Impacts of Human-Induced Climate Change on Kazakhstan, the Philippines, and India

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I. INTRODUCTION

Global climate change has profound implications for all spheres of economic activity and for ecosystem stability. It has impacts on agriculture, forestry, fisheries, human health, coastal areas, and all terrestrial and aquatic ecosystems. Its importance has been acknowledged through international dialogue at the highest level through the United Nations Framework Convention on Climate Change and the recent negotiation of the Kyoto Protocol.

In 1990, USAID began to explicitly address the issue of global climate change. Prior to this point, the Agency's efforts to promote energy efficiency, sustainable forestry, and the conservation of biodiversity, though not specifically targeted at addressing global climate change, had direct impacts on greenhouse gas emissions. Since 1990, USAID has addressed global climate change both through reducing the sources and increasing or preserving the sinks for greenhouse gases.[1] The former is represented by its efforts to reduce emissions of greenhouse gases from the energy sector and the latter by efforts to increase the removal of atmospheric carbon by forests (USAID 1998).

In June 1997, President Clinton announced that the United States would make available at least $1 billion to assist developing countries and countries in transition diminish the danger of climate change. Through its Climate Change Initiative, USAID will implement the President's commitment to helping developing and transition countries address global climate change. The three areas of emphasis of this initiative will involve 1) decreasing the rate of growth in net emissions, 2) increasing developing and transition country participation in the goals of the United Nations Framework Convention on Climate Change (UNFCCC), and 3) decreasing the vulnerability of developing and transition countries to the threats posed by climate change.

This report aims to support the third area of emphasis of the initiative, reducing the vulnerability of developing and transition countries to climate change. Assessing this vulnerability is clearly a critical first step. Indeed, the initiative explicitly states that one of the new areas of emphasis, which will emerge as the initiative progresses, will involve "analyzing the specific regional and local vulnerabilities climate change poses." This document supports Agency efforts in this area by discussing the impacts of climate change on Kazakhstan, the Philippines, and India. These countries were chosen because they are considered "key countries" by USAID and country-specific vulnerability literature was available at the time of writing. This report is based on the currently existing literature on country-specific vulnerability assessments and does not speculate on local vulnerabilities based on broad global predictions.

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability as involving both the initial impacts of climate change upon a given system (e.g., coastal zones) and the ability of the system to adapt to these impacts (e.g., erecting barriers against sea level rise). A discussion of the ability of the various countries to adapt to the impacts of climate change is beyond the scope of this report.

The climate change impact assessments for the three countries are intended to be independent sections. Each assessment is divided into sectors such as agriculture, coastal zones, and livestock.

[1] Sinks refer to those parts of the global carbon system that remove carbon from the system (e.g., forests).

The choice of sectors for each of the countries reflects the state of knowledge as of this writing. No attempt is made to analyze the discrepancies between the predictions of different climate models. Such an exercise would require a detailed technical discussion of climate modeling that would be beyond the scope of the report. This report aims to provide the latest information on the impacts of climate change and is intended to be accessible to a broad audience.

Predicting the impacts of climate change on a national scale is a challenging task. The complexities involved in first modeling the changes in climate and then the effects of these changes on various sectors leads to predictions with a wide degree of variation. However, it is important that policy-makers know the range of possible impacts and appreciate the scientific uncertainty of the predictions. This will enable them to plan development interventions for a range of possible contingencies and recognize the areas in which the support of future research is warranted. The primary audience for these assessments is mission officers involved with the issue of climate change and the USAID Climate Change Team. However, others concerned with the impacts of climate change in the countries targeted will also find the report useful for the reasons mentioned above.

II. KAZAKHSTAN

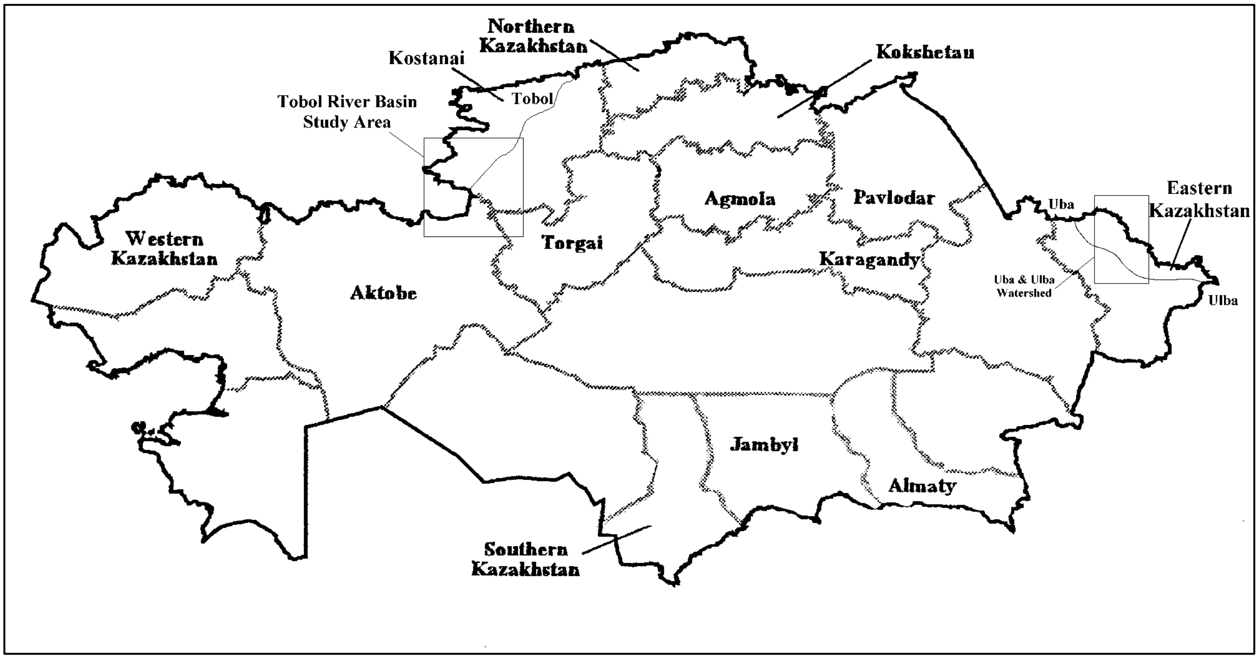

Figure 1: Map of Kazakhstan Highlighting Oblasts and River Basins Mentioned
Source: Adapted from Lenhart et al. 1996

Physical Features and Climate

Kazakhstan is located in Central Asia, northwest of China. Its land mass of 2,669,800 km^2 makes it the ninth largest country in the world. The hilly uplands in central Kazakhstan divide the northern belt of steppes from the deserts and semi-arid areas in the south. The west is dominated by the lowlands of the Caspian depression, in sharp contrast to the high mountain ranges along the south and southeastern borders. Water resources are more plentiful in the north than in the drier south of the country.

Northern Kazakhstan has numerous lakes and the large river systems of the Ural and the Emba in the west, which drain into the Caspian Sea, and the Irtysh River, which originates in the northeast and flows northwards to Russia. The only major river in the south is the Syr-Dar'ya which rises in Kyrgyzstan and, in the past, emptied into the Aral Sea.[2] The south is not only drier but also warmer than the north.

The climate of Kazakhstan is strongly continental with hot summers and cold winters. The north is colder with average temperatures in January of –18 ºC, compared to –3 ºC in the south. In

[2] The waters of the Syr-Dar'ya and Amu-Dar'ya Rivers were excessively used for irrigation in the 1960's leading to the drying of the Aral Sea, which, by the early 1990s, had lost one-third of its original area.

July, the average temperature in the north is 19 ºC and between 28 and 30 ºC in the south. Precipitation varies greatly with as much as 1,600 mm in the mountains, 250 mm in the north, and less than 100 mm in the deserts.

