual irrigation system capacity. If the assumptions used in this study are reasonable, now is the time for planning future water supply and storage systems and developing alternatives crops that can adapt to less water. Further research is needed to assess other sources of uncertainty—in particular, changes in wet and dry periods, and to analyze the possible impact on other crops grown in the region."

Adaptive Capacity

The impact of climate change on a society will be felt by how well it can adapt to climate change, that is, its adaptive capacity. Adaptive capacity is defined by the IPCC as, "The ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences."[xliv] Thus, adaptive capacity is distinguished from both the effects of climate change and the degree to which those effects influence the systems that are in place, as noted in the previous sections.

Although the specific determinants of adaptive capacity are a matter of debate among researchers, there is broad agreement that economic, human, and environmental resources are essential elements. Some components of this adaptive capacity are near-term, such as the ability to deliver aid swiftly to those affected by flooding or droughts for example. Other components include a high enough level of education so that people can change livelihoods, a quantity of unmanaged land that can be brought into food production, and institutions that provide knowledge and assistance in times of change. For instance, Yohe and Tol[xlv] have identified eight qualitative "determinants of adaptive capacity," many of which are societal in character, although the scientists draw on an economic vocabulary and framing:

1. The range of available technological options for adaptation.
2. The availability of resources and their distribution across the population.
3. The structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be employed.
4. The stock of human capital, including education and personal security.
5. The stock of social capital, including the definition of property rights.
6. The system's access to risk-spreading processes.
7. The ability of decision-makers to manage information, the processes by which these decision-makers determine which information is credible, and the credibility of the decision-makers themselves.
8. The public's perceived attribution of the source of stress and the significance of exposure to its local manifestations.

The Caribbean and Central American Region in a Global Context

Researchers have only recently taken on the challenge of assessing adaptive capacity in a comparative, quantitative framework. A global comparative study of resilience to climate change, including adaptive capacity, was conducted using the Vulnerability-Resilience Indicators Model (VRIM—see description in box).[xlvi]

Vulnerability-Resilience Indicators Model (VRIM)

The VRIM is a hierarchical model with four levels. The vulnerability index (level 1) is derived from two indicators (level 2): sensitivity (how systems could be damaged by climate change) and adaptive capacity (the capability of a society to maintain, minimize loss of, or maximize gains in welfare). Sensitivity and adaptive capacity, in turn, are composed of sectors (level 3). For adaptive capacity these sectors are human resources, economic capacity, and environmental capacity. For sensitivity, the sectors are settlement/infrastructure, food security, ecosystems, human health, and water resources. Each of these sectors is composed of one to three proxies (level 4). The proxies under adaptive capacity are as follows: human resource proxies are the dependency ratio and literacy rate; economic capacity proxies are GDP (market) per capita and income equity; and environmental capacity proxies are population density, sulfur dioxide divided by state area, and percent of unmanaged land. Proxies in the sensitivity sectors are water availability, fertilizer use per agricultural land area, percent of managed land, life expectancy, birthrate, protein demand, cereal production per agricultural land area, sanitation access, access to safe drinking water, and population at risk due to sea level rise.

Each of the hierarchical level values is comprised of the geometric means of participating values. Proxy values are indexed by determining their location within the range of proxy values over all countries or states. The final calculation of resilience is the geometric mean of all eight sectors.

Adaptive capacity as assessed in that study consists of seven variables, in three sectors, chosen to represent societal characteristics important to a country's ability to cope with and adapt to climate change:

Human and Civic Resources

- *Dependency Ratio:* proxy for social and economic resources available for adaptation after meeting basic needs.
- *Literacy:* proxy for human capital generally, especially the ability to adapt by changing employment.

Economic Capacity

- *GDP (market) Per Capita:* proxy for economic well-being in general, especially access to markets, technology, and other resources useful for adaptation.
- *Income Equity:* proxy for the potential of all people in a country or state to participate in the economic benefits available.

Environmental Capacity

- *Percent of Land that is Unmanaged:* proxy for potential for economic use or increased crop productivity and for ecosystem health (e.g., ability of plants and animals to migrate under climate change).
- *Sulfur Dioxide Per Unit Land Area:* proxy for air quality and, through acid deposition, other stresses on ecosystems.
- *Population Density:* proxy for population pressures on ecosystems (e.g., adequate food production for a given population).

Adaptive capacity for a sample of 10 countries from the 160-country study is shown in Figure 18 (base year of 2000). There is a wide range of adaptive capacity represented by these countries; the three countries from the Caribbean—Belize, Mexico, and Haiti—are in the high-middle and lowest ranks, both in the sample and overall:

- Russia ranks 32nd and Libya 34th (in the highest quartile).
- Indonesia ranks 45th, Belize 48th, Mexico 59th, and China 75th (in the second quartile).
- The Philippines ranks 91st and India 119th (in the third quartile).
- Morocco ranks 136th and Haiti 156th (in the lowest quartile).

Any country-level analysis must take into account the comparative ranking of the country in the overall 160 groups of countries.

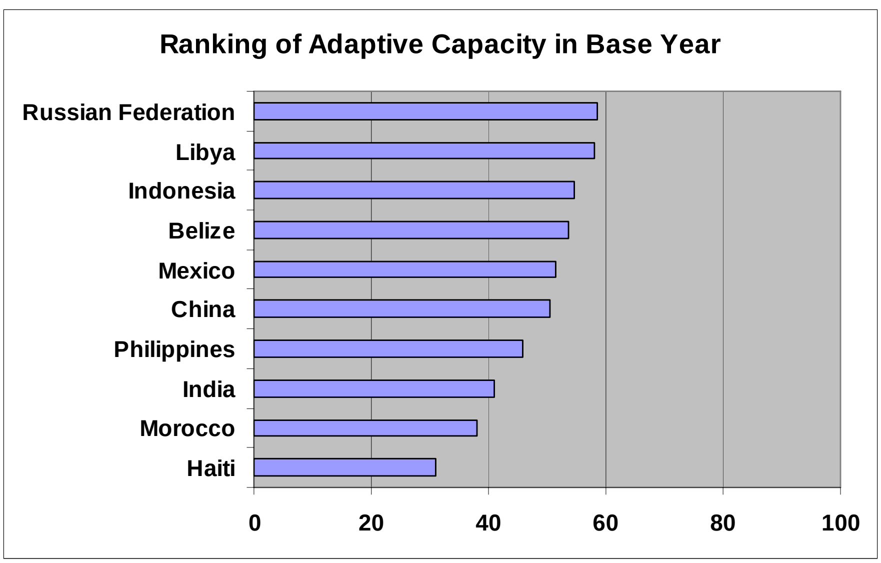


Figure 18. Sample of 10 countries' rankings of adaptive capacity (2000).

Figure 19 shows the contribution of each variable to the overall ranking with slight differences occurring because of the methodology (see box above). Belize ranks fairly high because of favorable environmental capacity proxies (comparatively high percentage of unmanaged land, low emissions, and low population density). Mexico also ranks in the second quartile of countries overall, but with different strengths: in human and civic resources (comparatively favorable dependency and literacy levels) as well as environmental capacity (low emissions and low population density—but a less favorable percentage of unmanaged land). Haiti ranks poorly on almost every proxy variable, with the exception of emissions, which are comparatively low.

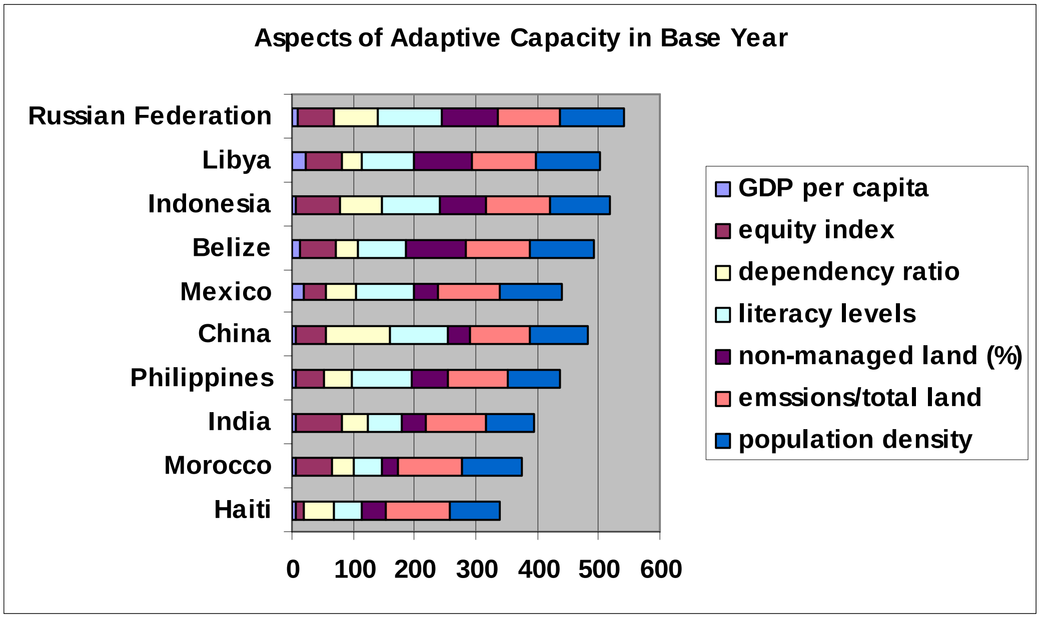


Figure 19. Variables' contributions to adaptive capacity rankings.

Figure 20 shows projected adaptive capacity growth over time for the 10-country sample. Projections are made for two scenarios: rates of growth are based on the IPCC's A1 scenario in its Special Report on Emissions Scenarios, the A2A1 (delayed growth) and the A1v2 (high growth) scenario as adapted from the IPCC A1 and A2 scenarios by the IPCC participating model (MiniCAM). Both scenarios (A2A1 and A1v2) feature moderate population growth and a tendency toward convergence in affluence (with market-based solutions, rapid technological progress, and improving human welfare).

The scenarios used in this study differ in the rate of economic growth, one modeling high-and-fast economic growth and the other delayed growth. In the delayed-growth scenario, the three Caribbean and Central American countries show almost stagnant, then modest growth. In the high-growth scenario, all countries improve their adaptive capacity, although the overall gap among different countries widens (i.e., initially lower-ranking countries do not show as high

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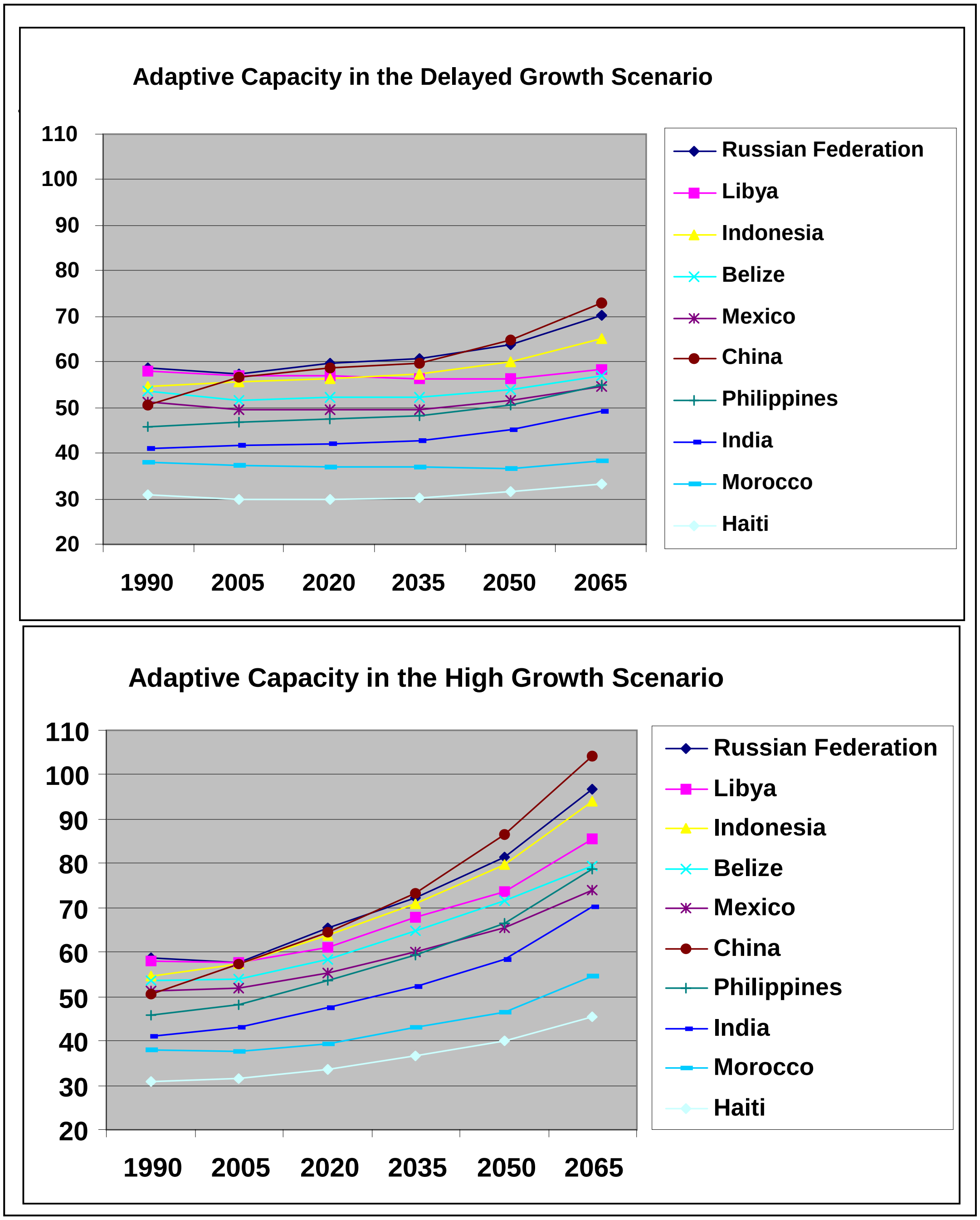

Figure 20. Projections of adaptive capacity for 11 countries under a delayed growth scenario and a high growth scenario. Source: Based on E.L. Malone and A.L. Brenkert, "Vulnerability, sensitivity, and coping/adaptive capacity worldwide," *The Distributional Effects of Climate Change: Social and Economic Implications*, M. Ruth and M. Ibarraran, eds., Elsevier Science, Dordrecht (in press).

growth rates as initially higher-ranking countries). Both scenarios show the Philippines improving its adaptive capacity at a higher rate than Mexico and, in the high-growth scenario, overtaking Mexico.

Caribbean and Central American Countries Compared to Each Other

Turning to the specific set of countries included in this report,[8] Figure 21 shows the base year values by sector and by proxy variable for all nine Central American and Caribbean countries. Here the differences among countries in elements of adaptive capacities are clear, e.g., human resources strengths in Panama and Cuba, environmental capacity strengths in Belize and Honduras.

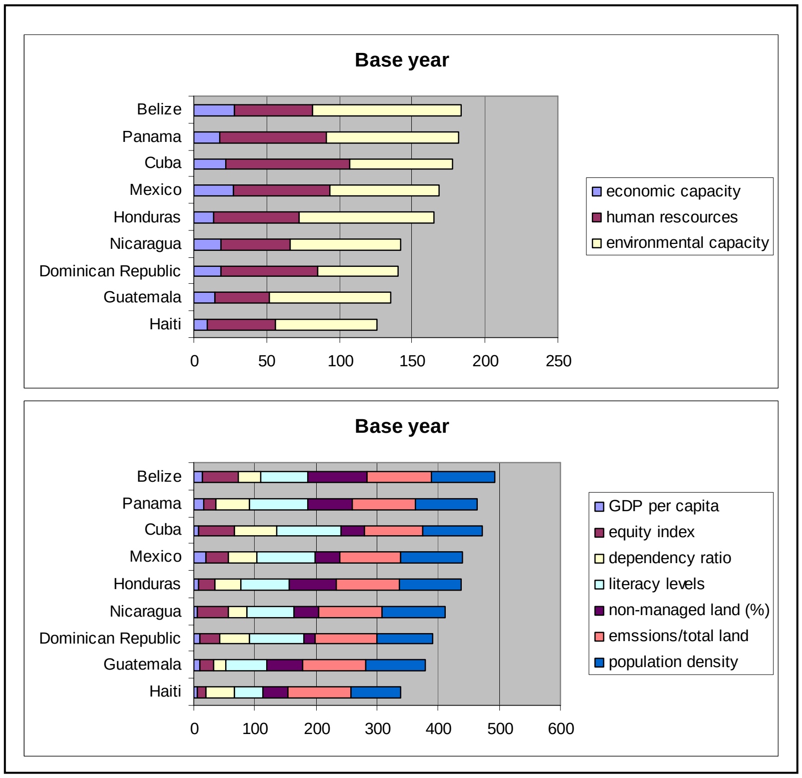

Figure 21. Base year rankings of adaptive capacity in nine Caribbean/Central American countries. Source: Based on E.L. Malone and A.L. Brenkert, "Vulnerability, sensitivity, and coping/adaptive capacity worldwide," *The Distributional Effects of Climate Change: Social and Economic Implications*, M. Ruth and M. Ibarraran, eds., Elsevier Science, Dordrecht (in press).

[8] Except Puerto Rico.

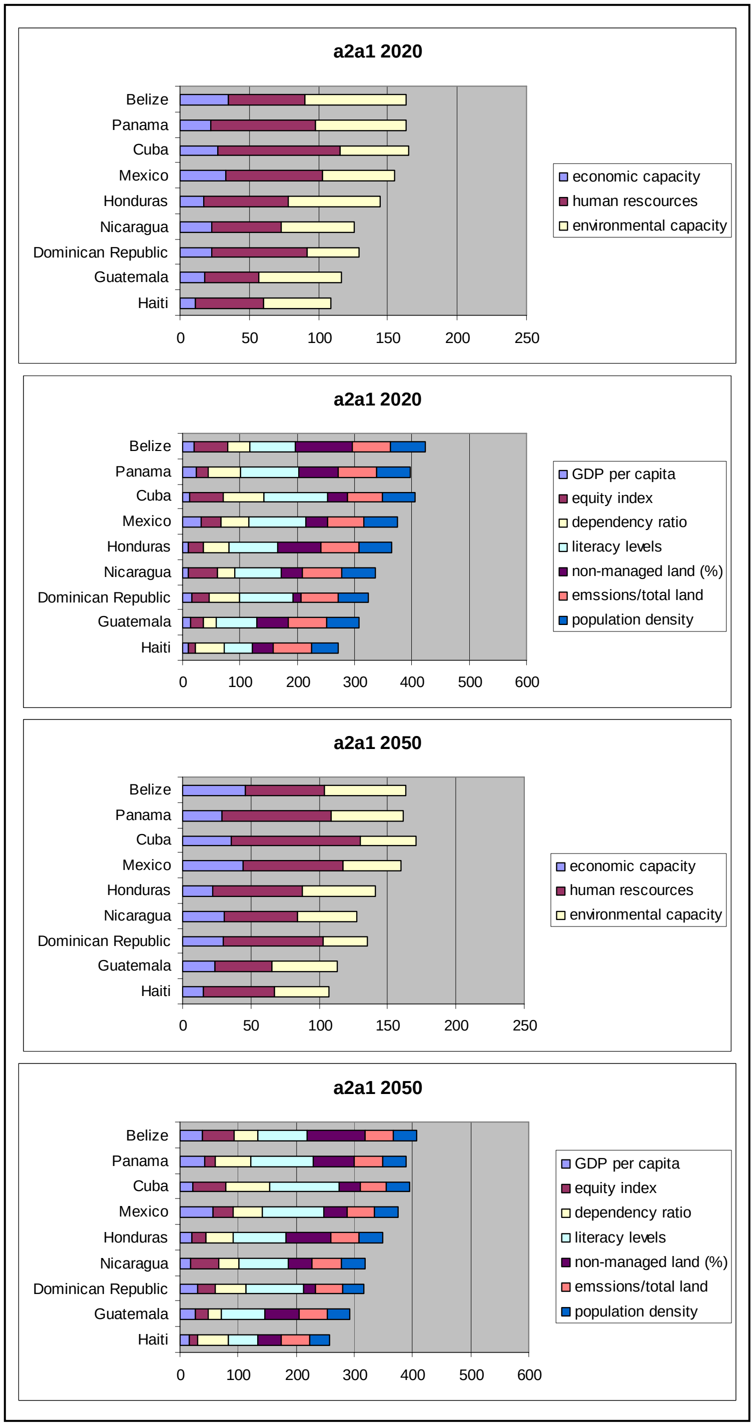

Figure 22. 2020 and 2050 snapshots of the low-growth scenario for Caribbean/Central American countries, with sector results and proxy variable results. Source: Based on E.L. Malone and A.L. Brenkert, "Vulnerability, sensitivity, and coping/adaptive capacity worldwide," *The Distributional Effects of Climate Change: Social and Economic Implications*, M. Ruth and M. Ibarraran, eds., Elsevier Science, Dordrecht (in press).

For projections, Figure 22 provides two snapshots of the low-growth scenario (A2A1) for 2020 and 2050. In both future years, many countries are projected to experience a decrease in environmental capacity, in some cases partially compensated for by increases in other areas (e.g., GDP per capita in Belize and Mexico; literacy levels in Panama, Cuba, and the Dominican Republic).

Key Contributors to Adaptive Capacity by Country

As stated above, there are several key indicators/parameters for any given country that can provide insight into its adaptive capacity, such as literacy rates, basic services, energy supply, and changes in production. In Latin America and the Caribbean, population has steadily increased since the 1900s and is expected to continue the trend through 2030. Availability of adequate human resources is a necessary condition to enhance adaptive capacity. It is also important that these resources have the appropriate level of education and access to basic services in order to have the ability to support economic growth.

Illiteracy continues to be a concern in some of the countries of interest. An illiterate person is defined as an individual unable to read and write a short simple statement on his or her everyday life. Significant progress has been made in most countries of the region. Nicaragua and Haiti, however, in 2005 still had greater than one third of the population older than 15 years of age classified as illiterate. This significantly affects economic growth, economic diversification, and adaptive capacity. Table 8 shows past and projected population for the selected countries, and Table 9 illustrates the level of illiteracy in the region.

Throughout the 1970s, 1980s, and 1990s the countries in Central America and the Caribbean experienced long periods of social unrest, capital flight, economic contraction, and large intra-regional and extra-regional migration. In many cases the best educated members of a population emigrated. Intra-regional migration during these three decades grew rapidly. Nicaragua and El Salvador, in particular, saw many of their best flee to Costa Rica beginning in the 1970s, and by 2000 over 8 percent of Costa Rica consisted of immigrants from those two countries. This was the direct result of the civil wars fought in both countries.

Country	1990	2000	2010	2030
Belice	186.0	245.0	306.0	413.0
Costa Rica	3 076.0	3 925.0	4 695.0	5 779.0
Cuba	10 605.0	11 129.0	11 236.0	11 077.0
El Salvador	5 110.0	6 276.0	7 453.0	9 652.0
Guatemala	8 908.0	11 225.0	14 362.0	21 804.0
Haití	7 108.0	8 576.0	10 085.0	13 350.0
Honduras	4 901.0	6 231.0	7 614.0	10 414.0
México	84 002.0	99 684.0	110 056.0	127 211.0
Nicaragua	4 141.0	5 106.0	5 825.0	7 140.0
Puerto Rico	3 528.0	3 834.0	4 056.0	4 383.0
República Dominicana	7 296.0	8 740.0	10 169.0	12 625.0

Table 8. Total Population (Thousands). Source: CEPAL/ECLAC [Comisión Económica para América Latina y el Caribe/Economic Commission for Latin America and the Caribbean], *Anuario Estadístico de América Latina y el Caribe: 2008* (United Nations 2009).

			Both sexes		
Country	1970	1980	1990	2000	2005
Belice	25.0	17.5	10.9	6.8	5.3
Costa Rica	11.8	8.3	6.1	4.4	3.8
Cuba	10.7	7.5	4.9	3.3	2.7
El Salvador	42.1	34.2	27.6	21.3	18.9
Haití	78.0	69.5	60.3	50.2	45.2
Honduras	49.4	40.1	31.9	25.0	22.0
México	26.5	18.7	12.7	8.8	7.4
Nicaragua	45.5	41.2	37.3	33.5	31.9
Puerto Rico	14.7	11.1	8.5	6.2	5.4
República Dominicana	32.8	26.0	20.6	16.3	14.5

Table 9. Percentage of Illiterate Population (15 years or older). Source: CEPAL/ECLAC [Comisión Económica para América Latina y el Caribe/Economic Commission for Latin America and the Caribbean], *Anuario Estadístico de América Latina y el Caribe: 2008* (United Nations 2009).

During the same period, Mexico also received many migrants from Guatemala and Nicaragua. At the end of the 1990s, Guatemala and the other countries in the region signed peace agreements and experienced the repatriation of many of their citizens from Mexico. By 2000, Mexico had a significantly smaller portion of immigrants from these countries than it had in 1990. There is also the added element of intra-regional seasonal migration exercised by those following the agricultural sector for employment. On a yearly basis, there are migrations from northern Panama to southern Costa Rica and from northern Guatemala to southern Mexico.

Migration from Central America and the Caribbean to the United States also increased during the same period. Caribbean-born immigrants accounted for almost 10 percent of the total US foreign-born population in 2000. The largest growth in the number of immigrants from Latin America to the United States occurred from 1990 to 2000 when a 97 percent increase occurred. Population grew from 7.2 million to 14.2 million. The 14.2 million people in 2000 included 9.1 million from Mexico, 879,000 from Cuba, 710,000 from Dominican Republic, 468,000 from Guatemala, 409,000 from Haiti, and 232,000 from Nicaragua. The proportion of the original total population that migrated to the United States during this period represented a wide range of the total population in the country of origin in the year 2000. The proportion ranged from 13 percent in the case of El Salvador, 9 percent for Mexico, 8 percent for Dominican Republic, 7.8 percent for Cuba, and 4 percent each for Haiti and Nicaragua.

The migration from Central America and the Caribbean, intra-regional and extra regional, has resulted in a systematic and regular transfer of funds from the United States and other countries to the families and relatives that remained in the countries of origin. The Inter-American Development Bank (IADB) estimates the region received US$7.8 billion through official channels in 2004, a 17 percent increase from the 2003 figure of US$6.7 billion.[xlvii]

Guatemala topped the list of recipients with almost US$2.7 billion in official flows in 2004, followed by El Salvador with US$2.5 billion. These two countries, which account for nearly two-thirds of the two million Central Americans counted in the 2000 US census, receive almost 64 percent of total remittance flows to Central America. They are the fourth- and fifth-largest remittance-receiving countries in Latin America and the Caribbean. Remittance growth in Guatemala tripled from 2001 to 2004. Honduras and Nicaragua followed at some distance, at around the US$1 billion, while Panama, Costa Rica, and Belize trailed with less than US$325 million in remittances in 2004. The low levels of the latter three reflect the fact that they have relatively few emigrants in the United States.

While much attention is given to remittances from developed countries, particularly the United States, there are substantial intra-regional remittance flows too. A 2003 study of Costa Rica and Nicaragua revealed that about one-third of remittances received in Nicaragua are sent from Costa Rica. Since Mexico is the second largest destination of Guatemalan workers after the United States, it can easily be concluded that some of the remittances going to Guatemala are coming from Mexico. Research conducted for IADB estimated that in 2002 about US $1.5 billion of the US$32 billion remitted to Latin America and the Caribbean were actually intra-regional.

Another key indicator of the level of adaptive capacity is the infrastructure for basic services. In most of the countries selected for this assessment the majority of the population is concentrated in urban areas, and the largest urban areas are found in the coastal areas of the countries. Basic infrastructure/services such as water, electricity, and sewage are important elements in the ability to reduce and recover from the impact of such extreme events as hurricanes, floods, and droughts. Table 3 depicts the level of basic infrastructure in some of the selected countries.

Another key contributor to adaptive capacity is the extent of forests in this region. Deforestation is a significant environmental issue for every country selected for this report. Puerto Rico does not suffer from this environmental problem. According to the IPCC assessment,[xlviii] by 2010 the forest areas in Central America will be reduced by 1.2 Mha. These areas are projected to be used for pasture and expanding livestock production. Table 10 illustrates the loss in forest area by country from 1990 to 2005.

During this timeframe Cuba was the only country that experienced increases in forest area. Except for the Dominican Republic, which maintained the size of its forest area, all the other countries have steadily reduced their forests, from 6 percent in Costa Rica and Mexico to 37 percent in Honduras.

	(Thousands of hectares, percentage and rate of variation)											
	Forest area (Thousands of hectares)			covered by forest (Percentage)			Accumulated variation in forest area (Rate of variation)			Average annual variation in forest area (Rate of variation)		
	1990	2000	2005	1990	2000	2005	1990-2000	2000-2005	1990-2005	1990-2000	2000-2005	1990-2005
Belice	1 653	1 653	1 653	72.5	72.5	72.5	–	–	–	–	–	–
Costa Rica	2 564	2 376	2 391	50.2	46.5	46.8	-7.3	0.6	-6.7	-0.7	0.1	-0.4
Cuba	2 058	2 435	2 713	18.7	22.2	24.7	18.3	11.4	31.8	1.8	2.3	2.1
El Salvador	375	324	298	18.1	15.6	14.4	-13.6	-8.0	-20.5	-1.4	-1.6	-1.4
Guatemala	4 748	4 208	3 938	43.8	38.8	36.3	-11.4	-6.4	-17.1	-1.1	-1.3	-1.1
Haití	116	109	105	4.2	4.0	3.8	-6.0	-3.7	-9.5	-0.6	-0.7	-0.6
Honduras	7 385	5 430	4 648	66.0	48.5	41.5	-26.5	-14.4	-37.1	-2.6	-2.9	-2.5
México	69 016	65 540	64 238	35.5	33.7	33.0	-5.0	-2.0	-6.9	-0.5	-0.4	-0.5
Nicaragua	6 538	5 539	5 189	53.9	45.6	42.7	-15.3	-6.3	-20.6	-1.5	-1.3	-1.4
República Dominicana	1 376	1 376	1 376	28.4	28.4	28.4	–	–	–	–	–	–
América Latina y el Caribe	**984 123**	**939 208**	**915 494**	**49.1**	**46.8**	**45.6**	**-4.6**	**-2.5**	**-7.0**	**-0.5**	**-0.5**	**-0.5**

Table 10. Forest area and proportion of land area covered by forest. Note: no data for Panama or Puerto Rico. Source: CEPAL/ECLAC [Comisión Económica para América Latina y el Caribe/Economic Commission for Latin America and the Caribbean], *Anuario Estadístico de América Latina y el Caribe: 2008* (United Nations 2009).

Several countries in Central America and the Caribbean as well as Mexico have made an effort to increase the amount of protected areas. Table 11 shows how the selected countries have changed protected areas from 1990 to 2007. Mexico is the largest contributor, having doubled the amount of land under protection and increasing the amount of marine areas many-fold during the same period.

TERRESTRIAL PROTECTED AREAS (*Square kilometers*)						***MARINE PROTECTED AREAS*** (*Square kilometers*)				
País	1990	2000	2005	2006	2007	1990	2000	2005	2006	2007
Belice	...	8 912	7 940	7 944	8 006	...	1 587	2 498	2 498	2 498
Costa Rica	...	12 755	13 333	13 266	13 558	...	...	...	5 209	5 210
Cuba	...	...	3 304	3 309	3 309	...	...	2 049	2 071	2 071
El Salvador	...	...	...	...	416	...	...	...	...	206
Guatemala	25 107	31 180	33 077	30 801	30 890	158	158	158	2 453	2 453
Honduras	...	...	28 821	31 636	...	...	...	665	1 155	...
México	76 640	131 775	148 505	180 210	187 004	4 408	35 255	40 660	40 660	45 021
República Dominicana	...	9 176	10 529	10 529	10 529	...	17 494	67 602	67 602	...

Table 11. Protected Areas in Selected Latin American and Caribbean Countries. Note: no data for Haiti, Nicaragua, Panama, and Puerto Rico. Source: CEPAL/ECLAC [Comisión Económica para América Latina y el Caribe/Economic Commission for Latin America and the Caribbean], *Anuario Estadístico de América Latina y el Caribe: 2008* (United Nations 2009).

Conclusions

The systematic evaluation of the impact of climate change in the Caribbean and Central American is only beginning. There are many limitations associated with data quality and quantity. Most of the countries, however, are beginning to quantify greenhouse gas inventories and run simulation models to estimate the potential impact associated with projected global average increase in temperatures, rise in sea level, and changes in rainfall.

UNDP and ECLAC are beginning a series of studies to quantify the impact of climate change in socio-economic and ecosystems in the region. Even if these studies are not yet available, leaders in the region now accept that, while the region does not contribute to global greenhouse gases in a significant way, it is highly vulnerable to the effects generated by severe climate variability. This has been observed over the past 20 years, and leaders understand that it is critical for them to develop sustainable development policies and to enhance their capabilities to respond and adapt to severe weather events.

Energy. Energy resources, production, and use vary widely across the countries under review. All the countries under review will experience population growth, economic growth, and industrialization, they will increase their need and demand for energy. All the countries rely on imported fossil fuels, with the exception of Mexico, which is a net exporter of energy resources. In most countries the largest generator of greenhouse gases is the energy sector. Although they are very small contributors to global emissions, most countries will benefit from increasing use of renewable energy. Most have begun efforts to evaluate and implement small projects, such as wind energy in Nicaragua and Costa Rica and an intensive effort in the Dominican Republic to evaluate hydro electricity.

Agriculture. The agricultural sector climate related research for most of the countries in this review is limited. Where research is available, productivity losses are projected for optimist,

This paper does not represent US Government views.

moderate, and pessimist scenarios for some key food crops with estimates that vary from 10 percent to more than 50 percent by the year 2030.

Water Resources. The majority of the population in most of the countries reviewed lives in coastal areas, which are highly vulnerable to severe climate changes. As populations continue to grow in the same areas, increasing water extraction and rising sea levels are expected to have severe impact on the quantity and quality of water available. Many of the aquifers of these countries are open to ocean waters and are already experiencing increases in salinity. Rising sea levels will accelerate the deterioration of aquifers and available water resources.

Migration. An increase in intra-regional and extra-regional migration during the 1980s and 1990s resulted from social unrest and economic contraction. Moreover, the inability of countries in the region to adapt and recover from severe climate events with major impacts on their economies will continue to promote migration outside the region, in particular, to the United States and Canada. The large number of immigrants coming to the United States in the past 20-25 years will facilitate this movement.

In addition, the observed and projected incidence of diseases and pathogens varies across the countries under review. In Central American countries, there has been a sharp increase in the number of diseases during the years following ENSO effects. The Government of the Dominican Republic has not observed and has not projected a correlation between climate change variability and increases in health effects of its population. It is not clear if it is a difference in the quality of information or the limitations of the models used in the initial assessments of each country.

Although most countries in the Central America and Caribbean region have started to evaluate the impact of climate change in their economic, social, and natural resources, there is limited understanding of the viable options to address the problems.

Many limitations that exist today on climate change preclude making projections good enough to take action. They include limitations in models used, quality of data, and quantity of relevant data. Equally problematic is the limitation of funding to undertake detailed modeling for each country in such a way that the result is information that also ranks, evaluates and recommends financial options.

Although the countries under review have submitted their First National Communications to the UNFCC (and Mexico has submitted its third communication), significant work and analysis remain. Reviewers must still capture the full impact on socio-economic systems and the ability of those systems to recover and adapt to and reduce the effects of severe weather events.

The first assessments submitted by these countries have laid the foundation for improving models used and for improving the quality and quantity of data. The initial studies have also illustrated the gaps that exist between the current level of knowledge and what is needed for the development of policies that will improve the adaptive and response capacities of the countries under review.

Annex A:

Accuracy of Regional Models

This is an excerpt from IPCC (2007), Chapter 11, Regional models; see IPCC 2007 for references.[9]

11.6.2 Skill of Models in Simulating Present Climate

In the Central America (CAM) and Amazonia (AMZ) regions, most models in the multi-model dataset (MMD) have a cold bias of 0°C to 3°C, except in AMZ in September, October, and November (SON). In southern South America (SSA) average biases are close to zero. The biases are unevenly geographically distributed. The MMD mean climate shows a warm bias around 30°S (particularly in summer) and in parts of central South America (especially in SON). Over the rest of South America (central and northern Andes, eastern Brazil, Patagonia) the biases tend to be predominantly negative. The SST biases along the western coasts of South America are likely related to weakness in oceanic upwelling.

For the CAM region, the multi-model scatter in precipitation is substantial, but half of the models lie in the range of –15 to 25 percent in the annual mean. The largest biases occur during the boreal winter and spring seasons, when precipitation is meager. For both AMZ and SSA, the ensemble annual mean climate exhibits drier than observed conditions, with about 60 percent of the models having a negative bias. Unfortunately, this choice of regions for averaging is particularly misleading for South America since it does not clearly bring out critical regional biases such as those related to rainfall underestimation in the Amazon and La Plata Basins. Simulation of the regional climate is seriously affected by model deficiencies at low latitudes. In particular, the MMD ensemble tends to depict a relatively weak Inter-Tropical Convergence Zone (ITCZ), which extends southward of its observed position. The simulations have a systematic bias towards underestimated rainfall over the Amazon Basin. The simulated subtropical climate is typically also adversely affected by a dry bias over most of south-eastern South America and in the South Atlantic Convergence Zone, especially during the rainy season. In contrast, rainfall along the Andes and in northeast Brazil is excessive in the ensemble mean.

Some aspects of the simulation of tropical climate with AOGCMs have improved. However, in general, the largest errors are found where the annual cycle is weakest, such as over tropical South America (see, e.g., Section 8.3). Atmospheric GCMs approximate the spatial distribution of precipitation over the tropical Americas, but they do not correctly reproduce the temporal evolution of the annual cycle in precipitation, specifically the mid-summer drought (Magaña and Caetano, 2005). Tropical cyclones are important contributors to precipitation in the region. If close to the continent, they will produce large amounts of precipitation over land, and if far from the coast, moisture divergence over the continental region enhances drier conditions.

Zhou and Lau (2002) analyse the precipitation and circulation biases in a set of six AGCMs provided by the Climate Variability and Predictability Programme (CLIVAR) Asian-Australian Monsoon AGCM Intercomparison Project (Kang et al., 2002). This model ensemble captures some large-scale features of the South American monsoon system reasonably well, including the seasonal migration of monsoon rainfall and the rainfall associated with the South America Convergence Zone. However, the South Atlantic subtropical high and the Amazonia low are too strong, whereas low-level flow tends to be too strong during austral summer and too weak during austral winter. The model ensemble captures the Pacific-South American pattern quite well, but its amplitude is generally underestimated.

Regional climate models (RCMs) are still being tested and developed for this region. Relatively few studies using RCMs for Central and South America exist, and those that do are constrained by short simulation length. Some studies (Chou et al., 2000; Nobre et al., 2001; Druyan et al., 2002) examine the skill of experimental dynamic downscaling of seasonal predictions over Brazil. Results suggest that both more realistic GCM forcing and improvements in the RCMs are needed. Seth and Rojas (2003) performed seasonal integrations driven by reanalyses, with emphasis on tropical South America. The model was able to simulate the different rainfall anomalies and large-scale circulations but, as a result of weak low-level moisture transport from the Atlantic, rainfall over the western Amazon was underestimated. Vernekar et al. (2003) follow a similar approach to study the low-level jets and report that the RCM produces better regional circulation details than does the reanalysis. However, an ensemble of four RCMs did not provide a noticeable improvement in precipitation over the driving large-scale reanalyses (Roads et al., 2003).

Other studies (Misra et al., 2003; Rojas and Seth, 2003) analyze seasonal RCM simulations driven by AGCM simulations. Relative to the AGCMs, regional models generally improve the rainfall simulation and the tropospheric circulation over both tropical and subtropical South America. However, AGCM-driven RCMs degrade compared with the reanalyses-driven integrations and they could even exacerbate the dry bias over sectors of AMZ and perpetuate the erroneous ITCZ over the neighboring ocean basins from the AGCMs. Menéndez et al. (2001) used a RCM driven by a stretched-grid AGCM with higher resolution over the southern mid-latitudes to simulate the winter climatology of SSA. They find that both the AGCM and the regional model have similar systematic errors but the biases are reduced in the RCM. Analogously, other RCM simulations for SSA give too little precipitation over the subtropical plains and too much over elevated terrain (e.g., Nicolini et al., 2002; Menéndez et al., 2004).

[9] Some references in this section have been changed to be internally consistent with this document and other references have been removed to avoid confusion.

Annex B:

Information Deficiencies that Preclude a Full Evaluation of the Impact of Climate Change on Central America, the Caribbean, and the Region's Adaptive Capacity

Regional leaders have not addressed the problem of the projected impact of climate change with possible policy changes or infrastructure investments because of a lack of systematic analysis that quantifies and qualifies the potential impact to the region. This lack of rigorous analysis restricts the development of relevant and economically viable options. There are significant gaps in the ability to fully understand all the dimensions of climate change at the economic, social, and/or environmental level in the region in a systematic way. There are gaps and deficiencies in data, systematic methodologies/analysis, and tools to monitor, share, and track information and events at the local, national, and regional levels. Efforts are starting to be made to reduce these gaps. Several entities at the national and regional levels are working to develop better analytical methods and information-sharing as well as better data and availability.

To increase the likelihood that this evaluation represents a reasonable assessment of projected climate change and its impact in Central America and the Caribbean as well as the region's adaptive capacity, the following gaps would need to be addressed:

- In physical science research, regional analyses will continue to be limited by the inability to model regional climates satisfactorily, including complexities arising from the interaction of global, regional, and local processes. Uncertainties in the occurrence and impact of the ENSO phenomenon, hurricane activity, and storm surges for example leave important gaps in knowledge needed for climate projections. One gap of particular interest is the lack of medium-term (20-30 years) projections that could be relied upon for planning purposes. Similarly, scientific projections of water supply and agricultural productivity are limited by inadequate understanding of various climate and physical factors affecting both areas. Research agendas in these areas can be found in the synthesis and assessment reports of the US Climate Change Science Program (http://www.climatescience.gov) for instance and the National Academy of Sciences (e.g., http://books.nap.edu/catalog.php?record_id=11175#toc). Similar types of issues exist for the biological and ecological systems that are affected.

- In social science research, scientists and analysts have only partial understandings of the important factors in vulnerability, resilience, and adaptive capacity, much less their interactions and evolution. Again, research agendas on vulnerability, adaptation, and decision-making abound (e.g., (http://books.nap. edu/catalog.php?record_id=12545).

- Important factors are unaccounted for in research; scientists know what some of them are, but there are likely factors whose influence will be surprising. An example from earlier research on the carbon cycle illustrates this situation. The first carbon cycle models did not include carbon exchanges involving the terrestrial domain. Modelers assumed that the exchange was about equal, and the only factor modeled was deforestation. This assumption, of course, made the models inadequate for their purposes. In another example, ecosystems research models are only beginning to account for changes in pests, e.g., the pine bark beetle.

- Social models or parts of models in climate research have been developed to simulate consumption (with the assumption of well-functioning markets and rational actor behavior) and mitigation/adaptation policies (but without attention to the social feasibility of enacting or implementing such policies). As anthropogenic climate change is the result of human decisions, the lack of knowledge about motivation, intent, and behavior is a serious shortcoming.

Overall, research about the impact of climate change on the Central America and Caribbean region has been undertaken piecemeal: discipline by discipline, sector by sector, with political implications separately considered from physical effects. Outside the National Communications, small-scale case studies have been done, but little systematic analysis. This lack of rigorous analysis can be remedied by integrated research into the energy, economic, environmental, and political conditions and possibilities.

Annex C:

Environmental Agreements Signed by Selected Latin American and Caribbean Countries

MULTILATERAL ENVIRONMENTAL AGREEMENTS

Year of signature and year that the country became party to the agreement (through ratification, acceptance, approval or adhesion)

Country	Ramsar /a /p	Patrimonio /b /p *Heritage*	CITES /c /q	Especies migratorias /d /r *CMS*	Derecho del mar /e *Law of the Sea*		Viena /f *Vienna*		Montreal /g		Basilea /h *Basel*		*Biological Diversity* /i		Cambio Climático *UNFCCC /j*	
	P	P	P	EV	F	P	F	P	F	P	F	P	F	P	F	P
Belice	1998	1990	1986	...	1982	1983	…	1997	…	1998	...	1997	1992	1993	1992	1994
Costa Rica	1991	1977	1975	2007	1982	1992	…	1991	…	1991	...	1995	1992	1994	1992	1994
Cuba	2001	1981	1990	2008	1982	1984	…	1992	…	1992	...	1994	1992	1994	1992	1994
El Salvador	1999	1991	1987	...	1984	...	…	1992	…	1992	1990	1991	1992	1994	1992	1995
Guatemala	1990	1979	1979	...	1983	1997	…	1987	…	1989	1989	1995	1992	1995	1992	1995
Haití	...	1980	...	...	1982	1996	…	2000	…	2000	1989	...	1992	1996	1992	1996
Honduras	1993	1979	1985	2007	1982	1993	…	1993	…	1993	...	1995	1992	1995	1992	1995
México	1986	1984	1991	...	1982	1983	1985	1987	1987	1988	1989	1991	1992	1993	1992	1993
Nicaragua	1997	1979	1977	...	1984	2000	…	1993	…	1993	...	1997	1992	1995	1992	1995
República Dominicana	2002	1985	1986	...	1982	...	…	1993	…	1993	...	1999	1992	1996	1992	1998

Country	Desertificación /k *UNCCD*		Kyoto /l		Rotterdam /m		Cartagena /n		Estocolmo /o *Stockholm*	
	F	P	F	P	F	P	F	P	F	P
Belice	…	1998	…	2003	…	2005	...	2004	2002	...
Costa Rica	1994	1998	1998	2002	1999	...	2000	2007	2002	2007
Cuba	1994	1997	1999	2002	1998	2008	2000	2002	2001	2007
El Salvador	…	1997	1998	1998	1999	1999	2000	2003	2001	2008
Guatemala	…	1998	1998	1999	…	...	…	2004	2002	2008
Haití	1994	1996	…	2005	…	...	2000	...	2001	...
Honduras	1995	1997	1999	2000	…	...	2000	...	2002	2005
México	1994	1995	1998	2000	…	2005	2000	2002	2001	2003
Nicaragua	1994	1998	1998	1999	…	2008	2000	2002	2001	2005
República Dominicana	…	1997	…	2002	…	2006	…	2006	2001	2007

Source: CEPAL- Anuario Estadistico, 2008

j/ UNFCCC: The United Nations Framework Convention on Climate Change, 1992.
k/ UNCCD: The United Nations Convention to Combat Desertification in Those Countries Experiencing Serious Drought and/or Desertification, 1994.
l/ Kyoto: The Kyoto Protocol to the United Nations Framework Convention on Climate Change, 1997.
m/ Rotterdam: The Rotterdam Convention on the Prior Informed Consent Procedure for Cartain Hazardous Chemicals and Pesticides in International Trade, 1998.
n/ Cartagena: The Cartagena Protocol on Biosafety to the Convention on Biological Diversity, 2000.
o/ Stockholm: The Stockholm Convention on Persistnt Organic Pollutants, 2001.
p/ The year that the countries signed the agreement is not available.
q/ All the countries that are party to this convention signed it between 1973 and 1974, the period in which the convention was open for signature.

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SPECIAL REPORT

MEXICO, THE CARIBBEAN, AND CENTRAL AMERICA: THE IMPACT OF CLIMATE CHANGE TO 2030

A COMMISSIONED RESEARCH REPORT

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NATIONAL INTELLIGENCE COUNCIL

CONFERENCE REPORT

CR 2009-07 May 2009

India: The Impact of Climate Change to 2030

Geopolitical Implications

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NATIONAL INTELLIGENCE COUNCIL NIC

India: The Impact of Climate Change to 2030

Geopolitical Implications

Prepared jointly by

CENTRA Technology, Inc. and Scitor Corporation

The National Intelligence Council sponsors workshops and research with nongovernmental experts to gain knowledge and insight and to sharpen debate on critical issues. The views expressed in this report do not reflect official US Government positions.

CR 2009-07
May 2009

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Scope Note

Following the publication in 2008 of the National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030, the National Intelligence Council (NIC) embarked on a research effort to explore in greater detail the national security implications of climate change in six countries/regions of the world: India, China, Russia, North Africa, Mexico and the Caribbean, and Southeast Asia and the Pacific Island States. For each country/region we are adopting a three-phase approach.

- In the first phase, contracted research explores the latest scientific findings on the impact of climate change in the specific region/country. For India, the Phase I effort was published as a NIC Special Report: ***India: Impact of Climate Change to 2030, A Commissioned Research Report*** (NIC 2009-03), of April 2009.

- In the second phase, a workshop or conference composed of experts from outside the Intelligence Community (IC) determines if anticipated changes from the effects of climate change will force inter- and intra-state migrations, cause economic hardship, or result in increased social tensions or state instability within the country/region. This report is the result of the Phase II effort for India.

- In the final phase, the NIC Long-Range Analysis Unit (LRAU) will lead an IC effort to identify and summarize for the policy community the anticipated impact on US national security.

In March of 2009, CENTRA Technology, Inc., convened a group of regional experts to explore the socio-political challenges, civil and key interest group responses, government responses, and regional and geopolitical implications of climate change on India through 2030. The group of outside experts consisted of social scientists, economists, and political scientists. While the targeted time frame of the analysis was to 2030, the perceptions of decision makers in 2030 will be colored by expectations about the relative severity of climate changes projected later in the century. The participants accordingly considered climate impacts beyond 2030 where appropriate.

The Central Intelligence Agency's Office of the Chief Scientist, serving as the Executive Agent for the DNI, supported and funded the contract.

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Executive Summary

The National Intelligence Council sponsored workshop entitled *Implications of Global Climate Change in India* on March 27, 2009, brought together a panel of India experts to consider the probable effects of climate change on India from a social, political, and economic perspective. ***The panelists judged the practical effects of climate change on India were uncertain, but they concluded India will most likely be able to manage them out to 2030.***

- ***Agriculture and rural society will face the most severe disruptions from climate change.*** India may need a second "Green Revolution"[1] to deal with these disruptions.
- Climate change will most likely cause mass migrations both within India and from neighboring countries, particularly Bangladesh. Refugee flows from other South Asian states are also possible. Internal migrations will mainly be from rural areas into India's cities, which are ill-equipped to deal with large influxes of environmental migrants.
- Climate change will in many cases exacerbate existing inequities in India's society and economy, potentially leading to internal social disruptions.
- ***While a general state failure in India is unlikely, India may accumulate a number of failed constituent states.*** The states most at risk are the densely-populated, under-developed, and politically unstable states of India's northeastern agricultural heartland.

Beyond 2030, India's ability to cope is unclear.

The principal regional challenges generated by climate change in South Asia will most likely be cross-border migration and water scarcity. The lack of effective regional institutions, longstanding political disputes, and India's preference for bilateral regional diplomacy will inhibit regional cooperation in confronting these issues.

- The region has a mixed record on resolving water disputes. As river flows decline, water disputes will intensify, leading to increased tension with Pakistan, Bangladesh, and China.
- Climate change may cause humanitarian crises or state failures in one or more of India's neighbors, including its nuclear-armed rival Pakistan.

A number of factors nevertheless inhibit India from aggressively pursuing climate change mitigation.

- ***The priority of the Indian state is sustained economic growth, in order to alleviate poverty and keep up with strategic competitors—mainly China. India will not sacrifice growth for the sake of climate change mitigation.***
- India views climate change mitigation as primarily the responsibility of the developed countries.

[1] "Green Revolution" refers to development and deployment of new agricultural products and techniques to improve productivity.

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- Although the state is engaged in planning climate change mitigation policies, India tends to be slow and ineffective in executing such plans due to bureaucratic inertia, lack of political will, and corruption.

Indian foreign policy is focused primarily on enhancing trade, investment, and access to advanced technology, as well as achieving strategic parity with China.

- India prefers that international standards and regulations on climate change mitigation be voluntary and take development targets into account.
- India perceives the United States and other developed countries should have a greater stake in reaching a climate change agreement. ***It has therefore adopted a maximalist negotiating position that will make any agreement very difficult.***
- India's position on climate change equity and responsibility is consistent with the articulated policy of China and most developing countries.
- ***India would be most anxious about any US attempt to strike a private climate change agreement with China***.

India is nevertheless open to persuasion on alternative paths to growth that not only address climate change effectively, but that in the long run will be better for sustainable growth.

- ***India is open to climate change mitigation policies that take its development needs and strategic interests into account. It would accept subsidies and technology transfers in exchange for its compliance on international climate change standards***.

Despite the serious climate related challenges India may be subjected to in the next two decades, India is a large and resilient state and society with considerable coping capacity.

- India has a long history of dealing with crises and has institutionalized methods of handling and mitigating them, even with limited resources.
- Indian economic growth continues to increase both state and private sector capacity. India will have increasing resources and capabilities at its disposal to deal with climate change-induced challenges.
- ***India has institutional buffers which aid in preserving overall stability, such as its democratic and federalized political system.***
- India's well-developed and resilient civil society provides a reserve of institutional capital, expertise, and innovation that can be applied to climate change-induced problems.

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Contents

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Introduction and Background

India is both a major greenhouse gas emitter and one of the most vulnerable countries in the world to projected climate change. The country is already experiencing changes in climate and the impacts of climate change, including water stress, heat waves and drought, severe storms and flooding, and associated negative consequences on health and livelihoods. With a 1.2 billion but growing population and dependence on agriculture, India probably will be severely impacted by continuing climate change. Global climate projections, given inherent uncertainties, indicate several changes in India's future climate:

- Global observations of melting glaciers suggest that climate change is well under way in the region, with glaciers receding at an average rate of 10–15 meters per year. If the rate increases, flooding is likely in river valleys fed by these glaciers, followed by diminished flows, resulting in water scarcity for drinking and irrigation.
- All models show a trend of general warming in mean annual temperature as well as decreased range of diurnal temperature and enhanced precipitation over the Indian subcontinent. A warming of 0.5^{o}C is likely over all India by the year 2030 (approximately equal to the warming over the 20th century) and a warming of 2-4^{o}C by the end of this century, with the maximum increase over northern India. Increased warming is likely to lead to higher levels of tropospheric ozone pollution and other air pollution in the major cities.
- Increased precipitation—including monsoonal rains—is likely to come in the form of fewer rainy days but more days of extreme rainfall events, with increasing amounts of rain in each event, leading to significant flooding. Drizzle-type precipitation that replenishes soil moisture is likely to decrease. Most global models suggest that the Indian summer monsoons will intensify. The timing may also shift, causing a drying during the late summer growing season. Climate models also predict an earlier snowmelt, which could have a significant adverse effect on agricultural production. Growing emissions of aerosols from energy production and other sources may suppress rainfall, leading to drier conditions with more dust and smoke from the burning of drier vegetation, affecting both regional and global hydrological cycles and agricultural production.

Uncertainties about monsoonal changes will affect farmers' choices about which crops to plant and the timing of planting, reducing productivities. In addition, earlier seasonal snowmelt and depleting glaciers will reduce river flow needed for irrigation. The large segment of poor people (including smallholder farmers and landless agricultural workers) may be hardest hit, requiring government relief programs on a massive scale. Finally, migration, especially from Bangladesh, may strain resources and India-Bangladesh relations.

The most important impacts of climate change will likely include the following:

- *Agriculture.* High-input, high-output agriculture will be negatively affected even as demands for food and other agricultural products rise because of an increasing population and expectations for an improved standard of living. Millions of subsistence and smallholder farmers will experience hardship and hunger through being less able to predict climate conditions. To a certain extent, trade may compensate for these deficits.

- *Water*. Glacier melt may yield more runoff in the short term but less in the medium and long terms. More severe storms (especially cyclones) will cause more damage to infrastructure and livelihoods and exacerbate salt water intrusion in storm surges. Changes in the timing and amount of monsoon rains will make the production of food and other agricultural products more uncertain, so that, even in good-weather years, farmers will be more likely to make decisions leading to lower-productivity.

- *Exacerbation of Inequality*. The welfare of those who are affected by climate change and who have limited means to adapt may act as a force that can change governments, strain public budgets, and foster unrest. About one-third of Indians are extremely poor, and 60 percent depend upon agriculture for their livelihoods.

- *Energy*. As India searches for additional sources of energy to meet rising demand, climate change mitigation efforts may constrain its use of indigenous and imported coal, oil, and gas, while development of nuclear energy will be slow at best and likely to encounter opposition. Other non-emitting technologies will require technology transfer and capacity-building.

- *Migration.* India receives immigrants from a number of countries. Under climate change conditions, it may be flooded with many more, particularly from Bangladesh. Such migration may exacerbate tension between the two countries as well as putting a strain on Indian central and state governments.

Adaptive capacity in India varies by state, geographical region, and socioeconomic status. Studies point to influential factors such as water availability, food security, human and social capital, and the ability of government (state and national levels) to buffer its people during tough times. Where adaptive capacity is low, the potential is greater for impacts to result in displaced people; deaths and damage from heat, floods, and storms; and conflicts over natural resources and assets.

This paper does not represent US Government views.

Social, Political and Economic Challenges

India faces an array of formidable existing social, economic, and political challenges such as poverty, low standards of health, and low agricultural productivity that will most likely be intensified by the effects of climate change. While experts are uncertain how climate change will affect India, it is likely to result in increased competition for scarce resources; increased stress on economic, social, and political systems across the board; and greater risk of extreme disruptive events such as severe droughts, floods, or storms. India's decisionmakers will need to balance between sustaining rapid growth, combating poverty, building social safety nets, and building greater capacity to deal with climate crises in order to succeed in the next century.

A particular concern is the emergence of 'tipping points' where worsening climate change impacts surpass the capacity of Indian institutions, infrastructure, and society to handle them. Although in many cases such 'tipping points' may result in serious but incremental worsening of ongoing challenges, they might also result in catastrophic failures.

Overall Socio-Economic Challenges

Poverty. Indians consider poverty the most severe and pressing social challenge to the country. India has achieved significant success in combating poverty beginning in the early 1980s. Almost sixty percent of the Indian population lived in poverty in 1980. That has been cut in half, with the fastest decline in the period since the economy began to grow significantly in the mid-1990s. While anti-poverty programs have helped, the key to bringing down the incidence of poverty on a sustained basis has been rapid growth. India has grown four percent or more in per capita terms since the late 1980s as opposed to less than two percent from 1950-80. During the last five years (2003-08), the per capita growth rate has been as high as 7.3 percent.

Despite the significant improvement, about one-third of the population (about 400 million people) lives on less than a dollar a day. India is thus home to the world's largest number of poor people and climate change is likely to significantly increase the proportion of Indians living below the poverty line. A disproportionate number of the poor are landless workers and marginal farmers who bear the greatest burden from disruptions to agriculture. The rural poor suffer from overlapping disadvantages. These include the growing incidence of casual labor; lack of alternative employment in labor-intensive manufacturing; low educational levels; and inadequate training programs for entry level jobs in the organized industrial and services sectors. Natural calamities such as floods, heavy rains, and droughts will most adversely impact poor populations that are less able to protect themselves from the vagaries of nature.

Inequality. Paradoxically, while India is intensely stratified culturally and economically, inequality receives a great deal less attention in India than in the international community as a whole. The focus in India is on growth rather than distributive justice. Impending climate change may focus much greater attention on inequality. The impacts of climate change in India will be distributed very unequally. In some cases, this may actually reduce existing inequities. For example, flooding may concentrate in more prosperous states such as the southern coastal states, Maharashtra, and Gujarat. Increased temperatures and shifts in rain patterns may increase agricultural yields in previously disadvantaged areas.

Despite the possibility of such optimistic outcomes, the majority of climate change impacts will most likely exacerbate existing inequities. While there is little evidence that climate change will benefit the richer segments of the population, their far greater capacity to handle climate change-induced challenges will widen the gap between rich and poor. Climate change is expected to have greater adverse effects on agricultural rather than industrial output and it will exacerbate rural-urban inequality. Climatic challenges will obviously be more severe in particular regions, increasing cross-regional inequality. Regional climatic inequalities may coincide with and reinforce existing economic inequities. For example, increased flooding may disproportionately impact poor coastal states such as Orissa and droughts may strike in lower per-capita income states such as Uttar Pradesh and Rajasthan. Furthermore, the burden of hardships and natural disasters such as floods will fall disproportionately on female members of the poor families, contributing to an increased gender gap.

Public Health. The relationship between climate change and health outcomes is complex. If temperature rises in warmer parts of the country, heat waves may become more intense and longer lasting, resulting in increased incidence of heat stroke and related diseases. Warmer climate also worsens air pollution and increases the potency of airborne diseases. Floods and droughts may lead to water contamination and worsen unsanitary conditions, increasing incidence of diseases such as malaria or dysentery.

The government is behind the curve in addressing public health problems. Corruption and inefficiency have been ongoing problems in the healthcare system as well as in other social services such as education. While considerable money and resources have been invested in primary health centers and community health centers in India, studies demonstrate that most of the health services-related money goes to private individuals who often only have a high school diploma. The lack of oversight allows many state-assigned healthcare providers to use the healthcare stipend from the state to supplement other forms of income while not providing healthcare services to the public. As a result, the public is forced to go to willing but sometimes unqualified private individuals to receive healthcare services.

As climate change worsens the public health challenge, India will require renewed vigor in implementing major policy reforms in the health sector. India needs to accelerate medical education at all levels to ensure access to trained medical personnel. It also needs to improve access to medicine and implement public health measures to combat the spread of infectious diseases by ensuring proper drainage and supply of clean drinking water.

Agricultural Challenges

India's agricultural sector—considered the Achilles' heel of the Indian economy—faces a major systemic crisis even without additional stress from climate change. Despite the Green Revolution, significant portions of the agricultural sector are locked in a labor-intensive, inefficient and marginally productive model that is increasingly not viable. To compound the problem, this already stressed sector will suffer the greatest direct impact from climate change. Agriculture generates less than 18 percent of India's GDP, and this figure is rapidly declining. The decline in the economic importance of agriculture as the industrial and service sectors have expanded is misleading when considering the impact of climate change. Seventy percent of Indians live in rural areas and nearly 65 percent of the workforce is engaged in farming, so challenges to agriculture will directly affect the majority of the Indian population.

The Indian agricultural states in which the impact of climate change is likely to be most severe are also those which have the lowest growth rates and the highest concentration of the poor. The states most at risk are in India's northeast, including the most populous states of Bihar and Uttar Pradesh, which have a combined population of 250 million, as well as the adjacent states of West

Bengal and Orissa. As agriculture becomes more difficult and more capital-intensive, marginal and small farmers will be forced to sell their land; economic inequality in the villages is likely to increase; and mid-sized farms will become less economically viable, unless farmers switch to high-end cash crops such as wine grapes and flowers.

Food Security. Gains in productivity from India's successful Green Revolution allowed India to achieve self-sufficiency in food, a source of great national pride. Nevertheless, projected climate change impacts will put pressure on India to make more effective use of its comparative advantages and turn away from self-sufficiency and towards crop specialization and trade on the international markets to maintain its food security. If such a transition does not begin early and achieve success, India could once again face acute food shortages due to more frequent disruptions and overall declines in agricultural productivity as a result of climate change.

The Rural Labor Surplus. Once food security occurred, the principal problem for Indian agriculture was to determine what to do with India's enormous excess rural population. Industry and services will have to take over as the mainstays of Indian employment, but will take time to expand to meet that challenge. In the near term, agricultural employment has to be maintained at high levels in order to keep the migration of labor into urban areas to a rate that Indian industrial expansion can accommodate. The surplus of rural labor has therefore favored the persistence of small, labor-intensive traditional farms. This keeps a larger-than-optimal population in areas at risk from climate change, increasing their susceptibility to marginal disruptions; limits the development of excess agricultural capacity to deal with climatic constraints; and discourages adoption of more efficient technological solutions that could aid in providing a response to climate change. Widespread climate stresses, such as major droughts or floods, could disrupt the village structure across entire regions of the country, putting tens of millions at risk.

Flooding. Flooding generated both by increases in runoff from melting Himalayan glaciers and more frequent severe storms will pose a major threat to India's heavily populated river plains. In low-lying coastal areas, sea level rise and storm surges will create similar challenges, with the added dimension of saltwater intrusion rendering soil infertile. Increased seasonal flooding is already affecting productivity in the state of Bihar, and more frequent major floods could disrupt agriculture and displace millions from the Indian agricultural heartland.

Droughts and Water Scarcity. In the longer term, glacial melting will reach a tipping point where increased river flows from runoff subside, replaced by serious water shortages as the smaller ice mass provides less water to feed India's rivers. The flows of the Indus, Ganges, and Brahmaputra could be dramatically reduced and many other rivers could become seasonal. The Gangetic plain, home to nearly half of India's population, may face a decrease in the water table to levels close to those in arid Gujarat. Such a development would threaten the sustainability of the agrarian economy across the northern Indian plain. In the northwestern states of Punjab, Haryana, and western Uttar Pradesh, depleting water tables, increasing soil salinity, and micro-nutrient deficiencies have already made wheat and rice crops that use intensive irrigation and nitrogenous fertilizer unsustainable. In addition, India will face more frequent and severe droughts long before the transition to sustained water scarcity

Energy Challenges

Just to maintain its current growth rate, India will need to more than double its energy consumption by 2020. The bulk of India's energy comes from fossil fuels, and India is poised to become a major contributor to global warming as emissions from power generation, industry, and transportation increase. The country remains gravely under-electrified, with over 40 percent of the population without access and another 20 to 40 percent without reliable and regular access. Nevertheless, the use of fossil fuels in electricity generation—about 80 percent of electricity is generated from indigenous and imported coal, oil and gas—has kept electricity relatively cheap. As urbanization and mobility requirements rise apace, the demand for modern forms of power and transportation are bound to rise considerably faster than the combined growth of population and per capita income.

Climate change will impact India's energy needs in several respects. Temperature increases and migration into urban areas can be expected to generate increased demand for electricity and other forms of energy, which is already growing as India's economy grows and becomes more industrial. Climate change will reduce demand for winter heating and raise demand for summer cooling. Hydroelectric capacity could be substantially reduced by a diminution of river flows, reducing the potential for it to substitute for fossil fuels in power generation. Some studies suggest climate change may adversely affect the efficiency of power generation and transmission. In addition, climate change mitigation policies such as caps on emissions and the necessity of developing cleaner energy production could impose greater constraints on the expansion of energy production in India.

Urban Challenges

India's cities will face increased challenges from climate change, although the direct effects on India's cities and towns may be less disruptive than those on rural areas. Overcrowding and poor air quality are already serious problems in India's cities, and these challenges will be worsened by climate change. Indian urban infrastructure is poorly developed and over-stressed in most cities. Floods and heavy rains are likely to collapse or sweep away shanties and makeshift urban dwellings where many of the urban poor live. Water scarcity due to glacial melting and shifts in rain patterns will reduce the supply of drinking water at the same time that migration into the cities increases the demand. Most significantly, the severe rural challenges will most likely be exported to the cities. A mass migration of displaced rural population into the cities could overwhelm critical urban systems such as health, transportation, housing, energy, and water. An influx of environmental refugees from the countryside also raises a serious challenge in terms of employment. Even if economic growth continues at a high rate, urban economies will have a difficult time accommodating large numbers of new workers, particularly if they arrive in surges due to climate change disruptions in rural areas. It is also unclear to what degree rural migrants will be absorbed into India's urban society. Conflicts between established urban populations and rural migrants could become a serious problem, particularly if employment is at issue.

Civil and Key Interest Group Responses

India has developed an impressive and active civil society which will play an important role in the adaptations necessary within the 2030 timeframe. The level of political mobilization and social engagement in India's diverse society of 1.1 billion people is high. Societal actors, ranging from NGOs and think tanks to the expanding middle class, are already playing an increasingly important role in managing India's social, economic, and political challenges, and this role can be fairly easily extended to dealing with climate change. Given the reluctance of India's government to make tough decisions on environmental issues, pressure and lobbying from civil society and NGOs has been critical in generating the will to move forward on mitigation policies. Strong issue leadership from civil groups may well be critical in altering Indian public opinion and state perspectives on climate change responses.

Interest Groups in Civil Society

The key interest groups in India are modern incarnations of the traditional mass-mobilizing agents of caste, class, and religion. Chambers of Commerce, Trade Unions, womens' groups and student organizations all play a role in society and politics, but they and other associations are secondary to the traditional groups. The interaction between the traditional groups is complex and often contentious. They do not represent monolithic blocks of interests, particularly on issues such as climate change which will have widely differing impacts on different regions and communities. In many localities the political environment is dominated by shifting coalitions between traditional groups, some leading, some supporting, and some marginalized. Traditional distinctions will come into play most forcefully if climate change produces very disproportionate effects on a particular group. Traditional civil groups may provide a reserve of social resilience and support networks that may help Indian society cope with climate change-induced challenges. On the other hand, traditional power structures may undermine state capacity by producing weak coalition governments, corruption of the administration and police, and the breakdown of law and order in some areas.

The Poor. India's poorest citizens are the least equipped to handle climate change-induced challenges but are likely to be the most severely affected by them. The majority of the poor are rural, but an increasing proportion are not tied to the land. The percentage of landless laborers rose from 17 percent in 1961 to 32 percent in 1991. Many of the poor are therefore likely to respond to climate change-induced challenges by migrating out of affected areas. Much of this migration will most likely be into cities and towns rather than into other rural areas. The urbanization of the poor will concentrate the burden on India's inadequate social services but may provide some insulation from the greater effects climate change will have on rural populations. The Indian poor have also tended to rapidly accept environmental innovations because they are acutely vulnerable to negative environmental impacts.

Although disaffection and unrest can be expected to increase as the poor face a more challenging environment, India's democratic system provides an outlet for their frustrations. Indian voting patterns are unique among large democracies in that the poor turn out in proportionately greater numbers to vote than those with higher incomes. Numbers count in a democracy and the poor are learning to use their political clout to make demands on the government. If the Indian poor become persuaded that climate change mitigation is critical to their quality of life, they can become a potent lever to push the state into action.

The Middle Class. A substantial and growing middle class has reinforced the previously small social and political elite. The Indian middle class is a mélange of groups from all religions, castes and regions based on income, professional achievements, and status aspirations. The burgeoning middle class and the wealthy in India have tended not to be receptive to environmental tradeoffs. Not only are they somewhat insulated from the worst effects of environmental problems, but they have the greatest stake in continuing economic growth and existing distribution patterns. It may therefore be more difficult to convince them to acquiesce to climate change mitigation policies than to convince the poor.

Farmers. The growing political power of Indian farmers makes them a key constituency in determining India's response to climate change. Indian farmers, like other segments of India's poor, have shown considerable adaptive capacity, as demonstrated by the success of the Green Revolution. Given proper incentives, they will adopt new agricultural practices and crops that will be better able to cope with climatic changes. For example, the rapid spread of pest-resistant genetically-engineered *Bacillus thuringiensis* cotton happened largely because of demand from farmers. On the other hand, their increasing reliance on irrigation water may seriously hinder efforts at settling regional water disputes and could be a major source of civil conflict within and between agricultural regions as water becomes scarcer.

Think Tanks and Research Institutions. Another important part of civil society that will be much needed as climate change impacts occur are the private organizations that collect and disseminate scientific and social knowledge. India has a great wealth of environmental and other think-tanks and NGOs, and an active print and electronic media network which carries studies and plans of great sophistication.

The Tata Energy and Resources Institute (TERI), New Delhi, led by Dr. Rajendra K. Pachauri, is India's foremost center of research and knowledge about energy and the environment. Recognition of TERI's role grew after Dr. Pachauri was elected Chairman of the Intergovernmental Panel on Climate Change (IPCC) established by the United Nations Environment Program and the World Meteorological Organization. The IPCC shared the Nobel Peace Prize with former US Vice President Al Gore for its work on climate change in 2007. TERI is joined by other world-class research organizations such as the Centre for Policy Research and the Centre for the Study of Developing Societies, national institutions such as the Indian Institutes of Technology, the Indian Institutes of Management, the Bhabha Atomic Research Centre and India's central universities. Many of these research organizations function in partnership with the government, and with international organizations of various kinds. NGOs have taken on the responsibility of dealing with climate change and have been active in efforts such as water conservation and irrigation rights. These national organizations are nevertheless islands of excellence that operate in an ocean of mediocrity. Indian civil society as a whole still lacks the comprehensive infrastructure to support their efforts. In addition, private environmental organizations face the same constraints as the Indian government in terms of uncertain and ambiguous climatic data.

Private Sector Economic and Industrial Interests. Indian industrialization has made private industry an increasingly influential voice in Indian policymaking. Private sector competition has grown during the past two decades even in areas traditionally dominated by state enterprises, such as railroads, airlines, ports, energy resources, banks, the regulatory Reserve Bank of India, and educational institutions at all levels. The Indian private sector in many respects competes with the Indian state. Many of the potential climate change mitigation strategies that India might adopt, while generated at the state level, will have to be implemented substantially by the private sector. The private sector may also play a less constructive role: many of India's industrialists, as in the United States, are lobbying Parliament not to impose carbon caps or adopt other policies to reduce emissions.

