THE EFFECTS OF GLOBAL CLIMATE CHANGE ON SOUTHEAST ASIA: A SURVEY OF LIKELY IMPACTS AND PROBLEMS OF ADAPTATION

A Study by

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I. INTRODUCTION

Southeast Asia is the rice bowl of the world, producing about 65% of the world's rice and, in the last decade, emerging once again as a major exporting region. Paddy rice, requiring plentiful water supplies, is the primary agricultural product of the Philippines, Malaysia, Thailand, and Indonesia. Singapore, a major trade entrepot and manufacturing center, is not involved in agricultural production. Brunei is a major producer of petroleum. Appendix A contains further descriptions of these countries.

The sectors most obviously affected by climate conditions in these countries are agriculture and forestry. Timber production to date has been carried out largely on a non-sustainable basis, but the countries of Southeast Asia are attempting to improve cutting practices and to replant forest areas to move toward sustainable forestry, for both commercial and environmental reasons. Tree plantation products, especially rubber, coffee, and coconuts continue to play an important role in these countries.

Fisheries are extremely important for the Philippines, Malaysia, Indonesia, and Thailand, both commercially and as a domestic protein source. In some areas, fish are an important by-product of paddy rice production, and fish farming has become an important activity in Indonesia and Thailand. The effects of climate change on marine fisheries are not clear, but their dependence on estuarian systems probably makes them sensitive to climate change.

Energy production and use will be affected by climate change. Energy supplies are primarily oil and coal, found mostly in Indonesia. A small amount of hydroelectric power is generated in the Philippines and Indonesia. To the extent that climate affects energy *use* (*e.g.* for transport, air conditioning, etc.), it affects the exportable surplus of energy products, especially from Indonesia.

Population movements accompany economic development and population growth. Often, these movements are into riskier, more marginal areas, especially when caused by population growth. For example, Indonesia has underway a major program of population relocation from the island of Java to some of the less densely populated islands like Kalimantan (Borneo) and Irian Jaya (New Guinea). This "transmigration" program generally moves population either from well-watered Java to dryer areas (*e.g.* West Kalimantan) or to the swampy coastal areas of Sumatra and Kalimantan. Climate change could affect the viability of the program in both locations quite unfavorably.

In evaluating the impacts of climate change on Southeast Asia, this study included six activities: (1) a search of the literature on climate change and the greenhouse effect to identify studies on climate change and its effects that were relevant to Southeast Asia; (2) obtaining results of climate change scenarios for Southeast Asia that had been generated by the leading global circulation models (GCMs); (3) interpretation and adaptation of these results for Southeast Asia and, in particular, for Indonesia; (4) identification of likely negative and positive effects of climate change in Southeast Asia; (5) inventorying of on-going research in Indonesia related to climate change; and (6) elucidation of further research needed to connect climate change scenarios with the full range impacts on agriculture, forestry, fisheries, energy production and use, and human well being.

The study results indicate the likelihood of significant net damages from climate change, in particular damages from sea-level rise and higher temperatures that seem unlikely to be offset by favorable shifts in precipitation and CO_2. This study also indicated the importance of better climate models, in particular models that can calculate climate change on a regional scale appropriate to policy-making. In spite of this potential, there seems to be a low level of awareness and concern, probably caused by the higher priority given to economic growth and reinforced by the great uncertainty in the forecasts. The common property nature of the global environmental systems also leads to a feeling of helplessness on the part of country governments.

II. THE USE OF GENERAL CIRCULATION MODEL DATA IN ANTICIPATING CLIMATE CHANGE IN SOUTHEAST ASIA[1]

This section describes some aspects of general circulation model (GCM) data for use in climate impact studies. The present study has relied on such data as the basis for evaluating the possible impacts of global climate change in Southeast Asia. This description focuses on the output from the GCMs, not on the structure or operation of the models. For a comprehensive discussion of the workings of GCMs, refer to Meehl (1984) for a general description, and Hansen, et al. (1983) for a more technical treatment.

A general circulation model is a three-dimensional model of the atmosphere which uses numerical equations to model the evolution of the atmosphere through time from some initial state. The GCM generates output for a number of different atmospheric variables, including surface temperature, precipitation, humidity, and run-off. The four major GCMs currently being used in climate impact studies are: (1) GISS - NASA Goddard Institute of

[1] This section paraphrases notes prepared by Dr. Roy Jenne of NCAR for the EPA-sponsored International Rivers Project (C.U. Natural Hazards Center).

Space Studies, New York City; (2) GFDL - NOAA Geophysical Fluid Dynamics Laboratory, Princeton, New Jersey; (3) UKMO - United Kingdom Meteorological Office; and (4) OSU - Oregon State University, Corvallis, Oregon. The models use different spatial resolutions, different schemes for incorporating phenomena such as individual storms, changes in cloud cover, etc., and arrive at somewhat different results. Magnitudes of differences among model outputs can be seen in Figures 1 and 2 for changes in temperature and precipitation for the case of doubled CO_2 for the large Southeast Asian "window" consisting of Burma, Cambodia, Laos, and Vietnam[2]. Differences in spring, summer and fall precipitation are especially large among the models. In these cases the models do not even agree on the sign of the calculated change.

A GCM "slices" the earth into grid cells in three dimensions. Different GCMs use different resolutions to model atmospheric behavior. The grid box used in the OSU GCM is 4° latitude by 5° longitude, the finest resolution currently in use. The GISS model uses 7.83° latitude by 10° longitude while the GFDL model uses 4.44° latitude by 7.5° longitude. The GCM output data for each grid cell are averages over the entire cell.

The amount of carbon dioxide in the atmosphere has been increasing gradually since the Industrial Revolution. Levels in 1880-1890 were roughly 280 parts per million. In 1958 the concentration was measured as 315 parts per million, the amount also used in the GISS model for its baseline run (henceforth called the $1xCO_2$ scenario). Today the concentration is roughly 350 parts per million. Hence, the $1xCO_2$ scenario can be viewed as simulating

[2] This window excludes important parts of Southeast Asia, especially the Philippines and Indonesia, but is used simply to illustrate the differences in model outputs for that part of the world.