This brief review of the topographical and climatic variation provides a framework upon which to consider the effects of climate change upon specific economic activities and ecosystems. The assessment of the impacts of global climate change will cover agriculture, grasslands, livestock, and water resources. More sector-specific background information is provided in the sections themselves. This report on Kazakhstan draws upon the 1996 "Climate Change Vulnerability and Adaptation Assessment in Kazakhstan" (United States Country Studies Program/Republic of Kazakhstan).[3]

Agriculture

Wheat is produced mainly in the semi-arid and arid steppe zones of the country. The semi-arid steppe zone includes northern Kazakhstan, the major part of the Kokshetau oblast, and the northern areas of the Aqmola and Pavlodar oblasts (see figure 1).[4] The arid steppe zone is found in the northern areas of West Kazakhstan; the oblasts of Aktobe and Torgai; and most of Kostanai, Aqmola, Pavlodar, and Karagandy oblasts. Most of the wheat grown in Kazakhstan is spring wheat which is grown in north Kazakhstan. Spring wheat is sown in the spring and harvested in the late summer and early fall. A small quantity of winter wheat, which is sown in the fall and harvested in summer, is also grown. In 1997, Kazakhstan produced 8,954,950 metric tons of wheat, representing 1.5 percent of global production. Future wheat production can be predicted using a model which incorporates, among other factors, climatic conditions.

The CERES–Wheat model was used to determine future wheat yields using climate predictions from three General Circulation Models (GCMs).[5] Of these, two were equilibrium models and the third a transient model. The two equilibrium models used were the Canadian Climate Center Model (CCCM) and that of the Geophysical Fluid Dynamics Laboratory (GFDL-R30 or GFDL for short); the transient model used was a transient version of the GFDL, abbreviated as GFDL-T. The equilibrium GFDL and CCCM models provide long-term predictions (2075), whereas the

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[3] Please refer to this document for all methodological and other details on climate modeling and sector vulnerability assessments. A forestry assessment was also carried out. However, there were significant differences between the forest distribution obtained from the forest simulation models and the actual forest distribution. Thus, due to the absence of reliable data, the determination of the vulnerability of the forest sector is not possible at this point in time.

[4] An oblast is a large administrative unit in Kazakhstan.

[5] CERES is the "Crop Estimation through Resources and Environmental Synthesis," version 3, as incorporated into the "Decision Support System for Agrotechnology Transfer" (DSSAT) software. The KazNIIMOSK model was also used to predict future wheat yields, but it does not take into account the direct effect of the increase in concentration of CO_2 (sometimes referred to as the "CO_2 fertilization effect").

GFDL-T provides short-term predictions (2030).[6] Future yield predictions were made for both spring and winter wheat.

The near-term predictions of spring wheat yield showed similar levels of decline for the climate predictions from both the GFDL and CCCM models. The respective values were –27 and –26 percent.[7] For the long term, the change in spring wheat yield was opposite, with a 31 percent *increase* under the GFDL-T climate model. Winter wheat yield is projected to increase by 21 percent, but only 1 percent of the cropped area is suitable for winter wheat (Pilifosova 1998).

Grasslands

The deserts of Kazakhstan are bounded by latitude 44° to 48° north and longitude 47° to 83° east and are used to graze small cattle. Their forage productivity varies from 0.2–0.3 to 0.5–0.7 Tonnes/hectare (T/ha) in dry weight. The vegetation is dominated by perennial brushes, low brushes, and subshrubs. As with agricultural crops, the growth of various species of grassland vegetation can be modeled to predict future growth patterns. Combining a model which predicts grassland growth with climate information from GCMs makes it possible to predict the growth of grasslands vegetation under different climate scenarios.

A model developed at the KazNIIMOSK institute was used with inputs from meteorological data and climate models to predict the biomass of grasslands vegetation under different climate models.[8] The data from the GFDL and CCCM climate models indicate that temperatures are generally warmer during the period of active growth of vegetation. In the first 30 to 40 days of growth, the temperatures are above current values by a maximum of 1–2 °C; this rises to 4–7 °C and higher in the fifth month and onwards. The first two to three months are wetter and those afterwards drier than current conditions.

The grasslands have three kinds of vegetation according to their degree of adaptation to hot and dry conditions. The kinds of vegetation are as follows:

- Ombrophyts – The subshrubs of *Artemisia terrae albae* and *Agropirum sibiricum* represent this group of plants which intensively uses moisture from precipitation and condensation.

- Trihogydrophyts – This group is represented by the subshrubs *Anabasis salsae* and *Cochia prostrata* and uses precipitation and ground water.

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[6] An equilibrium model is one in which a prediction of future climate is made for a doubling of the atmospheric concentration of CO_2 over pre-industrial levels (2 X CO_2). This doubling is predicted for the year 2075. On the other hand, transient models predict future climates assuming a steady increase in the atmospheric concentration of CO_2 (usually 1 percent/year). Running GFDL-T for the seventh future decade is equivalent to the year 2030 because, by scientific convention, it is assumed that transient models begin in 1971. Thus, running it for the seventh future decade provides climate conditions for the year 2030.

[7] In the Middle East and Arid Asia chapter of the 1998 Intergovernmental Panel on Climate Change (IPCC) "The Regional Impacts of Climate Change – an Assessment of Vulnerability" document, the yield reduction is given as 60 percent (p. 244). However, this value is based on earlier data than that mentioned in the 1996 "Climate Change Vulnerability and Adaptation Assessment in Kazakhstan" document (Smith 1998).

[8] In this paper, biomass refers to aboveground biomass. Biomass is the total living mass of an organism. The unit is tonnes/hectare (a tonne is a metric ton equal to 1,000 kg) of dry weight.

- Phreatophyt – This group consists of subshrubs like *Artemisia gwinggveloba* and *Haloxylon spp.* which have a deep penetrating root system and actively use ground water.

Effects of Climate Change on Ombrophyt Vegetation

The responses to climate change of the vegetation groups in the grasslands of Kazakhstan differ depending on the climate model and age of the vegetation. The biomass of the ombrophyt *Artemisia terrae albae* is expected to remain the same or increase during the first two months of vegetation. The CCCM climate model predicts an increase that varies from 0.01 in the first month to 0.1 T/ha in the second month. The GFDL climate model predicts no increase in biomass for the first month and a 0.01 T/ha increase in the second. After the second month of vegetation, both models show decreases in the biomass.

The decreases in biomass predicted after the second month of growth vary between 0.01 and 0.03 T/ha for the CCCM model, and between 0.07 and 0.09 T/ha for the GFDL model.[9] Thus, long-term climate models predict an increase in ombrophyt biomass for the first two months, followed by an abrupt decrease beginning in the third month and continuing till the seventh and last month of growth. The short-term GFDL-T model predicts a pattern of ombrophyt biomass increase which parallels that predicted by the long-term climate models.

The GFDL-T model predicts no increase in the first month, a 0.05 T/ha increase in the second month, and decreases varying from 0.02 to 0.06 T/ha from the third to the seventh month of vegetation. The following table summarizes the changes in biomass for the ombrophyts as discussed above.

[9] For all groups of plants, no data is available for the month seven prediction of the GFDL model.

Table 1: Predicted Biomass Changes for Ombrophyt *Artemisia terrae albae* (in T/ha of dry weight compared to current biomass)

Climate Model	Age of Active Vegetation (in months)		
	1	2	2–7
CCCM	+0.01	+0.10	–(0.01 to 0.03)
GFDL	0.00	+0.01	–(0.07 to 0.09)*
GFDL-T	0.00	+0.05	–(0.02 to 0.06)

*No GFDL data for month seven.
Source: Adapted from Pilifosova et al. 1996

Effects of Climate Change on Trihogydrophyt Vegetation

Anabasis salsae is a trihogydrophyt. The CCCM climate model predicts that there will be no change in its biomass in the first month of growth, but that there will be an increase of 0.07 T/ha in the second month. Unlike the trend observed for the ombrophyts, the CCCM model predicts that the increase in biomass continues in the third and fourth months of vegetation with increases of 0.02 T/ha. The reduction in biomass starts at the fifth month and varies between 0.02 and 0.03 T/ha. The prediction of the GFDL model does not depart from the ombrophyt trend of increasing biomass up to the second month and then reductions.