The interests of India's major industries may have a substantial if not decisive impact on which solutions India turns to in addressing climate-generated challenges. The automobile industry, for example, is threatening to become as much the backbone of the Indian industrial economy and transportation network as it has been in the US if current trends are any indication. The auto industry can be expected to lobby hard for investment in roads and highways rather than the more energy-efficient railway system. The industry is also driving a mass displacement of the two- and three-wheeled vehicles that today account for a major proportion of Indian motor vehicles by popular, affordable four-wheelers such as the Nano—a change that may well result in substantial emissions increases. On the other hand, the Indian auto industry has moved rapidly into production of electric cars such as the REVA and other fuel-efficient, low emission vehicles. This may partially mitigate the emissions and energy demand impacts from having more cars on the road.

Prospects for Civil Conflict

It is probable that climate change crises will further energize the discordant elements in India. Competition for dwindling resources and the delineation of scapegoats can provide combustible social and political fodder, but civil society in India has learned from long experience how to confront and live with adversity. To date Indian civil society has been successful in containing, but not eliminating, social and political violence over environmental issues such as water disputes.

Climate change-induced challenges may stress social resilience to the breaking point, particularly in cases where climatic stresses compound existing socio-economic stresses. For example, the concentration of negative climate change impacts on the poorest segments of Indian society is likely to intensify perceptions of inequality. If current growth and distribution patterns persist, this could lead to increased conflicts between social groups. These conflicts may not manifest themselves explicitly as economic or class conflicts. Many identity conflicts in India that are couched in religious or ethnic terms are in fact masked inequality conflicts. Tensions between rural and urban, commercial and laboring, employed and unemployed groups may play themselves out, for example, as Hindu-Muslim conflicts.

India unfortunately has many fault-lines readymade to accommodate such displaced inequality conflicts. Minority religious groups such as Sikhs, Christians in the northeast, and Christians and Muslims in Kerala are very politically active and at times have resorted to insurgent activity. The greatest threat to economic and political stability has been mounted by Maoist revolutionaries, referred to as Naxalities, recruited from among landless laborers and tribes in eastern and central India. They have spread their activities from approximately nine percent of India in 2002 to 30 percent in 2008, across 200 backward districts with high poverty levels, from Nepal to Andhra Pradesh, with the goal of transforming this corridor into a “compact revolutionary region.” The jobless poor in rural and urban areas are a natural recruiting ground for Maoist revolutionaries, as well as extremist Hindu groups who use violence against Muslims and Christians, which fractured states and local governments will find difficult to diffuse.

The overall threat posed by climate change-induced civil conflicts will depend on a number of factors, including the regional extent of the conflict and size of the groups involved; the capacity and response of the local government in affected areas; and the number of conflicts taking place simultaneously. India successfully handled past sequential crises including: the anti-Brahmin movement in Madras (now Tamilnadu), a communist insurgency in Telangana (now part of Andhra Pradesh), the 1970s Naxalite violence centered in eastern India, followed by the Khalistan movement in Punjab. Kashmir violence from 1989-2003 has receded from a major to a minor problem. Today, India is coping with tribal insurgencies in northeast India and Maoist violence in various areas from central through north India. India’s large population, large land mass and social diversity can sustain these type of challenges so long as too many do not occur at the same time.

State Response

The scale of anticipated climate change-generated challenges in India dictates that much of the response will have to originate at the level of the national government. India has adopted a system of coalition governance emphasizing slow moving consensus and flexibility. This government structure suggests that institutional responses to climate change will be slow, but effective at a moderate level.

State Priorities

Economic Growth. Economic growth has been at the top of the policy agenda of India's government for the past two decades, and is likely to remain the major policy goal of any government that comes to power. Indian policymakers view economic growth as a means to achieve fundamental national values regarding poverty alleviation and national security.

Successive Indian governments have learned that they will face a backlash from the increasingly politicized population if the economy does not grow. They confront two choices when faced with continued low economic growth: give in to the demands of the poor, resulting in the loss of support and violence by the more advantaged, or do nothing, risking the loss of support of and violence by the poor. This provides a powerful political incentive to sustain high economic growth rates. Indian policymakers are committed to sustaining nine to 10 percent growth annually for at least the next 10 to 20 years.

Climate mitigation proposals are more likely to be adopted if India's policymakers can be convinced that such proposals enhance economic growth. When announcing India's first National Action Plan on Climate Change in June 2008, Prime Minister Manmohan Singh emphasized the overriding priority of maintaining high economic growth rates in determining which climate mitigation proposals to adopt. He said the Action Plan "identifies measures that promote our development objectives while also yielding co-benefits for addressing climate change effectively." He went on to state that these measures would be more successful with assistance from developed countries, and pledged that India's per capita greenhouse gas emissions "will at no point exceed that of developed countries even as we pursue our development objectives."

Poverty Alleviation. Reducing poverty is a national mission in India that is ingrained in the political culture. India's policymakers focus on alleviating poverty often to the exclusion of other socio-economic problems, such as inequality.[2] Indian state planners have adopted the 'rising tide lifts all boats' model, counting on economic growth and increases in state capacity to improve conditions for all, including the most economically disadvantaged. Although economic inequality is becoming a more salient issue due to the inequitable patterns of India's growth, it remains far less of a state priority than poverty alleviation. This prioritization creates a paradox. India is not likely to trade growth for climate change mitigation even if the poor will suffer disproportionately from climate change impacts. Indian policymakers perceive continued growth as a means to reduce the ranks of the poor and shrink the size of the groups most at risk.

[2] Over one-third of the population (34.3 percent) lives on less than $1 USD a day.

National Security. The Indian government faces numerous critical national security concerns. The most prominent are the inter-related threats from Pakistan and Muslim fundamentalist terrorism. The national security concern that may have the greatest impact on climate change-related decision-making is India's competition with China for primacy in Asia and, in the longer term, globally. Competition with China is another driver of India's determination to maintain high rates of economic growth, even at the expense of the environment. India's high growth rates started much later than was the case in China, and have been partially curtailed by the global economic downturn. Indian policymakers feel threatened by China due to China's lead in economic development; ambitious defense modernization program; development of new forms of war-fighting, such as information warfare; support to Pakistan; and unresolved territorial claims, including a claim on the Indian state of Arunachal Pradesh. China has developed a deep-water naval base in Pakistan and has similar plans for Myanmar and Bangladesh, raising India's concern regarding strategic encirclement. So long as Chinese economic, political, and military expansion continues, India will feel obliged to strive for parity with China.

Climate Change Policy. Because the observable impact of climate change may continue to appear mild or manageable through 2030, Indian policymakers may not feel the sense of urgency needed to drive sustained commitment to long-term mitigation policies and tough trade-offs with development goals. International pressure by governments and NGOs may therefore play a crucial role in keeping climate change concerns at the fore of India's policy agenda. The principles underlying India's 2006 National Environmental Policy (NEP) are unlikely to be changed. The NEP identifies India's first priority as lifting its citizens out of poverty through development, even if this results in greater energy consumption. To maintain India's current growth rate, energy demand will more than double by 2020. The firm commitment to continued economic growth means that India's room to maneuver on climate change policy is constrained by whether the policy options under consideration hinder growth. India is unlikely to accept solutions that constrain growth unless it is faced with climate change impacts that would pose an even more disruptive effect than the solutions.

The Government of India's June 2008 National Action Plan on Climate Change identifies core national missions to address climate mitigation and adaptation. These include missions for promoting use of solar energy, incentives for decreasing energy consumption, conservation of energy as part of urban planning, improvement in water use efficiency, conservation measures of biodiversity, forest cover and ecological values to protect the Himalayan ecosystem, development of climate resistant crops and a new Climate Science Research Fund. It is not clear how these "national missions" will be implemented, since the government gives equal priority to promoting development while yielding "co-benefits" for climate change.

State Capacity

The Indian state has considerable bureaucratic strength and a long tradition of dealing with crises, disasters, and scarcity. Despite financial and developmental challenges, its capacity to cope effectively has improved over time. Local drought relief, for example, has been managed without severe loss of human and animal life in the post-Green Revolution era. Many existing approaches and response mechanisms available to the Indian state—some dating back to the British colonial period—can be adapted to deal with climate change impacts. Transportation networks have improved greatly, allowing the efficient movement of food to deficit areas. The state has also managed the system of purchasing of grain to be sold in ration shops or stored in silos and warehouses, albeit with a good deal of corruption. The systems in place allowed India to forego international aid in the wake of the December 2004 tsunami.

In addition, India's sustained economic growth over the last decade has led to an unprecedented increase in both state and private sector capacity. Whereas in prior crises poverty and under-development have limited the response of the Indian state, continued economic growth should increase India's financial capability to handle climate change. Even if India's growth rates were to decline to around six percent, which may reasonably be expected given the global financial slowdown, India will have an increasing array of tools and resources at its disposal in confronting climatic challenges. India will nevertheless require substantial international assistance in dealing with climate change-induced challenges, in terms of money, technology, and technical assistance.

State Planning. Past performance and current trends suggest that Indian state capacity will continue to expand and should be able to manage increased pressures from climate change effects out to 2030. The uncertainty about regional and local climate change effects will nevertheless inhibit the effectiveness of state planning and responses. India's long term prospects for managing climate change impacts beyond 2030 are more doubtful. Uncertainty in climatic trend lines beyond the 2030 timeframe prevents any accurate assessment of the state's capacity to respond over the longer term. If Indian policymakers become preoccupied with mitigating near-term impacts from climate change they will probably not have the leisure to implement measures to deal with more severe effects beyond 2030. Even if climate shifts over the longer term were more certain, the Indian democratic system inhibits administrations from planning beyond the next few election cycles.

Limitations on State Capacity. Although India has undertaken initiatives to plan for anticipated climate change impacts, it has typically had difficulty executing its plans promptly or effectively. On the one hand, the vast and layered Indian bureaucracy is a source of state resilience; on the other it is very slow to adapt and implement new policies. At the policymaking level, there has been a general unwillingness to move on climate change mitigation absent pressure from environmental crises, popular agitation, or lawsuits. Pervasive corruption also inhibits state effectiveness. The problem is especially acute at the local level, where the district court system—the linchpin for the enforcement of rules and regulations and the accountability of the bureaucracy—is fraught with corruption and inefficiency. Policy execution is further inhibited by limitations on access to funding, efficient technologies, and technical expertise.

Prospects for State Failure

Given the moderate projected climate change impacts and India's increasing state capacity, a widespread state failure is unlikely to occur before 2030. Although the challenges facing India are severe, the country has endured for more than sixty years in the face of predictions of impending state failure. Even if an extreme, sustained climate-induced crisis caused the central government to suffer a general failure, some of the state governments would likely retain enough capacity to function autonomously, at least on a temporary basis. The probable economic and humanitarian consequences of such a failure would nevertheless be catastrophic and require a response at the global level—the Indian state is effectively "too big to fail."

Stabilizing Factors. India has a number of institutional "buffers" that may aid in preserving state stability. The Indian democratic political system, with its broad participation even by the poorest citizens, is a major source of legitimacy for the state. It is also a mechanism to receive feedback on mitigation policies that should allow India to more effectively hone its responses to climate change over the longer term. India's federal system has been gradually strengthened since independence, reinforced by the emergence of a state-based political system within a centuries-old common market. The social tolerance of inequality, so long as poverty alleviation continues, may insulate the Indian government from popular disaffection due to disproportionate climatic impacts on certain groups. The ability of the state to turn to elements of civil society for assistance as well as feedback and pressure from civil actors and NGOs are further stabilizing factors.

India is not a police state and the number of security forces per capita is low. The repressive elements of the state—military, paramilitary, and police—nevertheless number in the millions. These forces represent an important tool that India can bring to bear in addressing climate change-induced challenges, both in the case of humanitarian response to large-scale disruptive events such as floods or cyclones, as well as in response to internal instability caused by population displacement, unemployment, socio-economic grievances, or resource competition. Indian security forces have shown the capacity to adapt to the requirements of the mission. In Kashmir, for example, the Indian security response was initially clumsy and ineffective, but over time its effectiveness improved. The Kashmir experience, as well as the challenge from terrorism, has led to needed reforms in the centrally-controlled military and paramilitary forces which will be key responders to large-scale climate change-induced disruptions. The local Indian police forces, in contrast, have yet to be reformed and are pervasively abusive and corrupt.

Failure of Constituent States. Even though a failure of the central government is unlikely, India may accumulate a collection of failed constituent states within its federal structure. While the South and West of India have benefited most from recent economic growth, the Hindi-speaking heartland of the East is characterized by low growth and low state capacities. In addition to being the least developed and most dependent on subsistence agriculture, these states are expected to suffer the most severe localized climate change impacts. This poses a serious risk that state governments will be unable to cope with accelerated climate change-induced challenges, even if the federal government is able to manage the challenges at a macro-level. The failure of constituent states will exacerbate interstate migrations and necessitate both greater federal intervention and greater reallocation of financial and other resources between states. The areas that are most at risk for climate change-induced state failure are also those that face the most serious challenge from Maoist-inspired insurgent groups. A positive feedback loop between insurgency and state failure may therefore develop, leading at best to chronic instability and at worst to sustained regional civil war and humanitarian crises.

State Climate Change Mitigation Policies

Agricultural Policies. The success of the Green Revolution demonstrates that India has the capacity for large-scale agricultural adaptation. India may well need a second Green Revolution to meet the challenges brought about by climate change. Such a process would require very substantial planning and subsidies from the Indian state over a sustained period.

Indian policymakers take great pride in having achieved self-sufficiency in food and are determined not to once again have to depend on foreign humanitarian aid to feed the population. This attitude may constrain willingness to compromise on autarkic food security in the face of climate-induced pressures until the problem reaches a crisis stage. India's existing infrastructure, expanded and improved up to 2030, should nevertheless be able to handle the movement of food and drinking water from surplus to scarce regions, especially in the states of the northern Deccan and Vindhyas (Rajasthan, Gujarat, Madhya Pradesh, and Maharashtra in particular), where there is likely to be more urbanization. Maintaining food security requires not only efficient food distribution but also sufficient food production. Average yields of food crops in India are still low by global standards. While increased productivity might ideally be able to keep pace with population growth, in practice climate change impacts on agriculture will make such productivity very difficult to maintain in the longer term. Measures such as expanding the use of drip irrigation, intensifying watershed/water harvesting efforts, and replanting land devoted to cash crops such as cotton and sugar cane with food crops may be able to mitigate some impacts on agricultural productivity. India already possesses the state institutions needed to conduct research on new varieties of crops that will be drought and saline water resistant and can readily expand them.

Autarkic measures will most likely not be sufficient to make up for declining food production and shortages due to extreme weather events such as droughts, floods, or storms. India will need to substantially modernize its agricultural sector and turn to the world market for at least some of its food needs. The Indian government's Planning Commission is already experimenting with different alternative agricultural models, including contract farming, public-private partnerships, and commercial cultivation of high-value crops such as flowers or potatoes. In addition to generating export revenue, high-value commercial agriculture may be a way to accommodate agricultural capacity currently wasted on inefficient subsistence models. Improved agricultural efficiency and mechanization will have the side-effect of displacing many surplus rural laborers. Any Indian agricultural reform strategy must therefore be complemented by an expansion of industrial and service sector employment opportunities. A phased displacement of vulnerable populations out of lifestyles and regions that will experience the greatest negative impacts from climate change could help mitigate those impacts. A long-term program to carry out this movement in an incremental way might allow India the time to put in place infrastructure and create economic opportunities for the displaced rural population, rather than being overwhelmed by sudden migrations due to climate-induced crises.

Energy Policies. India has few good alternative energy options. Programs to advance cleaner forms of power generation have been initiated but remain far from fulfilling their promise in view of fiscal, technological and end-user adaptation constraints, even assuming that they can provide power inexpensively. Given the large projected growth in production and consumption demands, a transition to cleaner but more expensive means of energy production would entail very large financial costs to India. As a result, for the foreseeable future growth will be tied to fossil fuels, particularly coal. Adoption of cleaner alternative methods of energy production will most likely be contingent on foreign technology transfers.

India will likely expand its use of nuclear power to address some portion of its future energy needs, although there is disagreement about the likely extent of the adoption of nuclear power. In the past nuclear development has been slow, but India now has more access to international sources of nuclear fuel and technical assistance. India may be encouraged to step up plans for increased nuclear power generation if domestic climate change mitigation policies and international standards constrain emissions from fossil fuel-based energy production. Notwithstanding a projected seven-fold rise in capacity, nuclear power will represent eight percent of the total power supply by 2030. It is not expected to rise above 15 to 20 percent by

2050, well after the horizon for carbon emissions that will matter for climate change up to 2080 or even beyond.

Hydroelectric power generation may prove less appealing to India for several reasons. It will face constraints due to projected shifts in rainfall patterns and river flows, particularly as the melting of Himalayan glaciers results in sustained diminutions in river flows. In addition, the fact that most of the Himalayan watersheds are outside sovereign Indian territory creates a risk that upstream activities by the controlling states, notably China, could severely compromise Indian hydroelectric power generation, as well as water security more generally.

The Indian government needs to address the energy challenge at least as much from the demand side as the supply side. This may prove very challenging as it is unclear if New Delhi has the ability to monitor, let alone control, energy use throughout the country. To a certain extent, India's delayed industrialization has been advantageous in terms of controlling both energy demand and increased fossil fuel emissions. India has been able to bypass some energy-intensive stages of industrialization, leapfrogging directly to more efficient solutions. In telecommunications, for example, India has moved directly to cellular phone use, avoiding having to create an energy-intensive landline phone system. Energy demand could be reduced through such measures as solar water heating, solar cooking, and greater use of bio-fuels. Green building designs and construction methods could also be implemented. These need not require the application of advanced techniques: for example, mud more efficiently dissipates heat than concrete, allowing Indians in mud dwellings to live comfortably in up to 120 degree Fahrenheit heat even without air conditioning. A move back to mud construction could therefore reduce the need for air conditioning, in turn reducing demand for electricity. On the other hand, if climate change is expected to bring heavy downpours, mud construction makes less sense. These sorts of design tradeoffs need to be considered in light of anticipated climate change impacts.

The expansion of the Indian transportation sector over the next twenty years is projected to account for a large share of growth in energy demand and will potentially be a major source of increased carbon emissions. The Indian state has the opportunity to incentivize more energy efficiency transportation developments. It could subsidize rail transportation and facilitate the expansion of the already extensive Indian railway system. Rail transportation is substantially more energy-efficient than road transportation. Urbanization and increased demand for personal vehicles, however, dictate that substantial expansion of the Indian road and highway system will take place. As previously discussed, India's auto industry has demonstrated the capacity to produce high-efficiency vehicles, and the government could subsidize the production and purchase of such vehicles.

Regional Implications

The regional impact of likely climate changes will affect India in numerous ways, from first-order environmental effects such as diminished river flows, sea level rise, and windborne aerosols to second-order socio-political disruptions such as cross-border migration, humanitarian crises, and possible state failure. The most significant sustained challenges may stem from reduced water availability and increased migration.

Geopolitics in South Asia

Although it is unified geographically, South Asia is a deeply divided region politically. India is by far the leading power in the region, but has preferred to take an almost exclusively bilateral

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approach in dealing with its South Asian neighbors. There is a virtual absence of South Asian regional institutions and a low level of intra-regional trade, investment, and other forms of economic interaction. The one regional organization that exists is the South Asian Association for Regional Cooperation (SAARC); both India and its neighbors have deliberately kept it weak. India is reluctant to accord much importance to this regional association due to fears that neighboring states might use it to restrain Indian power. India's neighbors worry that an effective multilateral institution would become an instrument of Indian hegemony. These considerations have kept contentious issues such as water sharing off SAARC's agenda. India is more interested in participating in the Association of Southeast Asian Nations (ASEAN), as the countries of Southeast Asia are far more significant trading, investment, and security partners. The lack of multilateral cooperation and institutions at the regional level is a significant complication to formulating a common response to shared climatic challenges.

India's domestic politics and that of its neighbors act as a further inhibitor to efforts at regional cooperation. The longstanding and intractable tensions and disputes in the South Asian region tend to mobilize aggrieved domestic constituencies and hamper the national governments' ability to make concessions and improve cooperation. A case in point is the dispute between India and Bangladesh over the Farakka Barrage located on the Ganges approximately 15 miles upstream from the border with Bangladesh. The barrage facilitates irrigation in three of India's most populous states—Uttar Pradesh, Bihar, and West Bengal—which provide about one-third of the representatives in the Indian Parliament. No Indian coalition government can afford to agree to any deal that results in a significant reduction of the water available for irrigation.

Instances like the Farakka Barrage dispute have encouraged the Indian government to repeatedly—and successfully—turn to 'stealth diplomacy.' Private consultations are used to keep issues under negotiation from public scrutiny and possible deal-breaking demands. India knows how to conduct quiet diplomacy and has done so with Pakistan on several occasions over the past decade.

The history of regional tension also means that active involvement by external powers may be a necessary ingredient in facilitating regional cooperation in addressing climatic challenges. Although India has followed a longstanding policy of excluding external powers from the region, that policy began to erode slightly with the end of the Cold War. India has realized that the outside world, and in particular the United States, might be helpful in India's relations with neighboring states. India is willing to consent to great power involvement if it is on Indian terms and serves to advance India's interests.

Regional Water Issues

The major rivers of the subcontinent arise in the Himalayas and their courses cross national boundaries. The great South Asian river basins support rich ecosystems and irrigate millions of acres of land, supporting some of densest populations in the world. The two major South Asian trans-boundary river systems that include India are the Ganges-Brahmaputra-Meghna system (which spans Bangladesh, Bhutan, China, India, and Nepal) and the Indus system (which spans Afghanistan, China, India, Nepal, and Pakistan). Regional cooperation on these transnational river systems has been conducted on a bilateral basis with mixed results. The lack of multilateral regional cooperation has created the paradoxical situation whereby South Asia faces water shortages despite there being ample water in the region. An integrated regional water management program could provide substantial benefits—such as increased hydroelectric and irrigation efficiency—but the political barriers to doing so have so far been challenging. Increased pressure on the South Asian water systems due to climate change might provide an incentive for increased cooperation, but given the level of mutual suspicion among the parties could also lead to conflict.

Water Issues with Pakistan. The Indus Waters Treaty signed in 1960 between India and Pakistan is the best example of regional cooperation over water. Outside involvement from the United Kingdom and United States was essential in this case, as India and Pakistan could not resolve their differences over sharing the water. The Indus Treaty stipulated the distribution of waters between India and Pakistan, the construction of canals and storage facilities (paid for by the US and the UK) and a Permanent Commission to adjudicate disputes, exchange data, and provide for on-site inspections. The Commission has been able to accommodate the expansion of the irrigation system in both countries and has continued to function over the past five decades, even during the two Indo-Pakistani wars and periodic tensions. Lessons learned from this example of water cooperation between adversaries include the need for external involvement and funding, concrete benefits to both sides, strong national leadership, and some degree of 'stealth diplomacy.'

In spite of the Indus Waters Treaty, Indo-Pakistani tensions—such as the two-decade old dispute over the Wular Barrage being built by India on the Jhelum River—mean that shared river systems will not be utilized to their full potential, which might become a serious regional problem as river flows diminish. The water dispute could become an increasingly relevant factor in Indian and Pakistani strategic calculations, although resort to military force specifically on the water issue is unlikely.

Water Issues with Bangladesh. India has had a long-standing dispute with Bangladesh over the Ganges-Brahmaputra-Meghna river basin, which includes the Farakka Barrage issue. A series of treaties have been signed since 1975—the latest in 1996—but no solution has been implemented. Bangladesh continues to protest the diminished flow of water and the adverse impact caused by the silting of vital waterways, factors likely to be significantly worsened as the overall river flow diminishes. India is constrained by a lack of funds and by domestic political factors that stall any solution to reduce the water available for irrigation in northeastern India.

Water Issues with China. Unlike India's other neighbors, China is not part of the South Asian geographic and climatic region, and faces discrete climate change impacts. China nevertheless plays a significant role in hydrologic issues in South Asia, primarily through its control of the Tibetan Plateau and Himalayan watersheds which are the source of several rivers that flow through the eastern quarter of the subcontinent. As glacial melting reduces river flows from the Himalayas, water competition between India and China may intensify. Tension may worsen as China moves ahead on plans to tap into Himalayan hydroelectric potential. The major issue concerns China's plans for a massive hydroelectric project in Tibet which is expected to be twice as large as the Three Gorges Dam, currently the world's largest hydroelectric project. The Tsangpo hydroelectric project would divert water from rivers draining from Tibet into South Asia. This is likely to become a major point of contention with India, and may inflame even further the unresolved border claims between the two countries.

Cross-Border Migration

The other major cross-border regional climate change issue facing India is an upsurge in cross-border migration from neighboring countries subjected to severe climate change impacts. There

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is already a large-scale movement of people from Nepal and Bangladesh into India for economic reasons, and climate change will most likely result in a significant increase in migration. Increasing cross-border migration has already triggered "sons of the soil" movements that demand the expulsion of these immigrants, most of whom are illegal. Efforts to restrict migration have failed and the Indian government recognizes that the only realistic long-term solution is economic development and increased prosperity in Nepal and Bangladesh. This issue, like that of water, will require a regional approach.

Immigration from Bangladesh. Illegal immigration from Bangladesh into India can be compared to that from Mexico into the United States and has already caused pressure on India's stretched resources in the Northeast and Bengal. Bangladeshis account for the majority of migrants presently in India. Although estimates on the numbers involved vary, they could amount to between 15 and 20 million people. India is now building a fence around Bangladesh to stop migration and placate anti-immigrant groups, but border control has so far proved ineffective. A 2008 Delhi High Court ruling has paved the way for deporting persons of Bengali origin unable to produce a birth certificate or other evidence of Indian citizenship. In India's northeastern Assam region, groups that face the threat of being demographically overwhelmed by immigrants have argued that the federal government in New Delhi is unable or unwilling to prevent illegal immigration. They have gone so far as to use the immigration issue as grounds for secession from India.

The majority of Bangladeshi immigrants have been illegal economic migrants from districts adjacent to Indian West Bengal. Anticipated inundation and salt water intrusion in the Ganges delta may displace tens of millions more Bangladeshis, many of whom may cross the border into India. India would not have the resources to cope with Bangladeshi immigrants pushing into West Bengal, Orissa, and the Northeast. On the other hand, Bangladesh has shown increasing capacity to cope with inundation. Up to 70 percent of Bangladesh is under water each monsoon season, but farmers have adapted by cultivating water crops such as rice and farming shrimp for export. Despite these adaptations, Bangladesh will most likely become less able to manage the issue as the loss of arable land continues and the scale of the climatic problems increases. About half of Bangladesh's population, unable to sustain themselves through agriculture, will migrate to cities by 2050, and much of this migration will probably be to India. In addition, major disruptive events such as cyclones may generate mass refugee movements into India on much shorter timescales than the overall shifts in climate.

Immigration from Nepal and Other South Asian Countries. Immigration from Nepal has so far been a much less contentious issue than the influx from Bangladesh. The number of Nepalese immigrants involved is much smaller—at most two to three million. Unlike Bangladeshis, most Nepalese immigrants enter India legally. The border with Nepal is open and there have been no efforts to erect barriers. India's concerns about Nepalese immigration are nevertheless likely to increase as climate change-induced pressures increase the flow of immigrants.

Sri Lanka's coastal areas had a preview of the disastrous effects of rising waters during the 2004 tsunami. Pressure from rising sea levels could cause Tamils from northern and eastern Sri Lanka, about 18 percent of the total population of 20 million, to migrate to Tamilnadu across the Palk straits, as well as to seek assistance from India. The entire country of the Maldive Islands could disappear due to sea level rise. The population of 300,000 is already experiencing flooding of some islands. India will be expected to assist and could become the host for the majority of the displaced islanders. Although immigration from Pakistan is not very significant, a climate-induced state failure in Pakistan might result in refugee flows across the Indian border.

Prospects for Regional Conflict

Climate change impacts mean that India, as the leading regional power, will most likely face increased requirements for humanitarian intervention in neighboring countries, either unilaterally or multilaterally. The prospect of climate-induced state failure in Sri Lanka, Nepal, or Bangladesh might necessitate strong Indian intervention. Short of state failure, major disruptive events such as cyclones—which are expected to strike with greater intensity and frequency—could similarly necessitate Indian humanitarian intervention, particularly in Bangladesh, Sri Lanka, or the Maldives. Setting aside humanitarian intervention, it is unlikely that interstate conflicts will be explicitly framed in terms of environmental issues such as water rights or migration. Climatic concerns may instead increase underlying tensions in the region, exacerbating conflicts over other issues.

Pakistan. Pakistan presents a special and particularly troubling case for India. Indo-Pakistani conflict remains a persistent risk, even absent climate-induced pressures. Pakistan might, in extreme circumstances, be pushed to contemplate military action to secure the sources of the Indus river system, which lie in the disputed territory of Kashmir. Given Indian military superiority, such a move is very unlikely and Pakistan's prospects of holding the territory in the long term would be remote. The presence of the Indus Waters Treaty, which has so far successfully guaranteed Pakistan's access to the rivers, even during armed conflict with India, also remains a mitigating factor.

A more likely climate change-induced conflict scenario involves the full or partial failure of the Pakistani state. Pakistan faces a serious risk of state failure even without climatic pressures. Even without details of climate change impacts on Pakistan to 2030 it is clear that climatic stress would intensify Pakistan's pervasive instability. A failure of central military authority could result in Pakistan breaking up into its constituent ethnic and regional sub-units. Climate change-induced challenges could also cause the breakdown of civil order in particularly vulnerable regions of the country, such as Punjab. The inability of the Pakistani government to cope with climate change-induced challenges could also increase support for radical solutions such as Taliban-style fundamentalist movements and prompt a generalized insurgency. Loss of military control would place the security of Pakistan's nuclear arsenal at risk. Any of these scenarios would pose a severe national security threat to India. India would likely feel obliged to intervene given a wholesale state failure in its nuclear neighbor.

China. India's strategic concerns about China may inhibit both the prospects for cooperation on regional or global climate change mitigation as well as India's willingness to sacrifice economic growth or redirect resources from national security needs. The most salient climate-related point of conflict could be China's move to divert the upstream waters of rivers originating in the Himalayan watershed. Tibetan hydroelectric projects could put at risk the tributaries of the Brahmaputra. If China was determined to move forward with such a scheme, it could become a major element in pushing China and India towards an adversarial rather than simply a competitive relationship. Border clashes related to control of the rivers are not out of the question. In 1962, India was defeated by China in a border war in the mountains of Arunachal Pradesh—the same area that would be affected by river disputes.

Prospects for Regional Cooperation on Climate Change Mitigation
Given the likely regional impacts from demographic and climate changes, states in South Asia need to adopt a more cooperative approach to address regional problems. No regional climate mitigation effort will be adopted without India's active support and most likely its leadership. Despite the numerous problems noted above that hinder regional cooperation, several factors may prompt India to take a more active regional stance. Regional cooperation enhances India's goal of playing a more significant role on the world stage. Conversely, tensions with its neighbors, especially with Pakistan, are distracting and make India a less attractive strategic partner. In addition, India's neighbors provide sources of energy that could improve the chances of India maintaining a high rate of economic growth—hydroelectric power in the case of Nepal, gas in the case of Bangladesh, and transshipment routes for Iranian and Central Asian gas in the case of Pakistan.

The biggest challenge, however, will be political leadership. Missing today from the model of the successful Indus Waters Treaty described above are strong national leaders in any of the South Asian states who can stand up to domestic obstructionism. Indian Prime Minister Manmohan Singh, a renowned economist, is probably the only regional leader with the vision to push regional climate mitigation efforts, although he heads a relatively weak coalition government. Regional cooperation on climate mitigation proposals will likely require "stealthy," non-publicized outside involvement and funding, probably led by the United States.

Overall Foreign Policy Implications

Since the adoption of market reforms in the early 1990s, India has radically reoriented its foreign policy. It has moved from an inward-looking security stance to a more outward- looking policy aimed at enhancing trade, investment, and access to technology. It has cultivated relations with countries that can help it achieve economic growth, such as the United States, Japan, and countries of the European Union. Nevertheless, India retains some residual autarkic tendencies and its growth model is far less export-dependent than that of China. If climate change caused an extreme diminution in resources, it might be the catalyst for a shift toward autarkic policies in India.

India's Foreign Policy Stance on Climate Issues
India's industrial growth and size mean that it is becoming one of the primary contributors to climate change, even though its per capita emissions are and will remain low by developed country standards. India therefore needs to reevaluate its strategy and values on climate issues—focusing more on curbing future impacts and less on historical injustices—if it is to assume a responsible global position. This will require reframing the climate debate in terms of India's self-interest in mitigating destabilizing impacts and promoting green economic growth rather than in terms of the global need to limit or moderate industrial development. As a latecomer to industrial development, India is not receptive to the latter argument.

Indian policymakers also remain hostile to what they perceive as high-handed foreign dictates on climate change policies that do not take India's development needs into account. Even as climate change impacts begin to be felt, suspicions remain that the climate issue is being used to protect the economic interests of developed countries. India's policymakers are likely to support issues related to climate change only if convinced that they also advance the goal of economic growth.

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While India favors a multilateral approach to managing global climate change mitigation, it prefers that the standards and regulations be voluntary and take development targets into account. India has been consistent in refusing to accept international greenhouse gas mitigation targets, for example, citing equity and economic grounds. India has remained firm on the principle that all countries have a right to equitable emissions in the atmosphere measured by per capita entitlement, an argument so far supported by China and other developing countries. India's view has been that the developed countries have exhausted the global commons and should bear the primary responsibility for responding to climate change. The developed countries should therefore reduce their emissions to start closing the gap in per capita emissions between developed and developing countries.

If the developed countries want India to adopt more climate-friendly policies and technologies, they will have to subsidize it through the large-scale transfer of technology and money. The developed countries have the efficient technologies India needs to effectively deal with the challenges of climate change mitigation, and India believes they have a responsibility to provide such aid. Large-scale transfers of wealth may be a tough sell in the current global economic climate. The acceptance of a per capita distribution of carbon permits in itself would represent a trillion-dollar transfer of wealth from the developed countries.

Indo-American Relations

Since the end of the Cold War, India has largely abandoned its ideological commitment to non-alignment and shown an increased willingness to engage with the United States and even allow US involvement in South Asian regional affairs. The US pressure on Pakistan to withdraw its troops from the Kargil enclave in Kashmir in the summer of 1999 demonstrated that US involvement on the sensitive Kashmir issue could be advantageous. A more recent example of US help was the assistance provided by the Federal Bureau of Investigation and US pressure on Pakistan to cooperate in the investigation of the November 2008 terrorist attack in Mumbai by operatives of the Pakistan-based Lashkar-e-Taiba (LeT). The successful US effort to exempt India from the international restrictions on export of nuclear fuel and technology significantly enhanced US standing in India. Polls over the past several years consistently show that the US is popular in India and that Indians perceive US foreign policy goals as not inconsistent with those of India.

Climate Policy Differences. India and the United States have been on opposing sides of the climate change debate. Although both sides cite equity considerations in support of their stances, India defines equity on a per capita basis while the US defines it in terms of contributions to emissions. India seeks further commitments on reducing emissions from the developed countries, citing the principle of "common but differentiated responses." India believes that the United States should take the initiative in making disproportionate adjustments to its own energy consumption and emissions before expecting India to take similar action. The United States insists on parity in treatment of all major emitters, an important reason it did not sign the 2005 Kyoto Protocol imposing mitigation targets only on developed countries. Although US-Indian dialogue on climate change continues, it frequently suffers from divergent interpretations by the two sides. Despite the fact that both the US and India endorsed the 2007 Bali Action Plan to advance the climate regime at the Copenhagen Conference of Parties in 2009, each reads the text differently. India, supported by China and the G-77, views the "nationally appropriate mitigation actions" by developing countries as contingent on transfers of technology and infusions of financing and capacity-building from the developed countries. This is a much more open-ended interpretation than that of the United States.

India considers itself to be in a relatively strong position to persuade the United States and other developed countries to pay for the changes needed to reduce emissions because arriving at an international climate change agreement means far more to them than to India. It has therefore adopted a maximalist negotiating position that the United States may find very difficult to accommodate. India may not fully take into account the difficulty in securing sufficient political support on the US side for substantial financial support to Indian climate change mitigation. Although outsourcing has given India some leverage with the United States by moving substantial supporting elements of US industries to India, this leverage is not at the level enjoyed by China.

Strains in Indo-American Relations. India perceives the United States has downgraded its relationship with India in favor of stronger ties to Pakistan and China. The Hyde Act was a major step backward in relations, nullifying closer cooperation with India on nuclear security and energy. The current lack of enthusiasm in Washington for following through on the terms of the nuclear deal negotiated under the Bush administration has sent a strong signal that nonproliferation concerns have been prioritized over closer ties with New Delhi. As a consequence, India is turning to France and Russia as nuclear energy partners.

The renewed US emphasis on the war in Afghanistan has led to increasing American ties with, and reliance on, Pakistan. Pakistan has extracted a high price in military and development aid from the United States for its cooperation against terrorism and the Taliban. Having been accorded the status of a major non-NATO ally, Pakistan has increased access to advanced US weaponry. Although US aid is intended to facilitate Pakistani engagement on the terrorism front, it has the side-effect of strengthening Pakistan's capabilities vis-à-vis India. Regardless of Washington's motivation, India feels threatened by deepening ties and aid to its main regional rival.

India tends to perceive the US relationship with China in similarly zero-sum terms. India and China to a large extent occupy the same geo-political space as major rising Asian powers and leaders among the world's developing countries. India regards itself as a peer competitor of China and is very sensitive to the greater relative international weight accorded to Beijing—for example, China has a permanent United Nations Security Council seat while India does not. India views any US move that disproportionately favor China with hostility. This applies to climate change as to other international issues. For example, if the United States were to negotiate a bilateral side-deal with China in advance of the Copenhagen negotiations, India's non-cooperation would be virtually assured and US-Indian relations jeopardized. Given India's upcoming elections, such a move would sour the views of the incoming Indian administration regarding the United States, regardless of whether there is a change in government.

To the extent that Indian policymakers perceive the United States is turning away from India and giving aid and comfort to its adversaries, their displeasure may well manifest itself in greater recalcitrance on climate change issues. From India's perspective, the United States has a history of vacillating between granting favor to India or its rivals. New Delhi does not forget past American fickleness and grudges are likely to be carried over into future policy debates.

Opportunities for Engagement. Ample opportunities exist for the United States to incentivize greater Indian cooperation on climate issues. In recent years India has set aside previous ideological divisions with the United States in order to take a more pragmatic approach aimed at furthering its own perceived national priorities. In the longer term, a strategic partnership with the United States offers India a stronger position vis-à-vis China. There is a possibility for a *quid pro quo* if the United States is prepared to offer a long-term security relationship in exchange for Indian concessions such as emissions caps. Indian uncertainty about Washington's commitment to building a partnership may require a demonstration of US bona fides. US actions that accord New Delhi equal prestige and precedence to Beijing may dispose India to greater confidence in US commitments and openness to compromises on climate change issues. A trilateral dialogue between the United States, India, and China in advance of Copenhagen, for example, might be viewed positively by New Delhi, whereas a bilateral US-China dialogue would be viewed negatively.

So long as direct military aid remains limited to counter-terrorism, US ties to Pakistan are not necessarily a disadvantage to India. The close relationship with Islamabad allows the United States to exert more leverage to curtail Pakistani provocations in Kashmir or tacit support to terrorist groups such as LeT, as well as to act as an honest broker in 'stealth diplomacy' between the rival countries.

While India is now taking the implications of climate change seriously, US pressure remains an important factor in sustaining commitment to climate change mitigation policies. India currently perceives its relative stake in climate change mitigation as less than that of the US and other developed countries. Although this is likely to change over time as climate change impacts on India intensify, in the near term securing Indian acquiescence in international mitigation policies may require US persistence and persuasion. This will require a combination of flexibility in accommodating India's developmental priorities and incentives in other areas, such as security, technology transfers, subsidies, and greater diplomatic engagement. In addition, unilateral US initiatives on reducing its own climatic impact would demonstrate US sincerity and resolve on the climate mitigation issue.

The Copenhagen Negotiations

Despite the urgency of the Copenhagen negotiations, a comprehensive agreement on climate change mitigation may not yet be possible. Failure to achieve an effective treaty at Copenhagen would be a major setback in the response to global climate change, but there would still be the opportunity for a side deal with India and/or China. The United States should be prepared to continue the dialogue at other venues and on a bilateral or more constrained multilateral basis. However, the United States should not alienate either of these key powers in the name of short-term diplomatic maneuvering. India remains one of the few countries where the United States maintains a broadly positive image, an advantage which should not be squandered through heavy-handed diplomacy.

The United States should approach India before the negotiations through 'stealth diplomacy' and seek to pre-negotiate a mutually acceptable compromise outside the public and international eye. India is broadly receptive to the idea of climate change mitigation but not at the expense of economic growth. It would be useful to reframe the argument in terms that recognize India's growth priorities and show how cooperation will serve India's economic interests. India would likely be receptive to a sliding scale of climate change mitigation benchmarks for India and other developing countries that still need to focus on growth. Such a scale would allow more relaxed standards until they reached levels of wealth and industrialization seen in developed countries. Copenhagen provides an opportunity for the United States to assuage Indian concerns about its commitment to a strategic partnership. The negotiations can be presented to India as one of the first tests of US and Indian resolve to ameliorate policy differences and take a joint lead on a critical global issue. Even limited symbolic US concessions may pave the way for strategic agreements down the road.

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CONFERENCE REPORT

INDIA: THE IMPACT OF CLIMATE CHANGE TO 2030

GEOPOLITICAL IMPLICATIONS

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NATIONAL INTELLIGENCE COUNCIL

CONFERENCE REPORT

CR 2009-09 June 2009

China: The Impact of Climate Change to 2030

Geopolitical Implications

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China: The Impact of Climate Change to 2030

Geopolitical Implications

Prepared jointly by

CENTRA Technology, Inc., and Scitor Corporation

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Scope Note

Following the publication in 2008 of the National Intelligence Assessment, ***National Security Implications of Global Climate Change to 2030***, the National Intelligence Council (NIC) embarked on a research effort to explore in greater detail the national security implications of climate change in six countries/regions of the world: India, China, Russia, North Africa, Mexico and the Caribbean, and Southeast Asia and the Pacific Island states. For each country/region we are adopting a three-phase approach.

- In the first phase, contracted research explored the latest scientific findings on the impact of climate change in the specific region/country. For China, the Phase I effort was published as a NIC Special Report: ***China: Impact of Climate Change to 2030, A Commissioned Research Report*** (NIC 2009-02, April 2009).
- In the second phase, a workshop or conference composed of experts from outside the Intelligence Community (IC) determined whether anticipated changes from the effects of climate change will force inter- and intra-state migrations, cause economic hardship, or result in increased social tensions or state instability within the country/region. This report is the result of the Phase II effort for China.
- In the final phase, the NIC Long-Range Analysis Unit (LRAU) will lead an IC effort to identify and summarize for the policy community the anticipated impact on US national security.

In April 2009, CENTRA Technology, Inc., convened a group of regional experts to explore the socio-political challenges, civil and key interest group responses, government responses, and regional and geopolitical implications of climate change on China through 2030. The group of outside experts consisted of social scientists, economists, and political scientists. Although the targeted time frame of the analysis was to 2030, the perceptions of decisionmakers in 2030 will be colored by expectations about the relative severity of climate changes projected later in the century. The participants accordingly considered climate impacts beyond 2030 where appropriate.

The Central Intelligence Agency's Office of the Chief Scientist, serving as the Executive Agent for the Director of National Intelligence, supported and funded the contract.

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Executive Summary

The National Intelligence Council-sponsored workshop entitled *Implications of Global Climate Change in China* on 3 April 2009 brought together a panel of experts[1] to consider the probable effects of climate change on China from a social, political, and economic perspective. The panelists judged that ***China has a robust capacity to handle the large-scale disruptions that probably will be caused by climate change and that China's trajectory of continued growth is likely to further increase its resilience through 2030. Beyond 2030 the ability for the state to respond is more problematic.***

- At present China ranks lower in resilience to climate change than Brazil, Turkey, and Mexico, but higher than India.
- China can adapt its administrative, planning, and resource allocation capabilities used for its fast-paced and successful development program to deal with climate change.
- China's development plan incorporates sustainability and posits a shift from energy-intensive heavy industry toward services and domestic consumption.
- In spite of state-imposed limitations, China's nongovernmental organizations and civil actors are increasingly capable and willing responders to climate change.

Climate change in China will nevertheless exacerbate a number of existing large-scale socio-political, economic, and environmental challenges.

- The combination of water scarcity, desertification, dust bowls, and shifting agricultural patterns appears likely to generate mass migration from China's northern and western margins into the heartlands of the east and south.
- China's cities and the non-agricultural sectors of China's economy will have to absorb millions of unskilled workers displaced from rural areas, resulting in higher unemployment, increased social tensions, and strain on infrastructure.
- Climatic pressure on agriculture and a move from staple crops probably will make China an important food importer.

In addition to domestic challenges, the trans-border impact of China's environmental problems could lead to increased political tensions, regional economic disruptions, and deterioration in the quality of life for hundreds of millions in the region.

- China may seek to assure its access to critical water and energy resources on its periphery either through economic means or the threat of force.
- Climate change may increase Chinese emigration into Russia, Mongolia, and other neighboring countries. China may face refugee inflows from Southeast Asia, North Korea, or other areas hard hit by climate change.
- China may divert water from the Himalayas to address its water and energy needs, putting downstream countries in South Asia and Southeast Asia at risk.

[1] The panel had expertise in political science, comparative world history, energy and climate practice, the Chinese economy, and sociology.

China's responses to climate change are likely to focus on large-scale solutions that significantly alter the environment.

- China undoubtedly will invest heavily in infrastructure projects to divert water to drier areas, control flooding, and address expanding urban needs.
- China is likely to accelerate market-based incentives for urbanization, migration, and business location decisions better adapted to climate change.
- Owing to the scale and inter-jurisdictional nature of climate change-induced challenges, the central government will be the primary responder, resulting in further centralization and the heightening of hierarchical controls.

China's response to climate change will nevertheless be inhibited by a number of structural, political, and economic factors.

- ***Panelists judged China's leaders consider sustained high rates of economic growth as essential for regime security, and they will not compromise these fundamental interests for the sake of climate change mitigation.***
- China will face drastic near-term rises in energy demand as its economy, industrial base, and standard of living increase.
- China will be forced to address energy demand primarily through domestically produced coal and imported oil, leading to a severe rise in China's contribution to global greenhouse gas emissions.

Climate change will create incentives for greater cooperation between China and other major powers as China increasingly assumes a leadership role in the international system.

- China's R&D and industrial development policies are increasingly focused on energy and environmental issues.
- ***Climate change is likely to increase China's overall dependence on international sources of energy, food, and technology.*** As a result, China probably will increase its presence and activity in international markets and resource-rich countries.

Despite a willingness to work with the United States when interests are aligned, China's attitude toward the United States is one of deep distrust. Securing China's commitment to a climate change agreement will require a multi-layered and nuanced diplomatic approach.

- China will face resource constraints and domestic destabilization that will limit its ability to make compromises with foreign partners or take aggressive mitigation actions.
- Engagement with Chinese academics, the bureaucracy, and civil actors will help disseminate foreign ideas in acceptable forms.
- China views India as a key strategic competitor and will feel threatened by any US attempt to strike a private climate agreement with India. On the other hand, China and India agree on issues of equity and responsibility for climate change and may cooperate against the developed countries' positions.

Contents

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Introduction and Background[2]

China is well known for its scale: it has the world's largest population, the third largest land area, and the fourth (nominal) or second (purchasing power parity) largest economy and is the second largest primary energy producer and consumer and the largest carbon dioxide emitter.

As a major global player in human-caused climate change, China is vulnerable to the adverse impacts of climate change:

- Over the past century (1908 to 2007), the average temperature in China has risen by 1.1 degrees Celsius (^{o}C).
- Although no significant trend was observed in nationally averaged precipitation totals over the past 50 years, a drying trend was observed in the Yellow River Basin and North China Plain.
- Over the past 30 years, the sea level and sea surface temperature have increased 90 millimeters (mm) and 0.9^{o}C, respectively.
- China has experienced more extreme events (floods, droughts, and storms) in recent years than ever before. These extreme weather events have caused direct economic losses per year of $25 to 37.5 billion in China.

One regional climate model projects a country-averaged annual mean temperature increase of 1.3-2.1°C by 2020 (2.3-3.3°C by 2050); another regional climate model projects a 1-1.6°C temperature increment and a 3.3-3.7 percent precipitation increase between 2011 and 2020, depending on the emissions scenario.

By 2030, sea level rise along coastal areas could be 0.01-0.16 meters (m), increasing the possibility of flooding and intensified storm surges, leading to degradation of wetlands, mangroves, and coral reefs.

Agricultural growing seasons will lengthen and the risk of extreme heat episodes will increase over time. Storms may intensify, but warming temperatures are likely to enhance drying in already dry areas, so both droughts and floods may increase.

China ranks lower in resilience to climate change[3] than Brazil, Turkey, and Mexico but higher than India. China ranks high in food security, human health, and human resources.

Projections of resilience show China gaining capacity quickly and outranking Brazil, Turkey, and Mexico by 2020.

In recent years, the Chinese Government has paid increasing attention to the negative consequences of climate change. In 2007, China laid out its roadmap to battle climate change in ***China's National Climate Change Program (NCCP)***, which was followed by a white paper in 2008 entitled, ***China's Actions and Policies on Climate Change***. Both documents reviewed China's past achievements and presented its plans in the following areas:

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[2] This section is a extracted from Executive Summary of the Phase I report (see Scope Note: http://www.dni.gov/nic/PDF_GIF_otherprod/climate_change/climate2030_china.pdf). Some of the judgments in this report (Phase II) may differ from the Phase I report.

[3] See the Phase I report, p. 23, for a description and discussion of resilience.

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- Strengthening government management in vulnerable sectors such as water resources, agriculture, forestry, and coastal regions.
- Building early-warning and monitoring networks.
- Raising public awareness.
- Enhancing R&D investment.
- Keeping an open and active attitude to utilize international resources.

China is demonstrating its determination to tackle climate change issues as an important domestic affair. However, some prominent climate impact issues—such as the underrated and underpublicized water crisis, as well as the underdeveloped social protection system—have seemingly not caught the government's attention. In addition, China must show an ability to actually implement its ambitious plans.

The negative consequences of climate change may expose the following sectors to high risk:

Water. Scarcity of natural water resources, fast-growing urbanization and industrialization, severe water pollution, cheap water prices, and the adverse impacts of climate change on water sources might lead to a water crisis in China. The drought regions in northern China may be prone to social unrest caused by conflicts about water rights and distribution between social groups and between sectors. The expected South-to-North Water Diversion Project may alleviate the water stress of some northern regions, but it will not provide a full solution (and has in any case been delayed). The forthcoming water crisis may adversely affect China's social, economic, and political stability.

Coastal Regions. Due to their flat and low landscape, China's coastal regions, the heartland of China's economic progress, are highly vulnerable to storm, flood, and sea level rise. The increasing frequency and intensity of extreme weather events such as typhoons has threatened economic development at local, regional, and national levels. China has been actively developing early warning systems and related monitoring systems, and improving the design standards of sea dikes and port docks. These efforts may help buffer some risk of natural weather extreme events.

Social and Political Uncertainties. With a large unemployed population, China's underdeveloped social safety net system is less and less able to protect those who need it. Rising expenses in healthcare, education and housing have been financial burdens for the average Chinese family. The export-oriented economy is vulnerable to a global financial crisis. The increasing dependence on foreign oil exposes China to an unstable world oil market. The adverse impacts of climate change will add extra pressure to existing social and resource (such as energy) stresses.

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Social, Political, and Economic Challenges

Climate change through 2030 is likely to subject China to severe ecological problems. It is not clear whether the resulting demands made on China will exceed the country's capacity to manage its economic, social, and political systems. If climate change-induced challenges occur gradually and can be forecasted and planned for accurately, China has the capacity to deal with them successfully. There are some grounds for optimism in the near term; the average trends underlying emerging climate change conditions in China imply only gradual adjustments. In addition, China's geographical location squarely astride the world's northern temperate zone appears to insulate the country from the more severe changes reportedly associated with coming global warming trends in tropical and arctic regions of the planet.

On the other hand, China already faces rising social tension over inequities and conflict over scarce resources, which will be magnified by unemployment from the current global economic slowdown and further exacerbated by near-term climate change trends. In addition, economic and social impacts are likely to come in bursts driven by major events such as a prolonged drought, a prolonged and especially heavy monsoon, a series of severe typhoons or dust storms, or an unusual sea surge causing a rush of increased coastal ground water salinity. There is a distinct risk of low probability, high consequence events in which a number of climate-related developments interact to produce negative synergies. Under such circumstances events could spin out of control, resulting in serious social and political crises.

When considering possible social, political, and economic challenges, it is worth noting that there are plenty of knowledge gaps in predicting the future effects of climate change. Currently, it is impossible to definitively model climate change, much less its impacts, in a useful time frame. In addition, the factors that affect water supply and productivity, the effects of dust clouds, and pests and agricultural diseases are poorly accounted for in current models. China's internal climate is very complex and varies across regions and at the local level. Social, political, and economic impacts, and by extension state capacity questions and societal responses, will exhibit substantial regional differences.

Hydrologic Challenges

China already faces an escalating water crisis brought on by increased water demands generated by expanding industry, urban populations, and agriculture. The impact of climate change on China's water resources will make this crisis considerably more severe, forcing large-scale mitigation measures to stave off the loss of arable land, disruption of agricultural patterns, and internal migration as many locations are rendered less habitable.

Over the longer term, phenomena such as glacial melting in the Himalayas, greater variability in the monsoons, and more frequent and intense storms will contribute to increasing irregularity of river flows, both from the watershed of the Himalayas and Tibetan Plateau and in the lowlands. In addition, rainfall will be more irregular, with episodes of drought punctuated by intense rainstorms. The total amount of rain received by particular regions will change, either increasing or decreasing as climate zones and weather patterns shift. This will place severe stress on farmers and agricultural systems dependent on traditional patterns of river flow and rainfall. Particularly in the case of regions still dependent on subsistence agriculture, this will generate environmental refugee flows and necessitate humanitarian intervention and reallocation of resources by the Chinese Government.

In addition, China will experience sustained shifts in water availability across large swaths of the country. Northern China will become drier. Southern China and south-central China, which already have substantial monsoon rains, will see even more precipitation as a result of climate change.

Water Scarcity, Droughts, and Floods. Sustained water scarcity is likely to occur across much of northern China, as well as more frequent and severe periodic droughts. These climate change impacts threaten a further deterioration of conditions already seriously affected by long-term water mismanagement, bringing costly damage or disruption to farms, non-farm businesses, and households. Climatic shifts will likely lead to southward and eastward encroachment by the Gobi Desert and severe water scarcity in the breadbasket of the North China Plain. Severe water shortages could generate broad stress across China's economy, population, and infrastructure. Scarcity will force increasingly difficult tradeoffs in water allocation between agriculture, industry, and population centers. Simultaneous population movements into China's cities will most likely restrict China's ability to divert water away from urban needs. China will therefore face the need to transition to less water-intensive farming and industrial techniques.

In the south and along China's coasts, the challenge will be overabundance rather than scarcity of water. The greatest impact will most likely come from more frequent and serious flooding, particularly in China's heavily populated river basins. Human tragedies and business losses resulting from flooding occur somewhere in China virtually every year, and these losses can be expected to increase substantially.

The North China Plain. The most disruptive impact of water scarcity in northern China may be felt in the North China Plain, the agricultural heartland of northern China. It is home to approximately 220 million people and encompasses the five provincial-level jurisdictions of Shanxi, Henan, Hebei, Beijing, and Tianjin. Although irrigated by the Yellow (Huang) River, water scarcity has forced the mining of groundwater, which is a nonrenewable and an unsustainable practice. There are already more than two million deep wells in the area, which combined with climate change will seriously deplete the water available to the region. The severity of population pressure on arid lands and declining water tables on the North China Plain was long kept a "state secret" starting in the mid-1980s to avoid alarming the populace. A sustained water crisis on the North China Plain would cause severe stress to both agriculture and the large rural and urban population, which may also be swelled up to 50 million environmental migrants and refugees fleeing desertification on the southern and eastern margins of the Gobi Desert.

Coastal Areas. Although China's coasts have plentiful access to water compared to the hinterland, climate change will put them at risk from sea level rise and storm surges, according to the Phase I report. New storm paths will open up northeastern costal areas to tropical storm damage, putting places like Shanghai and Tianjin at risk. Rising sea levels will increase saltwater intrusion in coastal farmlands, contaminating the soil and groundwater with salt. In addition, there may be loss of wetlands and low-lying arable land. Given China's coastal topography, the predicted rise in sea levels of 0.4-to-6.3 inches by 2030 will only impact certain coastal reaches of northern Jiangsu, some islands in the Yangtze River, and scattered strips of land in delta areas along China's coast.[4] Storm surges from more frequent coastal storms may pose a more significant threat of flooding in coastal delta areas. China's development patterns

[4] See interactive maps in this regard at http://flood.firetree.net.

have placed large populations and major capital assets in these areas, so the human and economic impact of such flooding could be considerable even if the affected areas are geographically limited.

Agricultural Challenges

China's agricultural sector will face acute stress from climate change, particularly as a result of impacts on water availability and distribution. This stress will be unequally distributed, with certain regions denuded by drought and desertification while others actually experience gains in productivity as a result of longer growing seasons or increased rainfall. The overall direct effect of climate change on agricultural productivity in China is uncertain. Although some estimates suggest that overall productivity may decrease by 5 to 10 percent by 2030, this depends on the highly unlikely assumption of no mitigating responses by farmers or the state. Some decline in productivity is likely, but the uncertainty of both the degree of climatic stress on agriculture and the effectiveness of responses makes it very difficult to predict its extent.

Economic growth will fuel dietary demand for animal proteins, which will require cheap grain as feed. This will force China to either subsidize grain production or look to foreign sources. The major socio-economic effect on agriculture, rather than a sustained decline in productivity, may be a sector-wide reallocation of agricultural activity between regions and between types of crops. Such a reallocation would involve mass movements of rural populations, both into new agricultural regions and into urban areas; the adoption of new cultivation patterns and farming practices; vast changes in rural infrastructure; and major shifts in China's domestic and external agricultural markets. Whether they participate in such a shift or not, farmers will face pressures to increase profitability as farming is rendered more difficult by climatic and agronomic effects. High-value commercial farming and crop specialization are likely to result, causing production of less profitable staples to decline. These pressures will likely make China a much larger food importer than it has been to date.

Agricultural Labor Surplus. Despite the rapid industrialization and urbanization of the past three decades, the proportion of China's population engaged in agriculture remains far above optimal levels. Over 300 million people are engaged in agriculture for income reasons, where a workforce of 210 million would be able to produce the same amount of output. By shifting production to different crops China could theoretically reduce the agricultural workforce to 100 million for the same amount of caloric output. Climate change may also open up vast new farm belts in Siberia and Canada, making new foreign food sources available to China and further decreasing the necessity for a large rural labor force. A shift comparable to that in Japan, where agricultural employment dropped from 40 percent in the 1950s to seven to eight percent by the 1970s, is a possibility in China. Sustained economic growth has so far provided sufficient employment for laborers moving off the farms to keep the sectoral shift manageable. The number of unemployed workers in China is nevertheless in the tens of millions, and increased agricultural efficiencies, mechanization, and stress from climate change may generate an employment crisis.

Desertification and Dust Bowl Eruptions. Even if the overall impact on productivity can be successfully mitigated, some of China's key agricultural regions, such as the North China Plain, will face acute climate change-induced agricultural stresses, primarily from water scarcity and contamination, but also from extreme events such as dust bowl eruptions. Unsustainable practices such as overgrazing and cropping of marginal lands have been a serious problem in Inner Mongolia and other semi-arid parts of China for many decades. Combined with climate change-induced water scarcity, these human impacts are exacerbating the spread of deserts and incidence of dust storms. The potential is increasing for dust bowls in northern and western China more serious than those in the central United States during the 1930s. As was the case in the United States, sustained dust storms would generate a mass exodus of environmental refugees from the affected areas as well as a severe and sustained decline in regional agricultural productivity. Depending on the timing of dust bowl eruptions and severe water shortages, these effects may be mutually reinforcing. Alternatively, water scarcity may preemptively move people and agricultural activity out of areas most at risk for dust bowl eruptions, mitigating their impact.

Pollution and Public Health Challenges

Industrial growth in China over the past several decades has caused major increases in pollution and environmental degradation. One of the challenges in addressing pollution is that much of it originates from aging, intensely-polluting industries in the poor interior of the country, where there are fewer resources available to move to cleaner technologies. On the one hand, climate change impacts may worsen the effects of some of this pollution and create mutually reinforcing stresses on the environment. On the other hand, climate change mitigation policies may also mitigate pollution and encourage China to move toward a greener economy.

Water Pollution. Industrial pollution of rivers and groundwater is a major problem in China, and climate change will make its effects worse. As climate change-induced water scarcity makes water a more precious resource, the need to keep China's water clean will increase. Flooding will bring large populations into contact with contaminated water. In addition, industrial water pollutants may enter the food chain as well as reduce soil fertility.

Air Quality and Aerosols. The special measures China had to take to improve air quality in Beijing for the 2008 Olympics highlight that China has per capita the world's worst polluted cities in terms of airborne particulates. It is a leading producer of pollutants such as carbon dioxide and sulfur dioxide which exacerbate climate change effects. The density of industrial aerosols will compound the effects of increased airborne dust produced by desertification and potential dust bowl eruptions. Urbanization intensified by climate change will put larger populations at risk from air pollution. Shifting rain and wind patterns may spread atmospheric pollutants over wider areas and contaminate already stressed ecosystems. Other countries in Asia, such as South Korea, have been able to make great strides in reducing air pollution, which China may be able to do as well. Paradoxically, some studies suggest airborne particulates may partially shield China from warming occurring at higher levels of the atmosphere. If so, reducing air pollution may intensify the predicted rise in air temperatures.

Public Health and Social Services. Climate change can be expected to place additional stress on China's already under-developed public health and social services systems. In the past 15 to 20 years, the availability of medical services, life expectancy, and the quality of natal care have increased. That said, China is still a roughly $3,000 per capita GDP society where social safety nets are a luxury. Panelists judged that as per capita GDP climbs to $15,000 per capita by 2030, coverage and cost of social safety nets will have improved significantly**.** However, progress to date has been unevenly distributed between rural and urban areas and remains inadequate in many regions across the country. Responsibility for social services has increasingly devolved from the central government to the regional or local level and Chinese citizens are required to pay an increasing share of the costs. Progress in expanding services has not kept pace with public expectations, creating a source of popular discontent. As a consequence of climate change, public health and social services systems will have to bear the burden of major influxes of population into some areas while in others local revenue bases, such as from agriculture, may dry up.

Demographic Challenges

Urbanization. Urbanization is one of the most important demographic trends in China right now. Rapid urban growth is creating a major strain on China's urban infrastructures, which will also be stressed by climate change. Such stress takes the form of urban expansion into rural areas, growth in size of cities and towns, and most significantly a major population shift from rural to urban areas. Urban areas might be faced with a mass influx of environmental refugees as a result of climate change. This movement might be too rapid for urban areas to absorb, particularly if refugees elect to stay in the cities permanently. One of the most critical issues is urban access to water. The water scarcity expected in northern China impacts the water needs of urban populations as much as it does those of agriculture or industry. Cities without water are a problem on an entirely different scale than crops without water, particularly if water availability declines rapidly or changes sporadically. The problem is compounded by the patterns of urban growth. Urban growth has been distributed throughout the more populated parts of the country as county seats expand into cities. Much of the expansion has therefore taken place in inland areas with inadequate water resources.

Urban expansion can follow a pattern like Tokyo—high density and high efficiency—or like Houston—a low efficiency sprawl. The way resources are priced has led China's cities to match the Houston model. Every square meter per person in housing increases the per capita amount of building materials. The average building in Beijing requires 70 kilograms of building materials per square meter. If China's urbanization follows a low density trajectory, it will therefore eat up a great deal more steel, cement, and other materials, which in turn will require more water and power usage to produce them. Such a pattern of urban growth will exacerbate climate change-induced stresses on resource availability.

Many of the people moving to the cities for work are younger Chinese. They have tended to send remittances back home, which helps to mitigate the problem of the labor force moving, while providing support to older relatives still on the farm. This is changing as rural transplants become more settled in urban life and ties to the rural areas become weaker. Combined with the aging population, this reduction in familial support places a greater burden on the state to provide for the elderly.

In addition, there is a deep rural-urban, socio-cultural divide in China, with urban populations tending to perceive rural migrants as backward and inferior. Urban residents and officials also tend to disregard the resource needs of rural areas, which is significant given the cultural and demographic shift of the Chinese Communist Party (CCP) toward urban members. Residents of Shanghai, for example, tend to see environmental and resource problems in Anhui as none of their concern. As climate change places urban and rural cultural groups in proximity and forces greater resource allocation to rural areas, social tensions and prejudices are likely to increase.

In addition to urbanization, China will face a number of other demographic challenges over the next two decades and beyond. Although the direct impacts of climate change on these phenomena may be minor, they will place additional stresses on China's resources and compete for resources that might otherwise be allocated to climate change.

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Aging of the Population. China's population control policies over the last several decades, notably the one child policy adopted in 1979, have skewed the country's demographics, resulting in a rapidly aging population. Over 400 million Chinese citizens of the so-called 'aging cohort' born before the one child policy are at or are soon to reach an age where they will no longer be economically productive. China lacks a state social security system or an adequate overall healthcare system to support them. China's Confucian ethics make it the filial responsibility of children to support their elderly parents and grandparents, but this traditional system of familial support has broken down. The growing mobility of the population and the trend toward urbanization have led younger Chinese to move away from their parents. In addition, the one child policy has led to the 'four-two-one problem:' a single worker will have to support two parents and four grandparents. The latter problem is a major roadblock to the adoption of a system like that in Singapore legally obligating children to be responsible for their parents. Whether the state institutes a social security system to take care of the elderly or the responsibility falls to their offspring, the demographic imbalance will produce a major transfer of resources from the working to the nonworking segments of the population. This could become a major problem on China's growth potential as it will need more resources to expend on elderly care and climate change-induced challenges. On the other hand, the increased need for healthcare and workers in social services to care for elderly may offer a new source of service employment.

Gender Imbalance. Due to Chinese cultural and economic preferences for male offspring, the one child policy also has resulted in a gender disparity in the population. There are significantly more male Chinese than female in the post-one child policy generations. This male-female imbalance will further restrict the potential size of future generations. In addition, it will leave large numbers of males without mates, generating a pool of unsettled manpower that could potentially be mobilized to threaten public order. These men are also a demographic likely to be disproportionately involved in climate change-induced shifts such as migrations and changes in employment patterns.

Economic and Industrial Challenges

Climate change almost certainly will have a significant impact on China's continued economic growth, but the magnitude of that effect is uncertain. China's economic resilience to climate change will be contingent on the manner and effectiveness of the country's responses both to climate change-induced challenges and structural transformation of its evolving economy. China has undergone several decades of rapid economic growth, and current projections indicate that China will be or will almost be the largest economy in the world by 2030. Although China's economic development model has produced spectacular economic growth, it has had a number of unfortunate by-products of which environmental damage has been a prominent one. Environmental constraints, either local or global, may nevertheless significantly hamper China from reaching its long-term growth targets. Climatic pressures increasingly will play into Chinese economic decisionmaking and may force or accelerate a change in China's economic behavior. Even absent climate change-induced impacts on the economy, export-led growth has reached a point of diminishing returns. China needs to transition away from its investment-driven export-led economic model to one driven more by domestic consumption and services. In addition, panelists judged China will need to master a series of new technologies, including information technology and nanotechnology if it is to continue their economic success to 2030 and beyond. This change in China's growth model could produce more political contention and strife, with adverse consequences for the environment.

Energy Challenges. China already faces drastic near-term rises in energy demand as its economy, industrial base, and standard of living expand. The country has transitioned from two decades of energy demand rising slower than economic growth to the past seven years of energy demand exceeding economic growth. China's economic growth has become increasingly energy intensive as heavy industry plays a leading role in the economy. The dynamic of increasing energy demand is likely to accelerate over the next two decades, exacerbated by increased climate change-induced urbanization and infrastructure demands. As a result, China will have little room to maneuver in terms of limiting energy production for the sake of climate change mitigation.

China has little option but to address energy demand primarily through domestically produced coal and imported oil, which will lead to a severe rise in China's contribution to global greenhouse gas emissions. In addition, if China's economy continues to grow in an energy-intensive manner, it will produce an unsustainable strain on global energy resources. Energy-intensive development also generates suboptimal employment growth. For example, the five most profitable industries in China use half of its energy and produce half of its carbon dioxide but only employ 14 million people. China will therefore face increasing pressure from economic and social as well as climate change standpoints to transition to a less energy-intensive, service-oriented economic model. In addition, there is substantial room to increase the efficiency of China's industrial plant, which is largely old and energy-intensive.

Employment Challenges. Climate change is likely to significantly exacerbate the challenge of creating jobs for China's workforce. China's labor market is in the midst of a multi-stage transition from agriculture to light export-oriented industry to heavy industry to services and domestic consumer products. This complex process dictates that a large proportion of workers are in flux between jobs or between economic sectors.

The types of jobs and skills that are in demand are evolving. Simply being an able-bodied worker will no longer guarantee someone a job. Although in part employment has shifted toward skilled industrial labor, a large part of the shift has been toward new areas of semi-skilled and unskilled employment such as services and construction. The service sector is a ripe area for job creation that can be expected to boom as standards of living increase. Although the service sector requires a new and unfamiliar skill set to rural migrant laborers, the rest can be learned through on-the-job training provided that workers have basic literacy. Compulsory education is expanding to rural areas, providing a foundation that will make it easier for those leaving the countryside to find work. In the medium-term there also will be almost unlimited job opportunities in the construction industry, although many workers regard construction work as too hard. Not only is the economy expanding, and with it a need for more structures of all sorts, but older, poorly made structures are deteriorating and need to be replaced.

In the past the Chinese industrial sector could rapidly take in large numbers of unskilled workers for tasks that do not require a high degree of training. This capacity has declined as growth in the low-skilled labor-intensive export sector has slowed, leading China's labor market to under perform over the past five years. Some of the shortfall in unskilled employment will be offset as rising standards of living expand domestic demand for consumer goods, allowing light export industries to re-orient to serve the domestic market. Climatic stresses will likely prompt the expansion in areas such as healthcare and social services, providing employment in those sectors. The state focus on climate change and environmental initiatives also could bring "green" jobs into the economy in significant numbers.

China's high rate of growth in the last three decades has kept employment levels high even as the nature of the labor market has changed rapidly. Official unemployment estimates tend to hover in the 4.0-4.5 percent range, although actual unemployment may be closer to 9.5 percent. Assuming the continuation of current trends, China's economy would likely be able to continue to accommodate the shifting pool of labor. That may not be the case when the effects of climate change are factored in. Climate change pressures will increase internal migration and disrupt traditional modes of employment, particularly in rural areas. This will significantly intensify the large influx of unskilled rural labor into the urban and industrial labor markets driven mostly by desperation rather than employment opportunities. As a result, major discontinuities could occur between demand for jobs and demand for labor, which could drive China's unemployment rate much higher and generate severe socio-economic tensions.

Political Challenges

Climate change is likely to exacerbate the major political dilemmas that China will face over the next two decades. The world currently sees China becoming more successful under authoritarian rule than some democracies. As China struggles to respond to climate change-induced challenges, the flaws in China's political system probably will become increasingly apparent to China's population, the government itself, and the world at large. In the longer term, China's party-state regime faces a need to increase its responsiveness and accountability to the public or risk losing its already questionable legitimacy. Increased public responsiveness need not imply democratization. The idea of "consent of the governed" resonates more with Chinese citizens than the word "democracy." The Chinese do not demand the form and structure of a democracy to ensure that the government operates with their consent. Democratic elections are one way to give the public influence over public policy, but are not always an effective mechanism in the face of entrenched elite interests. Elections provide a safety valve for public dissatisfaction that is not available in an authoritarian system, but there may be other ways for citizens to vent stresses that may be exacerbated by climate change.

Panelists observed that according to the published government statements, the Chinese government has no intention of allowing broad-based democratization to replace its monopoly on power. Nevertheless, the government recognizes that some form of governance reform and greater public say will be necessary to avoid a crisis of legitimacy in the longer term. The precise form it will take remains unclear. Through the Institute of Policy Studies at the Chinese Academy of Social Science, the regime is seeking to determine whether a government can receive the benefits of democracy without becoming a democracy. For example, can the government receive citizen feedback without accountability if it does not comply or respond to the wishes of its citizens? The Chinese Government wants citizens to provide input and vent their frustrations but wants to retain a monopoly on policy decisionmaking. For example, NGOs or the Internet could provide alternative channels to receive feedback without direct accountability or elections. On the other hand, strengthening such mechanisms could create other challenges to the regime. China's senior leadership has conducted seminars in which civil experts are allowed to lecture without interruption, allowing greater freedom to express unorthodox views. There also have been experiments with limited democratic elections of junior party-state officials at the local level and in rural areas.

The debate within the leadership concerns the pace and scope of political reforms. The added challenges of climate change will strengthen the political hand of those in China and especially within the Chinese Communist Party. Arguably, too rapid movement in the direction of

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democratic reform and economic liberalization would jeopardize the stability and rapid decisionmaking capabilities that Chinese officials believe are at the heart of effective climate-change adaptation. Climate change-induced pressures could therefore considerably delay government-driven political reform in China, particularly if challenges prove intractable or long-lasting.

