University of Colorado at Boulder

Center for Space and Geosciences Policy

Norlin S549
Campus Box 361
Boulder, Colorado 80309-0361
(303) 492-1171

April 1, 1991

Dr. Dixon M. Butler
NASA HQ Room B209
Code EEU
NASA
Washington, DC 20546

Dear Dr. Butler:

We are pleased to report on our progress during year 2 of NASA Grant 1415 in support of Research in Geosciences Policy. The complete annual report for the second year is attached to this letter. We have separately requested a no-cost extension of the second year (my letter of February 8, 1991) and work during that extension will be separately reported at its conclusion.

This letter summarizes our activity in the two proposed tasks. The attached report contains full reports. The first section of the attached report, "Introduction and Rationale", raises several interesting points that indicate how our results support a broader program of research on global change. I especially commend that section to your attention.

SUMMARY OF YEAR 2 ACTIVITY

TASK 1.: Preliminary Research on Adaptation to Global Change

We proposed to study cases of difficult adaptation to global change as part of our overall task of informing policymakers of the implications and importance of Earth science research.

Our work plan called for a round of preliminary studies followed by selection of the most promising cases for further research. We have supported six preliminary studies on adaptation to global change at regional, national, and international levels. The status of the studies is as follows:

1. Global Warming and U. S. Water Law: An Overview, M. Cooper. This was completed in year 1 and the study report was submitted with our first annual report.

2. The Montreal Protocol: An Assessment in Terms of Negotiation Theory, A. Chase. This was completed in year 1 and the study report was submitted with our first annual report.

3. Nation-State Behaviour and the Global Environment: An Initial Search for Patterns, D. Cook. A preliminary paper was submitted last year; the final report is submitted herewith,

(NASA-CR-188038) RESEARCH IN GEOSCIENCES POLICY Year 2 Status Report, 1 Jan. - 31 Dec. 1990 (Colorado Univ.) 134 p CSCL 13B
N91-22619 --THRU-- N91-22623
Unclas
G3/45 0001982

as part of our second annual report.

4. Global Change and Biodiversity Loss: Some Impediments to Response, K. Borza and D. Jamieson. Last year an abstract was submitted; the final report is submitted herewith as part of our second annual report.

5. The Effects of Global Climate Change on Southeast Asia: A Survey of Likely Impacts and Problems of Adaptation, S. Njoto and C. W. Howe. Last year an abstract was submitted; the final report is submitted herewith as part of our second annual report.

6. Colorado Water-Use Policy: Adaptation to Global Warming, A. Moss. Last year an abstract was submitted, but this project was never completed, in part because the graduate student working on it (Moss) left school.

Although five out of six projects were very successful and although there is a large body of expertise at the University, these reports do not seem to be adequately focussed on topics relevant to agency needs. Having concluded the studies we started, we plan now to reconsider these efforts, and to propose a different approach as a possible renewal.

TASK 2: Assessment of User Needs for an Applications Information System (AIS)

Our 1988 proposal focused on user involvement in AIS design, one of the key recommendations of the 1987 NASA report, *"Linking Remote-Sensing Technology and Global Needs: A Strategic Vision. A Report to NASA by the Applications Working Group"*(L.R. Greenwood chaired the group). However, as reported last year we changed our plans to focus instead on the NASA EOCAP project and elicit the needs of applications users by studying EOCAP participants. We did not search for areas where applications user needs overlap with science user needs because it became obvious that the relevant information system EOS/DIS, was quite properly going to be driven by science users and that applications users would have to accommodate to a scientific EOS/DIS. As shown in the report entitled "A Remote Sensing Applications Update" which is included in the attached annual report, we found that effective accommodation might be possible by means of a "commercial" outlet for EOS data.

Conclusion

The work has progressed satisfactorily and substantive results are contained in the attached second annual report. During the extension period the question of a possible renewal will be addressed.

Please do not hesitate to call me if you have questions.

Sincerely,

Radford Byerly

STATUS REPORT

Second Year Activities

RESEARCH IN GEOSCIENCES POLICY

NASA Grant NAGW-1415

C.U. Proposal No. 0288.08.0212B

Period Covered: January 1,
1990 to December 31, 1990

Radford Byerly, Jr. Director
Sally McVey, Assistant Director
Center for Space and Geosciences Policy
University of Colorado at Boulder
Campus Box 361
Boulder, Colorado 80309-0361
303/492-1171

CONTENTS

PAPERS

INTRODUCTION AND RATIONALE

This report contains reports of results in tasks one and two of our project. There are three papers from task one and one from task two. This introduction attempts to show how they are related to each other and to the agency's broader programs and goals.

Task 1: Preliminary Research on Adaptation to Global Change

David Cook's paper on treaty ratification (of which a preliminary version was submitted last year) shows that it may be difficult to obtain broad international agreement on environmental protection measures. To the extent that it is important to have virtually all nations agree in order for such protection to be effective, this work is important. Cook has shown that historically poor nations are unlikely to ratify environmental treaties, and the reason is probably that they are distracted with pressing immediate problems of survival and cannot see that to postpone dealing with environmental problems today may only make them worse tomorrow. Figure 1 is a summary of Cook's historical data. He also constructed a statistical model to explain the historical behavior. The statistical model is based primarily on four interrelated attributes of each country. First, is there a national office of an international non-governmental environmental organization promoting an agenda on global environmental issues? Second, does the population enjoy a relatively high standard of living? Third, is the population growth rate low? And finally, does the country have a complex economy and a high rate of GNP per capita? If all the answers to these questions about a country are "no", that country will generally be unlikely to ratify global environmental treaties. Conversely, countries receiving affirmative answers on these four questions will be likely to ratify.

These results allow us to identify countries likely to support global environmental treaties. In addition, it points to some of the reasons why countries do or do not support such treaties, telling us something about how such treaties should be developed and what they should contain. The majority of countries are poor and unlikely to ratify global environmental treaties, yet in the case of a convention on greenhouse gas emissions, the support of a majority of countries is of vital importance to the ultimate effectiveness of a treaty.

Clearly one thing that could be done to improve ratification rates is to involve more countries in global change research, so that they will understand the potential problems. Each country could also be encouraged to study potential impacts of global change on its economy and society, thus bringing the problems home. NASA's EOS program could contribute directly in both these areas by making available global change information that many countries would not be able to obtain in any other way.

Through the analysis of his model results Cook found that the presence of non-governmental environmental organizations (NGOs) in a country increased the likelihood that it would ratify treaties. Such groups could serve as conduits for information on global change impacts, and could stimulate broad participation in global change research activities.

Sukrisno Njoto and Charles Howe studied impacts on Southeast Asia, with a focus on Indonesia. Njoto is an Indonesian native and Howe has worked there often.