SOUTHEAST ASIA

Temperature Change for Doubled CO2

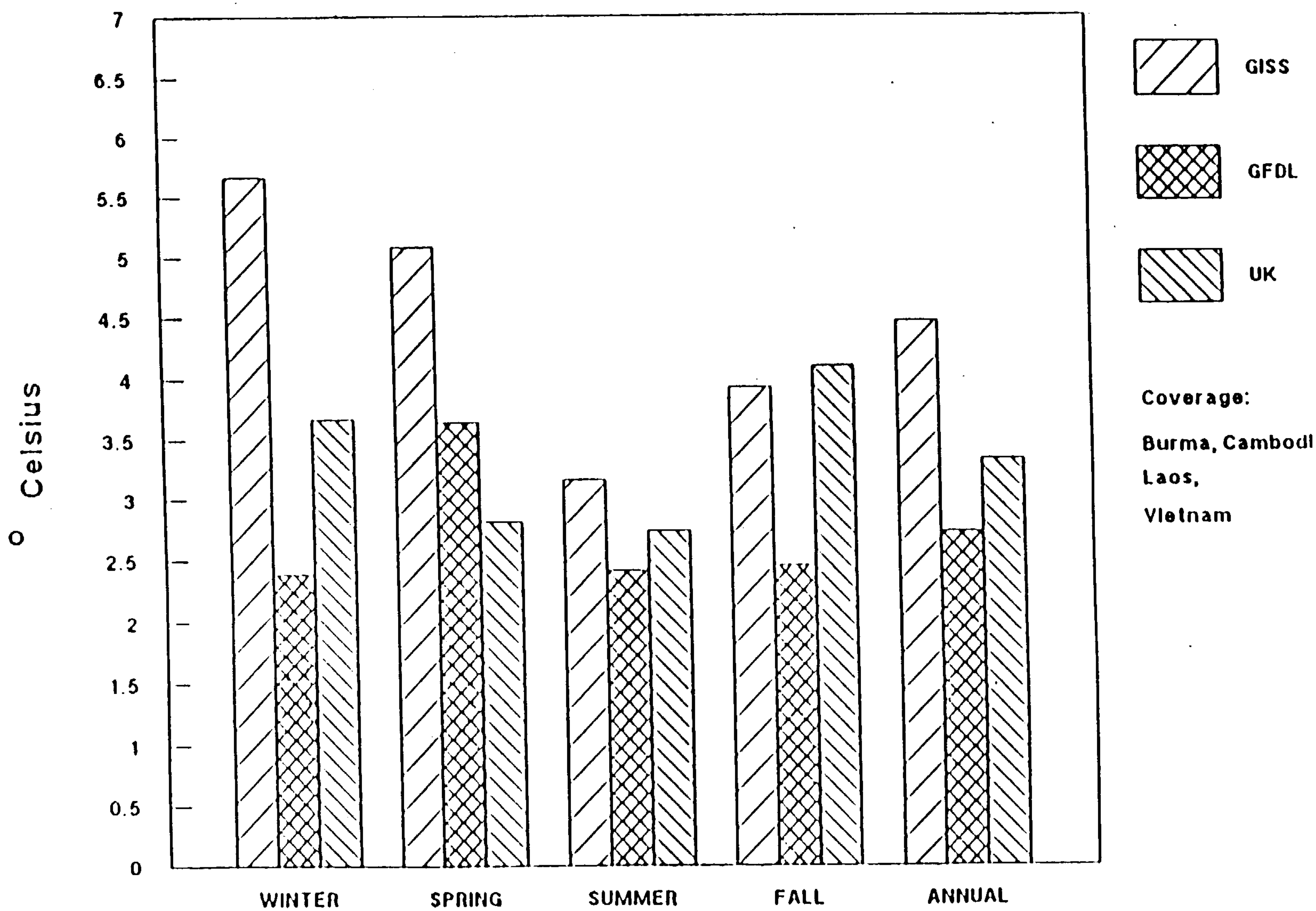
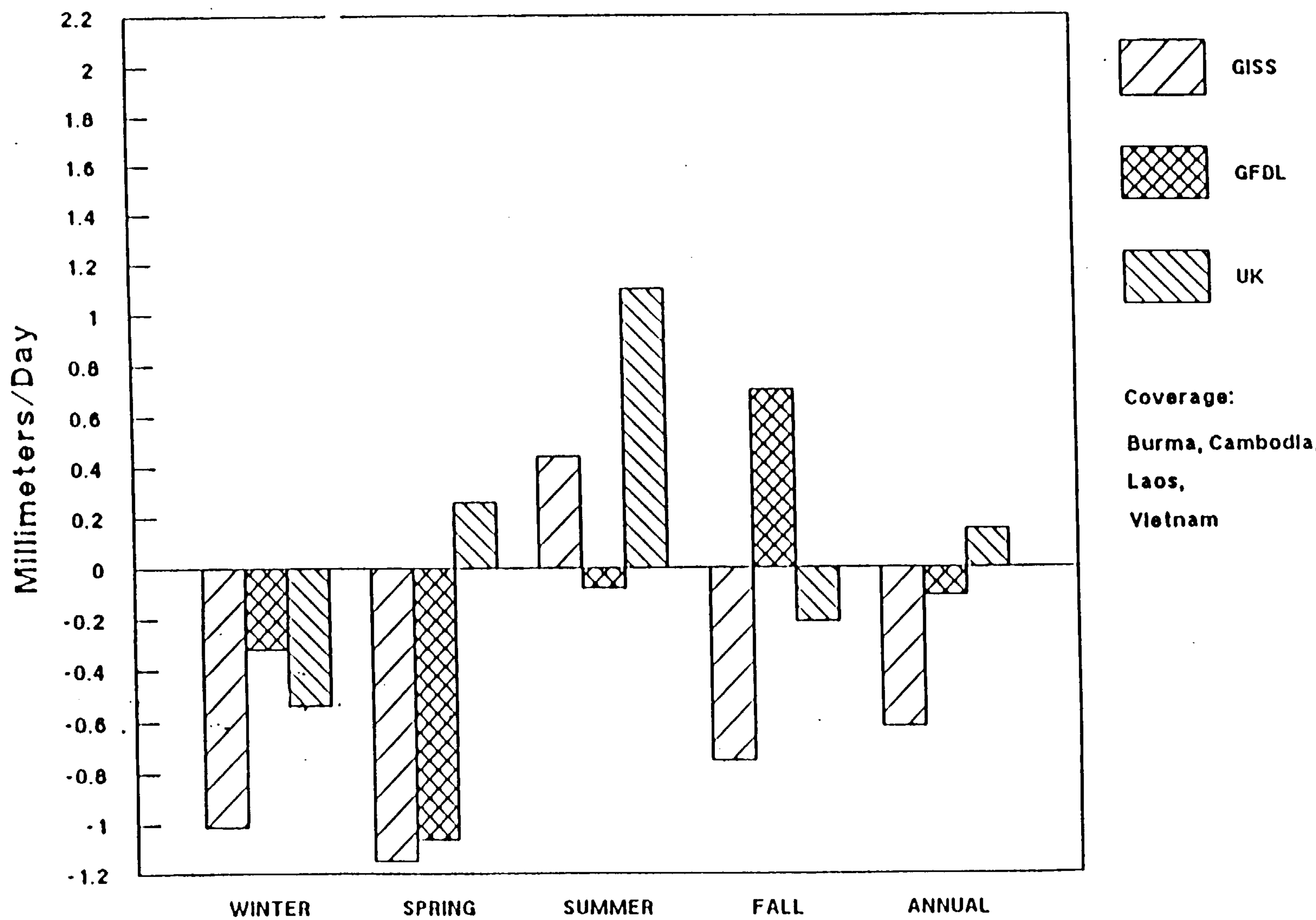


Figure 2

SOUTHEAST ASIA

Precipitation Change for Doubled CO2



a climate of the late 1950s, with today's climate falling somewhere in between a 1xCO_2 and a doubled CO_2 level (henceforth called the 2xCO_2 scenario).

Two types of GCM runs can be generated: equilibrium runs and transient runs. The equilibrium runs instantaneously double the amount of atmospheric carbon dioxide and the model is run until it reaches thermal equilibrium. There is no reference to a rate of change of temperature, precipitation, etc., in an equilibrium run of the models. These runs simply represent a 2xCO_2-atmospheric steady state at some time in the future. This type of run for the GISS model has been used to generate likely changes in climate variables for Southeast Asia and for the island of Java, Indonesia in this study.