On the other hand, climate change will most likely significantly increase political instability, as well as provide disaffected groups with a ready-made set of issues around which to mobilize. Climate change may therefore raise the prospects of a political challenge from below. Chinese political history is punctuated by often violent instability in the face of hardships when there is a sense that a fundamental social contract between state and society has been violated. The repressive capabilities of the Chinese state are considerable, and the prospects of a violent overthrow of the regime as a result of climate change are very remote. In addition, significant political change in China is unlikely in the absence of any credible political organization being offered as an alternative to the CCP. Nevertheless, a "populist revolt" could bring about a relatively peaceful political transition to post-communist rule by 2030 or beyond. Despite temporary disturbances at the time, the removal of the monopoly party-state's limits on private enterprise and throttlehold on civil society would likely enhance state capacity to cooperate with business, civic organizations, and international entities to address climate change challenges.

Civil and Key Interest Group Responses

State Corporatism

Although China has come a long way from the totalitarianism of the Mao era, the presence and influence of the party-state apparatus remains pervasive. Nevertheless, the groups and institutions that comprise civil society in more open political systems are relatively abundant and well-organized. The vast majority exist under the auspices and supervision of the state rather than as autonomous actors, however. The party-state assigns officials and social leaders to run state monopoly associations for sensitive social groups such as industrial labor, villagers, women, youth, non-party professionals in various fields, business executives, and ethnic and religious groups. Prominent examples include the Communist Youth League, All-China Federation of Trade Unions, and All-China Women's Federation. In addition, government ministries, state-owned enterprises, and sectoral bureaucracies have their own social institutions, including schools, hospitals, research centers, and museums. The bulk of civil society in China is therefore not strictly distinct from the state. It comprises what can be termed a "quasi-state," with varying degrees of practical autonomy and influence but with groups ultimately responsible to the party-state. This system of "state-managed civil society" is known as state corporatism.

The socio-political space allowed for autonomous civil society is small and tightly bounded. Even most civil groups that did not originate within the state or party systems forge strong links with the party-state at various levels to act effectively and escape official persecution. Those that do not do so find themselves marginalized or even outlawed. The party-state regards independent civil actors with deep suspicion, even when they provide services the regime finds useful. The regime fears that legitimating societal mobilization could be the beginning of the end for the monopoly of unaccountable power held by the CCP, the maintenance of which is the regime's number one priority. Issue advocacy and even criticism of particular officials or policies may nonetheless be tolerated, as long as it is limited in scope and does not call into question the broader legitimacy or actions of the party-state system.

There are some advantages to the state corporatist system, including the ability to quickly raise public awareness of issues. The party-state has ready access to broad-based and compliant civil organizations that can be used to disseminate the state's agenda on climate change and other issues to the public. Examples include the campaigns to publicize the White Papers of Agenda 21 on sustainable development in 1994 and on climate change policies and actions in 2008. In addition, although the civil actors that make up China's quasi-state are inhibited from most forms of autonomous advocacy, their links to the state provide an alternative avenue through which to exert influence on state decisionmaking, particularly at the local level. The basic system of monopolies is nevertheless under pressure from the reality of an increasingly pluralistic society.

Social Resilience

The financial, human, and environmental resources that China's society can bring to bear will, to a significant extent, affect the management of the consequences of climate change. A robust civil society committed to reversing the causes and addressing the effects of climate change may be crucial for success. Chinese environmental history is filled with instances of severe environmental challenges and responses from both state and society. This history shows a remarkable capacity in China for responding to environmental challenges, which the public response to the May 2008 earthquake in Sichuan demonstrated. The public at large, as well as previously marginalized NGOs and civil groups, stepped up to participate in the relief. The earthquake may prove to be a turning point for public awareness of China's environmental challenges.

China's history also reveals weaknesses in environmental stewardship resulting from bureaucratic corruption, aversion to risk, and self-gratifying social behavior. However, the greatest hindrances to an effective civil response to climate change-induced challenges are the limitations on autonomous societal action by the CCP-dominated state regime. The state may well preclude civil society from effectively responding to climate change.

Overall Social Responses

Migration. China can expect a number of cross-cutting broad-based civil responses to the kinds of pressures and challenges climate change will bring. Mass migration is probably the most daunting of these. Internal migration for economic reasons already represents one of the principal challenges to China's economy and social stability. It has primarily taken the form of rural migration into urban areas, but also of migration of laborers between urban areas. The combination of water scarcity, desertification, possible dust bowls, and shifting agricultural patterns appears likely to generate a massive migration from China's northern and western margins into the heartlands of the east and south. This will pose important resettlement challenges for national and local governments in China. The most likely destination areas already have very high population densities, both rural and urban. Although the broad pattern of population movement can be predicted, specific climatic crises may generate large-scale, rapid migration of refugees, the sources and destinations of which are not easily predictable. Such rapid migration could pose the most serious challenge to China's stability.

Anti-Government Protests. Despite state repression, protests are a growing phenomenon in China. If more extreme climate events occur, tensions between civil society and the government might increase. The environment has been a rallying point for civil advocacy and protest, and perceived government failures to adequately respond to the impacts of climate change will most likely generate wide-scale public responses or demonstrations. In the wake of the Sichuan earthquake parents of the children killed in the quake went to court to prosecute the officials who built the shoddy schools and lined their pockets with the leftover money. China's courts and other administrative infrastructure are not designed to accommodate public grievances directed at the state but may face such issues more frequently in the future.

The obvious natural causes of many localized climate change-induced events such as floods or droughts may blunt the political anger that might otherwise be directed at the government, as long as the government is seen as responding adequately to disaster conditions and has shown preparedness for such events. On the other hand, protests may move from mild, non-violent advocacy to rioting and even uprisings if the public perceives that climate-change-related policies are unfair or ineffective. If emergency assistance is inadequate, social unrest and attacks on local governments and the CCP will surely erupt. Charges of corruption, in the form of embezzlement of funds initially targeted for climate change mitigation, also will be a rallying cry for protesters. The Chinese Government has considerable experience in responding to protests, but the state tendency to respond with arrests and repression to public criticism of the government may escalate matters as groups increasingly feel that their legitimate grievances are being suppressed.

Philanthropy. Based on it responsiveness to other crises, China's population probably will respond to greater stresses and more frequent natural disasters with increases in charitable giving. The Sichuan earthquake was a recent example of the Chinese willingness to donate and volunteer through private as well as state channels. Philanthropy in China is pervasive. For example, instead of waiting for government response, Chinese citizens filled their cars with supplies and headed to the site. Charitable giving on an individual basis is not regarded as threatening by the party-state as such activities by organized NGOs. Although such individuals cannot influence processes at the national level, over time they will gain the ability to influence processes of local government.

Socio-Economic Interest Groups

Rural Society & Rural Interests. Rural interests will be among those hardest hit by climate change-induced challenges. Farmers, herders, and village-dwellers are already under stress from socio-economic shifts that threaten the rural way of life. Over the next 20 years they will face both more frequent and more severe climate-related crises as well as sustained climatic shifts that will force them to adapt or relocate.

The primary interface between China's rural population and the state is at the level of village governance. Rural interests are not well represented at higher levels of government. Unlike under Mao, China's current rulers have a distinctly urban focus. On the one hand, this limits the advocacy potential of rural interest groups. On the other hand, the central government is willing to allow greater freedom of action in forming local associations and even sanctioned experiments in local democratization in rural areas. The demands of responding to climate change-induced challenges will necessitate much greater attention to rural areas by the state. Although this will bring an increase in resource allocation to rural issues, it also will bring greater scrutiny and likely a reduction in state tolerance for rural political experimentation.

The overall response of farmers and herders to climate change will depend to a large extent on what mitigation policies the state puts in place. The large size of the rural population and the endemic corruption, incompetence, and resource deficiencies of the government at the village and township level will hamper the pace and effectiveness of mitigation policy implementation.

Unless the state is able to adopt proactive mitigation policies and successfully implement them, local farmers and herders will by default be the first responders to rural climatic stresses.

Although many projections of climate change impacts on agriculture assume negligible adaptation by farmers, substantial technical evolution and innovation is occurring in China's farming households. The state corporatist system is effective at rapidly raising public issue awareness. If information about climate change is widely disseminated, farmers are likely to take proactive mitigation measures. The nature and effectiveness of such measures and their impact on agricultural productivity cannot be accurately predicted. In addition, state interests in maintaining high levels of production of cheap grain for the cities and military may conflict with farmers' interests in switching to more viable crops. In such cases, the state is likely to veto optimal agricultural responses to climate change.

Although some farmers may develop effective adaptations to climate change, others may respond to local agricultural stress by turning to unsustainable practices or competing, possibly violently, for resources with their neighbors. The role of the state and possibly NGOs in disseminating best practices for agricultural adaptation will be a crucial factor in mitigating such problems.

The predominant rural reaction to climatic stress is likely to be increased migration, both into urban areas and into more productive rural areas. Rural households will likely accelerate outmigration and consolidate farms in drought-prone regions. Inter-rural migration is likely to result in a more concentrated rural population with increased resource competition and rural conflict. This concentration of human pressure will likely affect the spread of climate change-induced challenges even into areas that suffer less direct climatic stress. In addition, as younger members of rural populations migrate to urban centers of modern employment, those left behind will be less able to cope with agricultural stresses.

Herding populations in China tend to occupy marginal land such as the steppe surrounding the Gobi Desert that will be especially at risk from climate change impacts. Animal husbandry practitioners will have greater incentives to adopt mitigation measures as standards for responsible rangeland management appear more affordable. Herding populations are even more likely than farmers to respond to climate change through migration. This will reduce the number of ruminant animals on marginal land, but increase their concentration in better-resourced areas, increasing the possibility of violence between farmers and herders. The possibility for conflict is intensified by the fact that many herders belong to ethnic minorities such as Mongolians while farmers are more likely to be Han.

Urban Interests and the Middle Class. Although China's per capita GDP remains far below levels in most developed countries, economic growth has nevertheless produced a sizable and growing middle class. Particularly in the wealthy coastal cities such as Shanghai, the standard of living of the urban middle class affords access to lifestyle luxuries rather than just necessities. This also results in dietary changes which include a demand for more meat. As is the case in many developed countries, the desire to live in a cleaner, more sustainable environment is one of the ways in which this lifestyle freedom manifests itself. China's urban middle class will likely follow the same pattern previously seen in developing Japan and South Korea, where economic growth brings the willingness and money to pay for cleaner energy and a cleaner environment. As climate change-induced challenges become increasingly prominent, the middle class may become an important source of resources to bolster China's responses and mitigation measures.

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China's cities have become complex conglomerations of established urban families, formerly rural families who have settled in the cities, and migrant laborers who move from city to city seeking jobs. This mixture can be volatile, placing stress on employment and the rural-urban cultural divide. On the other hand, more urban residents originate from rural families than from urban families and this will only increase due to climate change. Over time this shift should help mitigate rural-urban cultural incompatibilities as rural people acclimate themselves to urban living and a hybrid urban culture develops. The timing of such a cultural reconciliation relative to when the cities will be hit by severe climatic challenges will play a large part in determining the level of urban instability and cultural conflict China will face.

Urban inhabitants are less likely to respond to climate change with migration than people living in the rural areas. There is no economic or climatic incentive for urban dwellers to move to rural areas. Without an option to displace urban stresses through migration, cities are likely to experience greater levels of socio-economic conflict, rioting, crime, and anti-government protests.

Business & Industrial Interests. China's economic development has created a large and rapidly expanding set of private and semi-private business interests, spread across many sectors including the energy industry, heavy industry, high technology, environmental goods and services, service sector industries, and others. The emergence of distinct interest group identities within the private sector has been slow, and those identities in many cases remain latent. The challenges and possibly new opportunities generated by climate change may sharpen conflicts among different economic interests and facilitate cooperation between those facing similar issues. This is already accelerating the mobilization of latent identities into full-fledged commercial and industrial interest groups.

As with other civil groups, business is closely tied to the state. Businesses are not independent entities that lobby the government, but their ability to influence state policy is nevertheless considerable. State-business ties operate on two primary tracks. Industries are overseen by state officials and ministries responsible for their sector of the economy. This ensures industries have a constituency within the government and receive allocation of state resources and planning attention. In many cases the same leaders act as sectoral officials and commercial executives. In addition, there is a well-established patronage system through which businesses cultivate personal ties with state officials. Family members of power-holders pervade the world of business. Unofficial networks of well-connected families are de facto a very powerful set of lobbies that have had a major influence on state policy in areas relevant to climate change.

The influence of business and industrial interests—both official and unofficial—has so far worked against effective state responses to climate change-induced challenges. Commercial interests lead the effort to make money no matter the environmental impact. Entrenched quasi-state groups that control the most polluting heavy industries have colluded with leading families tied to the energy industry to forestall environmental regulation and ensure China continues to build polluting power plants. When government reformers tried to create an 'energy czar' so that China could manage both its energy needs and its environmental imperatives, such groups undermined the effort. Even state-owned enterprises such as China National Petroleum Company (CNPC) have learned to manipulate the state for their own profit. Similarly, networks enriched by the energy industry have blocked state efforts to reduce China's National Oil Enterprises' ties to the Government of Sudan, even though China receives little of the oil produced and much international criticism. In addition, access to foreign funding increasingly has allowed private businesses to take autonomous positions vis-à-vis the state. The capacity of China's state apparatus to effectively respond to climate change may be significantly hampered by profit-seeking business and industrial groups.

Ethnic Minorities

Ethnic minorities make up only about eight percent of China's population, which represents in excess of 100 million people with nine groups comprising over five million members.[5] In many cases, such as with Islam or Tibetan Buddhism, religious divisions occur along ethnic lines. Ethnic minorities are concentrated mainly on China's periphery, many in areas that will face serious climatic challenges such as water scarcity, flooding, and desertification. Particularly acute climatic stress on regions where minorities are concentrated may be translated into ethnic unrest if the state is slow to respond or the Han majority is seen as receiving disproportionate assistance. In addition, minorities may increasingly migrate into traditionally Han-dominated areas, raising the potential for ethnic strife. The most sensitive issues are likely to involve groups already in conflict with the central government, notably China's Tibetan and Uighur populations.

Xinjiang and the Uighur: Numbering over eight million, the Uighur are a Muslim Turkic people residing in Xinjiang in China's arid west. The Uighur are closely related to populations in the former Soviet Central Asian countries and historically regard Xinjiang as "East Turkestan" rather than western China. They have carried out a protracted ethnic and religious-based separatist campaign, including acts of terrorist violence. The conflict has been worsened by China's "Develop the West" policy encouraging migration of Han Chinese into Xinjiang. Xinjiang is mainly desert, with water, grazing land, and population concentrated in only a few areas. Han-sponsored development efforts have already put considerable stresses on water and other resources, and climate change-induced water scarcity and desertification could intensify violent Han-Uighur conflict and lead to a regional crisis if not effectively addressed.

Tibet and the Tibetans. Over five million Tibetans reside in Tibet and neighboring provinces such as Qinghai and Sichuan. Despite the high-profile international campaign for Tibetan independence, the Chinese Government has made progress in forcibly assimilating Tibetans by emphasizing economic and technical development while suppressing traditional cultural and religious practices. As in Xinjiang, large numbers of Han Chinese also have been encouraged to migrate into Tibet, reducing native Tibetans to an underclass. Those Tibetans clinging to traditional ways of life in rural areas will suffer disproportionately from the environmental impacts of climate change on Tibet as well as from ongoing economic development and resource exploitation. This will likely lead to accelerated assimilation as more Tibetans are forced into urban living and dependency on state largess as well as increased Tibetan-Han tensions.

Religious Groups

Religious groups have a growing presence in Chinese society after years of suppression and enforced marginal status. For the majority of China's population, scientific atheism remains an unstated orthodoxy supported by the state. This orthodoxy is nevertheless tinged with quasi-religious Chinese cultural practices incorporating elements of Taoism, Buddhism, and Confucian philosophy. More explicit forms of folk religion are quietly making a comeback along with adherence to non-indigenous religions such as Christianity. With the prominent exception of Tibetan Buddhism, the Chinese Government tends to be more tolerant of religious practices

[5] The Zhuang, Manchu, Hui, Miao, Uighur, Tujia, Yi, Mongolians, and Tibetans.

among ethnic minorities, whose religion is seen as part of their culture. In contrast, the party-state has tended to view Christianity as particularly threatening because it is not primarily confined to marginal minorities, as is the case with Islam. The officially sanctioned Protestant association has 20 million members, but there are also a large number of underground or unregistered churches.

Religious groups still suffer broad official discrimination but local governments, with less central support and increasing responsibilities, are tapping into traditional religious interest groups for humanitarian work in providing social services such as education and disaster relief. For example, unregistered Protestant Christian churches and nonprofits, both domestic and international, were among the first and most effective responders to the May 2008 earthquake in Sichuan. Central authorities banned media coverage of their contributions, but local authorities have gained a new appreciation for what they can offer. In addition, religious leaders have increasingly taken on community leadership roles, whether in the village or urban neighborhoods. Religious groups and religious-based nonprofits have the potential to become an important social support structure and response mechanism to climate change-induced challenges. The extent to which the party-state will allow them to assume such a role remains to be seen, given that they could also become focal points for organized dissatisfaction with the regime and its policies.

Nongovernmental Organizations

As China's socio-economic system has become increasingly pluralistic, there has been a tremendous proliferation of civil non-profits. Domestic and international non-governmental organizations involved in charity, poverty alleviation and development, and environmental protection have been prime beneficiaries of state permissiveness since the mid-1990s. Boundaries on NGO activities will likely continue to loosen in the future. NGOs are in many cases better suited than the state to address climate change-induced challenges at the grassroots level. They might therefore end up institutional "winners" as a consequence of the climate changes that are hypothesized over the next twenty years. As with other civil actors, the extent to which NGOs will develop into effective institutions depends on what the state permits them to do. This in turn will depend on the policy "frames" that they adopt. NGOs will need to frame and publicize their issues in terms that generate policy legitimacy and governmental allies. One such avenue, used successfully on tobacco legislation, is to partner with members of the National People's Congress, which can publicly demand and disseminate issue reports from responsible agencies of the central government. In any case, the institutional constraints faced by NGOs will ensure that the majority have little influence on opinion or policy. The minority who have influence may profoundly impact how China is able to deal with climate change.

Government-Organized NGOs. State corporatism, unlike socialism, does not require that the state be the sole purveyor of civic organization. Nonstate groups are tolerated as long as they are ultimately subject to state oversight and authority. In order to facilitate this, Government Organized NGOs (GONGOs) are an integral feature of the state corporatist system. Created and organized under state auspices, GONGOs are often set up as officially sanctioned monopolists of civic activity in particular sectors. In both intent and practice, GONGOs often crowd out the development of independent NGOs. GONGOs are the only domestic NGOs allowed to operate at the national level, but their activities are strictly limited to their functional identity. GONGOs responsible to the Ministry of Civil Affairs, for example, are to contribute to poverty relief rather than addressing climate change.

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China's GONGOs vary widely in their degrees of practical autonomy and legitimacy. Some GONGOs, such as the China Charities Federation or China Christian Council, are sham associations run by elderly retired bureaucrats or by loyal party members or followers. These sorts of GONGOs are largely discredited in the eyes of their involuntary constituencies and their attempts to promote disaster relief or environmental protection are viewed with skepticism. Other GONGOs have made efforts to improve their accountability, autonomy, management practices, staff structure and training, and organizational culture, often to obtain foreign funding and support as state funding is cut. Examples include CAST, the official association for science and technology professionals headed by Deng Xiaoping's daughter, Deng Nan, as well as the China Youth Development Foundation, headed by Hu Jintao associates from the Communist Youth League.

GONGOs are likely to become a primary vehicle through which the party-state disseminates and promotes climate change-related policies. GONGOs can be used to mobilize social responses and resources in a way that is controlled and not threatening to the authority of the party-state. To perform a large-scale mobilization role effectively, however, GONGOs will have to boost their public credibility, legitimacy, and flexibility in defining their missions more broadly. Such reforms are likely to increase their de facto autonomy and result in a convergence between GONGOs and independent domestic and international NGOs.

State Limitations on NGOs. Domestic NGOs operating outside the GONGO realm are constrained due to regime paranoia that they will become competitors to the party-state. Even at the local level the party-state is more concerned with the potential threat from NGOs than the ability of NGOs to solve issues. The state therefore raises major bureaucratic obstacles to NGO development and activities, which NGOs have devised ways to circumvent.

NGOs are required to register with the state, but the state makes it difficult to do so. In addition, NGOs—with the exception of the Red Cross—are banned from raising funds domestically. NGOs are often established through family money, but as their size increases they rely on foreign funding. In contrast, the growth of private enterprise is encouraged. As a result, NGOs often register as businesses to avoid bureaucratic red tape, which consequently obscures the actual number of NGOs operating in China.

The scope and scale of NGOs are strictly limited. The state discourages them from addressing multiple issue areas and they are prohibited from cooperating with each other. The government prohibits national NGOs except a handful of GONGOs and limits NGOs from growing too large or crossing administrative boundaries. NGOs have in some limited cases responded to official constraints on scale by proliferating downward—splitting off local and provincial-level branches from larger GONGOs.

NGOs are vulnerable to shifts in government tolerance. Protest, even of violations of the government's own rules, may lead to repression and/or imprisonment by the Chinese Government. NGOs that become too successful may find their employees arrested or disappear. NGOs have the best chance of surviving this precarious situation if they are fully transparent to the state. Their most important points of contact in the local government may be the secret police whom the NGO cultivates and keeps fully informed.

Large-scale challenges such as climate change or the global economic downturn highlight the Chinese state's need for the input of private resources to address them. The state was forced to allow unprecedented private involvement in the massive relief and rebuilding following the 2008

Sichuan earthquake. NGOs might also be used to address other policy goals, such as providing a low-risk venue for citizen feedback to the government. As a result, a renewed attempt to provide a regulatory framework and policy environment conducive to growing rather than restraining the nonprofit sector is likely.

Environmental NGOs. NGOs may have greater opportunities to play a constructive role in meeting climatic challenges than the daunting state-imposed limitations would suggest. The Chinese Government has been particularly tolerant of NGO activity on environmental issues. The government is well aware that the country needs the help of environmentalists, domestic and international, to control and limit the causes of climate change. The government, particularly the Environmental Protection Agency, has therefore been willing to encourage and ally with at least some independent environmental NGOs. Recognizing that local corruption and inefficiency often hamper environmental protection, the state has used NGOs as a mechanism for improving policy implementation.

Because of this permissive state attitude, NGOs are perhaps more effective in environmental protection than in any other area. At the local level, social and ecological movements have been allowed to protest and even achieve reversals of state policy on issues such as dam construction, at least temporarily. The NGOs nevertheless find it difficult to influence policy, having to work through official agencies whose primary interest is to "control" rather than "listen" to them. Exceptions often require special connections or status. For example, the sponsor of the first major private Chinese NGO study of the environment, *The China Environment Yearbook* of 2005, is both the founder of Friends of Nature and also a member of a famous family.

Environmental NGOs are likely to become more visible and vocal as climate change issues become more prominent. The global and domestic environmental movements are mutually influential and involvement of China's younger generations at home and abroad will be increasingly significant. Official tolerance will be contingent on environmental advocacy remaining strictly limited in scope and avoiding broad criticisms of the party-state. In addition, given the Chinese Government's aversion to pluralistic solutions, it may seek to develop new models of environmental protection that do not rely on environmental NGOs, even if this reduces effectiveness in dealing with climate change.

International NGOs. The Chinese Government views foreign NGOs with suspicion even though it recognizes their useful contributions to addressing many socio-economic and environmental issues. Paranoia that the United States and other foreign governments are using NGO infiltration to promote regime change in China was heightened by the role played by political advocacy NGOs in the eastern European 'Color Revolutions' of 2004-05. The 'Color Revolutions' led the government to impose a freeze on development of the non-profit sector that has eased recently as security concerns have abated. International NGOs (INGOs) nevertheless exert a significant influence on the mindset and practices of both officials and domestic NGOs in China, particularly at the local level. INGOs operating in China are expanding their employment and training activities. For example, Clear World Energy Inc., established in 2003 and headed by a Swedish national, invests in clean energy and climate change-related businesses and nonprofit social enterprises in China and elsewhere.

As China faces growing large-scale challenges from climate change, INGOs are a channel through which international funding, resources, and expertise can flow into the country to boost both state and social capacity. As their importance as environmental and social actors increases,

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the party-state will most likely seek to develop institutional mechanisms to exert control and oversight over INGO activity in China. It is unclear how effective this will be, particularly as a need for climate change-related expertise and resources increases. In addition, INGO partnerships with domestic Chinese NGOs are likely to boost their effectiveness and profile, as well as making the INGOs advocates for domestic NGOs vis-à-vis the party-state.

Another important international factor is the increasing flow of international philanthropic funding into China. In order to avoid funds being diverted to corrupt local officials or to state priorities, international donors such as transnational corporations operating in China prefer to fund NGOs rather than state entities. Corporate and EU donors have been especially interested in funding NGOs who conduct green projects. This new source of funds has enhanced the resources and autonomy of many of China's NGOs, even some GONGOs. Groups raising funds overseas must choose between appeasing the local government which allows them to operate and responding to the international donors. NGOs are increasingly moving toward pleasing their funding sources to keep their cash flow steady. This practice also has increased demands for accountability and adherence to international NGO standards. This has led to the phenomenon of "NGO Incubators," organizations that facilitate the development of legitimate NGOs and connect them with international donors.

State Response

Party-State Leadership

The 200 senior officials with executive responsibility at the central and provincial levels will be responsible for the bulk of the critical decisionmaking on climate change. The senior leadership includes leaders assigned oversight of core functions such as media and education, state personnel, intelligence and security, military, and economic and foreign affairs. The senior leadership is not a static group. In the post-Mao era, China's leadership has developed a system of pre-planned generational turnover of its leaders. The most recent such turnover was in 2002, when the "Fourth Generation" of CCP leaders under Hu Jintao succeeded to power. Each successive administration brings with it a revised policy agenda, although there has so far been a great deal of overall continuity. As climate change impacts become more severe, climate change mitigation can be expected to remain important on the leadership agenda. The administrative burden on senior leadership is considerable. There is also tension between focusing on pressing problems and planning for the long term. If major competing priorities such as a sustained economic downturn arise, attention to climate change mitigation may become more rhetorical than practical.

The leadership policymaking process is not transparent, but internal leadership politics are likely to be less harmonious than they are represented. There are bureaucratic tugs of war over issues such as central versus provincial interests and environmental protection versus poverty alleviation. Leadership cliques and patronage networks advocate for their particular interests and policy preferences. The leaders of the major bureaucratic interests push their own agendas, often at each other's expense. The perennial division between leadership reformers and hardliners is likely to play into climate change mitigation policymaking. Climate change remains a fairly new issue on the national agenda, one that the leadership is not accustomed to dealing with. Climate change mitigation may require the inclusion of a broader selection of actors than the leadership is used to including in its decisionmaking, including nonstate groups. In addition, addressing climate change will require major policy initiatives and reforms, which in turn will require the hardliners within the leadership to be appeased. In the past, hardliners have threatened to block major reforms unless they are accompanied by crackdowns in other areas. Hardline measures may be the cost of doing business for leaders pushing tradeoffs or concessions associated with climate change mitigation. This raises the concern that major domestic climate change reforms might bring with them harsh measures directed against either domestic groups or internationally.

Although the transfer of power between different leadership generations and administrations has managed smoothly for the most part, inter-generational conflicts remain an issue. The mindset of older technocrats is affected by the legacy of the hierarchical system of vertical control. Younger, better educated, better trained officials are now coming into the upper echelons of leadership, including from the quasi-private sector. They are more willing to test the limits of the system and more receptive to innovation, whether it originates inside or outside the state. This raises the question of how the Chinese leadership's approach to problems of risk and uncertainty—risk culture, risk perception, risk management—is evolving. Climate change questions involve areas of uncertainty, the assessment of which involves risks—their estimation and acceptability and the distribution of the costs and benefits of accepting risks. Chinese leaders and citizens have traditionally been risk averse, particularly the current Hu Jintao administration. Effective climate change mitigation measures may nevertheless require successor administrations over the next several decades to take substantial risks impacting critical areas such as agricultural production, water management, and industrial development. Risk-averse leaders may find themselves paralyzed, which could delay or derail an effective state response.

The People's Liberation Army. In addition to the civilian leadership, the People's Liberation Army (PLA) has a major role in setting the policy agenda, although it is increasingly less influential as the focus of the leadership has shifted to the economy. Nevertheless, the PLA receives a major share of the state's resources and can be expected to resist diverting attention to climate change mitigation. On the other hand, the PLA has a major role in responding to natural disasters such as floods, storms, or earthquakes. The PLA has cultivated a popular role as the savior of the Chinese people and will be eager to take the lead in responding to climatic disasters. The PLA also is becoming more interested in developing capabilities to respond to overseas humanitarian contingencies, which may be increasingly climate-related. Climate change has the potential to become a major new mission area for the PLA, which could become a constituency advocating for more resources for climate change response. This brings a risk because it would distort resource allocation to aspects of climate change mitigation with greater PLA involvement, which could produce a less than optimal response overall.

Regime Security. The most fundamental priority of the small policy elite who run the Chinese party-state apparatus is the maintenance of the integrity of the regime and its continued monopoly on power. They accomplish this through a combination of many means including effective repression and co-optation or prevention of the development of potential competing political groups. They have so far been able to maintain a degree of popular legitimacy even without accountability or democracy, mainly by maintaining high rates of growth supplemented by appeals to popular nationalism. Their most important credential may be their demonstrated competence in dealing with challenges and delivering results to the people. Climate change-induced challenges may put significant strain on their ability to continue to deliver satisfactory solutions. This could prompt greater resort to repressive measures to maintain CCP rule.

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Regime security concerns will also likely hinder moves toward legitimating societal mobilization to help address climate change.

Development and Economic Growth. Continued economic development and sustained high rates of growth are a key priority for the party-state. Since the economic reform era began in 1978, the ability to facilitate continued economic growth has become the principal credential legitimizing the regime's unaccountable monopoly on power. Development is seen as a basic right that cannot be infringed upon. At the same time, previous development patterns in the region, such as in Japan or South Korea, demonstrate that the rate of growth eventually reaches a plateau as the economy nears developed parameters. The rate of economic growth in China is already decelerating, raising regime concerns about arresting any further decline. Reductions in growth could have profound political implications because much of the regime's popular legitimacy depends on continued high growth rates. On the one hand, climate change-induced challenges will likely place growth in jeopardy, increasing the regime's incentive to deal with such challenges effectively. On the other hand, certain types of mitigation measures, such as curbs on industrial energy use, as well as reallocation of resources to address climatic impacts, also could threaten China's ability to grow.

Despite the emphasis on growth, China's leaders realize that unrestrained growth cannot continue without attention to other development objectives such as education, the environment, promoting innovation, reducing inequality, and promoting a harmonious society. China's current five-year plan for 2006-2010 set forth new goals to address climate change as part of a shift in development strategy from rapid growth to sustainable growth. This shift had been foreshadowed by the adoption of a concept of "Scientific Development." Scientific Development is China's conceptualization of many of the elements associated with international models of sustainable growth. While it is admirable in theory, few in the government fully understand what the term means and inculcating it into the state bureaucracy has proven difficult. Moreover, the current economic slowdown has made achieving the restructuring goals of the current five-year plan unlikely. The draft under way for the next five-year plan, which probably had impressive climate change goals, probably is undergoing significant reworking.

Internal Stability. The concern of China's leaders with internal stability is a subsidiary expression of their overriding priority of regime security. Of all the top-tier state priorities, internal stability is likely to suffer the most direct challenge as a result of climate change. Given the projected scope and secondary effects of climate change, China will face significant political instability. Although this may create incentives for greater resource allocation to climate change mitigation, there are also many other projects where funds can be used to shore up state stability. The regime risks treating the symptoms—socio-economic and resource conflicts, displacement of populations, and humanitarian crises—rather than addressing the climatic root causes. In addition, especially at the local level, long term action s for climate change mitigation may be sacrificed in order to maintain near term social order, for instance if employment is threatened.

State Capacity

In many ways, the capacity of the Chinese state is increasing and the government will likely be able to address the consequences of climate change with some success. The state is experienced in coping with large-scale challenges and has amassed a good track record of doing so effectively. The economic and socio-political challenges from predicted climate change seem less difficult than the challenges from China's economic reforms in recent decades. Those reforms have fostered a comprehensive state system for financing and implementing a fast-paced and successful development program. This system also provides the state with ideal mechanisms for funding and supervising a wide range of programs that both respond to immediate climate-change-induced crises and longer-term impacts of climate change.

Over the past 30 years China has refilled reservoirs of social capital, built up technical and human resources, and developed institutional adaptability and national scientific and technological capabilities that should allow it to manage the challenges of climate change. The state has become more professionalized, its revenue base is ample, and it has demonstrated effectiveness in mobilizing funds for use in public investments and crisis-related outlays. It has been willing and able to borrow from the best global practices in developing policies. Its mechanisms of social control, increasingly tested, remain quite functional.

China is pouring a lot of money into social safety nets such as the healthcare and welfare systems. These systems have been acutely under-developed and remain inadequate but are improving quite rapidly. Nevertheless, the scale of the problems social safety nets will be called upon to deal with may increase exponentially due to climate change impacts.

China's wealth and state capacity can be expected to grow significantly over the next 20 years. By 2030 China will most likely match the United States in the overall size of its economy, albeit at a significantly lower level of per capita GDP. Although the challenges it will face are daunting, overall state capacity should be sufficient to manage most contingencies out to 2030. Beyond 2030 the ability for the state to respond is more problematic.

State Planning and Policymaking. China began long-term, twenty year projections focused on population and resources as early as 1980. State research on sustainable development picked up steam starting in the early 1990s. These projections are incorporated into the cycle of Five Year Plans that form the long-standing structure of China's development policy planning. In recent years the state's long experience with 5, 10, and 20-year projections has been bolstered by the availability of more and better quality data and more openness to inputs from outside experts. The capacity of the central government to research and plan for environmental protection, energy conservation, and climate change has steadily improved.

China's reliance on expertise from the state bureaucracy and think tanks in formulating policy has proven surprisingly effective. Nevertheless, this policymaking process is changing. Although still mainly a closed process, policymaking is increasingly open to input from a broader spectrum of elites in business, academia, and the sciences. The composition of the senior policy elite has shifted, primarily through the inclusion of representatives of the leading sectors of the economy. Executives from the energy, petroleum, steel, and banking sectors have increasingly superseded ministerial bureaucrats on the Central Committee. Although in the state corporatist system the role these business leaders play is not distinct from the responsibilities of government ministries for their sector, this shift will likely result in policies more favorable to private industry, possibly at the expense of overall national interests. Government by experts may increasingly be replaced by government by commercial interest groups. The bureaucrats and experts of the National Reform and Development Commission and State Council's Development Research Center will have a hard time forcing climate change policy decisions over the heads of powerful corporations.

Policy Implementation. Despite effective state planning and policy decisionmaking, translating goals and guidelines into actual policy changes and implementing them down to the local level remains a substantial challenge. The growth of the market sector and decentralized political

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authority combine to create a mismatch between central goals and results on the ground. China's policy record since market reforms began in 1978 illustrates that the state's policy implementation capacity is considerable when it is fully applied, but only top priority issues receive state attention. Many Chinese policy statements, laws, and regulations focused on environmental protection receive high marks for language, concepts, and intent but are not effectively implemented or enforced. In part, they may fall victim to competing priorities. China's robust stimulus and infrastructure investment program in response to the global financial crisis, for example, may hinder or overshadow the implementation of policies designed to mitigate climate change through a less energy intensive path to development.

China's impressive state capacity will mean little if climate change does not remain a top-tier state priority and receive the full backing of the central government to ensure local compliance on policy implementation. Although China's leaders have been calling for local leaders to pay attention to these problems, they have not always pushed environmental policies hard enough. In some cases, the central government has responded to difficulty in implementing new laws and policies by giving up and deferring them for considerable periods. Weak attempts by the state center to implement best environmental practices are readily circumvented by local power-holders prioritizing their own income possibilities and growth at any price. From the local perspective, the capacity of the state to carry out environmental policies looks less than impressive. An additional roadblock to policy implementation on environmental and climate change issues is the inadequacy of the State Environmental Protection Agency. It is understaffed, under-resourced, does not have significant reach into local levels of government, and lacks the authority to close down polluters.

Policy implementation is also hampered by a longstanding political phenomenon regarding rhetorical initiatives originated from the senior leadership, dating back to the Mao era. China's political leaders have a tendency to make pronouncements using symbolic rhetoric, such as "Cultural Revolution," "Three Represents," or "Scientific Development," the meaning of which is unclear to the vast majority of state and party officials. The bureaucracy then shifts to implement the new policy without a clear understanding of what it means. A process of trial and error then ensues until the leader provides positive feedback on the results. In the meantime, policies may not be implemented or may be incorrectly implemented in an inconsistent fashion across the system. Anecdotal evidence suggests that climate change and environmental initiatives may be susceptible to this problem.

Crisis Management. China's ability to draw on major national resources to address both natural and political crises to 2030 rapidly and effectively will be substantial. China has experienced an impressive crisis management learning curve based on the lessons of the 1998 "once in a century" floods, the 2003 SARS epidemic, the snowstorms in south China, and the 2008 earthquake, as well as military tension or incidents involving the United States. Emergency management response capabilities have improved and building state capacity for crisis management remains a high priority. China's currently evolving crisis management systems should be able to handle projected climate change-related challenges satisfactorily. The government's crisis management capacity may be less of a problem than its capacity to maintain discipline in enforcing remedial measures once a crisis has passed.

Limitations on State Capacity. The Chinese state continues to exhibit chronic problems that limit its capacity. These include well-known problems of governance such as weak inter-ministerial coordination to overcome stove-piping, local governments resisting national policy directives, and endemic corruption. Predictions about state capacity to respond to climate change need to take the limitations and internal contradictions within the system into account.

China's state structure is still organized according to a residual Leninist "stovepipe" command and control bureaucracy. The state is divided into vertically-organized functional hierarchies each responsible for a particular sector or functional area of state activity. These hierarchies extend all the way from the upper echelons of the central government down through the provinces to localities and into segments of civil society associated with the hierarchy's area of responsibility. This structure facilitates central control of critical issue areas, but the stovepipes tend not to interact with each other. There may be insufficient coordination between parallel offices responsible for coal or rail transportation in a particular province, resulting in duplicating efforts and wasting resources. In addition, the CCP has its own parallel, duplicate structures at all levels of government.

Overall, the stovepipe state corporatist structure, while it provides the state with formidable abilities to marshal resources and personnel, is wasteful of state capacity. As climate change constrains state resources, this may become a serious deficiency. In addition, climate change produces broad-based effects that will require effective coordination and tradeoffs between many functions of the party-state, cutting across the bureaucratic stovepipes. This may be resisted by bureaucratic elements with a vested interest, perhaps involving patronage relations, in the existing hierarchical administrative system.

Center-Local Conflicts. Government authorities at different levels of the government—central, provincial, and local—have significantly divergent institutional interests. Following the reconsolidation of tax revenues in favor of the central government in 1994, many provincial and local governments were left with large ongoing budgetary shortfalls. Local levels of government in the agricultural heartland of central China, which will be hard hit by climate change-induced challenges, are particularly impoverished. The central government continues to delegate increasing administrative responsibilities to the provincial and local level, often in the form of unfunded mandates. The resulting major gap in interests and financial resources between the different levels of government is a primary challenge for effective state response to issues such as climate change.

Chinese leaders probably will see climate change as prolonging the need for efficient centrally directed capabilities. If China's leaders are as committed to improving the environment as they seem, they are in a position to address at least the worst problems resulting from climate change. The recentralization of finances has provided the center with the funds to address pressing large-scale issues, such as environmental issues or the current economic crisis. This centralization of finances also strengthens China's hierarchical political system, which has both advantages and disadvantages. As long as higher levels have funds, lower levels will look to them rather than the constituents they are supposed to serve. This system undermines responsiveness to lower levels while increasing the control of higher levels. Not only is any transition toward democracy undermined, but it appears that the incentive to provide public goods, of which the environment is a prime example, is diminished. On the other hand, higher levels can demand compliance with targets for public goods such as the environment.

Although climate change will require centrally administered solutions, effective responses also will depend heavily on crisis management, effective policy implementation, and innovation at the local level. A paradigm shift among the rank-and-file Party and state bureaucrats and local officials will also be necessary if climate change mitigation is to be successfully implemented. Despite incorporating "Scientific Development" goals into the official cadre evaluation system, the Party's personnel system has yet to overcome the de facto incentives for local officials to pursue immediate gains from "rapid growth at all costs." Although local officials will be happy to submit huge "wish lists" for central funds to deal with climate change, the local focus for actual projects will be on very short-term priorities, not long term climate change. Local leaders will be in a very difficult situation as internal instability driven by climate change increases. They typically seek to avoid and suppress problems rather than address them.

The central government may set climate change-related policy targets, but such targets can be difficult to measure and easy to evade. The failure of the central party-state to effectively empower local levels of government or enforce its dictates will undermine its legitimacy. This will have important political ramifications, both positive and negative. Given various types and differing severity of climate change effects across different parts of China, many problems would be more effectively dealt with at the provincial level. There may be increased incentives to move toward a truly federal system with greater authority accorded to the provinces. Local authorities may also become more reliant on international and local NGOs and private philanthropy to bolster their capabilities. Instances such as the Sichuan earthquake demonstrated that NGOs and civil society can effectively contribute. Increased dependence will likely render local authorities more responsive to civil interests, regardless of whether there is a formal opening or democratization of the government. On the other hand, local discontent can be expected to increase, particularly if responses to climate change-induced crises are ineffective. A vacuum in local state capacity may allow local criminals and gangs to usurp control in some areas and corruption and black market activity probably will be exacerbated.

Corruption. Corruption and black marketeering remain prevalent in China despite periodic vigorous official anti-corruption campaigns. Corruption results in substantial diversion of state and private funds and resources away from their intended applications, reducing state capacity. Corruption concerns impose extra oversight burdens on the central government and popular perceptions of corruption undermine regime legitimacy. Although most corruption operates at the local level, local governments typically lack the authority to deal with corrupt officials, forcing the central government to take responsibility.

In addition, economic development also has allowed vested interests to become more entrenched and state and private enterprises to become increasingly blurred. Elite families and state and private sector leaders have formed complex patronage networks that seek to maintain the status quo and enrich their members. To date, corruption in China serves as a market mechanism compensating for bureaucratic inertia. The rise of corrupt elite networks may make more obstructionist forms of corruption more prevalent. The requisite flow of resources to local levels of government and proxy actors to address climate change-induced challenges may increase the opportunity for corrupt actors to enrich themselves at the expense of successful responses to the problems.

Prospects for State Failure

China's party-state will face significant challenges as a result of climate change. In addition to overall social, political, and economic challenges, it will have to overcome or mitigate systemic contradictions within the party-state itself. Nevertheless, it seems highly unlikely that climate change will cause a complete failure of the Chinese state, or even a sudden violent change of political system within the next two decades. Although it may face political crises, for example due to a succession dispute or failed political reforms, China's commitment to maintaining its economic momentum and innovativeness will not be derailed by climate change. China's trajectory of increasing state and civil capacity mitigates the prospects that even large-scale challenges will lead to a critical failure.

On the other hand, both the central government and civil groups in the quasi-state and private sector have increased their capacities partially at the expense of local and provincial government capacities. Local and provincial institutions will bear the brunt of climate change-induced challenges. Unless they are properly resourced or the central government or civil groups step in to support them, acute climatic impacts could produce partial state failures at the local or even provincial level. Such localized failures are likely to prompt greater central government intervention and more resource allocation to response and mitigation measures.

State Climate Change Mitigation Policies

In the 2008 update to the current five-year plan, China adopted an ambitious and unprecedented set of sustainable development and climate change goals under the banner of the National Climate Change Program (NCCP). The NCCP reflects strong national leadership and a nationally-coordinated, professionalized response to both international trends and obligations as well as to domestic challenges. China is nominally making a major push to increase its overall adaptive capacity to cope with climate change, including raising public awareness, enhancing research and development, and seeking to leverage international resources. There are nevertheless grounds for caution in taking China's claims about future commitments or demonstration projects at face value. Past initiatives often have proven to be a combination of wishful thinking and public relations.

China can readily adapt the administrative system it used to finance and implement a fast-paced and successful development program to develop and implement climate change policies. The kinds of investments and economic policy adjustments that China has been implementing for at least 30 years can also be used to manage climate change. Measures such as price increases, investment outlays, and precautionary preparations have long-run importance for reducing the severity of subsequent outbreaks of climate-change-related events. Institutions and mechanisms such as China's planning commissions and government-guided investment programs are also the ideal for funding and supervising a wide range of programs that both respond to immediate climate change-induced crises and longer-term responses to climate change.

Developing effective responses will nevertheless be a daunting task. Many of the required initiatives are very large scale and costly. Chinese policymakers in any case tend to think big in terms of solutions, such as moving the capital south or diverting whole river systems north. The lack of capacity at the local and provincial level, as well as the inter-provincial and cross-border nature of many of the major climate change-related problems, will strengthen the central government's role in addressing them. The lack of transparency in China's policymaking may have a problematic effect on policy selection. Leaders may be inclined to keep the most severe problems secret. Without feedback from the public and a broader selection of officials in the affected areas and nonstate experts, the internal state debate may produce consideration of drastic measures that could put large populations at risk. Issues of corruption and poor preparation will crop up, but the current trend in China shows the high likelihood that appropriate reforms and policies will continue to emerge.

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China will most likely turn to a variety of different approaches to manage climate change-induced challenges. The degree of climate change, the severity of the impacts, and their timing will have a decisive impact on where China ultimately decides to place its emphasis. Taken as a whole, China's responses to climate change are likely to result in an increasingly human managed environment. That is, state action on a large scale will alter the country's environment to mitigate or compensate for climate change. It seems inescapable that this project of environmental management will increase China's claims on global energy and other resources, but depending upon the technological trajectories of the project, relatively more or relatively less energy and resources could be required.

Incentives and Market-based Structures. Climate change mitigation will require comprehensive attention to adjusting incentive structures in China's economy, society, and government. China is likely to accelerate introduction of market-based incentives for sensible urbanization, migration, and business location decisions better adapted to climate change. For example, the state could have a major impact on the nature of urban expansion through building codes and taxes on materials.

The party-state will also need to create incentives for its own officials to focus more on climate change. The major professional incentive structure for lower level government officials is the cadre evaluation system which measures their performance. The cadre evaluation system emphasizes measurable achievements in areas like revenue collection, public order, and family planning, with the greatest weight being placed on economic growth. By making economic development the number one criterion for cadre evaluation, the party-state aligned personal and local interests with national goals. The resulting emphasis on economic growth is at least in part responsible for China's ability to rapidly implement economic development policies. This strategy has also had more problematic effects in terms of causing officials to engage in cutthroat competition to gain recognition of their jurisdictions as leading producers, with no regard to environmental consequences or efficiency.

The cadre evaluation system could in theory be used to promote progress on climate change mitigation. The adoption of "Scientific Development" in fact prompted efforts to incorporate environmental protection into the evaluation system. In practice this has not been very effective because environmental improvements are difficult to measure compared to other elements such as economic growth. The government attempted to develop a "green GDP" to act as a metric but has for the time being abandoned the idea. If an effective climate change mitigation metric could be developed and incorporated into the evaluation system, it would create a significant incentive for lower-level officials to implement state climate change and environmental policies, albeit possibly in an inept or superficial fashion.

Resource Price Reform. China has benefited from low prices for energy, water, and raw materials, which is one of the driving factors behind China's wasteful and profligate economic development pattern. Resource prices are already on the rise as a function of growing demand, but China is also becoming a wealthier country more able to continue to afford higher prices. To raise costs sufficiently to create incentives for conservation and greater efficiency, the state may need to intervene by imposing taxes on resource use and regulating rates. Price reform on its own may not be sufficient without other changes in usage patterns and incentives because resource demand is in many cases fairly inelastic.

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Conservation and Rationing. Rationing of critical resources is an unattractive option for a number of reasons. Less available resources will be a constraint on continued economic growth, with attendant risks of unrest and loss of capacity needed to deal with climate change. Severe rationing may generate prompt political unrest among affected constituencies. In addition, rationing systems are an open invitation to corruption in allocation decisionmaking. In spite of these major disadvantages, the Chinese Government may have little recourse but to impose rationing if price reforms and infrastructural solutions do not keep pace with water, energy, and other resource shortages brought on by climate change.

Voluntary conservation is a different matter. China's leadership is aware of how wasteful and inefficient many of the country's economic structures and practices are. The leaders are equally aware that resource constraints will shortly become a hard reality in China. Some degree of conservation, rationalization, and increased efficiencies will be a necessity. Accomplishing this proactively and on a gradual basis is clearly preferable to being forced to do so under crisis pressures. Two principal factors have constrained movement on conservation. Waste and inefficiency are so ingrained in China's current industrial system that enforcing conservation could constrain growth, something China is not willing to do. In addition, industries and local officials have little systemic incentive to want conservation and have often proven able to avoid or deflect central government initiatives in this area. Progress will require stronger state commitment, altered incentive structures, and greater pressure on offenders. The state may be able to leverage the support of NGOs or the public at large in bringing pressure to bear.

Enforcing Environmental Standards. China will face major proximate challenges from pollution of air and water, particularly in urban areas. What China does to address its pollution problems could be key in determining the direction of its carbon emissions. For example, if China switches to cleaner power to reduce aerosols, greenhouse gas emissions could also be reduced while if they just put screens on their smokestacks to capture aerosols, greenhouse gas emissions will continues. Although China in many cases has industrial and environmental standards on the books that exceed those in fully developed countries, the Chinese treat them as eventual goals rather than putting them into practice. The problem of lagging policy implementation needs to be attacked head on. In the automobile industry, for example, China's standards are higher than the US Government's Corporate Average Fuel Economy (CAFÉ) standards. Although the principal purpose of the high standards is to disadvantage foreign manufacturers, if implemented effectively they would substantially improve fuel economy. Instead, they are largely ignored and China's cars remain inefficient. Because the state attempts to keep fuel prices depressed to bolster economic growth, there is little market incentive to move to hybrids or other high-efficiency vehicles. This may change since China is positioning to becoming the main electric car producer.

Infrastructure Solutions. China has a long tradition of developing and maintaining large-scale infrastructure to manage weather and climate contingencies. For example, the government has made substantial flood control investments and maintains dikes and river embankments. Climate change-induced challenges will necessitate infrastructure projects on the largest scales, involving massive expenditures of resources and manpower. Climate change-augmented urbanization will necessitate major expansions of transportation, power, and communications infrastructure. Major infrastructure projects will be necessary from the local to the national level, in sectors ranging from agriculture to water management and energy.

Crisis Management and Disaster Response. China's current government has already demonstrated a strong ability to be able to respond, with military personnel as the core resource, to provide relief services when serious natural disasters strike. Each severe climate change-induced event such as a drought or storm will bring a flurry of costly emergency assistance, such as water trucks, food, income supplements and government-directed bank loans to offset short-term hardships. More frequent extreme weather events, particularly if they occur in quick succession, will put a premium on building state capacity for crisis management, including development of emergency manpower other than the army. Increasing recourse to allowing responses from groups in civil society such as NGOs may be necessary.

Managing Public Responses. China has a long tradition of expecting good government to plan for and respond effectively to natural crises. As China grows wealthier and more resources are available to the state, public expectations undoubtedly will only grow higher. Failure to effectively deal with climate change-induced crises will erode regime legitimacy and threaten political stability. In many cases, political repercussions from climate change will be difficult to distinguish from the political repercussions of major economic reforms. Chinese Governments at all levels will need to discern which public complaints are legitimate and which are not. Chinese authorities are almost certain to continue to develop the combined strategy of ameliorating underlying conditions responsible for social unrest while using the People's Armed Police to assure social stability and minimize property damage and loss of life.

Overall Economic Restructuring. China's economic development already dictates a move away from heavy industry and toward services and production of domestic consumer goods. Nine percent growth in per capita consumption is more beneficial to the average Chinese citizen than 13 percent overall GDP growth based on exports and investments. This shift may also constitute an effective climate change mitigation strategy, a synergy that may provide considerable impetus to effective climate change responses in China. Heavy industry such as steel production is very resource-intensive, not only in terms of raw materials but also water and electricity. Economic restructuring will inherently facilitate greater resource efficiency and slow the growth in demand for energy. The Chinese Government also recognizes that improved efficiency and profitability requires that they start moving industrial production offshore, to Brazil, for example, then selling it back to the growing Chinese consumer market. Despite the emphasis of recent economic growth, China does not enjoy a comparative advantage in heavy industry. For instance, steel produced almost anywhere else will require a less carbon-intensive process than in China. As China's industry moves offshore, additional opportunities to improve efficiency will open up.

Energy Policy

China's ongoing economic development will drive continued increases in energy demand for some time to come. The Chinese leadership will not accede to limiting energy use if it is at the expense of economic growth. Nevertheless, they are committed to improving energy efficiency. The Chinese are already becoming more efficient in certain areas. For example, modernization of plant and equipment is replacing older, inefficient equipment with more efficient, newer equipment. There is plenty of opportunity to extend such improvements, for example by adopting a low resistance delivery system for electricity to reduce waste in transit.

In many cases, China already has access to the technological solutions it would need to reduce emissions and increase efficiency of resource use, but simply doesn't implement them because they would raise production costs. For example, the simple step of washing the coal used in China's power plants before burning it would measurably reduce emissions, but carries a high costs both in money and water. In cases such as this, the state can encourage implementation by fining polluting industries.

Energy costs in China are already increasing, which in theory ought to result in moves toward conservation and efficiency of use. In practice, China's current industries have relatively inelastic energy demand, so their energy usage has continued unabated. Energy-inefficient but cheap industrial processes have hampered efforts at using rate hikes to encourage energy conservation; even with rate hikes, payments have been delayed, with no concrete moves toward improving efficiency until the state actually shuts off the power. It would obviously be very economically disruptive for the Chinese Government to take such steps on a wide scale. China's planned move away from its export-led heavy industrial economic model may provide a solution. Services and consumer-oriented industry not only use less energy but have greater energy demand elasticity, so they will be more responsive to energy prices and ready to accept rational conservation measures. A slowdown in steel and cement production could produce a reduction in green house gasses equal to the output from Germany's entire coal-based generation.

Energy supply is as much of a concern for China's leaders as energy demand. China places a premium on security of supply in its energy policy. Any limits to China's access to energy is perceived as a threat to job creation and regime stability. This is problematic in that China's domestic energy resources are in most cases limited relative to its energy demand. In the case of electricity, energy security dictates reliance on abundant but polluting domestic coal. Coal cannot provide the whole answer, and for other types of energy such as fuel for transportation, China's policymakers know they will have to depend on foreign energy sources. They have tried to compensate by seeking to purchase direct control of energy sources rather than relying on international energy markets, but that has not worked in practice. Even China's own state-owned energy companies sell most of what they produce on the international markets rather than providing it cheaply to China.

Control of supply routes such as the Arabian Sea or Straits of Malacca by potentially hostile powers such as the United States renders China's practical energy security illusory. Climate change may actually improve China's foreign energy supply options. Warming may make arctic energy more accessible and open the sea lanes through the Arctic Ocean, potentially as early as 2015. China has ad hoc status as a non-arctic state in the Arctic Council and is beginning to build ships to meet arctic standards.[6] The arctic route may provide China cheap access to Russia's oil and natural gas, particularly as more Siberian ports become accessible.

Energy Production. China's energy production profile is likely to change significantly over the next two decades. Ideally, China would like to move away from coal, both because it is carbon-intensive and polluting and because the coal mining industry is unsafe and the government would like to shut down many mines. It currently has no other cheap, secure short-term options, but this is beginning to change as structural changes in the coal industry raise production and transportation costs. In any event, China's coal supply will begin to approach inadequacy by 2030, mandating a shift to other energy sources. The capital investment in China's coal-fired power plants will likely not inhibit such a shift. China's controlled financial system means that the building costs are depreciated after a decade, so abandoning the plants does not generate a

[6] The Arctic Council is an intergovernmental forum promoting cooperation, coordination, and interaction among the arctic states, with the involvement of the arctic indigenous communities and other arctic inhabitants on common arctic issues, in particular issues of sustainable development and environmental protection in the Arctic.

loss. Coal will remain a prominent aspect of China's energy production profile, but its relative and absolute share of production will decline considerably over time.

Petroleum constitutes China's second most important energy source. Although China has domestic oil fields, they do not approach levels where self-sufficiency is an option. There is a strong push to reduce the demand for oil, but projected increases in demand from private automobiles and other modes of transportation render such efforts unlikely to succeed. Even if China aggressively pursues a de-carbonization program, projections indicate that emissions reductions for the first 25 years will come from industry and power generation. Oil demand for transportation will most likely not decline significantly until after 2030.

Nuclear, hydroelectric, and renewable sources such as wind and solar will most likely assume increasing importance in the Chinese energy sector. China's electricity production capacity is projected to grow to 1,000 gigawatts by 2020. Fossil fuels could provide about 700 gigawatts, but at the cost of massive carbon emissions that would have a profound impact on the world climate. If China were to cut its fossil fuel use by half, it would need to make up about 650 gigawatts from other sources. China is looking to develop smaller, safer nuclear reactors and could fairly quickly build up its nuclear energy program to produce up to 250 gigawatts of electricity. Non-hydroelectric renewable may be able to eventually provide a further 200 to 250 gigawatts.

China has a number of large-scale hydroelectric projects in the planning stage, including the Tsangpo project in Tibet, which would be the world's largest. Climate change may impose significant limits on the reliability of hydropower, since a combination of glacial melting and reduced or more irregular rainfall is likely to cause reductions in river flows. There are also significant regional implications associated with all-out hydroelectric exploitation of the Himalayan watershed because many of the rivers in question terminate in other countries. The actual potential of hydropower may be markedly less than the theoretical hydroelectric contribution of up to 300 gigawatts. Nevertheless, taken as a whole, other energy sources could feasibly compensate for a 50 percent cut in fossil fuel consumption in China.

Natural Gas. Despite impressive gas finds inside China, there is not enough domestic natural gas to accommodate a major expansion of natural gas use as a cleaner alternative to coal and fuel oil. Despite concerns about security of supply, Chinese companies are aggressively pursuing natural gas contracts overseas. The most likely supplier would seem to be Russia, but in practice there are major drawbacks. Despite more than a decade of negotiations, little headway has been made on building natural gas pipelines from eastern Siberia to China. Even if agreement on pipelines could be reached, the economics of Russia's gas markets are unfavorable to China. Chinese consumers will never pay for gas what German utilities pay for it, so Russia will send the gas west rather than east. In addition, Russian gas would have to be piped right past existing natural gas fields in western China to reach consumers on the coast. China therefore might as well exploit its own fields. Moreover, Russia has shown itself to be a very unreliable supplier, repeatedly shutting off gas to Ukraine and Europe for political reasons.

The pipeline plans were also made when prices for liquefied natural gas (LNG) were higher. LNG is now a much more attractive option for China than gas pipelines. It can be delivered by tanker to China's eastern urban centers. China has focused on Iran, Qatar, Indonesia, and Australia as potential natural gas suppliers. Iran may not be a viable option so long as international sanctions remain in place. It lacks liquefaction technology to convert its gas to

LNG form and sanctions bar China from providing it. As an alternative to costly pipelines, Russian natural gas could be liquefied and shipped to China by sea. The opening of arctic shipping lanes and Siberian ports may make this option a viable one.

If China can secure an overseas supply, LNG power plants are significantly cleaner than coal- or oil-fired plants. An LNG plant produces about half the carbon emissions of the most efficient coal-fired power plant, let alone the average Chinese coal-fired power plant. China's plans call for the construction of 15 LNG power plants, but such plans are always more ambitious than reality. The scale of energy production involved means that even 15 plants would not decisively reduce China's emissions. In the long term, world natural gas markets will continue to be tight, limiting its potential as an expanding source of energy for China. In practical terms, while China's LNG expansion will have a major impact on the world LNG market, it will likely not have such a large impact on China's emissions.

Water Policy

China's climate change mitigation policies will in the first instance depend on how the government handles the major hydrologic changes that will occur in the country. Water scarcity, particularly in the north, will force either wholesale population movements out of the most severely affected areas or massive diversion of water between regions. Either of these results would impose a daunting logistic burden on the Chinese state. The state's initial approach has been to deal with the problem through large-scale infrastructure projects in the same vein as the Three Gorges Dam. China already has initiated a massive South-to-North water diversion project, which will use thousands of miles of canals to divert water from the Yangtze River to the Yellow River. The first phase of the project is scheduled to be completed next year, the second phase by 2030. Additional large-scale infrastructure projects of this type will be required to address the escalating northern water crisis. Such projects are nevertheless only likely to alleviate, not solve, the problem of water shortages.

China's current government has already demonstrated a strong ability to be able to respond, with military personnel as the core resource, to provide emergency assistance when water-related crises such as floods or drought strike. Depopulation of rural areas through migration to cities will somewhat ease pressure to occupy rural areas most at risk for water-related crises. On the other hand, urbanization, particularly the expansion of cities in the drier inland areas, will necessitate major investments in urban water infrastructure, from the level of increased water piping in individual buildings to new reservoirs and water treatment plants. There is a risk that if this is undertaken at the local level, it will be done in a wasteful and irrational manner that worsens water inequalities between cities and between urban and rural areas. A large degree of central planning may be needed on allocation of water resources, to include water rationing and economic incentives for sensible construction and investment patterns.

The state can employ market-based mechanisms to create incentives for water conservation or changes in water-use and settlement patterns. Ideally, as Chinese society becomes wealthier, water will get more expensive. In practice, the true public cost of water may not be passed on to the consumer. The state can compensate for this by raising water charges and levying higher taxes on drier areas. Large infrastructure costs will be associated with providing water in some areas but not in others. The pricing of water by location has been politically unpopular but would help reconcile water demand with water availability. Taxation levels and water fees that reflect the true public cost of sustaining economic and household activities in drier northern China will facilitate longer-term beneficial market-based adjustments in behavior such as conservation and migration to wetter regions. In addition, China's heavy industry is very water-intensive, so higher prices will also incentivize the desired transition to a service and consumer goods-based economy.

Enforcement of a water pricing mechanism could be difficult, as cutting off water to businesses and households in payment arrears will generate backlashes. Corruption and favoritism in allocating rates and forgiving payment arrears are likely, and even if they do not widely occur, the public is likely to perceive them. Because of the political risks, political gridlock or weak policymaking could hinder the raising of prices, although each severe water shortage will increase political will to take action. The state could also require purchase of insurance against flood and cyclone damage in wetter areas or drought or water shortages in drier areas. This sort of insurance can convert large infrequent crisis-inflicted costs into predictable significant annual charges. Such predictably higher payments in crisis-prone regions will create an incentive framework for sensible crop selection, housing, and business location decisions.

Agricultural Policy

One of the major decisions the state will face is whether to permit and facilitate diversification away from grain production. Most agricultural studies suggest that failure to do so will significantly hamper the adaptive capacity of China's farmers and lead to significant declines in production. A transition to higher-value crops that are less water-intensive will be necessary for farmers to maximize profitability in drought-prone regions. In addition, such crops can be profitable on smaller agricultural plots, whereas grain is only profitable on large plots using mechanized farming. This switch would therefore facilitate the continuation of labor-intensive small farming, easing pressures of migration to cities.

Despite the advantages of permitting crop switching, China's leaders may be reluctant to accept such a solution. Cheap grain is needed to feed urban dwellers and the military, so a move away from grain production is a strategic decision that would have to be made at the highest level of government. The government may prefer to increase subsidies for grain production to avoid becoming reliant on foreign sources. Perhaps the one area in which China has maintained near total self-sufficiency has been agriculture—if one ignores China's large fertilizer imports. Food security, and grain self-sufficiency in particular, is an almost sacrosanct strategy. The Chinese Government has stated frankly that agricultural self-sufficiency is necessary to ensure social stability and that in an international crisis food might be used as a weapon. Subsidies nevertheless cannot mitigate the basic problem that grain-based agriculture will face decreasing productivity due to climatic shifts. In the longer term, China will be forced to go to the international market on a large scale, raising the question of whether the world is capable of "feeding China." China's food procurement policy may parallel its overseas energy policy. China may create agricultural trading companies similar to its state-owned oil corporations and seek to purchase overseas farmland suitable for grain production. As with energy, these policies will most likely not be able to free China from the global food market.

China is reforesting, converting uplands from grain to forestry that will act as a terrestrial carbon sink. In combating erosion, China's long experience with tree-planting and dune-fixing as steps to fight desertification should continue to attract government resources, especially as grazing pressures subside and allow such programs to be more effective. Enhanced government investments of the kind already implemented so widely have a high likelihood of adequately moderating increased eruptions of dust storms and continued spreading of deserts.

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Regional Implications

The trans-border impacts of China's environmental problems are of concern to many countries as other countries will feel the effects. It seems unlikely that this situation would lead to international conflict, but it could lead to increased political tensions, regional economic disruptions, and deterioration in the quality of life for hundreds of millions in the region.

As resources become more constrained, while China's resource demands continue to grow, China will likely seek to assure its access to critical resources on its periphery. Such resources could include energy resources in Siberia, Central Asia, and beneath the China Seas; water resources in the Himalayas and in Siberia; and arable land that might open up as climate zones shift. China's capacity to take action to secure its vital interests can be expected to improve as it continues to develop its military capability.

Regional Water Issues

One of the more direct consequences of climate change for the region may be seen in South and Southeast Asia as a result of the combination of glacial melt in Tibet and Chinese river management practices. The Himalayas and Tibetan Plateau form the principal watershed feeding the rivers of East, South, and Southeast Asia. Through control of Tibet China can exert source control over much of the water in those regions. China's development program in Tibet has not traditionally taken into account the fragility of the plateau or the interests of downstream countries. As climate change imposes increasing water scarcity on China and other countries in the region, the water resources of the Himalayas will become an increasingly important strategic asset.

The implications of China's water management decisions are already becoming a major long-term national security concern for countries such as India and Vietnam. China is engaged in a number of major hydroelectric projects in Tibet that threaten the water access of South and Southeast Asian countries. Projected hydrologic effects of climate change on China dictate that China's interest in Himalayan water will most likely shift from hydropower to irrigation and drinking water. Chinese planners are well aware that projected water scarcity will necessitate large-scale diversion of water to address domestic needs. As scarcity becomes more severe, China will have very little room to compromise with downstream countries.

China is in a very good position with regard to Himalayan water. Not only does it securely control the sources of the major rivers, but existing international law favors the upstream country in disputes over water rights. Despite the existence of regional water management institutions such as the Mekong Commission, China has little incentive to consent to some form of equitable regional water management scheme. Cooperation would, by default, reduce China's control of critical water resources it will need in the future. Downstream countries have little recourse. None is in a position to challenge China's upstream control of the rivers, and initiating a conflict over water rights would risk potentially catastrophic Chinese reprisals such as wholesale diversion of rivers. The water issue is nevertheless likely to create serious ongoing tensions that may play themselves out in other venues. In the longer term, conflict could occur over Siberian water resources, including not only the Amur River but Lake Baikal, which holds the world's largest single volume of fresh water.

Aerosols

China has one of the largest dust contributions in the world from dust blowing off of the Gobi desert and its industrial and environmental aerosols threaten other countries in the East Asian region. Continued drought and desertification in northern China will increase the trans-border movement of dust and other particles, to the immediate detriment of Korea and Japan, with impacts on North America and the global climate as well. Countries on the receiving end of China's aerosols have incentives to assist China in coping with its air quality challenges, through technology transfers and provision of funding for aerosol mitigation measures and reclamation of denuded land.

Regional Migration

Cross-border migrations prompted by climate change could prove destabilizing for China as well as its neighbors. Whether migration occurs into or out of China will depend on relative neighboring government successes in addressing the effects of climate change.

Chinese Emigration. Emigration into neighboring countries such as Russia, Mongolia, or Vietnam might act as a safety valve for China's population in response to acute climatic stress. The capacity of those countries to accommodate large numbers of Chinese immigrants is nevertheless limited even without climate change-imposed resource constraints.

Emigration from China is not likely to be confined to China's Han majority. Ethnic minorities such as Mongolians, Uighur, and Tibetans might cross the borders into Mongolia, Central Asia, or India and join with their kin. In some cases this might alleviate ethnic conflicts involving those groups, but they might also use neighboring countries as bases from which to continue conflicts with the Chinese state.

Heightened stress on populations in the host countries could result in conflict between Chinese migrants and locals. China already witnessed similar episodes during riots in Indonesia, where members of the well-established ethnic Chinese communities were attacked and women raped. More recent Chinese migrants may find themselves in even more precarious positions vis-à-vis hostile local groups. The Indonesian violence caused a furor in Beijing, and China can be expected to react harshly to future anti-Chinese violence in neighboring countries.

Siberia and the Russian Far East. The numbers of Chinese economic migrants crossing the border into the Russian Far East are already considerable. As yet, most of them move back and forth over the border rather than settling, but sustained climatic pressure could change that. Pressure from desertification in China's Northeast could increase Chinese migration into the Amur River valley and Russia's Maritime Provinces—areas where ethnic Russian demographics are in decline. The potential exists for the Russian Far East to become demographically Chinese, a process that will likely be accelerated by climate change. This shift could create serious tension between Russia and China, eroding the recent improvements in bilateral relations between the two powers.

Mongolia. Mongolia is wary of large inflows of Chinese as the Mongolian construction and mining industries depend on Chinese migrant labor. Native Mongolians are not interested in industrial jobs. They either subsist as herders on the steppe or work in the service sector in the capital. Mongolia recently suffered two years of severe drought, which generated tension between Mongolians and Chinese as herders were forced to seek other employment. Climate change is likely to inflict more drought and large-scale desertification on the Mongolian steppe, which could leave a large unemployed Mongolian workforce competing with Chinese migrants. Ethnic conflict in Mongolia could spread to China's own Mongolian population, which is likely to face particularly acute stress from climate change.

Immigration and Refugees. Increased immigration and refugee flows into China as a result of climate change are distinct possibilities, depending on the severity of climate change impacts on other countries along China's periphery. Immigration is not likely to significantly stress China's capacity, given that the relative numbers involved would be miniscule compared to the likely domestic migration within China. China is likely to try to keep refugee and immigrant groups geographically contained. China has pursued a similar policy with the significant refugee flows it has received from North Korea, not only environmental refugees but also political and economic ones. North Korea's capacity to cope with climatic pressures is very questionable given the ruinous state of its economy. As has been the case with past humanitarian disasters such as famines, a climate change-induced catastrophe in North Korea would by default spill over into China's Northeast. Climatic pressures from desertification and water scarcity could also create refugee flows from China's arid neighbors such as Mongolia and the Central Asian republics. A worrisome unknown for China's government is the extent to which refugees would join with their ethnic kin within China, potentially worsening internal ethnic instability and conflict.

China might also become an attractive destination for migrants from tropical parts of Asia that may receive more severe climate change effects, particularly if China copes relatively well with climate change. Migration from Southeast Asia could assume proportions similar to that between Latin America and the United States. If China fares markedly better than countries in Southeast Asia it will likely have an incentive to bolster these countries' adaptive capacities and promote regional cooperation in order to forestall large-scale migration.

Overall Foreign Policy Implications

China's rapid rise and apparent ambivalence toward many of the values and institutions of the existing global order has raised concerns that China is a revisionist power that will seek to overturn the international system. The situation does not appear to be that clear cut. China is ascendant toward a leadership position in the international system. Chinese leaders see the present moment as one in which China should become the global hegemon, succeeding the United States just as the US replaced Britain as the global hegemon after World War I. As China assumes a leadership role in the international system, it will need to collaborate with other powers such as the United States, Europe, and Japan in managing global crises associated with climate change.

China's approach to such a leadership role is less clear. China's leaders perceive their country as unique, a "G-1." Since the de facto demise of revolutionary Maoist ideology, they do not identify themselves as the standard-bearer of an international movement or ideology such as democracy or Communism. Instead, they see China as a civilization unto itself, a global moral pole whose values and achievements others can emulate but not join. China does not necessarily view the international system as constraining it, nor does it necessarily seek to replace existing institutions with its own.

China has on the whole avoided either integrating with or undermining international institutions. This is not to say that China has treated such institutions with disregard. In fact, it has been willing to join international institutions and agreements, as long as doing so does not subordinate it to international authority. On the other hand, China is not willing to be the dominant power in institutions it joins, as long as no one else is either. For that reason it has avoided institutions the United States exerts a decisive influence over, such as APEC, while embracing ASEAN +3 and the United Nations, as well as aid from the IMF and World Bank. China played an instrumental role in creating an international security organization, the Shanghai Cooperation Organization (SCO). Its approach has been pragmatic and cynical, using international institutions and agreements that best serve China's interests.

China's overall approach toward international institutions is an important indicator of how it will approach international cooperation on climate change mitigation. Its posture suggests a lack of fundamental commitment to most international institutions and agreements except in an instrumental way. This reflects a sense that international regimes such as the Framework Convention on Climate Change (FCCC) are not always designed in ways that reflect its interests. Similarly, China accepts international standards on environmental degradation in the same way that it accepts human and labor rights—formally but not substantively. For example, China sits on the board of the International Labor Organization, even though it has no intention of allowing free labor unions.