Southeast Asia is a rice bowl for the world; a major exporter, it produces sixty-five percent of the world's rice. Agriculture and forestry are important sectors of its economy and both may be vulnerable to climate change. By looking at one example in some detail, i.e. Indonesia, our work shows the difficulty that will be encountered in any attempt to develop a global-scale response to global climate change.

The root of the problem is that many governments of less-developed countries are swamped with well known day-to-day problems and effectively cannot look ahead to future problems that are as uncertain as global climate change. Almost no research related to global change was found to be underway in the area, despite the fact that both investigators are very familiar with Southeast Asia and Indonesia.

The uncertainty is graphically illustrated by consideration of the results of climate models. For example various models predict significant change in precipitation with a doubling of carbon dioxide, but disagree on the sign of the change. One model shows a reversal of the monsoon pattern, with the wet season becoming dry and vice versa. Given this uncertainty it is no wonder that local officials are reluctant to take global change into account.

Nevertheless they probably should at least account for the possibility of change in making some of their decisions. For example, the Indonesian government is currently attempting to relieve population pressure on Java by encouraging "transmigration" to other less-populated islands. Not only does this involve cultural upsets, but the migrants are also going to somewhat different climates. Some are being settled in low lying areas susceptible to sea level rise. The point is that climate change could significantly impact the chances of success of the transmigration program. For example more rain in the dry season would probably help agricultural productivity, but more rain in the wet season would only increase floods, etc. And sea level rise could flood some settlement areas.

The connection to Earth Science and space remote sensing is made by the obvious need for better models. They need to be more precise, i.e. to specify local changes, and above all to be truly more credible. Thus not only is more data needed but also a better understanding of Earth systems.

While models are being developed policy making cannot stop, but it must be informed by the likelihood of climate change, with proper acknowledgement of the uncertainties involved. There is a need to develop specific ways to deal with these uncertainties in policy making. A general recommendation is that policies need to have enough resilience to accommodate potential climate change, but this needs elaboration into more specific recommendations. Resilience to climate change might also provide robustness with respect to other unanticipated events, particularly weather events.

Karen Borza and Dale Jamieson studied how biodiversity and global change will interact, and in particular they studied impediments to response to biodiversity loss.

The concept of biodiversity is intuitively simple but surprisingly difficult to define. Perhaps in part because of this it is also difficult to know crisply why we should value biodiversity, and together these two difficulties make responding to biodiversity loss difficult from the start.

Clearly there is need for more information, for example information on habitat loss. Further, better understanding of earth systems would enable us to predict the future consequences for biodiversity of present actions.

Borza and Jamieson found that NGOs have had good success in dealing with biodiversity loss issues. Since many biodiversity loss problems are in less-developed countries, this finding ties in with Cook's finding less-developed countries are less likely to ratify treaties that would reduce biodiversity loss and that the presence of environmental NGOs in a country increases the likelihood that it will ratify an environmental treaty. This is relevant because some problems of biodiversity loss may be addressed through treaties.

Finally, this also relates to the work of McVey discussed below. She found that remote sensing data will be increasingly useful in managing natural resources (such as habitats and ecosystems), which is part of what we will need to do to minimize biodiversity loss.

Task 2: Assessment of User Needs for an Applications Information System

We studied the population of users represented by the EOCAP projects, and found that they were largely involved with resource management. Because of a renewed interest in environmental matters resource management activities are demanding more and more information, a demand which can be met in large part -- or in some cases only -- by data from space used in connection with new GIS technology. LANDSAT data is popular with many users but its uncertainty constrains investments in the development of applications. Applications users know of the EOS system in general terms, but do not see how it will benefit them. Many of these users will be called on to work on problems arising from or related to global change. That is, resource management will become more not less important as impacts of global change manifest themselves. Further, Earth remote sensing is a uniquely valuable tool for large-scale resource management.

Our results (including results of Borza and Jamieson, above) suggest that a successful

Earth Observing System, as part of a U.S. Global Change Research Program, is likely to reinforce pressure to manage natural resources, and consequently to create more pressure for EOCAP-type applications. The current EOCAP projects, though small, are valuable because of their technical and commercial results and also because they support a community whose contributions will increase along with our ability to observe the Earth from space.

Maintaining remote sensing applications programs would provide another dimension of use for EOS data and accordingly additional support for EOS. Although many of the systemic problems facing U.S. Earth remote sensing programs are still with us (i.e. data continuity and commercialization), progress is being made in small-scale programs like EOCAP. NASA is properly focussing on earth science in its EOS program. Nevertheless EOS data may ultimately be very useful in management of earth resources.

The issues of Landsat commercialization and applications interact to complicate the situation with respect to the use of EOS data outside the global change research program. On the one hand the primary purpose of EOS might be undercut politically by a large number of applications users who felt excluded from EOS data. On the other hand, the reason for EOS is scientific and science users must be given top priority: That is, given limited and strained resources, if EOS is operated in part to serve applications users, its primary users and purpose will be compromised Thus we are faced with a quandary: how to deal with applications users.

It is possible that the Land Remote Sensing Commercialization Act of 1984 might offer a solution to this quandary. That is, it is possible that "commercialization" could provide the needed separation between the primary scientific purposes of EOS and its data and the potentially broader, practical usefulness of its data. An approach worth studying would be to offer one or (better) two "ports" into the EOS Data and Information System to commercial data providers. The exact definition and operation of a "port" would have to be negotiated, but basically NASA through commercial entities would offer EOS data at cost plus a fee or royalty. Having two competing offerors should keep data prices to users down to reasonable levels. A competitive selection would award the ports to the two bidders proposing the best deal to the government and to applications users. It could be made clear that in doing so NASA's purpose would be to make EOS data available cheaply and fairly to existing commercial and other applications users; <u>not</u> to promote or generate an applications community. Such an approach could benefit the EOS program: EOS could concentrate on Earth system science, and leave applications to other relevant organizations.

N91-22620

EXPLAINING PATTERNS IN THE RATIFICATION OF GLOBAL ENVIRONMENTAL TREATIES

David W. Cook

for the
Department of Geography

in cooperation with the
Center for Space and Geosciences Policy

University of Colorado
Boulder, Colorado

PREFACE

This study has been undertaken by the Center for Space and Geosciences Policy at the University of Colorado, Boulder, as part of our research in geosciences policy supported by NASA grant NAGW-1415. The work was done as thesis research by David Cook under the supervision of Professor John O'Loughlin of the Department of Geography with oversight by Sally McVey and Radford Byerly of the Center for Space and Geosciences Policy. Detailed explanations and documentation may be found in the thesis(1).

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report is based on a study of the ratification behavior of 160 countries with respect to thirty-eight global environmental treaties. The study identifies and explains patterns in the ratification of the treaties, providing two means of assessing the likelihood that any given country will support global environmental treaties.