Transient model runs gradually increase the amount of CO_2 in the model and produce new climate conditions for every future decade. The rate of increase of atmospheric carbon dioxide, essential in such runs, depends on estimates of future population and energy use. Different rates of CO_2 increase will result in different rates of warming (see Hansen et al., 1988). Since carbon dioxide is actually increasing over time, a transient run is potentially the more realistic of the two types of run. However, transient models require more costly computing time and, consequently, are not used as often.

The model-generated numbers in the GCM output data sets are all based on the input of starting values provided from historical sources. Temperature differences between the 1xCO_2 scenario and the 2xCO_2 scenario are computed by month, season, and annually. Precipitation differences are expressed as a ratio of the 2xCO_2 value to the 1xCO_2 value. The model also calculates other variables such as solar radiation and runoff. Surface runoff would, of course, be of interest but the GCM runoff results are considered not to be at all reliable.

While the scientific community appears to place confidence in GCM predicted worldwide average changes in variables like temperature and precipitation, the models are known to represent regional changes badly, especially in heavy monsoon regions or where topographic features such as mountains dominate surface weather formation. This difficulty can be seen in the 1xCO_2 and 2xCO_2 precipitation outputs generated by the GISS model for the window containing Java and shown in Figure 3. The model output shows rainfall peaking in May or June, while the historical data indicates those months beginning the dry season (see monthly historical data in Table 1 on page 16).

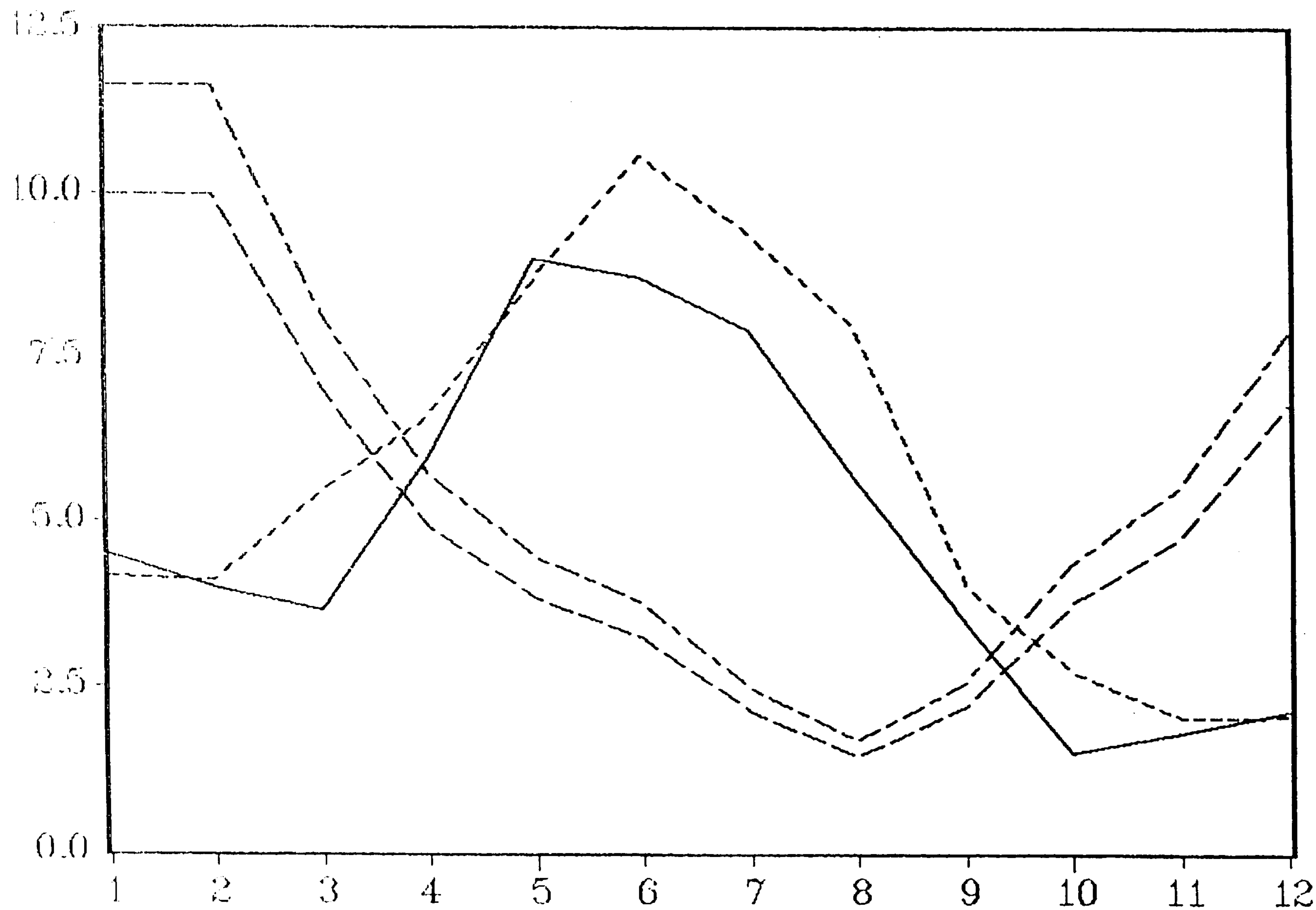
III. LIKELY IMPACTS OF CLIMATE CHANGE ON SOUTHEAST ASIA

For much of Southeast Asia, it seems likely that temperatures will rise, precipitation will fall, and that some sea-level rise will occur. This is supported by Figures 1 and 2. However, there will be differences in the changes among areas. Temperature, precipitation and sea level changes also will impact different sectors of the national economies of the region in different ways. We have summarized the most important potential impacts in the accompanying Impacts Matrix (Figure 4).

Sea-level rise seems the most likely outcome of global change. Current knowledge is not adequate to make an accurate prediction of future sea level rise, but it is important to predict the likely range. It has been suggested that global warming, due to increasing atmospheric CO_2, would be able to melt the west Antarctic ice sheet and, combined with a rise in the temperature of the surface ocean layer, would raise the global sea level about 0.3 to 0.5 m by 2050 and about 1 m by 2100 (IPCC, Working Group I, 1990). Sea level rise

Figure 3

Model Generated and Historical Rainfall for Java



$P1XCO_2$ = Precipitation under current CO_2 based on the GISS model
$P2XCO_2$ = Precipitation under double CO_2 based on the GISS model
$PH1CO_2$ = Historical precipitation under current CO_2
$PH2CO_2$ = Historical precipitation under double CO_2[1]