The prediction of the GFDL model for trihogydrophyts is no change in biomass for the first month and an increase of 0.02 T/ha in the second month. After the second month, there are reductions in biomass that vary from 0.03 to 0.07 T/ha. The short-term changes in biomass are partially similar to those predicted by the CCCM model in that they both predict increases up to the fourth month of growth.

The increase in biomass predicted by the short-term GFDL-T model is no change in the first month, a 0.02 T/ha increase in the second, and increases of 0.05 T/ha for the third and fourth months. Following this, there is no change in biomass for the fifth and sixth months, and then a large reduction of 0.19 T/ha in the seventh month.

The data presented above for the trihogydrophyts is anomalous in that none of the models exhibit a similar pattern of predictions. The following table summarizes the changes in biomass for the trihogydrophyts as discussed above.

Table 2: Predicted Biomass Changes for Trihogydrophyt *Anabasis salsae* (in T/ha of dry weight compared to current biomass)

<table>
<tr><th rowspan="2">Climate Model</th><th colspan="6">Age of Active Vegetation (in months)</th></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td colspan="2">5–7</td></tr>
<tr><td>CCCM</td><td>0.00</td><td>+0.07</td><td>+0.02</td><td>+0.02</td><td colspan="2">–(0.02 to 0.03)</td></tr>
<tr><td>GFDL</td><td>0.00</td><td>+0.02</td><td colspan="4">3–7: –(0.03 to 0.07)*</td></tr>
<tr><td>GFDL-T</td><td>0.00</td><td>+0.02</td><td>+0.05</td><td>+0.05</td><td>5 and 6
0.00</td><td>7
–0.19</td></tr>
</table>

*No GFDL data for month seven.
Source: Adapted from Pilifosova et al. 1996

Effects of Climate Change on Phreatophyt Vegetation

Artemisia gwigveloba is a phreatophyt. The prediction of the CCCM model is for biomass increases of 0.01 and 0.10 T/ha in the first and second months of growth, respectively, and no changes after the second month. The GFDL model predicts decreases of 0.01 and 0.04 T/ha for the first and second months, respectively; an increase of 0.29 T/ha in the sixth month, and no changes in the remaining months. Thus, except for the sixth month prediction of the GFDL, both long-term models show biomass changes in the first two months and then no changes in the rest of the growing period. The short-term GFDL-T model predicts no change in the first month, a decrease of 0.02 T/ha in the second, and increases of 0.29 and 0.28 T/ha in the sixth and seventh months, respectively. The following table summarizes the predictions discussed above.

Table 3: Predicted Biomass Changes for Phreatophyt *Artemisia gwigveloba* (in T/ha of dry weight compared to current biomass)

<table>
<tr><th rowspan="2">Climate Model</th><th colspan="5">Age of Active Vegetation (in months)</th></tr>
<tr><td>1</td><td>2</td><td colspan="3">3–7</td></tr>
<tr><td>CCCM</td><td>+0.01</td><td>+0.10</td><td colspan="3">0.00</td></tr>
<tr><td rowspan="2">GFDL</td><td rowspan="2">–0.01</td><td rowspan="2">–0.04</td><td>3–5</td><td>6</td><td>7</td></tr>
<tr><td>0.00</td><td>+0.29</td><td>No data</td></tr>
<tr><td rowspan="2">GFDL-T</td><td rowspan="2">0.00</td><td rowspan="2">–0.02</td><td>3-5</td><td>6</td><td>7</td></tr>
<tr><td>0.00</td><td>+0.29</td><td>+0.28</td></tr>
</table>

Source: Adapted from Pilifosova et al. 1996

Livestock

The oblasts of Almaty, Jambyl, and South Kazakhstan contain one-third of the country's sheep livestock. The duration of hot weather conditions, which increases with climate change, adversely affects the amount of wool produced and the number of lambs born. A study was done in the three major sheep rearing oblasts using the CCCM and GFDL models to predict the effect of changing climate on sheep livestock production.

The CCCM model predicts the worst conditions for sheep rearing. In the oblasts of Almaty, Jambyl, and South Kazakhstan, wool productivity declines an average of 16 percent; and the number of lambs diminishes by an average of 11 percent. The corresponding predictions of the GFDL model are an 11 percent loss of wool productivity and a 13 percent reduction in lamb production. There is no data available for the short-term GFDL-T model. The following table presents the percentage reductions in wool productivity and lamb production in the main sheep producing oblasts.

Table 4: Percentage Losses of Wool and Lamb Production in Main Sheep Rearing Oblasts (compared to current production)

Oblast	Climate Model	Loss of Wool Productivity	Reduction in Lamb Production
Almaty	CCCM	11%	5%
	GFDL	7%	11%
Jambyl	CCCM	17%	2%
	GFDL	10%	6%
South Kazakhstan	CCCM	19%	26%
	GFDL	15%	21%

Source: Adapted from Pilifosova et al. 1996

The above table indicates that the greatest losses in sheep livestock production will be experienced in South Kazakhstan. Regarding Jambyl and Almaty, the former will experience a greater loss of wool productivity and the latter a greater loss of lamb production.

Water Resources

The mountain ranges of Altai, Sauro-Tarbagatai, Dzungaria, and Tien Shan in the east and south are the sources of the main rivers. Kazakhstan's water resources are estimated to be 121 billion m^3 or 24,000 m^3/km^2. Most of the water resources are surface water with some reserves of underground water of mixed quality. An assessment of the vulnerability of the Uba and Ulba watershed in the Altai mountains and the Tobol river basin in the plains of northern Kazakhstan provides insights into the sensitivity of Kazakhstan's water resources to climate change (see figure 1). The former is representative of rivers in Rudnii Altai and the latter of conditions in North Kazakhstan. In addition to the climate models used in the other sector assessments, the GISS climate model was also used.

The prediction of the climate models varies between and within watersheds. Under the assumption that the concentration of CO_2 will be double pre-industrial levels, the climate models predict that the Uba and Ulba watershed will experience changes in water volume between –29 and +6 percent.[10] The models predict that the water volume in the Tobol river basin will change between –29 and +25 percent. The following table presents the predictions of the climate models.

Table 5: Changes in Water Volume for the Uba and Ulba Watershed and the Tobol River Basin Under Doubled Atmospheric Concentration of CO_2

Study Site	Climate Model	Change in Water Resources
Uba and Ulba Watershed	CCCM	–23%
	GFDL	–29%
	GFDL-T	–1%
	GISS	+6%
Tobol River Basin	CCCM	–24%
	GFDL	–26%
	GFDL-T	–29%
	GISS	+25%

Source: Adapted from Pilifosova et al. 1996

The "Climate Change Vulnerability and Adaptation Assessment in Kazakhstan" report cautions that the results obtained for the Uba and Ulba watershed and the Tobol river basin cannot be applied to other river systems in the country with different runoff formations, in particular those fed by glaciers. The predictions of the GFDL climate model are given greater weight with the authors concluding that on the whole a reduction of 20–30 percent in water resources is to be expected with a doubling of the concentration of atmospheric carbon dioxide.

[10] The tenth decade output of the GFDL-T model which produces results for 2070 was used here, as opposed to the seventh decade output used for the assessment of the other sectors (see also footnote 4).