When mapped, national ratification totals reveal a pattern of high ratification within the OECD countries (W. Europe, N. America, Japan, Australia, and New Zealand) and low ratification in Africa, Asia, the Middle East, and Central and South America. A country's standing within the range of high to low ratification rates can be explained well by the statistical model developed in this study.

This statistical model is based primarily on four interrelated attributes of each country. First, is there a national office of an international non-governmental environmental organization promoting an agenda on global environmental issues? Second, does the population enjoy a relatively high standard of living? Third, is the population growth rate low? And finally, does the country have a complex economy and a high rate of GNP per capita? If all the answers to these questions about a country are "no", that country will generally be unlikely to ratify global environmental treaties. Conversely, countries receiving affirmative answers on these four questions will be likely to ratify.

This research allows us to identify countries likely to support global environmental treaties. In addition, it points to some of the reasons why countries do or do not support such treaties, telling us something about how such treaties should be developed and what they should contain. The majority of countries are poor and unlikely to ratify global environmental treaties, yet in the case of a convention on greenhouse gas emissions, the support of all countries is of vital importance to the ultimate effectiveness of a treaty.

Three approaches are suggested to encourage ratification among those countries least likely to ratify. First, these countries must be included in the data collection and research related to climate change studies; national or regional data must be integrated with global scenarios and applied in national or regional climate impact analysis to "bring home" the nature and extent of potential greenhouse-driven climate impacts in a given country or region. Second, developing countries are likely to require assistance in overcoming barriers to treaty compliance, particularly in the areas of technology, capital, scientific information, and administrative capabilities. These needs should be addressed in the convention; in order to insure this, developing countries should be included in the drafting of the convention. Finally, the involvement of international non-governmental environmental organizations in developing countries should expand in several ways. These organizations might assist in the dissemination of climate impacts research results. Their legal and policy staffs could facilitate developing country participation in treaty negotiations, and they could carry a message to the international trade and banking communities about the long-term environmental importance of improving the developing countries' position within the world economy.

EXPLAINING PATTERNS IN THE RATIFICATION OF GLOBAL ENVIRONMENTAL TREATIES

I. INTRODUCTION: PROBLEM AND PROJECT

Human activity is causing an increase in the concentration of radiatively active gasses in the atmosphere. By means of the "greenhouse effect" these gasses trap heat and help maintain the Earth's temperature equilibrium. The increasing concentrations of these gasses are likely to cause an increase in the surface temperature of the Earth, leading to multiple changes linked to climate. A warming will generally shift climate zones poleward, causing a migration of farming and forestry zones. A warming will also alter atmospheric circulation patterns, leading to changes in the timing, location, and quantity of clouds and precipitation with related impacts on agriculture, forestry, and river basin management.

Finally, global warming is projected to cause sea levels to rise due to thermal expansion of the seawater as well as melting of both land and sea ice. A rise in sea level will threaten coastal cities and inundate many critical wetland areas.

These climate related impacts are potentially very disruptive. The poorer developing countries have the fewest resources to apply to adjusting to the likely changes. They also contribute the least to the cause of the problem. Most of the increasing greenhouse gas emissions come from carbon dioxide production (from fossil fuel combustion) and chlorofluorocarbon (CFC) releases, primarily in the industrialized nations. Increasing methane production also contributes to the problem. Methane emissions are derived from the digestive systems of cattle, and decomposition within rice paddies and landfills. Finally, deforestation leads to a net increase of carbon dioxide in the atmosphere. While many industrial nations have already substantially deforested themselves, a number of developing nations are being deforested rapidly due to international demand for tropical woods, a need for foreign trade to support the payment of foreign debts, and domestic policies promoting settlement in forested rural areas.

It is unlikely that the global warming problem will be solved if any significant segment of humanity fails to cooperate in its solution. Because they are the principal cause of the problem and because their development path influences all other countries, the industrialized countries almost certainly will have to alter their technology, science, economics, values, and policy. In contemplating such overall changes the emerging understanding of the Earth's overall biophysical systems must be incorporated into the planning of government, industry, and individuals world-wide.

The potential magnitude of the global warming problem has sparked substantial global concern, perhaps unrivaled by previous environmental concerns. However, there are barriers to a cooperative global solution to the problem. The need to create a development path enlightened by an understanding of critical earth systems is a substantial challenge to all nations, but the necessary intellectual and financial capital lies primarily in the developed world. When combined with the stark reality of pressing, immediate needs for food, water, and shelter in the least developed countries, it is no surprise that treaty ratification on global environmental issues is high in the developed world and low in the less developed countries. By modeling the national disparities in overall wealth and in living conditions, we are able to explain real world ratification behavior quite well.

This project was undertaken because coordinated global action to reverse the trend toward global warming seems both necessary and unlikely. Our results can be used to help focus efforts to broaden multi-national participation in treaties designed to solve global environmental problems. Our work presents two methods for identifying which countries are likely to ratify (or not ratify) global environmental treaties: One method is a simple summary and analysis of past ratification behavior, the other employs a statistical model based on certain national attributes to explain past and project future ratification behavior. Both approaches lend insight into the behavior of nations in regard to treaty ratification, and thus suggest how more countries might be induced to ratify treaties; a first step in broader implementation of the treaties.

This report is based on thesis research done at the University of Colorado by David Cook in conjunction with the Center for Space and Geosciences Policy and the Department of Geography. Detailed explanations and documentation may be found in the thesis (1).

II. PROCESS

We combed the record of multi-lateral environmental treaties and identified thirty-eight fitting our definition of global environmental treaties. To be considered in the study a treaty had to be open to all countries of the world for ratification and it had to deal with an environmental issue of global or nearly global concern. Country's ratifications of these treaties were summed, yielding a listing of high to low ratifiers.

Drawing on international relations theory, we have developed an explanation of what might make countries more or less likely to ratify global environmental treaties. This explanation is made up of four propositions, grouped into two pairs of related concerns. The first proposition is that people in the wealthier countries in the core of the world economy (2) possess the resources to perceive and respond to global environmental problems. In various ways these people can be characterized as able to afford to pay attention to such problems. This is true both of the general population and among the scientific and political communities as well. The second proposition is an inverse to the first. To provide a sharper focus to the simple view of the world economy which divides it into "core", "semiperiphery", and "peripheral" nations, we looked at several indicators of how well basic survival needs are met in a country to see if ratification levels would be lower for countries in which higher proportions of the population are confronted with immediate survival issues. Our third proposition was that the relative openness of the government would be a critical factor in the translation of popular priorities into foreign policy. And finally, we proposed that non-governmental organizations pressing for government action on global environmental issues might influence ratification behavior.

This does not constitute an exhaustive explanation of the ratification behavior of states. The influence of economic and political interests also play critical roles and are generally given much attention in the analysis of the behavior of states. This research is an effort to augment that traditional analysis by testing the importance of overall wealth, living conditions, type of government, and organized citizen opinion in explaining global environmental treaty ratification.