Figure 4
IMPACTS MATRIX FOR SOUTHEAST ASIA

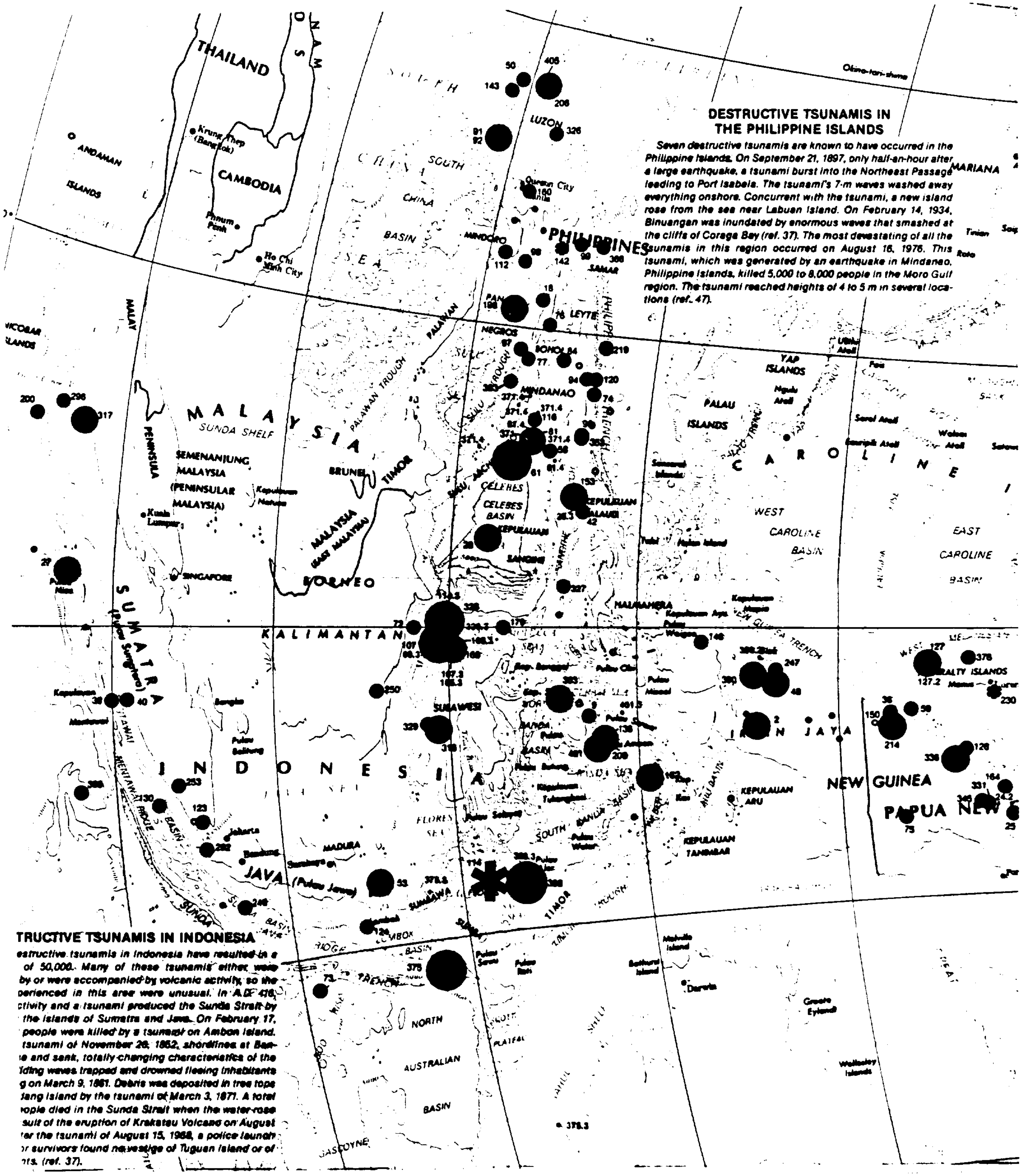
SECTORS:	Agriculture	Fisheries	Forestry	Energy	Water Systems	Direct Human Impacts
CLIMATE CHANGES: Sea Level Rise	Loss of coastal rice paddy Loss of floating rice in estuaries Increased storm surge damages Loss of coastal irrigation systems	Loss of wetland breeding areas Loss of mangrove swamps in nutrient chain Loss of reef protection	Loss of mangrove pole production More agriculture pushed into forest areas, cutting of forests More agroforestry	Temporary increase in in use due human resettlement	Salt water intrusion into ground-water systems	Coastal resettlement required Increased storm surge damage
Increased Temperatures	Yield reductions in field crops and horticulture, possibly partly offset by increased CO_2 Greater storage problems for grains, especially rice	Damage to coral reefs Reduction in survival rate in flood areas	Reduced growth rates Reduced productivity of agro-forestry	Increased demand demand for air conditioning and other cooling	Greater evapo-transpiration	Discomfort, lower productivity Heat-related illness Increased population in higher altitude areas
Changes in precipitation (probably small annual decrease averaged over Southeast Asia)	Small losses for paddy rice but large losses for dryland dry season crops	Reduced riverine breeding areas during flood season	Reduced growth rates of trees	Reduction in hydro-electric output, especially in dry season	Loss of irrigation water, especially during dry season Loss of some potable surface-ground supplies	Reduced quantity/quality of drinking water

of as little as 0.15 m may double the probability of damaging storm surges along some coastlines (Gortnitz, et al., 1982).

Among the impacts of sea level rise are shoreline retreat, increased flooding, and landward movement of salt water in fresh water aquifers. Shorelines will retreat since the low land will be covered and other land along the shore which is not as low will be eroded. A rise in sea level also allows storms, especially tsunamis in the case of Southeast Asia, to strike and erode the beach farther inland. Low-lying areas not lost to a rising sea will experience increased flooding. According to Hoffman, 1983, a typical scenario would be the following: the higher sea level will provide a higher base on which storm surges can build. Beach erosion and deeper water may allow large waves to strike farther inland. Tsunamis which frequently impact Southeast Asia will strike further inland. Figure 5 shows the high incidence of tsunamis in Southeast Asia.

Sea-level rise will also cause both surface and sub-surface salt water to move landward. This will alter local availability of fresh water as aquifers become saline and as riverine salt tongues move further inland. Coastal ecosystems such as mangroves will be affected. Mangroves provide shoreline protection from action of waves and promote the accretion of sediment to build up new depositional terrain above the high-tide level. Mangrove swamps are the basis for most riverine, estuarine, and coastal fisheries in the tropics. Detritus from mangroves forms the basis of the food chain for both shrimp, other crustaceans, and many varieties of fish. Mangroves are also extremely valuable as a source of building materials, providing long, strong, slender poles for all types of local construction. However, mangroves require alternating salt and fresh water to survive. With sea level rise, current mangrove swamps may be fully immersed in salt water.

Figure 5
Destructive Tsunamis in Indonesia and Philippines



ce: Lander, 1989

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Although mangroves are quick to regenerate and spread to suitable habitats as the sea level rises, present land-use patterns and intensities will prevent this natural adaptation (Hekstra, 1989). Since paddy rice and swamp rice are major agricultural products in the tropics, land immediately inland from the mangroves is usually used intensively. The spread of mangroves would be prevented by this intensive use and many mangrove stands would disappear. In the Gulf of Thailand (specifically the bight of Bangkok), the mangrove fringe already has been largely cleared, and landward canals, dug to bring fresh water to the rice fields, have become channels for the intrusion of salt water and storm surges from the sea (Hekstra, 1989).

The impact of sea level rise on migration and transmigration may become very important. The situation in Indonesia is described in Section IV. Surveys and careful feasibility studies that take into account the possibility of sea level rise are needed before settling transmigrants.

There seems to be general agreement that average global temperatures will rise. In Southeast Asia, this increase will be imposed on top of levels of temperature and humidity that are already debilitating in many areas. The effects of termperature increases are likely to be reductions in plant, animal, and human productivity and net human migration to higher altitude areas. Greater evapotranspiration will increase the demand for irrigation water while diminishing supplies.