III. THE PHILIPPINES

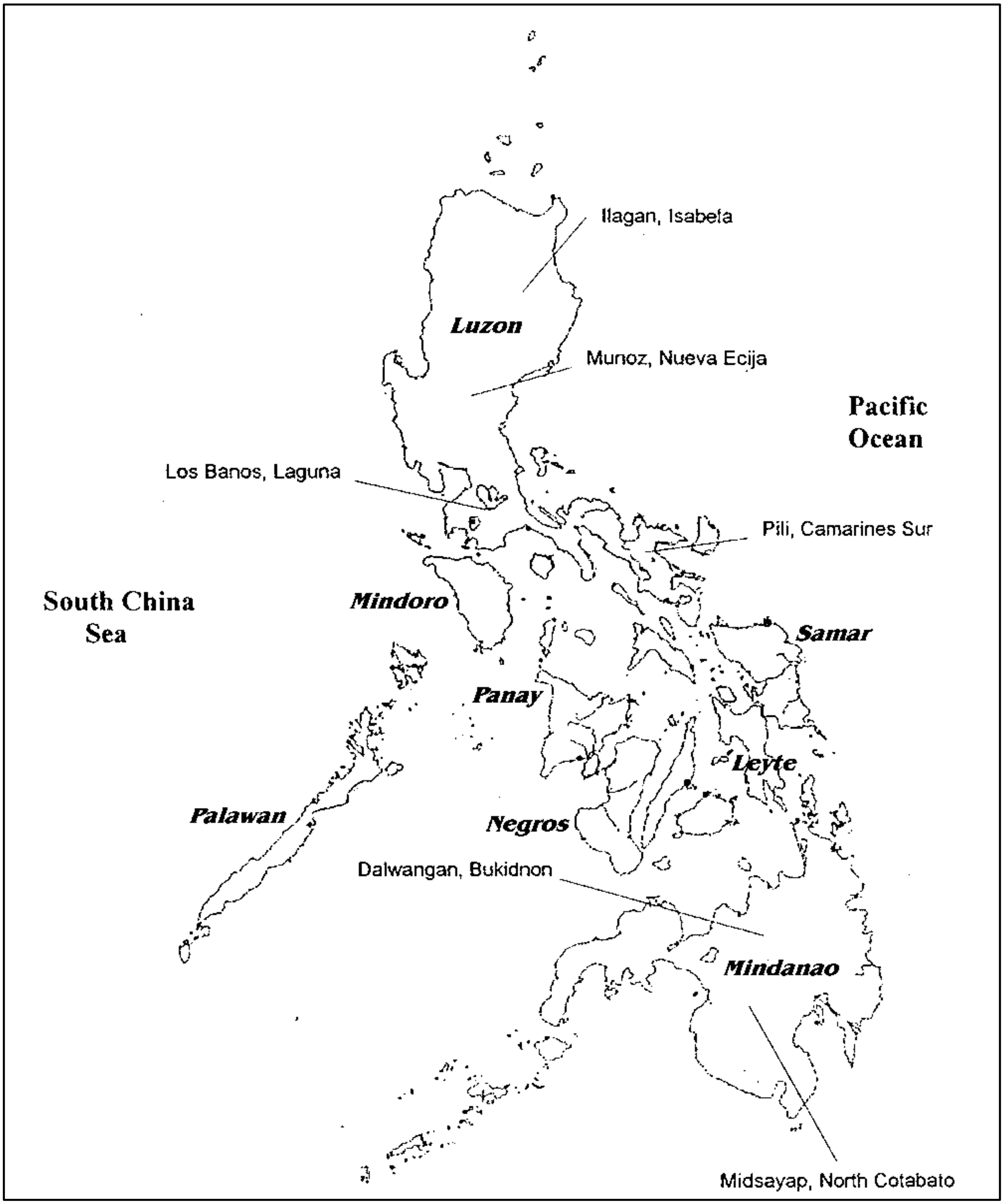

Figure 2: Map of the Philippines Showing the Location of the Study Sites in the Philippines Country Study Agricultural Assessment
Source: Adapted from Maglinao et al. 1998

Physical Features and Climate

The Philippines is an archipelago off the coast of Southeast Asia. Its 7,100 islands total 300,176 km^2 in area, and span 1,850 km at their longest north-south extent and 1,125 km at their widest east-west extent. The country is surrounded by the Pacific Ocean, with the Philippine Sea to the east, the Celebes Sea to the south, the Sulu Sea to the southwest, and the South China Sea to the west. The two largest islands are Luzon in the north and Mindanao in the south.

Luzon, Mindanao, and nine other islands (Samar, Negros, Palawan, Panay, Mindoro, Leyte, Cebu, Bohol, and Masbate) compose 92 percent of the land mass. Only approximately 1,000 of the 7,100 islands are populated, and fewer than one-half of these are larger than 2.5 km^2. The terrain is largely mountainous, with narrow coastal plains and interior valleys and plains comprising the limited lowland areas.

The northern Luzon highlands are composed of the Cordillera Central in the west which rise to between 2,500 and 2,750 meters, and the Sierra Madre in the northeastern portion of the island. Major plains include those of Central Luzon, the northeastern Cagayan Valley, and the Agusan Basin in the far south. The country's most extensive river systems are the Pulangi (Rio Grande), which flows into the Mindanao River; the Agusan, in Mindanao, which flows north into the Mindanao Sea; the Cagayan in northern Luzon; and the Pampanga, which flows south from east Central Luzon into Manila Bay. Laguna de Bay, southeast of Manila Bay, is the largest freshwater lake in the Philippines.

The climate is of the maritime tropical type, with temperature and rainfall patterns highly determined by topography and prevailing winds. The northeast monsoon (November to March) provides rainfall to the eastern sides of the archipelago exemplified by Surigao in Mindanao which receives an annual total of 3,560 mm. The southwest monsoon (June to September) provides rainfall to the western sides of the islands, such as Manila on the western side of Luzon which receives 2,100 mm of rainfall annually. Mean annual sea-level temperatures rarely fall below 27 °C. From July through October, typhoons strike the northeastern islands, and are especially hazardous for northern and eastern Luzon and Samar. This background information on topography and climate provides the baseline information upon which to consider the effects of climate change upon the specific sectors of agriculture and accelerated sea level rise (ASLR) in coastal zones.

Agriculture

In terms of area harvested, rice and corn are the two most important crops in the country. Rice is the most important crop and is grown by one-third of the farmers on a predominantly subsistence basis. Rice is harvested from an area of 3,842,270 hectares (ha) and the quantity produced in 1997 was 11,269,000 tonnes. Corn is the second most important crop, occupying 2,725,820 ha with a 1997 production of 4,332,420 tonnes. It is used for consumption especially in the central part of the country, and is also used as animal feed and raw material for industry. Climate variability has caused great losses in yield for both corn and rice.

Between 1968 and 1990, approximately half of the losses of yield in rice and corn were caused by extreme weather events such as tropical cyclones and floods. In the same span of time, droughts accounted for a third of the losses and weather-related pest outbreaks for one-fifth of the losses in production (Matthews et al. 1997). Recent research has attempted to determine the effects of future changes in climate on rice and corn production in the Philippines.

A study by the Philippine Country Study on Climate Change examined the effects of future climate change on the production of rice and corn under a variety of climatic, irrigation, and growing conditions (Maglinao et al. 1998). Another study looked at the effects of climate change on rice production across Asia (Matthews et al. 1997). Using models that predict crop production combined with future climate scenarios generated by General Circulation Models (GCMs), it is possible to determine how yields will be affected by global climate change. The selection of GCMs and crop prediction models varies between studies.