In the final analysis, China's approach suggests that their strict compliance with international agreements cannot be counted on if the terms of the agreement begin to significantly detract from state interests and priorities. While violating a formal treaty obligation would put Beijing in a difficult position, China's leading global position and economic clout should insulate it from most adverse consequences. Given China's leverage in finance and other arenas, it would be very difficult for the United States to force Beijing to adhere to a climate agreement if Chinese leaders decided to abandon it.

China's Foreign Policy Perspectives on Climate Change

China strongly believes in equitable responsibility and therefore expects countries that are primarily responsible for greenhouse gas emissions to bear the greater share of the costs for mitigating climate change. Chinese leaders contend that the US and other industrialized democracies hypocritically export their polluting industries, while China is unfairly used as a scapegoat. At the same time, China realizes that regardless of who is principally responsible, climate change will have significantly negative consequences for China resulting in the need for implementing mitigation and adaption programs.

Climate change is likely to increase China's overall dependence on international sources of energy, food, and technology. China remains wary of international markets that it cannot control, preferring outright control of resources. As its external dependence increases, it will most likely seek to establish a growing forward presence in the world. This will likely take the form principally of Chinese companies purchasing critical resources in foreign countries. China probably will pursue greater cooperation with foreign partners and engagement in setting the terms of international trade. In addition, if faced with insecure sources or supply lines, China may see a need to establish diplomatic or military footholds in regions of interest. These processes are already under way in many areas of the globe, including Africa and Latin America.

China's leaders approach international cooperation on climate change and other issues in terms of how it will benefit their interests. International cooperation is not perceived as good in itself. Nevertheless, the need for international support and cooperation in addressing climate change mitigation will ideally put a growing premium on maintaining good relations with neighboring countries and access to Western resources, technology, ideas, information, and expertise. This has already increased Western influence on Chinese economic planning through the carrot and

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stick approach—project funding on the one hand and pressure to meet international standards on the other.

China's International Climate Change Challenges

Global Migration. By 2030 major parts of the world, especially in tropical and subtropical regions, will be facing more serious climate change challenges and possibly serious natural disasters and consequently political instability and social disorder. Like the developed countries, China may become an appealing destination for environmental migrants and refugees seeking relative order and stability. China is unlikely to accede to large-scale immigration given its cultural traditions and the massive internal migration the state and society will already have to contend with. Under these circumstances, China will find itself with two major policy imperatives—to take action to reduce and divert the international flow of climate change refugees, and to collaborate with the developed countries to intervene on behalf of undeveloped or underdeveloped nations struggling to cope with both poverty and climate change repercussions.

On the other hand, the effects of climate change are likely to result in emigration of Chinese overseas. As segments of Chinese society become increasingly wealthy, they will look for more environmentally attractive living conditions outside of China. It is likely that middle-class and wealthy Chinese will expand their overseas property investments and emigration. Should this reach an unprecedented scale, an anti-Chinese backlash may develop overseas, raising the salience of emigration to China's foreign policy.

International Pressure. Although China portrays itself as a champion of the developing world, its interests diverge from those of the G-77 countries as it rapidly becomes wealthier and more industrialized. This divergence is especially relevant to climate change issues. China faces growing international pressure due to its status as a leading greenhouse gas emitter and polluter, yet the G-77 countries lack leverage with China as they are desperately in need of Chinese investments. China responds aggressively to public criticism and smaller countries may suffer serious economic consequences if they do not seek cover in a multilateral forum.

International rhetorical pressure, while in many instances are easy for China's leaders to dismiss, carries a reputational impact. China perceives itself as a global moral pole and its leaders seek approval for their environmental policies. The Chinese promote their efforts in solar panel installation for hot water heating. They highlight their re-forestation projects but do not want to be held accountable for cutting down forests in the Russian Far East, Burma, Laos, Cambodia, and Indonesia. They show their commitment to becoming a world leader in building electric cars but do not want to be criticized for erecting polluting coal power plants while choosing not to lower emissions by using available technologies. They see themselves as a late-comer to the oil business with their need to meet China's energy crisis by buying oil from countries such as Burma, Iran, Sudan, and Angola, yet are demonized for acting in the sake of survival.

Countries may impose more concrete forms of pressure on China, such as trade sanctions, to push the country towards compliance with climate change mitigation measures. Although the standard model for trade negotiations is to exclude these types of externalities, climate change affects the trading system in a number of ways, such as the cost of production. WTO rules reduce the utility of trade sanctions as a lever to push climate change mitigation, but some options may include a ten 10 percent cost premium for carbon or the inclusion of climate change impact statements in all bilateral trade interactions.

Tariffs also could be levied on emissions-intensive industries. The specific domestic context associated with such tariffs would need to be considered such as a US tariff on Chinese steel production. Big steel mills such as Baoshan Steel operate through set-price contracts which would be insulated from a new tariff, conversely smaller mills which have to buy on the spot market would be affected. As a result, with a tariff in place Baoshan Steel would surpass its domestic competitors. Unintended consequences of this sort could render an ill-considered tariff counterproductive.

US Diplomatic Approaches

The US Government might use a number of approaches to effectively engage and convince China on climate change mitigation. It might be more fruitful to package these as part of a larger deal on improved US-China relations rather than focusing exclusively on climate change. In addition, several of these approaches depend on the US Government taking China's interests and perspectives more firmly into account. Increased sensitivity on Washington's part will not persuade Beijing to believe that the United States is concerned with China's interests. On the other hand, if Washington projects that it understands China's position, it is in a better posture to advocate climate change mitigation as a win/win scenario.

Proactive Confidence Building Measures. China's attitude toward the United States is one of deep distrust. The Chinese polity is suspicious that the US will undermine Chinese growth and undercut Chinese exports, which is seen by the Chinese Government as crucial for job creation and regime stability. Chinese leaders' suspicion is reinforced by such cases as the US Congress blocking the legal purchase by a Chinese State Owned Enterprise (SOE) of American oil assets in Asia. China's mistrust of US government motives is a major roadblock to arriving at a climate change agreement.

An effective climate change mitigation agreement between China and the United States would incorporate substantial compliance verification and trust-building mechanisms, akin to the Cold War-era confidence building measures between the United States and Soviet Union. In part, this could be accomplished through technical means, such as a system of regularized exchanges of inspections, technical monitoring, and remote sensing verification by over-flights or space-based platforms. Space-based platforms are also technically important for monitoring climate change, and China could be given shared access to such data. Such increases in mutual transparency would obviously be highly sensitive. Each country would most likely have to accept sensors and inspectors on its territory that would provide visibility into critical elements of its economy such as power generation.

In addition, the United States could be proactive in instituting emissions cuts and other climate change mitigation measures. This would concretely demonstrate US sincerity, particularly if taking action first placed the United States at a competitive disadvantage. Although this approach could convince China to reciprocate, the United States should be mindful that what China would offer in return is politically acceptable in Beijing. China is not likely to take action that would significantly constrain its growth in return for the United States taking the first.

Sensitivity to China's Development Goals. Although neither China nor the United States will compromise growth for climate change mitigation there is room to develop common ground. China's development goals are not as divergent from climate change mitigation goals as was the case a few years ago. China's plan to shift from an export-led heavy industrial development model to one based on services and domestic consumption will reduce emissions and provide opportunities for sustainable practices and other climate change mitigation measures. China's projected new growth model is fairly constructive from an energy and climate standpoint. China's views on climate change are conditioned by where China wants to be in 5 or 10 years, not so much where it is now. The US Government's assumption that present-day conditions are a baseline for action is not compatible with China's development plans. An understanding of China's planned trajectory will prevent the United States from over-compensating China for changes in behavior.

Framing the debate in terms of carbon emissions is not optimal in terms of receiving Chinese policy buy-in. Even if emission controls succeed in the long term, Chinese emissions will grow considerably in the next decade. In the near-term, China can do little to address emissions while at the same time maintaining its growth, so emissions-based arguments are perceived by Beijing as unfair persecution. China does not feel it bears equal responsibility for emissions with the developed countries. China was responsible for eight percent of emissions in the last century, while the United States was responsible for 30 percent. In addition, some of the emissions control measures being advocated, such as carbon collection and storage cannot be proven and have no economic co-benefits, possibly even worsening energy security. Greater emphasis on energy efficiency measures offers a pathway for China to decouple carbon emissions from economic growth and would make the emissions reduction debate more palatable in Beijing. China wishes to avoid being singled out as the world's largest source of greenhouse gasses and the origin of most of the world's most recent carbon emissions. Chinese leaders do not want to be exposed for lacking the state institutions needed to deal with climate change. Losing face on such issues is not likely to put China in a receptive frame of mind.

Technology Transfers and Scientific Cooperation. Chinese research and development (R&D) and industrial development policies are increasingly focused on energy and environmental issues. The prospects of China building a more synthetic environment in response to climate change offers interesting possibilities for international cooperation in directing the project toward a relatively less energy and resource intensive trajectory. The expanding capabilities of China's R&D system will likely establish it as a leader in new climate change mitigation technologies in the longer term. In the near term it will need to acquire technology overseas. During negotiations for improved international cooperation on climate change, China is likely to press its case for the industrialized countries to be more forthcoming with technology and assistance. While roadblocks such as dual-use technology export provisions make technology transfers at the government level unlikely, much of the sharing of energy saving technology will occur through commercial channels.

Opportunities for mutually beneficial scientific and technological cooperation between China and other countries in the world undoubtedly will arise. The United States and other developed countries have the technology, but China has the low cost manufacturing capability that will be necessary to produce green technology en masse. A case can be made for a cooperative approach where an American company provides designs to be produced by a Chinese company and sold to Bangladesh. Climate change mitigation can be sold to China as a new green export industry. The opportunity to participate in green technology rollout gives China a substantial profit incentive to come to a climate change mitigation agreement. This will have to be weighed against the commercialization of technologies that might provide the most impact if provided to poor recipients as aid.

Building Bridges. The panelists observed the United States should make a major effort to build cooperative academic, professional, business, and government links with Chinese counterparts involved in climate change-related activity at all levels. The best channels through which to build common understanding between US and Chinese leadership are to cultivate links with a broad spectrum of actors within the Chinese state and society. Their views will percolate up to the leadership, who will far more readily accept ideas coming from Chinese subordinates and advisors than from US negotiators. Attention at the elite level in China is a scarce resource and the more avenues the US government employs to send its message to China's leadership, the better its chances of being assimilated.

Engaging with officials and academics, particularly in China's robust government-funded think tank sector, would facilitate dissemination of American technical and scientific perspectives on the impacts of climate change and the optimal solutions. As part of this engagement, it would be worthwhile to pay attention to the terms of the evolving Chinese discourse on "Scientific Development." Relevant US Congressional committees should be encouraged to link with the Environment and Natural Resources Protection Committee of China's National People's Congress. Additionally, panelists recommended the Executive Branch seek contacts with members of China's State Councils' Inter-Agency Joint Meetings on Environment; with the Leadership Group on Climate Change, which is chaired by the Prime Minister; and with the Metallurgy Ministry and the Energy Ministry which, along with the State Planning Commission, tend to be allied with energy and heavy industry interests who oppose environmental action. Panelists observed that US mayors that are actively involved in environmental issues should engage in partnership with sister cities in China that face serious pollution issues. Bearing in mind that leadership succession is determined far in advance in China's political system, engaging directly with China's heir could be fruitful, although this would be a very sensitive move in terms of his domestic position with the other regime leadership and should therefore be handled privately and discreetly.

This broad-based engagement could also include military-to-military ties. Despite periodic tense incidences, the United States Department of Defense has constructively looked for ways to work with the Chinese. Encouraging communication reduces the risk of an inadvertent conflict as in the recent cooperation against Somali piracy. Climate change-related humanitarian missions present collaborative opportunities. Humanitarian response to climate change is one of the best examples of a recurrent, discrete problem on which the United States and Chinese armed forces can work well together. For example, the People's Liberation Army Navy (PLAN) and the US Navy could jointly respond to a severe storm, flood, or drought in Southeast Asia. China's economic and military growth means that it will increasingly have the wherewithal to contribute significantly in such instances.

According to the panel, the United States should be careful to keep engagement with elements of civil society on climate change issues transparent to the Chinese Government. There may be particular sensitivity to American approaches to Chinese NGOs. To preserve the freedom of action and effectiveness of Chinese NGO partners, they should only be contacted by US NGOs, not the US Government, and then only with the awareness of the Chinese Government. Such precautions need not apply across the board, but keeping a respectful degree of distance may ease some of China's inherent suspicion of American meddling in its domestic affairs.

Sensitivity to Domestic Constituencies. Despite the superficially monolithic qualities of China's party-state, China's international actions do not always reflect its overall national interests.

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Actors such as major corporations—including state-owned enterprises—and well-connected families have shown the capacity to successfully hijack state policy for their own profit. China's oil involvement with the controversial regime in Sudan is a prime example. Even when faced with considerable international pressure and awareness that China was not receiving commensurate benefits from Sudanese oil, the party-state proved unable or unwilling to change its policies. International pressure on climate change issues could run into similar roadblocks if powerful domestic interests in China stand to lose out, even if compliance is in China's overall interests.

Panelists observed the domestic constituencies need to be taken into account when the United States engages with China, and vice versa. Even in China's opaque authoritarian system, climate change mitigation proposals will have to survive an extensive ratification process. Attention to the actors and institutions that will be involved in that process would help tailor negotiations to produce proposals with optimal chances of receiving approval. The US can encourage cooperation and build confidence by explaining the need for China's assistance in selling an agreement to the American people. For example, if China would be willing to agree to limits on steel and coal, it would be easier to pass an agreement in the United States. In return for China's assistance, the US administration could offer to help the Chinese leadership sell the agreement to other constituencies within the party state. This reinforces the need for China and the US to view each other's constituencies as their own.

Multilateral Discussions. A multilateral approach may be the best avenue for bilateral cooperation between Beijing and Washington. While on some level, China's leadership may prefer a "G-2" approach to bilateral cooperation with the United States, as proof that China is also a superpower, on balance China is not comfortable dealing with the United States bilaterally. China perceives the US has ulterior motives and aims to subvert China's authoritarian power and re-establish the United States' global presence as the world's indispensable power. Alternatively, China prefers to have third-parties present, even if the negotiation is de facto bilateral.

The presence of a third party in negotiations is more important than the third party's particular identity. China would be more comfortable if any major autonomous actor was included in the discussions, such as Japan or South Korea. The Chinese particularly favor the other BRIC countries (Brazil, Russia, and India). Larger multilateral forums where China will feel it has allies and regional groupings such as ASEAN or the EU would also be suitable. The US could cooperate with the EU in its Clean Development Mechanism projects with China on emissions controls. Cooperative efforts are also possible via broader international bodies such as the UN's Intergovernmental Panel on Climate Change, the World Bank, or the Asian Development Bank. In sum, almost any forum or multilateral discussion where Beijing would feel less threatened by the weight of the United States would produce better results than strictly bilateral discussions.

The Copenhagen Negotiations

Taking into account China's perspective, the Copenhagen negotiations will most likely result in an agreement expecting the large emerging economies to make commitments—automobile standards, technical improvements in particular industries—that lay the groundwork necessary to put in place *future* mitigation measures without harming their economic growth. In lieu of emission caps for China—which no one really expects—a more reasonable alternative would be to develop an external international framework under a post-Kyoto agreement that would incentivize China moving away from emissions-intensive industries while compensating economically in other ways. Such a framework would allow China to comply with an international climate agreement while still fulfilling its macroeconomic goals.

Take India Into Account. Panelists recommended the US Government negotiating position take into account the unstable and complex triangular relationship between the United States, China, and India. Effective climate change mitigation, as well as US strategic interests, require careful management of relations with both of these rising Asian giants. India and China are long-term strategic competitors, including climate change-related issues such as access to the Himalayan water. Either country would perceive a bilateral American approach to the other as a major slight and an indicator of the United States' long-term strategic intentions. On the other hand, India and China have parallel positions vis-à-vis the international climate change negotiations. Both support per capita approaches to measuring emissions, stress the importance of maintaining growth and believe that developed countries must bear the lion's share of climate change mitigation measures. They are likely to diverge on the climate issue as China's growth brings its emissions profile more into line with the developed countries and as climatic disputes between the two powers become more salient. An effective agreement at Copenhagen will require the assent of both India and China.

Avoid Binary Distinctions. To further facilitate Chinese Government cooperation, panelists further recommended the US avoid the "us versus them" binary term. China's ambiguous status relative to the developing and developed countries does not lend itself to binary categorization. Leading Chinese economist, Hu Angang, proposed in April 2009 that the binary "developed" and "developing" categories used in the United Nations Framework Convention on Climate Change (FCCC) be replaced at Copenhagen by four categories along a spectrum based on the Human Development Index.

Similarly, Chinese leaders do not imagine the Chinese state as a flawed authoritarian regime competing with a democratic United States. Ruling groups in Beijing do not identify with authoritarian regimes in Moscow, Pyongyang or Rangoon. Instead, they see China as unique—a success such as the world has never known. According to the panelists, their focus should be on shared yet differentiated responsibilities to the planet, with China recognized as one of the global leaders in solving the world's problems.

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CONFERENCE REPORT

CHINA: THE IMPACT OF CLIMATE CHANGE TO 2030
GEOPOLITICAL IMPLICATIONS

This Paper Does Not Represent US Government Views

CONFERENCE REPORT

CR 2009-16 September 2009

Russia: The Impact of Climate Change to 2030

Geopolitical Implications

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Russia: The Impact of Climate Change to 2030: Geopolitical Implications

Prepared jointly by

CENTRA Technology, Inc., and Scitor Corporation

The National Intelligence Council sponsors workshops and research with nongovernmental experts to gain knowledge and insight and to sharpen debate on critical issues. The views expressed in this report do not reflect official US Government positions.

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Scope Note

Following the publication in 2008 of the National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030, the National Intelligence Council (NIC) embarked on a research effort to explore in greater detail the national security implications of climate change in six countries/regions of the world: India, China, Russia, North Africa, Mexico and the Caribbean, and Southeast Asia and the Pacific Island States. For each country/region we have adopted a three-phase approach.

- In the first phase, contracted research explores the latest scientific findings on the impact of climate change in the specific region/country. For Russia, the Phase I effort was published as a NIC Special Report**:** ***Russia: Impact of Climate Change to 2030, A Commissioned Research Report*** (NIC 2009-04, April 2009).
- In the second phase, a workshop or conference composed of experts from outside the Intelligence Community (IC) determines if anticipated changes from the effects of climate change will force inter- and intra-state migrations, cause economic hardship, or result in increased social tensions or state instability within the country/region. This report is the result of the Phase II effort for Russia.
- In the final phase, the NIC Long-Range Analysis Unit (LRAU) will lead an IC effort to identify and summarize for the policy community the anticipate impact on US national security.

In April of 2009, a group of regional experts convened to explore the sociopolitical challenges, civil and key interest group responses, government responses, and regional and geopolitical implications of climate change on Russia through 2030. The group of outside experts consisted of social scientists, economists, and political scientists. While the targeted time frame of the analysis was out to 2030, the perceptions of decisionmakers in 2030 will be colored by expectations about the relative severity of climate changes projected later in the century. The participants accordingly considered climate impacts beyond 2030 where appropriate.

This work is being delivered under the Global Climate Change Research Program contract with the CIA's Office of the Chief Scientists.

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Executive Summary

The National Intelligence Council-sponsored workshop entitled *The Implications of Global Climate Change in Russia*, held on May 18, 2009, brought together a panel of Russia experts to consider the probable effects of climate change on Russia from a social, political, and economic perspective. **The panelists concluded that Russia is reaching a point where serious deterioration of its physical and human capital is a major obstacle to sustainable economic growth and Russia's capacity to adapt and protect its people will be tested out to 2030. Climate change will add additional stress to energy and transportation infrastructure burdens.** However, given Russia's high overall state capacity and the mixed or comparatively tolerable nature of most anticipated climate change impacts over the next twenty years, climate change is unlikely to lead to a general failure of the Russian state.

Energy is the most important determinant of Russia's economic future and state capacity and climate change will have significant direct and indirect impacts on the energy sector.

- Russia's economy is vulnerable to the uncertain effects of climate change and international climate change mitigation policies that may reduce world oil and gas prices.
- Russia will need to make massive investments in its oil and gas infrastructure, including upgrades to existing infrastructure and development of new resources. Climate change will add to the cost and technical difficulty of these projects.
- Climate change-induced effects such as permafrost melting will pose a serious threat to Russia's pipelines and other aging energy and transportation infrastructure, which is already in need of replacement.

Russia has attributes that provide it with a greater capacity to respond to the negative effects of climate change than some industrialized countries and most underdeveloped ones. The state has robust capacities in areas such as analysis and forecasting, and emergency response. Russia retains, even if aging, significant Soviet-era industrial infrastructure. The population is accustomed to privation and has developed informal networks to address shortfalls in government-provided services and resources. Demand for oil and gas in Asia will keep Russia's energy revenues, and therefore state resources, at high levels through 2030.

Russia nevertheless faces limitations that may inhibit an effective response to climate change.

- Centralization of power has diminished the capacities of local and regional governments, the normal first responders to climate change-induced challenges.
- The state prioritizes development and security with little regard for environmental issues, and a significant proportion of the leadership voices the view that a warming climate is a net benefit for Russia. Energy infrastructure demands will divert resources away from climate change adaptation and mitigation.

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- Civil society—the ability for citizens to mobilize through NGOs and interest groups—is underdeveloped and civil responses to climate change, such as ecological movements, face state repression.

The considerable variation in the negative effects of climate change across the vast Russian territory also will challenge the central government's ability to respond. While climate modeling cannot reliably identify the specific effects of climate change at a local level, existing data provides insights into climatic challenges that may become most prominent in Russia's different regions.

- Melting of the Arctic permafrost threatens to undermine urban, industrial, and transportation infrastructure across northern Russia and its primary agricultural regions may face severe stress from water shortages, temperature increases, and shifts in crop zones.
- Russia will face major internal and cross-border migration, mainly into its cities, which may increase ethnic tensions. Conversely, the expected decline in the working-age population may reduce competition for employment and resources.

Russia will also face climate change-induced challenges originating outside its borders as climate change will increase competition for resources and population pressures along Russia's periphery, particularly in Central and East Asia and the Caucasus. Climatic pressures may drive migration into Russia, and the influx of migrants could stimulate xenophobia and ethnic violence.

Despite the many challenges, climate change will generate a number of benefits in some parts of Russia.

- Russia will have more water overall, which benefits hydroelectric potential, irrigation, and urban water supply.
- Warming will reduce energy demand for heating, and allow agriculture and settlement in currently inhospitable northern areas of Russia.
- Melting of the Arctic ice pack will open shipping routes along Russia's northern coast and allow access to previously inaccessible Arctic energy resources.

At Copenhagen, Moscow's probable overarching strategy will be to leave the contentious negotiations to the United States, China, India, and the European Union. Moscow will look to take full advantage of the United States' interest in brokering deals with India and China, and will take every opportunity to extract favorable concessions. Moscow may try to position itself as an important swing player and broker between the West and the developing world.

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Contents

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Background and Introduction[1]

The Russian Federation is already experiencing the impacts of climate change in the form of milder winters, melting permafrost, changing precipitation patterns, the spread of disease, and increased incidence of drought, flooding, and other extreme weather events. Many of these observed climate impacts are having concrete, negative effects on Russians' quality of life. By 2030, Russia will start to feel the impacts of climate change in relation to both water and food supply. Nonetheless, a significant proportion of the country's senior leaders continue to voice the view that a warming climate is a net benefit for Russia. Although Russia has a number of attributes that provide a greater capacity for resilience[2] in response to the negative effects of climate change than some other industrialized countries and most developing countries, as the impacts of the change continue and intensify over the coming years, Russia's capacity to adapt and protect its people will be severely tested.

The most important impacts of climate change in Russia will likely include the following:

- ***Energy*.** A warming climate holds the possibility of milder and shorter heating seasons, which in turn may lead to reduced energy demand. Increased water availability—particularly along those Siberian rivers that are used for hydroelectric power—should result in increased power production in certain parts of the country. On the other hand, existing and future energy infrastructure for the all-important petroleum industry will experience more pronounced challenges, including structural subsidence; risks associated with river crossings; and construction difficulties as permafrost thaws earlier and deeper, impeding the construction of vital new production areas. These challenges have the potential for a material, negative impact on the single greatest source of revenue to the Russian state—the oil and gas industry.
- ***Water*.** Many parts of Russia's immense territory will experience increases in the availability of water, including much of Siberia, the Far North, and northwestern Russia. This change will bring certain positive impacts, including for hydroelectricity generation. Nevertheless, managing the increased flows will pose other problems, especially when these increases coincide with extreme weather events such as downpours or springtime, ice-clogged floods. In addition, increasing water shortages are predicted for southern parts of European Russia, areas that already experience significant socioeconomic and sociopolitical stress. Moreover, a number of densely populated Russian regions that are already subject to water shortages are expected to face even more pronounced difficulties in decades to come.
- ***Agriculture*.** As growing seasons become longer and precipitation patterns change, it will become possible to cultivate northern lands that previously were too cold for agricultural purposes. It may also become possible to raise new crops and new crop

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[1] This section is extracted from the Executive Summary of the Phase I report (see Scope Note): ***Russia: Impact of Climate Change to 2030, A Commissioned Research Report*** (NIC 2009-04, April 2009). Some of the judgments in this report (Phase II) may differ from the Phase I report.
[2] See the Phase I report, p. 35 for a discussion of adaptation and resilience capacity.

varieties. A changing climate may nevertheless prove inhospitable to expanded agriculture, as whether longer growing seasons and warmer agricultural lands will result in increased yields of new or existing crops remains to be seen. Moreover, agriculture will become more reliant on irrigation (especially in the southern parts of European Russia), pesticides and herbicides, and more vulnerable to droughts and other extreme weather.

- ***Migration*.** Russia, which is already the top choice for immigrants after the United States, is likely to experience greater migration pressure from Central Asia, the Caucasus countries, Mongolia, and northeastern China.[3] The latter areas are expected to experience increased water shortages and resulting economic stress. In addition, internal migration pressures may occur as residents of Russia's many northern cities face increasing economic and climate-related challenges.
- ***Accentuation of existing socioeconomic and sociopolitical stresses*.** Russia is better equipped to deal with the impacts of climate change than many of its neighbors. Nonetheless, by 2030, climate change appears likely to accentuate some of the stresses that currently plague Russia. Some of the most affected regions already feature attenuated and unsettled socioeconomic and sociopolitical situations and most of the impacts of climate change will manifest themselves in smaller cities and in the Russian countryside. For example, the long-turbulent North Caucasus region will be drier, hotter, and less prosperous than it is today. Primorskiy Kray and the Russian Far East, which have long struggled to develop peacefully next to China, appear likely to experience even greater migration pressures, which could exacerbate longstanding cross-border tensions.

[3] Data as of 2005; see Migration Policy Institute: http://www.migrationinformation.org/DataHub/charts/6.1.shtml; viewed 23 Sep 2009

Social, Political, and Economic Challenges

Regional Challenges

Predicting the economic, social, and political impacts of climate change across the vast territory of Russia is difficult because of the lack of micro-level climate change modeling. Affects that may appear moderate when averaged out over such a large area may in fact produce extremely intense problems at the local level that may exert disproportionate destabilizing influence. Existing data nonetheless can at least be used to identify those climatic challenges that may potentially become most prominent in Russia's different regions.

Northern European Russia. The principal climate change-induced challenges facing Russia's northwest appear to be permafrost melting, which threatens to undermine urban, industrial, and transportation infrastructure, and flooding, both along the coast because of sea-level rise and along rivers due to increased river flows. Major urban centers and ports such as St. Petersburg and Murmansk will face significant risks of flooding from extreme weather events.

Southern European Russia. Russia's traditional "breadbasket" region will face serious agricultural challenges as a result of drying and warming. Crop zones may shift and rural communities will face increased stress because of water shortages and possibly increased ethnic tensions. Considerable internal migration and migration from Russia's more severely affected southern neighbors may occur. Sea-level rise will be a long-term problem along the Black Sea coast.

The North Caucasus. One of the poorest and most ethnically diverse areas of Russia, the North Caucus is expected to become even hotter and drier. Already high unemployment rates will most likely grow, increasing the region's volatility and further pressuring internal economic migration to elsewhere in the Russian Federation.

Siberia. The most disruptive climate change impact in Siberia may be the large-scale melting of the permafrost, with attendant disruption to infrastructure. River basins will face a greater risk of flooding and the region will probably see significant migration from Central Asia.

The Russian Far East. Eastern Siberia and the Far East will become wetter, with risks of coastal and river flooding, particularly along the Lena River. The region may be the target of major Russian energy infrastructure expansion, which will be complicated by permafrost melting. Migration from Northeastern China will also probably continue, creating the possibility of a demographic sea change.

Overall Economic Challenges

The classic factors of economic growth for any country are the quantity and mainly the quality of its physical and human capital and the rate of technological change. So far in its transition from central planning to the market, post-Soviet Russia has been able to exploit its inheritance of physical and human capital. But this Soviet-era legacy is now reaching a point where serious deterioration of Russia's physical and human capital is a major obstacle to sustainable economic growth. It is almost certain that Russia will not be able to solve these economic challenges by 2030 and although it can survive and even prosper in the short to medium term without seriously addressing these challenges, by 2030 the costs of managing the annual impact of the physical and human capital deficiencies will be a major burden on Russia's economy.

In addition, Russia already faces a geographic challenge to its economic cohesiveness. If looked at in terms of "effective national territory"—defined as those parts of a state that contribute to the national economy at a level greater than that relative to its population—Russia resembles an archipelago of urban, economically dynamic islands amidst an ocean of vast, relatively undeveloped geographical space. Its effective national territory forms an "economic spine" that supports the rest of the country economically and strategically.

Moreover, the wealth that is largely generated by extractive industries across Russia's vast territory is concentrated in large state-sponsored monopolies in Moscow. Local populations and regional governments receive very little of their industries' profits and have very little say in corporate decisionmaking. This geographic disconnect encourages Russian industries to treat the resource areas they exploit and their inhabitants as disposable. It also removes industrialists from the proximate effects and impacts of climate change and gives them little incentive to be responsive in terms of adopting mitigation measures, leaving it instead to the under-resourced local governments.

Energy Challenges

Climate change has the potential for a material, negative impact on the single-greatest source of revenue to the Russian state—the oil and gas industry. In some respects, however, the effects of change may prove positive, such as in reduced energy consumption for heating, a major source of energy demand in Russia. Increased river flows may boost hydroelectric potential, and arctic melting may allow exploitation of previously inaccessible subsea hydrocarbon deposits.

The energy sector, particularly the revenue derived from hydrocarbon exports, is the most important factor that will affect Russia's near, mid-, and long-term future.[4] The market value of Russia's oil and gas resources—its resource rent—is primarily a function of how much Russia is able to produce and world market prices. Oil and gas rents are and will remain a far more important driver of Russian politics, economics, and foreign policy than climate change.

Although climate change will directly affect the production and transportation arenas of Russia's energy sector, the effect this will have in turn on resource rents is unclear. It does not follow that production levels or rents will fall because the total volume of Russia's oil and gas rents depends much more on price than on quantity. Between 1996 and 2007, the volume of oil produced increased by 63 percent. Nevertheless, price increases accounted for around 84 percent of total oil rent growth, while volume increase accounted for only 16 percent.

While production levels of oil and gas may slip in the years ahead as a result of climate change-induced impacts on energy infrastructure, the key question is how climate change may affect oil and gas prices, which have historically been more volatile than production

[4] Andrew C. Kuchins, *Alternative Futures of Russia to 2017* (Washington DC: Center for Strategic and International Studies, December 2007).

levels. Presumably global supply of and demand for oil and gas—the fundamental determinants of price—will be affected by climate change, although the magnitude and direction of these effects could be quite uncertain. In addition, the global response to climate change will have a huge but still-indeterminate impact on demand for energy, particularly in light of decisions of the major economic powers regarding a move away from fossil fuels.

Oil and Gas Infrastructure and Development Challenges. The bulk of Russia's energy extraction infrastructure dates back to the Soviet period and therefore Russia was able to unleash tremendous excess capacity—and realize windfall revenues over the past decade—by applying more up-to-date techniques to the inefficient and wasteful legacy infrastructure. The gains in efficiency from this so-called "brownfield miracle" have now largely run their course, production levels—for example in Western Siberian oil and gas fields—are waning, and Russia will need to turn principally to "greenfield" development of new energy sources to keep production up. Many of the potential greenfield sources are in remote and exceptionally harsh locations in Russia's far northern and eastern regions. Vast new transportation infrastructure will be needed even to reach these areas, let alone transport the extracted energy to customers. Oil and gas extraction present roughly equivalent technical challenges and costs, and deposits are located in equally difficult geographic regions of Russia. Climatic challenges will further complicate this development, as permafrost melting and more volatile weather will impede access to and construction of vital new production areas.

In addition, Russia will face huge replacement costs for its Soviet infrastructure on top of the costs associated with new energy development. Climate change-induced effects, particularly permafrost melting, again are likely to add even more to these expenses because the Soviet-era infrastructure was built on the permafrost and designed accordingly—as the permafrost thaws earlier and deeper it will cause structural subsidence and force the replacement of a considerable amount of infrastructure that might otherwise simply have been repaired and updated. In contrast, the greenfield infrastructure can be designed from the outset to compensate for the altered conditions. Climate change may therefore render greenfield development, even in remote areas, more competitive with brownfield replacement than would otherwise be the case.

Regardless, Russia's development of the technically and climatically challenging new energy projects and replacement of its existing infrastructure will be the largest capital expenditure projects in the history of the planet. Russian sources estimate that developing oil and gas deposits in the Arctic regions will cost $500 billion, about the size of Russia's entire hard currency reserves at their peak in mid-2008. Not surprisingly, the current economic downturn has significantly reduced Russia's enthusiasm for launching these projects in the near term. While they have subsequently rebounded, oil and gas prices declined nearly threefold since the summer of 2008, dropping well below the $70 per barrel that the Russian Government considered necessary to make Arctic development feasible.

Challenges to Transportation Infrastructure

Climate change is anticipated to cause potentially serious periodic disruptions to Russian transportation and increase the strain on transportation infrastructure. As opposed to creeping environmental change in which effects occur slowly over time some climate-induced changes, such as flooding in major river basins including St. Petersburg, more snow in non-European Russia, and more frequent mudflows and landslides, will present immediate challenges to transportation and may separate Moscow, the economic center, from the regions and industries that fuel of the national economy. Such disruptions to commerce and economic activity may be sporadic and difficult to predict or to prepare for and will necessitate large-scale investments in infrastructure.

Permafrost melting is a major concern for the maintenance and viability for commodity flows of transportation systems, including those that serve the oil and gas pipelines in central and eastern Siberia. Because a significant proportion of road and railway networks are constructed on permafrost, increased melting could swallow the transportation networks of large expanses of Russia's territory into a swampy morass for a significant part of the year. Russia has a comparatively under-developed road and highway network and is far more dependent on railroads for long-distance transportation than most industrialized countries. Beyond the effects of permafrost melting on the rail system, increased river flows may threaten the structural integrity of railway bridges.

Waterborne transport faces mixed impacts from climate change. New ports and shipping routes in the Arctic may be offset by increased threats of flooding of existing ports and higher incidence of severe storms. Increased river flows may facilitate the use of rivers as transportation arteries, particularly in Siberia, but also brings increased risks of catastrophic flooding and ice jams. Additionally, the structures located at thousands of river crossings are unlikely to accommodate increased water levels associated with climate change.

Agricultural Challenges

The future impact of climate change on Russian agriculture is uncertain. Warming will lead to longer growing seasons, less frequent bitter winters, and more northerly areas open to cultivation. Expected resulting increases in yields will be at least partially mitigated by other climate change-induced effects such as greater weather variability, more frequent severe weather events, and the spread of plant diseases and pests into new areas.

The expected northward migration of planting zones will be a complex process with mixed impacts. The climatic conditions suitable for warm-climate crops such as cotton, grapes, tea, citrus, and other fruits and vegetables will move northward from Central Asia and the Trans-Caucasus into the North Caucasus and Volga regions. Depending on the specific crops, the northward shift may involve a broadening of the zone of potential cultivation. Alternatively, it may entail a shift in both northern and southern margins of the planting zone such that current cultivation areas will no longer be able to support historic crops. The latter scenario may have catastrophic effects on single-crop dependent agriculture such as in Central Asia. The outlook is further complicated by the fact that although climatic bands may shift, soil bands such as the Chernozem (Black Earth) will not. If climatic movement pushes crops into areas with unsuitable soil, yields may drop significantly and it may no longer be possible to cultivate certain crops at all.

Although new agricultural areas will open up, the areas on which Russia has historically depended and around which its agricultural infrastructure is organized will suffer increased stress. Many of the fertile Chernozem agricultural regions of southern European Russia—such as Belgorod, Voronezh, Kursk, Lipetsk, Orel, and Tambov Oblasts—are expected to experience water shortages and sustaining agriculture here will require increased irrigation and reliance on chemical additives. In the longer term, Russia faces a need to refocus its agricultural enterprises northward, which may entail uprooting an entire region's socioeconomic system.

Urban Challenges

As migration to urban areas increases, climate-induced hardships, such as the water shortages anticipated for the Moscow Oblast, will affect increasing numbers of people. Energy blackouts and brownouts resulting from unreliable or insufficient energy supplies can cause local economies and productivity to grind to a halt. Heat waves are likely to lead to increased levels of secondary pollution and public health stress. Water treatment in cities could be impaired and waterborne illnesses could rapidly affect an entire city. Infrastructure in many Russian cities is already decrepit and inefficient, and could be further damaged by climate change-induced effects.

Although overall climate change effects do not appear likely to create chronic or insurmountable disruptions for Russia's urban population, an increase in extreme weather events—including heat waves, storms, flooding, water shortages or contamination, and outbreaks of disease—could threaten cities with sudden local disasters.

Demographic Challenges

Unrelated to climate change but a factor certain to compound the impact of that change are demographic challenges that threaten Russia's human capital—that combination of the number and age of its citizens, their health, their education, and their location. A health crisis threatens productivity; a mismatch exists between the types of skills being produced by the educational system and economic needs; and mobility problems prevent reallocation of human resources in an effective manner.

A declining population is another aspect of this demographic challenge. The Russian Federation today is a great deal more homogeneous than was the Soviet Union but Russia's population has been in decline since the end of the Soviet Union. The Slavic population had been falling even before that time, although this drop was offset by high birth rates in the non-Slavic population. As a result, the Soviet Union was less than 50 percent Russian by 1989. Today the population is about 80 percent Russian, boosted by migration of ethnic Russians from the Former Soviet Republics since 1991.[5]

The population decline, although it has slowed in recent years, is primarily the result of a substantially higher mortality rate, particularly among working-age males, than other countries in Europe. Estimates of life expectancy by Russia's State Statistics Agency (Rosstat) suggest that after 2008 Russia will see the beginning of a decade-long precipitous decline in working-age population. By 2015, that group is projected to decline by 8 million and by 2025 by 18-19 million. This decline is more serious when one factors in the high numbers of the population who are incapacitated due to chronic health problems.

[5] Although Russia hosts nearly 160 ethnic groups, the only minorities with over a 1 percent representation in the population are Tatars, Ukrainians, and Chuvash.

Given the downward demographic dynamics in Russia's Slavic population, increased immigration was already poised to play a greater role in filling Russian labor needs in the first half of the twentieth first century, leading to a more diverse nation with higher percentages of Asians and Muslims. Increased immigration because of climate change-induced stress in Central Asia and China can be expected to accelerate these trends. The prospects for further ethnic diversification as a result of immigration and disparities in birth rates have revived late Soviet-era fears that ethnic Russians may become a minority in Russia, although such fears do not appear to be borne out by the demographic facts. Popular conceptions of an internal Muslim demographic time bomb also seem exaggerated. There are less than 11 million Muslims in Russia, and their birth rates are dropping. Traditional Muslim birth rates among the larger Muslim ethnic groups such as Bashkirs and Tatars are not much higher than those among Slavs, and birth rates have even declined in the Caucasus.

Ecological Challenges

The effects of climate change will not be limited to human systems. Effects such as changes in growing seasons, permafrost melting, more frequent forest fires and floods, and the spread of disease will have broad-based impacts on Russian ecosystems. Entire ecosystems may shift into new geographic areas, such as the sub-Arctic taiga forest encroaching on more northerly areas previously dominated by tundra. In some parts of the North, warmer climatic conditions may lead to increased biodiversity. On the other hand, the stress associated with flora and fauna moving into new areas and competing with native plant and animal life may result in extinctions threaten and more species. The impact of climate change on Russia's vast wilderness ecology is particularly significant in part because many indigenous peoples depend on these ecosystems. Natural ecological change will in some cases be worsened by the secondary impact from human actions that are driven by increasing economic and climatic stress.

Climate change effects such as increasing sea-surface temperatures, changes in ocean circulation patterns, sea-level rise, changes in water levels in lakes and streams, and river and coastal silting caused by increased river flows, could create problems for fish populations. In the Caspian Sea, for example, an anticipated decrease in water levels is expected to reduce the number of sturgeon, an important industry in the region. It is not clear how climate change will ultimately affect fishing, but preliminary evidence suggests that in some cases fish schools are beginning to move to new waters, and in other cases fish stocks are decreasing.

In addition, climate change is likely to exacerbate the threat of disease caused by insects and vermin. Milder winters allow pests to thrive in more northerly areas, and Russia is already beginning to see an increased incidence of diseases more familiar in warmer regions.

Political Challenges

The sheer size of its territory and wide dispersion of its population have posed a perennial governance challenge for the Russian state. The country's extreme regional social, economic, and ethnic disparities are difficult to reconcile with the strong tendencies toward centralization of power and authority in Moscow. The oil center of Khanty-

Mansiysk in western Siberia, for example, enjoys a per capita GDP comparable to that in the United States, while Vladikavkaz in the Caucasian republic of North Ossetia has a per capita income 30 times smaller. Moscow faces a huge political challenge in providing effective governance to cities and regions on both ends of this spectrum and every point in between.

During the Yeltsin years, state authority was diffused among the constituent regional and local levels of government, particularly to the ethnically defined republics within the Federation. Under Vladimir Putin, Moscow reversed this trend and undertook a sweeping recentralization of authority. The federal subjects—oblasts, republics, and krays—were grouped within seven large federal districts with centrally appointed governors. Local executives are heavily influenced by Moscow but locally elected. Although local parliamentary bodies are technically still elected, in practice higher authorities suggest candidates, whose election campaigns are state-funded. Power trickles down from the Federation level, curtailing the influence of budding, local-level civil society. Further erosions of federal subject authority may occur, such as the political restructuring of critical resource areas away from the control of the more sovereign federal subjects, such as the ethnic republics. This could be undertaken officially through boundary changes, or more insidiously by de facto economic relationships. The recentralization of authority already has aroused resentment among local actors who have sought to renegotiate their political rights and regain some of sovereignty from Moscow.

Such federal-local tension may be exacerbated if local authorities find themselves under increased stress because of climate change. Given Russia's geographic extent, regional climate change impacts will vary widely and may be best addressed at local and regional levels of government; but the state's tendency toward centralization of authority in Moscow may adversely affect the country's ability to respond to local climate change-induced challenges, worsening these problems and even causing them to spill over and affect the country more broadly.

Civil and Key Interest Group Responses

Civil Society

The legacy of Soviet-era control over political and social activity continues to undercut civil society in Russia and the other former Soviet countries, both through lingering social inhibitions and continued state repression. Political and social activism has tended to be scrutinized, if not outright discouraged, by the government. As a result, few individuals will admit to involvement in a non-government organizations (NGOs), social organization, opposition political party, or civic group and most are cynical about what can be achieved through such channels.

Informal Networks. Absent overt civil society mechanisms, many Russians have developed alternative, informal social networks to deal with day-to-day issues such as commodity shortages, which are likely to play a major role in how the public responds to the effects of climate change. The black market thrives and Russia is host to a large number of unofficial networks based on clan allegiance, ethnic identity, and any number of other criteria. These networks command a great deal of social power outside of the government, but are tolerated as long as they do not infringe upon the state's domain. Indeed, it is arguable that these networks actually strengthen the state: aided by the networks, the Russian people may feel they do not need to mobilize politically.

Ecological and Environmental Movements. Some civil organization nonetheless has occurred related to the environment and the environmental effects of climate change. The development of ecological movements, particularly in Siberia, has been increasing, bolstered by the interaction between these movements and indigenous cultural and ethnic preservation movements. Such collaboration is likely to increase as Russia feels greater effects from climate change.

In the Siberian North, where initial effects of climate change are being felt, indigenous activists are conducting their own environmental measurements because they distrust reports from the regional and central government. They have merged "folk knowledge" about climate change with broader scientific reporting and accelerated indigenous people's concerns. As a result, a high level of public awareness about climate change effects, such as methane outgassing from melted permafrost, now exists in this region. Public awareness in other parts of Russia is also likely to increase along with global awareness, particularly with the advent of more precise and reliable climate change measurements.

Local mobilization around environmental issues already has managed to convince Moscow to change course in some instances, as happened in the case of a pipeline proposed for the Lake Baikal area. More commonly, even when local and indigenous responses exceed what Moscow had expected, as in the case of a local referendum against a planned hydroelectric dam on the Lower Tunguska in Krasnoyarsk Kray, broader economic considerations remain the deciding factor. Even if local mobilization against mega-infrastructure projects such as dams and pipelines intensifies, it is not likely to rise to a level that seriously challenges state security or deters decisionmakers from pursuing national-level plans they perceive to be in Russia's overall interest.

Rural Responses

In general Russia's rural areas will bear the worst strains from climate change, including the immediate effects on agricultural productivity, interrupted connectivity to cities and sources of non-local commodities and energy, as well as health impacts of increased bogs, floods, disease vectors, altered temperature patterns, and food quality and supply. The ability of rural populations to cope will depend on several factors including the health of the local economy, the ongoing, toxic Soviet environmental legacy, and the degree of new climate change related stresses. However, rural residents may be more likely than then urban residents to have back up food supplies, traditional ways of dealing with sickness, and strong social networks.

The West and South. In considering how the Russian countryside will respond to climate change, it is important to distinguish between agricultural and non-agricultural rural populations. Russian agriculture—and its rural population—is concentrated in southern and central European Russia, from the Black Earth of the Ukraine to the southern Urals. Conditions in these areas vary: in southern Russia, the rural areas are more vibrant, with agricultural towns of 10,000-100,000 inhabitants who benefit from a favorable climate. The more northerly agricultural areas, in contrast, feature small, 19th-century-style farms with low productivity and elderly populations.

These two markedly different rural agricultural models are likely to have quite different responses to climate change. Elderly rural dwellers are unlikely to move or generate conflict in the face of climatic stress, nor are state resources likely to be directed toward maintaining marginally productive agricultural areas. This way of life is already dying out, and climate change may simply accelerate the process. The response in the more intensive agricultural areas of the south is likely to be far more dynamic. Migration to the cities is likely to increase, as are demands for aid from the state, particularly in the area of expanding irrigation infrastructure, and conflict over water and other resources may become commonplace.

The East and North. The majority of Russia's territory, particularly in Siberia and the Far East, is a demographic and agricultural desert and will have a very different experience of climate change than the west and south. Russia's northern lands are a zone of poverty, soaring unemployment, industrial over-extension, and instability. The small and widely separated population is overwhelmingly urban and the tiny rural population—primarily indigenous peoples—is engaged in herding, hunting, fishing, and resource extraction, not agriculture.

The rural inhabitants of Siberia and northern European Russia have already begun to experience climate change-induced pressures, resulting in a loss of traditional means of subsistence and forcing many to move to increasingly larger towns and villages; however, any mass migration appears unlikely given the mixed impact climate change may have in these areas. Moreover, although shifts in traditional practices and ways of life will be traumatic, such shifts are already under way as a result of resource development and northern populations, already resilient to climatic challenges, are already responding to the leading edge of climate change.

Prospects for Rural Unrest. Historically, stress on rural areas was a major source of destabilizing political unrest in Russia but severe challenges to the state from the countryside are no longer plausible in post-Soviet, urbanized, industrial Russia. Rather, as noted previously, it is the lack of federal interest in or attention to their plight may be the most challenging aspect of rural society's response to climate change.

Urban Responses

Nearly three-quarters of Russia's population is urban. In some cities, the overall effect of climate change may be only a moderation of the harsh weather perhaps a welcome change for Russian urbanites. Given gradual climatic shifts, Russia is likely to have the resources to adapt its urban infrastructures to new conditions. Nonetheless, urban dwellers may face disruptions to transportation, food and water distribution, electricity, heating and air conditioning, waste removal and treatment, and public health. Such effects, perhaps severe in isolated cases, may be felt primarily by the very young, the very old, those with compromised immune systems, and those residing in hospitals or other institutions. Russians have low expectations regarding their government but climate change-induced challenges may shed more light on existing deficiencies and lead urbanites to demand more from their local and central government

Prospects for Urban Unrest. Russia's more recent historical experience suggests that the greatest danger from political unrest comes from the major cities, such as Moscow and St. Petersburg where the concentration of population and economic and political power means that a serious climatic event there could have major repercussions for the stability of Russia as a whole. The most serious threat may be a major flooding event in St. Petersburg. A truly catastrophic event of this magnitude in which federal and regional officials and agencies demonstrate tragic incompetence would be a massive blow for the state to absorb. Moscow is less threatened than St. Petersburg and other major cities. Owing to its privileged status, authorities will ensure the capital receives the resources it needs to cope.

Ethnic Minority Groups

Climate change may have a particularly significant impact on Russia's diverse ethnic minorities, depending on where they reside. Climatic shifts may disrupt traditional ways of life among groups—who are already under economic pressure—and in some cases force them to migrate and be subsumed within the larger Russian population and subjected to cultural dislocation, discrimination, and even violence. Climate change may spark increased resource competition among co-located ethnic groups. Groups living in isolated areas may suffer disproportionately from disruptions to the transportation network.

Moreover, climatic stress can be a key element inter-ethnic tensions devolving into violent conflict. For example, in northeastern Kenya in early 2009, drought and resulting crop failures sparked increased tribal clashes over water and pasture lands, high food prices, and the decimation of goats and sheep by a viral disease. Many minority groups in Russia live at a subsistence level in marginal areas where fairly minor climatic shifts could generate considerable local stress and resource conflicts that might play themselves out along ethnic lines.

The North Caucasus. The North Caucus region—the most ethnically heterogeneous region in the world and the site of numerous recent inter-ethnic or ethno-nationalist conflicts—often is cited as having the most potential for ethnic conflict as the result of climate change. As noted previously, while the region is projected to bear the brunt of climate change-induced drying and warming trends, it is one of Russia's poorest and least-prepared areas to cope.

However, when the North Caucasus is considered in aggregate, the region is extensive and expected climatic impacts in particular areas do not appear to correlate with existing ethnic fault-lines. Indeed, the regions expected to bear the brunt of water shortages and agricultural disruptions—the steppe and the Black Earth—do not have heterogeneous populations or unstable political situations; while areas characterized by social and political tensions—from Kabardino-Balkaria to Dagestan—appear more likely to experience agriculturally friendly trends such as increased water availability, more mild winters, and warmer weather. The North Caucus will certainly remain an ethnically charged region, but climate-induced conflict does not appear likely.

Siberian Indigenous Peoples. Indigenous peoples have shown a prescient grasp of the profound impacts climate change may have on their native regions. Siberians never needed scientists to tell them that their food chains were more fragile than other areas farther south. The lasting effects of marks from all-terrain vehicles and the easy destruction of, lichen, the main food source for reindeer, that rejuvenates in multi-year cycles or not at all, alerted them early after Russian mining and energy developers entered their territories. They have already seen and felt the loss of their hunting, fishing, cattle, horse and reindeer breeding territories in numerous places, at increasingly alarming rates. With projected climate changes they fear increased forest fires, oil pipeline fractures, and the return of long submerged illnesses—anthrax for animals, small pox for humans. Indigenous peoples, who believe in the delicate interrelationship of humans to nature, are already voicing their concerns over environmental degradation and climate change and tend to conceptualize climate change as nature taking revenge for human transgressions. These beliefs have manifested themselves in increasing interest in environmental issues and interaction with ecological groups.

To the extent that indigenous groups mobilize politically, they may become useful political levers for other interest groups. In the 1990s, ethnic Russian interest groups used indigenous mobilization as a way to leverage support for their own interests. In such situations, minority groups could become levers that challenge state authority even if their intrinsic political clout is minimal.

Internal Migration

The Russian Government's recently published climate change doctrine highlighted internal migration as a key concern arising from climate change. Russia already faces a great deal of economically driven internal migration, with movement from the East into the West, and from rural to urban areas.

Climate change will also "pull" migration into more northerly areas: the likely opening of new oil and gas fields in the north and east and the massive accompanying infrastructure projects will draw labor into previously sparsely-populated areas of Russia, as will the potential opening of Arctic shipping routes. Although large-scale shifts in population will no doubt cause social and economic strains, voluntary migration in response to labor demand is likely to be considerably less destabilizing than involuntary movement of refugees out of stricken areas.

However, large-scale, sudden or protracted internal migration because of climate change could create local distortions in the labor market, increasing competition, frustration, and racial violence. The urban metropolises of Moscow and St. Petersburg are already experiencing tensions and violence directed against Caucasian migrants and immigrants of Central Asian descent. Indeed, anti-immigrant hostility and xenophobia are deeply rooted and widespread on the streets of Russia and a growing number of violent neo-Nazi and others groups already blame minorities and immigrants for a host of economic and social problems.

The most destabilizing type of internal migration could be the displacement of agricultural populations into previously homogeneous rural areas and towns where they will compete for resources with established groups.

State Responses

While the Russian state will need to expend considerable effort to address climate change -induced challenges, historically it has successfully tackled large-scale challenges under harsh conditions. Given Russia's high overall state capacity and the mixed or comparatively tolerable nature of most anticipated climate change impacts over the next twenty years, climate change is unlikely to lead to a general failure of the Russian state.

The Russian political elite has historically viewed climate change as a net positive for Russia, anticipating that warming will alleviate some of the challenges associated with the country's cold climate. This attitude is now changing: some Russian leaders now realize the possibility that climate change may have a number of deleterious social, economic, and political effects on Russia, an awareness that is likely to lead to measures to alleviate some of the most dramatic impacts.

Climate change is likely to generate complications and challenges for the state in two principal areas. First, the differential impact of climate change across the Federation will complicate centralized governance and policymaking in Moscow. Russian authorities already face considerable challenges in managing a vast federal state with extreme regional socioeconomic disparities and considerable ethnic diversity. The addition of differing, and in some cases opposing, climatic shifts and consequent movement of people and economic activity will only make the Federation more difficult to govern.

Second, as previously noted, climate change will affect how the Russian state and its (largely state-sponsored) energy industries implement the massive infrastructure projects and investments needed for the continued development and solvency of the critical Russian oil and gas sector. These projects will have to be undertaken regardless of climate change, but climatic impacts may render the process more expensive and technically challenging.

Climate Change Mitigation Policies

In May 2009, in preparation for the Copenhagen Climate Conference later this year, Russia's Ministry of Natural Resources and Ecology unveiled a climate doctrine that outlines the country's response to climate change. The doctrine, prepared without public scrutiny, came as a surprise, particularly because of the change in tone among Russian officials that it reflects: rather than emphasizing the benefits of milder winters, the opening of the Arctic coast, and longer growing seasons, the doctrine warns of serious climate-induced challenges and outlines adaptive measures.

According to the Minister for Natural Resources and Ecology, Yuri Trutnev, Russia will need to take a strategic, long-term approach to adapt to climate change, looking at least to 2030 and as far as 2050 in some sectors. The climate doctrine is intended to provide guidelines for planning and instituting that policy approach, and calls for a range of initiatives:

- Increased research in order to acquire more precise and reliable data on climate change. Russia should establish a climate change oversight body and potentially a national center for climate studies.
- Expanded and updated state environmental regulation and legislation to bring Russia into line with international norms on climate change; more stringent regulation of

industrial carbon and emissions; measures to stimulate responsible resource use and efficiency; and better natural resource management.

- Structural change in Russia's economy aimed at increasing the resilience of key economic sectors such as agriculture, transport, and energy, to include a redistribution of resources and economic activity to meet shifts caused by climate change.
- Development of alternative energy sources to help meet domestic energy needs, as well as increased energy efficiency, an initiative in which Russia had not previously shown much interest.
- Participation in international climate change initiatives.

Although the doctrine reflects some new sensitivity on the part of the Russian Government to potential adverse consequences of climate change, it is not clear if the policies articulated in the doctrine go beyond rhetoric in part because the Moscow's support for the initiatives has to date been vague. In addition, critics have charged that the doctrine does not go far enough in addressing the root causes of climate change and rather focuses on alleviating the effects.

State Priorities

Except in wartime, few states have historically prioritized state security in as stark terms as Russia. The Russian Federation and its Soviet precursor have been willing to sacrifice progress in virtually every social, economic, and technological area in order to focus on security and the military. Even today, with an emphasis on energy export-led economics, state security remains the ultimate priority of Russia's decisionmaking elite.

Russia's approach to state security is characterized by caution and paranoia. Having weathered a huge economic and political crisis in the 1990s, Russian leaders are very conservative and place a premium on precautionary measures. Moscow feels a sense of vulnerability because of its relative demographic and geopolitical decline vis-à-vis both its longstanding rivals and new, rising powers. As a result, Russian planners and decisionmakers typically focus on worst case scenarios and remain largely unwilling to depend on other countries for food, energy, or physical security.

A state whose primary goal is security will respond quite differently to climate change effects than one oriented toward economic efficiency. The goal of efficiency dictates policies such as competition, pluralism, entrepreneurial independence, and participation in the global division of labor. An emphasis on security, in contrast, leads to excessive control, a high degree of redundancy, lack of specialization, resistance to interdependence and openness, and a focus on building up reserves of various kinds. Climate change-related tradeoffs will be framed in terms of their net effect on state resilience more so than their economic impact. Climate change-induced challenges are likely to necessitate a broad range of state interventions including mega-infrastructure projects and local-level responses to discrete incidents.

To insure that these challenges do not rise to levels that threaten security, the state must bolster its overall capacity to respond and adapt. Therefore, if expenditures are seen as preserving state power and stability, the Russian state may be willing to spend more on climate change mitigation than a growth-oriented state. Although Russia favors efficiency and global cooperation in responding to climate change, Russian leaders, preferring autarkic solutions, will most likely not allow the country to be placed in a dependent position.

Policy Decisionmaking. The current Russian leadership has tended strongly toward a pragmatic approach to policymaking aimed at keeping Moscow's options open until the outcome is fairly certain. The Russian Federation is much less bureaucratic than the Soviet Union; decisionmaking is more personal and less institutionalized; planning is less complex and deliberative; and the policymaking process is opaque and in many cases a formal process may not exist. Another critical feature of decisionmaking in Russia is the conflation of Kremlin officialdom and the corporate elite, to the point that the distinction between state policy and corporate policy is often arbitrary.

Overall, the Russian state leadership expends much less effort to monopolize decisionmaking than was the case in Soviet era, primarily stepping in if an issue is deemed a national security threat and/or requires a major state initiative to address it. In such cases, both the Soviet and post-Soviet regimes have shown a capacity to rapidly come to decisions and act on them, which may facilitate the rapid adoption and implementation of major initiatives to deal with climate change related incidents. But such actions will tend to be reactionary and done with an abbreviated policy formulation process that has in the past led to deeply ill-considered policies with disastrous long-term side effects.

State Capacity

Russia faces a very complex planning, prioritization, and implementation challenge regarding its responses to climate change. Nevertheless, heavily industrialized and well-educated, with an outsized national security establishment, the Russian state already has a robust capacity to respond to climate change, which could be boosted even more with investments over the coming years.

Analysis & Forecasting. Russia has a strong scientific establishment and its research institutes and universities provide ample expertise and infrastructure with which to gather data on climate change, analyze it, and produce forecasts. The lead agency involved in such efforts is the Federal Service for Hydrometeorology and Environmental Monitoring (Roshydromet), the Russian equivalent of the US National Oceanographic and Atmospheric Administration (NOAA).

Emergency Response. Russian capabilities in emergency response and disaster consequence management are relatively robust. The lead agency for emergency response is the Ministry for Affairs of Civil Defense, Emergency Situations and Disaster Relief—better known as the Ministry of Emergency Situations or the Emergency Control Ministry (EMERCOM)—the Russian equivalent of the US Federal Emergency Management Agency (FEMA). EMERCOM has a reputation as a dynamic and effective agency, and has capabilities to respond to a wide variety of climatic incidents throughout the Federation, including forest fires, floods, and storms. Acting through the Prime Minister's office, EMERCOM can draw on assistance from the Ministry of Defense and Ministry of the Interior, as well as assistance from foreign and international disaster response agencies.

This paper does not represent US Government views.

Environmental Protection. In contrast to emergency response, environmental planning and prevention are weak. Environmental oversight within the Russian state bureaucracy is housed in the Ministries of Regional Development and of Natural Resources and Ecology, both of which are primarily charged with facilitating economic development and resource extraction. These ministries collaborate with the increasingly compliant, non-elected republic and regional governments. This creates a conflict of interest situation in which development goals supersede environmental concerns and ecological oversight is pro forma or corrupted. Problems include data collection, secrecy, and, especially, a lack of systematic efforts to curtail or repair environmental harm with sustainable development.

State Resources. As mentioned earlier, Russia's oil and gas wealth is by far the most essential element of its "adaptive capacity." A historical correlation exists between the value of oil and gas rents, on the one hand, and Russian and Soviet economic performance and political behavior, on the other (Figure 1). When resource rents are high, the Russian political system tends to be assertive, centralized, and less prone to reform. When the rents grew in the 1970s and early 1980s, the Soviet Union entered an expansive phase both economically and politically. The subsequent collapse of oil rents was followed in short order by the collapse of the Soviet Union. The sharp growth of oil and gas rents in the late 1990s-2000s correlates with the resurgence of authority and stability for which Vladimir Putin is often given credit.

The future price of oil (and gas, which follows the oil price closely) is one of the most uncertain of all economic parameters. Taking a high-price scenario of oil prices averaging $120 a barrel through 2030 and a low-price scenario of $40 a barrel, forecasts of Russian oil and gas output can be used to give a plausible range for Russia's future resource rents. In either case, rents would provide Russia with a great deal of wealth to meet significant climate and aging infrastructure challenges if they can be efficiently and effectively applied to that end. In the high-price scenario, Russia would enjoy a staggering amount of wealth over the next 20 years, on average 30 percent higher than in the historically boom year of 2008. Even under the low-price scenario, the average annual rents would be 80 percent higher than in the preceding 21-year period, 1987-2008. Only the unlikely combination of an extended period of very low oil prices and poor policy in managing rents will produce a Russia as poor and weak as it was in the 1990s.

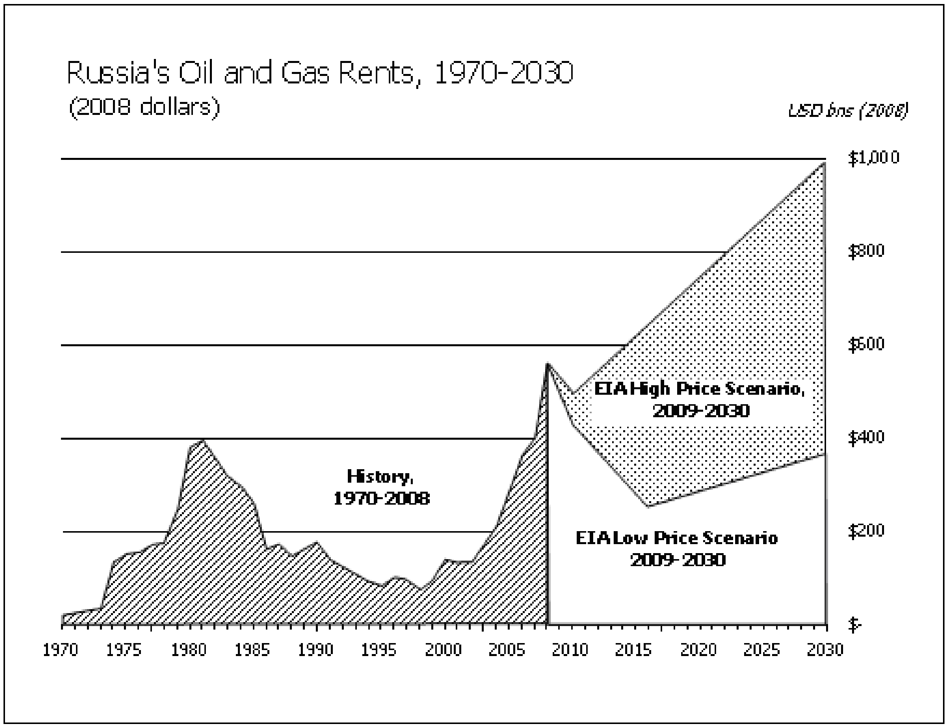

Figure 1. Russia's Oil and Gas Rents, 1970-2030. Source: Clifford G. Gaddy, data from US Energy Information Administration (EIA), "International Energy Outlook 2008."

State Repression. When considering whether instability generated by climate change might pose a threat to state security, it must be taken into account that the Russian Federation has an extensive and capable repressive internal security apparatus at its disposal. The Federal Security Service (FSB) is a pervasive presence that has largely reclaimed the virtually unchecked powers it had in its previous incarnation as the Committee for State Security (KGB). The Ministry of the Interior (MVD) disposes of some 200,000 fully equipped internal security troops with which to put down armed insurrections. Special Purpose Police Squad (OMON) riot control units are stationed in every Russian oblast and major city.

Civil groups and non-governmental organizations are allowed, but are continually scrutinized, discouraged, and hindered in their activities in many indirect ways. Such coercive measures may be directed at ecological movements that might otherwise assist the state and society in responding to climate change-induced challenges. State coercion already has included publicly discrediting leading ecological figures and permitting or directing attacks on ecological groups by nationalist extremists.

"Level" of the Response

The governments of the constituent republics, oblasts, and krays in many respects will be better positioned to observe and respond to the considerable variety of climate change-induced challenges across Russia. Horizontal mobilization across republics, oblasts, and krays is possible—perhaps organized around shared climate change impacts. State centralization, however, has robbed the federal subject governments of authority and resources, which may dramatically reduce their effectiveness as first responders to the effects of climate change.

Ineffective policy responses from Moscow, lack of consideration of local or regional interests, and lack of attention to local or regional problems arising from climate change may lend increased impetus to demands for decentralization from the constituent levels of the Federation government. Climate change may thus become a rationale that regional and local governments can use in negotiations with Moscow for greater authority and resources.

Territorial Integrity. Russia is set to undergo a geographic shift in economic activity and population unrelated to climate change in which regions distant from Moscow may experience significant gains in population, development, and economic power. If coupled with a perception that Moscow is unresponsive to local concerns—such as local effects of climate change—this increased clout may cause governments in the peripheral federal subjects to question their allegiance to the Federation. For example, if Sakhalin Oblast, in the Russian Far East, north of Japan, becomes a key energy producer, its leaders might question how it serves their interests to continue to be integrated with Russia rather than pursuing closer ties to their proximate customers in Northeast Asia.

That being said, the central government is highly unlikely to allow threats to the Federation's territorial cohesion to fester, as the precedent of Chechnya illustrates. The reassertion of Federal power under Vladimir Putin has for the time being reined in the federal subject governments, and if they try to reassert themselves over the next two decades they will have a steep hill to climb. In addition, Moscow has shown interest in creating more cohesive national infrastructure as a means of strengthening ties with distant regions, and is incorporating that strategic intent into its development projects. The Eastern Gas Program, for example, envisions investment in gas-dependent industries (such as fertilizer production) in the Russian Far East and the connection of the Far Eastern gas fields with fields as far west as Lake Baikal. These efforts may be driven by a desire to reinforce cohesion more than economic considerations: if Moscow is able to maintain political influence over its distant territories in the Russian Far East, resource development in the region could serve as a catalyst to hasten the integration of Russia with the economies of the Pacific Rim.

Urban Planning. Climate change-related problems in cities have the potential to rapidly become severely destabilizing. To the extent that municipal governments remain under-resourced and subject to cumbersome, overly centralized state control, they have the potential to become weak links in Russia's state response capacity.

Environmental Protection. The federal subject governments are much closer to the ecological issues facing their regions than the central government and are more responsive to local ecological activism. The federal subjects of the Siberian North, strongly influenced by the beliefs and traditions of their indigenous inhabitants, have been particularly active in autonomous environmental preservation measures. The Sakha Republic, for example, features an excellent network of ecological protection zones: two major federation level preserves, five national parks, 78 reserves, and numerous other protected areas of local interest. The Sakha Republic Ministry for the Protection of Nature publishes yearly reports available on the Internet documenting at least some efforts at monitoring ecological devastation and planning for more Sakha preserves in the face of huge pressures for further development of the republic. Nevertheless, local authorities are sometimes loath to admit their failure to protect the health of their communities by publishing data on environmental degradation and pollution. In addition, local authorities have in many cases allowed mineral and energy exploitation to become priorities, overriding local interests even while giving lip service to the importance of ecology and "lands of traditional means of subsistence."

State Economic Policies

The former Soviet regime managed its resources and economy poorly and fell so deeply in debt to Western governments that it sacrificed its financial, and in effect its political, sovereignty. From this experience, Vladimir Putin and his associates concluded that financial and fiscal health were essential. Consequently, as oil prices rose, the Putin regime prioritized the use of the windfall to pay off the country's foreign debt and build reserves. Russia's foreign exchange reserves, now the third largest in the world, play a critical role primarily in protecting Russia's financial sovereignty and secondarily ensuring the welfare of its citizens. Looming increases in expenditures and greater economic uncertainty as a result of climate change are apt to reinforce these tendencies.

Marginally but not dramatically lower levels of revenue derived from hydrocarbon exports may also spur more rapid, but still limited diversification of the Russian economy. Public rhetoric in favor of "diversification away from oil" notwithstanding, Moscow is not likely to diversify away from oil and gas despite its vulnerability to the vicissitudes of commodity prices.

Energy Policies

Russia enjoys a major comparative advantage in hydrocarbon-based energy production that will persist regardless of increased production costs associated with climate change. Indeed, for the foreseeable future, Russia will remain reliant on fossil fuel commodities and its energy planning envisions only modest diversification away from hydrocarbons, mainly as an excuse to subsidize particular alternative energy industries. To the extent that diversification to supplement oil and gas does occur, hydroelectricity, nuclear power, and liquefied natural gas are the most likely choices.

The Russian Government nevertheless is showing interest in energy efficiency for the first time. A recent World Bank study concludes that Russia can save up to 45 percent (equivalent to nearly six million barrels of oil per day) of its total primary energy consumption by adopting measures that could pay for themselves within four years,[6] putting Russia in an excellent position to address any increase in demand or decline in production as a result of climate change. In addition, Russia has announced the intention to bring domestic energy prices up to international export parity by 2011. To the extent that Russia's domestic energy demand is elastic, this measure should reduce energy consumption, which is inflated by artificially low domestic energy prices.

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[6] World Bank and International Finance Corporation, *Energy Efficiency in Russia: Untapped Reserves* (Washington, 2008)

A focus on increasing efficiency may delay implementation of the necessary energy-infrastructure improvement programs, but it cannot substitute for them. Indeed, as noted previously the major focus of Russia's domestic energy policy will be the vast capital expenditures associated with replacing the aging Soviet-era infrastructure that forms the core of Russia's energy production enterprises. Russia and its investment partners will need high prices in order to lay out the initial investments and will also need to be able to count on sustained high prices over the considerable period it will take to bring greenfield energy infrastructure online. Developing oil fields in eastern Siberia will require $70 a barrel oil prices to be a profitable venture.

Russia's simultaneous need to replace its aging infrastructure and to modify its infrastructure to take climate change into account is in some respects fortuitous. For example, an important preventive measure to reduce the chance of spills if climate change renders the permafrost-based pipeline systems unstable would be to elevate pipeline infrastructure and deepen its physical foundation to minimize risks of subsidence. As long as Russian infrastructure planning incorporates those changes necessary to cope with such climate change effects as permafrost melting, or exploit opportunities, such as the opening of new ports in the Arctic, Russia will only have to invest once to address both issues. Greenfield development in the Barents Sea and Far East will require a great deal of new construction projects. Historical infrastructure, much of which will need replacement, will be less important in supporting most of the greenfield projects, although some will still rely on existing networks. Development areas such as the Yamal Peninsula, for example, will require incremental new construction but will be connected to existing infrastructures.

Russia will face an increasing incentive to accept foreign involvement in these expensive and risky energy development projects, at least on the financing end of the project. Extending the existing pipeline infrastructure to reach the proposed Yamal field will cost $10 billion, even before considering costs of field development. The economic incentives pressing Russia in this to involve foreign investors nevertheless be filtered through a security lens by Kremlin decisionmakers and much of the critical supporting infrastructure—roads, railroads, bridges, ports, new settlements—will be paid for by the Russian state.

Lastly, these large-scale infrastructure projects undoubtedly will be accompanied by waste, corruption, environmental degradation, and outright construction errors. Assuming errors are even fixed, repairs and replacements will require all the more capital outlays. For example, a new oil pipeline being built near the Lena River in the Sakha Republic is being built as a trench, rather than a tunnel, with increasing possibilities of oil spills in conditions of melting permafrost, even though the necessity of surrounding pipelines with tunnels or building them aboveground is obvious to locals in the area.