The consensus of the GCM models is that rainfall will decrease for Southeast Asia as a whole. The seasonal pattern of changes will be critical. Less rainfall during rainy seasons probably would have negative net effects on crop yields but would tend to reduce flood damage. Less rainfall during the dry season could be highly damaging to dry season upland crops. Decreased dry season precipitation would decrease base-load capabilities of hydropower.

IV. CLIMATE CHANGE IN INDONESIA

When the paucity of data and the difficulty of communication with the appropriate agencies in the several Southeast Asian countries became evident, it was decided to study Indonesia most intensively -- as a special case study to take advantage of the authors' extensive experience in Indonesia. After library research, the next activity was an attempt to determine which research activities in Indonesia are related to climate change. The following agencies or institutions were contacted: (1) the Ministry of Population and Environment; (2) The University of Indonesia; (3) The Ford Foundation; (4) the U.S. AID Mission; (5) Gadjah Mada University; (6) Bogor Agricultural Institute; and (7) Bandung Institute of Technology.

Some of these sources then directed us to the Meteorological and Geophysical Agency that was primarily concerned with measuring standard meteorological variables; the National Institute for Space and Aeronautics that focused on ozone, CO_2 and aerosols in the atmosphere; the Geophysical and Meteorological Department at Bandung Institute of Technology that was doing research on sea-level rise at a very micro level (measurement and effects at Jakarta and Surabaya); and the Agrometeorological Department at Bogor Agricultural Institute that is conducting a study of the impacts of climate variability in conjunction with the UNEP project "Socio-Economic Impacts and Policy Responses Resulting from Climate Change: A Study in Southeast Asia". While the last two studies sound highly related to climate change, we were unable to obtain study results or reports.

We conclude from these attempts that there is a low awareness of the issue of global climate change with low commitment of research or policy resources to the topic. While Indonesia's efforts may be better than those of other Third World or low middle income countries, one would think that the obvious relevance of major climate changes to a nation of 13,000 islands would prompt greater concern.

Temperature and Precipitation Changes for Java

The GISS model has a cell that centers on Java reaching somewhat beyond the island but not encompassing any other major islands. Values predicted by the GCMs are averaged within the entire rectangle, *e.g.* temperature, temperature change, precipitation, precipitation change, etc. Table 1 gives the steady-state model outputs by month for precipitation and temperature for the $1xCO_2$ and $2xCO_2$ scenarios.

Also included in the table are historical monthly precipitation data averaged over various weather stations for the period 1951-1986 and our best estimate about the likely precipitation pattern under the $2xCO_2$ scenario. The latter series is simply the historical series raised by 16.5% (in contrast to the decrease shown in Figure 2 for other parts of Southeast Asia). The percentage increase in annual precipitation was used in place of monthly changes because of the extreme deviation of model-predicted rainfall from the historical monthly pattern. However, this deviation may simply indicate that the model is basically not very good, but it is all we have for Indonesia.

Table 1 also includes the historical monthly surface temperatures ($TH1CO_2$) and our best estimate of monthly temperatures under the $2xCO_2$ scenario, ($TH2CO_2$). We determined the latter by adding the change in average annual temperature predicted by the model (3.73 degrees) to the historical series.

TABLE I

Precipitation and Temperature of Java

	$P1XCO_2$ mm/day	$P2XCO_2$ mm/day	$PH1CO_2$ mm/day	$PH2CO_2$ °C	$T1XCO_2$ °C	$T2XCO_2$ °C	$TH1CO_2$ °C	$TH2CO_2$ °C
January	4.4910	4.1440	9.9910	11.635	27.020	30.830	26.110	29.840
February	3.9710	4.0790	9.9910	11.635	27.190	31.100	26.110	29.840
March	3.6350	5.4530	7.0270	8.1830	27.200	31.170	26.670	30.400
April	5.9330	6.5810	4.9110	5.7190	27.410	31.110	27.220	30.950
May	9.0150	8.7360	3.8100	4.4370	27.650	31.240	27.220	30.950
June	8.7350	10.589	3.2170	3.7460	27.420	31.310	26.940	30.670
July	7.9500	9.4030	2.1170	2.4650	26.760	30.520	26.670	30.400
August	5.6180	7.9640	1.4400	1.6770	26.100	30.010	26.670	30.400
September	3.4520	4.0060	2.2010	2.5630	25.660	29.250	27.220	30.950
October	1.4900	2.7180	3.7250	4.3380	25.660	29.270	26.940	30.670
November	1.7990	2.0150	4.7410	5.5210	26.040	29.640	26.670	30.400
December	2.120	2.0390	6.7730	7.8870	26.540	30.060	26.390	30.120

$P1XCO_2$ = Precipitation under current CO_2 based on the GISS model
$P2XCO_2$ = Precipitation under double CO_2 based on the GISS model
$PH1CO_2$ = Historical precipitation under current CO_2
$PH2CO_2$ = Historical precipitation under double CO_2[1]
$T1XCO_2$ = Temperature under current CO_2 based on the GISS model
$T2XCO_2$ = Temperature under double CO_2 based on the GISS model
$TH1CO_2$ = Historical temperature under current CO_2
$TH2CO_2$ = Historical temperature under double CO_2[2]

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1 $PH2CO_2 = PH1CO_2 + (PH1CO_2 \times 16.454\%)$, where $16.454\% = (P2XCO_2 - P1XCO_2) / P1XCO_2$ (yearly)

2 $TH2CO_2(\text{monthly}) = TH1CO_2(\text{monthly}) + [T2xCO_2(\text{yearly}) - T1XCO_2(\text{yearly})]$

Thus we have assumed that the general shape of the historical monthly pattern of precipitation and temperature will be largely maintained but will be augmented by increasing monthly precipitation by 16.5% and monthly temperature by 3.6°C: i.e. that Java would be hotter and wetter. The most likely patterns of precipitation were exhibited in Figure 3. The model predictions of temperatures under the $1xCO_2$ and $2xCO_2$ scenarios are shown in Figure 6, along with the historical average monthly temperatures increased by 3.6°C.