This view of the underpinnings of the ratification behavior of states was translated into a statistical model using the following national attribute data to represent our four propositions:

1) The first component is represented by a country's position in the world economy (core, semiperiphery, or periphery). Based on per capita GNP and the complexity of national economies, this indicator provides a summary of the relative economic strength of a country.

2) The second proposition is represented by three indicators: a) Rating on the physical quality of life index (PQLI), a composite of infant mortality, life expectancy, and literacy. This index provides an indication of how well medium-term basic human needs are met in each country. b) The number of calories per day in the average diet. This indicator is to represent the status of people's immediate survival needs. c) The population growth rate gives a sense of the rate at which a country's (economic) resources are being diluted by an expanding population.

3) The third component is represented by type of government, based on an analysis of relative freedom and type of political system in each country (3). It is included to represent the relative strength of the linkage between public policy and the other national attributes included in the model.

4) Finally, the fourth proposition is represented by the presence (or absence) of chapters of the International Union for the Conservation of Nature and Natural Resources (IUCN) and/or Friends of the Earth (FOE) in each country. This indicator is included to represent the influence of organized citizen opinion on public policy. These organizations were selected because both have explicit policy agendas on a variety of global environmental issues.

III. RESULTS

The likelihood that a country will support global environmental treaties can now be assessed two different ways: 1) by examining the historical record, or 2), by examining the cluster of interrelated national attributes used to successfully explain the historical record. The record on global environmental treaty ratification is shown in table 1 on page 18, listing the number of ratifications by each country of the world out of a total of the thirty-eight treaties in the study. To the extent that generalized past behavior is an indicator of future behavior, this list can be used to estimate a country's likelihood of ratifying future treaties.

When mapped, national ratification totals reveal a regional pattern of high ratification within the OECD countries (W. Europe, N. America, Japan, Australia, and New Zealand) and low ratification in Africa, Asia, the Middle East, and Central and South America, as shown by the map in figure 1 on page 22. In general, a country's location serves as an indication of its propensity to ratify global environmental treaties.

A country's standing within the range of high to low ratification rates can be explained well by the statistical model developed in this study. By updating national attribute data, such a model may continue to serve a predictive function over time, whereas location and the historical record may become less useful indicators as circumstances change.

A country's position within the world economy is the strongest indicator of ratification behavior. The correspondence between ratification and position in the world economy can be seen by comparing the map in figure 1 (pg. 22) with the map in figure 2 on page 23. The geographical pattern of high to low ratifiers closely matches the pattern of core to periphery states in the two maps. Figure 3 (on page 24) depicts the overall data on ratification in the form of a bar graph which sub-divides the countries into world economy categories. All these figures show that among the world community of nations, low ratifiers predominate and are largely peripheral states; high ratifiers are mostly core states, and the countries of the semiperiphery ratify within the range of overlap between core and periphery. Table 2 (on pages 19-21) contains the data plotted in the bar graph and also illustrates the correspondence between the number of treaties ratified by each country and its position within the world economy.

The whole group of treaties was also broken down and analyzed in several sub-groups. Analysis of treaty subgroups showed that treaties on environmental issues of a "truly global" scope engendered higher ratification than either treaties on "nearly global" issues or treaties on "regional issues of global concern". Environmental treaties with a "military" component were the only sub-group to approach the ratification rates of the "truly global" treaties. This suggests the possibility that global scale environmental problems are perceived as serious threats warranting national concern on par with security issues.

In other sub-group analysis, we found a particularly strong difference in ratification levels on "nature" issues (birds, wetlands, whales, wildlife, etc.) when comparing the wealthy (high ratifiers) and the poor countries (low ratifiers). As expected, the treaties which focused on nature issues garnered fewer ratifications among the less developed countries.

IV. CONCLUSIONS

This study leads us to conclude that countries will generally be more likely to ratify global environmental treaties if international environmental organizations are active within their borders. The likelihood they will ratify also increases with their standard of living and with a more advantageous position in the world economy. A lower population growth rate is also associated with higher ratification rates on global environmental treaties.

Conversely, poor countries are least likely to participate in global environmental treaties. Because the solutions to many global environmental problems will require coordinated action, including those poor developing countries least likely to participate, there must be a special effort to encourage and enable their participation.

The presence of more pressing and immediate problems is one reason for low ratification rates among less developed countries. In the case of global warming, a disinclination to ratify a treaty may also be linked to unfamiliarity with the problem due to a lack of research on the potential local and regional impacts of climate change. For this reason, we suggest the following approaches to increase the participation of the developing countries in the treaty process:

1) Expand research, data gathering and analysis, dissemination and application of information on causes, dynamics, and consequences of human induced climate change with a particular focus on regions in the developing world.

2) Develop regional and local preventive and adaptive responses to climate change, with an emphasis on those which also address existing immediate issues of high priority in developing countries. Thus, to the extent that the problem is understood, its implications must be made real for countries without resident scientific communities presently capable of doing so.

3) If a developing country's leaders then come to perceive the problem as significant within their own sense of priorities, they may then wish to participate in the treaty development process in order to create a treaty that will work for their country. Creating a treaty that will work for the developing world may require the transfer or development of scientific information and expertise, capital, technology, and the administrative capability to pursue a development path consonant with the goals and needs of each nation and with the constraints of the treaty.

4) Various governmental and non-governmental international organizations may play important roles in facilitating the above three approaches to broadening global environmental treaty ratification. Such organizations might assist in the development of climate impacts research and the dissemination of research results. Their legal and policy staffs could facilitate developing country participation in treaty negotiations.

5) Finally, based on the fundamental influence of wealth on treaty ratification behavior, such organizations could carry a message to the international trade and banking communities about the long-term environmental importance of improving the developing countries' position within the world economy. More countries are likely to act with respect for the global environment when they can afford to, and/or when it can be shown that they can't afford not to.

NOTES

1. This report is based on thesis research done at the University of Colorado by David Cook in conjunction with the Department of Geography and the Center for Space and Geosciences Policy. The complete study, "The State in Nature-Society Relations: Explaining Patterns in the Ratification of Global Environmental Treaties" will be available through inter-library loan from the Norlin library at University of Colorado by January 1992. The thesis is also available from the libraries of the Center for Space and Geosciences Policy, Campus Box 361, Boulder, CO 80309, the Department of Geography, Campus Box 250, Boulder, CO 80309, and the author: David Cook 3003 5th St. Boulder, CO. 80304 USA.