Hydroelectricity. Increased river flows are expected to substantially boost Russia's existing hydroelectric capacity and hydropower potential but, as with the rest of the energy sector, the hydroelectric infrastructure will require substantial investment. Whereas in many countries, notably China and India, hydropower development is an international flashpoint, this is unlikely to be the case in Russia. Although most of its major rivers run almost entirely within Russia's borders, eliminating the common international issue of diversion by downstream countries, Russia may be less likely to pursue hydropower because oil and gas development will absorb most of the infrastructure investment.

Nuclear Power. The nuclear power industry currently supplies 16 percent of Russia's electricity needs, and Russia plans to produce at least a quarter of its domestic electricity through nuclear power by 2030. The industry is managed by Atomenergoprom, a civilian nuclear power monopoly subordinate to the Russian State Corporation for Atomic Energy (Rosatom). Atomenergoprom includes Energoatom, which operates Russia's civilian reactors; the nuclear fuel producer and supplier TVEL; nuclear goods and services exporter Tenex; and nuclear facilities builder Atomstroyexport. Although Atomenergoprom has ambitious plans to expand its export activity, international concerns about proliferation make nuclear exports to some countries even more politicized than gas pipelines. The nuclear industry, like oil and gas, needs to replace aging Soviet-era infrastructure; however, in the event of a prolonged global financial and domestic budgetary crisis, the nuclear industry will have to compete with the far more profitable hydrocarbon industries for state funding and political cover, which may constrain nuclear power expansion. In order to fund domestic infrastructure needs, Russia may turn to increased exports to such customers as Iran in order to fund domestic infrastructure needs, with corresponding implications for global security.

Liquefied Natural Gas. As Russia moves to develop new natural gas fields, it has the option of diversifying from pipeline-based gas delivery into liquefied natural gas (LNG). Pipelines create a hardwired relationship between Russia and its customers, primarily in Europe, and increasingly in China. Pipelines require consistent demand to be profitable, and cannot easily be redirected to new customers. Pipeline-delivered natural gas is therefore less commoditized than oil, which is bought and sold on the world market rather than being directly delivered to specific customers. In contrast, tanker-shipped LNG allows more flexibility; the LNG can be shipped to different customers as demand shifts. This flexibility may become more appealing to Russian leaders and to the gas monopoly Gazprom if they assess that some customers, particularly in Europe, may try to move away from a fossil fuel-based economy. On the other hand, a less hardwired natural gas sector is likely to increase natural gas price volatility, making Russia's economy more vulnerable to external shocks.

Gazprom is likely to add LNG to its repertoire while retaining pipelines as its principal focus. Historically Gazprom has avoided LNG in order to protect its pipeline monopoly, but it has entered the LNG business with its participation in the Sakhalin-2 natural gas development project in the Russian Far East. The firm also has drawn on foreign contractor expertise in LNG and deep-water gas drilling, as in the case of the Shtokman field in the Barents Sea. Nevertheless, incremental updating and expansion of the existing pipeline-based natural gas export system remains cheaper than development of a greenfield liquefaction capability.

Water Policies

As discussed previously, Russia faces major technical and engineering challenges to manage the impact of hydrologic changes and soil subsidence from melting ice, but the country has long battled harsh climatic and geological conditions with considerable perseverance and ingenuity. Russia's water supply is expected to increase overall, but much of the increase will occur in sparsely populated areas such as Siberia. Indeed, the differential climate change impact on water availability across Russia raises the question of whether the state will turn to large-scale water redistribution. Water will be relatively overabundant in the north, while the south, where Russia's key agricultural areas and most turbulent regions are located, will face shortages. Dating back to the Soviet period, Russian leaders have considered reversing the Siberian rivers to flow south, rather than unused into the Arctic Ocean. Such grandiose civil engineering projects may be fanciful, but more reasonable projects to transfer water from swollen northern rivers to the drying southern cities and fields are plausible. The expected major increase in flow from the Volga River, for example, could supply irrigation to the adjacent steppe regions expected to face water shortages.

Russia will most likely need to build new reservoirs, dams, and water pipelines to adapt to a new hydrological environment. Such projects would have to compete for resources with the equally massive infrastructure investments required in the energy sector.

Transportation Infrastructure

At the same time, the Russian state faces a large-scale requirement to upgrade the country's transportation network to adapt to changing climatic conditions. Many of Russia's roads, railways, and bridges are constructed on permafrost and its melting is likely to necessitate laborious improvement of thousands of miles of roads and railways in northern Russia, arteries needed for the expansion of infrastructure in the North. Potential competing focuses for investment include a more substantial snow removal system, ways to prevent ice-jamming of major rivers, flood control systems, and fortified bridges and river crossings. Much of these infrastructure improvements will have to be undertaken before substantial progress can be made on the all-important energy infrastructure issue. Accordingly, portions of the transportation network associated with the energy sector will no doubt receive priority, potentially leaving other parts of the country and their inhabitants with damaged or inadequate access to transportation for an extended period.

Regional Implications

Russia not only enjoys a better climatic outlook than many of its neighbors, but it has comparatively greater ability to cope with climate change. As a result, the most daunting climate change-induced challenges Russia will face out to 2030 may originate from outside its borders.

Regional Energy Issues

Climate change is likely to affect Russia's relations with its regional energy clients in two principal respects. Firstly, climatic stress on Russia's pipeline infrastructure will likely lead to increased maintenance costs and increased development costs for new oil and gas fields. Russia probably will pass these costs on to its customers in Europe and East Asia. Secondly, Europe is likely to forge ahead with efforts to transition away from fossil fuels and to alternative sources of energy in the interest of reducing emissions and mitigating longer-term climate change. This would jeopardize demand from Russia's primary energy customer.

Dynamics between Russia and its European energy customers are troubled. Russia shut down its gas supplies to Ukrainian transit routes in January 2009, and the situation escalated into a gas blockade affecting much of Europe. Gas supplies were shut off for eighteen days until Russia and Ukraine finally signed a memorandum of agreement. Russia's leaders may have been hoping to demonstrate Russia's critical role in European energy security and to persuade European countries to fund new pipelines that would increase European access to Russia's gas supplies. But Russia could face a shortfall in its gas production once European demand recovers if Russia does not invest in new gas field development. President Medvedev underscored the importance of constructing the proposed Nord Stream pipeline on the Baltic Sea bed to provide direct gas links to Germany and the South Stream pipeline that would bypass Ukraine, carrying Russian gas exports over the Black Sea bed to the Balkans and Central Europe. In addition, Prime Minister Putin promoted Yamal Two, the proposed pipeline westward through Belarus and Poland, and the expansion of Blue Stream, by way of the Black Sea from Russia to Turkey, as well as a proposed gas pipeline eastward to China that would parallel a planned oil pipeline. Some question whether or not Russia has the gas resources to fill these pipelines, however.

The European Union has not responded to the gas crisis in an integrated manner by investing in diversified pipeline projects with Russia, although some individual European states have made such investments. Rather, the EU has launched a serious effort to find non-Russian sources of natural gas, such as the proposed Nabucco pipeline which would allow access to Caspian gas via Turkey, bypassing Russia. Because pipelines represent a major investment and a long-term relationship, the reliability of the supplier is a critical consideration and Nabucco does not have sufficient non-Russian supply to be convincingly viable. Russia's provocative use of its gas pipelines as economic "weapons" may have branded it an unreliable supplier with serious long-term consequences for the country's natural gas industry and have put European investment across Russia's energy sector in some jeopardy. Without European investment, the proposed improvements to Russia's export capacity would take longer to bring on line.

In addition to oil and gas, Russia exports electricity to Scandinavia, Ukraine, and the Baltic States, and imports it from the Trans-Caucasus. Expected gains in Russia's hydroelectric potential as a result of climate change raise the possibility that electricity exports could be expanded. At the same time, greater risks to transmission lines from soil subsidence and stronger winds are likely to complicate long-distance electricity transmission schemes.

The Arctic Ocean

In contrast to their conservative attitude toward other aspects of climate change, Russian scientists and officials have paid keen attention to the dramatic developments associated with rising Arctic temperatures and melting ice caps that have accelerated in the last several years. Having by far the longest contiguous Arctic coastline and a preponderance of ice-capable naval capabilities, Russia is ideally positioned to exploit the opening of the Arctic Ocean as an arena for trade and resource exploitation.

A key Russian Federation Security Council policy document entitled "On Defense of the Russian Federation's National Interests in the Arctic," frames Russia's goals in the

Arctic, stating [7] that “the Arctic must become Russia’s main resource base,” and lists “active development of natural resources” as the first priority of the Russian Federation in the region. It calls for “international recognition of the outer boundaries of Russia’s continental shelf in the Arctic,” an oblique reference to Russia’s claims of the Lomonosov and Mendeleev Ridges that would give Russia jurisdiction over half of the Arctic Ocean. Russia claims that these subsea ridges extending far out into the Arctic Ocean are linked to the continental shelf and thus part of Russia’s legitimate maritime territory. Russia claims nearly a half million square miles of seabed beyond its recognized 200-nautical mile exclusive economic zone.

Direct conflict over Arctic resources may be unlikely, since the majority of the energy reserves in the Arctic are in uncontested areas. The incentives for cooperation—both in resource extraction and support to Arctic economic activities—may be greater than has been conventional wisdom. In the limited areas that are contested, states that anticipate exploiting resources have already begun to maneuver in support of their claims. Denmark, which chairs the Arctic Council for the next two years, has made clear that it considers securing Arctic resources a priority. Negotiations are complicated and Russia is sensitive to the fact that all the parties in disputes over Arctic territory except Russia are NATO members (the United States, Canada, Denmark, and Norway).

Beyond the Arctic’s potential energy resources, the melting of the polar ice cap has major international implications, specifically for maritime transit. Formerly impassible sea lanes, such as Canada’s fabled Northwest Passage, are already beginning to open to shipping as the pack ice in the Arctic Ocean recedes. The opening of the so-called Northern Sea Route (NSR) along Russia’s Arctic coast promises to cut thousands of miles off the shipping routes between Europe, East Asia, and the North American Pacific coast. These shipping routes will create new strategic interests on Russia’s northern periphery for Russia, NATO, and non-contiguous countries anticipating heavy reliance on the NSR, particularly China and the EU.

The sea lanes of the Arctic Ocean will remain perilous: rising water temperatures will increase the power and severity of Arctic storms, which along with icebergs will potentially hamper shipping and the exploitation of offshore energy deposits. Russia is likely to play a major role in search-and-rescue (SAR) and weather monitoring for Arctic shipping in the rough northern seas, which may facilitate a more cooperative approach among the Arctic states. For example, the US Coast Guard already works well with the Russians in the Arctic.

The receding ice also opens up potential ports along the Russian northern coast, which could allow Russia to more easily export onshore energy from northern Siberia. Historically, Russia’s main strategic challenge was to secure access to warm water ports for both military and economic purposes. In effect, climate change will bring the ice-free ports to Russia, removing one of the most durable strategic rationales for Russian expansionism. Russia is already building a new class of winterized, ice-capable tankers to transport oil in rough Arctic waters.

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[7] Заседание Совета Безопасности Российской Федерации, (Russian Federation Security Council Meeting) «О защите национальных интересов Российской Федерации в Арктике» (On the defense of Russian Federation’s national interests in the Arctic), 17 September 2008; NIC 2009-04, p. 34.

New ports on Russia's Arctic coast may provide vital shelter to ships during violent storms along the NSR, along with SAR and emergency infrastructure, and refueling stations. Although Russia's fleet of Arctic-capable icebreakers may be less required given the receding ice, the ships may assume a SAR role as shipping traffic increases. Lastly, revitalization of Arctic ports may be a means to extend state administrative control into previously isolated areas of Russia's North. To date, Russia's commitment to developing its Siberian ports has been mainly rhetorical, but this is likely to change as the NSR opens to shipping traffic.

Russian enthusiasm about the Arctic surged at the time of rapid economic growth and high oil prices, peaking in 2007 with the planting of a Russian flag on the seabed beneath the North Pole. The current global economic downturn significantly reduces the incentives for Arctic development, both onshore and offshore. Observations of Russian media indicate that the "Arctic buzz" has waned since the onset of the economic crisis in the fall of 2008. Nevertheless, Russia's sense of entitlement to the Arctic's resources and the likely continued opening of the ocean because of melting ice ensure that the "buzz" will be heard again.

Fishing Conflicts

Climate change may generate increased disputes over fishing rights in the Arctic and Russia's peripheral seas. Changes in the movement of fish schools could bring Russian and other fishermen into conflict over new fishing grounds and exacerbate competition in existing grounds, particularly in the Arctic Ocean and the Baltic Sea. While unlikely to drive international conflict at the strategic level, particularly when compared to the sub-sea resource issue, fishing conflicts have great potential to generate local incidents that raise the overall level of tension in the seas along Russia's periphery.

Disputes over fishing rights and the relocation of fishing grounds could become a larger factor in relations between the Arctic states, particularly Russia and Norway, which have had disputed control of waters—in terms of sub-sea resources and fishing rights—in the western Barents Sea for decades.

Cross-Border Migration

Immigration into Russia currently follows a "pull" scenario: migrants enter Russia pulled by better employment opportunities. In European Russia and Siberia, the majority of migrants come from Central Asia and the Trans-Caucasus (Armenia, Azerbaijan, and Georgia), while temporary Chinese laborers are a major presence in the Far East. Climate change-induced migration would instead follow a "push" scenario, in which adverse climatic effects in neighboring countries would drive migration of environmental or economic refugees into Russia. Water shortages and more frequent droughts, particularly in Central Asia, Mongolia, and Northeast Chin, could push large numbers of people into Russia and become a source of instability, especially in hard economic times. As with internal migration, however, it is not clear that populations under climate-induced stress will respond by migrating rather than taking measures to adapt.

Moreover, any climate change-induced migration into Russia may in fact be less destabilizing than previously considered, as an increase in "push" migration may coincide with a decline in "pull" migration. Much of the immigration into Russia has been essentially a redistribution of population after the collapse of the empire. A large proportion of migrants have been ethnic Russians residing in the former Soviet Republics, but that source of migration is now almost depleted. The attractive influence of social networks and economic incentives may also be reaching a saturation point. In the medium term, as "push" migration becomes a larger factor, Russia will begin experiencing the previously mentioned expected steep decline in working-age population, and the demand for labor will increase. Russia might consider a guest worker program similar to those in Europe.

Migration from Central Asia & Mongolia. Climate change may have an especially severe effect on conditions in arid Central Asia, particularly in terms of water shortages and disruption of agricultural patterns; but a number of factors, including historical precedent, suggest that a rapid and destabilizing exodus from Central Asia into Russia is unlikely. Environmental conditions in Central Asia—such as air contamination of large swaths of Kazakhstan and Uzbekistan resulting from the drying out of the Aral Sea—degraded significantly in the late 1980s and continued to deteriorate rapidly in the 1990s. Although these adverse conditions affected all ethnic populations in the region, the overwhelming majority of migrants to Russia were ethnic Russians, as by and large, non-Russian groups remained in their home countries. Moreover, most large population centers in Central Asia lie far from Russia's borders in the southern parts of the region, such as the Fergana Valley. Iran, South Asia, and even western China are closer potential destinations for migration than Russia. Passenger transit is limited and costly, and the Russian Border Guard Service—now part of the FSB—mans border checkpoints at the main road and rail entry points from Kazakhstan into Russia.

Although it may face similar climate change-induced pressures to the Central Asian states, Mongolia has too small a population to pose a migration challenge to Russia. If migration from Mongolia increased, the ethnic Mongolian populations on the Russian side of the border would probably help absorb the newcomers. Moreover, "push" migration out of Mongolia is more likely to be directed toward China.

Migration from the Trans-Caucasus. Migration from Azerbaijan, Georgia, and Armenia may prove particularly troublesome given the existing ethnic tensions. Bitter memories persist of the Russian apartment bombings in 1999 that were blamed on people from the Caucasus and contributed to the intensification of Russia's military engagement in Chechnya. To date, migrants from the Trans-Caucasus have preferred to settle in the large cities of European Russia where they can find work rather than in the North Caucasus where conditions are similar what they seek to escape.

Chinese Migration. The numbers of Chinese economic migrants crossing the border into the Russian Far East are already considerable and increased migration could create tension between the two countries, eroding recent improvements in bilateral relations. Unlike the Central Asian states, however, China ranks high in terms of resilience to climate change, so "push" migration may be less of a factor and the Chinese state, with its increasing adaptive capacity, is likely to be able to act to cushion adverse climate change impacts. Nevertheless, sustained climatic pressure from desertification in China's Northeast could still increase Chinese migration into the Amur River valley and Russia's Maritime Province (Primorskiy Kray), areas where the ethnic Russian population is in decline.

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Moreover, labor shortages in the Russian Far East will continue to drive "pull" migration from China, although climate change may somewhat alter the pattern of this migration. The southern areas of permafrost, now near China's border, are likely to move northward 90-120 miles, which may negatively affect agriculture in the Amur River region because of soil deterioration and more pests and make the area less attractive to Chinese agricultural migrants. At the same time, Arctic warming could shift the northern borders of the forests and steppes north by up to 600 miles and tundra areas become more hospitable. In the longer term this shift could open more of the interior to the timber industry, which already employs many Chinese migrants in Primorskiy Kray and other parts of the Russian Far East. These shifts could gradually induce more Chinese migrants to penetrate further into the Russian interior rather than clustering near the border.

A real potential exists for the Russian Far East to become demographically Chinese, although driven more by an outflow of Russians than an influx of Chinese. Although the Far Eastern Federal District comprises over a third of Russia's territory, less than six million people live there, concentrated in the cities on the Chinese border. The region has suffered a very sharp decline in population since 1991 as Russians are moving west in search of greater economic opportunities and better living conditions, and the population is projected to drop to 4.5 million by 2015.

Water Disputes

Fairly few areas in Russia are likely to be the center of major disputes over control of fresh water resources between Russia and its neighbors. Disputes between regions within Russia are far more likely to cause trouble. The major shared water resource in Russia is the Amur River, which runs along the Sino-Russian border. The flow of the Amur is projected to increase significantly because of climate change, so conflict seems unlikely. Projected sustained water shortages in northern China could lead to interest in Lake Baikal, which holds one fifth of the world's unfrozen fresh water, more than all the North American Great Lakes combined.

Peripheral Instability

Resource and ethnic conflicts and humanitarian disasters within countries neighboring Russia are likely given their limited adaptive capacities compared to Russia. Russian humanitarian intervention appears very likely given Russia's traditionally paternalistic attitude toward its "Near Abroad." Some interventions in hard-hit regions such as Central Asia could require considerable resources.

Foreign Policy Implications

Russia's Global Engagement

Because international engagement is not Russia's preferred option for addressing its critical interests, Russia will most likely seek autarkic solutions to problems related to climate change where it can and accept international cooperation where it must. Given the regional variation in projected climate change effects and Russia's probable expanding state capacity, Moscow will address most problems by transferring resources from one part of its territory or economy to another. Disruptions to agriculture may render the country more dependent on international markets for food and put pressure on Russia to address the ports and transportation infrastructure.

Russia is already seeking large-scale international investments in its energy sector, but as projected costs rise, Moscow will be less able to set the terms for such agreements and will have to take greater care not to alienate prospective investors. This may inhibit Russia from adventurism and "pipeline warfare" and encourage a more cooperative stance with lender countries. Russia may also have a greater need for foreign expertise in its energy industries, for example in the area of deep-water oil drilling, which could lead to more openness to foreign investment and partnerships in production.

The regional implications of climate change along Russia's periphery could easily translate into broader foreign policy concerns. Climate-induced stress and resource competition could deepen NATO and United States involvement in the Caucasus, Central Asia, and the Arctic, all areas of vital interest to Russia. Russia is unlikely to tolerate such encroachment, even if it is framed in cooperative or humanitarian terms.

Russia's Global Energy Policy

Russia's long-term financial solvency rests on its ability to ensure that it has reliable customers for its oil and natural gas exports in order to continue as a principal world energy supplier. In doing so, Russia will have to change its energy policies in reaction to the inevitable shifts in the structure of the global energy markets. Russian expectations of the future of oil prices will determine the range of climate change policy options it feels able to consider.

With the exception of natural gas through pipelines, Russia will face difficulties preserving itself as a monopolistic provider of energy because its customers will naturally seek diversification and security of supply. Russia's most important international relationships will be with its primary longer-term energy customers, particularly China.

Russia's position as a fossil fuel-based energy supplier will not be threatened if the United States and/or Europe move aggressively away from fossil fuels or away from dependence on foreign sources. Projections suggest that demand and therefore prices of Russian supply will stay high because of increases in energy demand in developing markets such as China and India. A Western move away from fossil fuels would nevertheless be troublesome and costly to Russia, forcing Moscow to reorient its exports and the attendant distribution infrastructure. Russia already faces a major medium-term shift toward Asia as its principal energy export market, but Western alternative energy policies could accelerate that shift, making more difficult the reorientation and recapitalization of Russia's energy infrastructure.

Despite projected Asian demand, Russia needs to prepare for a contingency involving a reduction in overall world demand for oil by diversifying its portfolio as an energy supplier to include more focus on natural gas and nuclear energy. In keeping with its conservative tendencies, Russia is likely to pursue both options.

Nuclear energy is a lucrative business area for Russia's energy export sector. Russia has the production capabilities and technical expertise to be a key world supplier of civilian nuclear technology and its ability to provide nuclear technology at relatively low prices makes it attractive to some customers. If Russia couples provision of nuclear reactors with reprocessing or disposal of spent fuel rods, the proliferation fears associated with customers acquiring weapons-grade nuclear materials might be assuaged. This is essentially the agreement Russia made with Iran concerning provision of nuclear fuel for the Bushehr nuclear plant.

Russia's Foreign Policy Perspectives on Climate Change

Russia does not yet consider the climate change issue a top-tier priority. Although this is likely to change over the next decade as more hard evidence of its disruptive impact surfaces, Russia still probably will feel less motivation to address climate change than the United States and others. Moscow also does have a legitimate rationale to regard climate change as not wholly negative, given that, while mainly disruptive, it is likely to generate beneficial effects in some areas. Nevertheless, as previously noted, evidence such as its recent climate change doctrine does suggest that Russia's views may be coming more into line with the international community.

Even if Russia is realizing that climate change is a serious issue, Russia's position on climate change has been, and is likely to remain, divergent from that of many other countries, including the United States. Much of the international debate on climate change mitigation, including the prospective debate at Copenhagen, has focused on measures to address the factors generating climate change, such as greenhouse gas emissions. As a primary fossil fuel supplier, Russia has little incentive to constructively engage in a debate that ultimately aims to extinguish the country's primary source of revenue. Even if it successfully manages the domestic energy challenges brought about by climate change, Russia's continued reliance on fossil fuel production will exacerbate rather than mitigate global climate change. Russia has therefore tended to treat climate change as a fait accompli and preferred to focus on adapting to and treating its effects rather than attacking the causes. Russia nonetheless is willing to accept international restrictions on emissions and initiatives toward alternative energy as long as it can be confident that demand for its oil and gas will continue to grow in Asia and the developing world.

US Engagement with Russia on Climate Change

Constructive engagement on climate change will be hampered by Russia's distrust of the United States. Beyond the legacy of decades of strategic confrontation, Russia has more proximate and concrete concerns that Western policy decisions pose direct threats to its security. Russia feels threatened by recent expansion of NATO into Eastern Europe, and particularly plans to admit more former Soviet Republic such as Ukraine or Georgia. Expanded US involvement in Central Asia, NATO operations in the Balkans, and moves toward establishing a US missile defense shield in Europe contribute to a siege mentality in the Kremlin. Russia's proactive stance in the Arctic may be an attempt to turn the tables and keep the United States and NATO at arm's length.

The Cold War experience, however, illustrates that Russia and the United States can cooperate in some areas even in an atmosphere of distrust and strategic competition. Therefore, the two may be able to cooperate and engage constructively on climate change mitigation. Moreover, Russia's assessment of the US approach to energy and climate change—in particular, how Moscow assesses US energy policy will affect oil and gas prices—will play a significant role in its internal approach to climate change. If Russia sees the United States making clear steps towards alleviating climate change, Russia will begin to adjust its own policies in response, such as by ensuring that international oil and gas prices stay high or becoming a key supplier of alternative energy technologies such as nuclear power. That said, ultimately Russia will care more about the policies adopted by Europe or China, its primary customers.

Russia is more likely to respond constructively to approaches framed in terms of energy policy rather than climate change policy. Specifically, Russia has much to gain from energy efficiency and an emphasis on technical cooperation regarding efficiency highlights action that can benefit Russia and help mitigate climate change. US companies also have expertise in areas such as deep-water drilling that might open doors to a more cooperative approach to Arctic energy exploration. In terms of alternative energy, nuclear energy may be a fruitful area for US-Russian cooperation on climate change-related issues and proliferation-resistant nuclear technology to meet the needs of international nuclear energy markets. The United States has pursued a framework for providing nuclear fuel reprocessing—a service Russia also offers—multilaterally through the Global Nuclear Energy Partnership (GNEP). Russia has expressed openness to cooperation with the United States or other countries on such approaches.

Technical and scientific cooperation on climate represents another potentially fruitful area of engagement. For example, the United States might pursue Russia's expressed interest in developing better data and models with which to assess the future effects of climate change. The United States also might involve Russia in joint efforts to model future climate scenarios. Joint modeling may not result in unified analytic results, but would at least foster a common understanding of the parameters of the issues involved. Alternatively, such an initiative might be undertaken at the non-governmental level, partnering with Russian think tanks and research institutes.

The Copenhagen Negotiations

Russia's approach to the climate change negotiations is likely to be pragmatic and opportunistic and focused on ensuring that the terms of any deal are to its benefit or at least cost Moscow nothing. Russia believes it has less at stake in the climate change debate and more freedom to extract concessions from the participants. The practical effect global climate change agreement is a secondary concern for Russia, although it would likely welcome a deal that mitigates some of the sources of climate change without constraining its oil and gas exports.

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Russia's overarching strategy at Copenhagen probably will be to leave the contentious negotiations to the United States, China, India, and the European Union. Russia will look to take full advantage of the United States' interest in brokering deals with India and China, and will take every opportunity to extract favorable concessions. Moscow may position itself as an important swing player and broker between the West and the developing world.

Russia expects that the results of Copenhagen will not differ radically from the 1997 Kyoto Protocol. They presume that such a Kyoto-like system would be based on substantial individual pledges to reduce emissions according to the signatories' particular developmental situation. The terms of Kyoto were highly beneficial for Russia because emissions pledges were based on percentage changes from 1990 baseline levels: the economic collapse of the former Soviet countries after 1991 caused a major reduction in emissions, and it was easy for Russia to keep its emissions below the limitation set based on the 1990 baselines. One of Russia's objectives at Copenhagen will be to retain the favorable 1990 baseline, over European objections.

Russia's recent rhetorical recognition of the challenges posed by climate change may be a strategic move intended to better position itself to secure favorable concessions at Copenhagen. By appearing more in line with prevailing views of climate change, Russia may hope to find other participants more favorable towards its positions and to lay the groundwork to request exemption from certain climate change mitigation measures.

Russia's primary focus may be to secure favorable terms for its major capital projects and insure that any agreement reached at Copenhagen includes less restrictive terms for foreign investments. Because of its high projected investment needs, Russia will seek to secure joint international investment and credits for their energy infrastructure projects on the grounds that they will increase efficiency and thereby help mitigate climate change. Gazprom, for example, argues that investment to help them upgrade their gas pipeline system and credits for reducing gas flaring by a significant amount would be beneficial in combating climate change. Gazprom and other elements of the Russian energy industry have identified climate-related international investment as a major potential source of funding.

Although Russia may exhibit a flexible position on climate change, it has very little room to maneuver in terms of concessions that would negatively affect its oil and gas sector. It is also very unlikely to accept conditions that it regards as threatening its sovereignty. Russian willingness to accept the terms of an international climate deal could evaporate if these core interests are challenged or its paranoia over an international anti-Russian conspiracy is triggered.

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CONFERENCE REPORT

RUSSIA: THE IMPACT OF CLIMATE CHANGE TO 2030: GEOPOLITICAL CHANGE

This paper does not represent US Government views.

CONFERENCE REPORT

CR 2009-21 December 2009

North Africa: The Impact of Climate Change to 2030:

Geopolitical Implications

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North Africa: The Impact of Climate Change to 2030: Geopolitical Implications

Prepared jointly by

CENTRA Technology, Inc., and Scitor Corporation

The National Intelligence Council sponsors workshops and research with nongovernmental experts to gain knowledge and insight and to sharpen debate on critical issues. The views expressed in this report do not reflect official US Government positions.

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Scope Note

Following the publication in 2008 of the National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030 (NIA 2008-01, June 2008), the National Intelligence Council (NIC) embarked on a research effort to explore in greater detail the national security implications of climate change in six countries/regions of the world: India, China, Russia, North Africa, Mexico and the Caribbean, and Southeast Asia and the Pacific Island States. For each country/region we are adopting a three-phase approach.

- In the first phase, contracted research explores the latest scientific findings on the impact of climate change in the specific region/country. For North Africa, the Phase I effort was published as a NIC Special Report, ***North Africa: The Impact of Climate Change to 2030 (Selected Countries), A Commissioned Research Report*** (NIC 2009-05), of August 2009.
- In the second phase, a workshop or conference composed of experts from outside the Intelligence Community (IC) determines whether anticipated changes from the effects of climate change will force inter- and intra-state migrations, cause economic hardship, or result in increased social tensions or state instability within the country/region. This report is the result of the Phase II effort for North Africa.
- In the final phase, the NIC Long-Range Analysis Unit (LRAU) will lead an IC effort to identify and summarize for the policy community the anticipated impact of climate change on US national security.

In August 2009, a group of regional experts convened to explore the sociopolitical challenges, civil and key interest group responses, government responses, and regional and geopolitical implications of climate change on North Africa through 2030. The group of outside experts consisted of social scientists, economists, and political scientists. The group focused on Algeria, Egypt, Libya, Morocco, and Tunisia. Although the targeted time frame of the analysis was out to 2030, the perceptions of decision makers in 2030 will be colored by expectations about the relative severity of climate changes projected later in the century. The participants accordingly considered climate impacts beyond 2030 where appropriate.

This work is provided under the Global Climate Change Research Program contract with CIA's Office of the Chief Scientist.

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Executive Summary

The National Intelligence Council-sponsored workshop entitled, *The Implications of Global Climate Change in North Africa*, held on 20 August, 2009, brought together a panel of experts to consider the probable effects of climate change on North Africa from a social, political, and economic perspective. The workshop focused on Algeria, Egypt, Libya, Morocco, and Tunisia. ***The panelists concluded that systemic state failures attributable solely to climate change to 2030 are not likely. However, climatic stress coupled with socioeconomic crises and ineffective state responses could generate localized social or governmental collapses and humanitarian crises.*** The effects of climate change in North Africa will exacerbate the region's existing challenges of insufficient water and food resources, low economic growth, inadequate urban infrastructure, and weak sociopolitical systems.

- Climate change will reduce water availability and quality, creating the potential for severe water shortages in both cities and rural areas. By 2030, three-quarters of Egyptians will have inadequate access to fresh water.
- Droughts, flooding, salinization, and overall water scarcity will adversely affect agriculture, threatening food security and forcing farmers off their land.
- Climatic stress will add to the already substantial migration from rural areas into cities, exacerbating the region's urban challenges. Cities will face deteriorating living conditions, high unemployment, and frequent civil unrest.
- ***The region is likely to face civil conflicts over scarce resources such as water, arable land, food, or employment, which may be expressed in sectarian, ethnic, or anti-regime tensions.***

North Africa faces increased risks of interstate conflict with southern neighbors over the next 20 years owing to the impacts of climate change.

- Attempts by Sudan or other upstream states to expand their use of the Nile River in response to climatic stress would seriously threaten Egypt and could provoke armed conflict.
- North African states may be drawn into conflicts or climatic crises in the vulnerable Sahel region to the south. Conflicts involving nomadic populations could easily see migrants cross state borders.

Climate change will likely increase the already substantial emigration of North Africans to Europe. The region will serve as a route for transmigration of Sub-Saharan Africans fleeing severe climatic stress.

- North African states will seek to encourage emigration as a safety valve, relieving demographic, resource, and employment pressures.
- European and North African cooperation to prevent an influx of Sub-Saharan African migrants may result in European states turning a blind eye to North African human rights abuses as long as migration is kept under control.

North Africa's capacity to adapt to climate change is inhibited by underdeveloped and disempowered civil societies and the dominance of repressive but often ineffectual regimes.

- A few key decision-makers dominate state policymaking and economic activity in North Africa. Their main objective over the next two decades will be to bolster regime security and resilience against climate change-induced instability.
- North African regimes are based on coercion and corrupt patronage systems and are lacking in institutional capital, ingenuity, and flexibility. State institutions are often unable or unwilling to provide public services or respond effectively to crises.
- Longstanding state suppression of civil mobilization and a lack of social capital will significantly constrain the capacity of civil society to address climate change.
- ***Ineffective state responses and state suppression of civil society allow Islamist groups to fill the void. Climatic stress will create opportunities for both moderate and extremist Islamist groups to expand their influence in North Africa.***

Nevertheless, North African states and societies have repeatedly shown the capacity to withstand sustained challenges without overall systemic collapse.

- North African states have robust capacity to maintain social control in the face of challenges and destabilization. They are adept at controlling information, deflecting blame, and suppressing opposition.
- Despite widespread institutional deficiencies, North African states have demonstrated the capacity to marshal considerable national resources and tackle large-scale infrastructure projects.
- Climate change is one of the few cross-cutting issues having the potential to spur more serious efforts at regional cooperation.
- Among the North African states, Libya and Algeria are less economically vulnerable to challenges that arise from climate change because their economies are supported by exporting fossil fuels and are not dependant upon agriculture or tourism.

North African states will actively seek Western assistance in addressing climate change. While the four Maghreb states will turn primarily to Europe, Egypt will rely more on the United States.

- North African states will leverage the threat of unrestrained migration or regional collapse to secure increased Western aid.
- Europe has a strong interest in preventing spillover from climate change-induced instability in North Africa and will likely intervene to avert state failures or social collapses. North Africa will absorb an increasing proportion of Europe's attention and resources.

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Introduction and Background[1]

Climate model projections available for North Africa indicate a clear increase in temperature over the next 20 years that is expected to continue throughout the 21st century, probably at a rate higher than the estimated global average. Model simulations also suggest a drying trend in the region, particularly along the Mediterranean coast, driven by large decreases expected in summertime precipitation. Because coastal areas historically receive by far the largest amount of rainfall in North Africa, future decreases will likely have a significant and noticeable impact. Precipitation trends in the interior semiarid and arid regions of North Africa are more difficult to predict due to the very small amount of natural precipitation that characterizes these areas. Climate change will induce some variations in precipitation patterns, but the trend is not clear, as some models predict slight increases and others predict slight decreases in annual precipitation amounts.

The Regional Climate Change Index (RCCI)[2] identifies the Mediterranean as a very responsive region to climate change (“Hot-Spot”). Given the ecological and socioeconomic characteristics of the southern Mediterranean countries, the impact of climate change may be more marked than in other regions of the world. Still, most of the predicted impacts in the region are already occurring regardless of climate change (e.g., water stress and desertification). Climate change is expected to exacerbate these trends.

Based on global climate projections and given inherent uncertainties, the most significant impacts of climate change in North Africa (Morocco, Algeria, Tunisia, Libya, and Egypt) will likely include the following:

- ***Water Resources Stress.***[3] All countries of North Africa are presently experiencing water stress. Model simulations show a general decrease in rainfall across North Africa, with median decreases in average annual precipitation of 12 percent and 6 percent projected for the Mediterranean and Saharan regions, respectively. This general drying trend for North Africa is punctuated by seasonal variations in projected precipitation that differ by region. Predicted decreases in average annual rainfall, accompanied by projected increases in the population of the region, may impede access to water for millions of inhabitants. In addition, with decreasing water levels, other ecological effects such as salinity in coastal areas and deterioration of water quality may increase.

[1] This section is extracted from the Executive Summary of the Phase I report (see Scope Note): ***North Africa: The Impact of Climate Change to 2030 (Selected Countries), A Commissioned Research Report*** (NIC 2009-05, August 2009). Some of the judgments in this report (Phase II) may differ from those in the Phase I report.

[2] The RCCI is calculated for 26 land regions from projections of 20 global climate models using the Intergovernmental Panel on Climate Change (IPCC) emission scenarios.

[3] Water Stress, as used by the IPCC, refers to a per capita water availability of below 1,000 cubic meters per person per year; sometimes IPCC referenced sources also use a ratio of withdrawals to long-term average runoff of 0.4. The IPCC formally defines a country as water stressed when withdrawals exceed 20% of renewable water supply.

- ***Agriculture.*** Model results are inconsistent regarding future changes in crop yields and agricultural growing seasons in North Africa, and we do not know whether variations in temperature, precipitation, or atmospheric CO_2 will be the dominant factor. One modeling study suggests that future increases in atmospheric CO_2 concentrations will increase maize yields in Morocco, while other modeling studies suggest that future increases in air temperature will have a negative effect on growing seasons and crop yields in Egypt. Relatively heat-tolerant species, such as maize, are expected to suffer the smallest losses in yield and growing area, while heat-intolerant crops, such as wheat, are expected to suffer the largest losses. In addition, intensive irrigation practices in the region may result in further salinity, which may lead to desertification. Adaptation strategies, including modifications in sowing dates to match climate changes and development of heat-tolerant crop varieties, will likely mitigate some of the expected negative effects on North African agriculture. Development of regional and local climate models in the coming years that include projections of Mediterranean Sea level rise and decreases in the Nile River flow are expected to provide more accurate estimates of future changes in North African agricultural regions.

- ***Migration.*** In recent years, North Africa has experienced vast migration pressures from both migrants that settle in the region from the south or that use North African countries as a transit area to reach Europe. Thus far, experts have not cited climate change as a driving force for migration in the region; nevertheless, a warmer climate and changing precipitation patterns, which will likely reduce viable cropland and reduce access to water, will increase urbanization and make accommodating the needs of a growing population more difficult. Besides food and water necessities, climate change-related migration may also imply greater demands on infrastructure along the coasts as well as ethnic, racial, or religious clashes.

- ***Natural Disasters.*** Because of the lack of historical data from tide gauges in the region, the wide range of future estimates in sea level, and the paucity of regional climate model projections for the Mediterranean Sea, a definitive estimate of sea level rise along the coastline of North Africa in the next 20 years is not possible. However, the intensity and frequency of floods along the Mediterranean coast are expected to increase by the middle of the 21st century. Compared to other regions, the impacts of sea level rise in North Africa are expected to be stronger in terms of social, economic, and ecological factors. Highly populated and agriculturally important coastal cities are the most vulnerable.

In addition, two more potentially serious impacts are the following:

- ***Tourism.*** Tourism is an important source of income for most countries of North Africa. Of concern, however, are the large quantities of water this sector demands and the little attention that governments of this region have given to water provision in the past. Thus, increased water scarcity, sea level rise, and increasing temperatures will likely have a negative impact on this sector and consequently the economy of most North African countries.

- ***Energy.*** The economies of Algeria, Libya and (to a lesser extent) Egypt are dependent on the hydrocarbon industry. Because of the revenues they receive from exporting fossil fuels—mostly to Europe—they are to some degree more resilient to the deleterious impacts of climate change. Any shift in the interest of other regions in importing natural gas and oil from North Africa, conversely, may make these North African countries considerably more vulnerable. However, there is no indication now that Europe and other importing regions will stop importing from North Africa in the next few decades.

Based on a comprehensive global comparative study of resilience to climate change (including adaptive capacity) using the Vulnerability-Resilience Indicators Model, a wide range of adaptive capacity is represented in this group of countries from Libya (ranking 34^{th} in a 160-country study) to Morocco (ranking 136^{th} in the same study). Under a high-growth scenario of the future, all countries gain adaptive capacity, especially Libya. However, under a delayed-growth scenario, all of these North African countries lose adaptive capacity.

Social, Political, and Economic Challenges

Even in the absence of global climate change, North Africa will face significant sociopolitical challenges over the next two decades. The region will have to contend with pressures created by a burgeoning youth population, tenuous economic growth, persistent unemployment, and urbanization and related stresses including inadequate housing and infrastructure. The effects of climate change in North Africa will likely exacerbate these existing political, economic, and social challenges, potentially worsening them to the point of plunging the region into crisis.

Hydrologic Challenges

North Africa is one of the world's most arid regions, and the lack of water represents one of the most important challenges facing North African states and societies. Water availability is the primary determinant of settlement patterns in the region, a fact illustrated most dramatically by Egypt's Nile Valley. Water stress and scarcity are major problems across the region due to major population growth and economic development as well as to arid conditions. As a result, significant segments of the population in North Africa depend on a limited number of tenuous water sources that are in danger of depletion even under current climatic conditions. The most extreme examples are the oasis settlements of the Sahara, where densely concentrated populations depend on a single source of groundwater. Such conditions render North Africa particularly vulnerable to climate change-induced hydrologic challenges.

The hydrologic impacts expected as a result of climate change to 2030 will differ across the region. North Africa comprises at least three distinct hydrologic systems. Egypt is almost entirely dependent on water from the Nile, which in turn is fed by drainage from the highlands of East Africa. The Mediterranean coasts of the Maghreb depend on direct rainfall, groundwater, and drainage from the Atlas Mountains. Without appreciable rainfall, the Sahara depends entirely on subterranean aquifers.

The Nile Valley. Almost all of Egypt's population and agriculture is concentrated in a narrow strip along the banks of the Nile and in the Nile Delta. Any serious disruption of the Nile's flow, whether due to climate change or human activity, represents a threat to Egypt. Upstream water diversion schemes by Sudan and Ethiopia have been a recurring source of regional tension, a dynamic that climatic stress is likely to intensify over the next 20 years. The probable direct effects of climate on the Nile's flow are less clear. The sources of the Blue Nile in Ethiopia and the White Nile in the East African Great Lakes region depend substantially on the monsoon rains originating in the Indian Ocean. Shifts in the monsoon will probably exert a greater influence on the fate of the Nile than climate change in North Africa proper.

Climate change within the region will nevertheless exacerbate a number of threats to the lower Nile and Nile Delta. Although sea-level rise is not likely to threaten most of North Africa's coast to 2030, much of the Nile Delta is already at or even below sea level. Even marginal sea-level rise combined with storm surges could create disastrous flooding in the delta. Egypt's second largest urban center, Alexandria, is at high risk for catastrophic flooding that could cause billions of dollars in damage and threaten millions of inhabitants. One of the principal reasons for construction of the Aswan High Dam, completed in 1970, was to control seasonal flooding along the Nile. As a result of doing so, however, the dam reduced the replenishment of fertile silt, leading to erosion of the Nile Delta. Reduced flows also allowed encroachment of saltwater into the delta, contaminating the groundwater. On the other hand, the water impounded in Lake Nasser may provide Egypt with a means to compensate if climate change causes variations in Nile flow.

Threats to water quality and increasing urban demand for potable water will likely pose greater hydrologic challenges for Egypt than outright water scarcity. Water quality in Egypt is already poor, subject to pollution and high salinity, and causes a high incidence of waterborne illnesses and infections. Climatic stress on agriculture will likely cause greater use of fertilizers, contaminating drinking water. In the Nile Delta, salinization of groundwater resulting from over extraction will significantly reduce available potable water. By 2030, three-quarters of Egyptians will have inadequate access to fresh water.

The Coastal Maghreb. The Mediterranean and Atlantic coasts of the Maghreb have a wet-dry climate that on the one hand brings periodic and often sustained droughts and on the other hand causes occasional extreme precipitation that leads to flooding. Climate change will likely exacerbate both of these extremes. Droughts in the region are already increasing in frequency and severity; this trend will likely continue through 2030. Droughts have caused serious damage to agriculture in Morocco and Tunisia and could put tens of millions of North Africans at risk for water stress. Population, agriculture, and economic activity in the Maghreb are disproportionately concentrated in areas at risk for flooding. More frequent and severe floods will damage both urban and rural infrastructure, agriculture, and housing, as well as threatening water quality. In addition to low-lying coastal plains, the valleys of the Atlas Mountains in Morocco and Algeria and the margins of the periodic salt lakes such as Chott el Djerid in Tunisia are subject to flash floods due to extreme rainfall. A related threat from extreme rainfall is mudslides, particularly in Algeria where the Atlas Mountains rise steeply above the densely populated coastal plain. In 2001, extreme rainfall triggered mudslides in Algiers that killed over 500 people and generated significant urban unrest.

In addition to periodic extreme weather events (draughts and floods), the coastal Maghreb is projected to suffer an overall 12 percent decrease in annual precipitation to 2030. Given the existing high level of demand for water resources in the area, such a decrease will create major socioeconomic stress. Both urban and rural water distribution infrastructure in the coastal Maghreb is fairly extensive but inefficient and antiquated. Higher temperatures will increase evaporation, already a major cause of water wastage due to the widespread reliance on inefficient surface irrigation systems. Aside from major disruptions to rain-fed agriculture, reductions in runoff, reservoir levels, and river flows could lead to sustained urban water shortages. Water scarcity will likely become a major driver of sociopolitical unrest and migration.

In addition to rainfall, the other major water source is groundwater drawn from aquifers. The Maghreb's coastal aquifers face severe strain due to increasing rural and urban water demand. Climate change-induced reductions in precipitation will both increase reliance on groundwater and reduce renewal from runoff. In addition, coastal saline intrusion will contaminate coastal aquifers—saline contamination of drinking water is already a problem in Tunisia. The Maghreb states will increasingly need to tap into the inland aquifers under the Sahara. Libya has taken the lead in doing so with its "Great Manmade River" (GMMR) project, and consequently will not face the same water stress its neighbors will suffer to 2030. The GMMR is tied to a prehistoric non-renewable water source that will ensure adequate water supply in Libya for at least the next half century. The supply life of the GMMR may be extended if other aquifers provide an additional water source or are found to be replenishable, however, there are no known Saharan aquifers of similar scale.

The Sahara. The socioeconomic impacts on North African states from climatic changes in the Sahara are likely to be minimal due to the lack of agriculture and low population. Many areas of the Sahara already experience decades without rainfall; climate change will only worsen conditions incrementally. The most significant regional impact may be the drawdown of Saharan aquifers that provide water to neighboring areas such as the Mediterranean coast and the Sahel. Drying and warming trends as well as depletion of aquifers may also accelerate desertification in the semiarid strip along the interior margins of the Atlas Mountains, an area disproportionately inhabited by Berber minorities. In addition, even marginal climatic shifts could put acute water stress on the isolated Saharan oases, which host densely concentrated populations living under very marginal conditions. Climatic stress on desert scrub vegetation will threaten the marginal grazing that underpins the nomadic, pastoral lifestyle of desert-dwelling Berber groups such as the Tuareg. The oases are also milestones on the trans-Saharan migration routes, and Sub-Saharan African migrants, who are often halted at the oases for considerable periods of time, are likely to suffer the worst privations.

Agricultural Challenges

Despite the region's aridity, North Africa hosts substantial agricultural activity in the Nile Valley and coastal plains and highlands of the Maghreb. Although agriculture is no longer the dominant economic sector in any North African country, it remains important in all but Libya.[4] Egypt accounts for roughly half the region's agricultural production, and Morocco and Algeria are also major agricultural producers. A disproportionately large segment of the labor force is engaged in agriculture, both directly and in the processing or trading of agricultural products, particularly in Tunisia and Morocco.[5]

Over the next two decades, climate change-induced stress on the agricultural sector will threaten the livelihoods and subsistence of millions across the region. The primary climatic challenges facing North African agriculture to 2030 are likely to be the aforementioned impacts on the region's already constrained water resources. Droughts, flooding, salinization, and overall water scarcity will adversely affect agriculture. Other climate change-related effects may have a more mixed impact. Whereas expected temperature increases and reduced growing areas and growing seasons will adversely affect agricultural productivity, carbon dioxide fertilization may sharply increase productivity in some cases. Climatic impacts on agriculture will depend on highly

[4] Agriculture accounts for 16 percent of GDP in Morocco, 13 percent in Egypt, 11 percent in Tunisia, 8 percent in Algeria, and only 1.7 percent in Libya.

[5] Agriculture accounts for 55 percent of the labor force in Tunisia, 45 percent in Morocco, 32 percent in Egypt, 17 percent in Libya, and 14 percent in Algeria.

localized conditions, the tolerances of specific crops, and the effectiveness of agricultural adaptation measures.

Egypt and the Maghreb have differing agricultural systems based on their differing hydrology. Egyptian agriculture is entirely dependent on Nile irrigation, while the Maghreb hosts a mix of rain-fed and groundwater-irrigated agriculture. In both cases, water availability is the decisive factor. In Egypt the scarcity of arable land is also a critical factor, and climate change-induced urban expansion and soil salinization will further reduce land available for cultivation. In addition to basic resource constraints, North African agriculture is characterized by significant inefficiencies in crop selection, irrigation practices, land management, and food distribution. Even where climate change does not substantially reduce productivity, more frequent agricultural disruptions and more variable conditions will substantially increase volatility in agricultural production. Population growth and more frequent droughts have already forced increased importation of food—due to its weak agricultural sector, Libya already imports three-quarters of its food. The region's cities already face perennial food scarcity and high food prices. All of the North African countries except Libya have price subsidies for basic foodstuffs, and price increases have been met by food riots. The need for price subsidies, more food imports, and investment in agricultural adaptation will increasingly constrain state budgets in the region.

Climatic stress may necessitate the substitution of hardier, less water-intensive crops such as maize, for current staples such as wheat and rice as well as greater reliance on fertilizers and intensive irrigation, further straining water resources. Although North Africa has high crop yields, agriculture remains highly inefficient with substantial potential for gains from mechanization, better irrigation, and other modern farming techniques. Such adaptive measures also will make agriculture less labor-intensive, further increasing the already substantial flow of population into North Africa's cities. Agriculture will be less able to act as an employment safety valve for underemployed or seasonally employed unskilled workers. Stress on rural communities may lead to civil unrest or encourage radicalization.

Demographic Challenges

Dramatic population growth over the last half century has seriously strained North Africa's limited resources and inadequate socioeconomic structures. Over the next two decades the effects of overpopulation and climate change will pose a mutually reinforcing threat to the region's water and food resources, economies, urban infrastructure, and sociopolitical systems. Harsher climatic conditions are likely to further concentrate population in the limited areas suitable for large-scale habitation. Population growth has produced a demographic "youth bulge"—some 60 percent of North Africa's population is under the age of 25. Fertility rates are declining in North Africa as family planning has improved. However, over the next two decades the region will have to contend with a large group of people passing through their most economically productive years without adequate employment opportunities.

Urbanization. Rapid urbanization has long been the source of significant disruptions in North Africa, and climate change will exacerbate these challenges. Although the current level of urbanization varies widely across the region, cities across North Africa are experiencing a major influx of population from rural areas.[6] Morocco, Algeria, Egypt, and to a lesser degree Tunisia, already suffer from overpopulation in their major cities. Algeria, for example, has some of the world's highest per unit occupancy rates and faces a severe housing shortfall. The region's largest city, Cairo, is one of the world's most densely populated urban areas, with nearly seven million inhabitants in the city and a further ten million in the surrounding metropolitan area. Such concentrations of population will create major problems for Egypt and other North African states in managing water needs and other climatic stress. Worse, climatic pressure is likely to significantly increase rural-to-urban migration, further swelling excessive urban populations. Cities in North Africa face over-urbanization and under-urbanism—they have too many rural migrants who are not integrated into urban society or economic structures. Climate change will place additional stress on already inadequate urban infrastructure, exacerbating water, food, and housing shortages, poor sanitation and water quality, and inadequate employment opportunities. Urban heat waves will not only threaten public health but will have an adverse effect on economic activity as people stay off the streets. Conditions in the region's burgeoning urban slums ("shanty towns")—already incubators for extremism and urban unrest—will face the most degradation.

Economic Challenges

After varying degrees of socialist economic policies in the last century, in recent decades most North African states have undergone economic liberalization. The trend is toward increased privatization of state-run enterprises, diversification from agriculture or petrochemicals into light industry and tourism, and greater foreign trade and investment, particularly with Europe. Economic reforms have often been slow due to large, corrupt, and inefficient government bureaucracies and entrenched economic interests. Economic development has also failed to address major structural economic problems such as high unemployment, pervasive poverty, a lack of skilled labor, and over-dependence on externally determined rents from hydrocarbons, phosphates, tourism, and emigrant remittances. Nevertheless, the region will likely continue its trajectory toward greater economic liberalization to 2030.

With the partial exception of Tunisia, living standards among the general public across North Africa have not kept pace with economic growth. The centralization of ownership and revenues has concentrated economic benefits among the narrow political and economic elite. Gross income inequality is a major source of public disaffection in North African societies. The distinction between rich and poor is probably most stark in Morocco and Egypt, while Tunisia is more economically equitable if politically repressive. Poverty remains a major problem across North Africa, reducing state and social capacity and forcing states to subsidize basic necessities—Egypt spends roughly 7 percent of GDP on subsidies, a significant drain on the economy.[7] Climate change will only further impoverish the region through reduced agricultural productivity, over-urbanization, reduced employment opportunities, and higher food and water prices.

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[6] The urban share of the population is 78 percent in Libya, 67 percent in Tunisia, 65 percent in Algeria, 56 percent in Morocco, and only 43 percent in Egypt.

[7] Some 23 percent live below the poverty line in Algeria, 20 percent in Egypt, 15 percent in Morocco, and about 7 percent in Libya and Tunisia.

Climate change-induced challenges will cause costly disruptions to North Africa's economic systems. Although the agricultural sector will suffer the most direct effects, the massive government expenditures required to head off or cope with climatic challenges will impact economies across the board. State investment and subsidies that still underpin much of the region's economic activity could be jeopardized. In addition, climate change mitigation will divert resources from programs to address poverty, unemployment, and poor living conditions, such as Morocco's National Initiative for Human Development (INDH). Collateral effects such as over-urbanization and sociopolitical unrest will further undermine economic performance.

Unemployment. North Africa's economic development patterns have failed to generate adequate urban employment for either skilled or unskilled labor. Economic growth has focused on non-labor-intensive sectors such as tourism or oil and gas. As a result, even oil-rich states such as Libya have massive unemployment.[8] Unemployment is most severe among the region's disproportionately large young population. In Algeria, for example, youth unemployment is estimated to be as high as 43 percent—the region's highest. Unemployment statistics do not tell the full story, however, because they do not account for the region's rampant underemployment. Many of the "employed" only work the equivalent of one or two hours per day, and many of the region's growing number of university graduates are forced to take low-paid jobs far below their skill level. Conversely, many of the displaced rural laborers moving into the region's cities lack the educational and technical skills necessary to succeed in a modern urban environment. The combination of urban economies incapable of creating adequate employment opportunities and a mass displacement of population from rural areas into cities as a result of climatic stress could create an employment crisis across the region. In Egypt, the return of up to half a million overseas workers as the Arab Gulf states slowly nationalize their own labor forces will compound the problem. Cities like Cairo, Casablanca, Alexandria, Algiers, and Oran are already overflowing with thousands of angry and unemployed young men who congregate in ghetto-like environments passing their days leaning on walls with little to no hope of escaping their fate.

Energy. Whereas the economies of Egypt, Tunisia, and Morocco are a diversified mix of services, light industry, and agriculture, the economies of Libya and Algeria are dependent on oil and natural gas exports.[9] Because climate change will not directly impact hydrocarbon extraction, unlike agriculture or tourism, these countries may prove more economically resilient to challenges that arise over the next 20 years. On the other hand, they face a grave threat from a likely reduction in hydrocarbon demand from Europe, which currently consumes the vast majority of North African hydrocarbon exports. Climate change will likely have a mixed impact on other aspects of the region's energy sector. More unreliable and infrequent rainfall will reduce the potential for hydroelectric power in the Atlas Mountains. On the other hand, the potential for wind and solar energy may increase.

[8] Unemployment is 30 percent in Libya, 14 percent in Tunisia, 12.5 percent in Algeria, 10 percent in Morocco, and 8.5 percent in Egypt.
[9] Hydrocarbons account for over 95 percent of export earnings and between a quarter and a third of GDP in Algeria and Libya.

This paper does not represent US Government views.

Tourism. The expansion of tourism is an important aspect of economic growth and diversification in the region, particularly in Tunisia, Morocco, and Egypt. An ambitious plan to expand tourism over the next two decades is intended to provide a major source of revenue in the region, contributing significantly to spending on social development. Morocco, for example, has plans to develop six large new coastal resorts and boost tourism to 20 percent of GDP, surpassing agriculture. In addition, Morocco is becoming a popular location for Europeans to purchase holiday homes. Libya also plans to dramatically increase tourism, and Muammar al-Qadhafi's son Saif al-Islam has sponsored a "green" tourism project in Cyrenaica. Climate change poses a particularly acute threat to the tourism sector, since tourists will quickly elect to go elsewhere in the face of harsher conditions such as water scarcity and increased temperatures. In addition, tourist-oriented development is highly resource-intensive. For example, tourists consume far more water than local inhabitants and are far less likely to accept austerity measures. As climatic stress becomes more severe, the disproportionate resource allocation to foreign tourists is likely to cause increasing tension with local populations. It is already becoming an issue in Morocco's tourist centers such as Marrakesh and Fes Medina.

Civil and Key Interest Group Responses

Social Adaptive Capacity

North Africans have long lived close to the land and harbor no illusions about the challenges of contending with natural ecosystems. Over the centuries they have responded adeptly to drought, locusts, desertification, and water scarcity. In recent decades, North African society has changed significantly in response to social, economic, political, technological, and religious dynamics. It is unlikely that the next twenty years will see any less dynamism. The fact that the region is perceived as relatively static testifies to civil society's ability to adapt to or mitigate new conditions without fundamental disruptions. On the other hand, North Africa scores poorly on most social metrics linked to adaptive capacity. North African society is marked by a rigidity and brittleness that comes from underdeveloped civil societies and economies dominated by highly articulated authoritarian states. Sources of revenue and employment and channels of social and political expression are constrained to a few systemic avenues, making them vulnerable to critical failures. Moreover, the predominance of the state is likely to inhibit or overshadow adaptation at the level of civil society.

The level of human and social capital in North Africa has historically been relatively low. Tunisia has a substantial educated, cosmopolitan middle class but its social potential is inhibited by intense political repression. Social capital is nevertheless on an upward trajectory in North Africa. Education and literacy have expanded dramatically in Libya and are improving in the other countries as well, although Morocco lags with only a 52 percent literacy rate.[10] North Africa is producing more university graduates and educational and professional opportunities for women have also improved. Although improvements in higher education have not been mirrored by improved employment opportunities, educational trends suggest that the region will have a greater level of

[10] Literacy is 82 percent in Libya, 74 percent in Tunisia, 71 percent in Egypt, 70 percent in Algeria, and 52 percent in Morocco. Similarly, Libyans spend an average of 17 years in school, comparable to Europe, while the figure is 14 years in Tunisia, 13 in Algeria, and only 10 years in Morocco.

human capital that could potentially be applied to climate change adaptation and mitigation over the next two decades. In addition, many North African citizens exhibit a level of sociopolitical consciousness that creates the potential for social activism and political engagement, given a lessening of state repression.

Awareness of Climate Change

The technocratic elite and intelligentsia in North Africa are aware of the global debate on climate change, and especially the high level of attention to the issue in Europe. The latest Arab Development Report, for example, devoted significant attention to climate change. It is not clear, however, to what extent elites have internalized the implications of climate change. The prevailing attitude remains opportunistic, seeking ways to profit from climate change mitigation. Moreover, North Africa's educated and professional classes have learned to keep their opinions limited to "technical" or academic discussions. They avoid weighing in on state policy so as not to implicate their governments for lack of foresight in combating the effects of climate change. Those who criticize too loudly will not be tolerated at home; often their only resort is living and writing from exile. Ultimately, elite opinion about climate change may depend largely on the degree to which particular groups are or are not insulated from its effects.

Awareness of climate change as a coherent phenomenon is much more limited among the general populace. Nevertheless, many in the public are beginning to have to cope with the practical effects of climate change, such as water scarcity or higher temperatures, on a day-to-day basis. Whether they connect increasing hardships to a broader pattern of climate change will depend to a large extent on how the state-controlled media frame the issue. In addition, although domestic media in North Africa are strictly controlled by the regimes, there is wide access to satellite television channels such as al-Jazeera. Such outlets provide a means to circumvent state censorship and propaganda and allow citizens to hear alternative perspectives. Al-Jazeera and other international Arabic-language media could play a significant role in raising awareness of regional climate change and highlighting deficiencies in state responses. Nevertheless, an increase in social awareness of climate change is not likely to produce major change due to the lack of capacity for broad public opinion to decisively influence state policy.

Civil Society and the State

North African sociopolitical systems are characterized both by the decisive dominance of the state and by a deep divide between civil society and the state's ruling elite. Wealth, privilege, and power are overwhelmingly concentrated in the hands of a relative few. The attitudes and interests of these ruling elites will determine state policy on climate change, as on all other issues. Broader civil society across North Africa has been marginalized and suppressed. Since independence, many social groups have formed associations and social movements and engaged the state across a variety of socioeconomic, cultural, and political issues. In Egypt there are hundreds of registered nongovernmental organizations (NGOs). Such groups are co-opted by the state and tolerated only so long as they do not criticize the state or challenge state domination of the political discourse. As a result, civil society groups have been largely ineffectual and have minimal ability to influence policy. This has led to a pervasive sense of social powerlessness in the face of the state and a corresponding over reliance on state responses to challenges.

Climate change-induced challenges could galvanize NGOs and civil society to mobilize and advocate for reform, but such actors are unlikely to change the sociopolitical status quo. Ultimately, change in North Africa will in most cases depend on concerned groups garnering support from champions within the ruling elite. In Libya, for example, Qadhafi's son, Saif al-Islam, has promoted green development programs. Nevertheless, activism on climatic issues could strengthen the capacity of civil society over time, particularly where civil groups respond more effectively than the state. Civil groups may be more effective in responding directly to climate change-induced challenges at the grass-roots level than in attempting to influence state policy. The state, however, will set the parameters for how much civil activism is permitted. North African states presently remain strongly intolerant of direct or even indirect criticism of state policy or the ruling elite. Based on present political trends, an evolution toward greater openness and tolerance seems probable in Morocco and Algeria but less likely in Tunisia or Libya. However, current state attitudes are not a reliable indicator of how state-civil society relations may develop over the next 20 years. Periods of openness and repression in the region have been cyclical and unpredictable. For example, Tunisia was fairly open in the 1960s and 1970s but is now the region's most repressive regime. In contrast, Algeria has moved from tight control to a comparatively active civil society with regular strikes and challenges to the state.

Civil Responses to Climate Change

To a large extent the response of groups within North African civil society to climate change will be driven by how the state responds. Most civil responses to climate change are likely to manifest at the individual or local level—for instance, farmers changing planting schedules or irrigation methods and urbanites conducting more business at night to avoid the heat. The state is likely to inhibit social mobilization for larger-scale responses. If the state is able to respond effectively, civil society is likely to remain quiescent. The track record of states in the region, however, suggests that their responses to climate change-induced challenges may in many cases be deficient or seriously disruptive of civil society. State responses may involve large-scale disruption of social structures or local communities, such as by forcing relocation out of threatened areas or out of the way of public works projects. Since states in North Africa are largely organized for the benefit of narrow elites, the state's response is likely to focus on mitigation measures that benefit those groups. State responses and resource allocation decisions that manifestly disadvantage or disrupt some segments of society while benefiting others are likely to provoke civil dissatisfaction that may manifest in political unrest, radicalization, or social mobilization.

An acute state failure to address climate change that results in intolerable conditions for significant segments of the population may constitute a sociopolitical tipping point, in essence a breaking of the social compact between North African states and civil society. At that point, civil actors may determine that fundamental systemic change is necessary. The results of such a situation will depend on the specific reactions by state elites and by the public; reform, repression, or revolution are all possibilities. A combination of climatic stress and inadequate state responses over the next two decades could prove the catalyst for a major sociopolitical shift in North Africa. On the other hand, North Africans tend to hold a religiously based view that "what will be, will be." Owing to this fatalistic mindset, North Africans are unlikely to blame the state for climate related stresses, making it more difficult to attain the aforementioned tipping point.

Islamism. Climate change-induced challenges over the next 20 years will provide a major opportunity for Islamist groups to step up as both effective civil responders and political challengers to North Africa's state elite. Islamist groups have emerged as the only viable opposition force because they have resisted state cooptation and because the state has blocked other avenues for social mobilization. In addition, they have established a track record of effective humanitarian responses to mudslides, earthquakes, and other natural disasters, often providing immediate medical, shelter, and food aid that are normally the responsibilities of the state. In many cases Islamist groups may fill the void left by inadequate state responses or the weakness of other types of potential civil responders. Moderate Islamist groups could play a constructive role, providing highly visible humanitarian assistance that empowers autonomous civil actors and contrasts with ineffectual state responses, thus pressuring state actors to respond more effectively. Moderate Islamists could use the climate change mitigation issue to bolster their argument that existing North African governments are illegitimate and exploitative, creating momentum for political reform.

On the other hand, Islamic extremists across the region may exploit climate change's destabilizing impacts and ineffective state responses to promote the spread of militancy and anti-regime violence. Indeed, Islamist militants could point to climate-induced catastrophes as evidence of God's wrath against "apostate regimes" whose un-Islamic behavior has plunged the region into desperate circumstances. Alternatively, climate change could be cast as yet another outrage perpetrated by the West, an argument Usama Bin Ladin has made in the past. Moreover, Islamic extremist groups could take advantage of dire socioeconomic conditions to recruit more followers, particularly among disaffected youth in the shanty towns of Morocco and Algeria. The concentration of unattached, unemployed young men in overstressed North African cities as well as disaffected, marginalized rural communities under acute climatic stress will provide ideal recruiting grounds for extremists.

Internal Migration. Climatic stress will add to the already substantial movement of population from rural areas into cities, exacerbating the region's serious urban challenges. For the most part, such migration is unlikely to differ in kind from existing rural-to-urban migration patterns. It will generate higher unemployment, further strain on urban resources, further expansion of shanty towns, and increased social friction. The decisive question will be whether increased migration reaches an urban tipping point after which the region's cities begin to suffer critical failures of infrastructure, services, economy, and society. In turn, that may depend on the manner and degree to which the state intervenes to sustain urban systems.

Climate change-induced migration may also include patterns other than persistent rural-to-urban migration. In Morocco, for example, cyclical fluctuations in agricultural production have produced a corresponding cyclical migration back and forth between rural and urban areas. To the extent that climatic impacts exhibit a similar fluctuation in intensity, they may produce similar transient migration. In addition, differential climatic impacts in particular areas may drive rural populations to migrate into new rural areas with more abundant resources and less climatic stress. Because such areas are bound to already be inhabited, such movements are almost certain to cause resource conflicts and extend the collateral effects of climate change even into less directly affected areas. In addition, the combination of water scarcity and stress on marginal agriculture could drive more Berber-speakers into Arab-speaking coastal communities, creating a potential for ethnic conflict.

Prospects for Civil Conflict

Climate change-induced challenges have great potential to aggravate North Africa's existing ethnic, sectarian, and social rivalries, potentially generating destabilizing internal conflicts. The region's court systems and other mechanisms for conflict resolution are weak, and mechanisms for cooperative interest aggregation have been deliberately suppressed by the state. As a result, groups under climatic stress are likely to resort to conflict rather than working together. At the most essential level, climate change-induced civil conflict will involve conflict for scarce resources such as water, arable land, food, or employment. The competition for arable land and water is perhaps the most salient of all issues in the region; it also underlies the conflicts in neighboring Darfur, Chad, Niger, and Mauritania. Such resource conflicts will often manifest themselves along inherent cleavages or fracture lines in North African societies. In the face of climatic stress and resource competition, social groups are likely to fall back on primordial ties of family, tribe, and religion. Ethnic, sectarian, and sociopolitical differences which in their own might not lead to outright conflict may be far more contentious when mobilized as expressions of underlying resource conflicts.

The most likely and obvious avenue for civil conflict in North Africa is the ongoing regional struggle between secular and fundamentalist elements within Islam, and by extension between radical Islam and the state. Climate change-induced challenges over the next two decades may well play to the advantage of militant groups. As previously noted, climate change and inadequate state or secular responses to it may be readily incorporated into Islamist groups' complex of grievances. Climatic challenges will divert the resources and attention of the state as well as potentially further discrediting it while creating conditions favorable to radicalization and jihadist recruitment. In Egypt, sectarian conflict also could arise between Muslims and Coptic Christians as desperate socioeconomic conditions take a toll on a population in search of scapegoats. Some 9 percent of Egypt's population is Coptic, the region's only sizable religious minority.

Although North Africa is not an ethnically diverse region, an important cultural faultline exists between predominantly coastal Arab-speakers and the Berber-speaking groups of the interior. The Maghreb states have made repeated efforts to assimilate or suppress the culture and language of the Berber-speakers. In Algeria this has led to confrontations between Berber groups such as the Kabyles of the central Atlas Mountains and the government. Because they are concentrated in marginal areas such as the Saharan oases and the Atlas Mountains, Berbers are likely to suffer disproportionate climatic stress. This could exacerbate clashes with the state or with Arab-speaking groups, particularly in combination with migration. Berber identity could become a rallying point for broader socioeconomic or environmental grievances.

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Setting aside ethnic and sectarian divisions, the divide between the ruling social, economic, and political elite and the public at large has obvious potential to define climate change-inspired grievances. The region's weak social contracts have always implicitly distinguished between the privileged and the masses, and elites are likely both to suffer the least and receive the most state assistance in the face of climate change. A major climate change-induced disparity in conditions, resource access, and state assistance could generate rioting, anti-state violence, and even a revolutionary atmosphere. Because it is directly threatening to the ruling elite, conflict along socioeconomic lines is even more likely than other forms of civil unrest to prompt a swift and violent state response. The greatest socioeconomic disparities and therefore the greatest potential for class-oriented conflict are found in Morocco and Egypt.

Prospects for Social Collapse. Although social collapse facilitated by environmental degradation has taken place in Darfur and to some extent in the Horn of Africa, climate change to 2030 is very unlikely to prompt a general structural collapse of North African societies. Both cities and rural areas will face acute stress, but the preponderant role of the state is likely to mitigate failures of social institutions and maintain a minimal level of social order. Nevertheless, patterns of urbanization and migration probably will create widespread disruption and attenuation of existing societal structures, whether family, community, or clan. The growing prevalence of young, unemployed men without families in urban centers creates conditions for social atomization and the creation of new social structures such as radical networks or gangs. Under such conditions, a serious climate change-induced crisis such as an acute water or food shortage could lead to localized social collapses within shanty towns or in marginal hinterland territories. The response of the state to such a localized crisis will be the key consideration—the failure of social support structures would create abject dependence on the state. Absent a robust state response, such a situation could lead to rioting, a surge in internal migration, or the rise of alternative service providers such as Islamist groups.

State Responses

All five North African states have similar political systems. Regardless of the differing trappings of monarchy, revolutionary heritage, or republicanism, all are governed in an authoritarian fashion by autocratic elites. All five states are highly centralized, with final authority concentrated within a small elite group. The state maintains a predominant position relative to civil society and the public, using coercion and consensus to achieve social acceptance of the existing system. Although the level of repression varies between states, with Tunisia and Libya the most extreme, and has varied cyclically over time, authoritarian regimes are well entrenched in every state in the region. Each of the five North African states is headed by a leader who promotes a cult of personality to serve as the legitimizing instrument for his rule, the most extreme examples being President Zine El Abidine Ben Ali of Tunisia and Muammar Qadhafi of Libya. The essential authoritarian character of North Africa's political systems is not likely to change over the next 20 years, even if other circumstances in the region shift significantly. Climate change seems unlikely to be a catalyst for political reform. The region's authoritarian regimes have weathered the international and domestic challenges and dynamism of the past half century and are likely to persist through 2030, although perhaps in a weakened and unstable form.

State Decision-Making

State policy decisions in North Africa are made in the context of very narrow elite interests concentrated at the top of the political pyramid. Decision-making is unpredictable because so few people make the decisions. While this system subordinates broad public interests to those of a few leaders, it also allows the state to rapidly shift gears and mobilize to tackle issues that the key decision-makers identify as critical priorities.

State Priorities. The consolidation and maintenance of political and economic power by the ruling elite trumps all other state priorities. State elites are determined to sustain their authority at any human, financial, social, or political cost. To the extent that climatic factors generate major threats to regime survival in North Africa, they will attract resources and attention. The central concern of state leaders, however, is more likely to be controlling the sociopolitical implications of climatic challenges rather than mitigating the problems themselves. Their approach may therefore overemphasize security responses rather than holistic social, political, economic, and environmental ones. Adherence to legal niceties and international agreements will be contingent on the requirements of regime security. The gap between what North African states are legally committed to and what they actually do remains wide and is expanding. On the other hand, North African states have always faced resource constraints and environmental challenges, so awareness of the need to manage such issues is high in the region. Resource management and dealing with environmental challenges are recognized priorities that will receive state attention even if they do not rise to the level of major challenges.