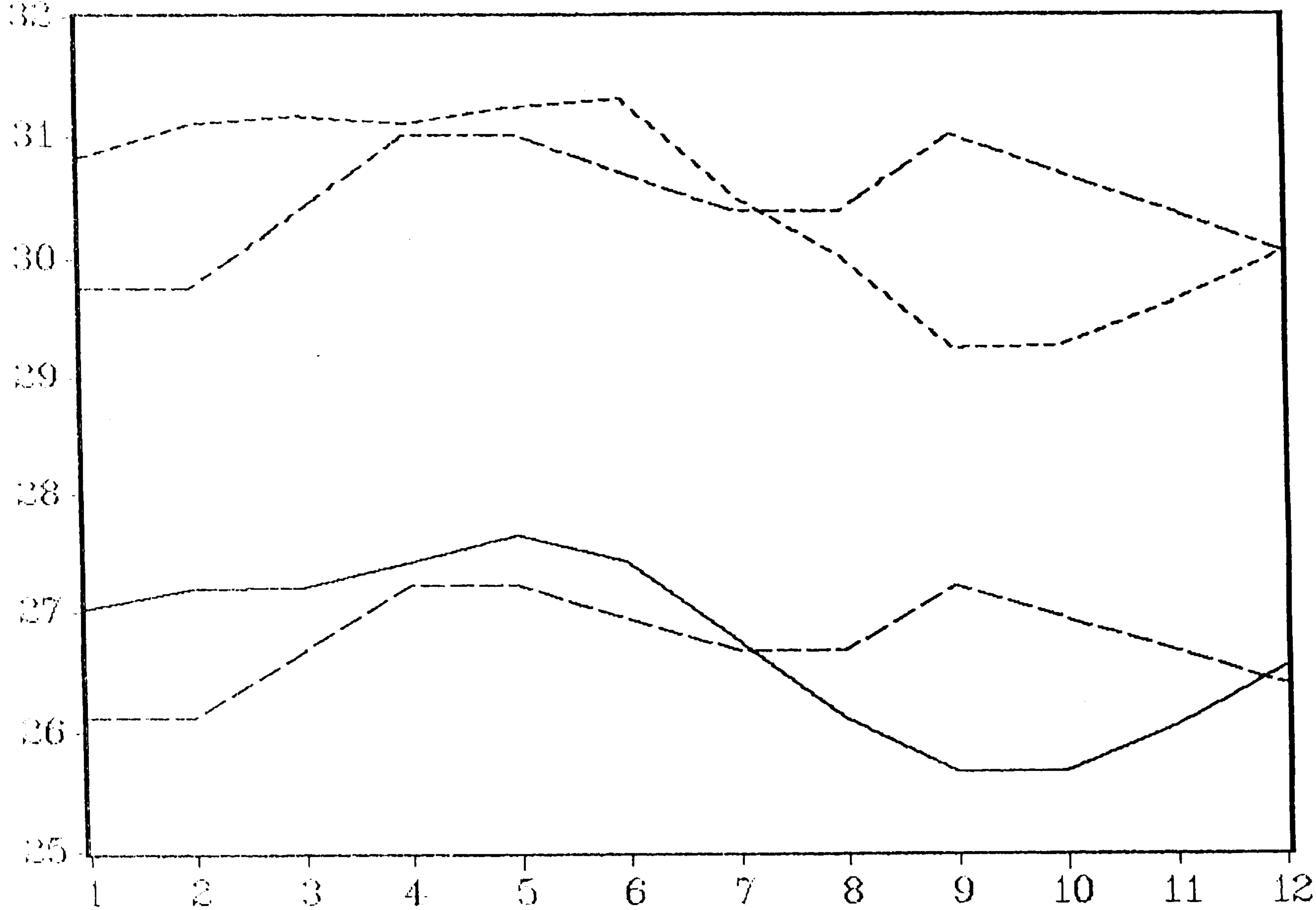
The lack of agreement between model calculations and historical data raises a question: How can one make policy based on models that are patently suspect? There are two answers to this question. First, in the present study we have made some bold assumptions about how the climate will change, and have moved ahead to consider policy questions, with full realization that our considerations are no better than our assumptions. Second, one can make a policy decision to improve the models -- a decision that has been made and is now being implemented. An important result of this work is to validate the importance for policy of such implementation.

We must now explore some of the implications of these changes. We recall from the impacts table that agriculture is the sector most likely to be affected by all dimensions of climate change: Temperature, CO_2, precipitation, and sea level rise. The major crops of Indonesia are shown in Table 2.

"Paddy sawah" is continuously flooded paddy rice, the main crop and staple of Indonesia. Its production will be affected in the following ways:

Figure 6

Historical and Predicted Average Monthly Temperatures



$T1XCO_2$ = Temperature under current CO_2 based on the GISS model
$T2XCO_2$ = Temperature under double CO_2 based on the GISS model
$TH1CO_2$ = Historical temperature under current CO_2
$TH2CO_2$ = Historical temperature under double CO_2

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TABLE 2

Production and Yield Rate of Major Food Crops of Indonesia

(thousand ton)

Crops	1982	1983	1984	1985	1986
Paddy Sawah	31,775.6	33,294.3	36,017.3	37,027.4	37,739.6
Paddy Ladang	1,808.0	2,008.8	2,119.1	2,005.5	1,987.1
Maize	3,234.8	5,086.9	5,287.8	4,329.5	5,920.4
Cassava	12, 987.9	12,102.7	14,167.1	14,057.0	13,312.1
Sweet Potatoes	1,675.6	2,213.0	2,156.5	2,161.5	2,090.6
Peanuts	436.8	460.4	534.8	527.9	641.9
Soyabeans	521 .4	536.1	769.4	869.7	1,226.7

Source: Biro Pusat Statistik, 1987

1. During the rainy season, the added rainfall will have little or no affect on currently cultivated sawah. In typical rainy seasons, there is plenty of water. Sawah is limited by lack of suitable land.

2. During the dry season, the area of sawah is typically about 35% of that cultivated during the rains. With the 16.5% increase in dry season precipitation, some expansion of sawah will occur.

3. Sea level rise will cause a loss of sawah in low coastal areas, for example in West Java and in coastal areas of Sumatra, East Kalimantan, Sulawesi, and Irian Jaya. Table 4 identifies the general areas at high risk from sea level rise.

4. The increase in CO_2 in the air will have a slight positive effect on yields.

5. The effect of increased temperature on sawah is likely to be negligible. Table 3 suggests that the projected temperature range of approximately 29° to 31°C is in keeping with the "optimum" temperature ranges for all stages of plant growth. Since nearly all Indonesian paddy rice is transplanted from seed beds, the upper limit on "seeding emergence and establishment" can be maintained by site selection and shading of seed beds. The impact on "rooting" after transplanting could be negative, since the optimum range is indicated to be 25° - 28°C.

The net effect of temperature and precipitation changes on paddy rice is thus difficult to quantify, some of the factors above being positive, others negative. It appears likely that there will be no large-scale changes in paddy rice production on an annual basis.

Dryland rice (paddy ladang) is of much less importance than paddy rice in Indonesia but is much more subject to vagaries of climate. It is grown only during the rainy season

TABLE 3

Response of Rice Plant to Varying Temperature at Different Growth Stages

	Critical Temperature (°C)		
Growth Stages	**Low**	**High**	**Optimum**
Germination	16-19	45	18-40
Seeding emergence and establishment	12	35	25-30
Rooting	16	35	25-28
Leaf elongation	7-12	45	31
Tillering	9-16	33	25-31
Initiation of panicle primordia	15	---	---
Panicle differentiation	15-20	30	---
Anthesis	22	35-36	30-33
Ripening	12-18	>30	20-29

Source: De Datta, 1981, Table 2.4 (Adapted from Yoshida, 1978) and the additional precipitation projected (16.5% of a very low 1.0 mm/day) will not be sufficient to permit dry season planting. However, the increased rainfall should enhance the yields during the rainy season. The cultivated area is likely to expand to a small extent. Overall, the production of dryland rice will be increased, but not to an extent of national importance.

The impacts of the projected temperature and precipitation changes on the remaining crops (maize, sweet potatoes, peanuts, cassava, and soybeans) will be much the same as the effects on dryland rice. With the exception of cassava, these crops are planted only in the rainy season and grown without irrigation. The increased precipitation will enhance all the crops, while the higher temperatures may have some negative effects on maize and soybeans.