2. We divide the world economy into three categories: core, semiperiphery, and periphery. A nation's placement among these categories is based on its GNP per capita ratio and the complexity of its economy. For example, many of the middle eastern oil states have a high GNP per capita but are not considered core states because they lack complex economies; they are largely dependent upon the export of a single minimally processed commodity. Core countries are characterized by their possession of a relatively high concentration of the processing and profit-making activities within the world economy. The economies of peripheral countries are dominated by extractive processes such as forestry, agriculture, and mining with much of the related processing and profit-making taking place in the core. Semiperipheral countries are characterized by a mix of core and peripheral processes. This view of the world economy can be likened to a "town and country" relationship on a global scale. This classification system is drawn from world systems theory and is explained in more depth in the thesis cited in note 1 above, and in the work of Terrence Hopkins and Immanuel Wallerstein. See for example: Hopkins, Terrence K., Immanuel Wallerstein and associates. (1982). "Patterns of Development of the Modern World-System." In <u>World Systems Analysis</u>. Beverly Hills, CA.: Sage, pg. 41-82; and Wallerstein, Immanuel (1976). "A World System Perspective on the Social Sciences." In <u>British Journal of Sociology</u> 27, September, pg. 343-353.

3. Data on the level of freedom and type of political system in each country were drawn from <u>Freedom In the World</u> by Raymond Gastil, 1987, New York: Greenwood Press.

APPENDIX OF TABLES AND FIGURES

Table 1 Cumulative National Ratification Totals
Thirty-Eight Global Environmental Treaties

Norway	32	Peru	13	Laos	7
Sweden	30	Panama	13	Congo	7
United Kingdom	29	Czechoslovakia	13	Bolivia	7
Spain	29	Sri Lanka	12	Belize	7
Denmark	29	Niger	12	Unit. Arab Em.	6
United States	28	Malta	12	Singapore	6
Switzerland	28	Luxembourg	12	Saudi Arabia	6
Netherlands	28	Liberia	12	Maldives	6
Italy	28	Gabon	12	Kampuchea	6
Finland	28	Fiji	12	Honduras	6
USSR	27	Cuba	12	Haiti	6
Japan	26	Bangladesh	12	Guinea	6
West Germany	26	Bahamas	12	Cen. Af. Rep.	6
France	26	Afghanistan	12	Zaire	5
Mexico	25	Israel	11	Swaziland	5
Belgium	25	Cyprus	11	Sudan	5
Poland	24	Seychelles	10	St. Lucia	5
Yugoslavia	23	Rumania	10	Sao Tome	5
Portugal	22	Madagascar	10	Paraguay	5
New Zealand	22	Lebanon	10	Mauritania	5
Tunisia	21	Kuwait	10	Lesotho	5
South Africa	21	Jamaica	10	Antigua & Bar.	5
India	21	Indonesia	10	Tanzania	4
Hungary	21	Colombia	10	Taiwan	4
Australia	21	Cameroon	10	Rwanda	4
East Germany	20	Uganda	9	North Korea	4
Canada	19	Trinidad	9	Guinea-Bissau	4
Egypt	18	Thailand	9	Ethiopia	4
Bulgaria	18	Pakistan	9	El Salvador	4
Argentina	18	Mauritius	9	Burkina Faso	4
Senegal	17	Malaysia	9	Bahrain	4
Ireland	17	Ecuador	9	Vanuatu	3
Greece	17	Algeria	9	Guyana	3
Chile	17	Dem.Yemen (S.)	8	Gambia	3
Brazil	17	Yemen (N.)	8	Djibouti	3
Nigeria	16	Turkey	8	Burma	3
South Korea	16	Surinam	8	Brunei	3
Iceland	16	Qatar	8	Botswana	3
Uruguay	15	Oman	8	Barbados	3
Ghana	15	Mongolia	8	Zimbabwe	2
Dominican Rep.	15	Malawi	8	St. Vincent	2
Austria	15	Libya	8	Somalia	2
Papua New Guinea	14	Iraq	8	Mozambique	2
Morocco	14	Iran	8	Grenada	2
Kenya	14	Costa Rica	8	Eq. Guiana	2
Jordan	14	Cape Verde	8	Dominica	2
Ivory Coast	14	Zambia	7	Chad	2
Guatemala	14	Vietnam	7	Burundi	2
China	14	Togo	7	Bhutan	2
Benin	14	Syria	7	Albania	2
Venezuela	13	Sierra Leone	7	West. Samoa	1
Solomon Islands	13	Nicaragua	7	Comoros	1
Philippines	13	Nepal	7	Angola	1
		Mali	7		

Table 2 **The Pattern of Correspondence Between Treaty Ratification Totals and Position Within the World Economy.**

# R.	Core States	Semiperipheral States	Peripheral States
32	Norway.		
30	Sweden.		
29	Denmark, UK.	Spain.	
28	Finland, Switzerland, Netherlands, Italy, USA.		
27		USSR.	
26	France, Japan, W. Germany.		
25	Belgium.	Mexico.	
24		Poland.	
23		Yugoslavia.	
22	New Zealand.	Portugal.	
21	Australia.	Hungary, S Africa.	India, Tunisia.
20		E. Germany.	
19	Canada.		
18		Argentina, Bulgaria.	Egypt.
17		Brazil, Chile, Greece, Ireland.	Senegal.

Total number of treaties ratified is listed at the left.
Table 2 is continued on the next page.

Table 2 (cont) **The Pattern of Correspondence Between Treaty Ratification Totals and Position Within the World Economy.**

# R.	Core States	Semiperipheral States	Peripheral States
16	Iceland.	S. Korea.	Nigeria.
15	Austria.	Uruguay.	Dominican Republic, Ghana.
14			Benin, China, Guatemala, Ivory Coast, Jordan, Kenya, Morocco, Papua New Guinea.
13		Czechoslovakia, Venezuela, Panama.	Solomon Islands, Peru, Philippines.
12	Luxembourg.	Malta.	Afghanistan, Bahamas, Bangladesh, Cuba, Fiji, Gabon, Liberia, Niger, Sri Lanka.
11		Israel.	Cyprus.
10		Jamaica, Lebanon, Rumania.	Cameroon, Colombia, Indonesia, Kuwait, Madagascar, Seychelles.
9		Malaysia.	Algeria, Ecuador, Mauritius, Pakistan, Thailand, Trinidad, Uganda.
8		Iran.	Cape Verde, Costa Rica, Iraq, Libya, Malawi, Mongolia, Oman, Qatar, Surinam, Turkey, N. Yemen, S. Yemen.
7			Belize, Bolivia, Congo, Laos, Mali, Nepal, Nicaragua, Sierra Leone, Syria, Togo, Vietnam, Zambia.

Total number of treaties ratified is listed at the left.
Table 2 is continued on the next page.