Elite Attitudes Toward Climate Change. Ruling elites in North Africa do not see climate change as an immediate threat to their authority. They therefore feel free to take an opportunistic attitude toward climate change, supporting climate change mitigation policies that have collateral economic or political benefits to their particular interests. By the same token, elites are aware that concern over the environment and climate change plays well internationally, particularly in Europe, making green initiatives and climate change mitigation politically advantageous. In addition, elites are conscious of the potential for climate change-induced civil unrest and socioeconomic instability and have an incentive to take measures to diffuse them. They are highly unlikely to countenance measures that involve broad social mobilization or social disruption, both of which are potential threats to their political security. Generational turnover in leadership over the next 20 years is unlikely to decisively alter underlying elite attitudes and objectives. For example, younger leaders such as King Mohammed VI in Morocco and Muammar Qadhafi's son, Saif al-Islam, in Libya have shown interest in environmental and climate issues. Their policies, however, have exhibited the same political calculus and are rooted in the same authoritarian system as their antecedents.

State Capacity

North African states have historically proven able to withstand sustained environmental, political, social, and economic changes and challenges. State structures in the region have been so resilient that the resulting perception of political stasis has masked the region's dynamism in other areas. The extraordinary tenacity of North African regimes provides a reserve of state resilience that has allowed them to maintain power in defiance of expectations. This resilience has not necessarily translated into effectiveness in tackling national and regional challenges, however. State capacity in areas other than regime security has often proven inadequate and unresponsive. Be it Morocco's Makhzen or Algeria's "Le Pouvoir," the entrenched and ossified political system has produced stagnation and an inherent inability to develop and implement necessary reforms. The state bureaucracy lacks latent reserves of dynamism, ingenuity, or the institutional capacity to rise to the challenges presented by climate change. In addition to the direct implications for future responses to climate change, ineffective state action on a wide range of other issues has created a host of competing deficiencies which will divert already limited state resources.

The dominance of the state sector means that North African states have control over a large proportion of national resources, which taken in aggregate are considerable. The centralization of control of national resources under the state is accompanied by intense politicization of resource allocation. Scarce resources, such as water, are allocated according to political favoritism and patronage systems rather than need or rational distribution. These allocation decisions made by a few elite actors may have a greater impact on scarcity and efficiency of use than direct climatic effects. On the other hand, this central control should allow North African states to undertake large-scale civil engineering and climate change mitigation. Governments of these states have shown the capacity to successfully tackle massive civil infrastructure projects, particularly in the area of water resource management—critical to climate change mitigation. Egypt's Aswan High Dam and Libya's Great Man-Made River are examples of the types of projects that will be increasingly necessary over the next 20 years. Egypt has launched the New Valley Project to divert water from Lake Nasser to irrigate the Toshka Depression in the Sahara, significantly expanding the country's agricultural land and living space by 2020. The efforts expended on such ambitious projects, however, have not always been matched by sensible planning—Libya's failed attempt at irrigated oasis agriculture at Al Kufra is one example.

States in the region may prove far less able to tackle the sustained, widely distributed impacts of climate change on their populations than in responding with massive civil engineering projects. North African states have shown longstanding inability or unwillingness to respond to public needs and provide services. The prevailing systems of patronage and corruption inhibit state institutions from functioning in a consistent, professional manner. The wide state-society divide creates state institutions that are not accustomed to being responsive to public concerns and grievances. North African governments have instead shown a tendency to react to public grievances by attempting to avoid or suppress them rather than address them. These deficiencies are unlikely to improve over the next two decades and may be worsened under increasing resource pressure. This could become a serious source of destabilization as climate change causes serious public grievances to proliferate.

Climate Change Mitigation and Development Planning

Most climate change mitigation in North Africa will be undertaken as a result of discrete decisions in response to specific climatic impacts rather than as a result of holistic mitigation planning. Mitigation measures will vary down to individual areas and communities within states, as well as differing according to the specific perspectives of

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the elite decision-makers who champion them. Nevertheless, because of the region's perennial resource scarcity, North African states are accustomed to conducting significant amounts of development planning. Development planning, infrastructure design criteria, and economic policies over the next two decades will be forced to take the impacts of climate change into account. The future viability of North African development plans will depend on whether climate change produces incremental changes in conditions or a radical discontinuity. In addition, North African development models from the colonial period to the present have emphasized water-intensive economic activities such as inefficiently irrigated agriculture, tourism, phosphate processing, and light manufactures. Plans for future development build on this legacy, with particular emphasis on European tourism. Hotels, resorts, and golf courses create very high hydrologic demands; climate change may not be reconcilable with this development model. For countries such as Morocco, Tunisia, and Egypt, where tourism is a key component of the economy, pressures to alter development patterns that reduce water usage, limit building expansion on arable land, or suspend highway construction, will be very difficult. Libya's nascent tourism industry has far fewer vested interests in existing patterns, and Libya is developing "green" tourism in Cyrenaica.

Water resource management will be the most important aspect of climate change mitigation in North Africa. North African states are accustomed to sustained water resource constraints and have institutional experience planning for and managing water resources. One likely response is more investment in desalinization plants as the increased costs of scarce water makes them more economically viable. Libya is already investing significantly in desalinization research and other states are likely to follow suit. All North African states will need to significantly upgrade urban water infrastructure. The Maghreb states are likely to increase construction of reservoirs, dams, and other water management infrastructure in the Atlas watershed. Additional states are likely to follow Libya's example and invest in major infrastructure projects to tap into Saharan aquifers. In Egypt, water management infrastructure projects on the Nile are likely to be expanded. Mega-projects such as the New Valley Project will need to be carefully assessed in terms of gains in arable land versus strain on water resources.

Although North African farmers have proven adept at adapting individually, many of the problems agriculture will face will require major state-level intervention and investment. To mitigate harsher and more variable growing conditions, states will need to update rural infrastructure, particularly irrigation systems; encourage and subsidize crop substitution away from rice and wheat toward more temperature and water stress-resistant crops such as maize; and adopt more efficient land use patterns. Overall, maintaining the agricultural sector will take a larger share of state budgets. As climate change-induced disruptions increase volatility in production and prices, states will need to increase market intervention to stabilize and subsidize prices and supplies or face widespread social unrest. Increasing dependence on food imports will eat into state revenues.

One of the most complex aspects of climate change mitigation will be addressing the expected growth and climatic stress on North Africa's cities. North African states have been ineffective in managing urbanization. Since state policies will focus on the needs of the privileged and of foreign visitors, the wide disparity in levels of infrastructure,

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services, and standards of living between districts in the region's cities will likely worsen. As state resources become increasingly tight, the shanty towns may receive only the bare minimum of development attention.

Because North Africa is not a major direct contributor to global greenhouse gas emissions, it faces less international pressure than other regions to mitigate the causes of climate change. Libya and Algeria, however, are major suppliers of fossil fuels to Europe, so their indirect contribution to European emissions is considerable. Oil and gas production are essential to economic development in Libya and Algeria, and these countries have no interest in limiting exports in order to curb emissions. Indeed, they will do as much as possible to sustain rather than diminish consumer dependence on hydrocarbons. European policy will ultimately determine how the contribution of North African oil and gas to global emissions is addressed.

Social Control

The implications of climate change in North Africa—notably migration, stress on both rural and urban areas, unemployment, and increased resource competition—are likely to generate volatile sociopolitical conditions that will pose significant threats to the existing political structure. The responses of North African states to these threats may be more decisive for the fate of the region than their direct responses to climate change impacts. North African states have robust capacity to maintain social control in the face of domestic challenges and destabilization. Regimes depend on a combination of entrenched patronage systems, robust *mukhabarat* (security) apparatuses, and the support of external allies—a combination that has proven highly effective at maintaining political control. They have a track record of effectively suppressing dissent and unrest or remaining resilient where unrest has persisted, such as the civil conflict in Algeria.

States in the region may seek to suppress or distort information on climate change-related challenges. They seek to control access to any information that could provide a basis for opposition to the state, even information as seemingly innocuous as census data. The proliferation of new media and alternative information sources, however, will make it difficult to maintain such censorship. North African regimes are also adept at deflecting blame, and policy failures may be attributed to sub-ministerial-level bureaucratic scapegoats or foreigners. In addition, all states except Libya have exploited so-called "democratic elections" as a way to demonstrate to their own people and outside observers that they are responsive to rising expectations and accountable to the public.

State-civil society relations in the region are cyclical and specific dynamics will vary between states. Overall, however, increased climatic pressure to 2030 is unlikely to facilitate moves toward greater openness, reform of political institutions, or democratization. Climate change-induced increases in unemployment, derailment of economic progress, and increased public disaffection will make it less "safe" for elites to allow the public more voice. North African states may instead respond to this challenge with widespread repression, human rights violations, and suppression of civil society, NGOs, independent media, and other dissenting voices. Security forces are more likely to be used to suppress civil reactions to climatic crises rather than to provide humanitarian support. More states are likely to adopt Tunisia's practice of systematically isolating, opposing, and ultimately eliminating any opposition. In the process, they are

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likely to damage overall adaptive capacity by inhibiting constructive contributions by civil actors.

Prospects for State Failure

North African states are far more likely to face conditions of pervasive instability than instances of outright state failure. The same factors accounting for state resilience that have allowed regimes to persist and even strengthen for decades despite perennial predictions of collapse are likely to forestall systemic state failure to 2030. In addition to robust internal security capabilities, which can be mobilized to suppress unrest brought about by climatic crises, North Africa's European partners will step in to prevent state failure. The dynamics of shifting factions and interest groups further mitigate the potential for collapse. States may respond to stress with coups or factional "regime changes" that rearrange the leadership hierarchy without altering the underlying political system. Ultimately, the state system is likely to persist as long as the regime connections (*wasta*) and patronage networks continue to secure the loyalty of the elite classes, the military, and the security services.

The stress associated with climate change coupled with an ineffective government response could nevertheless significantly undermine the social fabric and state institutions. The state-society divide remains wide and deep with the potential for civil unrest and political instability always present. A severe climatic crisis combined with other acute challenge could potentially bring about partial of state failure. While regimes may remain in power by force even while public services, governance, and most institutional state functions fail, the implications for the population and socioeconomic system would be dire. Under this scenario, there may be swaths of territory that are ungoverned, "no-go" zones in urban areas, and huge segments of the population living in abject poverty. Failed-state conditions may prevail in certain areas while the state as a whole continues to function at a reduced level. If the state and existing socioeconomic systems are unable or unwilling to provide basic services, people will turn to alternative sources. Examples in the Horn of Africa and elsewhere suggest that a combination of Islamist organizations, tribal or clan militias, and criminal networks are likely to step in to compensate for the lack of state-provided services. The most likely alternatives are Islamist groups, which in some areas already have become the main service providers.

Regional Implications

North Africa in many respects comprises two distinct regions: the Maghreb (Morocco, Algeria, Tunisia, Libya, as well as Mauritania and Western Sahara) on the one hand, and Egypt (as well as Sudan) on the other. Whereas the Maghreb looks to Europe, Egypt is oriented more toward the Middle East and the Arabian Peninsula. Turkey is the development model for Egypt, not Western Europe. The dialects, dress, and lifestyles are different—in the Maghreb people eat couscous, in Egypt they eat bread. Egypt's hydrology and agricultural practices are markedly different from those of the Maghreb. As a result, the two sub-regions will face differing types of climatic mechanisms. In sum, there is much that divides Northwest from Northeast Africa and relatively little that unites the two subregions.

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Prospects for Regional Cooperation
Interstate relations in North Africa are characterized by competition and rivalry rather than cooperation. For example, the border between Morocco and Algeria has been closed since the mid-1990s due to continued sparring over Western Sahara. States in the region tend to view regional challenges such as climate change and environmental degradation in zero-sum terms. They rarely adhere to the diverse legal arrangements, treaties, and constitutional provisions that commit them to cooperation on environmental protection, desertification, illegal immigrants, and other issues. The lack of regional cooperation is a major limitation on the region's overall capacity to confront climate change-induced challenges. Ideally, North African states could respond to the challenges of climate change by setting up critical regional institutions to foster cooperation and the adopting joint policy responses. North African states enjoy complementarities in terms of distribution of natural and human resources—Tunisia providing human capital, Libya and Algeria possessing significant hydrocarbon reserves, and Morocco and Egypt serving as major agricultural producers. Cooperating while playing to their comparative advantages would enhance regional adaptive capacity.

Climate change is one of the few cross-cutting issues with the potential to spur more serious efforts at regional cooperation. In the same way that a common threat from Iran and Iraq prompted the states of the Persian Gulf to form the GCC, a common threat from climate change could facilitate regional integration in North Africa. While climate change-induced challenges might promote greater horizontal cooperation across North Africa, however, they are more likely to increase interstate competition and conflict. The regional bias in favor of competition, self-interest and mutual suspicion among state leaders, and pressure from resource scarcity work against the development of a cooperative approach.

Regional Integration. To date, regional integration in North Africa has been an elusive goal despite a common culture, language, religion, and set of environmental challenges. Initiatives such as the Arab Maghreb Union (AMU) have stalled due to a combination of civil unrest, economic turmoil, and interstate tensions. Established in 1989 with the aim of working toward a common market and coordinated economic policies, the AMU is modeled in part on the European Common Market and in part on the Gulf Cooperation Council (GCC) of the Persian Gulf. Of the various African and Arab multilateral organizations, it comes closest to encompassing the region of interest, including Morocco, Algeria, Tunisia, and Libya, as well as Mauritania, but excluding Egypt. Other regional institutions, such as the African Union, the League of Arab States, or the Tripoli Charter among Egypt, Libya, and Sudan, offer even less promise as bases for regional integration. Prospects for genuine regional integration will likely remain poor over the next two decades. In any case, multilateral institutions are very unlikely to be sufficiently empowered to play a significant role in addressing climate change in the region.

North Africa and Europe
The most important regional relationship for the Maghreb states is with Europe, particularly the Southern European states of France, Spain, and Italy. Geographically, Southern Europe is nearly as close to the population centers in the region as those countries are to each other. Egypt is a separate case, with stronger ties to the United States and the Middle East than to Europe. This difference reflects the division between

the eastern and western Mediterranean basins which has persisted since ancient times. Past colonial ties continue to dictate the relative weight of relations between individual European and Maghreb states—France is closely tied to Algeria, Tunisia, and Morocco; Spain to Morocco; and Italy to Libya. Beyond the legacy of colonialism, the European Union (EU) pursues a "hub and spoke" approach to engagement, forging individual ties with each Maghreb state rather than treating the region as a whole. This encourages a "stovepipe" pattern of relations in which the Maghreb states compete with each other to build ties to Europe rather than building up cooperative capacity within North Africa. This approach both decreases North Africa's leverage vis-à-vis Europe and inhibits movement toward regional cooperation. Although Europe has the influence to promote North African regional cooperation, its policies tend to have the opposite effect—potentially to the detriment of both regions.

In many respects, the states of the Maghreb have closer relations with Europe than they do with each other. They tend to look north to Europe for largesse and solutions rather than laterally to their neighbors. Although the bulk of the Maghreb's trade and foreign investment is oriented toward Europe, in many respects the economic linkage is a shallow one, centered on European tourism as well as North African energy and agricultural exports. Despite Europe's demographic decline and North Africa's labor surplus, European business engagement with North Africa is relatively modest, in part due to inadequate levels of human capital. In response to illegal immigration, drug trafficking, and terrorism, security ties have grown much more robust in recent decades; this trend is likely to continue through 2030.

Cooperation on Climate Change Mitigation. Although Southern Europe and the Maghreb may face similar climatic changes over the next two decades, their different sociopolitical systems will produce divergent collateral challenges. Nevertheless, the prospects for cooperation with Europe in addressing climate change-induced challenges are better than those for cooperation between North African states. Europe's main interest lies in preventing spillover from climate change-induced instability in North Africa, principally in terms of migration, but also access to energy, terrorism, and transnational crime. As with the North African states themselves, Europe's concern for direct climate change mitigation in North Africa is overshadowed by the need to address the security challenges arising from climate change. Nevertheless, Europe advocates strongly for greater policy sensitivity to climate change in North Africa and is likely to provide large and comprehensive climate change mitigation aid packages to its North African partners. Ultimately, Europe has a strong interest in averting state failures or social collapses in North Africa and has the resources to step in to prevent such developments. In the event of climatic-induced crises, European intervention may constitute the last line of defense of the North African state.

***Regional Energy Issues*.** Libya, Algeria, and to a lesser extent Egypt are major energy suppliers to Europe and are likely to remain so to 2030. Although Europe is likely to reduce its dependence on oil in an effort to curtail greenhouse gas emissions, demand for natural gas is likely to increase as an alternative. All three North African energy producers have substantial natural gas reserves, particularly Algeria. Europe has a strong interest in expanding gas ties with North Africa to diversify its gas supply away from dependence on Russia. Europe's energy relationship with North Africa will become more hardwired as additional gas pipelines to Spain and Italy come online over the next two decades. As with other aspects of trans-Mediterranean relations, North African states have competed more than cooperated with each other in pipeline construction.

In addition to natural gas, North Africa has the potential to become an exporter of solar or wind-generated electricity to Europe. Construction of solar arrays in cloud-free North Africa connected to Europe via high tension power lines could become a second energy link between the two regions. Besides the direct energy benefits, Europe could situate solar energy projects in non-gas-producing states in order to dilute the threat of energy monopoly. Both gas and solar energy development in North Africa would have the collateral effect of providing employment and revenues in the region that might diminish the incentive for emigration to Europe and increase adaptive capacity. On the other hand, these industries are not labor intensive and the state would appropriate most of the revenues.

Cross-Border Migration

The threat that climate change to 2030 will drive major increases in cross-border migration is one of the principal preoccupations for Europe and the North African states. North Africa is both a source of migrants and a transit region for external migrants. Both of these dynamics are likely to be significantly expanded by climatic stress in Africa, and both are directed primarily at Europe. Although migration probably will have less direct adverse impact on North African states than other climatic challenges, it is likely to be the principal manifestation of climate change-induced spillover into Europe. To date, the vast majority of cross-border migration from and through North Africa has been economically or politically driven, rather than environmental. This pattern will be altered as climate change affects North Africa more significantly, but the degree to which it will drive increased migration remains unclear. As climate change impacts are felt more strongly in the Sahel and Sub-Saharan Africa, however, they will become leading drivers behind the larger African migration pattern northward toward Europe.

Climate change is likely to render North Africa a less attractive final destination for migrants even as it increases transmigration into Europe. High levels of climatic stress and rampant unemployment in the North African states not only are intrinsic deterrents to immigration but will cause states in the region to take more strenuous steps to curb migration. For the same reasons, sustained climate change-induced challenges are not likely to result in substantial horizontal migration between the North African states. Although localized crises might propel transitory intra-regional migration flows, North Africans will most likely continue to migrate out of the region rather than within it.

North African Emigration to Europe. North African emigration to Europe, much of it illegal, is already a major regional dynamic and will only become more so as a consequence of climate change. North African immigrants form a major segment of Europe's Muslim population, and North Africa is the primary focus of European concerns about immigration. Many North African immigrant communities are now well established and increasingly demographically important in Europe. Although the most prominent such community are the Algerians in France, Europe also hosts large Moroccan and Tunisian communities. Recently, migration from Egypt and Libya has also increased. While second- and third-generation North African immigrants have moved into professional fields throughout Western Europe, recent immigrants still tend to occupy unskilled laboring positions and are mainly concentrated in Southern Europe. In addition to permanent migration, large numbers of seasonal migrants travel to Southern Europe, principally to work in agriculture. Spain's proximity to Morocco and the remaining Spanish enclaves of Ceuta and Melilla on Morocco's Mediterranean coast permit a major flow of Moroccan day laborers to Spain.

The demographic ascension of Europe's Muslim population is an increasing concern to European governments, both in terms of the alteration of European cultural, ethnic, and religious composition and the threat from Islamic extremism. As a result, North African immigration is a high-priority security and foreign policy issue for Europe. Although not explicitly opposed to immigration, European authorities seek to curb illegal immigration and regulate if not reduce legal migration. Although the Southern European states could bolster their practical capabilities to interdict illegal immigrants coming across the Mediterranean, they are inhibited by legal constraints. EU laws and procedures on migration, human rights, and asylum seekers render it difficult for European countries to turn away African immigrants. Because immigrants can claim EU legal protections if they reach EU territory, many migrants travel to outlying European territories such as the Spanish enclaves of Ceuta and Melilla, the Canary Islands, Lampedusa, or Malta.

North African states have an interest in promoting continued robust emigration to Europe. Emigration acts as a "safety valve" to alleviate pressure on resources and employment in North Africa. Climate change is expected to significantly exacerbate both of these challenges; thus continued emigration will become even more important to North African states over the next 20 years. In addition, North Africans in Europe provide remittance revenues that play a significant role in North Africa's economies. The challenge for North African states is to overcome European aversion to such migration. To that end, North African authorities may increasingly seek to manage emigration flows while engaging closely with Europe on migration issues. North African states have shown willingness to provide social services and other support for their expatriate communities. The trump card in securing European concessions on North African immigration appears to be the even greater European aversion to Sub-Saharan African migration. The next 20 years are likely to see a grand bargain between Europe and North Africa on migration. In essence, such a bargain is likely to involve European acceptance of regulated North African immigration in exchange for North African efforts to curb migration from further south.

Egyptian emigration is also an important regional issue, although it is currently oriented to the east rather than the north. Egyptian migrant workers customarily go to the Persian Gulf, not Europe. Remittances from the hundreds of thousands of Egyptians who work in oil-producing countries constitute Egypt's single greatest source of foreign exchange. In recent years, however, Saudi Arabia and the Gulf States have sought to nationalize their labor force, displacing Egyptians and other guest workers with locals. Returning migrant workers will swell the ranks of Egypt's unemployed, multiplying the destabilizing effect of climate change on the country. Over the next two decades, Egyptians are likely to look increasingly toward Europe, potentially adding a large demographic boost to migration flows.

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Sub-Saharan Migration. Although the Sahara Desert represents a substantial barrier to migration, it has not prevented a perennial migration flow from the south along traditional routes through the desert oases or along the Nile. Current levels of migration from the south are manageable in size, but they may increase significantly as a result of climate change. The marginal agricultural and pastoral systems of the Sahel—as well as Mauritania and Western Sahara—are already under severe threat from desertification, drought, overgrazing, and overpopulation. Over the next two decades populations both in the Sahel and further south in West Africa and Equatorial Africa are likely to suffer severe climatic challenges, exacerbated by low levels of state and social adaptive capacity. One of the principal climate change-induced concerns in the Sahel is the fate of Lake Chad. The lake has been shrinking dramatically for decades due to a combination of human and environmental factors and may disappear altogether as a result of climate change. Lake Chad provides water to over 20 million inhabitants of Chad, Cameroon, Niger, and Nigeria. Under such conditions, North Africa will receive large immigration from Sub-Saharan Africa, although the potential magnitude is unclear. The direction of migration flows within Sub-Saharan Africa is difficult to predict, and many migrants may not attempt to cross the Sahara. Climate change, particularly water stress on the oases, may render the desert even more inhospitable to migrants. Large-scale refugee flows in Sub-Saharan Africa, such as those resulting from conflicts in the Congo, Rwanda, and Burundi, have tended to move fairly short distances into refugee camps in neighboring countries, while the Sahara crossing is approximately 1,000 miles.

Moreover, North African states are already beginning to take harsh action to curtail migration. Migrants are often interned under very poor conditions in Saharan oases such as Al Kufra in Libya, where they suffer considerable abuse and are prey to the slave trade and other forms of exploitation. North African states have also parlayed European fears of mass influxes of Sub-Saharan African migrants into assistance in setting up internment camps, increasing border security, and implementing deterrent measures such as improved services in countries of origin. Libya, the main transmigration route, has received major funding from Italy for migration control measures.[11] Such European assistance is likely to increase considerably through 2030 as a preventive measure even if actual migration flows prove less than anticipated. Europe seeks to build a *cordon sanitaire* against Sub-Saharan African migration in North Africa. European states may be willing to turn a blind eye to North African human rights abuses of migrants as long as migration flows are kept under control.

In addition to interned transit migrants, increasing numbers of Sub-Saharan Africans are settling in North Africa, either by choice or because their entry into Europe is frustrated. Faced with anticipated soaring unemployment and resource constraints, North African states have limited capacity to absorb immigrants. Expansion of immigrant minorities is likely to worsen social tension and could spark ethnic violence. As a result, it is in the interest of North African states to pursue a binary outcome in terms of transmigration—either a smooth and continuous flow into Europe, or the wholesale prevention of immigration across their southern borders. European preferences and aid will drive them

[11] Some 70 to 80 percent of the 65,000 to 120,000 annual Trans-Saharan migrants in the Maghreb transit through Libya, with the remainder moving through Algeria and Morocco. Egypt also receives large numbers of Sudanese migrants.

toward the latter course, which is likely to involve widespread human rights abuses and possible conflict with southern neighbors. In addition, an influx of Sub-Saharan African migrants into Europe would increase competition with North African migrants. Reduced access to employment opportunities in Europe would endanger both revenue from remittances and Europe's role as a "safety valve" for North African unemployment.

Prospects for Regional Conflict

The anticipated impacts of climate change in North Africa will likely increase the potential for regional conflict, particularly over scarce water resources. Most North African interstate conflicts are likely to remain localized and bilateral, in part because of the great distances between population centers. As water grows increasingly scarce, competition for trans-border water resources such as the Nile and the underground aquifers of the Sahara will become fiercer and could devolve into outright hostilities. Beyond the potential for "water wars," the legacy of colonial borders in the region has led to a number of territorial disputes, including between Libya and Chad over the Aouzou Strip; Egypt and Sudan over the Hala'ib Triangle; and Morocco and Algeria, both over their common border and over the status of Western Sahara. The latter is a perennial source of tension between Morocco and Algeria that remains a major obstacle to regional integration and cooperation. Tense bilateral relationships could deteriorate further in the face of climate change-induced dislocations. Frictions over a number of issues, from the activities of Islamist militant groups to illegal immigration flows, could lead to a variety of aggressive measures including economic sanctions and even war. Although civil conflicts are more likely than interstate conflicts, internal disputes have historically not spilled over into neighboring countries. The Algerian civil war lasted two decades without major impacts on its neighbors and Western Sahara has endured 35 years of civil war without major impacts except insofar as neighboring states exploit the conflict. Nevertheless, future internal conflicts might not be as contained as in the past due to the trans-border aspects of climate change, such as migration.

The Sahara and the Sahel. There is greater potential for climate change-induced conflict in the Sahel and Sahara than between the states in North Africa. The states of the Sahel have far fewer resources and may face more severe climate change-induced challenges that exacerbate existing crises. The risks of state failure or serious civil or cross-border conflict are high. The conflict in Darfur provides an example of what environmentally driven conflict in the Sahel might look like. Mali, Niger, Chad, and even northern Nigeria are likely theaters for climate change-induced conflict. Such conflict could easily spill over the extremely porous borders into North Africa's Saharan south, following the flow of refugees. The nomadic tribes such as the Tuareg that inhabit the North African-Sahel boundary do not recognize international borders. Cross-border smuggling, human trafficking, and other illegal activity are likely to increase with greater migration and climatic stress. The Sahara-Sahel corridor is also likely to host an increased jihadist presence, further threatening North African and global security. The North African states could be drawn into interventions to secure their southern borders or opportunistically expand their influence in a chaotic Sahel. The example of Libya's wars in Chad illustrates how such adventurism could become a quagmire.

The Nile. Conflict between Egypt and its southern neighbors over the waters of the Nile constitutes the most serious risk of major interstate conflict in the region over the next two decades. Ensuring access to Nile waters is a fundamental national security priority for Egypt, driving Cairo's focus to the south rather than toward its western Maghreb neighbors. Although Egypt received the lion's share of Nile water in the 1954 Nile Waters Agreement, it has nevertheless used and needed far more than its allotted share. This perennial source of friction with Sudan, Ethiopia, Uganda, and other upstream states will worsen if climate change significantly reduces precipitation in the East African Highlands. Any upstream efforts to divert more water from the Nile would pose a grave threat to Egypt, which Cairo is prepared to deal with forcibly. For example, realization of Ethiopia's longstanding plans to dam the Blue Nile would likely provoke Egyptian air strikes. Egypt's position restrains both climate change mitigation and development options across a large swath of East Africa, particularly Sudan, which may suffer severe climatic impacts. Water wars between Egypt and Sudan are a significant risk in the next two decades. The probable independence of South Sudan after the 2011 referendum will further complicate control of the Nile.

Overall Foreign Policy Implications

Foreign policy interests in North Africa are first and foremost a function of how such interests can protect and promote the power and privileges of the narrowly based ruling elite. As such, foreign policy considerations are pursued in a very instrumental fashion regardless of their impact on broader societal concerns. The preeminent climate change-related foreign policy objective for North African regimes over the next two decades will be to develop relationships and access to resources that bolster regime security against climate change-induced instability. North African states are therefore likely to adopt more open foreign policies that seek greater engagement with the United States and Europe.

Despite similar overall foreign policy goals pertaining to climate change mitigation assistance, the North African states are not likely to act as a concerted regional bloc. Each government will pursue its own foreign policy reflecting its specific interests and orientation, often in competition with its neighbors. As in other areas, the foreign policies of Egypt and of the Maghreb have differing orientations. Egypt's most important relationships are with the United States and the Middle East, while the foreign policy of the Maghreb is Euro-centric. These distinctions will most likely persist over the next two decades.

Climate Change Mitigation Assistance

Facing severe political, economic, and social dislocations, North African countries will work assiduously to win sweeping aid packages from Western donors. Foreign assistance will play a critical role in North Africa's climate change mitigation efforts over the next two decades, compensating for inadequate domestic capacity. On the other hand, without sufficient oversight, foreign aid is likely to fall prey to the same problems that dilute domestic state capacity in the region. In addition to financial aid and investment, North African states will seek Western technical expertise and technology transfers. While the Maghreb states will look primarily to Europe as a source of climate change mitigation aid, Egypt will look first to the United States. Unlike Sub-Saharan Africa, North African states are less engaged with China on development issues.

Barring a major shift in North African elite attitudes, states in the region are likely to approach climate change mitigation aid from an opportunistic perspective. North African states will try to extract as much as they can from international donors. They may not seek the types of foreign assistance directly applicable to their most pressing climatic challenges. Instead, they are likely to push for security and economic development-oriented assistance that benefits state and elite interests rather than necessarily mitigating climatic impacts. For example, hydrocarbon-rich states such as Algeria and Libya will seek compensation for expected losses in income as oil and gas consumers come under increasing pressure to reduce their carbon footprint. They may seek financial assistance and technological expertise to develop alternative sources of energy such as solar and wind power. In addition, North African regimes will seek increased military and security assistance to enhance regime security under the guise of combating climate change-induced regional and domestic instability.

As climate change becomes more of a driver of cross-border migration, North African states will hold out the need to stem migration flows as a justification for significant increases in climate-related foreign aid. They may also demand increased access to European markets as another incentive for North Africans to stay home rather than seek economic opportunity in Europe. Because of the direct threat it poses to Europe, the migration issue could become the strongest bargaining chip for North African states. Depending on the magnitude of climate change-induced migration flows, they might resort to outright blackmail, threatening to unleash unimpeded flows of migrants unless granted massive amounts of foreign aid. In a more general sense, they may play the "climate change card," citing the threat of climate change-induced regional crisis to garner Western aid, as they have done with the "terrorism card."

The United States and North Africa

Relations between the United States and North Africa have varied widely over time and between states in the region. The strongest US relationships are with Morocco and especially Egypt. Relations with Tunisia and Algeria are also solid and improving, bolstered by cooperation against international terrorism. Although relations with Libya remain tenuous, the formerly implacable hostility has eased since Libya abandoned its WMD programs and adopted a more conciliatory policy in 2003.

Although the evolution of US relations with the North African states over the next 20 years is difficult to predict, the challenge of climate change will likely encourage increased engagement. To the extent that US relations with all five North African states continue to improve, the United States could act as a facilitator for greater regional cooperation. For the Maghreb states, relations with the United States will most likely continue to be secondary to their relations with Europe. States in the region may attempt to leverage competition for regional influence between the United States and Europe, particularly France. Conversely, Egypt is a close ally of the United States with weaker ties to Europe. The US stake in Egypt is much greater than in any other country in the region; climate change-induced crises in Egypt would impact US interests far more than climate change in the Maghreb. Ultimately, the differing relationships may encourage a division of labor whereby Europe concentrates on support to the Maghreb and the United States on support to Egypt.

US Interests in North Africa. Over the next two decades, climate change is likely to raise the profile of North African instability as a threat to US global interests. The principal US interests at stake in the Maghreb are terrorism, energy, and the region's potential to destabilize Europe. The Maghreb and the Sahara-Sahel corridor constitute a fertile ground for terrorist activity, and climate change is likely to significantly exacerbate the threat. Ties with North African populations in Europe increase the potential for militants in the Maghreb to threaten key US allies, a factor also likely to worsen due to increased migration. Although North African energy exports to the United States have become more important in recent years, the region is more significant in terms of the energy security of US allies in Europe. The Maghreb has the potential not only to export instability to Europe but to absorb a significant share of European attention and resources. An unstable Maghreb could therefore make Europe a less reliable and capable ally for the United States. The principal US interests in Egypt concern security in the Middle East as opposed to Europe. Egypt is a major US ally in the region and a leader in the Arab world, playing a crucial role on the Israeli-Palestinian issue and the struggle against Islamic extremism.

Security Relationships. Security issues are the primary focus of US relations with North African states. The predominance of security and military concerns has led to disproportionate US engagement with security apparatuses in the region, strengthening regimes in ways that may damage long-term prospects to meet the challenges of climate change. US policy in the region has become even more security-centric as a result of the continuing struggle against radical Islamic terrorism. While terrorism has deepened US security ties with states in the region, it has also narrowed the scope of US engagement, which may not be in the long-term interests of either party. As with their bilateral relations with Europe, North African states view security cooperation with the United States in terms of regional rivalries.

North Africa's governing elites have been more than willing to exploit the US preoccupation with security issues in the region to acquire both military equipment and intelligence information to advance their own security interests. To secure greater US support, regimes often portray threats that are more criminal, such as cross-border activities by Saharan nomads, as terrorist-related. They may similarly redefine climate change-related unrest and opposition activity as terrorism, particularly due to the probable prominent role of Islamist organizations. The United States needs to be wary of enabling state repression of actors who might have a constructive impact on climatic challenges and sociopolitical reform. Conversely, the United States may be able to exploit North African states' need for greater security assistance due to climate change-induced instability to increase military access and cooperation. Faced with greater security challenges, states in the region may be more welcoming of United States African Command (AFRICOM) and more open to US military operations in North Africa. Such access could become critical if jihadists gain a greater foothold in the region.

US Climate Change Mitigation Assistance. The most important contribution the United States can make to North African climate change mitigation probably is the provision of technical expertise. Promoting more informed, efficient, and effective decision-making on infrastructure, resource allocation, and development planning will act as a force multiplier for both financial aid and domestic regional capacity. In addition to direct climate change mitigation assistance, overall increases in development assistance and investment will boost regional adaptive capacity. In the longer term, promoting North African economic development is a more effective means of providing the resources needed to address climate change than simply continuing foreign aid. Bolstering the region's economies will spur infrastructure development and job creation, directly addressing climate change-induced unemployment and other deleterious impacts. At the same time, the United States could incentivize more sustainable development patterns suited to the constraints climate change will impose on the region. The United States can provide development advice and assistance in a wide range of critical areas, ranging from health to agriculture.

In most respects, US assistance will most likely parallel that from Europe—a mix of foreign aid packages, investment, and technical assistance. There are a number of areas, however, in which the United States has comparative advantages relative to Europe in the kinds of assistance it can provide. The region's most critical needs in terms of climate change mitigation assistance are in water resource management. The inefficiency of existing water management infrastructure is a major contributor to the region's vulnerability to climate change. The United States, far more so than Europe, has long experience dealing with water resource issues that could be shared with North African countries. The American Southwest is hydrologically comparable to North Africa and could provide an instructive model for water resource management and irrigation policies in both the Maghreb and Egypt. In addition, unlike Europe, the United States can offer North Africa genetically modified crops that could dramatically improve agricultural adaptive capacity. The downside is that European restrictions on such crops would close European markets to North African exports. On the other hand, introduction of genetically modified crops could significantly mitigate domestic food security issues in the region.

Although efforts to raise awareness of climate change, engage with civil society, and promote political and social reforms also could produce beneficial results, the effectiveness of such efforts will be determined by how sensitive they are to the sociopolitical realities of the region. North African states are adept at circumventing Western political pressures involving human rights abuses, democracy promotion, and other liberalizing measures in civil society. They are hostile to intrusions into their internal affairs, particularly the delicate issue of state-society relations. The United States should not expect North African states to subordinate regime security and elite self-interest to climate change mitigation. There could be a backlash from states in the region that could damage mitigation efforts and relations with the United States as a whole. For example, public relations campaigns to raise climate change awareness could easily be perceived as critical of local regimes for their inaction and ineffective responses and of elites for contributing to unsustainable development. Similarly, empowering NGOs and civil actors and promoting other forms of social mobilization could be viewed as threatening by North African regimes even if directed at mitigating climatic challenges.

The Copenhagen Negotiations

North Africa is unlikely to play a substantive role in the Copenhagen climate change negotiations. The region is not a significant global source of greenhouse gas emissions and has more to gain from engagement with Europe on the climate issue than from a global agreement. In general, North African states are likely to go along with the overall position adopted by the G-77. In addition, Libya and Algeria can be expected to push for compensation for prospective losses in hydrocarbon revenues under a more stringent emissions regime.

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NATIONAL INTELLIGENCE COUNCIL

CONFERENCE REPORT

NORTH AFRICA: THE IMPACT OF CLIMATE CHANGE TO 2030: GEOPOLITICAL IMPLICATIONS

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CONFERENCE REPORT

CR 2010-02 January 2010

Southeast Asia: The Impact of Climate Change to 2030:

Geopolitical Implications

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Southeast Asia: The Impact of Climate Change to 2030:

Geopolitical Implications

Prepared jointly by

CENTRA Technology, Inc., and Scitor Corporation

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Scope Note

Following the publication in 2008 of the National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030, the National Intelligence Council (NIC) embarked on a research effort to explore in greater detail the national security implications of climate change in six countries/regions of the world: India, China, Russia, North Africa, Mexico and the Caribbean, and Southeast Asia and the Pacific Island States. For each country/region we are adopting a three-phase approach.

- In the first phase, contracted research explores the latest scientific findings on the impact of climate change in the specific region/country. For Southeast Asia and the Pacific Island States, the Phase I effort was published as a NIC Special Report: *Southeast Asia and Pacific Islands: Impact of Climate Change to 2030, A Commissioned Research Report* (NIC 2009-04, June 2009).
- In the second phase, a workshop or conference composed of experts from outside the Intelligence Community (IC) determines whether anticipated changes from the effects of climate change will force inter- and intra-state migrations, cause economic hardship, or result in increased social tensions or state instability within the country/region. This report is the result of the Phase II effort for Southeast Asia and the Pacific Island States.
- In the final phase, the NIC's Long-Range Analysis Unit (LRAU) will lead an IC effort to identify and summarize for the policy community the anticipated impact on US national security.

In July 2009, a group of regional experts convened to explore the socio-political challenges, civil and key interest group responses, government responses, and regional and geopolitical implications of climate change on Southeast Asia through 2030. The group of outside experts consisted of social scientists, economists, and political scientists. While the targeted time frame of the analysis was to 2030, the perceptions of decision makers in 2030 will be colored by expectations about the relative severity of climate changes projected later in the century. The participants accordingly considered climate impacts beyond 2030 where appropriate.

To support research by the NIC on the National Security Impacts of Global Climate Change, this assessment on the climate change impacts on Southeast Asia and Pacific Islands through 2030 is being delivered under the Global Climate Change Research Program contract with the CIA's Office of the Chief Scientist.

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Executive Summary

The National Intelligence Council-sponsored workshop entitled, *The Implications of Global Climate Change in Southeast Asia and the Pacific Island States*, held on July 21, 2009 brought together a panel of regional experts to consider the probable effects of climate change on Southeast Asia from a social, political, and economic perspective. The workshop focused on Indonesia, Vietnam, Cambodia, Laos, Thailand, the Philippines, Malaysia, Singapore, and Burma. The panelists concluded that ***Southeast Asia faces a greater threat from existing manmade environmental challenges than from climate change to 2030.***

- The impact of dam building on the Mekong River Basin poses a potential catastrophic threat to agriculture, fisheries, and human habitation in Cambodia and Vietnam's Mekong Delta. Disruption of the Lower Mekong will pose a greater near-term challenge to mainland Southeast Asia than global climate change.
- Unsustainable development practices such as deforestation and overfishing threaten to bring about the near-term collapse of vital regional ecosystems, including the tropical forests and the fisheries of the South China Sea.
- Massive manmade forest fires threaten the environment and public health across the region and are major contributors to global greenhouse gas emissions.

While the states of Southeast Asia will face similar threats from climate change to 2030, the severity of the threats will vary both between and within states.

- The region will face a serious water management challenges as climate change renders water resources more unreliable. Both urban areas—such as Bangkok, Dili, Kula Lumpur, Manila and Singapore—and rural areas across the region may face threats from water scarcity, flooding, and storms.
- Food security is already a problem in many Southeast Asian states, including the Philippines, Laos, Cambodia, Burma, and Indonesia. The most at-risk areas for climatic or environmental disruption are "rice basket" regions that feed not only the rest of their countries but others in the region as well. The most serious of which is Vietnam's Mekong Delta, which feeds as much as half the country's population.

Climate change will increase prospects for conflicts within states. Disruptions to traditional lifestyles, water and food stress, and more frequent or more severe natural disasters will destabilize Southeast Asian societies and increase social tension. The poor, ethnic and religious minorities, and those living in peripheral areas of states will suffer disproportionately.

- The highland regions of Laos and Vietnam are a classic example of ethnic minority concentration in disadvantaged peripheral areas. A similar dynamic has helped drive long-standing conflicts in Burma.

- Large-scale migration from rural and coastal areas into cities and will increase friction between diverse social groups already under stress from climate change. The country most in need of massive resettlement planning is Vietnam.

In addition to creating outright refugees, climate change may drive major increases in migrant workers seeking employment in neighboring countries. Overseas migrant labor acts as a safety valve for employment pressures and a source of economically critical remittances. Conflicts over migrant workers are already on the rise in the region and countries under increasing domestic employment and societal pressure are unlikely to welcome a major influx of foreign labor.

- Climate change may drive cross border movements of Vietnamese and Indonesians to Malaysia, Cambodians and Laotians to Thailand, Burmese to Thailand and Malaysia, and Filipinos throughout the region.
- Millions of Filipinos and Indonesians currently work overseas within or outside the region—over two million Indonesians work in Malaysia alone, where they make up over 10 percent of the country's population.

Civil society will likely bear much of the initial burden of responding to climate change in Southeast Asia. The nongovernmental organization (NGO) and civil society sector is growing across the region, and climate change-induced challenges will likely be forces for deepening citizen participation and influence.

- Where civil society is robust, such as in the Philippines and Thailand, it is likely to grow stronger and expand its engagement with climatic and environmental issues.
- In authoritarian regimes such as Burma, Cambodia, and Laos, the state's hostility to civil society mobilization is a major limitation on adaptive capacity, resulting in relatively underdeveloped NGOs and civil society.
- Civil organizations have considerable experience filling in the widespread gaps in state-provided social services, addressing social problems such as education, poverty, and public health. Indonesia, for example, relies on civil society for relief efforts—including groups with links to militant Islamist organizations.

The combination of climate change and other environmental, social, political, and economic factors could cause the failure of one or more states in the region by 2030.

- Laos, Burma, and Cambodia are most at risk of partial or complete state failure.
- Although Vietnam will face the most severe overall challenges in the region, its national resilience renders it unlikely to fail.
- Indonesia may suffer local state failure or disintegration in peripheral areas of the archipelago, but is unlikely to suffer overall failure.

China has a major economic and political presence in the region and may play a greater role in determining the trajectory of Southeast Asia to 2030 than climate change or any of the states in the region.

- China's development activities in Southeast Asia, such as dam construction and resource extraction, pose as great an environmental threat as climate change.
- China's assertive presence in Southeast Asia and unwillingness to compromise on sovereignty over the South China Sea or the damming of the Mekong River will create friction with states in the region, especially Vietnam and Indonesia.

The framing of climate change as a Western-generated phenomenon creates the potential for major anti-Western backlashes over virtually any climate change-induced crisis that arises in the region.

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Contents

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Introduction and Background [1]

Southeast Asia and the Pacific Islands are at risk from the impacts of climate change in the next 20 years due to the region's large and growing population, long coastlines, abundant low-lying areas, reliance on the agricultural sector, and dependence upon natural resources. This report focuses on Cambodia, Indonesia, Laos, Malaysia, the Philippines, Singapore, Thailand, and Vietnam. These countries have a diverse range of governments, populations, religions, economic growth, development, and allocation of natural resources, but they all have a similar tropical maritime climate and face similar threats from climate change.

The effects of climate change have already begun in the Southeast Asia and Pacific Islands region:

- Average annual surface temperatures in the region increased by 0.5-1.1 °C during the period 1901-2005.[i]
- Precipitation patterns are changing regionally, with increases in some locations and decreases in others. For example, annual rainfall decreased across most of the southern regions of Indonesia (Java, Lampung, South Sumatra, South Sulawesi, and Nusa Tenggara) and increased across most of the northern regions of the country (Kalimantan and North Sulawesi) during 1931-1990.[ii]
- Sea level is rising, but the magnitude of the rise varies regionally. During the period 1993-2001, the largest increases in sea level (15-25 mm per year) in the region occurred near Indonesia and the Philippines, while only moderate changes (0-10 mm per year) occurred along the coasts of Thailand, Cambodia, and Vietnam.[iii]

Global circulation model projections indicate that climate change will continue to occur in the region throughout the 21st century:

- Climate model simulations clearly indicate that average annual temperatures are likely to increase across the region by approximately 1°C through 2030, and they will keep increasing through the remainder of the 21st century.
- The magnitude, location, and trends of future precipitation changes are much less certain due to the inherent difficulty of modeling such changes. Future precipitation changes due solely to climate change are difficult to resolve because they are superimposed on significant inter-annual variations that occur naturally in the region. Climate model simulations suggest that net precipitation rates will increase across the region in the next 20 years, but decreases probably will vary geographically and temporally.
- It is difficult to project future changes in monsoon patterns and the effects of El Niño-Southern Oscillation (ENSO) on precipitation in the region, due to the challenges

[1] This section is extracted from the Executive Summary of the Phase I report (see Scope Note): NIC Special Report: *Southeast Asia and Pacific Islands: Impact of Climate Change to 2030, A Commissioned Research Report* (NIC 2009-04, June 2009). Some of the judgments in this report (Phase II) may differ from the Phase I report.

associated with modeling these phenomena. Climate model results suggest that the onset of the monsoon in Thailand, Laos, Cambodia, and Vietnam may be delayed by ten to 15 days during 2030-2070, but the duration of the monsoon will not change.[iv] There is no evidence from climate model simulations that ENSO events will become more frequent due to climate change, but their intensity may increase.[v]

- Sea level will continue to rise, although rates will vary across the region. By the end of the 21st century, sea level is projected to have risen by approximately 30-40 cm.[vi]

There is overwhelming evidence that climate change will impact a variety of sectors in Southeast Asia and the Pacific Islands through 2030. All of the major effects of climate change on the region are interrelated; thus it is impossible to assess one impact independently of the others. The most high-risk impacts of climate change in the region are related to fresh water and ocean water resources, and include the following:

Sea-level Rise. Throughout the region, rising sea level causes a number of devastating effects in the region, including saltwater intrusion into estuaries and aquifers, coastal erosion, displacement of wetlands and lowlands, degradation of coastal agricultural areas, and increased susceptibility to coastal storms. These effects are interrelated with impacts on agriculture, natural disasters, river deltas, water resources, coastal ecosystems, human livelihoods and infrastructure, and national security. Sea-level rise has overarching socioeconomic impacts as well, due to loss of income associated with degradation of agricultural areas and loss of housing associated with coastal inundation, for example.

Water Resources. Future changes in regional water resources are closely tied to changes in precipitation. The number of local regions under severe water stress is projected to increase dramatically in the next few decades, although model results suggest that the region as a whole will not be at risk for water shortages. Fresh water resources on all island nations in the region are especially vulnerable to any variability in precipitation because many rely on rainwater collection for their supply of fresh water. The management of water resources is one of the most challenging climate-related issues in the region, as it is central to health and sustainable development. The impacts of climate change on water resources are interrelated with impacts on agriculture, river deltas, forests, coastal ecosystems, diseases and human health, and national security.

Agriculture. Assessment of the specific impacts of climate change on agriculture is challenging because it is difficult to reliably simulate the complicated effects of future variations in temperatures, precipitation, and atmospheric CO_2 concentrations on crop growth. Temperature increases associated with climate change could result in a northward expansion of growing areas and a lengthening of the growing season. Rising atmospheric CO_2 levels are expected to stimulate plant photosynthesis, which would result in higher crop yields. Studies show that the beneficial effects of CO_2 on plants may be offset by average temperature increases of more than 2°C, however. Overall, it is likely that future crop yields will vary by region and by crop, with yield increases in some locations but decreases in others. Management of the agricultural sector by regional nations is critical to their economic growth and national security. The impacts of climate change on agriculture are interrelated with impacts on sea level, river deltas, natural disasters, water resources, and national security.

Coastal Regions. Coastal regions are some of the most at-risk areas for the impacts of climate change in the region due to their prevalence and high population density.

Mangroves and coral reefs across the region are two key coastal ecosystems that are expected to be significantly impacted by climate change. Many coastal areas are already degraded by pollution, sediment-laden runoff, and destructive fishing practices. Climate change-related destruction and degradation of mangroves and coral reefs will exacerbate these effects and result in long-term economic repercussions because these ecosystems are central to the tourism, agriculture, fishing, and aquaculture industries. The area's coastal regions are also susceptible to inundation associated with sea-level rise and destruction of infrastructure from flooding and storm surges, which are likely to increase as a result of future climate change. Careful management and safeguarding of coastal regions by regional governments is therefore essential in the next 20 years, as the effects of climate change manifest themselves. Impacts on coastal regions are interrelated with sea level, river deltas, natural disasters, water resources, agriculture, forests, and human livelihoods and infrastructure.

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Social, Political, and Economic Challenges

Agricultural Challenges

Southeast Asia is a globally important agricultural region which is a major exporter of agricultural and forestry products. Despite trends toward urbanization and growth of light manufacturing and services, agriculture remains the major employer in the region. Large segments of the population in Southeast Asia remain dependent on subsistence agriculture, particularly in the less developed countries such as Laos, Cambodia, and Burma. The only countries without an important agricultural sector are the micro-states of Singapore and Brunei.

Southeast Asian agriculture faces a wide array of existing challenges. The region's monsoonal climate generates highly variable weather conditions including severe storms and extreme droughts and flooding. The productivity of the region's arable land is threatened by unsustainable agriculture practices, erosion caused by loss of forest cover, industrial pollution, and pesticides. Limited infrastructure in the less developed countries, particularly Laos and Cambodia, hampers the movement of agricultural goods beyond local markets, and monoculture—growing of a single crop—is prevalent. These factors combine to render the agricultural populations most vulnerable in the countries that also have the least capacity to cope with climatic challenges.

The overall impact of climate change on agricultural productivity in Southeast Asia to 2030 is uncertain. To a large extent, it appears likely that climatic impacts on agriculture will be determined by a complex interaction of localized factors. Benefits from longer growing seasons, expanded growing areas, increased photosynthesis, and CO_2 fertilization may be offset by delays in the monsoon, unreliable precipitation, temperature increases, inundation of fertile coastal areas, and increases in pests and plant diseases. Crop yields may increase in some areas and decrease in others, perhaps consistently, perhaps on a shifting basis. Changes in overall conditions will be overlaid by more frequent extreme weather events, which will severely disrupt agriculture on a recurring basis.

Some of the most disruptive climate change-induced effects may be the loss of fertile agricultural land and shifts in growing areas. Land availability is already a major problem in densely populated areas such as Java or the Mekong and Red River Deltas. Sea-level rise, flooding, and erosion will all contribute to a reduction in arable land, particularly in fertile riparian and coastal areas. This will increase the density of farmers on the remaining land, making conflicts more likely. Moreover, the concentration of high-density, intensive farming in areas—such as coasts, river flood plains, and deltas—that are the most vulnerable to climate change-induced challenges acts as a force multiplier for adverse impacts on the region's agricultural sectors. Adaptation to shifts in growing areas will involve the movement of farmers onto new land—most likely land already occupied by others—or switching to new crops. Traditional agricultural communities that have occupied the same location and grown the same crops since time immemorial will have difficulty adapting to such shifts.

Rice Production. Rice is not only Southeast Asia's most important agricultural product but by far the region's most important dietary staple. Although Indonesia is the world's third largest rice producer, domestic demand makes it the largest world importer. The region nevertheless leads the world in rice exports—Thailand is the world's largest rice exporters, and Vietnam the second largest. Both Laos and Cambodia are essentially rice monoculture economies—agriculture dominates the economy and employment, and rice dominates agriculture. A failed rice harvest could cause not merely an economic disaster, but a humanitarian one as well.

The impact of climate change on regional rice production is the single most important agricultural consideration to 2030. As is the case with other aspects of agriculture, climate change is expected to have mixed consequences for rice production. Production may increase in parts of Indonesia and Malaysia while prospects for the Philippines and Thailand are uncertain. Rice production is water intensive, and more intermittent rainfall or delays in the monsoon may dramatically cut rice yields. Upland cultivation will suffer from erosion and increased surface runoff due to deforestation and increased rainfall. If rice paddies remain flooded for longer periods due to increased rainfall or sea-level rise, rotting vegetation will increase methane emissions, contributing to greenhouse gas emissions. In coastal areas, rice paddies face risks of saltwater intrusion from sea-level rise and storm surges. The threat is especially serious in Vietnam, where fresh water from the Mekong and Red River Deltas allows a second rice crop to be cultivated during the dry season, making a critical contribution to Vietnam's rice production and export. By 2030, salinity intrusion in the rice paddies of the Mekong is expected to push up to 12 miles inland during the dry season, causing a loss of dry season rice production.

Rural Labor. Although the region hosts many major urban areas and rural-to-urban migration averaged over three percent per annum from 2000 to 2005, many countries in Southeast Asia remain heavily rural. With the exception of Malaysia, at least two-thirds of the population in the states of the Southeast Asian mainland remains rural. The populations of Laos, Cambodia, and Burma are overwhelmingly rural, while in Indonesia almost half the population remains rural.[2] Even in mixed economies such as Thailand, Indonesia, the Philippines, and Vietnam, agriculture remains a huge employer.[3]

Much of the economic growth in the region has been in light manufacturing, commerce, and services that are comparatively less labor-intensive than traditional agriculture. The beneficiaries have mainly been established urban populations, and the demand for new labor from rural areas, while it has increased, has not done so precipitously in most countries. As a result, many countries in the region have had trouble addressing the surplus rural labor generated by high population growth rates. In Indonesia, for example, the government turned to a controversial transmigration program to relocate surplus rural labor from overcrowded Java and Madura to less populous islands rather than into industrial jobs in Java's cities. Urban industrial growth was not robust enough to accommodate them. These dynamics pose a huge problem for the next two decades. Climate change is likely to drive mass, involuntary migration from overstressed rural

[2] Rural population shares are Cambodia 78 percent, Indonesia 48 percent, Laos 69 percent, Malaysia 30 percent, the Philippines 35 percent, Thailand 66 percent, and Vietnam 72 percent. Singapore is 100 percent urban.

[3] Agriculture accounts for 75 percent of the labor force in Cambodia, 43 percent in Indonesia, 80 percent in Laos, 37 percent in the Philippines, 42 percent in Thailand and 58 percent in Vietnam.

areas into overstressed cities. Absent a sea-change in industrial growth patterns, urban economies in the region will not be able to provide employment to the newcomers. The result could be mass unemployment in both the cities and the countryside. The humanitarian threat from rural unemployment or major losses of rural income is compounded by the fact that much of the rural population in Southeast Asia already lives in poverty. In addition, because of the number of men leaving the countryside in search of work, the poor, marginal rural labor force is disproportionately female. Climate change-induced rural challenges will therefore disparately impact women.

Food Security. Despite the region's agricultural productivity, overpopulation and mismanagement of food distribution mean that food security is already a problem in many Southeast Asian states, including the Philippines, Laos, Cambodia, Burma, and Indonesia. Singapore is dependent on the importation of nearly all its foodstuffs, but the country's relative wealth allows it to purchase ample food on the world and regional markets. Agricultural disruptions arising from climate change to 2030 will raise food security to the top tier of national challenges in the region. Climate change will likely cause both absolute food shortages and sharp increases in food prices. In many cases, the most at-risk areas for climatic or environmental disruption are "rice basket" regions that feed not only the rest of their countries but others in the region as well. The most serious such challenge to 2030 is likely to be the loss of Vietnam's Mekong Delta, which feeds as much as half the country's population.

Food security will be a particular problem where rural populations are heavily dependent on subsistence agriculture. Climate change will increase the frequency of localized agricultural crises depriving subsistence farmers of food and livelihood. This will drive a major increase in rural to urban migration; it will also shift millions from self-sufficiency to dependence on the region's underdeveloped food distribution networks. Infrastructure limitations may prevent surplus food from being used to address local shortages in other areas. Laos, the region's most acutely underdeveloped state, is especially susceptible to this problem. Uneven distribution of food security could be a major source of unrest, especially where it correlates with ethnic or other differences.

Land currently allocated to export crops may have to be reallocated to domestic needs. Crop prices are also likely to increase significantly due to reductions in supply and disruptions of distribution networks. States such as Laos or Cambodia that lack the financial resources to purchase substantial amounts of food overseas are likely to become chronically dependent on humanitarian food aid.

Deforestation. Massive deforestation across Southeast Asia is one of the region's most serious current environmental problems. Southeast Asia hosts roughly five percent of the world's forests and is a major source of global forest products, including valuable hardwoods such as teak. Unsustainable forestry practices represent a greater and more proximate threat to the region's forests and the indigenous peoples who depend upon them than does climate change. Fast-rising global demand for palm oil, rubber, coffee, and other plantation crops have led to the replacement of large swathes of tropical forest with plantations. Indonesia has one of the largest tropical forests in the world, but its rate of deforestation is the highest in the world, more than 14,000 square miles a year. At current rates of deforestation Indonesia and many other Southeast Asian countries will have lost the vast majority of their forest cover by 2030.

In addition, climate change will significantly exacerbate collateral threats associated with deforestation. Heavier monsoon rains caused by climate change will combine with deforestation to drastically reduce the absorption of runoff, leading to increased erosion, flooding, and landslides. These problems already pose major threats across the region, including in the Philippines, Indonesia, Burma, Laos, and Cambodia.

Climate change is also expected to bring hotter, drier conditions during the dry season, which is likely to increase the extent and incidence of forest fires in the region. In recent decades Southeast Asia has suffered some of the world's worst forest fires, notably in 1997. Forest fires and peat bog fires associated with deforestation have been estimated to contribute 80 percent of Indonesia's greenhouse gas emissions, which are among the world's largest behind China and the United States. The major cause of the fires is large-scale burning of forest vegetation and carbon-rich peat bogs for land clearance, primarily in Sumatra and Borneo. Up to 30 percent of total global carbon is currently sequestered in peat bogs in Indonesia and Malaysia, which can smolder underground for years, igniting forest fires every dry season. Forest fires generate an annual blanket of smoky air over the region that can cover as much as two million square miles. Indonesia is the largest contributor to this phenomenon, which is euphemistically called "the haze." The haze represents a major regional environmental hazard that has a significant economic and public health impact not only on Indonesia but on neighboring Malaysia and Singapore. Burning may substantially decrease as Indonesia runs out of forest land suitable for clearance.

Coastal and Maritime Challenges

The maritime impacts of climate change are critical to Southeast Asia due to the concentration of population, agriculture, and economic activity in low-lying coastal areas.[4] In Indonesia, for example, coastal and marine development, including fishery production and shrimp farming, account for 25 to 30 percent of GDP and provide employment for 20 million people. The region's coastal lands and waters are already under threat from environmental and developmental pressures such as pollution, sediment-laden runoff, and destructive fishing practices. Climate change will exacerbate the degradation of the region's coasts through sea-level rise, coastal erosion, increased storm activity, and damage to littoral ecosystems. The archipelagoes of the Philippines and Indonesia, with some 22,000 and 33,000 miles of coastline respectively, are by far the most susceptible to coastal climatic impacts and are also expected to experience the greatest sea-level rises in the region. Nevertheless, the greatest proportional humanitarian and socio-economic impacts may be felt on the densely populated, agriculturally vital deltas of Vietnam and Burma. Further offshore, changes in ocean conditions may significantly disrupt marine ecosystems.

Fisheries. The seas of Southeast Asia host some of the world's most important fisheries, and fish is the most important source of dietary protein for many of the region's

[4] The percentage of the population living within 60 miles of the coast is 98 percent in Indonesia, 87 percent in the Philippines, 78 percent in Vietnam, and 40 percent in Thailand.

inhabitants. Despite large-scale commercial fishing both by locals and by Chinese, Japanese, and American fishing fleets, much of the region's fish catch goes to individual subsistence fishermen. Fish stocks in the region have been under threat for the last several decades from overfishing and pollution. Maritime climate change will cause shifts in water temperature, salinity, ocean circulation, and acidity. At a minimum, the movement of fish schools will be altered, but at some point climatic effects could have a gross disruptive impact on the marine food chain. Crucial regional fisheries such as those of the South China Sea could be seriously depleted or even collapse entirely. The economic and food security impact from such a catastrophic scenario could create instability across the region.

Coral Reefs. The coral reefs of every littoral state in Southeast Asia are already seriously threatened by coastal economic development, shipping lanes, overfishing, sedimentation, and wastewater pollution. Climate change is expected to compound the pressure on reefs, primarily through coral bleaching and reduced marine biodiversity brought about by rising ocean temperatures. Indonesia's 18,000 square miles of coral reefs generate annual economic benefits estimated at US$1.6 billion, while the Philippines' approximately 9,000 square miles generate US$1.1 billion. Thailand, Indonesia, and the Philippines have already suffered major coral bleaching episodes. Even though coral reefs usually recover from bleaching events, more frequent disruption of the reefs would have a significant regional impact on both fishing and tourism.

Coastal Erosion and Island Losses. The impact of erosion on coasts will vary across the region, depending on coastal topography and other factors. Coastal erosion will particularly threaten the coasts of Vietnam, Indonesia, and the Philippines. In addition to fishing, intensive agricultural activity is concentrated along Southeast Asia's coasts and particularly in the fertile silt of the region's river deltas, such as the Mekong and Red River Deltas in Vietnam and the Irrawaddy Delta in Burma. Saltwater intrusion is already a problem in delta regions and is expected to move further inland, contaminate the soil and irrigation water of low-lying croplands in areas such as Java and Sumatra. Over the long term, most of the deltas in the region will be permanently submerged or eroded away. Inundation of fertile coastal farmland will be compounded by storm surges that will destroy additional farmland and infrastructure, reaching far inland in flat delta regions. Sea-level rise, changes in sea temperature and salinity, and storm activity will also threaten the coastal mangroves. Like forested hillsides on land, the mangroves play a crucial role in anchoring the fertile silt washed down into the deltas. If the mangroves die off, deltaic erosion would accelerate dramatically. Vietnam stands to lose over 14,000 square miles of delta, and significant deltaic areas may disappear in Thailand and Indonesia as well.

Sea-level rise is set to completely submerge numerous small islands in the region, especially in Indonesia. Islands and reefs often form the basis for offshore oil and gas claims, making their potential disappearance a contentious issue. Some estimates indicate Indonesia may lose 2,000 small islands to sea-level rise by 2030. It is worthwhile to put this impressive figure in perspective, however. Less than half of Indonesia's more than 13,500 islands are inhabited, so even the large-scale loss of islands may not be directly felt by the Indonesian population. The most serious socio-political impact may be the effect losing key boundary islands will have on territorial and seabed claims.

Coastal villages, towns, and cities will face the risk of inundation as a result of sea-level rise, more frequent major storms, and associated storm surges. Storms and flooding will take a considerable toll in destroyed housing and infrastructure and socio-economic disruption. Public health risks will increase due to such factors as contamination of drinking water. Coastal settlements at risk include some of Southeast Asia's most important cities, such as Bangkok, Jakarta, and Rangoon. While major coastal cities will likely suffer the greatest economic losses, the humanitarian toll may be higher in smaller coastal settlements which lack the infrastructure to cope with disasters. Cyclone Nargis in 2008 illustrates this distinction—although Rangoon suffered extensive damage, the vast majority of deaths occurred elsewhere in the Irrawaddy Delta.

Hydrologic Challenges

The overall abundance of water in Southeast Asia is tempered by the monsoonal wet-dry seasonal variation. Southeast Asia thus faces both challenges from excessive water (flooding, erosion due to runoff, severe storms) and from water scarcity (droughts and reduced river flows). The combination of high population density and water-intensive agriculture in some areas also leads to severe localized stress on water resources and distribution systems. Water quality is also a major issue, with high levels of industrial and agricultural pollutants tainting many water sources.

Climate change will have a mixed impact on regional water resources in Southeast Asia. Although the region as a whole does not appear likely to suffer a major loss of water to 2030, shifts in hydrologic systems and precipitation patterns could nevertheless create severe local crises. Precipitation projections vary, but in general significant increases in precipitation are predicted in western maritime Southeast Asia and the southern Philippines. Southern Vietnam, East Malaysia, and particularly eastern Indonesia and the northern Philippines are predicted to suffer sharp decreases in rainfall. In practical terms, this intra-regional variation renders the overall net water availability in the region irrelevant—local conditions will determine incidence and severity of water stress. In addition to geographic variations, the already strong seasonal variation in precipitation will become even more extreme, bringing more severe droughts, flooding, and storms, and exacerbating water management problems across the spectrum. On the mainland, climate change-induced glacial melting in the Himalayas, the source for the major rivers of mainland Southeast Asia such as the Mekong, Irrawaddy, and Salween, is expected to generate increased near-term river flows but drastic decreases in the longer term as the glaciers disappear.

Because water stress-induced crises could arise from either extreme—water scarcity or excess—such crises could occur virtually anywhere in the region. The most at risk areas will be those subject to pre-existing water scarcity or abundance. For example, Thailand is among the countries with least potable water available per capita, and its northeastern Isan region is already drought-prone. The margin of available water resources relative to population and agricultural and urban water use is already narrow in most of the densely populated areas of the region, such as Java. Water excess poses the greatest threat to low-lying flood-prone areas such as the region's river basins and deltas. Water stress in such areas could generate large-scale refugee flows and humanitarian crises that the region is ill-equipped to handle. In addition, agricultural areas where cultivation is dependent on finely balanced traditional hydrologic patterns will face severe disruption. The foremost example is the lower Mekong Basin, where agriculture depends on the complex and unusual hydrology of the Mekong River.

Urban Water Challenges. Although many of Southeast Asia's agricultural areas will face acute water stress, the potential for disastrous humanitarian consequences may be greater in the region's cities. Urban growth already strains the region's water infrastructure, which is underdeveloped in many areas. During the height of El Nino cities such as Bangkok, Dili, Kuala Lumpur, Manila, and Singapore went through sporadic water shortages and rationing. The combination of unreliable rainfall and massive urban growth as people are displaced from the coast and countryside could deplete critical aquifers and lead to severe urban water shortages. Southeast Asian states will face the need to allocate a significantly greater proportion of water resources to urban areas, diverting water away from already stressed water-intensive agriculture. Water resource allocation is already a point of contention within and between the states of Southeast Asia. For example, Singapore depends on Malaysia for most of its water, which has led to recurring tension between the two countries. Although most of the governments in the region subsidize water, cities across Southeast Asia are likely to face sharp increases in water costs.

In addition to shortages, some cities will also face increased risk of severe flooding. Urban flooding is already a widespread phenomenon in the region, both as a result of wet season riparian flooding and storm surges. During the 2008 monsoon season both Hanoi and Vientiane had their worst flooding in generations. In early 2009 extreme rainfall caused a dam near Jakarta to collapse and sweep away a suburban neighborhood. Manila and Bangkok face similar flooding challenges. The impacts from more frequent and severe urban flooding will be compounded by major urban population growth and overstressed infrastructure.

The Mekong River. By far the most serious water resource issue in the region concerns the Mekong River Basin. Between now and 2030, the events taking place in the Mekong River Basin will have greater adverse impact on the ecology of mainland Southeast Asia than will global climate change as a whole. The Basin is an area of over 900,000 square miles, home to more than 320 million people in six countries—Burma, Thailand, Laos, Cambodia, Vietnam, and China's Yunnan province. Of those countries, Laos, Cambodia, and southern Vietnam are almost wholly dependent on the Mekong River. In Vietnam alone, some 30 million people are dependent on the Mekong River Delta. The Delta accounts for half of Vietnam's rice production and Mekong fisheries provide 80 percent of the dietary protein intake in southern Indochina.

The Mekong Basin is already under stress from pollution, overpopulation, declining fish catches, deforestation, and erosion and saltwater intrusion in the delta. Like other rivers in mainland Southeast Asia, the Mekong is expected to suffer disruptions in flow as a result of glacial recession in the Himalayas and more variable precipitation. Sea-level rise, salinity intrusion, and coastal erosion will pose major threats to the river's delta in southern Vietnam. Sea-level rise in the delta will put at risk large swathes of cultivable land, critical fisheries, and nearly two million inhabitants. Although climate change poses a longer term threat, the massive hydroelectric dam construction program under way on the river poses a much greater and more proximate threat.

The risk to the Mekong stems from the river's complex hydrology. The strong seasonal variation in precipitation associated with Southeast Asia's monsoon climate generates a unique "flood pulse" hydrologic pattern in the Mekong River. The coming of the monsoon rapidly swells the river's flow, sending a flood wave downstream that irrigates the fertile rice paddies and croplands of the lower Mekong in Cambodia and Vietnam, also bringing nutrient-rich silt to rejuvenate the soil. In addition, the Mekong's flood pulse drives the hydrology of Cambodia's Great Lake, the Tonle Sap. The lake supports three million people and its exceptionally rich fisheries provide 60 percent of Cambodians' protein intake as well as stocking the fisheries of the Mekong Delta. The lake empties into the Mekong at Phnom Penh, but the Mekong's monsoon flood pulse reverses the flow, driving water back north into the lake. As a result, the Tonle Sap quadruples in size during the wet season, irrigating much of central Cambodia. The lake also acts like a tidal basin, preventing the increased monsoon flow from flooding or scouring the away the Mekong Delta. When the Mekong's flow drops during the dry season, the vast reservoir of freshwater held in the Tonle Sap empties back into the Mekong Delta. This doubles the dry season flow into the delta and permits year-round rice cultivation that accounts for much of the area productivity.

If all the dams and infrastructure projects are implemented, the Mekong Delta will disappear much faster than it would due to Sea-level rise*sea-level rise*. The river's complex hydrologic system could be catastrophically disrupted even by modest dam construction and water diversion, let alone the massive programs now underway. Without the seasonal flow reversal into the Tonle Sap, the lake would shrink drastically, devastating Cambodian agriculture. Without dry season drainage from the Tonle Sap, the Mekong Delta would no longer be able to produce a second rice crop. The migratory fish population would be cut off from spawning grounds in the Tonle Sap or further upstream, collapsing the fisheries. In addition, even a few dams on the lower Mekong will prevent renewal of the delta silt deposits and the reduction in flow will allow permanent saltwater intrusion that would kill the mangroves and prevent rice cultivation. The disruption of the lower Mekong hydrology would represent a massive catastrophe for southern Indochina. Simultaneous huge losses in rice production and in the fish catch would generate a food security crisis for millions in Cambodia and Vietnam. In combination with accelerated erosion, millions of Vietnamese would be driven from the Mekong Delta, one of the most densely populated areas in Southeast Asia. This would not only generate a humanitarian crisis but could lead to major conflicts across southern Indochina.

Demographic and Public Health Challenges

Southeast Asia has experienced rapid population growth that has led to overpopulation and consequent strains on land availability, food security, water resources, and social stability. Large segments of the region's population are concentrated in fairly small, overstressed areas such as Java, the Mekong and Red River Deltas, the Bangkok area, and islands across the Philippine and Indonesian archipelagoes. Such population concentrations are already at high risk from climate change-induced challenges, and population is likely to become even more concentrated as a result of climate change. Climate change is likely to spark the next wave of urbanization, which none of the countries in the region are prepared to deal with. Whereas rural-to-urban migration has traditionally been a safety valve to alleviate rural poverty and discontent, it will increasingly become a matter of survival. At the same time, the capacity of Southeast Asia's cities to absorb migrants will decline as a result of climate change-induced stress on already inadequate infrastructure.

As a result of high population growth rates in recent decades and a fairly low life expectancy in some states, Southeast Asia has a relatively young population. Demographically younger countries tend to be those with lower levels of economic development and weaker state capacity, such as Laos (median age 19), Cambodia, the Philippines, and Timor-Leste (all median age 22). Reduced opportunities and greater climatic and economic hardships may create a generation of alienated youths with adverse impacts on the social stability of countries in the region.

Public Health Challenges. Public health has been a persistent challenge for Southeast Asia. Apart from Singapore and to a lesser extent Thailand, the region has weak health care infrastructure, particularly in Burma and Laos. Public health sectors in many countries are already struggling with very high prevalence of chronic diseases such as HIV/AIDs as well as periodic severe outbreaks of a host of tropical ailments. Sanitation and water treatment also remain rudimentary in many areas. Although public health systems may become more robust over the next two decades, they are nevertheless likely to be severely taxed by the effects of climate change. Regional vulnerability to disease will increase as higher temperatures and humidity combine with projected increases in population, urbanization, and declining water quality. The collateral effects of food, water, and heat stress may weaken immune systems, and climate change-induced migration will aid in the spread of diseases.