In summary, the effects of projected temperature, precipitation and CO_2 changes on food production in Indonesia are likely to be positive from the point of view of plant physiology. Losses of paddy rice in flooded and storm-damaged areas will occur as a result of sea level rise, but this will be at least partially offset by increased water for field crops during the rainy season.

There will be negative effects on livestock, especially dairy cattle, which already suffer from high temperatures during the dry season. The agricultural labor force will also be negatively affected by the hotter, more humid climate.

The remaining important impact of increased precipitation will be on flooding and reservoir storage. Seasonal flooding is a problem throughout Indonesia. During the rainy season, rivers are continuously at flood stage, causing transportation problems, flooding fields, and frequently flooding towns. Flash floods kill significant numbers of people each year. Soil erosion is very high during the rains, and the flooded streams carry the soil to the sea. In some areas, e.g. the north coast of Java, this silt load affects fishing and fish breeding areas. Beaches are adversely affected.

Increased rainfall will exacerbate the flooding and siltation problems. Opportunities for building dams to contain flood waters are severely limited by geography and economics: there are few good reservoir sites and the construction costs of dams and the opportunity costs of the land required are very high. Dams for the seasonal storage of flood waters and provision of irrigation are uneconomic in most parts of the world, even where good dam sites exist and where "high-tech" agriculture can control and utilize the water effectively. There is little opportunity for changing these patterns in Indonesia.

Sea Level Rise

The impact of sea level rise on migration and transmigration in Indonesia may become very important. Since two-thirds of the population lives in Java but a high proportion of natural resources are in Sumatra and Kalimantan, the Indonesian government has been trying to transfer millions of inhabitants from Java to those islands. Unfortunately, tidally influenced swamps of those islands have been selected for settlement sites. Immigrants are not only faced with serious problems such as fresh water and soil compaction that limit their prospects for future agriculture adjustment, but they also face social and culture difficulties. These problems will become worse with sea level rise. Indonesian areas judged to be at high risk are listed in Table 4.

TABLE 4

INDONESIAN AREAS AT HIGH RISK FROM SEA LEVEL RISE

Area	Latitude	Longitude	Description
Sumatra:			
Lhokseumawe	N5^0	E97^0	Swamp
Tanjungbalai	N3^0	E100^0	Swamp
Rantau Prapat	N2^0	E100^0	Mangroves
Bagan Siapi-api	N2^0	E101	Mangroves
Pakanbaru	N1^0	E101^0	Mangroves
Jambi	S1^0	E103^0	Mangroves
Palembang	S3^0	E105^0	Mangroves
Java:			
Tanjung Krawang	S6^0	E107^0	Paddy
Ujung Kulon	S7^0	E105^0	Mangroves
Pangandaran	S8^0	E108^0	Mangroves
Grajagan	S9^0	E114^0	Mangroves
Bali:			
Kuta	S9^0	E115^0	Swamp
Borneo:			
Samarinda	S1^0	E117^0	Mangroves
Balikpapan	S2^0	E117^0	Mangroves
Banjarmasin	S3^0	E115^0	Swamp/Mangroves
Sampit	S3^0	E113^0	Swamp
Sulawesi:			
Pasangkayu	S1^0	E119^0	Swamp
Palopo	S3^0	E120^0	Mangroves
Timor:			
Kupang	S10^0	E124^0	Swamp
Dili	S8^0	E126^0	Swamp
Irian Jaya:			
Inanwatan	S2^0	E132^0	Mangroves
Kokonau	S5^0	E136^0	Swamp/Mangroves
Agats	S6^0	E138^0	Swamp/Mangroves
Pulau Yos Sudarsa	S8^0	E138^0	Mangroves
Merauke	S9^0	E140^0	Swamp/Mangroves
Teba	S1^0	E138^0	Mangroves

V. PROBLEMS IN ADAPTING TO CLIMATE CHANGE IN SOUTHEAST ASIA

Human adaptation to climate change, along with the climate change itself, will determine the net effects of the change. Adaptations take many forms, including moving to new locations, changing cropping patterns, changing housing structures, etc. It is desirable to obtain timely and well-informed adaptations, although the optimal speed of adaptation depends on the uncertainty surrounding the change.

Societal responses to variability of local weather and to regional climate change have been extensively studied as a key to actions that might be useful in response to global climate change (see Sewell, Rosenberg et al. 1989; Riebsame & Jacobs, 1988; Glantz, 1989). It follows that factors that inhibit adaptation will increase the human and environmental costs of global climate change. A major factor that is inhibiting careful consideration of possible adaptations to climate change is the great uncertainty contained in all forecasts. While there may be broad scientific agreement on the global changes likely to ensue from CO_2, methane, and CFC build-up, there are still enough skeptical voices in the scientific community to occasion caution in policy matters. The regional inaccuracies of the GCMs inhibit policymaking since many adaptive policies must be taken on a regional level, *e.g.* response to drought, developing water supply, conserving water and energy, and preparing for floods.

In the Third World, the immediate pressures of agricultural production, industry, employment, health, and population make it difficult to give much weight to problems that lie far in the future. Although the countries of Southeast Asia rank for the most part in the lower middle-income range (as defined by the World Bank), they still face pressing problems of rural poverty, education, health and population control. Because of the global common-property nature of the atmosphere, oceans, forests, and fisheries, it is difficult for any one country to justify committing resources and effort to planning for adaptation to uncertain future climate change.

In the field of agriculture, adaptation is based on knowing how different crops will respond to various scenarios of climate change. Crop response functions are highly specific to regions and are costly to derive from field experiments. Many countries have not developed the information that would, if available, permit the forecasting of both the effects of climate change and the effectiveness of different adaptations.

In some countries, high population densities make some forms of adaptation difficult. On the island of Java where average population density exceeds 1000 persons per square kilometer, no "new" land exists for resettlement of persons displaced by sea level rise or increasing drought. As noted earlier, if land is uninhabited, mangroves would move inland at appropriate spots as sea levels rise. If, however, those inland areas are populated by persons with no alternative locations, mangrove migration will be stopped.

Cultural diversity can increase the complexity of adaptation by making relocation difficult. In parts of the Third World, major conflicts have been incited by trying to resettle culturally and ethnically diverse groups on land claimed by others.

VI. THE NEED FOR FURTHER STUDIES

Clearly, a lot of uncertainty remains in the preceding projections. Yet some change is indicated, and countries with so much at stake as those of Southeast Asia cannot afford to ignore the implications of today's estimates of future climate conditions. The most obvious need is for an accurate assessment of the effects of a 0.5 to 1.5 meter sea level rise on the important islands and coastal areas of Southeast Asia. Since the past century has exhibited slow but continuous sea level rise, it seems likely that these processes will continue and perhaps accelerate. The Indonesian areas of high risk presented in Table 4 are crude estimates.

A second need is for studies of the effects of climate change on forests which are major carbon sinks, the sources of most of the world's hardwoods, and the potential home of expanded agro-forestry. At present, the main forestry problem is short-sighted, unsustainable management. The effects of climate change on forest growth, regrowth, and on agro-forestry could be profound.

The effects of the projected changes on the human population will be very important, especially relating to health and work productivity. Water-related diseases like malaria and dengue fever have been resurging in some regions of Southeast Asia. The implications for the vectors of these and other diseases need to be explored.