In the work done by the Philippine Country Study, the CERES–Rice and CERES–Corn models were used to predict future rice and corn yields, respectively, using climate scenarios determined from four GCMs.[11] The GCMs used were the Canadian Climate Center Model (CCCM), and those of the Geophysical Fluid Dynamics Laboratory (GFDL), the Goddard Institute of Space Studies (GISS), and the United Kingdom Meteorological Office (UKMO). All four GCMs were run at double the pre-industrial atmospheric concentration of carbon dioxide (2 X CO_2).[12] The pan-Asian study used the GFDL, GISS, and UKMO GCMs under 2 X CO_2 conditions; however, the choice of crop models—ORYZA1 and SIMRIW—differed from those used in the Philippine Country Study.

In the Philippine Country Study analysis, the CERES models were used to simulate the growth of two varieties of rice and corn under the four different climate scenarios predicted by the GCMs. Several simulations were made with the planting dates spread over all the months of the year. Both rain-fed and irrigated crop growth was simulated using the growing recommendations of both the National Cooperative Testing Program (NCT) and the Gintong Ani Program of the Philippines Department of Agriculture.[13] The changes in yield were made by comparing yields predicted by the CERES models to current crop yield data. The methodology employed in the pan-Asian study differed in that simulations were made only for the wet and dry seasons, and not for all months.[14] The predictions for the changes in rice yield follow.

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[11] CERES is the "Crop Estimation through Resources and Environmental Synthesis," version 3, as incorporated into the "Decision Support System for Agrotechnology Transfer" (DSSAT) software.

[12] Only changes in temperature, solar radiation, and total rainfall were considered; disregarding potentially important factors such as changes in pest and disease incidence, strong winds associated with a new pattern of tropical cyclones, and changes in soil conditions caused by the doubling of atmospheric CO_2.

[13] The NCT growing recommendations are a set of standard crop-specific methods used in the Philippines that involve transplanting/planting dates, fertilizer amounts and timing of application, and soil preparation. They are not site-specific. For details, see Maglinao et al. 1998 (p. 8).

[14] The changes in yield were not quantified in the Philippines Country Study report. Sowing and transplanting dates followed the recommendations of the International Rice Research Institute (IRRI).

Predicted Changes in Rice Yields for the Philippines Country Study

The growth of the varieties IR64 and IR72 were simulated under climatic conditions from the GCMs. The five study sites used were Nueva Ecija, Laguna, Camarines Sur, Bukidnon, and North Cotabato, which span the north-south extent of the country, with Nueva Ecija located in Luzon in the north, and North Cotabato in Mindanao in the south (see figure 2). The yields were compared to current crop yield data. The predicted changes in yield under different combinations of growing conditions follow.

Changes in Yield Predicted for Rainfed Rice Grown Using the NCT Recommendations. The yield predictions of the CERES–Rice model under all climate scenarios from the GCMs were highly variable. However, the following broad trends are discernible:

- The variety IR72 encountered crop failure more often than IR64 especially when planted in the early months of the year (January–March).[15]

- For both IR72 and IR64, planting during the second half of the year resulted in yield reductions more frequently than in the first part of the year. This was particularly evident at the Nueva Ecija and Camarines Sur sites.

- The climate predictions from the GISS model result in yield reductions in most months of the year for the Camarines Sur, Laguna, and North Cotabato sites.

Changes in Yield Predicted for Irrigated Rice Grown Using the NCT Recommendations. When irrigation was incorporated into the CERES–Rice model, the predictions of rice yields were significantly different than under rain-fed conditions. Irrigation significantly reduced the number of planting months that result in decreased yields at the Camarines Sur and North Cotabato sites. Irrigation had virtually no effect on reducing the number of unsuccessful planting months at the Laguna site. At the Bukidnon and Nueva Ecija sites, the effect of irrigation was intermediate.[16]

Changes in Yield Predicted for Rice Grown Using the Gintong Ani Recommendations. The Gintong Ani growing recommendations involve irrigation and site-specific measures to increase rice yields. Some of the predictions of changes in yield that are worth noting are as follows:

- Regardless of the climate scenario, increases in yield were forecast for all planting months at the North Cotabato site. Similar increases for all planting months were not predicted for the other sites.

[15] Crop failure is defined as the models predicting that the crop will die and not produce any yield.

[16] This deviates from the Philippine Country Study report which states that the effect of irrigation at the Bukidnon site was small and the effect at the Nueva Ecija site was similar to that at Camarines Sur and North Cotabato. However, according to the data presented in the report, the number of instances in which irrigation improved yields over rain-fed cultivation for the Bukidnon and Nueva Ecija sites was ten and eleven, respectively, for IR64. For IR72, the corresponding numbers were twelve and thirteen. These figures are much lower than those for the Camarines Sur (16 for IR64, 19 for IR72) and North Cotabato sites (22 for IR64, 31 for IR72).

- The percentage increase in yield for the Gintong Ani recommendations ranged from 0.5 to 10 percent, which was significantly higher than the 0.1 to 0.7 percent increases of the NCT recommendations.

Predicted Changes in Rice Yields for the Pan-Asian Study (Matthews et al. 1997)

This study only used the variety IR64. The rice growth models ORYZA1 and SIMRIW predicted a similar pattern of changes in yield across the different climate scenarios. Both predicted an increase in yield for the GFDL GCM and reductions for the GISS and UKMO models.

ORYZA1 predicted an increase of yield of 14.1 percent for the GFDL scenario, and reductions of 11.8 and 4.7 percent for the GISS and UKMO models, respectively. The corresponding predictions for the SIMRIW model were +9.4, –13.7, and –5.4 percent, respectively.

Predicted Changes in Corn Yields for the Philippines Country Study

The growth of the varieties P3228 and sweet corn were simulated under climate scenarios from the GCMs. As with rice, the predictions of changes in yield were made relative to current crop yield data. The study sites used were Isabela, Bukidnon, and North Cotabato. The results for corn growth under the NCT and Gintong Ani recommendations follow.

Changes in Yield Predicted for Corn Grown Using the NCT Recommendations. Unlike the variable predictions for rice, the predictions for corn are quite constant. A general reduction in yield was predicted for most planting months regardless of climate scenario. Results that stand out at a more detailed level of analysis are as follows:

- Regardless of climate scenario, yield reductions were predicted for both P3228 and sweet corn between April and August.

- At the Isabela site, losses in yield were predicted for both varieties under the GISS climate scenario and for sweet corn under the UKMO scenario.

- Under the GISS climate scenario, losses are predicted for all months at the Bukidnon site.

- At the North Cotabato site, uniform losses are predicted for both varieties under the CCCM climate scenario.

- From December through March, irrigation led to increased yields. This positive effect of irrigation was most pronounced at North Cotabato, less so at Bukidnon, and the least at the Isabela site.

Changes in Yield Predictions for Corn Grown Using the Gintong Ani Recommendations. In contrast with the NCT results, the yield predictions using the Gintong Ani recommendations were overwhelmingly positive. Reductions in yield were only predicted for some planting months between April and September. This was particularly the case for North Cotabato. However, the loss in yield was less than that for the NCT growing recommendations.

Coastal Zones

This section will address the dangers posed to coastal zones by accelerated sea level rise (ASLR). It draws upon the work done by the Philippine Country Study for the Manila Bay area, entitled "Vulnerability Assessments and Evaluations of Adaptations on Coastal Resources Due to Accelerated Sea Level Rise." Due to the absence of topographic and bathymetric maps of sufficiently high resolution and the high cost of satellite imagery, an alternative approach called the Aerial Video-assisted Vulnerability Analysis (AVVA) was used.