Economic Challenges

Southeast Asia is an economically heterogeneous region with widely varying levels of economic development. At one extreme, Laos and Cambodia remain underdeveloped agricultural economies, with most of their population engaged in subsistence rice farming. At the other, the city-state of Singapore is a trading, financial, and manufacturing powerhouse. Although each economy faces specific challenges, the region has also faced a number of common challenges, including major regional financial crises, the need to transition from agriculture to manufacturing and services-based economic models, depletion of natural resources, and the challenge of addressing widespread poverty.

Southeast Asia was badly shaken by the Asian Financial Crisis of 1997-1998 and is again under severe stress from the continuing global economic downturn. As was the case after the financial crisis, success in economic restructuring and recovery will be a key determinant of socio-political stability over the next two decades. Most Southeast Asian states have staked their domestic political legitimacy on the maintenance of economic growth and development coupled with spending on social programs such as poverty reduction, agricultural subsidies, and public health. In those countries that fail to undergo a robust recovery, persistent economic weakness and climate change-induced stress will compound each other. Climate change is likely to seriously threaten both economic growth and state budgetary largess on a sustained basis, which could translate into widespread political instability.

Resource Depletion. The rapid depletion of natural resources such as timber, hydrocarbons, and minerals is a major problem across the region, with the loss of timber being particularly acute. Many of the countries in the region, particularly Indonesia, Malaysia, the Philippines, and Burma depend heavily on natural resource rents for state revenues. Over the next 20 years unsustainable resource exploitation is likely to undermine the flow of public funds, as well as generating intense competition over resources. Climate change-induced disruptions such as storm activity, flooding, and erosion will make natural resource extraction more costly and difficult. Climate change will thus disrupt a principal source of public revenues while generating a major simultaneous need for increased public expenditures to combat climate change-induced impacts. This will increase the need for sustainable development models as well as economic diversification programs such as that undertaken in the East Malaysian state of Sarawak, which responded to depletion of timber resources by turning to manufacturing, commercial agriculture, and services.

Poverty. Millions of Southeast Asians live in poverty, with a narrow margin of subsistence and few resources to respond to climate change or cushion a loss of income resulting from it. In both Vietnam and Indonesia, 85 percent of the population lives on less than $2.00 a day. Poverty is far worse in countries such as Laos, Cambodia, and Burma. Thailand, Malaysia, and particularly Singapore have higher overall standards of living—in Thailand less than five percent live on $2.00 a day or less. Poverty reduction is a major aspect of economic development in the region and a major source of popular legitimacy for leaders and regimes. In Indonesia, for example, President Yudhoyono was re-elected in large part because of his allocation of subsidies to the poor. Income inequality in Southeast Asia has increased since the 1997 Asian Financial Crisis, which stalled the momentum built up by poverty reduction efforts in the preceding decades.

Climate change in Southeast Asia will disproportionally affect both the poorer countries in the region and the poorer populations within individual countries. Poorer states are more susceptible to state breakdown and poorer populations face greater risks and vulnerabilities. The net effect may be to push millions into a position of abject dependence on humanitarian aid, most of which will have to come from overseas. Shortages of available funds in the long-term will force leaders to make hard choices between climate change adaptation and policies such as poverty reduction.

This paper does not represent US Government views.

The Energy Sector. A global shift away from reliance on fossil fuels in response to climate change could cause some loss of revenues for Southeast Asian economies that depend on hydrocarbon resource rents, such as Malaysia, Indonesia, and particularly Brunei. Even if developed countries move away from fossil fuels, however, growing demand in the developing economies combined with dwindling world supply may keep oil and gas revenues high.

The region's abundant energy resources, particularly fossil fuels and hydroelectricity, mean that Southeast Asia is not likely to face a major overall energy deficit to 2030. As with food and water, the problem is more the need to expand energy distribution infrastructure so that energy can be sent where it is needed. Massive climate change-driven urban growth will increase urban energy demand and energy costs across the region over the next two decades. Countries in the region expect to meet much of the increased electricity demand with hydropower, driving potentially disastrous dam construction, notably on the Mekong River. Despite the attractiveness of hydropower, climate change may have an adverse impact on the region's hydroelectric resources due to reduced river flows.

Trade and Industries. Aside from extractive resource-based industries such as mining, hydrocarbons, and timber, industrial growth in Southeast Asia has been focused on light manufacturing such as electronics, textiles, clothing, and food processing. Heavy industry is not an important economic factor and the pace of industrialization has been solid but not explosive. Although destructive events such as storms or floods could cause damage to plants and equipment, the major climate-related challenge will likely be the need to absorb an influx of rural labor into the industrial labor pool. A growing industrial labor surplus may drive down wages and quality of life for urban workers. Conversely, climate change-induced urbanization may drive a shift toward more rapid industrialization.

Situated astride some of the world's most important maritime trade routes, Southeast Asia has long been a major trading region, with Singapore its unquestioned hub. Southeast Asian countries do a brisk trade in both manufactures and primary products such as hydrocarbons, minerals, and timber. In addition, re-export trade is very important due to the region's location on the trade routes from Northeast Asia to South Asia, the Middle East, and Europe. Climatic pressure may reduce the availability of certain resources and goods, altering the composition and volume of trade in the region, with significant impacts on Singapore and other states. Increased storm activity may depress maritime trade and along with sea-level rise may threaten port infrastructure. In addition, the possible opening of new, shorter Arctic trade routes between Northeast Asia and Europe could have a major effect on re-export trade over the longer term.

Tourism. The tourism industry is very important in Southeast Asia and may suffer disproportionately from climate change. Tourism is an established economic staple in Thailand, Indonesia, and the Philippines. It accounts for over seven percent of GDP in Thailand, which receives upwards of five million visitors each year. In recent years tourism has also become a major driver of economic growth in the less developed countries of mainland Southeast Asia, particularly Cambodia and Vietnam. Cambodia's burgeoning tourism sector brings two million visitors a year to the ruins of Angkor Wat and the beaches around Sihanoukville and Kep, providing much needed hard currency. Eco-tourism is also very important in places such as East Malaysia and Indonesia. In the East Malaysian state of Sabah, for example, eco-tourism brings roughly two million visitors a year and is the second largest sector in the local economy.

Despite its economic benefits, tourism also increases environmental degradation and disrupts local socio-economic patterns. For example, the many new tourist hotels around Siem Reap in central Cambodia are draining the area's water table, to the detriment of local agriculture. In addition, tourism-driven development has led to conflicts over real estate and forced farmers from their land. These factors will become more disruptive as climate change further restricts water and land availability. Moreover, degradation of coastal, coral reef, and rainforest ecosystems due to climate change poses a major threat to regional tourism, particularly coastal and eco-tourism.

Civil and Key Interest Group Responses

Civil society will likely bear much of the initial burden of responding to climate change in Southeast Asia. The nongovernmental organization (NGO) and civil society sector is growing across the region, and climate change-induced challenges will likely be forces for deepening citizen participation and influence. Where civil society is robust, such as in the Philippines and Thailand, it is likely to grow stronger and expand its engagement with climatic and environmental issues. Even where civil society is weak, the challenges posed by climate change are likely to force it to expand to fill the void left by ineffective or selective state responses.

In authoritarian regimes such as Burma, Cambodia, and Laos, the state's hostility to civil society mobilization is a major limitation on adaptive capacity, resulting in relatively underdeveloped NGOs and civil society. On the other hand, populations in those states may be more resilient to sustained hardship. The states with more open political systems, such as the Philippines, Indonesia, or Thailand, tend to have well-developed social resources and civil society organizations. These groups range from family-clan organizations to national-level socio-religious networks. Even in nominally open, democratic countries in the region, however, the capacity of civil society to influence state policy in Southeast Asia will likely remain relatively limited. The divide between civil society and political, economic, and bureaucratic elites in the region remains wide and mechanisms to redress public grievances are weak. Rather than challenging or pressuring the state, civil society is more likely to work in parallel to the state. Civil organizations have considerable experience filling in the widespread gaps in state-provided social services, addressing social problems such as education, poverty, and public health. For example, Indonesia relies on civil society for relief efforts—including groups with links to militant Islamist organizations. This backup social support network could readily be mobilized to address climate change-induced challenges.

Public awareness of climate change-related issues remains weak across much of Southeast Asia but most likely will strengthen as challenges manifest themselves with increasing frequency and severity. Awareness is a prerequisite for mobilization and effective action, but not a guarantee of either. Sensitivity to environmental issues among the educated urban elite is important but may not translate into action in the rural periphery where it is most needed. One of the most important roles civil society can play regarding climate change is to help translate sensitivity into action on the climate change issue.

Political mobilization is already on the rise across the region, among both elites and the traditionally depoliticized masses. Farmers in Thailand have mobilized to protest the government's decision to import Chinese agricultural products, while many young, Western-educated Indonesians can be found heading environmental groups. Climate change will expand the range of grievances around which such mobilization will take place and consequently increase the scope of active civil society. Much of this mobilization will occur at the local level, where civil society groups may be better able to pressure local government. The expansion of participation by civil society in the political process may not always be constructive. In Thailand, for example, the coups and political turmoil in Thailand have resulted in the growth of the competing Red and Yellow Shirt protest movements whose clashes with each other and the state have sometimes turned violent. Similar "uncivil society" movements may arise around climate change-induced social conflicts.

Climate change is likely to expand civil mobilization even in heretofore authoritarian states in the region, potentially leading to more open political processes. Vietnam probably provides the strongest example of this process. Thousands of village and local organizations have emerged that are not under the direct control of the pro-government umbrella group for "mass movements," the Vietnamese Fatherland Front. Although the National Assembly remains controlled by the Communist Party, it is becoming more important and better at representing local interests. Because the Vietnamese Government will rely on the assistance of NGOs to help mobilize to prevent damming of the Mekong River, the state is likely to become more comfortable with such groups over time. By 2030, this emerging trend toward increasing openness may render Vietnam one of the more representative governments in the region, even if it remains a one-party state.

Interest Groups in Civil Society

Environmental Movements. Over the last decade, environmental movements have increased in size and influence, forming networks across the region and increasingly spreading into rural and peripheral areas. The growth of environmentalism has been spurred by concern among the expanding middle class over unrestrained devastation of the region's environment by such practices as logging, mining, and overfishing. Environmental groups obviously have an important role to play in raising awareness of climate change and pressing for mitigation measures. Moreover, the increasing social salience of climate change-induced challenges will likely continue to bolster the membership and influence of environmental groups.

Although their policy leverage remains limited, environmental groups are becoming increasingly engaged in the political process. In Malaysia, for example, environmental groups were able to secure concessions by joining the political opposition, thus allowing the latter to cross the two-thirds threshold in parliament. Environmental groups are well established in the Philippines and increasingly influential in Indonesia and Thailand.

Over the next two decades, environmental groups might take hold even in repressive regimes such as Burma, Laos, Cambodia, and most promisingly in Vietnam. Authoritarian regimes tend to permit such groups space in the public discourse because they are seen as non-threatening. As the example of former Soviet states shows, however, such groups can become the first wedges that allow broader civil society to make inroads against state repression.

On the other hand, the state and powerful economic interests have in many instances responded with violence as environmental movements have increased in prominence and mobilization. Under the government of Prime Minister Thaksin Shinawatra in Thailand, for example, environmental activists were murdered and efforts were made to marginalize environmental activism nationally. Environmental activists have similarly been targeted in Cambodia and elsewhere in the region. Such violence is likely to increase as climate change creates new environmental conflicts and raises the stakes on competition over resources.

The Media. The degree of freedom of the press varies widely across Southeast Asia. In the more authoritarian states in the region, the media remains strictly controlled. Like other institutions in the region, the media generally is not well-informed about climate change and its implications for Southeast Asia. Nevertheless, the media has already begun to play a significant role in covering environmental issues, at least at the local level. Although explicit criticism of state policies is generally prohibited in states such as Vietnam or Laos, the media circumvents this by covering what is going on in China as a metaphor for domestic issues. In the more developed countries such as Indonesia, new media and the Internet are becoming increasingly important.

Religious Organizations. Southeast Asia hosts a number of large, influential religious organizations that could play a critical role in addressing climate change. The Catholic Church in the Philippines and the Buddhist *Sangha* in Thailand have taken strong stands on environmental issues. For example, Buddhist monks in Thailand have taken action against deforestation by blessing trees so that no one will cut them down. Indonesia hosts two large mass-based Muslim organizations, the *Nadhlatul Ulama* which claims 40 million members and *Muhammadiya* with 35 million members. These organizations have helped mobilize Indonesian society behind government efforts such as family planning and childhood vaccination. All of these institutions are well organized at the local level, and their leaders are influential nationally. They therefore serve as important political transmission belts, bringing local concerns to the national level and vice versa. With sufficient political and financial backing, they could help raise awareness of climate change and techniques to mitigate it.

Business Interests. Business interests are and will remain the most important nonstate actors with regard to policymaking on climate change mitigation and response. Business interests have strong ties to the state and are the civil groups most able to exert pressure on state decision-making. In general, business interests and allied political elites are concerned with present profits rather than warnings about the future. Many climate change mitigation measures will be expensive, will require industries to radically change their practices, or will significantly reallocate resources. Business interests—particularly extractive industries such as mining, logging, or energy—are likely to use their influence to oppose climate change mitigation measures, as they have opposed other environmental oversight or sustainability measures.

Some influential elements within the economies of Southeast Asia have an interest in addressing climate change. Insurance companies and investors may press for climate change mitigation because of the losses they might suffer from climate change-induced damage. There is money to be made from green technology and the massive infrastructure projects needed to respond to climate change may bring new industries to the fore, challenging the hold established economic interests have on the political and economic systems of the region. Mobilization of countervailing economic forces may turn out to be a more promising avenue to address climate change than the activities of less self-interested groups within civil society.

Criminal Networks. Southeast Asia hosts a wide array of major criminal networks, primarily organized around trafficking. The region is a major drug producer and transit point for illicit drugs. The cultivation of heroin and other drugs forms the primary economic activity in the "Golden Triangle" region of northern Laos, Burma, and Thailand. Human trafficking is likewise a serious problem in Southeast Asia where an estimated 200,000 to 500,000 people are trafficked each year. Climate change will divert state resources away from combating crime and create opportunities for criminal networks to expand their activities. For example, refugees and stressed populations are particularly vulnerable to trafficking. Criminal networks may profit from trafficking natural resources that increase in value due to climate change mitigation efforts. For example, tropical timber could increase in value on the black market as efforts expand to keep forests standing to mitigate climate change and as timber shortages grow.

Internal Migration

Among the most destabilizing impacts climate change may have in Southeast Asia will be large-scale population shifts both within and between countries. It is difficult to project the source, magnitude, and direction of migration within the region without detailed projections of climatic impacts on particular areas. This is particularly the case when considering migration within states in the region. Intra-state migration might involve population shifts driven by highly localized pressures. Even migration over very short distances—a few tens of miles from outlying districts into a city, for example—could have profound socio-economic effects. Further complicating the migration picture, rapid movements due to extreme climatic events or tipping points will be superimposed on gradual movements due to long-term climatic shifts. Nevertheless, at least two dynamics are likely to recur in intra-state migration throughout the region: movement into cities, and movement away from vulnerable coastal areas.

Rural-to-Urban Migration. The most significant aspect of internal migration in Southeast Asia probably will be the mass population movement from the countryside into the cities. The massive rural influx will create serious social tensions and will place a major strain on urban infrastructure already strained by the effects of climate change. Municipal governments will in most cases be unable to keep pace with urban growth and to provide adequate social services and urban planning. Newcomers may end up in shantytowns that lack the infrastructure needed to counter the impacts of climate change. They may not be welcomed by the established urban population, particularly if they are ethnically or culturally distinct. Competition for housing and real estate are already fierce in many cities, and this will only intensify. Unchecked urban growth may bring about major increases in crime, unemployment, and other destabilizing factors. Currently, many urban migrants maintain ties with their native villages and in times of urban economic downturns will often return there, where traditional familial and social networks provide an informal social safety net. This safety valve may no longer be viable due to climate change-induced rural disruption.

Setting aside the city-state of Singapore, Peninsular Malaysia probably has the most robust urban infrastructure and greatest capacity to absorb rural refugees into its light industrial economy. Malaysia is already heavily urbanized, however, and faces comparatively less climatic threat to its rural areas. Among the more rural states, Vietnam should be able to absorb the refugees from the countryside better than other countries in the region due to the rapid growth of its urban export-led manufacturing. That said, Vietnam's cities are still likely to be overwhelmed by the magnitude of internal population movement the country will face as the Mekong Delta succumbs to climate change or dam-building. In Cambodia, the Philippines, and Laos the government, urban infrastructure, and economy are particularly unprepared to absorb an explosive growth in rural migration to the cities.

With the exceptions of Indonesia and the Philippines, the states in the region only have a limited number of major urban centers apiece—in the case of Cambodia and of course Singapore, only one, and in Laos, none. While major established cities probably will receive the lion's share of migration, another aspect of rural-to-urban migration will be the rapid growth of smaller regional towns and cities into new urban centers. These communities will face an even greater challenge than the large cities, since by and large they lack the infrastructure or economic base to accommodate major rapid expansion. This phenomenon may be especially prevalent in Thailand. Despite Thailand's fairly expansive territory and large population, Bangkok is currently the sole major city, but explosive growth will occur in regional cities in the hinterland over the next two decades.

Inland Migration. Apart from rural-to-urban migration, the other major aspect of climate change-induced internal migration in Southeast Asia will likely be a movement of population inland from the coasts. The region's coastal areas will become less hospitable and economically viable as a result of Sea-level rise, increased storm activity, declining fisheries, and degradation of coastal ecosystems. While many coastal cities may suffer periodic catastrophic events such as floods or major storms, coastal fishing and farming communities will face such challenges as well as sustained climatic stress on their means of subsistence. Rural coastal populations are therefore more likely to be forced to relocate. In the next 20 years population retreats from receding coastlines will intensify the search for areas where potable ground water has been traditionally plentiful, s creating social disorder.

Similarly, many of the inhabitants of the region's smaller islands are likely to relocate to larger islands or the mainland, where there is more shelter from adverse weather and sea-level rise, more reliable sources of fresh water, and greater economic opportunity. The latter type of migration probably will be most significant in Indonesia and the Philippines. Climate change-induced internal migration in Indonesia may result in a consolidation of population onto the larger islands with more resources and better infrastructure. These migration patterns will overlay continued diffusion of population from overpopulated Java to Kalimantan, Papua, and elsewhere in the archipelago. Indonesian internal migration has already proven to be a cause of ethnic conflict, which is only to worsen. In the Philippines, major migration is probable from Palawan and other low-lying islands to Luzon and perhaps Mindanao—the latter raising a serious threat of increased sectarian conflict.

The majority of those displaced from coastal areas are likely to join the flow of rural population into the region's major urban areas. Some coastal farmers will instead move into rural areas farther inland, where they will have to compete for land with established rural populations and may need to switch to new crops as well. Vietnam is the country at greatest overall risk for mass inland migration. The decimation of the Mekong Delta will push millions of Vietnamese north into Ho Chi Minh City and beyond into the Central Highlands, as well as over the border into Cambodia. A more generalized movement of ethnic Vietnamese from lowland to upland areas throughout the country will likely cause ethnic conflict or displacement of native ethnic minorities.

Prospects for Civil Conflict

Increased socio-economic stress resulting from climate change-induced challenges will act as an accelerant or force multiplier for existing friction within the states of Southeast Asia. The particular conflict dynamic through which this friction expresses itself will vary from state to state and locality to locality. The variation in probable climatic impacts between internal regions and localities makes it inevitable that some climate-change induced challenges will be disproportionately felt by particular communities and groups within society. When differential effects coincide with ethnic, sectarian, political, or socio-economic divisions, they could easily stoke existing resentment and lead to conflict. Inadequate state responses to climate change-induced challenges may also feed civil unrest. In most cases, several varieties of conflict will be closely intertwined. The more these circumstances are combined, the more acute the risks of civil conflict. The particular areas and groups most strongly driven toward conflict by climate change will depend on the severity of climatic effects at local levels, which cannot as yet be accurately projected. In overall regional terms, however, climatic stress will create more opportunities for social frictions to flare into civil conflicts.

A number of major underlying dynamics fuel the potential for civil conflict in Southeast Asia. They are closely related and in most cases multiple dynamics will be active simultaneously. All are susceptible to aggravation by climatic stress in the region.

Domestic Migration. Domestic and cross-border migration may be the single greatest driver of civil conflict in Southeast Asia. As has been previously noted, climate change is likely to generate very large population shifts within the region. In practice, domestic and cross-border movements will be overlapping, and many of the resulting conflicts will likely combine both civil and interstate elements. In terms of intra-state migration, the intensity of potential conflict may depend in large part on how rapidly the movement of people occurs. The movement of large numbers of environmental refugees into new areas already facing climatic stress is a potent recipe for civil conflict. The more gradual the shift, the more ability local and national societies and governments will have to adapt to a new distribution of population. In cities whose populations swell beyond the capacity of their infrastructure and economies, the added stress of periodic climate-induced shortages of water, food, or electricity or episodes of flooding or heat waves are likely to create an extremely volatile situation. In rural areas already struggling to cope with disruptions to agriculture and water supplies, migration is very likely to result in intense and often violent competition for land, water, and other necessities between established communities and newcomers.

Socio-economic Inequalities. Climate change-induced challenges are likely to disproportionately affect the poor, exacerbate existing economic inequalities, and increase economic hardships. This may increase the salience of socio-economic and class conflict, which has not heretofore been a major catalyst for political conflict in Southeast Asia. Class differences in the region have been mitigated by ethnic differences. In addition, societies in the region have traditionally mitigated socio-economic differences using patronage. Patron-client ties were a means of building trust and crossing the class divide between the haves and have-nots. Patronage networks also provided a rudimentary social safety net that cushioned some of the adversities faced by the region's poor. The patronage system has deteriorated as populations have increased and become more urbanized and state funds available for patronage have decreased. Southeast Asia's poor are now more alienated from local elites, disengaged from the political process, and discontented. This large reservoir of public disaffection can be mobilized behind a wide array of grievances. In the Philippines, the lingering Communist-based insurgency will take advantage of rural poverty. In Thailand the socio-economic and rural-urban split persists and shows no signs of dissipating, particularly as long as deposed former Prime Minister Thaksin Shinawatra is politically active.

Majority-Minority Dynamics. With few exceptions, the states of Southeast Asia are ethnically diverse. Ethnic conflict between majority and minority groups is an ongoing problem that could become significantly worse when combined with climatic stress. Such conflicts may revolve around control of critical resources, economic disparities, discrimination and limited opportunities, or access to the political process. The more common majority-minority dynamic involves marginalization, persecution, or attempts at forcible assimilation of minority groups by the dominant majority. For example, political control in both Laos and Vietnam rests with the lowland ethnic majority, while highland minorities are marginalized. The bloodiest and most persistent majority-minority conflicts in the region have been between the Bamar majority in Burma and a host of ethnic minorities such as the Karen, Kachin, and Shan. In other cases the overall majority group exerts dominance even in regions where it is not the majority; this is the case with Malay dominance in East Malaysia, where Bumiputra minorities form the majority of the local population.

Successful minorities may also face persecution, both from resentful majorities or other disaffected minority groups. The most prominent example is the ethnic Chinese diaspora throughout the region, which has enjoyed considerable commercial success. The ethnic Chinese face resentment from groups of rural origin who are less well established in business and urban commerce. This has led to sporadic outbreaks of anti-Chinese violence, particularly in Indonesia.

Sectarian divisions play less of a role in most areas, but there are notable exceptions. The sectarian majority-minority conflict in the southern Philippines between the Catholic majority and the Muslim Moros has been a perennial driver of insurgency, political instability, and terrorism. The Muslim minority in southern Thailand is engaged in a similar conflict with the Buddhist majority. This revolt has intensified in the last year, damaging Thailand's reputation as well as draining government resources. In the Central Highlands of Vietnam, ethnic and sectarian divisions coincide, with Catholic highlander minority groups threatened by an influx of secular Kinh (ethnic Vietnamese) lowlanders. Climate change-induced Kinh migration into the minority-dominated uplands is likely to worsen ethnic divisions in Vietnam.

Marginalized groups, whether they are in the numerical majority or minority, face an intrinsically greater risk from climate change. They are typically more economically disadvantaged, enjoy a narrower margin of subsistence, have less political influence, and are less likely to receive state assistance. The need to respond to climatic stress may reinforce ethnic solidarity built up in the face of pre-existing adversity and exacerbate shared grievances, potentially leading to conflict.

Core-Periphery Dynamics. Most of the states in Southeast Asia comprise a more economically developed and populous "core" area, typically centered on the capital city, and a less developed periphery. The dominance of power, wealth, and resources by narrow political and economic elites located in the core puts the periphery in a far less advantageous position to face climate change. The political dynamic between core and periphery could therefore be crucial in how states and societies in the region respond to climate change.

Peripheral areas are geographically, politically, and economically remote from the heartlands and capitals of states in the region. These areas are typically underdeveloped, have poor infrastructure, little access to government services, and fewer economic opportunities. They are likely to be dependent on either subsistence agriculture or natural resource extraction such as logging or mining. These features make peripheral areas highly vulnerable to climate change-induced challenges. Localized impacts in peripheral areas, such as water shortages or agricultural stress, are often ignored by the central government, magnifying the adverse effects. At the same time, communities in peripheral areas face the risk of greater marginalization as climatic stress forces governments to focus on threats to more proximate and politically and economically influential regions. The inhabitants of peripheral areas could easily respond to increased climatic stress and lack of central government aid with local unrest, anti-state insurgency, or demands for regional autonomy or secession.

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The core-periphery dynamic is also closely linked to the majority-minority dynamic, creating a mutually reinforcing source of conflict. From hill tribes to Dayaks, ethnic minorities are often concentrated in peripheral areas. Core-periphery disparities are therefore often viewed through an ethnic lens. The highland regions of Laos and Vietnam are a classic example of ethnic minority concentration in disadvantaged peripheral areas. A similar dynamic has helped drive long-standing conflicts in Burma. The military government and ethnic majority dominate the central basin of the Irrawaddy River. The Arakan Hills to the west and the extensive highlands along the Thai and Chinese borders to the east are inhabited by disadvantaged and marginalized minority groups who have warred continually with the state.

Thailand faces a Muslim insurgency in its peripheral southern provinces on the Malay Peninsula and unrest in the highland northeast fed by spillover from Burma. In the future, Bangkok might face unrest in the agricultural northeastern Isan region, which retains ethnic ties to Laos despite assimilation policies and is largely dependent on the threatened Mekong River. The fact that the Thai Government regards the Chao Phraya River as a “Thai” river while the Mekong is seen as a peripheral “minorities” river affects the policy priority Thailand places on the Mekong issue.

Most of the vast archipelagoes of Indonesia and the Philippines consist of peripheral areas. These areas are also among those likely to suffer most from climatic impacts such as sea-level rise, shifts in forest belts, coastal degradation, and water and agricultural stress. Borneo is a peripheral area for both Malaysia and Indonesia and faces severe environmental threats, particularly from deforestation. Indonesia probably has the greatest potential for wide-ranging core-periphery conflict. Most of Indonesia’s population is concentrated on Java and Sumatra, with half the country’s population on Java alone. State control is tenuous and tensions and sporadic conflicts are endemic in Aceh in far northwestern Sumatra, Kalimantan (Indonesian Borneo), Sulawesi, the Maluku islands, and Papua. Peripheral islands like the Malukus and Sulawesi have limited water and arable land and are particularly vulnerable to climate change. Ethnic and sectarian frictions could be exacerbated on these islands, especially if the government reinstates some sort of transmigration policy to relieve population pressures on Java. In the Philippines, the Muslim southern periphery of Mindanao and the Sulu Archipelago is a perennial source of conflict and terrorism. Climatic stress is likely to exacerbate conflict in Mindanao.

Resource Competition and Scarcity. Natural resources have historically been relatively abundant in Southeast Asia. In recent decades, however, resources have come under severe strain as a result of population growth and unrestrained, unsustainable resource exploitation. Resource depletion has been most apparent in rampant deforestation and overfishing, both of which have reached crisis proportions. Climate change appears set not only to exacerbate problems facing these already depleted natural resources but to introduce significant scarcity in additional critical areas such as food, water, and arable land. Even resources that are not anticipated to decline across the region—such as water—will be subject to local shortages and stress.

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Resource competition could play out at a number of social levels. A diminished pool of resources will likely increase the prospects for conflict between individual farmers and fishermen, potentially destabilizing local communities. Inter-communal violence and seizure of land, water resources, livestock, or fishing grounds will likely increase at the village level. Smallholders may attempt to seize land or water from larger owners, generating conflict between local groups and local or even national elites. Where control over resources coincides with ethnic or sectarian divisions, resource competition may erupt into ethnic conflicts. Ethnic nationalism remains highly salient in the region, often encouraged by state policies that reinforce ethnic and regional differences, and provides a vehicle to aggregate and mobilize individual grievances over resource distribution. Overall, competition for scarce resources could become a significant source of rural unrest throughout the region. Research in Indonesia has shown that land and water conflicts are already increasing, particularly in remote areas with water shortages.

Coastal and deltaic regions are likely to face the greatest natural resource challenges as a result of climate change. Those areas face not only degradation of fish stocks and coastal ecosystems but also wholesale loss of arable land and living space to the sea. Large-scale social unrest is possible in coastal communities, particularly the most threatened areas such as the deltas of Vietnam or Burma. Coastal and deltaic regions may not necessarily be the most prone to resource conflicts, since the loss of land and livelihood is likely to force the local population to migrate elsewhere. Conflict may prove more prevalent in agricultural areas further inland, where much of the rural population will attempt to persevere in the face of climatic stress while migrants from areas such as the coasts will move in. Cambodia may be particularly vulnerable to this sort of scenario, with internal conflict driven by agricultural stress exacerbated by a large influx of Vietnamese fleeing the Mekong Delta.

In addition to competition over resources necessary for subsistence, competition for resource rents is also likely to increase. Economic instability and stress on traditional revenue sources such as agricultural products will put a premium on control of lucrative commodities such as oil and gas, timber, and minerals. Much of this conflict will be between elites and business and criminal elements rather than farmers or laborers. The local population will nevertheless be profoundly affected by the resulting violence and interruptions in employment and revenues.

Conflict over resources will not be confined to rural areas. Faced with burgeoning populations, cities will need to drastically increase their resource intake. This will probably manifest itself most acutely in terms of access to water resources. Competition between cities is likely to increase significantly, and within cities periodic shortages are likely to generate protests and rioting. In addition, climate change is likely to generate considerable conflict over access to employment. As cities experience massive influxes of new labor and agricultural or fishing employment dries up or becomes unreliable, jobs are likely to become very scarce in many areas. Large unemployed segments of the urban population represent an acute threat to social stability. Violence may be directed particularly at commercially successful urban minorities, as has occurred periodically against ethnic Chinese in Indonesia.

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State Responses

The challenges associated with predicted climate change to 2030 will put severe pressure on the states of Southeast Asia. Climate change will not only exacerbate existing socio-economic and environmental problems facing the states of the region, but simultaneously create a host of new challenges for them to respond to. Adaptive or maladaptive state responses to the challenges of climate change in Southeast Asia will be a test of good governance, political will, and state capacity.

State Decisionmaking

Although the governments in the region vary widely in terms of their structure, capacity, stability, and approaches to policymaking, power traditionally tends to be concentrated in the hands of narrow governing elites which steer the developmental paths of their countries and set state policy. The nature and effectiveness of state responses to climate change in Southeast Asia will depend primarily on the decisions and priorities of those governing elites.

Good governance entails the formulation and implementation (to the degree possible given the state's resource base) of political, social, and economic policies clearly designed to promote the public good. In Southeast Asia, public policies more often are intended to promote the interests of the ruling elite and vested economic interests than the public good. States in the region share a bureaucratic, hierarchical structure that insulates decision-makers from pressure by the public and civil society. State leaders will be loath to contravene the interests of powerful elites for the sake of climate change mitigation. The lack of leadership capacity and political will to take politically or economically painful measures to address climate change will likely prove one of the most significant obstacles to effective state responses. In addition, greed, incompetence, and ingrained corruption play a major role in government decision-making across the region, often trumping objective, cost-effective planning and administration.

State Priorities. In most Southeast Asian states, the most important—although usually unstated—state priority is to maintain the political and economic power of the ruling elites. Although this is accomplished in part through varying levels of state coercion, economic legitimacy is a more important overall pillar of elite control. Economic development is the principal overt state priority in the region, both in developed states such as Singapore and those struggling to overcome an agrarian Communist past, such as Laos or Vietnam. The governing elites in the region maintain their public legitimacy through the promise of economic growth and increasing prosperity, as well as by disbursing subsidies and funding poverty alleviation. For example, the Vietnamese Communist Party knows that unless it improves the standard of living of the Vietnamese people, its political power will be in jeopardy.

The region's "development first" mentality has fostered general disregard for sustainability or environmental damage, even in the face of pressure from international actors or civil society or such obvious adverse effects as "the haze." Climate change, which has yet to manifest major tangible effects, is even more easily dismissed by skeptical leaders in the region. For example, even though Indonesia is highly vulnerable to climate change, most Indonesian policymakers have yet to show evidence of serious

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alarm or urgency. As a result, climate change will remain at best a secondary priority until its effects begin to demonstrably challenge state security and economic viability in the region. Nevertheless, regional states are beginning to show greater concern about environmental challenges such as public health, food security, or water management. Even if policymakers have yet to link these discrete environmental issues to climate change, action to address such issues will have beneficial collateral effects in adapting to future climate change.

Taking into account the limited urgency accorded to environmental and climatic issues, there is nevertheless significant variation between the states in the region. These issues are taken most seriously in Vietnam, Singapore, and the Philippines. Driven primarily by concerns over the fate of the Mekong River, Vietnam has recently shown more alertness to environmental challenges than its neighbors. It is not yet clear whether Hanoi's concerns over the Mekong will translate into a proactive stance on broader environmental and climatic issues in the region. Singapore is more serious about environmental issues due to its constrained geography and lack of direct dependence on resource exploitation. The Philippine Government is aware of the country's vulnerability to climate change and takes it seriously due to its long experience with environmental disasters but lacks political will. Climate change is less of a priority in Thailand, Laos, Cambodia, and Burma. Indonesia's international rhetoric on the issue has not yet translated into genuine domestic policy motivation. As an oil exporter and one of the region's least vulnerable states to climate change, Malaysia has largely ignored the issue.

Changing Leadership Perspectives on Climate Change. The prevailing attitude toward climate change among most Southeast Asian leaders is dismissal. Continuing international debate over the causes and effects of climate change and equivocal or contradictory scientific data encourage skepticism on the part of policymakers. Most lack technical backgrounds and tend to dismiss scientific or technical reports. Over the next two decades, however, a number of dynamics may shift leadership perspectives on climate change. First and foremost, as climate change unfolds in Southeast Asia, leaders will be presented with increasing evidence of the threat it poses to their states. Nevertheless, climate change will in many cases need to generate major socio-political challenges or economic impacts before states in the region muster the political will to respond. For example, the Thai state is likely to address the issue when its surplus agriculture and aquaculture industries start to see significant downturns in output or in the face of socio-political schisms from an event such as a major drought in the Isan region. If climate change is mainly gradual and incremental, leaders may adjust to the "new normal" without mustering the political will to make drastic decisions on climate change mitigation.

A dramatic shift in perspectives could result from one or more unprecedented, catastrophic events attributable to climate change. Such events would provide tangible examples of the systemic threats to social, political, and economic well-being. Possible examples include a mass crop failure, a collapse of regional fisheries, or a climate change-induced disaster affecting a concentrated population, such as a massive urban flood. Disastrous climatic events may shift overall elite attitudes or, alternatively, generate splits within the ruling elite. Conflicts between elite factions may be generated

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or exacerbated by debates over how to respond effectively to climatic challenges. Such conflicts may significantly influence the political direction in some Southeast Asian states. In Thailand, for example, the 2004 tsunami discredited the political opposition, facilitating the re-election of Prime Minister Thaksin Shinawatra. Climate change may become part of a broader clash between “old” and “new” thinkers among elites. Cyclone Nargis provides an example of these dynamics at work. The storm shifted the attitude of the Burmese junta on how to respond to humanitarian disasters and the importance of climatic issues. Cyclone Nargis also split the junta over how much foreign assistance to admit.

Leadership perspectives may also shift over the next several decades due to generational turnover. A younger generation of leaders who emerge in a context of increasingly apparent climatic changes may be more concerned about climate change mitigation and muster the political will to take on entrenched elites who perpetuate unsustainable practices. For example, Indonesia’s dynamic President Susilo Bambang Yudhoyono has set as his priorities poverty alleviation, development, and environmental preservation in that order. The current Vietnamese Prime Minister, Nguyen Tan Dung, from Ca Mau province on the tip of the Mekong Delta, is extremely concerned about the damming of the Mekong and its potential effects on the Delta. Not all generational leadership transitions will be so constructive. In Thailand, the passing of King Bhumibol, currently 81 years old and in poor health, may generate extraordinary political unrest. The succession may threaten Thailand’s ability to cope with the global climate change challenges of the next few years, if not longer.

Political Responses to Climate Change

The need to mobilize popular support and resources behind large-scale, costly climate change mitigation policies will inevitably politicize the climate change issue. While political mobilization is necessary and will boost adaptive capacity, over-politicization could lead to policies driven by political advantage rather than efficient climate change mitigation. Scarce resources could be diverted to corrupt, ineffective pork barrel projects which provide no climatic benefits. For example, if Vietnam’s National Assembly continues its slow rise to prominence it could become a locus for rampant pork barrel resource allocation. Because climate change-induced challenges will have different impacts in different regions and localities, governments will be compelled to make difficult resource allocation choices. Such decisions may become highly politicized, and perceptions of favoritism could provoke inter-regional or center-peripheral conflicts.

As both leaders and populations in the region are more forcefully confronted with climatic and resource challenges, they are likely to respond with increasing economic and environmental nationalism. Such responses are most likely in Indonesia, Vietnam, and Burma. Nationalistic responses could either help or hurt efforts at climate change mitigation and conservation. On the one hand, nationalism is a basis to argue for protecting and conserving the nation’s sovereign natural resources and environment. On the other hand, it is a means for entrenched elites to gain legitimacy and counter criticism from civil society or outside actors on environmental issues. Leaders could argue that outsiders or domestic malcontents are attempting to limit the nation’s sovereign right to exploit its own resources in order to develop.

Governments in Southeast Asia have varying degrees of authoritarian and democratic elements, and could respond to climate change-induced challenges by leaning in either direction. Climate change-induced political instability could lead to coups and regime changes, but changes in the overall structure of government are less likely. For example, the single-party political systems in Vietnam and Laos will likely persist to 2030 and beyond. The conditions of global climate change may in some respects favor the prospects of such enlightened despotisms or police states more than democratic regimes. The greater the repressive capabilities of the state, the easier it may be for it to ride out the socio-political consequences associated with climatic shifts as well as pursue broad, sustained mitigation and adaptation programs. On the other hand, cracking down without effectively addressing the underlying problem could lead to a degenerative spiral of destabilization. More open forms of government have greater accountability and are better able to cooperate with society to effectively tackle large-scale changes and challenges—the state is able to share the burden of response with civil society. Conversely, greater institutional responsiveness and accountability may also restrain the state from using its capacity to full effect or overcoming civil resistance to necessary but unpopular climate change mitigation measures. Ultimately, there is no guarantee that the varied political systems in the region will be able to come up with a balanced approach to coping with climate change, either domestically or regionally.

State Capacity

The states of Southeast Asia have widely varying levels of overall capacity to meet climate change-induced challenges. Raw state capacity correlates strongly with economic development. At the high end, Singapore's proportionate state capacity probably exceeds that of many Western states. Conversely, poverty-stricken Laos has extremely limited state capacity. In general terms, Malaysia, Thailand, and Vietnam fall toward the high end of the spectrum between Laos and Singapore, while Indonesia and the Philippines occupy the middle and Burma and Cambodia are at the lower end. In practice, however, simply ranking the raw resources and capabilities available to states in Southeast Asia may paint a misleading picture. State capacity will depend on specific decision-making on the mobilization and management of human and physical resource and will be significantly constrained by widespread deficiencies in governance and political will. Governments in the region have a long track record of inability or unwillingness to deal with social, political, economic, and environmental issues. They may not confront the challenges of the future any more effectively than those of the past and present.

Even where states muster the will to tap into the inherent adaptive capacity of their states and societies, the leadership's political capability to move the institutions of the state to carry out mitigation policies may be limited. The center cannot drive enforcement along the periphery by itself; doing so requires the involvement of local and provincial governments, as well as the judiciary, police, armed forces, and others. These potential enforcers are often part of the problem. State responses will be most significantly constrained by such factors in the same underdeveloped countries where inherent capacity is already weakest.

In many areas, state capacity has been hollowed out or eroded by corruption and criminal activities. Corruption is widespread at all levels of government in the region. Many key industries in Southeast Asia, such as logging or mining, operate at least partially illegally. In Indonesia, for example, corruption plagues the nexus of the government and the timber industry despite promises of reform. Local and even national authorities are beholden to the international criminal networks that control Indonesian mining and logging. Rampant criminality and corruption are particularly severe in Burma, Cambodia, and Laos. The Cambodian regime is more of a criminal conspiracy than a government—corrupt, weak in capacity, and lacking transparency. Burma, traditionally a leading opium producer, is now one of the world's leading producers of methamphetamines, and Laos continues to be a major opium producer.

In terms of individual state capacity levels, Singapore has the human capital, national resilience and political will to deal with the challenges of climate change, but depends on its neighbors for resources. Vietnam is a strong state with a much improved infrastructure and reserve of human capital. The government has the political will and capacity to marshal resources and respond quickly to challenges, but it remains a poor country with constrained state resources. Malaysia and Thailand are also fairly strong states with robust national infrastructures, plenty of human capital, and the capacity to marshal resources effectively should a crisis emerge. Indonesia has a weaker state capacity, lacks political will, and the technical competence of the Indonesian government bureaucracy is questionable. The public health sector is weak, the government is unable to stem deforestation, and there is so far only moderate capacity for agricultural innovation. The Indonesian government exhibits a systemic failure to translate rhetorical policies into actual policies. Nevertheless, democracy has been firmly established and the government's capacity to deal with the effects of climate change is improving.

Laos, Cambodia, Burma, and the Philippines are unlikely to be able to respond in time or cope with the consequences of climate change absent strong political will and outside assistance. The Philippine state is hampered by a fractious and disorganized government, abysmal national infrastructure, and very weak resource management. Burma remains a weak, underdeveloped state fractured by decades of civil conflict, but the military regime can mobilize the limited state capacity to address issues when necessary. Neither Cambodia nor Laos have much in the way of human capital, national resilience or political will to deal with the issues of global climate change. They will be highly reactive and heavily dependent on foreign assistance and aid programs. Laos in particular has an inadequate infrastructure, particularly in rural areas: the nation has no railroads, a rudimentary road system, and limited external and internal telecommunications. Laos' poverty, inadequate infrastructure, and dependence on subsistence agriculture make it arguably the country with the least ability to cope with climate change-induced challenges.

Financial Resources. Besides material resources, the states of Southeast Asia will need considerable financial resources to address the problems of climate change. For the region's less economically developed states, these resources will have to come from overseas donors. Burma, for example, may become more financially dependent on China. Not only are many climatic impacts likely to be very expensive to address, but their secondary effects on the region's economy and resources may also reduce revenues, creating considerable pressures on state budgets. Pressures on public finances are likely to produce deficits in the delivery of public goods such as education and health care. The need for new sources of income may trigger a vicious cycle of dependence on unsustainable resources that trigger more intense climate change effects.

Most Southeast Asian states depend to varying degrees on natural resource rents, but the region's resource bases are depleting. Climate change will further narrow the resource base, exacerbating shortages of land and resources. Deforestation is already producing acute stress in areas such as East Malaysia that depend on the dwindling timber industry. Much will depend on how well states in the region are able to manage their diminishing resources. For example, Timor-Leste has managed its oil resources relatively well, while Cambodia is sitting on reasonable oil wealth that is disappearing into a black hole rather than adding to state capacity. Cambodia's oil revenues largely disappear into the personal bank accounts of Prime Minister Hun Sen.

The Judicial System. The capacity of Southeast Asia's court systems to manage local conflicts arising from climate change will be a pivotal dynamic in determining whether climatic challenges lead to internal instability. In the Philippines, for example, the judicial system has handled many important environmental cases. The courts will face a significant increase in disputes related to climatic and environmental issues and their consequences. Unfortunately, the region's court systems tend to be weak and corrupt, lacking in competence, independence, efficiency, and resources. The courts have little capacity to override even local officials and the relevance of their rulings depends on the often limited willingness and ability of the executive authorities to implement them.

The Military. The lack of well-developed civil disaster response capabilities in many states in Southeast Asia means that the military will in many cases act as the first responder and logistic facilitator for state responses to climate change-related incidents. In addition, the prospects for large-scale, heterogeneous civil unrest and even interstate conflict as a result of climate change mean that the military will be a key element in maintaining state security. Singapore has the most capable and professional armed forces in the region. The armed forces in most other countries in the region are beset by corruption, politicization, profit-seeking activity, and a lack of resources and training. These institutional problems severely limit the capacity of military forces in Southeast Asia to respond effectively to climate change-induced challenges.

Military coups have been a common feature of Southeast Asia's politics. Prime Minister Thaksin Shinawatra of Thailand was unseated by a coup in 2006. The military rules outright in Burma, as it did in Indonesia for much of the country's history. The imposition of military rule in the event of major national crises arising from climate change is a distinct possibility in most states in the region. Most of the region's armed forces are also heavily involved in legal and illegal economic activity, including drug production and trafficking, logging, and other extractive industries that could align the military against climate change mitigation efforts. In many cases military units are forced to resort to self-financing due to chronic budget shortfalls, but weak state oversight also allows endemic corruption.

In recent years, military reform has taken place in some of the region's militaries. The Indonesian military is showing some movement toward shedding its legacy of corruption and politicization, aided by moves to fully fund the military budget. It remains unclear whether reforms will filter down to the local level, which in many areas is dominated by corruption and criminality.

Crisis Response. More so than the sustained, incremental effects of climate change, large-scale crises generated by extreme weather events or ecological or socio-political tipping points will pose a serious threat to state stability in Southeast Asia. Given the limitations in state capacity across the region, such crises will sorely test state responses, as well as divert resources from other development goals and create an atmosphere of sustained political uncertainty. States in the region have varying capacity to cope with crises, and for those that cannot cope effectively, the consequences may be large-scale humanitarian disasters. For example, Indonesia was able to cope with the 2004 Indian Ocean Tsunami, albeit with heavy reliance on assistance from foreign donors and civil society groups. In contrast, Burma failed a similar test with 2008's Cyclone Nargis—most of the deaths were caused by the failed state response rather than the cyclone itself. These and other natural disasters that have struck Southeast Asia over the last few years have prompted efforts to improve disaster response. Singapore, Malaysia, and to a lesser extent Thailand have strong capacity to respond to environmental catastrophes, and are also less at risk than other states in the region. Vietnam has growing competence in disaster response and emergency management although its resources are limited. The governments of the Philippines, Laos, and Cambodia have limited capacity to respond to natural disasters and are among the states most at risk from such challenges.

Decentralized Implementation. Central governments face a variety of structural obstacles to effective policy implementation and enforcement. The state apparatus in most Southeast Asian countries tends strongly toward inertia and implementation and enforcement capabilities are in most cases weak. In addition, Indonesia, Thailand, and Vietnam have undertaken decentralization programs in recent years, which have transferred critical powers away from the central governments. Decentralization constrains the ability of the central government to transfer resources and funds from those parts of the country least affected by climate change to adaptation programs in areas experiencing difficulties. Moreover, decentralization increases reliance on the will and capacity of local levels of government for implementation. Local capacity varies widely. In places such as West Kalimantan, income from natural resources has produced an effective government that has significantly improved public services. In other places, local governments are controlled by powerful political or economic interests that squander public resources. Decentralization also results in competition for access to resources, funding, and authority between local jurisdictions. In Jakarta, for example, multiple jurisdictions of authority in management of land within the city boundaries limit investment in infrastructure and render the city more vulnerable to climate change.

Climate Change Mitigation Policies

Effective, comprehensive national climate change mitigation policies face difficult political hurdles. Not only will mitigation measures require very ambitious planning and resource allocation far in advance of the catastrophic observable impacts, but tangible results from such measures may take decades to emerge. States in the region have yet to begin serious planning for such eventualities, but current trends and climatic projections suggest a wide array of areas in which state climate change mitigation action will be needed.

Substantial innovation will be needed to adapt the region's agricultural systems and rural communities to the new, more variable conditions anticipated due to climate change. Traditional agricultural models may no longer be viable and subsistence-level farmers may lack the capacity to adapt on their own. In many cases, the state will need to step in to provide advice on new farming practices and access to new crops more suited to the new conditions, identify new growing areas, and potentially resettle farmers. Climate change-induced constraints will necessitate improving the efficiency of agricultural water use. Thai agriculture is already in the process of commercializing, making it more resilient than subsistence-oriented agriculture elsewhere in the region. Vietnam is coming to terms with the changing circumstances better than other Southeast Asian countries, but the government faces an immediate food and security challenge as the majority of the population lives in the vulnerable river deltas.

Many of Southeast Asia's existing forests will perish over the next 20 years, whether from deforestation or climate change. Some countries, such as Thailand and Vietnam, have already begun reforestation programs, but others, such as Cambodia, Laos, and parts of Indonesia, may face the loss of all significant forest cover before such programs are under way. Rather than replacing previously indigenous species of trees, adaptation will require reforestation with different species appropriate to new growing conditions. Serious efforts also will be needed to reduce the burning of forests and peat bogs—progress on that front could bring about a major reduction in regional emissions without sacrificing economic development.

Regional states will face simultaneous large-scale needs for improvements to urban, coastal, transportation, and water management infrastructure, all of which will be extraordinarily expensive and potentially disruptive. Water resource management is one of the most fundamental and daunting climate change mitigation challenges facing the states of Southeast Asia. Southeast Asian states will need to rely far more heavily on manmade water management infrastructure to distribute water resources rather than on natural drainage patterns. In most states this will require the construction of whole new systems of reservoirs, dams, canals, water pipelines, and aqueducts. Water conservation will become a priority and variable precipitation will force increased exploitation of groundwater resources. To combat more frequent flooding, flood management infrastructure will need to be improved both inland and on coast. Water treatment, irrigation, and transportation systems will need to be reinforced against flooding. States will need to construct extensive levees, canals, and seawalls to protect their coasts and ports from sea-level rise. Concurrently, states will need to plan for major urban population growth. Water treatment and distribution, power, housing, urban transportation, public health, and food distribution will need to be rapidly expanded to avoid major degradation of urban living conditions that are already tenuous in many parts of the region. Education and job training will be needed to prepare rural population for urban employment, as will state investment and subsidies to urban industries, such as green manufacturing, to provide that employment. As cities expand, construction will be a major employer of incoming rural labor.

States may also need to develop planned resettlement programs away from threatened coastal and rural areas to avoid destabilizing, uncoordinated mass migrations. The historical legacy of Suharto-era Indonesia's transmigration (Transmigrasi) program will make it extremely difficult for any future government to undertake a similar program. The program, which relocated millions of people from overpopulated Java and Madura to less populated areas, was plagued by mismanagement and corruption and ultimately ignited ethnic conflict in many areas. Climate change will drive mass migration and resettlement whether or not the states seek to manage it. Even poor state management may be better than none. The country most in need of massive resettlement planning is Vietnam. The country's Ho Chi Minh City Metropolitan Area development plan envisions building up the city into an urban center the size of New York City. If pursued aggressively, such a plan could help absorb the millions who will be displaced from the Mekong Delta and other coastal areas.

Given limitations on state capacity, political will, and policy implementation, in many Southeast Asian states the most likely outcome appears to be a delayed or less than effective response to climate change in the region. Constraints of time, funds, and resources dictate that the states of Southeast Asia will only be able to undertake a limited number of the mitigation measure outlined above—in effect, states will need to conduct national triage. Regardless, the region will require major injections of assistance from outside powers to effectively cope with climate change to 2030 even on a constrained basis.

Prospects for State Failure

Climate change to 2030 will have severely disruptive effects in Southeast Asia, particularly in deltas and coastal areas. The impact of the severe localized effects that climate change causes is significantly magnified when such changes occur within a small state that depends on a limited resource, population, and agricultural base. Some states in Southeast Asia are less capable of responding to climate change and some may not succeed in adapting. Absolute state failure is unlikely barring a catastrophic climatic event. States in the region are more likely to suffer temporary state breakdowns, the failure of local constituent governments, and probable long-term instability. At the very least, states will suffer more frequent and unpredictable challenges and will have to bolster state responsiveness, planning, and awareness or risk undermining regime credibility. The prospect of state failures is not as alarming to regional leaders as might be expected, since most have taken precautions to avoid facing the consequences of their policy mistakes.

The states with the greatest potential for severe instability and those most at risk for state failure are not necessarily the same. Vietnam, for example, faces among the most serious challenges to 2030 and is likely to suffer massive population displacement and food and water stress. The Vietnamese state, however, is strong, motivated, and used to perseverance, so it is unlikely to fail. Prime Minister Hun Sen's grip on political power in Cambodia is ruthless and firm, and will be further strengthened if off-shore oil and natural gas resources are developed successfully. In contrast, states such as Laos or Timor-Leste may suffer comparatively milder challenges but their weak state capacity, limited resources, and narrow margin of subsistence make failure more likely. Timor-Leste, with its relatively immature political system, is the most likely state in the region to fail, particularly if it absorbs major collateral challenges from Indonesia. Laos and Cambodia have dealt with precarious situations for much of the last several decades. Both may have a reserve of resilience to persist at a very low functional level even in the face of severe disruption. Whether the formal state survives or not, that such an outcome would be tantamount to state failure in terms of the impact on the population.

Burma also faces a major risk of state failure due to the combination of an unpopular autocratic regime, international isolation, extreme levels of corruption and crime, and well-established ethnic insurgencies already in control of large swathes of territory. The junta has negotiated what it calls "peace agreements" with many of these ethnic minorities. In most cases, these do not extend the center's authority into the ethnic areas nor create peace but permit some minority groups to profit from resource extraction and drug trafficking while giving the junta a portion of the profits. Climate change will likely intensify existing conflicts between the Bamar majority and the ethnic groups along the periphery as well as between the repressive military regime and its citizens. In addition, the likelihood of spillover from catastrophic instability in neighboring Bangladesh further erodes Burma's prospects.

Although unlikely, state failure in Indonesia would pose the most serious challenge to the region. Indonesia is a fairly robust state with considerable resources and capabilities, but its heterogeneous and geographically non-contiguous nature makes it particularly prone to localized failures. Rather than an outright collapse, a state failure in Indonesia is far more likely to take the form of disintegration. Inter-communal tensions could spiral out of control in areas where climatic stress is expected to be most severe, such as the eastern portion of the archipelago, including the Malukus, Sulawesi, and Papua. Jakarta's administrative relevancy and authority, already attenuated by decentralization, could erode altogether in these peripheral areas of the archipelago. The viability of the state itself could be put at risk as it was after the collapse of the Suharto regime, and it might splinter between local governments and military warlords.

Singapore is in the best position to remain stable in the face of climate change—it is run by a powerful authoritarian government while facing few challenges. Malaysia is similarly well situated to overcome climate change-induced challenges. Although Thailand and the Philippines may be more prone to instability and face moments of crisis, they are also unlikely to fail.

Regional Implications

Prospects for Regional Climate Change Cooperation

Regional cooperation will be necessary to effectively address climate change in Southeast Asia. Despite the existence of a regional multilateral organization, the Association of Southeast Asian Nations (ASEAN), prospects for effective regional cooperation are mixed. Events such as the 2004 Indian Ocean Tsunami or outbreaks of pandemic disease have spurred some steps toward expanding regional cooperation and state planning.

Apart from humanitarian crisis response and public health, however, regional cooperation in Southeast Asia has been mainly rhetorical. Political will to tackle climate change remains limited and regional cooperation is lower on the agenda than domestic responses. Regimes in the region are motivated by self-interest rather than concerns over regional public goods. In the absence of a tipping point generated by a climate change-induced catastrophe, the path toward cooperation in the region is likely to proceed at a cautious, limited pace.

The Association of Southeast Asian Nations (ASEAN). As the political face of Southeast Asian multilateralism, ASEAN appears to offer a promising institutional base from which to address climate change-related issues. It already has extensive bureaucratic structures in place intended to deal with climatic and environmental issues. ASEAN's environment programs include working groups on Coastal and Maritime Environments, Environmentally Sustainable Cities, Nature Conservation and Biodiversity, and Water Resources Management. ASEAN has expressed considerable rhetorical concern about climate change, but its track record in dealing with regional environmental issues is weak. In the past 20 years ASEAN has not implemented any programs to address climate change.

ASEAN's paralysis in part reflects the low priority of climate change among its member states and in part the organization's structure. It was designed as a deliberately weak institution inhibited from interfering with the sovereign independence of its member states. ASEAN is and will remain a consensus-based organization, leading to slow, lowest common denominator policymaking. The member states retain individual discretion to implement any initiatives adopted by ASEAN, which in many cases means they are not effectively enforced. For example, five years of discussion of the disastrous 1997 forest fires and the resulting regional "haze" resulted in a weak ASEAN Agreement on Trans-boundary Haze Pollution in 2002. Indonesia, the primary offender behind the "haze" still refuses to ratify this watered-down agreement. Meanwhile, the "haze" continues to afflict the region every fire season. These sorts of results are typical of ASEAN's environmental efforts. Public health is the one major transnational area in which ASEAN has been effective.

Climate change will put greater pressure on ASEAN to respond to bilateral conflicts, transnational issues, and humanitarian challenges. ASEAN's response to Cyclone Nargis in 2008 demonstrated its utility as a facilitator for multilateral crisis response, increasing the organization's institutional self-confidence and setting a precedent for a more active role. ASEAN may play a similar role in response to future climate change-induced crises, but its institutional constraints limit how quickly and effectively it can respond and its prospects for improvement are not encouraging. To effectively address climate change on a regional basis, Southeast Asia either needs a radical reform of ASEAN or a new, more robust multilateral organization. States in the region would need to accept a multilateral framework with genuine oversight and enforcement powers. It would need to engage outside powers such as China and the United States to be effective. ASEAN and its constituent structures such as the Treaty of Amity and Cooperation in Southeast Asia (TAC) provide a viable basis upon which to build such a framework.

China's Role in Southeast Asia

Although some of the transnational challenges the region will have to cope with to 2030 will play out between states within Southeast Asia, many also will involve China. China is the most influential external Asian actor in Southeast Asia and its involvement in the region will increase by 2030. China's influence runs through nearly every major regional issue in Southeast Asia, including two of the most critical and contentious—control of the Mekong River and of the South China Sea.

China's expanding presence in Southeast Asia is a spillover effect of China's economic dynamism as much as it is a product of a grand strategy. China seeks markets for its goods, profitable investment opportunities, and access to natural resources. Southeast Asian economies are becoming increasingly dependent on China, which will erode the ability of countries in the region to stand up to China's policies. China is in an advantageous position to compete for resources and protect its economic interests against local actors. As a result, China may continue to extract a wide range of Southeast Asian resources even as local states experience climate change-induced scarcity.

China's diversified resource extraction presence in Southeast Asia links it to a wide range of sectors, including fishing, timber, mining, fossil fuels, agriculture, and hydropower. As climate change exacerbates challenges in these sectors, China may take much of the blame for adverse environmental effects in the region. For example, Vietnam may be set to lose the Mekong Delta to climate change regardless of whether China or other countries build upstream dams. Vietnamese leaders and citizens may nevertheless prefer to blame human agency rather than impersonal climatic forces. Over time, the degree to which Southeast Asians blame China for regional challenges could significantly shift the relationship between Beijing and the states in the region. China's heavy-handed stance and perceived contribution to climate change could arouse considerable nationalist resentment in the region and generate an anti-Chinese backlash, especially in Vietnam, Indonesia, and Malaysia. Such a reaction against China's exploitative resource policy in Southeast Asia could threaten China's economic interests in the region.

In many respects, China's prioritization of economic interests, extractive resource policies, and inattention to sustainability or collateral effects mirrors the policy perspectives prevalent in most states in Southeast Asia. Like most regional states, China has little intrinsic interest in climate change in the region. This could change if turmoil from climate change begins to spill over into southern China or disrupts China's access to critical resources. China's response, however, could be to suppress or control the problem rather than try to solve it.

Even if it is couched in the softer terms of a "regional sphere of influence," the reality of increasing Chinese dominance in Southeast Asia will be one of the central political factors in Southeast Asia to 2030. China's dam construction appears likely to ultimately result in Chinese control over the water system of Asia. Control of access to critical water resources will put the downstream countries of mainland Southeast Asia at China's mercy. This assumption of direct control over water may be replicated in other sectors as well. China is developing ports, roads, and oil pipelines in Burma, with the aim of creating a strategic link between China's Yunnan Province and the Indian Ocean. China

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increasingly exerts de facto suzerainty over the northern areas of Laos and Burma, through its plantations and economic presence if not by overt policy.

China's uncompromising position on the damming of the Mekong River and its assertiveness in the South China Sea may generate tensions between China and states in the region. China's relations with regional states are mixed. It is Burma's key ally and benefactor, providing substantial military and economic aid. The governments of Laos and Cambodia are closely tied to China, but the people are not. Leaders in Thailand are confident about their ability to deal with China. The states likely to prove most intransigent are Vietnam and Indonesia, rising powers with strong national identities and contentious histories with China. Vietnam and China have competed for influence in Southeast Asia since the 1970s and have engaged in periodic maritime and border clashes, including an ill-fated Chinese invasion in 1979. China's dam-building on the Mekong River poses a profound, even existential threat to Vietnam. Indonesia perceives itself as the natural leader and regional hegemon in Southeast Asia, putting it at odds with China's ascendance toward regional hegemony.

Regional Migration

Southeast Asia already faces a regional migration problem in the form of illegal cross-border migration. Cambodia and Laos face illegal migration and incursions from Vietnam. Vietnam in turn is concerned with increasing numbers of migrants from Cambodia in the south and China in the north. Thailand faces significant security threats from Muslim separatists in southern Thailand crossing back and forth over the Malaysian border, and major refugee flows and illegal crossings from Burma. The flow of illegal migrants brings with it criminal activity, particularly human and drug trafficking.

Climate change-induced challenges will contribute to pressures for cross-border migration, creating the potential for regional conflict. Southeast Asia may experience movements of Vietnamese and Indonesians to Malaysia, Cambodians and Laotians to Thailand, Burmese to Thailand and Malaysia, and Filipinos throughout the region. In addition to creating outright refugees, climate change may drive major increases in migrant workers seeking employment in neighboring countries. Millions of Filipinos and Indonesians currently work overseas within or outside the region—over two million Indonesians work in Malaysia alone, where they make up over 10 percent of the country's population. Overseas migrant labor acts as a safety valve for employment pressures and a source of economically critical remittances. Conflicts over migrant workers are already on the rise in the region, however, and countries under increasing domestic employment and societal pressure are unlikely to welcome a major influx of foreign labor.

Boat People. The maritime geography of Southeast Asia means that many population movements will occur not over land borders but by sea—the phenomenon of migrant "boat people." During the late 1970s, the Communist victory in the Vietnam War generated an exodus of Indochinese boat people. Malaysia, Thailand, and Singapore pushed the refugees back to sea, with devastating humanitarian consequences. The Southeast Asian states' willingness to accept the refugees as nations of first asylum was obtained only with the promise of extensive international aid and permanent resettlement elsewhere. Over a million boat people were resettled in the West, alleviating pressure on Southeast Asia.

Today, Southeast Asia faces an influx of boat people from South Asia, principally Rohingyas, a Burmese minority largely displaced into Bangladesh. The flood of Rohingyas into southern Thailand and Malaysia is already a major problem. In Thailand, the navy has pushed the refugees back out to sea, as occurred in the 1970s. No country in the region wants them, and at a time when the United States and Europe both view immigration as a problem, it is difficult to imagine outside actors willing to accept large numbers of immigrants from Southeast Asia. Climate change—most likely in the form of sudden, more severe storms and flooding—is likely to create a vast new flow of boat people moving between the islands of Indonesia and the Philippines as well as into neighboring countries such as Australia and New Zealand.

Southern Indochina. Some of the most destabilizing cross-border migration over the next two decades probably will occur in Cambodia, southern Vietnam, and eastern Thailand. The two primary components of migration in this region will most likely be Vietnamese moving into sparsely populated areas of northeastern Cambodia or even into the densely populated provinces in southeastern Cambodia; and Cambodians into Thailand. The driver of this migration pattern will be the disruption of the lower Mekong River, whether caused by upstream damming or climate change impacts such as sea-level rise and saline intrusion. This migration will bring culturally antagonistic groups into contact with one another and could lead to a regional conflict in Indochina.

Although many ethnic Vietnamese (Kinh) displaced from the Mekong Delta would move north within Vietnam, others also could move into eastern Cambodia. In addition, as more lowland Kinh move into the Central Highlands, Vietnamese minorities could be driven over the border into Laos and Cambodia. Given the intense animosity between Vietnamese and Khmers, this movement portends a high probability of bitter ethnic and national conflict. Cambodia itself will also be under severe environmental stress if the vital Tonle Sap and lower Mekong are disrupted. The combination of water stress and the influx of Vietnamese could force large numbers of Cambodians out of the country's rural heartland. If they move north or west into Thailand, serious ethnic and border conflict could occur.

Burma and Bangladesh. Bangladesh is likely to suffer catastrophically due to climate change, with the potential for millions of refugees to be displaced from the Ganges Delta, particularly in the wake of severe storms and flooding. Although most of the resulting cross-border migrants probably will move into India, significant numbers of refugees might move into the Arakan region of western Burma as well. In addition, refugee camps in Bangladesh host large numbers of Rohingya driven from Burma. Climatic pressure in Bangladesh will drive them out of the camps. Rohingya refugees could try to cross back into Burma, where the regime is ill-equipped to handle a large refugee influx and hostile to the Rohingya. Many displaced Rohingya would join the flood of boat people seeking entry into other Southeast Asian states.

Chinese Migration and the Chinese Diaspora. The Chinese diaspora is also a source of tension in the region; it has led to periodic explosions of anti-Chinese violence, particularly in Indonesia. The tensions surrounding the established diaspora will over the next several decades be supplemented by increased flows of Chinese migrants. A major expansion of Chinese emigration into Southeast Asia could intensify economic, social, and political instability. In Thailand hundreds of thousands of illegal Chinese migrants have set up businesses, with much of the revenue flowing back to China. Meanwhile, Thailand's broader economy has suffered, in part due to competition with China, helping fuel Thailand's recent political instability. The existing trend of Chinese migration from southern Yunnan province into the northern panhandle of Laos also will intensify. A plan to build a city of 50,000 Chinese laborers near the Laotian capital of Vientiane prompted public protests. Local concerns about the influx of Chinese may lead to violence in some areas, particularly if coupled with environmental stress. A similar dynamic may play out in Burma, where Chinese migrants from Yunnan make up almost as large a proportion of the population of Mandalay as the dominant Bamar (Burmans). Some Southeast Asian countries may become suspicious of their Chinese minorities, perceiving them as Fifth Columnists or extensions of Chinese imperial domination. As China becomes more assertive in the region and its ability to project power increases, Beijing may feel obligated to defend the Chinese diaspora from local grievances.

Prospects for Regional Conflict

Climate change to 2030 is likely to exacerbate existing bilateral and multilateral disputes in Southeast Asia and generate new ones.

Migration Conflicts. Cross-border migration represents by far the greatest potential driver of large-scale interstate conflict in Southeast Asia. Other points of contention, such as maritime disputes, carry more risks of provoking military clashes, but these are likely to be limited in scope. Large-scale cross-border population movements, particularly when combined with historic cultural and national antagonisms, could potentially escalate into major regional wars, involving practices such as ethnic cleansing or genocide. The most dangerous climate change-induced migration flashpoints probably will center on the nexus of Cambodia, Thailand, and Vietnam. In addition, Thai and Burmese forces have engaged in border clashes in recent years that Thai security officials claim have left hundreds dead.

Territorial Disputes. Conflicting territorial claims both on land and at sea have been a perennial source of conflict in Southeast Asia. Major land disputes have either long since been settled or—as with the Philippines' claims to the Malaysian provinces of Sabah and Sarawak—remain dormant. Outstanding border disputes remain between Vietnam and China, Laos and Thailand, and Cambodia and Thailand. Tensions are mainly driven by symbolic, nationalist issues. The recent Thai-Cambodian dispute, for example, concerned control of portions of the historic Preah Vihear temple ruins, awarded to Cambodia by the International Court of Justice in 1962 but still claimed by Thailand. Climate change may increase the salience of border disputes as displaced populations encroach on border areas and illegal immigration expands in scope.

Resource Competition. Climate change-induced financial pressures will place a premium on securing access to natural resources rents. Zero-sum competition rather than cooperation may become the regional norm. Existing conflicts over oil and gas claims probably will be joined by more clashes over dwindling timber resources and potentially even production areas for illicit drugs such as opium. Continued legal and illegal logging by Thai firms and nationals in Laos, Burma, and Cambodia could provoke conflict. As both China and India become major players in resource extraction in the region, their activities will both complicate and exacerbate Southeast Asian resource competition.

Climatic pressures also will drive competition for less lucrative but far more essential resources such as water, arable land, and fisheries. If scarcity of staple resources remain manageable, states probably will compete more for revenue-generating resources. Once a tipping point is reached where a state feels it can no longer provide enough food or water for its population, however, it faces a threat that may well provoke a desperate resource grab. For example, Singapore has the military capacity to seize control of Malaysian water resources in the unlikely event that future water scarcity seriously reduced the available water resources in the area or prompted Malaysia to withhold water for its own use.

Trans-border Environmental Spillover. Disputes over environmental spillover effects will become increasingly prominent in the region as a result of climate change. If climate change worsens the forest fires in Sumatra and Borneo, leading to more fire seasons like that of 1997, tensions between Indonesia and its neighbors could reach a breaking point. Malaysia, Singapore, and other Southeast Asian countries have suffered the effects of the haze generated by the fires year after year, while Indonesia has not taken serious domestic steps to curb rampant burning. Other similar trans-border threats may arise as a result of climate change. The most serious conflicts probably will involve upstream water management of trans-border rivers. Under conditions of water scarcity or irregular rainfall, upstream users might divert water from downstream countries. By far the most significant and potentially contentious issue is that of the Mekong.

Maritime Disputes

At various times most Southeast Asian states have had maritime disputes with their neighbors, and many unresolved disputes remain. Singapore has disputes over maritime boundaries and islands with both Malaysia and Indonesia. Cambodia has similar disputes with Thailand and Vietnam, and unresolved issues remain between Indonesia and Timor-Leste. China occupies the Paracel Islands also claimed by Vietnam and Taiwan. The salience of the remaining maritime disputes in the region has increased with growing competition for seabed hydrocarbon resources and fisheries. The increasing tendency of Southeast Asian states to send naval and coast guard forces to protect their claims is in turn increasing the potential for disputes to escalate into open conflict. The active dispute between Malaysia and Indonesia over the Ambalat block, a fossil fuel-rich area of seabed in the Celebes Sea off eastern Borneo, is a case in point. In May 2009, tensions over Ambalat led to a confrontation between Malaysian and Indonesian warships.

Climate change will increase existing competition over dwindling maritime resources. For example, as fish stocks have declined, conflicts have increased among fishermen who regularly enter waters outside of their national boundaries. Shifts in fisheries due to climate change will intensify fishing conflicts. Based on previous patterns, the Vietnamese will likely be the most aggressive in pressing their fisheries claims. As states in the region compete bitterly for resources and face greater domestic political pressure, they may not act with restraint in the face of maritime provocations.

Coastal changes and loss of islands due to sea-level rise might generate demands for revisions of baselines and jurisdictional boundaries, increasing the potential for maritime disputes. The loss of strategically located islands could have profound ramifications in terms of the Law of the Sea and seabed fossil fuel rights.

The South China Sea. The multilateral dispute over control of the South China Sea is the most significant maritime dispute in Southeast Asia and the one most likely to spark a major regional naval conflict. The South China Sea is the world's largest sea at over a million square miles and among the world's most important maritime trade routes. The sea hosts major fisheries and seabed hydrocarbon reserves and forms the maritime boundary between China and Southeast Asia. China, Taiwan, Vietnam, Malaysia, Indonesia, Brunei, and the Philippines have been party to a series of complex and longstanding disputes over various portions of the sea. The most contentious concern is the Spratly Islands, a series of tiny rocks and coral atolls whose central location make them critical determinants of maritime claims. China, Taiwan, Vietnam, the Philippines, Malaysia, and Brunei claim sovereign control over some or all of the islands. Tensions escalated in the mid-1990s, contributing to a naval arms race in the region, but agreements such as the 2002 "Declaration on the Conduct of Parties in the South China Sea" have led to over a decade of relative calm. The maritime claims nevertheless have not been definitively resolved and increased competition over fisheries and seabed hydrocarbons appears set to resurrect the South China Sea dispute.