The tropical climate is debilitating at present, although the hard work of rural people throughout Southeast Asia belies this. Sickness is endemic and takes a large toll in human productivity and well being. Those who have experienced the heat and humidity of Southeast Asia will realize that a temperature increase of 3.6°C would make work much more difficult, living much less comfortable. Cities can install more air conditioning, but this will be beyond the financial capabilities of many urban dwellers and physically impossible in rural areas. These direct human impacts may be the most significant effects of all.

APPENDIX A

DESCRIPTION OF SOUTHEAST ASIAN COUNTRIES

Indonesia

The Republic of Indonesia is a geographically diverse country spread across an archipelago of more than 13,000 islands, with a land area of about two million km^2. It is a part of the Malay archipelago in Southeast Asia, located between N6^{0}08' and S11^{0}15' latitude and between E94^{0}45' and E141^{0}05' longitude. Indonesia has a population of approximately 200 million that is growing at 2.0 percent annually. It is the world's fifth most populous nation. Jakarta is the capital city of Indonesia located in West Java.

Sumatra, Java, Kalimantan (formerly known as Borneo), Sulawesi, Madura, Bali, East and West Nusa Tenggara, Timor, Maluku and Irian Jaya are the major islands, yet two-thirds of the population lives in Java, which has one of the highest rural population densities in the world. On the other hand, a high proportion of some primary resources such as energy resources, timber, mineral and agricultural commodities are located in the less populated islands like Sumatra, Kalimantan and Bali. Eighteen percent of the land is used for agriculture with the major crops being paddy sawah[3], paddy ladang[4], cassava, maize, potatoes, peanuts, and soyabeans.

In general, as a tropical country located on the equator, Indonesia has a climate of high humidity, usually 80 to 90 percent; high temperatures, for most areas, a mean monthly

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[3]Paddy sawah is wet land paddy which means any kind of rice grown under flooded field conditions.

[4]Paddy ladang is dry land paddy which means any kind of rice grown under rain-fed conditions in fields without flooding.

temperature of 22 to 27 degrees Centigrade; and high rainfall. In 1986 Padang, West Sumatra received 14.39 mm/day (Biro Pusat Statistik, 1987).

Malaysia

Malaysia is at the southern end of the Malay Peninsula. The nation also includes Sarawak and Sabah on Kalimantan island. With a mountain range running the length of the Peninsula, the country has an area of 332,370 km^2 and is mostly covered by dense jungle and swamps. (Taylor, 1981). Furthermore, with population around 17.4 million (est. mid-1989 by the 1990 Almanac), Malaysia is a multiracial society, with approximately 60 percent Malays and other indigenous groups, 31 percent Chinese, and the remainder largely Indian. Kualalumpur is the capital city of Malaysia.

Although the Malaysian economy has undergone some important structural changes, the agriculture sector still remains a major dynamic force, with plantation crops like palm oil, cocoa, and logs. Output of the food crops, especially paddy rice, has fallen in recent years, in part because of the migration of the young and educated people from the farms to towns and from agriculture to industrial occupations.

As a country located close to the equator, similar to Indonesia, Malaysia also has a climate of high humidity (commonly 82 to 86 percent), high temperatures (around 25 to 27 degrees Centigrade), and high rainfall (most areas receive daily between 5.21 and 10.14 mm) (Taylor, 1981).

Thailand

Thailand occupies the western half of the Indochinese Peninsula and the northern two-thirds of the Malay Peninsula in Southeast Asia. Its neighbors are Laos on the north and northeast, Cambodia on the east, Malaysia on the south and Burma on the north and west. The area of the country is 514 thousand km^2 and the population is about 55.6 million (est. mid-1989), most of it is supported in the fertile central alluvial plain drained by the Chao Phraya River and its tributaries. Bangkok is the capital city.

Even though the development and modernization of the Thai economy have taken place rather steadily over many decades, these processes in the last ten years seem to have qualitatively changed the economic structure. In 1978 agriculture was still the leading sector, producing 24.5 percent of GDP (Gross Domestic Product), while manufacturing produced 20.0 percent. By 1981, manufacturing had replaced agriculture as the largest sector and by 1988, the share of manufacturing had increased to 24.4 percent, while that of agriculture had declined to 16.9 percent (World Bank, 1989). Rice was the leading export commodity for many years, but by 1985 it was surpassed by textiles. Thailand is now undergoing a rapid transformation from a primarily agriculture-based economy to an industrial economy.

Thailand has a climate of high humidity. Historically Bangkok's average daily temperature is around 23 to 33 degrees Centigrade and its daily average precipitation is 4.02 mm (Ruffner and Blair, 1984).

Philippines

The Philippine Islands are an archipelago of over 7,000 islands lying about 500 miles off the southeast coast of Asia. Only 7 percent of the islands are larger than one square mile, and only one-third have names; the largest are Luzon in the north, Mindanao in the south and Samar (the 1990 Almanac). With an area of 300 thousand km^2, the Phillipines have a population of about 65 million (est. mid-1989). Population growth remains high at 2.8 percent per year. As the population grows, the pressure on rural land mounts, and poor farm families migrate to new upland locations or to the cities. The results are a rising level of unemployment in urban centers and a deterioration of upland forests as migrants settle land unsuitable for conventional farming techniques. Manila is the capital city located on Luzon island.

About 41 percent of the land is used for agriculture with the major crops being coconut, sugarcane, rice, corn and tobacco. Agricultural productivity has been affected by the gradual deterioration of soil and forest resources as a result of rapid population growth in upland areas and weak public sector management. The productivity of coastal fishermen is also affected since shifting cultivation in upland areas and poor soil management techniques lead to erosion which causes siltation of rivers and corral reefs. Also, poor management of forest resources has resulted in over-extraction of prime species without adequate replanting for future production.

In general, like other southeast Asian countries, the Philippines has a climate of high humidity. Manila has average daily temperatures of 23 to 32 degrees Centigrade and daily average precipitation of 5.71 mm. (Ruffner & Blair, 1984).

Singapore

The Republic of Singapore is the smallest country in Southeast Asia, with an area of 570 km^2. The population is 2.7 million and the country consists of the main island of Singapore, off the southern tip of the Malay Peninsula between the South China Sea and the Indian Ocean. There are extensive mangrove swamps extending inland from the coast, which is broken by many inlets (the 1990 Almanac). The capital city is also called Singapore.

Agriculture accounts for only 11 percent of the land use; the main crops are vegetables and fruits. The economy is concentrated mainly in petroleum products, ship repair, rubber processing, electronics, and biotechnology. The per capita income is $14,435 (1987), the highest among the southeast Asian countries.

Singapore's climate is very humid. Its has a high temperatures (commonly between 23 to 31 degrees Centigrade) and a high rainfall (daily average precipitation of 6.61 mm) (Ruffner and Blair, 1984).

Brunei

Brunei is an independent sultanate on the northeast coast of Kalimantan island in the South China Sea, wedged between the Malaysian states of Sabah and Sarawak. About three-quarters of the thinly populated country is covered with tropical rain forest which contains rich oil and gas deposits. With a population of 300,000 (est. mid-1989), Brunei is the smallest country in Southeast Asia. The capital city is Bandar Seri Bengawan.

With an area of 5,765 km^2, Brunei uses only 3% of its land for agriculture; the principle products are fruits, rice and pepper. Like Singapore, this country tends to concentrate in crude petroleum and liquified natural gas. Brunei's climate is very humid, relatively hot, and has heavy rainfall.

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