The AVVA analysis was carried out for the Intergovernmental Panel on Climate Change (IPCC) predictions of sea-level rises of 0.3, 1.0, or 2.0 m by the year 2100 (low, high, and worst-case estimates). The AVVA methodology encompasses video imagery taken from a height of 50–500 m, ground truth measurements, archival research, and data analysis using simple land loss and response models.[17] Using the AVVA's component analyses in a coordinated manner made it possible to determine the current status of the coastal areas in Manila Bay and how they were likely to be affected by specific rises in sea level. The key findings were:

- In the event of a 1 m sea level rise, most areas along the coast of Manila Bay will be submerged by the year 2100. Among these areas will be the municipalities of Las Piñas, Paranaque, Malabon, and Navotas in Metro Manila; Hagonoy and Malolos in Bulacan province; and Cavite City, Noveleta, Kawit, Imus, and Bacoor in the province of Cavite.

- Areas with a high density of population, such as Navotas and Malabnon in Metro Manila, and Limay and Orani in Bataan province may survive ASLR, but will be highly vulnerable to severe storm surges.

- Higher water temperatures will cause "bleaching" of the coral reefs of the Manila Bay area.[18]

- Salt water intrusion will increase salinity in the estuaries of Manila Bay which will adversely affect the mangroves there.

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[17] Ground truthing refers to marking points on the coast that would correspond to sea level rises of 0.3, 1.0, and 2.0 m. Contour lines that join the points for each elevation are then drawn using the actual points or points determined through extrapolation. The resulting contours make it possible to determine which areas of the coast would be affected by sea level rises of 0.3, 1.0, and 2.0 m.

[18] Bleaching refers to the dislodging of the microscopic algae that live within the tissue of the coral polyps. High temperatures will lead to the death of these algae. The algae remove CO_2 and ammonia, and supply O_2, amino acids, and carbohydrates to the polyps. While coral polyps can survive bleaching incidents if water temperatures return to normal within a short period of time, persistent high water temperatures could lead to the death of the reefs.

IV. INDIA

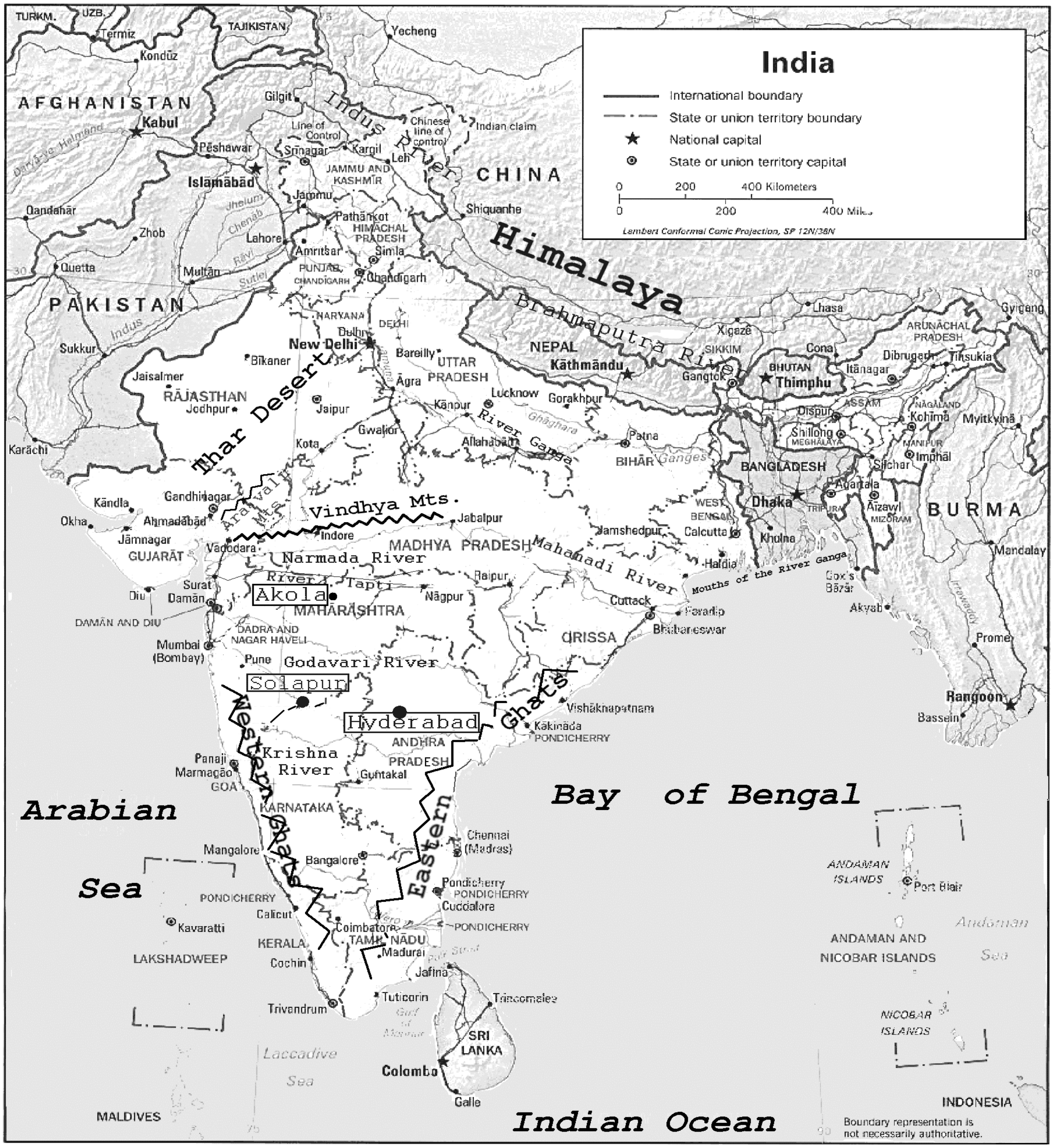

Figure 3: Map of India Showing Major Physical Features and Study Sites in the Sorghum Assessment

Source: Research and Reference Services Project 1998

Physical Features and Climate

India has a land mass of 3,287,263 km^2 making it the seventh largest country in the world. It borders Pakistan on the northwest; Myanmar (Burma) on the east; and China, Nepal, and Bhutan on the northeast. The Bay of Bengal is to the southeast and the Arabian Sea to the southwest. The country can be regarded as having three regions according to terrain: the Himalayan mountainous areas in the north, the plains of the Indus and Ganga in the center, and the plateau and highlands of the peninsula in the south.

The Himalayas extend from the northwest to the northeast in a series of intertwining ranges with peaks divided by gorges. This large mountain range includes peaks over 7,600 m in elevation, and its glaciers feed the Indus, Ganga, and Brahmaputra rivers. Deposits of silt from these rivers form the central plains which are generally below 300 m. To the south of these plains, lies the southern plateau and highlands. The plateau is called the Deccan plateau and has a maximum elevation of 1,000 m. Other highland regions in the south, include the Aravali range in the northwest part; the east-west aligned Vindhyas; and the Western and Eastern Ghats which run roughly parallel to the southwest and southeast coasts. The important rivers of peninsular India, from north to south, are the Mahanadi, Godavari, Krishna, Kaveri, Narmada, and the Tapti. Location with respect to the main topographical regions greatly influences climatic conditions.

The Indian climate is of the tropical monsoon variety and is broadly characterized by three main seasons: hot and dry from March to May, hot and wet from June to September, and cool and dry from October to February. These seasons are experienced differently depending upon location. In May, the north is dry, with an average temperature of 32–35 ºC. In the Ganga delta, which gets much more rain in this part of the year, the temperature decreases to a May average of 30 ºC. The southern region is warmer still in the hot season with the May average in Tamilnadu being 32 ºC.

In northern areas such as Delhi and the Punjab, cool season temperatures range between 10 and 15 ºC; in the Ganga delta, temperatures in January are higher, averaging 19 ºC; whereas, in peninsular India, the cool season is even warmer with the average January temperature in Tamilnadu being 24 ºC. The Ganga delta gets more rain than northern India from the monsoons that start in June and July. The south of the country experiences a near-reversal of the monsoonal pattern with heaviest rains from October to January and drier conditions from June to September.