The key outstanding issue is China's claim. China considers the South China Sea a territorial sea based upon right of first discovery, a claim that is in direct conflict with the Law of the Sea and the claims of the other parties. China's claim includes portions of the continental shelves of Vietnam, Malaysia, and the Philippines. It extends as far south as Indonesia's Anambas Islands, including the Natuna Islands—which China claims despite acquiescing to de facto Indonesian control. China has sought to control economic activity in the sea, even objecting to oil drilling in Vietnamese territorial waters in the Gulf of Tonkin. The normal avenue of seeking a ruling from the International Court of Justice is closed because China will not submit to international arbitration of its sovereign claims. China adamantly refuses to accept any multilateral initiative that might question the legitimacy of its sovereign rights in the South China Sea, and its expansive claims are backed by growing military power. If China were to enforce its claims, it would end freedom of navigation in the South China Sea, a vital artery for trade and oil between Northeast Asia and points west. The strategic implications would be profound, and such a move could precipitate a major regional naval conflict.

Southeast Asian countries have tried to engage China on the sovereignty issue for 20 years but to no avail. China is unlikely to back down from its claims in the South China Sea but wants to be a responsible stakeholder in managing maritime resources. Setting aside sovereignty, progress is possible on settling the constituent disputes over fisheries and seabed resources and meeting the common challenges of climate change. The predicted new energy demands caused by development, urbanization, and climate change raise the stakes in the territorial and jurisdictional claims to potential oil and gas reserves. The littoral states will most likely come to a compromise with China on joint resource exploitation even if China's sovereignty claim is not directly addressed.

Climate change will complicate efforts to settle the South China Sea maritime dispute. Sea-level rise is likely to permanently submerge some of the disputed Spratly Islands, where some maritime claims are based on coral reefs that only emerge from the water at low tide. In response, China is reinforcing the islands and building up the reefs to be self sustaining. Climate change also poses a significant threat to the South China Sea's maritime ecosystems, which are at the point of collapse due to overfishing and pollution. The countries of the region have failed to arrive at an international agreement to stave off such an outcome. Efforts such as the Indonesian-led South China Sea workshop process to find areas of functional cooperation on environmental management have foundered on conflicting sovereign claims.

The maritime effects of climate change, such as changes in sea temperature, salinity, and acidity, will further deplete and strain the fisheries. Confrontations between illegal fishing vessels and national maritime police or navies are becoming routine. In addition, China's exploitation of Southeast Asian fisheries is backed by aggressive maritime patrolling deep into the claimed Exclusive Economic Zones of its ASEAN neighbors. Fishing confrontations involving China have led to tensions with both Indonesia and Vietnam.

The Mekong River

The challenges associated with the Mekong River represent a regional political and ecological tipping point for Southeast Asia. The concurrent effects of manmade development activities and climate change have created the potential for a regional disaster. The combination of agricultural disaster on the lower Mekong and resulting mass refugee flows could dominate the course of development, stability, and foreign relations in mainland Southeast Asia to 2030 and beyond.

Dam Construction. Energy demand and hydropower potential have led to an explosion of dam construction on the Mekong and its tributaries, posing a significant threat to the health of the Mekong Basin. There are already seven dams on the Mekong River system, most of them built on tributaries such as the Mun River in Thailand or the Nam Ngum in Laos. With China leading the way and providing investment and construction, the states of the Mekong Basin are set to triple or quadruple that figure. China's ambitious program in Yunnan Province projects a cascade of eight large to mega-sized hydropower dams, four of which were already under construction as of July 2008, with the possibility of eight more further upstream. China's upstream activities may have a far greater and more rapid effect on downstream volume in the major rivers of mainland Southeast Asia than climate change. China's diversion of Mekong River water may become even more critical if the Mekong's flow from Tibet is diminished due to climate change.

Although China receives the lion's share of the criticism for rampant dam construction, Laos, Thailand, and Cambodia are also planning a further 11 dams on the Mekong—seven in Laos, two on the Lao-Thai border, and two in Cambodia. The upstream reservoirs in China will act as cisterns to ensure adequate downstream river flow to the planned downstream Mekong dams during the dry season. Chinese companies are involved in more than half of the downstream dam projects. Both Thailand and Cambodia are also constructing water management infrastructures on Mekong tributaries.

The impetus behind the Mekong dam projects is the creation of a regional electrical grid that will facilitate the development of the Mekong Basin. By 2030, the Mekong and its tributaries will support an elaborate, interlocking electric power generation grid supplying Laos, northern Thailand, parts of Cambodia, and much of Yunnan. The economic stakes for dam construction are high, and the states of the Mekong Basin are set to compete for whatever developmental benefits they can obtain with little regard to the consequences for others further downstream. By adeptly playing off the Chinese against the Vietnamese and the Thais against both, poverty-stricken Laos is set to become a leading regional electricity provider.

The Mekong problem points to the larger issue that governments in Southeast Asia may not alter their policies even when confronted with definitive scientific warnings of the consequences. The riparian states continue to pursue infrastructure projects designed to interfere with the natural flow of the Mekong in spite of the potential adverse effects. Even Vietnam, despite facing disaster as a result of upstream dam construction, is building dozens of small and medium-sized dams in its Central Highlands, reportedly without adequate impact studies. The flow of foreign investment and the allure of establishing a Mekong Basin hydroelectric grid trump the scientific data. Dam construction is set to bring major economic and energy benefits to China, Laos, and Thailand. These states will suffer few of the adverse impacts on water availability, agriculture, and freshwater fisheries that will disrupt Cambodia and Vietnam. Paradoxically, climate change may have more prospects of bringing a halt to dam construction than concerns over collateral effects. The reduction in river flows to the dams due to the disappearance of the Himalayan glaciers could limit hydroelectric potential to the point that they are no longer viable projects.

Multilateral Management of the Mekong. The lack of cooperative and sustainable multilateral water management is one of the most serious potential sources of regional instability in mainland Southeast Asia to 2030. The Mekong issue is an example of the failure of inadequately empowered multilateral organizations in the region to provide effective management of high-priority environmental policy issues. The two multilateral organizations charged with managing development of the Mekong are the Mekong River Commission (MRC) and the Greater Mekong Sub-region (GMS). Cambodia, Laos, Thailand, and Vietnam are members of both organizations, while GMS members China and Burma have declined membership in the MRC, in part because of the MRC's criticism of upstream dam-building. While the MRC is concerned with riparian issues exclusively the GMS coordinates regional road networks and multilateral trade cooperation as well as hydrologic issues. Both organizations are weak, ineffectual consultative bodies whose executive authority is limited to managing the initiatives arrived at by consensus of the member states. They have no voice in the decision-making of the member states or independent ability to enforce regulation of the Mekong. The MRC and GMS nevertheless provide an institutional basis for the development of a future, more effective multilateral framework to address both developmental and climatic challenges in the Mekong Basin.

China and the Mekong. As in the South China Sea dispute, China is the central player whose policies will determine the course of development of the Mekong Basin to 2030. The states of mainland Southeast Asia have little effective leverage over China even when they can agree on a joint position. Because of its major strategic stake in pipelines and ports in Burma, China has proven responsive to Burma's concerns about dam construction on the Nu (Salween) River. On the other hand, Beijing has less direct stake in Laos, Cambodia, and Vietnam and may prove much less cooperative regarding its dams on the Mekong. Ultimately, China does not need the approval of any downstream state to build its dams in Yunnan. Nevertheless, China faces potential for political blowback if the countries of the lower Mekong Basin reach a consensus that the dams are threats to their security. Such a reaction could metastasize into a broader reaction against China's deep involvement in Southeast Asia. The dam construction is already becoming a major bilateral source of tension between China and Vietnam. Regional mobilization to restrain China's dam construction and other high-impact activities in Southeast Asia may have a limited window of opportunity. Once the dams are in place, China will exercise decisive control over the river and by extension, over the states dependent on it.

Broader Regional Implications

Northeast Asia. Japan, South Korea, and Taiwan—like China—have major interests at stake in Southeast Asia in terms of investments and resource access. The Northeast Asian countries have a strong incentive to provide assistance to Southeast Asian states in meeting the climatic challenge. Moreover, the states of Northeast Asia are critically dependent on both the free flow of maritime trade and oil through Southeast Asia and the South China Sea. Disruption of the sea lines of communication, whether caused by climate change or the activities of China, would be extremely destabilizing and could lead to regional conflict.

South Asia. India, like China, is a rising power with deepening involvement in Southeast Asia. Like the Northeast Asian states, India has a strategic maritime interest in maintaining open sea lanes through the chokepoints of Southeast Asia. India is opposed to the establishment of unchecked Chinese hegemony in Southeast Asia, which may give it common cause with states like Vietnam and Indonesia, not to mention the United States. India shares Southeast Asian concerns over water management and upstream dam construction by China, environmental refugee flows, food security, and the threat from climate change and overfishing to the fisheries of the Bay of Bengal and Andaman Sea. The gravest climate change-induced challenge shared between South and Southeast Asia, however, is the potential for a humanitarian emergencies and mass refugee flows from Bangladesh. Such a catastrophe could have major collateral effects on Burma and prompt mass migration into other Southeast Asian states as well.

Australasia and the Pacific. Climate change-induced instability in Southeast Asia would pose a major security challenge for neighboring Australia. In particular, deteriorating conditions in Indonesia could absorb most of Australia's attention and military resources. A worst-case scenario would be a massive flow of Indonesian refugees into Australia. A proximate threat to Australia's security would draw in the United States in support of its close ally.

Papua New Guinea will likely face major climate change-induced challenges of its own, including an acute vulnerability to sea-level rise and island loss. The country's poverty and underdevelopment provide little capacity to deal with such challenges. Moreover, Papua New Guinea's climate change-induced troubles could spill over into Indonesia's Papua province or vice versa. Illegal migration across the border between the two halves of New Guinea is already a problem, and climate change could create much larger refugee flows in either direction.

Overall Foreign Policy Implications

Most of the countries in Southeast Asia are Western-oriented and integrated into the global economy, with strong economic and political ties to the United States and the developed countries of Northeast Asia and the West. Even the formerly Communist states of the Southeast Asian mainland are becoming more outward-looking and integrated into Western economic and trade structures. The major exception is Burma, which remains the most disconnected and xenophobic state in the region. Climate change may affect foreign policies in different ways across the region, but the overall need for external assistance to meet humanitarian and climatic crises should encourage greater openness. For example, Cyclone Nargis has made Burma slightly more open to engaging with foreign aid organizations and states. Even where climate-induced crises force states to concentrate on internal challenges, limited state capacities will necessitate continued engagement with outside sources of aid.

The rise of China and its foreign policy toward Southeast Asia is likely to remain the central driver of the foreign policies of states in the region to 2030. The effects of climate change on China itself will in part drive China's domestic and foreign policies in ways that impact Southeast Asia. Moreover, each country in the region must strike a balance in its relations with China on the one hand and with the United States and its regional allies on the other. Climate change will factor into this balancing of foreign policy orientation, especially the degree to which states in the region decide or are compelled to rely on China rather than the West for assistance in combating climate change. States such as Burma, Laos, and Cambodia probably will increase their already heavy dependence on China. Malaysia, the Philippines, Singapore, and Thailand, with much stronger pre-existing ties to the West, will have more leverage to avoid becoming critically dependent on China. Vietnam and to a lesser extent Indonesia are likely to strongly resist dependence on China and could become more pro-Western in their orientations. Whether this likely split in orientation within the region becomes a source of major tension will depend to a large degree on how aggressively China decides to pursue regional hegemony over the next 20 years.

In addition to the China and foreign aid factors, the effect of climate change on Southeast Asia's relations with the West will depend on how the issue is framed within the region. To date, much of the global debate on climate change has been framed in terms of the West versus the developing world. The states of Southeast Asia share the concerns of other developing countries over the perceived inequity of having to accept limitations on their development to address problems caused by the already developed states. The United States and other Western states are seen as hypocritical on environmental concerns due to their own misuse of resources and environmental damage. If the states of Southeast Asia are asked to make major sacrifices or perceive their economic development options being limited, tensions will occur with the West.

The West is currently seen as the primary culprit, and as climate change-induced challenges become more severe and apparent, this could bolster anti-Western sentiment in the region. In many cases, Southeast Asian leaders unable to effectively address climate change-related issues will try to blame external actors, as they have done over regional public health issues. The framing of climate change as a Western-generated phenomenon creates the potential for major anti-Western backlashes over virtually any climate change-induced crisis that arises in the region. These nationalistic reactions may hamper cooperation on international mitigation efforts and strain broader relations between Southeast Asian states and the West, particularly the United States.

The West, however, may increasingly share the blame for climate change with China and other global actors. One emerging factor is the move by wealthy countries such as the Republic of Korea or Saudi Arabia to secure control over Southeast Asian commercial agriculture to grow crops to meet their own domestic food security needs. By doing so, they are using Southeast Asia's land and water to produce non-Southeast Asian food, in effect redistributing resources out of the region. As regional resources are strained by climate change, this may become a major point of contention.

China's growing involvement in the region, particularly in exploitation of natural resources that may exacerbate climatic effects, is generating an increasing tendency to blame China rather than Western actors. Deft Chinese investment in green technologies in Southeast Asia might deflect some negative perceptions of China's role as a contributor to climate change and threat to the region's environment. Nonetheless, the negative effects that are likely to be blamed on China—such as a crisis on the Mekong River—are of such a scale that China probably will not be able to counteract the damage to its image. The Mekong River issue is the most salient area where China risks a major regional backlash, and China's approach on the Mekong may be the most important determinant of what direction its relations with mainland Southeast Asia take to 2030. Over the next 20 years, countries in the region may come to regard China as a far greater climatic and environmental threat than the West and political mobilization may shift to an anti-Chinese focus.

Southeast Asia and Global Climate Change Policy

To date, Southeast Asia has played a relatively larger role in the debate over global climate change policy than the widespread dismissal of the issue within the region would indicate. For example, the ASEAN countries were early signers to the Kyoto Protocol, and have participated constructively in subsequent climate change policy forums. Indonesia has been particularly engaged, hosting the December 2007 Bali Conference on the United Nations Framework Convention on Climate Change (UNFCCC) as well as arranging a September 2007 climate change summit involving the eight leading tropical rainforest countries. Apparent commitment to the global debate notwithstanding, at the

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regional and individual state level climate change policy remains hollow and rhetorical, with little sense of urgency or common purpose. In a few cases, the surprising global engagement on the issue may be driven by pressure from civil society. Thailand and the Philippines have lively nongovernmental and “cause-oriented” sectors, and such voices are growing in Indonesia as well. For the most part, however, the engaged rhetoric and diplomacy on global climate change may represent the sort of superficial multilateral engagement characteristic of regional-level engagement in ASEAN. If so, the political will and capability of the Southeast Asian states to follow through effectively on international commitments is questionable.

Even if professed concerns over climate change are superficial, a number of different factors may explain the region’s level of involvement. Southeast Asian states may be motivated by unwillingness to allow the major powers to dictate climate change policies that might adversely affect Southeast Asia’s economic interests. Indonesia, for example, has a major interest in keeping the emissions debate focused on regulating industrial and transportation contributions to greenhouse gases rather than causes such as manmade forest fires. Countries in the region also do not want to end up having their future industrial development constrained. Conversely, global climate change mitigation policies have the potential to play out to the economic advantage of many states in Southeast Asia. Apart from Indonesia, most countries of the region still have a comparatively small carbon footprint. Tighter global emissions controls and carbon credit schemes are therefore comparatively advantageous to Southeast Asia. The light manufacturing capabilities and cheap labor in Southeast Asia may also be highly suitable for certain kinds of green technology production. In addition, engagement with the international climate change debate and apparent willingness to promote mitigation policies provide good public relations with Southeast Asia’s important trading partners in the developed world. Singapore’s 2006 decision to sign the Kyoto Protocol exemplifies these dynamics. The decision was primarily made to protect the country’s international image and to benefit from economic opportunities under the “Clean Development Mechanism” rather than from a desire to grapple with climate change.

Southeast Asia’s involvement in global climate change mitigation has so far been largely constructive and could become more important over the next 20 years. The continued growth of concern and mobilization on climate change within civil society may push governments in the region to take a more activist position. In particular, Thailand and conceivably the Philippines might become more vocal regionally and internationally due to civil activism. It is unlikely that ASEAN or any of its members will take the lead in championing fresh international norms to slow global climate change. Southeast Asia might nevertheless be among the first regions to support a positive approach if the developed world, India, and China establish an effective approach to global climate change.

The Role of the United States in Southeast Asia

Since the end of the war in Indochina, Southeast Asia has been a region of secondary importance to the United States. Although the United States has a number of critical economic and strategic interests in Southeast Asia, US policy in Southeast Asia since the late 1970s has largely been determined by US interests in neighboring Northeast Asia.

The states in the region have been mainly pro-Western and those that are not have been closed and inward-looking. Security problems in the region, while serious, generally have remained manageable and have not had major spillover. Following the withdrawal of the United States from its bases in the Philippines, the primary US military presence in Southeast Asia has been naval deployments to protect the region's sea lines of communications (SLOCs) and more recently anti-terrorism support to local governments. Trade and economics continue to dominate the US agenda in the region. Policy attention has not kept pace with the region's growing global importance and the growing US equities at stake there. The combination of climate change and China's growing regional dominance may put substantial US interests in the region in jeopardy over the next two decades. The negative interaction of climate change and unsustainable development policies raises the prospect of severe regional instability while China's increasing regional dominance threatens to exclude the United States from Southeast Asia and provoke regional conflicts.

US Interests in Southeast Asia. Southeast Asia is of critical economic importance to the United States in a number of respects. Most directly, the trade and investment links between Southeast Asia and the United States are very strong. Taken as a whole, ASEAN is a larger US trading partner than China. Serious climate change-induced economic destabilization in the region or economic exclusion by China would be very costly to the United States and US companies. Due to the important role the countries of Southeast Asia play in the global economy, instability in the region could also have serious indirect repercussions for the economic interests of the United States. It is in the interests of the United States to help maintain economic stability, free trade, and open markets in the region.

The maintenance of a free flow of maritime trade and military assets through Southeast Asia's vital SLOCs is of both critical economic and strategic interest to the United States. Half of the world's maritime trade passes through the region. A third of the world's oil passes through the Strait of Malacca, including nearly all the oil imported by China, the Republic of Korea, Japan, and Australia. Climate change threatens to increase piracy, already a major threat in the region, particularly in the Strait of Malacca. Piracy has declined significantly in recent years due to the establishment of joint maritime patrols by the littoral states combined with strong police work on land, particularly in Indonesia. Since most piracy in the region involves impoverished fishermen seeking an alternative livelihood, however, climatic stress on coastal communities and fisheries could drive a major uptick in piracy. China's assertion of sovereignty over the South China Sea, spurred in part by climate change-induced resource scarcity and fisheries impacts, would jeopardize freedom of the seas and could spark a broader regional conflict. The United States has a strong interest in promoting regional maritime security and heading off a regional conflict with China.

The United States has a strategic interest in promoting a Southeast Asia that is regionally integrated, at peace, and resists the hegemony of any power—particularly China. If China's regional dominance assumes an exclusionary character, it will threaten the interests of not only the United States but also key allies in the Asia-Pacific, including Japan and Australia. By 2030 Southeast Asia is likely to become the primary zone of contention between Asia's two rising giants, China and India. A relatively robust, integrated Southeast Asia supported by a US naval presence would act as a buffer between the two powers. In contrast, a weak, unstable Southeast Asia without a US presence could draw them into direct strategic conflict over the region.

A weakened and unstable Southeast Asia will also provide greater functional space for international terrorist groups, while climate change-induced grievances may push more disaffected recruits into such groups. Terrorists may flourish in peripheral areas expected to suffer severe climate change-induced stress, particularly the potential "arc of anarchy" in the islands from Sulawesi to Mindanao. Social disruptions and migration will provide more opportunities for terrorists to blend into local communities and move freely. State resources will be diverted to managing the effects of climate change, not only weakening the state's ability to combat terrorism but providing the terrorists with an opportunity to win hearts and minds by stepping in to fill shortfalls in social services. In addition, Southeast Asia will be subject to humanitarian crises of increasing frequency and scale. The United States is likely to be one of the primary international responders to such crises, as it was during the 2004 tsunami or Cyclone Nargis. The less the states in the region can do for themselves, the more the United States has to expend to help them.

The United States has an overall interest in preventing sustained economic or political weakness and instability in Southeast Asia. Developments in the region could not only have major direct adverse consequences for US interests but could affect the overall foreign policy of the United States in Asia and elsewhere. The effectiveness of Southeast Asian governments' responses to the climate change-induced challenges that face their societies is an important concern for the United States.

Sino-US Relations and Southeast Asia. Any realistic US policy options in Southeast Asia must take China's role into consideration. China factors into every US bilateral relationship in the region. The United States will be challenged to balance regional interests with the broad array of complex bilateral issues involved in the Sino-American relationship. Both the United States and China tend to be reflexively antagonistic when their geopolitical interests overlap, but climate change mitigation is a potential area for cooperation. The United States should carefully consider how China's growing influence in Southeast Asia will affect key US interests in the region.

Over the next two decades, the United States will face critical foreign policy decisions regarding its posture toward China's expanding influence in Southeast Asia. On the one hand, the United States could acquiesce to inevitable Chinese hegemony and focus on cooperation with China on climate change and other issues in the region. On the other hand, the United States could support those states in the region hostile to Chinese domination, building strong relationships with them as a counter to China. A middle ground might be to attempt to engage China in a multilateral regional structure that would introduce some institutional constraints on China's influence. Such an approach would have to be adroitly managed in order to assuage China's suspicions and aversion to joining what it perceives as US-dominated institutions.

The course the United States chooses regarding China has major implications for US climate change policy in Southeast Asia. If China's hegemony is considered a fait

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accompli, the important negotiations and agreements on climate change in the region will be between Washington and Beijing. The need to cater to the states in Southeast Asia proper would be secondary. This might result in more efficient mitigation policies in areas where the United States and China agree, but deadlock where they disagree. The viability of a multilateral course would similarly depend heavily on areas of Sino-US agreement and disagreement. Even if a multilateral approach is effective in moderating China's position in Southeast Asia, it might result in lowest common denominator climate change mitigation policies. Conversely, if the United States sides with regional powers, the focus of climate change policy would be on building state capacity in the region. This might be effective in improving regional resilience, but China would not share in the costs and would probably seek to undermine mitigation policies.

Climate change-driven regional dynamics such as antagonism toward China's exploitative role in the region or dependence on Chinese aid will play a significant role in the China-US-Southeast Asia interaction. If contentious issues such as the Mekong or the South China Sea are allowed to develop into full-fledged regional conflicts, it could have a decisive effect on the course of Sino-US relations to 2030 and beyond. The United States could play a useful role as a facilitator for negotiations toward an agreement on these potential inflammatory issues. US efforts to manage these disputes should take into account China's nationalism-driven refusal to compromise its sovereignty. The sovereignty issue is non-negotiable and should be avoided rather than confronted. China might be open to compromise solutions on allocation or joint development of resources and shared maritime access if they derive from an environmental and resource management perspective. The introduction of sovereignty into the debate would scuttle any prospect for agreement.

US-Southeast Asian Relations. Despite China's inroads in Southeast Asia, the United States remains in a strong diplomatic position in the region. Singapore, Thailand, and the Philippines have longstanding close relations with the United States. Despite periodic strains, the United States has also maintained constructive relationships with Malaysia and Indonesia and has made substantial progress in improving relations with Indochina. Only Burma and to a lesser extent Laos remain diplomatically isolated from the United States. Even those diplomatic obstacles are mitigated by the strong cooperative relationship the United States has built with ASEAN. The overall context for the United States to mobilize support for climate change mitigation in Southeast Asia is therefore robust relative to many other regions.

Southeast Asian states tend to be wary of becoming too closely tied to the United States, particularly as China becomes more assertive in the region. The China factor will determine what kinds of climate change-driven cooperative relationships states in the region are willing to accept. To date, Southeast Asian states have been unimpressed by Washington's disinclination to muster an effective counter to China's expanding influence. Their lack of confidence in the level of US commitment will affect their willingness to sign on to US-led climate change initiatives. The United States will need to demonstrate its bona fides in the region.

Aside from the crucial relationship with China, the two most important US relationships in the region to 2030 may be with Vietnam and Indonesia. The United States needs to carefully consider these relationships in light of their potential impact on US-China relations. The relationship between the United States and Vietnam is becoming closer because of shared concerns regarding China. Vietnam is eager to continue building the relationship and for US development assistance and investment. Vietnam is also more concerned about adapting to environmental and climatic challenges than other states in the region. Creating a partnership to tackle climate change adaptation in the region could be an easy sell as part of an expanding US-Vietnam relationship. On the other hand, a partnership with Vietnam carries significant risks of drawing the United States into a showdown between China and Vietnam over the Mekong or the South China Sea. Indonesia is by far the most important state in the region from a climate change perspective. The United States currently has an opportunity to assist Indonesia in developing its capacity to act in a leadership role in meeting the challenges of climate change in Southeast Asia. The new comprehensive partnership between the United States and Indonesia provides an avenue for the United States to engage across the board. A combination of US support, international pressure, and incentives such as debt alleviation could encourage Indonesia toward greater attention and commitment to proactive climate change mitigation.

US Engagement on Climate Change in Southeast Asia

US engagement with the Southeast Asian states on the climate change issue is likely to be a protracted and difficult process due to the lack of commitment to substantive action on the issue within the region. Different countries in the region will respond to different types of US diplomatic approaches on climate change and related issues. Some prefer multilateral approaches; others prefer to be consulted on a bilateral basis and included in the policy formulation process. Enthusiasm for greater US engagement in the region also varies widely. US efforts will be more effective when tailored to the circumstances and interests of each individual country in the region.

Highlighting the economic costs associated with climate change will be very important to achieving US policy objectives. In addition, states and leaders in the region are accustomed to dealing with problems such as food security, water supply, or public health as discrete issues. An approach that starts by addressing discrete aspects of the environmental and climatic issue that resonate in the region will be better received than a comprehensive climate change initiative. The latter will encourage rhetorical rather than substantive responses, while the former are manageable enough in scope so that states in the regions can engage effectively. Forstates in the region to buy into US initiatives, they will need evidence of a sustained US commitment backed up by considerable resources and policy attention.

While wary of involvement with the United States, most states in the region would welcome a quiet leadership role by the United States in addressing climate change-related challenges and in offering concrete program assistance. More so than China, the United States can act as a comparatively honest broker, able to keep needed regional programs on track despite internecine rivalries and maneuvering. The United States should also be prepared to bring diplomatic and economic pressure to bear in order to encourage climate change mitigation measures. Many leaders in the region may not be convinced of the need to start mitigation programs within the limited timeframe available. Ultimately, climate change mitigation measures implemented at the behest of the United States rather than because leaders are fully convinced of their necessity still represent progress.

Raising Awareness and Education. Awareness and acceptance of climate change issues remains superficial in Southeast Asia, posing a major obstacle to the adoption of effective mitigation policies. What is needed in Southeast Asia is not just wider knowledge about climatic issues but wider acceptance of the validity of the problem and the proposed solutions. The United States has a comparative advantage in terms of knowledge on climate, environment, and health issues. It can exploit this to provide education and outreach to Southeast Asian states, simultaneously promoting awareness of climate change. The region needs centers of excellence on climate and environment issues, and the United States could help establish them. It will be a challenge, however, to overcome the inclination of decision-makers in the region to ignore scientific reporting. Increased use of video, computer animation, and geographic information systems to visually convey climate data in a more striking and readily digestible format could help communicate the science of climate change more effectively. In addition, decision-makers as well as the public can be influenced indirectly by promoting climate change awareness among regional opinion leaders. The United States could hold workshops for Southeast Asian officials, parliamentarians, and members of the regional media to present the case for climate change mitigation in an accessible way. Such an education initiative would create regional stakeholders in the climate change discussion who can help reframe the climate change debate and increase the priority of climate change on the regional agenda.

Boosting Local Capacity. The United States could both improve its image and standing in Southeast Asia and ameliorate climate change-induced impacts by building up state capacities in the region. Most states in the region have broad deficiencies in multiple areas of state capacity and could significantly benefit from US assistance in areas such as urban planning and infrastructure, water resource management, civil engineering, agricultural policy, conservation, public health, and disaster response. The United States should continue to build on initiatives such as the July 2009 agreement to increase cooperation on education, public health, the environment, and water management between the United States and the states of the Lower Mekong Basin. The new Comprehensive Partnership with Indonesia is focused on education but could just as easily be focused on building capacity to address climate change.

Besides financial assistance, technical expertise, and humanitarian aid, another important element of capacity-building is to encourage the development of green technology and clean energy in the region. The United States could incentivize green investment by setting it as a precondition for closer economic relations. Green technology is an area of convergence between the United States and China, which is investing heavily to become a leader in renewable energy technology. Although China may undercut Western firms and offer competing investment and aid packages in Southeast Asia, the net result could still be beneficial from a climate change mitigation perspective.

Poor governance, lack of transparency, and corruption in the region will undercut efforts to increase the capacity of regional states to mitigate climate change effects. Resources directed to central governments may often not find their way down to the local governments which will be the primary responders to climatic challenges. Without robust US oversight of how assistance is used, much of it may prove ineffective. Encouraging governance reform, increased transparency, and state accountability will be an important aspect of capacity-building. The United States could enhance accountability and ensure resources are directed to relevant applications by emphasizing technology transfers and expertise and directing funding and investment to specific programs rather than providing general aid packages.

Given the lack of state capacity, the development of more effective environmental groups in civil society presents a possible alternative avenue for the United States to exert influence in the region. Outreach to civil society would have to be subtle and take the sensitivities of local governments and public sentiment into account or risk eroding the credibility of civil actors and subjecting them to state repression.

Military-to-military contacts and training could provide a vehicle to encourage the aspirations of the new generation of military leaders in the region toward greater professionalism, de-politicization, and rooting out corruption. More professional, reliable armed forces will increase state capacity. The US military could facilitate the growth of regional military capabilities for infrastructure-building and disaster response. Creating units equivalent to the US Army Corps of Engineers could play a major role in climate change mitigation.

Strengthening Multilateral Institutions. In addition to boosting the capacity of individual states, the strengthening of multilateral institutions in the region would create an effective joint framework to address climate change-related challenges. The United States can leverage its greater institutional experience, expertise, and capabilities in managing environmental issues to support Southeast Asian institutions such as the Greater Mekong Sub-region or Mekong River Commission. The newly-announced partnership between the Mekong and Mississippi River Commissions, for example, could pave the way for the development of broader-ranging regional environmental management organizations. United States engagement with multilateral institutions in the region needs to take place in a context that does not threaten either China or the Southeast Asian countries. One possible approach would be to use the Treaty of Amity and Cooperation in Southeast Asia as the normative basis for a new multilateral consultative framework, since both the United States and China are signatories.

The Copenhagen Negotiations

In approaching climate change negotiations with Southeast Asian states, the United States needs to bear in mind that in many cases governments in the region lack the capacity or will to deliver on their policy promises. Both ASEAN and individual states in the region have a long history of failing to act on their rhetoric and policy initiatives. Although Southeast Asian states may readily sign on to an agreement at Copenhagen, robust accountability will be necessary to insure that they follow through. To that end, the

United States needs to consider making aid to countries in the region conditional on performance and assured allocation to climate change-related applications.

Because of its size and status as a major emitter of greenhouse gases, Indonesia is the Southeast Asian state most critical to the climate change negotiations. The international community needs to make a major effort to motivate Indonesia to engage on the climate issue. Indonesia desires to play a constructive international role on the environmental issue commensurate with its importance as a source of greenhouse gas emissions. Indonesian leaders would rather have the country seen as a good international citizen than an obstructive polluter. As a largely agricultural developing country that is also a major emitter, Indonesia could act as an intermediary in negotiations between the developed and developing worlds.

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CONFERENCE REPORT

SOUTHEAST ASIA:
THE IMPACT OF CLIMATE CHANGE TO 2030:

GEOPOLITICAL IMPLICATIONS

This paper does not represent US Government views

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CONFERENCE REPORT

CR 2010-03 January 2010

Mexico, The Caribbean, and Central America: The Impact of Climate Change to 2030:

Geopolitical Implications

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Mexico, The Caribbean, and Central America: The Impact of Climate Change to 2030: Geopolitical Implications

Prepared jointly by

CENTRA Technology, Inc., and Scitor Corporation

The National Intelligence Council sponsors workshops and research with nongovernmental experts to gain knowledge and insight and to sharpen debate on critical issues. The views expressed in this report do not reflect official US Government positions.

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Scope Note

Following the publication in 2008 of the National Intelligence Assessment on the National Security Implications of Global Climate Change to 2030, the National Intelligence Council (NIC) embarked on a research effort to explore in greater detail the national security implications of climate change in six countries/regions of the world: India, China, Russia, North Africa, Mexico and the Caribbean, and Southeast Asia and the Pacific Island States. For each country/region we are adopting a three-phase approach.

- In the first phase, contracted research explores the latest scientific findings on the impact of climate change in the specific region/country. For Mexico, Central America, and the Caribbean, the Phase I effort was published as a NIC Special Report: ***Mexico, Central America, and the Caribbean: Impact of Climate Change to 2030, A Commissioned Research Report*** (NIC 2009-11), of November 2009.
- In the second phase, a workshop or conference composed of experts from outside the Intelligence Community (IC) determines if anticipated changes from the effects of climate change will force inter- and intra-state migrations, cause economic hardship, or result in increased social tensions or state instability within the country/region. This report is the result of the Phase II effort for Mexico, Central America, and the Caribbean States.
- In the final phase, the NIC Long-Range Analysis Unit (LRAU) will lead an IC effort to identify and summarize for the policy community the anticipated impact on US national security.

In August of 2009, a group of regional experts convened to explore the socio-political challenges, civil and key interest group responses, government responses, and regional and geopolitical implications of climate change on Mexico, Central America, and the Caribbean through 2030. The group of outside experts consisted of economists, political scientists and other social scientists. While the targeted time frame of the analysis was out to 2030, the perceptions of decision makers in 2030 will be colored by expectations about the relative severity of climate changes projected later in the century. The participants accordingly considered climate impacts beyond 2030 where appropriate.

This work is being delivered under the Global Climate Change Research Program contract with the CIA's Office of the Chief Scientist.

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Executive Summary

The National Intelligence Council-sponsored workshop entitled *The Implications of Global Climate Change in Mexico, the Caribbean, and Central America*, held on 31 August 2009, brought together a panel of regional experts to consider the probable effects of climate change on Mexico, the Caribbean, and Central America from a social, political, and economic perspective. The panelists concluded that through 2030 ***climatic changes in the region may aggravate civil unrest and internal conflicts leading to increased migration, and that strong, centralized states, and states with robust civil societies, will likely fare better than others.***

Although the region does not contribute to significant global greenhouse gases, it is highly vulnerable to the effects generated by increasing climate variability. Rising temperatures, rising sea levels, increased rainfall in some places, drought in others, and a greater frequency of extreme weather events such as hurricanes, floods, and heat waves are expected from climate change.

- Temperature rise, both on land and at sea, could affect crop growing patterns as well as the viability of fisheries on which some coastal populations depend.
- Sea level rise has the potential to create economic losses for coastal populations, particularly around ports.
- Rising temperatures, increased rainfall, and population displacement may exacerbate or contribute to the emergence of infectious diseases.

Climate change may increase prospects for conflict in the region. Increased resource scarcity may combine synergistically with weak states and economic inequalities to promote organized insurrection. Civil conflicts are more likely than state-on-state violence, though some internal conflicts may spill across borders.

- Potential inter-state flashpoints include the Dominican Republic and Haiti, the Guatemala-Honduras-Nicaragua zone of instability, and the US-Mexican border.
- In Mexico, water scarcity may intensify community vulnerabilities to water-related diseases and exacerbate social tensions over access to water for agriculture and domestic uses.

Large internal conflicts or large population migrations are unlikely for most states in the region (with the exception of Haiti). While increased migration is likely, it is only part of a range of potential responses, including adaptation, sub-state conflict, and interstate conflict.

- Migratory trends to Mexico and to the United States are likely to continue and may accelerate. A concomitant rise in migrant-related criminality is also likely.
- The adaptive capacities of states and populations within the region vary but the region has historically dealt well with slow-acting climatic changes.

Strong civil society organizations play an important role in moderating the effects of climate change as they provide a means of communication between local people and state actors. The strength of civil society varies among states in the region.

- Mexico and Panama possess robust civil society organizations, environmental and social NGOs, and ethnic organizations.

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- Guatemala, Nicaragua, and El Salvador are in the process of rebuilding civil society destroyed by conflict.
- In the case of Haiti, civil society is more present in Diaspora—primarily in the United States and France.

State centralization and control correlate well with emergency preparedness. All states in the region show some capacity to recover from damage caused by extreme weather events.

- Mexico and Cuba appear to have the greatest state-level capacity when it comes to emergency preparedness. In both settings, the armed forces play a role in managing emergency response.
- The smaller Caribbean and Central American states are less prepared to respond to climatic emergencies domestically, and Haiti is the least prepared.

Most states in the region lack the institutional mechanisms to effectively address the long-term threats posed by climate change.

- Development agencies including USAID and the Inter-American Development Bank are working with states in the region to gather information and develop tool kits to help governments assess their vulnerabilities and better prepare for the physical, economic, and human toll of extreme weather events.
- The Caribbean Community (CARICOM) has instituted several initiatives to bring governments and NGOs together in productive cooperation.

The United States will probably face ever-increasing pressure to provide humanitarian assistance to neighbors to avoid large numbers of refugees and to reduce the risk of local conflicts that could require US military intervention.

- States in the region may become increasingly inward looking and politically populist in reaction to economic disparity, resource scarcity, or civil conflicts exacerbated by climate change.
- Seeking collaborative and effective regional mechanisms to jointly manage climate change challenges may provide the United States new opportunities for strengthening relations with countries in the region.

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Introduction and Background[1]

Mexico, the countries of the Caribbean, and Central America examined in the Phase I report are at risk from the impacts of climate change in the next 20 years because they will be exposed to a greater range of climate changes and have a relatively weak adaptive capacity when compared to the world at large. Within the region, climate change is evident in increased temperatures, changes in precipitation, and sea level rise—and perhaps in weather variability and natural disaster events. Countries considered for the Phase I effort included Belize, Cuba, the Dominican Republic, Guatemala, Haiti, Honduras, Mexico, Nicaragua, and Panama; Puerto Rico was also discussed.

Steady increases within the region in the number of extreme weather events—hurricanes, storms, and droughts—and their effect on infrastructure, public health, loss of human life and agriculture may be attributable to climate change. The countries reviewed do not yet have a full understanding of the potential impacts of future climatic changes and are not prepared to prevent or reduce those impacts.

Regional leaders are aware of these challenges and have begun to make commitments and agreements that will enhance their understanding of future climate change, their own adaptive capacity, and where critical changes and investments need to be made. Leaders have not addressed the problem from a preventive perspective through policy changes or infrastructure investments because of a lack of systematic analysis that quantifies and qualifies the potential impact to the region, allowing the development of relevant and economically viable options. At present the region is still responding to climate change in a reactive manner.

- Regional leaders realize that leaving the situation "as is" will exacerbate their fragile economies, resources, and adaptive capacity but lack strategic plans to address the issue.
- Most countries in the region are signatories to many multilateral environmental agreements but are only now beginning to implement such agreements.
- There are significant gaps in the ability to fully understand in a systemic way all the dimensions of climate change impacts at the economic, social, and/or environmental level in the region. There are gaps and deficiencies in data, systematic methodologies/analysis, and tools to monitor, share, and track information and events at the local, national, and regional levels.

Efforts are starting to reduce systemic knowledge gaps. There is insufficient funding by regional governments to undertake detailed modeling that would result in information to rank and evaluate the financial viability of potential climate change adaptation projects. Several entities at the national and regional levels are working to develop improved analytical methods and information sharing as well as better data and data availability.

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[1] This section is extracted from the Executive Summary of the Phase I report (see Scope Note): ***Mexico, Central America, and the Caribbean: Impact of Climate Change to 2030, A Commissioned Research Report*** (NIC 2009-11), of November 2009. Some of the judgments in this report (Phase II) may differ from the Phase I report.

- In September 2008, the Economic Commission for Latin America and the Caribbean (ECLAC) announced that it would undertake multiple studies to review how climate change is affecting regional economies. Currently, the ECLAC consensus is that climate change is likely to impose serious economic consequences for the Central American and Caribbean regions, making it increasingly difficult to respond to the challenges of poverty reduction, higher human development, and environmental sustainability linked to the attainment of the United Nations Millennium Development Goals.
- Upcoming studies by the ECLAC are expected to contribute to a better understanding of the economic impact of climate change in the region and will outline the costs and benefits of needed related policy responses, both in terms of mitigation and adaptation.

In the Phase I report, information available for a selected set of Mexico, Caribbean, and Central American countries was reviewed to start understanding the projected climate change variability, given certain scenarios to 2030, as well as to start an initial assessment of these countries' current adaptive capacity to reduce such effects.

Very limited modeling and analysis are available for the countries of interest. Because of that, this initial analysis draws heavily on the respective governments' First National Communication to the Conference of the Parties of the United Nations Framework Convention on Climate Change (UNFCCC). These reports to the UNFCCC offer the most comprehensive and comparable information available today. In the case of Mexico, the third communication to the UNFCCC was used to review summary impacts. This report, however, was primarily focused on improving inventories of greenhouse gases across all types and production of energy as well as the greenhouse gases generated by major economic activity.

This review identifies the following high-priority risks:

- *Energy*. Energy resources, production, and use vary widely across the countries under review. As all the countries experience population growth, economic growth, and industrialization, they will increase their need and demand for energy. All the countries under review rely on imported fossil fuels, with the exception of Mexico, which is a net exporter of energy resources. In most of the countries, the largest generator of greenhouse gases is the energy sector. Although they are very small contributors to global emissions, most of the countries will receive economic benefits from increasing use of renewable energy. Most have begun efforts to evaluate and implement small renewable energy projects, such as solar energy in rural areas of El Salvador, wind energy in Nicaragua and Costa Rica, and an intensive effort in the Dominican Republic to evaluate hydro-generated electricity.
- *Agriculture*. The agricultural sector climate-related research for most of the countries in this review is limited. Where research is available, productivity losses are projected for optimistic, moderate, and pessimistic scenarios for some key food crops with estimates that vary from 10 percent to more than 50 percent degradation by the year 2030.
- *Water Resources*. The majority of the population in most of the countries in the review lives in coastal areas, which are highly vulnerable to severe climate changes. As populations

continue to grow in the same areas, increasing water extraction and rising sea levels are expected to have severe impacts on the quantity and quality of water available. Many of these countries' aquifers are open to ocean waters and are already experiencing increased salinity. Rising sea levels will accelerate the deterioration of aquifers and available water resources.

- *Migration.* In Central America, an increase in intra-regional migration during the 1980s and 1990s as well as extra-regional migration was the result of social unrest and economic contraction. Future patterns of migration are not expected to change significantly. Moreover, the inability of countries in the region to adapt and recover from severe climate events with major impacts on their economies will continue to promote migration outside the region, in particular to the United States and Canada. The large number of immigrants coming to the United States in the past 20-25 years will facilitate this movement.

Most of the countries under review have submitted their First Communication to the UNFCCC; Mexico has submitted its third. Significant work and analysis needs to be done to fully capture the impact on socio-economic systems and their current ability to recover, adapt, and reduce the effects of climate change.

The great variation of information available for each country reduces the ability to compare the full set of key indicators across all countries in a consistent manner.

Social, Political, and Economic Challenges

The projected primary effects of climate change in Mexico, Central America and the Caribbean include rising temperatures, rising sea levels, increased rainfall in some places, drought in others, and a greater frequency of extreme weather events such as hurricanes, floods, and heat waves. Projected secondary effects include the emergence or re-emergence of infectious diseases, shifting geographic ranges of crops for consumption and export, saltwater contamination of aquifers, and changes to animal habitats and biodiversity, among others.

In the short term, the extent to which these factors may exacerbate social tensions regarding control over and use of natural resources, provoke population movement within and from states, contribute to food scarcity, or lead to pandemic outbreaks will depend on the ability of governments and civil society groups in the affected states to prepare for and respond to emergencies, adapt to geographic and social changes, and develop ways to cooperate and communicate with international partners in emergency situations. In the long term, strengthening policies to contain states' contributions to further global warming through the emission of green house gases and deforestation will be essential.

Meteorological Challenges

Climate experts project that extreme weather events due to higher ocean water and air temperatures, including more frequent hurricanes, increased rainfall, droughts, and heat waves will characterize the effects of climate change in Mexico, Central America, and the Caribbean. Beyond loss of life and economic impacts, extreme weather events can displace people and create the conditions for disease outbreaks. In the Americas, the states that border the Caribbean and Gulf of Mexico bear the brunt of hurricane action.

- In 2008, Hurricane Ike devastated parts of Cuba, Haiti, and Jamaica. Heavy rains in the eastern Mexican state of Tabasco in 2007 covered at least 80 percent of the state with water, provoked a national emergency declaration, and dislocated at least 20,000 people.
- In 2007, Hurricane Felix, a category 5 storm, made landfall on the Nicaraguan Coast. Storms of this intensity could be the norm for future storms.
- In 1998, Hurricane Mitch, the second worst Atlantic hurricane on record, not only destroyed roads and bridges in Honduras, Nicaragua, and Costa Rica but also wreaked havoc in the Caribbean and Mexico. At least 11,000 people are believed to have died, and Mitch is estimated to have caused six billion dollars in damage. Outbreaks of cholera, acute respiratory infections, and dengue fever were also reported.

Mexico and Cuba appear to have the greatest state-level capacity when it comes to emergency preparedness. When Hurricane Mitch hit Central America in 1998, both states responded by sending personnel to help with rescue and reconstruction efforts. In both settings, the armed forces played a role in managing emergency response. Mexico has also engaged in emergency preparedness exercises with the United States and Canada through the former Security and Prosperity Partnership and in the context of the Global Health Security Action Group. However, the smaller Caribbean and Central American states seem to be less prepared to respond to emergencies and extreme weather events domestically; for example, Haiti is heavily reliant on external support for hurricane and flood recovery.

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Agricultural Challenges
Mexico, Central American, and Caribbean states have economies with significant agricultural sectors. In many of the states selected for this review, the agricultural land use vis-à-vis total land area varies widely. In 2005, Belize agricultural land was 6 percent of the total land area, reflecting the fact that over 50 percent of GDP comes from the services industry, particularly tourism, compared to Dominican Republic where agricultural land was 70 percent, Costa Rica and Haiti 57 percent, Cuba 60 percent and Mexico 55 percent of total land area. In the past 27 years, all of the states reviewed have maintained relatively stable ratios of agricultural land use to total land area.

The conversion of forests to agricultural use is likely to continue; however, the general projected drying trend in the area is likely to limit the types of viable agricultural crops. Although projected temperature changes may not differ much by season, changes in rainfall will likely lead to extended periods of drought and possible loss of soil fertility during the peak growing season in June, July, and August.

- Projections for productivity losses in Cuba range from 10 to 15 percent for rice, cassava, and corn; five to 10 percent for sugar cane; and 40 to 45 percent for potatoes.
- Coffee production in Veracruz, Mexico is likely to drop over 30 percent by 2020, degrading its economic value to the region.

Projections for other states in the region are similar, though they vary by state and study. Further, the rise in CO_2 levels could result in a fertilizing effect with crops having shorter growing cycles. The salinization of ground water supplies due to climate change and sea-level rise may also threaten agricultural productivity.

Many Central American and Caribbean states have major fishing industries. Climate change is likely to lead to changes in migration patterns and depth of fish stocks with possible negative effects on the fishing industry.

Mexico, the Central American states, and the Dominican Republic are engaged in free trade agreements with the United States, and some of the Caribbean states have established trade pacts with the European Union. These agreements regarding the flow of goods, including agricultural products and foodstuffs, may reduce some populations' reliance on locally grown crops. However, climate change is likely to negatively affect the fortunes of subsistence farmers, such as those in Mexico, Haiti, Guatemala, who are not engaged in commercial agricultural activities.

Coastal and Maritime Challenges
Climate change scenarios project that sea levels will rise, a phenomenon which could be a significant factor for the Caribbean islands and for coastal communities in Mexico and Central America. Sea level rise has the potential to create economic losses for coastal populations, particularly ports that could not only experience population dislocations but also shifts in commercial traffic.

The small islands of the Caribbean will probably experience a warming over the next century that may be somewhat smaller than the global annual mean warming. Projections for temperature increases in the Caribbean at the end of the 21^{st} century range from 1.4 ºC to 3.2 ºC with a median of 2.0 ºC. This level of warming is still likely to lead to significant sea level rise, deterioration of coastal areas and erosion of beaches, and increased invasion of non-native species, while reduced water resources could lead to an inadequacy of fresh water to meet demand during low rainfall periods. The amount of sea level rise is not likely to be uniform due to geographical differences in the islands. Extensive geographical, topographical, ecological, sociological, and population density information, gathered into a detailed geographic information system (GIS), is required before predictions are possible.

A rise in sea levels could also aggregate social tensions in many of the regional states. European or mestizo settlers have traditionally pushed indigenous populations in Mexico and Central America away from the most productive land to coastal areas or mountainous zones. Were sea level rise to provoke population movement, settled indigenous populations could experience further pressure from dislocated populations to move toward even less productive soil. This could further intensify emigration from marginal communities, creating conditions in which men migrate to more lucrative areas to seek access to land or income, while women and children bear the responsibility of maintaining the household and become vulnerable to further land-grabbing efforts.

Having suffered centuries of racial discrimination, often at the hands of state officials, socially marginal communities, including indigenous populations and those of African descent, may be cautious about official efforts to relocate them or mediate conflicts among communities. This is certainly the case in Mexico and Guatemala and most likely holds true for some Caribbean communities, as well. Collective action focused on the needs of indigenous peoples has characterized political movements in both states, although the extent to which such movements might gather greater support in the future is unclear.

Hydrologic Challenges

Depletion of aquifers and reduced rainfall in some areas will contribute to water scarcity, which may intensify community vulnerabilities to water-related diseases and exacerbate social tensions over access to water for agriculture and domestic uses. In Mexico, conflicts over water use have created tensions in local communities throughout the state, provoking marches, blockades, and efforts to take over institutions.

Mexico City is experiencing severe water scarcity and aquifer depletion. The city already sits on drained lakes, exacerbating infrastructure vulnerable to seismic activity. With a population of more than 20 million, the city must pump water from great distances and has had to ration water at least three times in 2009. Informal urban settlements rarely count on regular water service, and residents of such neighborhoods may have even more restricted access to water with rationing in effect. Irregular supply limits users' access to water for hygienic purposes and can lead to contamination when pipes are not flushed out on a regular basis.

Water scarcity can lead to tensions between states as well. It has already created conflicts between Mexico and the United States over the Rio Grande, as well as Mexico and Guatemala over the Usumacinta River. Most of the states in Central America share some form of water boundary, suggesting that measures must be put in place to resolve conflicts at state and community levels.

Demographic and Public Health Challenges

Mexico, Central America, and the Caribbean states all continue to experience population growth, albeit at somewhat different rates, leading to an increase in food demand. Most of the states in these regions depend greatly on agricultural production. Variations in crop yields, food crops, and cash crops present major challenges.

Increased rainfall, sea level rise, drought, and extreme weather events may provoke populations to migrate to more suitable habitats. The arrival of environmental migrants to existing settlements may provoke tensions with local populations and competition over scarce resources. Migration may also lead to the separation of families, with males leaving home to seek income-generating opportunities, placing the burden of household maintenance on women and older children.

Rising temperatures, increased rainfall, and the movement of populations into new areas may exacerbate or contribute to the emergence (or re-emergence) of infectious diseases, including diarrheal disease and acute respiratory disease, as well as vector-borne diseases such as dengue fever, malaria, leptospirosis, and Chagas disease.

- Since 1990 the region has experienced a series of re-emerging diseases following severe climatic events such as floods, hurricanes, and droughts.
- There is evidence of increases in several communicable diseases, such as dengue, malaria, and Hantavirus pulmonary syndrome; and the reemergence of a large host of infectious diseases following years in which there were El Niño/Southern Oscillation (ENSO) events.

While Mexico, Costa Rica, and Cuba have relatively strong health systems, many of the Central American and Caribbean states' health systems are weaker. The migration of health professionals from Mexico, the Caribbean, and Central America to the United States and Canada, and the fact that so many people do not have access to health care, creates vulnerabilities. Health systems in the region are already burdened by the increasing toll of chronic disease and will need to develop tools to anticipate climate-related outbreaks and develop lab capacity and response to address problems.

Economic and Energy Challenges

Since 1990, the region has experienced large disparities in states' GDPs. Some low values have been the result of economic contraction coupled with political unrest, capital flight, migration of the better-educated segment of the population, and the loss of foreign investments as experienced by Guatemala, El Salvador, Nicaragua, and Haiti from the late 1970s through the 1990s. The socio-political challenges of the 1980s and increases in extreme weather events in the 1990s had adverse effects on the fragile economies of the region. Instability in the economies exacerbated by the absence of law has greatly reduced the opportunity for recovery. States such as El Salvador, Guatemala, and Nicaragua were directly affected by civil unrest and increased weather-related natural disasters, while their neighboring states had to cope with an increase in migrating population because of the difficulties associated with war and natural disasters. These same states have also been severely affected by hurricanes, floods, and tropical storms in the past two decades.

The potential for resource scarcity, especially water, to negatively affect the economies in the region is highly probable. Many states have agriculture-based economies whose potential negative impact can be assumed. However, states with growing manufacturing sectors—

Mexico, El Salvador, Costa Rica, and Guatemala—also face challenges from scarcity in addition to increased competition from China and other regions. Tourism may also decrease along with remittances from immigrant populations abroad as those regions face their own economic troubles.

The states in the region, which have mostly fossil fuel-based economies, are mostly net importers of sources for energy production. Since 1984 they have continued to increase their overall energy consumption. With the exception of Mexico, primary and secondary energy production has remained below total annual consumption. Primary energy production refers to the production of energy products or sources found in their natural states, such as wood, natural gas, bagasse, and hydroelectricity. It also includes the amount of fuel extracted and the energy consumed in the production process and the supply to energy producers and conversion. Secondary energy production includes products or sources that are the result of conversion of primary energy products such as all those derived from petroleum refining, kerosene, and diesel.

As economies grow and the process of industrialization continues, most states in the region will remain highly vulnerable to variable petroleum base supply and cost as experienced in the past few years. Mexico is the only state in the region that is a net exporter of energy resources, though this is likely to change within the next decade. Between 1990 and 2007, regional energy consumption increased 158 percent. Moreover, Costa Rica, Nicaragua, and the Dominican Republic increased consumption by about 200 percent while Panama increased by 288 percent in the same period. Energy consumption is expected to increase as population and economies continue to grow.

Energy supply composition across the states remains predominantly based on petroleum, with the exceptions of Haiti, Nicaragua, and Honduras. Interestingly, these are the three states with the lowest annual GDP growth rates within the group from 1990 to 2007. On the other hand, Costa Rica, Cuba, Panama, and the Dominican Republic, who experienced the largest annual GDP growth rates in the same period, also have the largest shares of oil-based energy supply.

With the exception of Mexico, all states are net importers of petroleum-based products. Oil-based energy supply remains significant in particular in the case of the Dominican Republic, where it accounted for 74 percent of total energy supply in 2005 and 79 percent in 2002. Island nations such as Cuba, Puerto Rico, Haiti, and the Dominican Republic remain particularly vulnerable to the supply of petroleum-based energy products, since the raw material must be brought to the islands by ship for refining and processing. The recent discovery of oil reserves off the coast of Cuba should provide some improvement, but to what extent remains unclear. Hydroenergy plays a significant role only in Costa Rica, where it accounts for 18 to 24 percent of supply; for the rest of the states it ranged from 0.1 percent in Cuba to 9.8 percent for Panama.

Civil and Key Interest Group Responses

Potential Responses

Evidence from previous post-disaster research challenges the idea that full-scaled “flight-or-fight” responses are likely for populations in most states in the region, with the notable exception of Haiti, at least as a direct response to the impacts of climate change alone. Rather than limited to “flight-or-fight,” there are a range of responses to climate change-induced hazards that may or may not be adapted at varying spatial, organizational, and temporal scales.

Innovation/Intensification/Adaptation. Historically, people and societies have been able to respond to natural hazards and human-generated alterations in the socio-ecological system by adopting innovative (innovation/adaptation) and non-innovative (intensification) changes to ensure economic survival. Adjustments to living and livelihood patterns can stress people and governments but probably significantly less than the alternatives that follow below. Adjustments will be geared toward relevant stressors in the different states under consideration and can range from wholesale agricultural alterations in the crop or techniques to improve construction of buildings to withstand extreme climatic conditions. Hurricanes and other storms demand technological adjustments, while slower-acting change processes such as warming or changes in precipitation may respond well to modifications of existing production techniques. These adjustments are most likely the least socially, economically, and politically disruptive responses to climate change and will be aided by strong civil society institutions due to their ability to moderate relationships between localities and regions and central governments.

Abandonment/Migration. Many people in the region currently use temporary or permanent migration as a coping mechanism for socio-economic stressors brought on by economic or political hardship and occasionally by climate related phenomena. Large groups of people have previously relocated due to changes in resource availability, among other reasons. In worst-case scenarios, large-scale migration might occur out of areas and perhaps across international borders. This migration could place more pressure on an already stressed system and potentially lead to internal or international conflict. There are, however, many moderate migratory activities that can take place—such as rural to urban and rural to rural—all within a single country. States in the region have been urbanizing rapidly since the end of the Second World War, as has international migration. Slow-acting climate change processes may signal almost imperceptible increases in movement while faster acting change can challenge socio-ecological resilience.

New migrants, often representing the extremely poor, may pose a threat to the existing social order and potentially give rise to violent backlash. Criminal elements such as narcotic traffickers and smugglers often accompany migrants, exacerbating existing tensions between and within states. Recent examples of migration in the region include Haitians to the Dominican Republic; Guatemalans to Mexico and Belize; Salvadorans, Mexicans, Haitians, and Dominicans to the United States; and Nicaraguans and Panamanians to Costa Rica. Except for the 1969 Soccer War between El Salvador and Honduras, these movements resulted in muted violence, usually at the individual or occasionally community level.

Sub-state Conflict. The states in the region have varying experience with internal conflict throughout their histories. Four states—Guatemala, Nicaragua, Haiti, and Mexico—have had or currently have significant conflict-related, political ideologies fueled by drastic economic inequalities, while Honduras, Belize, and the Dominican Republic have remained relatively peaceful over the last 25 years. None of these conflicts can claim climate change as a necessary or sufficient condition for conflict. Increased resource scarcity, however, may combine synergistically with weak states and economic inequalities leading to organized insurrection. Groups already organized for conflict (though not resource conflict *per se*) include Mexico's Zapatistas (other similar movements exist across Mexico), Mexico's drug cartels, and loosely organized gangs like MS-13 in Central America.

Interstate Conflict. There exist precedents for cases of interstate conflict related to resource issues, among other reasons, and there is the potential for more to occur especially as migration and intra-state conflict stress developing-state governments. In the region of Mexico, Central

America, and the Caribbean, four major drivers of resource scarcity could lead to increased interstate violence: Agricultural land loss or degradation, forest loss and degradation, fresh water depletion or pollution, and fisheries depletion.

Adaptive Capacity

Most estimates of vulnerability rely on easily attainable statistics—economic capacity, human capital, and environmental capacity—that ignore less quantifiable but important factors on how human-natural systems interrelate, namely social interaction. Such estimates fail to recognize the enormous adaptive capacity most societies possess under the right social conditions.

At the local level, adaptation may result from individual or group innovation but appears unlikely to be widespread without governmental and civil society cooperation. Civil society in the region has a long, if uneven history. States like Mexico possess robust civil society organizations such as the Catholic Church, environmental and social non-governmental organizations (NGOs), and ethnic organizations. Other states such as Guatemala are in the process of rebuilding civil society, much of which was targeted during that state's civil war. In some cases, such as Haiti, civil society may be more present in migration destinations—primarily the United States and France—due to internal problems with Haitian social and economic interactions.

It is in enhancing adaptive capacity that civil society may play its most important role. In most of the region, important state functions such as environmental management, food distribution, and health care have been ceded to civil society of a religious, environmental, or ethnic nature.

- The Mexican NGO PRONATURA, or international NGOs, manage most parks and reserves in Mexico due to the state's inability to pay for and monitor environmental conditions.
- Haitian food distribution networks are largely based on the role of the Catholic clergy and laity or the increasing number of non-Catholic, Christian organizations.
- Domestic and international NGOs in Guatemala communicate ethnic demands and concerns to the state.

Development agencies including USAID and the Inter-American Development Bank are working with states in the region to gather information and develop tool kits to help governments assess their vulnerabilities and better prepare for the physical, economic, and human toll of extreme weather events. Additionally, the Caribbean Community (CARICOM) has instituted several initiatives to bring governments and NGOs together in productive cooperation.

- The Instituto de Nutrición de Centroamérica y Panamá (INCAP), based in Guatemala, provides advice and technical support to governments working to resolve nutrition problems associated with food scarcity. Under nutrition continues to be a challenge for some populations in Mexico, Central America, and the Caribbean, even as problems related to obesity, diabetes, and cardiovascular disease are beginning to pose economic and social challenges to regional health systems.
- In the Caribbean, CARICOM representatives agreed to establish the Caribbean Public Health Agency (CARPHA) to improve disease surveillance in the region.
- Belize hosts the CARICOM Caribbean Community Climate Change Research Center, which serves as a regional repository for climate data and conducts research on the projected effects of global warming in the region. The Center also provides climate change data to member

states to help them prepare for the United Nations Framework Convention on Climate Change (UNFCC) Conference of Parties in Copenhagen in December of 2009. Given that the states in the region do not significantly contribute to global warming, the Center provides considerable economic data charting the effects of warming on states' economies and the projected effects.

- The Caribbean Environmental Health Institute (CEHI), a CARICOM entity based in St. Lucia, provides technical assistance on water safety plans and on water-related climate planning throughout the region.
- A partnership involving the Pan American Health Organization, the International Water Association, and the Asociación Inter-Americano de Ingenieros Sanitarios (AIDIS) is introducing states to water safety to facilitate water quality planning at the catchment level, with experts from Honduras, Mexico, and Jamaica playing key roles in the organization.

In addition, the goals of many civil society organizations focus on capacity building at the local level. Knowledge dissemination (education) and production (research) carried out locally promises to enhance adaptive capacity through increased recognition of problems associated with climate change, alternative economic activities, and ability to communicate with the government when problems arise. This capacity building can be aided by international cooperation with international NGOs, government agencies, and private enterprise from the United States and elsewhere.

In those states with high levels of political pluralism, civil liberties, and participation (Panama, Mexico), civil society has the potential to play a positive role in mitigating the impacts of climate change. Weaker democracies, such as Guatemala, Nicaragua, and El Salvador, or Honduras, continue to strive to recover from civil war or natural disaster. It is difficult to predict how strongly centralized states (Cuba) or chronically disorganized states (Haiti) will be able to adapt to the predicted changes associated with climate change. Should adaptive capacities fail to meet the needs of climatic challenges, large-scale flight is likely with the United States and Mexico bearing the largest immigration burdens. In the case of Haiti, this is a near certainty.

State Responses

The region of Mexico, Central America, and the Caribbean lags most other major regions as an emitter of greenhouse gases that are believed to contribute to global warming, yet it is on the frontlines of the potential consequences, including mega-storms, droughts, and impacts on agriculture, eco-systems, and epidemiology. This blunt disparity is even greater for the small and micro-economies that make up most of Central America and the Caribbean. The region's relative paralysis and reactive approach to climate change may be driven primarily by other demands for their scarce resources, and a recognition that limiting carbon emissions within the region will barely impact the overall trajectory of global climate change.

Any effective effort to combat the host of climatic threats to the region must overcome other challenges in the region to include weak institutions, inadequate or deteriorating infrastructure, pollution, unmanaged deforestation, high levels of poverty, overcrowding of urban areas, and inefficient means of agricultural production. If fishermen and subsistence farmers are unable to earn a living through traditional activities because of global warming, they will need to learn new ways of generating income to support their families. It will be important for governments and development agencies to help such populations identify alternative livelihoods.

International Efforts
It is currently unclear how effective regional and international bodies can be, though several exist in many of the states in question. In many cases, state governments have partnered with international NGOs as a means of interstate cooperation and coordination.

- Health Ministers cooperate through the Sistema de Integración de Centroamérica (SICA) and CARICOM, and health is a recurrent theme at the Summits of the Americas.
- For the Caribbean states, participation in the United Nations Small Island Developing States Network has enabled some governments to gather information about the projected effects of sea level rise and to anticipate the changes that will affect their territories. Through their involvement in CARICOM processes, governments in the Caribbean participate in regional discussions about climate change preparedness and adaptation.
- Mexico, along with Canada and the United States, is a member of the Global Health Security Action Group (GHSAG) and has worked with Canada and the United States to develop mutual assistance protocols in the event of a public health emergency.

States in the region have also undertaken their own initiatives alone and in conjunction with neighbors.

- In 2008, Mexico's President Felipe Calderón proposed the establishment of a global "Green Fund" to provide support to states seeking to develop their capacities to adapt to climate change scenarios.
- In 2004, Mexico hosted the fourth World Water Forum, making a special effort to highlight water issues in the region.
- Mexico and Guatemala established an International Commission on Limits and Waters in 1961 that may serve as an example to others.

Mexico and Cuba have the greatest potential to play a global leadership role in combating climate change, although the small-island states of the English-speaking Caribbean may be galvanized to collective action and use their disproportionate vulnerability to climate change to help shape the debate. While most of the states in this region may lack the institutional mechanisms to effectively address the threats posed by climate change, Mexico can credibly claim sufficient resources to do so. Cuba, meanwhile, has thus far demonstrated great institutional capacity to deal with near-term threats such as hurricanes but is otherwise subject to similar constraints as its neighboring states.

Cuba and Haiti
Cuba and Haiti offer good case studies for the region. Both are post-revolutionary, low-technology, and low-income societies. Cuba has a highly centralized sociopolitical structure, formed mostly around the military, while Haiti is highly decentralized. These two cases highlight the range of state capacity for much of the region.

Cuba has a well-structured system of research programs that covers a wide variety of problems focused on understanding the economic, technical, intellectual, and cultural development of the state. The country has the capacity to mobilize its population in advance of hurricanes that periodically strike the island. The Cuban military is the organizational core of the state, marshaling human and political capital through its networks. Its one million-strong *Milicia Territorial* is in charge of natural disasters and has operated with amazing efficiency, as is evident from the extremely low human toll during the most severe storms. In 2004, two hurricanes (Charley and Ivan) and a prolonged drought caused $3 billion in losses, 33 percent more than the earnings from tourism that year, and with virtually no loss of life.

Despite these strengths, Cuba lacks any significant capacity to recover from storm damage. Reasons for this include:

- Cuba has been unable to generate sufficient internal resources to invest for a sustained recovery.
- Cuba's international credit-worthiness is poor; there is limited access to external credits and loans.
- It is impossible to restrict consumption further to divert resources to investment as consumption is already depressed.
- The enterprise management reform process (*perfeccionamiento empresarial*) is new and very slow in implementation and therefore the central control of enterprises and government functions remains.
- Political and social structural impacts hamper reconstructive efforts such as the decline in real wages, increase in disguised unemployment, steeper income stratification, and resource and wealth hoarded by the elites.

Worrying demographic trends further hamper Cuba's ability to address recovery and development issues. Cuba's population is declining due to low fertility, out-migration, and a dramatically aging population. Migratory trends have drastically altered the ethnic makeup of Cuba—70 percent of the Cuban population is black, mostly of Jamaican origin, up from 30 percent 60 years ago, and migration into the cities has resulted in extreme over crowding. Havana, which represents 0.67 percent of the nation's land mass, comprises 25 percent of the nation's population.

Haiti, on the other hand, is already a failed state, and faces an ecological crisis. There is virtually no state presence outside of Port-au-Prince, where 90 percent of all government employees live and work, leaving the rest of the country in the hands of non-governmental organizations. The Haitian government is among the weakest in the world in terms of providing essential public services.

Both the Haitian and Cuban cases contain lessons for states attempting to contend with the deleterious effects of climate change:

- Excessive state control and centralization of decisionmaking such as exists in Cuba might well work to prepare the populace in the face of natural disasters, but proves much less efficient in helping that state recover from the damages caused by those disasters.
- Complete decentralization and minimal state involvement, as in Haiti, neither prepares the populace nor has the capacity to recover after the storms.

Regional Implications

Should the societies in question fail to properly adapt to climate change, increased migration and competition for scarce resources may raise tensions between neighboring states to the point of conflict. Civil conflicts are more likely than state-on-state violence, though some conflicts may straddle this divide. Of the potential areas of future conflict exacerbated by the effects of climate change, three merit special attention:

The Dominican Republic and Haiti. There are multiple signs that the future trajectory of this relationship is unsustainable with the potential for an escalation in violence. Vastly different levels of development (with per capita GDP estimated at $8,100 versus $1,300 in 2008 in purchasing power parity terms), explosive population growth, unfettered out-migration from Haiti to the Dominican Republic, and deepening racial and cultural tensions all raise the risk of violent conflict. This could take the form of civil unrest in Haiti or actions taken against Haitians by the Dominican military. The fact that Hispaniola sits in a major storm path also raises the possibility of hurricane-induced catastrophe affecting one or both nations.

The Guatemala-Honduras-Nicaragua Zone of Instability. Although not as dire as the situation on Hispaniola, the Guatemala-Honduras-Nicaragua axis poses another regional flashpoint for many of the same reasons. The three states will likely experience rapid population growth against the backdrop of comparatively low levels of development (respectively $5,200, $4,400, and $2,900 in 2008 per capita GDP, figures which contrast sharply with Mexico at $14,200, and are lower than Belize at $8,600, and El Salvador at $6,200). Given the low adaptive capacity generally assessed for these states, and the projected population growth, extensive out-migration from Belize may combine with pressures on Mexico's southern border to provoke conflict. The relative exposure of Honduras and Nicaragua to powerful Caribbean storms further heightens the potential for disruption.

The US-Mexican Border. **Increases in the frequency and scale of natural disasters caused from climate change could have a threat multiplier effect on immigration to the United States. US immigration is principally rooted in issues of economic deprivation and disparity.** If certain areas of Mexico, Central America, and the Caribbean become uninhabitable—either due to rising sea levels and temperatures, or because traditional agricultural and water resources cannot be sustained—then pressure on the US-Mexican border will increase. The potential for new climate-related epidemics may also affect the prerogatives for border security. The US-Mexican border may emerge as a future flashpoint, not as an area directly affected by climate change, but rather as a force to contend with the intensified migratory patterns that result.

Overall Foreign Policy Implications

The region's relative impotence in shaping the future trajectory of global climate change, coupled with the likelihood that it will bear the brunt of some of the most severe repercussions, will likely exacerbate several troubling tendencies in the region's politics. In Central America and the Caribbean, these include populist measures to control domestic natural resources, greater suspicion and skepticism towards the United States, Europe, and traditionally dominant powers, and greater orientation towards powerful southern neighbors such as Brazil and Venezuela. Insofar as the predicted rapid growth of China and India contribute to high levels of carbon emissions, this may lead to a diminution of these states' relative authority and popularity.

If Mexico ceases to be a net oil exporter and does not harness the economic potential of new technologies, then it may falter as a regional force as well. This may result in Mexico, Central America, and the Caribbean becoming increasingly inward looking, consumed by internal problems, and remaining at the margins of global action on climate change.

In relations with the United States they will remain vigilant. The United States is the single greatest determinant of change in the region—from water division issues with Mexico to political hegemony and aid support. If the United States seeks collaborative and effective regional mechanisms to jointly manage the challenges of climate change, this may provide a new opportunity for strengthening relations.

The implications for US foreign policy are great:

- Providing ever-increasing humanitarian assistance to neighbors in need.
- Avoiding catastrophic waves of refugees.
- Avoiding the need to intervene militarily as so often done in the Caribbean.
- Gathering goodwill in this area of scientific expertise, goodwill that should be advantageous in serving other US geopolitical and national security purposes.

Cuba represents a potential US partner once Fidel Castro is no longer in power. Cuban doctors have lived and worked throughout the region, creating a goodwill network along with bolstering the local medical systems. Cuba's medical and pharmaceutical resources in the region are second only to the United States, and already well in place. The United States could partner with Cuba in the creation of a rapid deployment humanitarian force, using Cuban resources and US funds. The first step would be direct talks between the US and Cuban militaries, as the Cuban military is the most organized force in the state and has access to US forces through proximity at the Guantanamo Naval Base.

Additionally, the United States should partner with Mexico to contain carbon emissions and directly address climate change challenges. Having established relationships and plans in place will be essential in dealing with whatever is to come.

Climate Change Negotiations

In approaching climate change negotiations with Mexico, Central American, and the Caribbean states, the United States needs to bear in mind that in many cases governments in the region may lack the capacity or will to deliver on their policy promises. Moreover, with the exception of Mexico, most of the states in question are not significant greenhouse gas emitters. Belize is even a net remover of greenhouse gasses. Although the states of the region may readily sign on to a climate change agreement, their ability to affect global climate change is limited.

Mexico, along with India, China, and Brazil, feels that it represents the interests of the developing world. Mexico has the ability to take a global leadership position on climate change, more so than with its regional neighbors. It may sign a climate change agreement but likely will be unable to enforce it effectively.

This paper does not represent US Government views.

CONFERENCE REPORT

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