Table 2 (cont) **The Pattern of Correspondence Between Treaty Ratification Totals and Position Within the World Economy.**

# R.	Core States	Semiperipheral States	Peripheral States
6			Central African Rep., Guinea, Haiti, Honduras, Kampuchea, Maldives, Saudi Arabia, Singapore, U.A. Emirates.
5			Antigua, Lesotho, Mauritania, Paraguay, St. Lucia, Sao Tome, Sudan, Swaziland, Zaire.
4			Bahrain, Burkina-Faso, El Salvador, Ethiopia, Guinea-Bissau, Rwanda, Taiwan, Tanzania, N. Korea.
3			Barbados, Botswana, Brunei, Burma, Djibouti, Gambia, Guyana, Vanuatu.
2			Albania, Bhutan, Burundi, Chad, Dominica, Equatorial Guinea, Grenada, Mozambique, St. Vincent, Somalia, Zimbabwe.
1			Angola, Comoros, Western Samoa.

Total number of treaties ratified is listed at the left.

GLOBAL ENVIRONMENTAL TREATY RATIFICATION

National Ratification Totals for 38 Treaties Studied

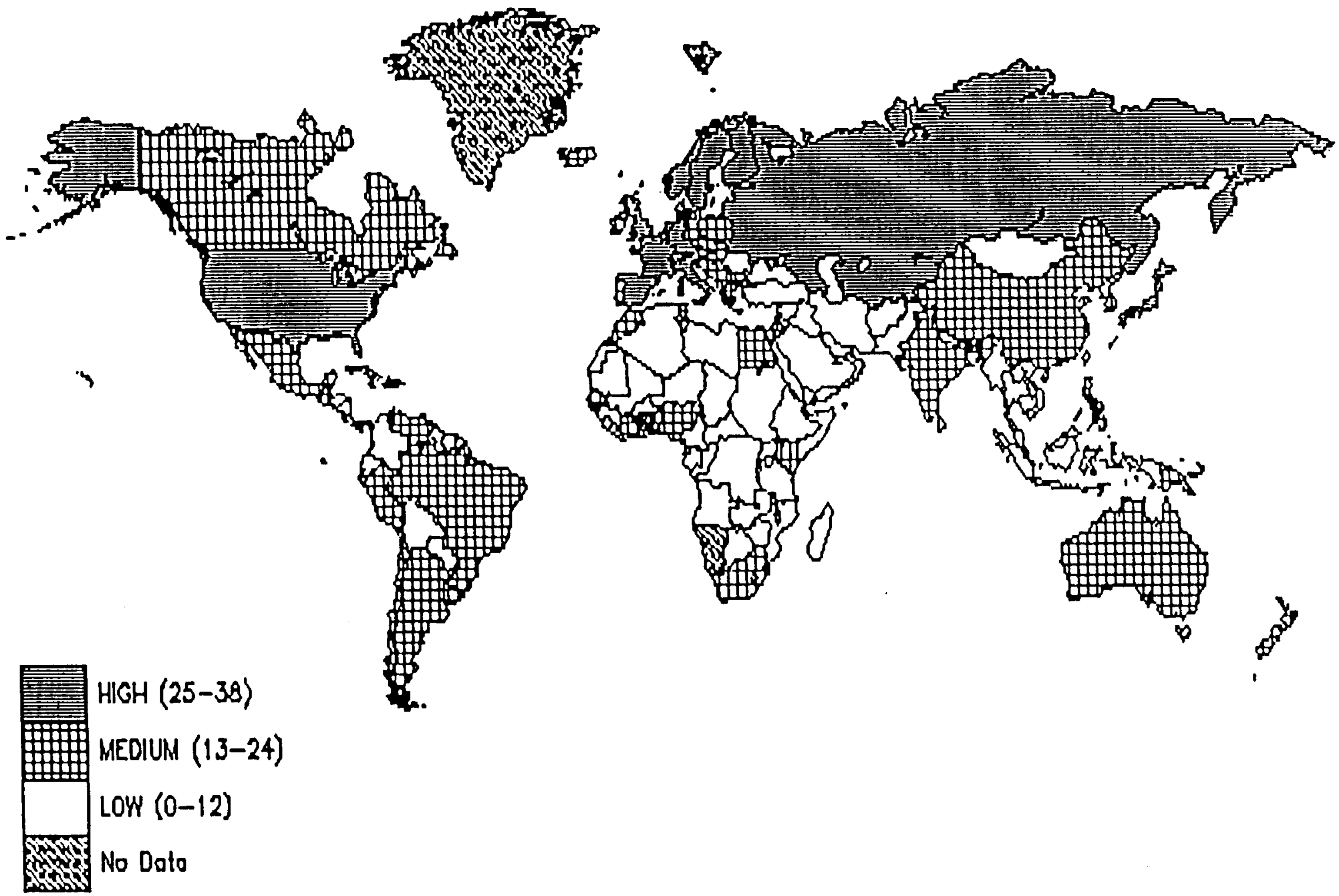


Figure 1

Position in the World Economy

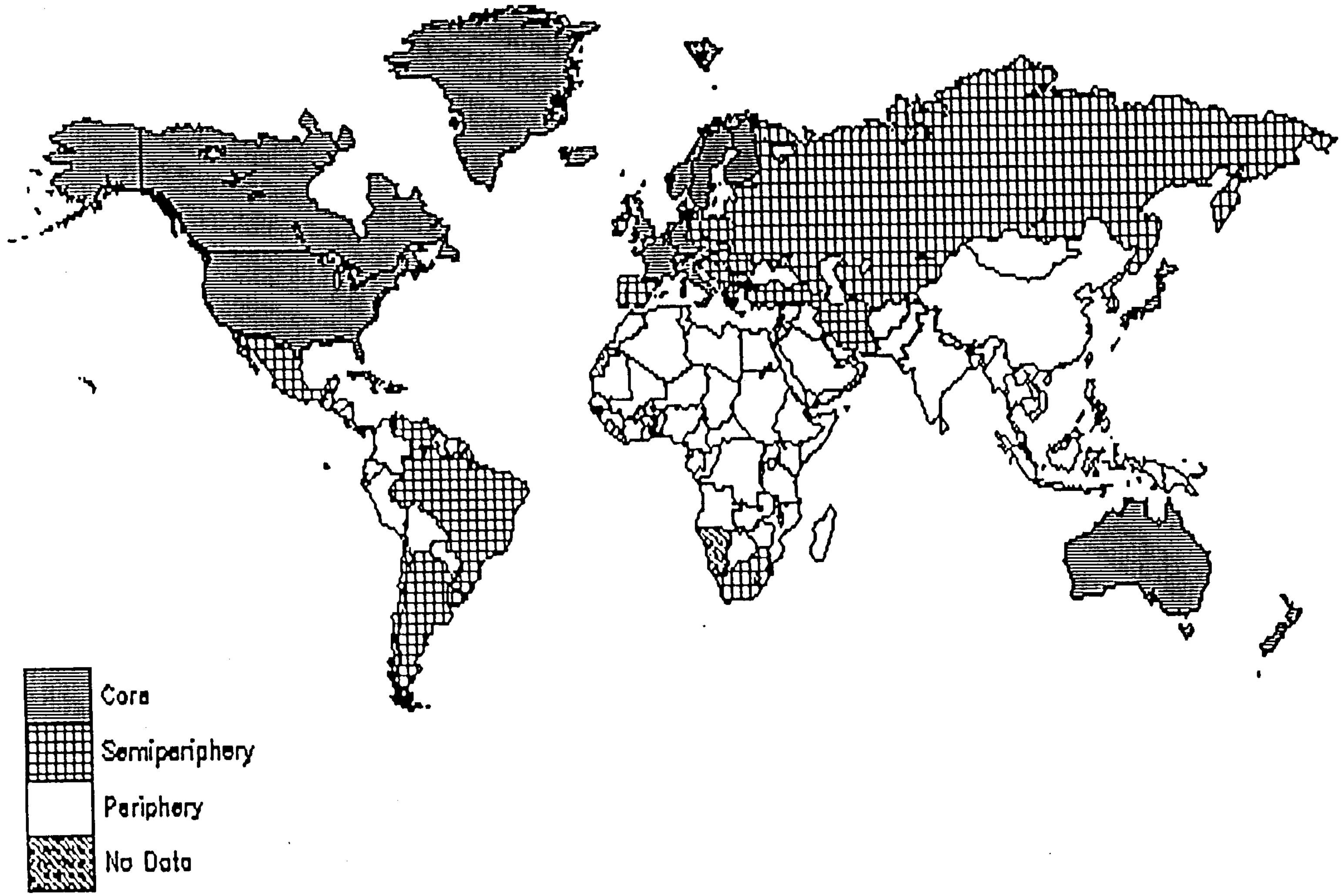
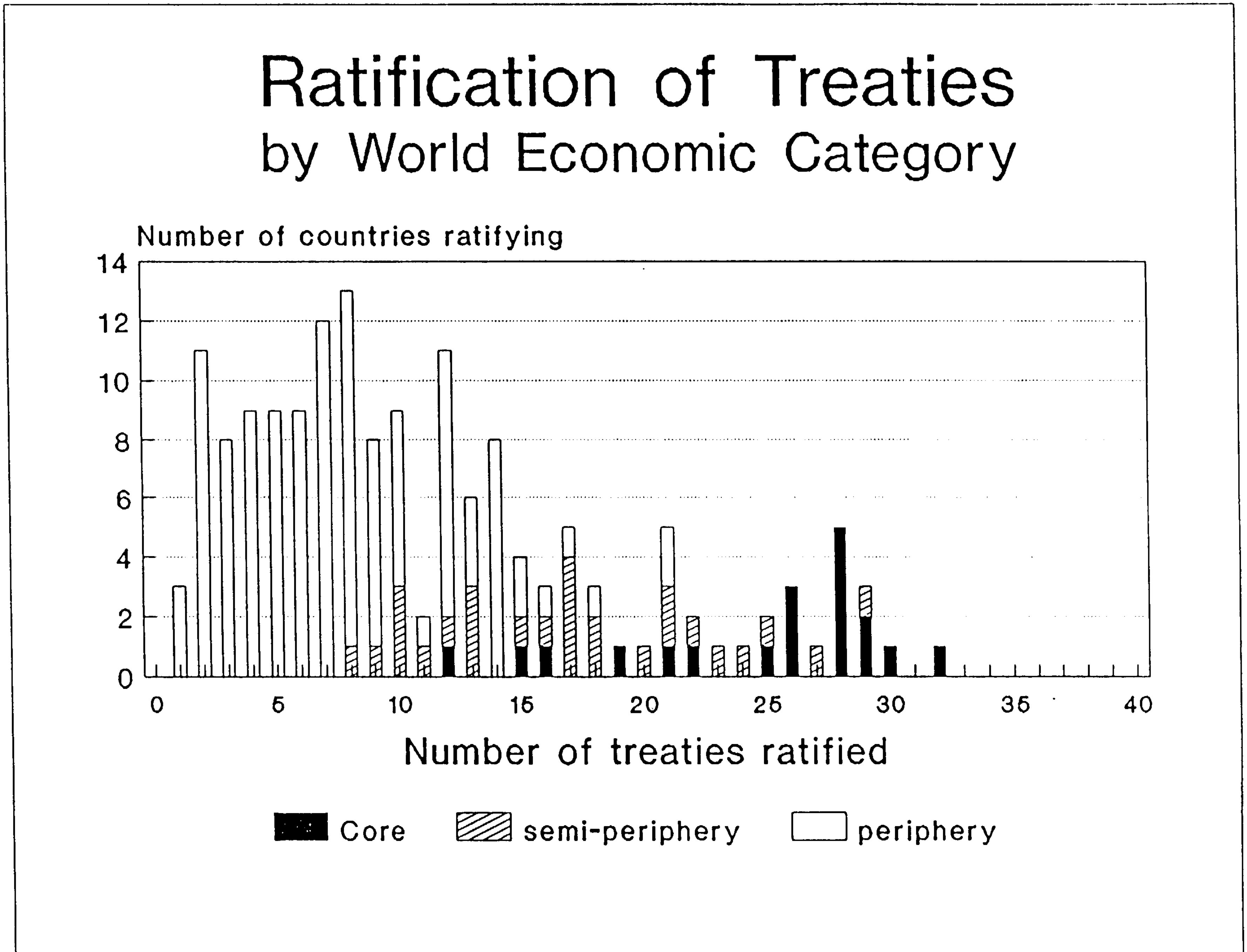


Figure 2



Ratification of Treaties
by World Economic Category
Number of countries ratifying
14
12
10
8
6
4
2
0
0
5
10
15
20
25
30
35
40
Number of treaties ratified
Core
semi-periphery
periphery