In general, rainfall increases from west to east across the country, within an average annual range of 500–1,500 mm. The west coast of peninsular India is an exception in that it receives high rainfall. The range of variation in precipitation in different parts of the country is well illustrated by the difference in average annual rainfall between the Thar Desert which receives less than 100 mm and Cherrapunji in Assam which receives 11,430 mm. This brief introduction to the climate and physical features provides a reference point to consider the impacts of human-induced climate change upon India. This report will address the effects upon the summer monsoon and agriculture.

Summer Monsoon

The summer monsoon is of vital importance to Indian agriculture and society in general. The arrival of the monsoon is anxiously awaited as it is not only of great significance to farming activities but also determines the timing of important cultural ceremonies.

Most of the monsoon activity that brings rain to the central plains of India is associated with low pressure systems or depressions which arise over the Bay of Bengal toward the end of May. These depressions move in a northwesterly direction and bring rains to the central plains from June to September. The actual onset of the monsoons is dependent upon a series of complex interactions involving the temperature of the Arabian Sea, the Bay of Bengal, and the south Indian ocean; land-sea temperature differences; and terrain. This complexity has made it extremely difficult to accurately model the summer monsoon and has led some investigators to doubt climate change predictions regarding India.

Gadgil (1995) points out, correctly, that a number of studies have used generalized global predictions to make claims about the impact of climate change on countries such as India. Many General Circulation Models (GCMs) cannot accurately predict the pattern of rainfall brought by the summer monsoon. Indeed, in an experiment which attempted to predict the average rainfall patterns for the decade of the 1970s, none of the GCMs used could accurately predict the actual distribution of the rainfall.[19] While forecasting the summer monsoon remains challenging, subsequent research has proven to be more satisfactory.

Researchers at the Max Planck Institute of Meteorology have recently had success in using a GCM to predict various characteristics of the summer monsoon (Lal et al. 1995). Using the Hamburg atmospheric GCM, ECHAM3, the researchers simulated the structure, intensity, frequency, movement, and duration of monsoons. Under a 2 X CO_2 (twice pre-industrial atmospheric concentration of carbon dioxide) scenario, the GCM was able to predict the change in monsoon patterns and temperature for the Indian subcontinent.

ECHAM 3 predicted that average annual temperatures in India will increase by 2.5 ºC in the winter and by 1.6 ºC in the summer.[20] The changes in temperature will not be geographically uniform, with the drier semi-arid regions in the northwest bearing the brunt of the warming (Lal et al. 1995; Lal 1994). The average annual temperature will be between 2 and 2.5 ºC in this area; central and northeast India will experience a 2 ºC rise; and the increase in peninsular India will only be 1 ºC. During the monsoon season, the increase in temperature will be the least for the central plains region. In this season, the rest of the country will experience temperature increases slightly lower than the annual averages.

With respect to changes in rainfall caused by climate change, ECHAM 3 predicted an increase in the average annual rainfall over India of 0.47 mm/day. During the cool season, no significant change in rainfall is projected. Most of the increase in rainfall will occur during the monsoon season.

The ECHAM 3 model was run under a 2 X CO_2 scenario to simulate monsoons that would occur over a five-year period. The results indicated that the annual average number of monsoons will not change as a result of climate change. However, there will be changes in the timing and

[19] The GCMs used were the CCC (Canadian Climate Center), UKMO (United Kingdom Meteorological Office), and the GFDL (Geophysical Fluid Dynamics Model).

[20] These values are smaller than increases of 2.33–4.78 ºC predicted by a set of different GCMs (GISS—Goddard Institute of Space Studies, GFDL, and UKMO) used in another study. However, the authors of this study noted that this prediction of temperature increases is probably an overestimate. Given this observation, the ECHAM 3 values are more likely to be accurate (Dinar et al. 1998).

location of the monsoons. The average number of depressions predicted for June over the five-year period dropped from the usual of 2.5 to 0.4. The average duration of monsoon depressions will increase by 0.9 days in July and 1.2 days in August. The path of the September monsoon will be more erratic and not conform to the usual northwesterly track.

Agriculture

About two-thirds of the Indian labor force is engaged in agriculture. Agricultural produce accounts for about one-third of the value of the country's annual domestic product. Rice is the dominant crop in terms of area harvested (42,200,000 ha in 1997), occupying one-fourth of the total cropped area, and is a staple food of a majority of the population. In terms of area harvested, wheat ranks next in importance to rice. India is also among the leading producers in the world of sugarcane, sorghum, tea, cotton, and jute.

In 1997, India ranked second in rice and sorghum production, with 22 percent and 14 percent, respectively, of total global output. Recent studies have attempted to quantify the impact of climate change on future rice and sorghum production (Matthews et al. 1997, Rao et al. 1995). A review of some rudimentary facts about the cultivation of these crops in India will serve as a background to the discussion of the impacts of climate change upon their future yields.

Rice

In 1997, India produced 123,012,000 metric tons of rice. Rice is grown in the summer (kharif) and winter (rabi). Kharif rice is sown from mid-May to the end of August, and harvested from late September to early February. Nine Indian states each produce more than 4 percent of the kharif rice with Uttar Pradesh, West Bengal, and Andhra Pradesh being the top three. Rabi rice is grown in a fewer states, with only five states producing more than 4 percent of the total. Andhra Pradesh and West Bengal alone account for 64 percent of rabi rice production. Rabi rice is sown from early November to the end of February and harvested from March to the end of May.

In a study that looked at the effects of climate change on rice production across Asia, Matthews et al. used grain production models with future climate data generated by GCMs. This pan-Asian study used the ORYZA1 and SIMRIW crop models with climate data from the GFDL, GISS, and UKMO GCMs under 2 X CO_2 conditions. Simulations of growth under 2 X CO_2 climatic conditions were made for the wet and dry seasons, and for the five different agroecological zones (AEZ) found in India.[21] Sowing and transplanting dates followed the recommendations of the International Rice Research Institute (IRRI). The rice variety assumed for India was IR64.

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[21] Agroecological zones (AEZ) are a system of zonation developed by the FAO (Food and Agriculture Organization) and modified for use by the CGIAR (Consultative Group on International Agricultural Research). These AEZs for rice were taken from the International Rice Research Institute's 1993-1995 Rice Almanac (Matthews 1998). AEZs specify areas that have particular conditions conducive to the growth of crops, e.g. "warm subtropics," "warm humid tropics," "subtropics," etc. For details on the geographical extent of the AEZs, refer to Matthews et al. 1995.

Naturally, the changes in yield varied according to the AEZ. The following table summarizes the percentage change in yield for sorghum for the different GCMs and crop models. The changes in yield are relative to 1993 production data.

Table 6: Changes in Rice Yield as Predicted by the ORYZA1 and SIMRIW Crop Models Under 2 X CO_2 Climate Scenarios (yield is in 1,000 tonnes)

Model	AEZ	1993 Yield	GFDL		GISS		UKMO	
			Yield	%Change	Yield	%Change	Yield	%Change
ORYZA1	1	32,807	34,305	4.6	29,272	–10.8	31,017	–5.5
	2	49,949	50,849	1.8	48,493	–2.9	46,002	–7.9
	5	227	210	–7.4	228	0.3	170	–25.2
	6	26,628	28,069	5.4	27,480	3.2	26,287	–1.3
	8	1,011	946	–6.4	867	–14.2	732	–27.6
SIMRIW	1	32,807	30,104	–8.2	26,417	–19.5	27,964	–14.8
	2	49,949	54,473	9.1	55,192	10.5	48,366	–3.2
	5	227	223	–1.7	244	7.3	224	–1.4
	6	26,628	21,339	–19.9	16,804	–36.9	2,011	–92.4
	8	1,011	910	–10.0	1,109	9.7	952	–5.8

Source: Adapted from Matthews et al. 1997

A list of the AEZs mentioned above follow:

1. Warm arid and semi-arid tropics

2. Warm sub-humid tropics

5. Warm arid and semi-arid tropics with summer rainfall

6. Warm subhumid subtropics with summer rainfall

8. Cool subtropics with summer rainfall

As detailed in table 6, climate conditions predicted by the UKMO GCM led to the greatest decreases in yield, whereas GFDL climatic conditions led to the least decreases and some cases where yields increased. The GISS GCM led to intermediate results, with both more cases of decreased yield and larger reductions, when compared to GFDL. These differences are partially attributable to the higher temperatures predicted by the UKMO model (a global increase of 5.2 ºC, as compared to 4.0 and 4.2 for the GFDL and GISS models, respectively). At high temperatures, rice spikelets become sterile and produce less grain (Matthews et al. 1997). Thus, small temperature differences of even 1 ºC can overwhelm the resistance of the spikelets to high temperatures and render them unproductive.

Sorghum

Sorghum is an important food grain in India. It is grown under mostly rain-fed conditions in a wide swath from Punjab in the north to Tamilnadu in the south. Production is concentrated in the states of Maharashtra, Karnataka, Madhya Pradesh, and Andhra Pradesh, which account for 83 percent of the production. It is grown in both the kharif and rabi seasons, and using either precipitation during the rainy season or stored soil water in the post-rainy season.

In the kharif season, it is planted from mid-May to early August, and harvested from November to early February. In the rabi season, sowing is from late September to November and harvesting from late February to early May. About three-quarters of the crop is grown during the kharif season and the remaining during the rabi season. In 1997, India produced 9,000,000 metric tons of sorghum. Using future climate information from GCMs together with crop production models such as the CERES-sorghum model makes it possible to predict future sorghum production.

Three GCMs—GISS, GFDL, and UKMO—were run at 2 X CO_2 conditions to predict future climate scenarios for three sites representative of sorghum growing conditions in India (Rao et al. 1995). The sites chosen were Hyderabad, Akola, and Solapur (see figure 3). Hyderabad and Akola are representative of rainy season cultivation and Solapur of post-rainy season cultivation. The variety CSH-5 was used for Hyderabad and Akola, and SPV 504 was used for Solapur. Simulations of sorghum growth were made under two concentrations of CO_2—current atmospheric concentration and 2 X CO_2—and the presence and absence of water and nitrogen deficiencies.[22]

At the Hyderabad study site, the differences in yield between rain-fed (water-stressed) sorghum under current atmospheric CO_2 and 2 X CO_2 conditions were negligible. This indicates that under water-stressed conditions, the increase in atmospheric CO_2 had little to no effect on sorghum growth. In the presence of sufficient water and nitrogen (hereafter referred to as "non-stressed"), a marginally positive increase in yield was observed for the 2 X CO_2 case. However, regardless of the GCM or concentration of CO_2, the simulated sorghum yield under nonstressed conditions was more than twice that of the sorghum yield under rain-fed conditions. The obvious

[22] Considering the effects of nitrogen and water deficiencies along with the effects of climate change makes it possible to compare the effects of climate change versus these other factors.

conclusion is that the availability of water and nitrogen is much more important to the growth of sorghum than the atmospheric concentration of CO_2.[23]

At Akola, the general pattern of differences in yield between sorghum under varying conditions of growth matched the findings at Hyderabad. The differences in yield between current CO_2 and 2 X CO_2 conditions was greater than at Hyderabad, but still negligible when compared with the differences between the rain-fed and nonstressed growth. With respect to CO_2 concentrations, the differences in yield were again negligible at the post-rainy season site of Solapur. Here too, there were large differences in yield between nonstressed and rainfed growth, and much smaller differences between sorghum grown under identical conditions except for CO_2 concentrations.

[23] Sorghum, like millet, corn, sugarcane, and other crops of tropical origin, is a C_4 plant. C_4 plants, as opposed to C_3 plants such as rice, wheat, and soybeans, do not benefit nearly as much from a higher concentration of CO_2. The distinction between these two categories of plants is based upon differences in the metabolism of photorespiration and leaf anatomy.

V. CONCLUSION

It is evident from the discussion of human-induced global climate change in Kazakhstan, the Philippines, and India, that climate change is predicted to have large and possibly devastating impacts on agriculture, water resources, sea level rise, and even the summer monsoon in south Asia. In general, most of the assessments of impacts have used climate predictions from GCMs and models that predict the effect of these changes in climate upon specific sectors like agriculture, water resources, and grasslands. The predicted effects have ranged from large reductions in the water volume in Kazakhstan, to varied effects upon corn and rice in the Philippines, to essentially no changes in sorghum production for India.

Many of the impacts discussed in this report are marked by their great degree of variability. Whether it is changes of –1 to –29 percent in the water resources of the Uba and Ulba watershed in Kazakhstan, or changes of –14.8 to +4.6 percent in rice yield for the warm arid and semi-arid tropical regions of India, the common feature is a large range of possibilities. Cases where the range of predictions is very high, such as for the changes in water volume of the Uba and Ulba watershed, demonstrate the need for better modeling procedures and/or the lack of reliable data. In other cases, such as the changes in rice and corn production in the Philippines, the predictions are less varied and more reliable. The high variability of some of the predictions is a reflection of the current state of the science of climate modeling, and should not be interpreted as invalidating the entire approach.

Modeling climate change itself is a complex endeavor; using the predictions of climate change models with crop or grassland biomass productivity models compounds the difficulties and magnifies errors. The enormous computing resources required to model climate change and its impacts limits the number of research centers in the wealthier nations engaged in this research. This is even more so the case in the developing and transition countries.

Building capacity in terms of the hardware needed to model the impacts of climate change and the training of scientists is needed in the developing world. Research to refine climate models and associated impact models should be done with the close collaboration and involvement of developing and transition country scientists. This is only possible if the capacity to conduct such research is augmented in these countries. Assessments are needed at the country and local level and these can be better accomplished through local scientific institutions. Local institutions are better placed to understand the coping mechanisms available to national institutions and communities.

In order to maintain the focus on the analysis of the impacts of climate change, the adaptation facet of vulnerability was not addressed in this report. However, what these impacts will mean to developing countries and countries in transition is dependent upon how well placed they are to adapt to the impacts. It is in understanding these abilities to cope with or adapt to the impacts of climate change that developing and transition country scientists are especially adept. Their knowledge of local conditions combined with an ability to develop sophisticated climate change models will produce assessments that are more accurate both in terms of the impacts themselves and in the adaptive measures proposed. Beyond assessing the vulnerability of developing and transition countries, is the next step of taking measures to combat the impacts of climate change.

Measures that can be taken are a direct offshoot of the vulnerability assessment process. In the case of agricultural impacts, the timing of planting and the choice of variety can greatly reduce losses in agricultural output. To illustrate, planting rice in the first part of the year and using the variety IR64 are adaptive measures that will reduce losses in rice yield for the Philippines. In other cases, such as sorghum production in India, little or no measures may be necessary to specifically prepare for climate change besides the nonclimate change related cultivation techniques such as ensuring sufficient nitrogen and water supply.

Once the steps needed to prepare for climate change are identified, developing and transition nations will need help to take these steps. From a development perspective therefore, there is much potential for capacity building activities to prepare developing countries to both assess their vulnerability and adapt to the future impacts of climate change. The U.S. Country Studies Program, partially supported by USAID, is a good example of a collaborative training and research program designed to accomplish the goals outlined above. This and other efforts will be needed to enable developing nations and countries in transition to withstand the threats posed by global climate change. Finally, the assessment of impacts and discussion above has been predicated upon the assumption that present contributions to greenhouse gases will continue. Global efforts to reduce greenhouse gas emissions will ensure that the impacts of climate change and the consequent threats to developing and transition countries are minimized.

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