Figure 3

N91-22621

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

A Study by

Sukrisno Njoto and Charles W. Howe

Department of Economics and Environment and

Behavior Program, Institute of Behavioral Science

Sponsored by the

Center for Space and Geosciences Policy

University of Colorado

December 1990

CONTENTS

List of Figures and Tables

Figures

Tables

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

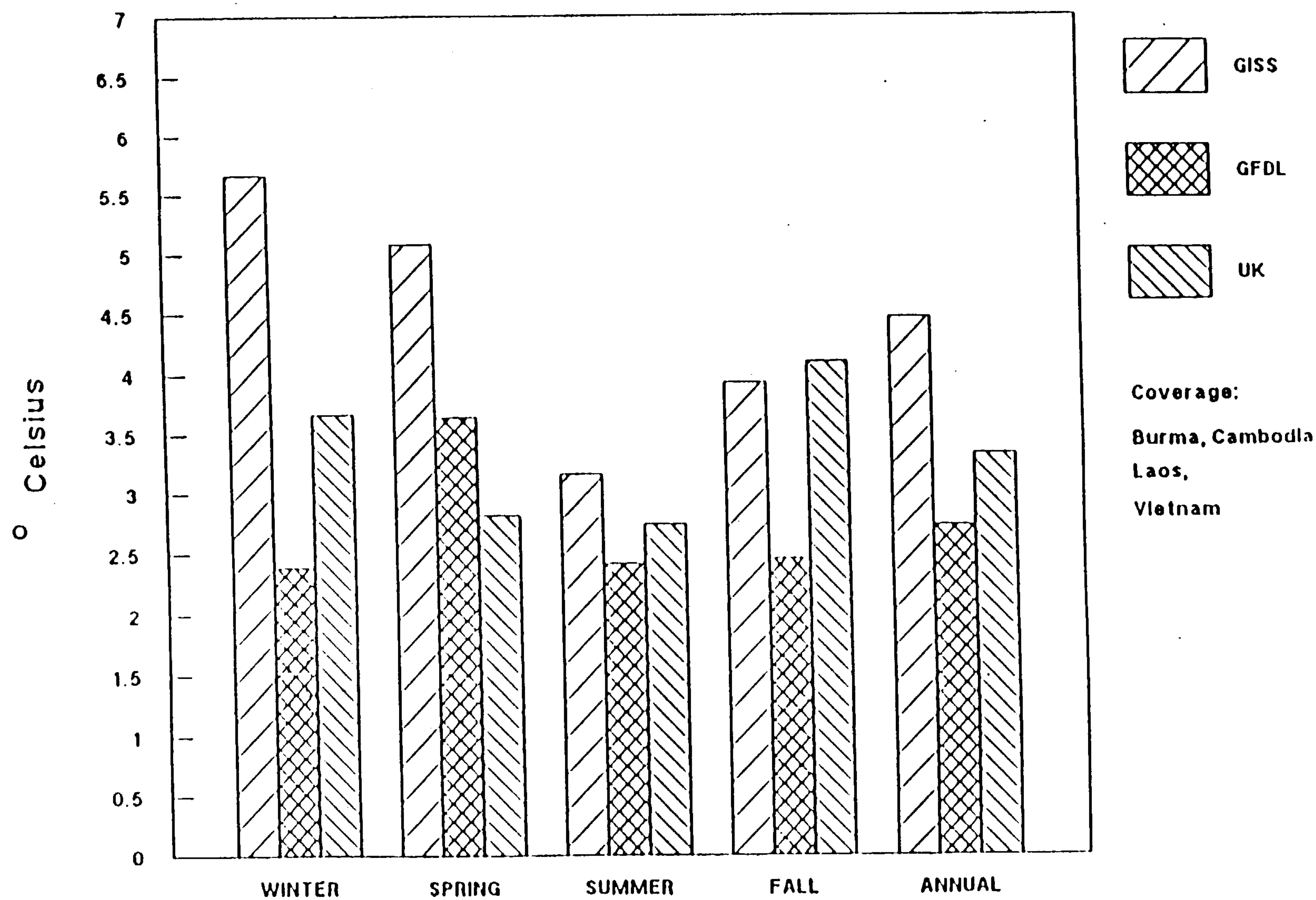
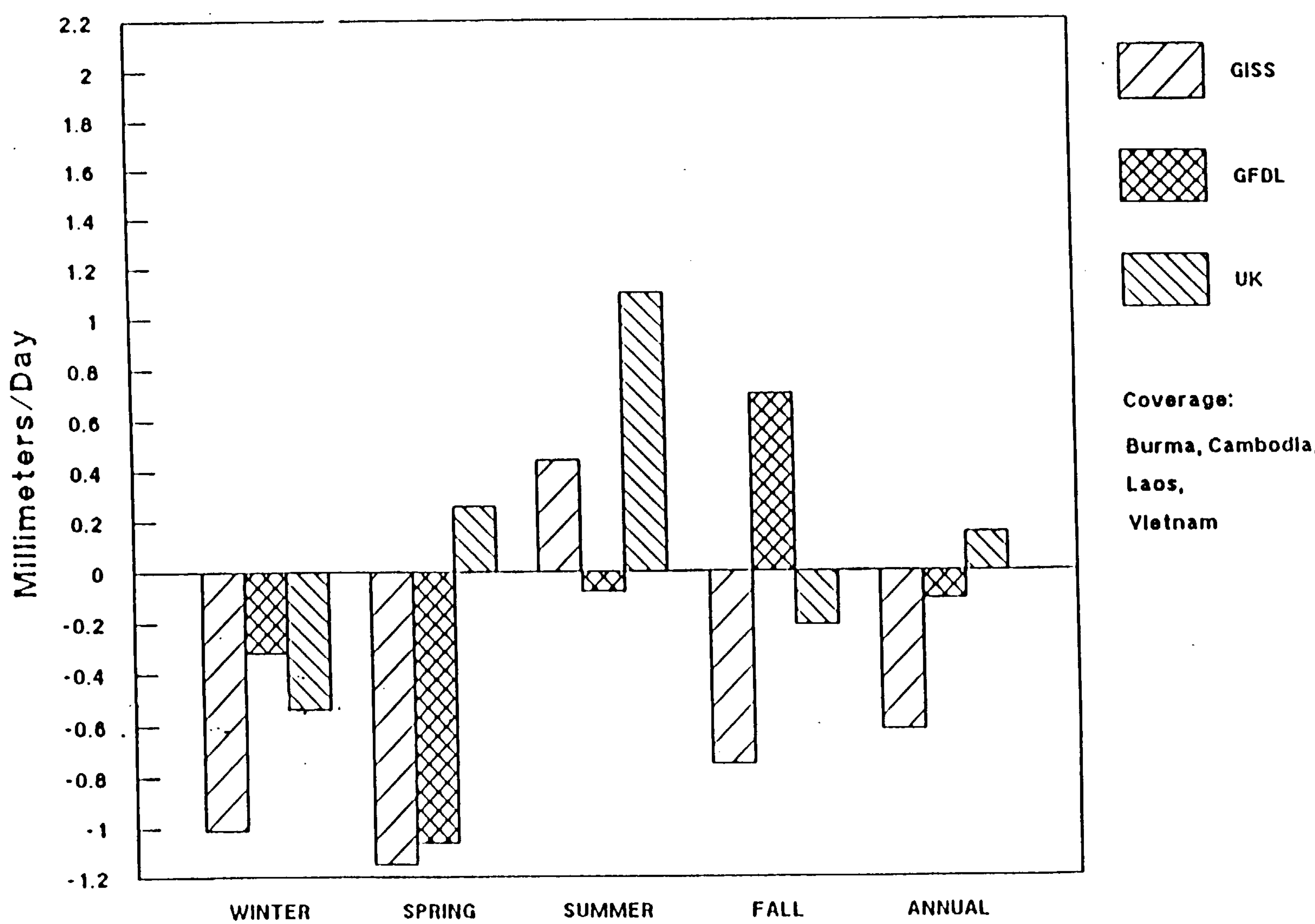


Figure 2

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).

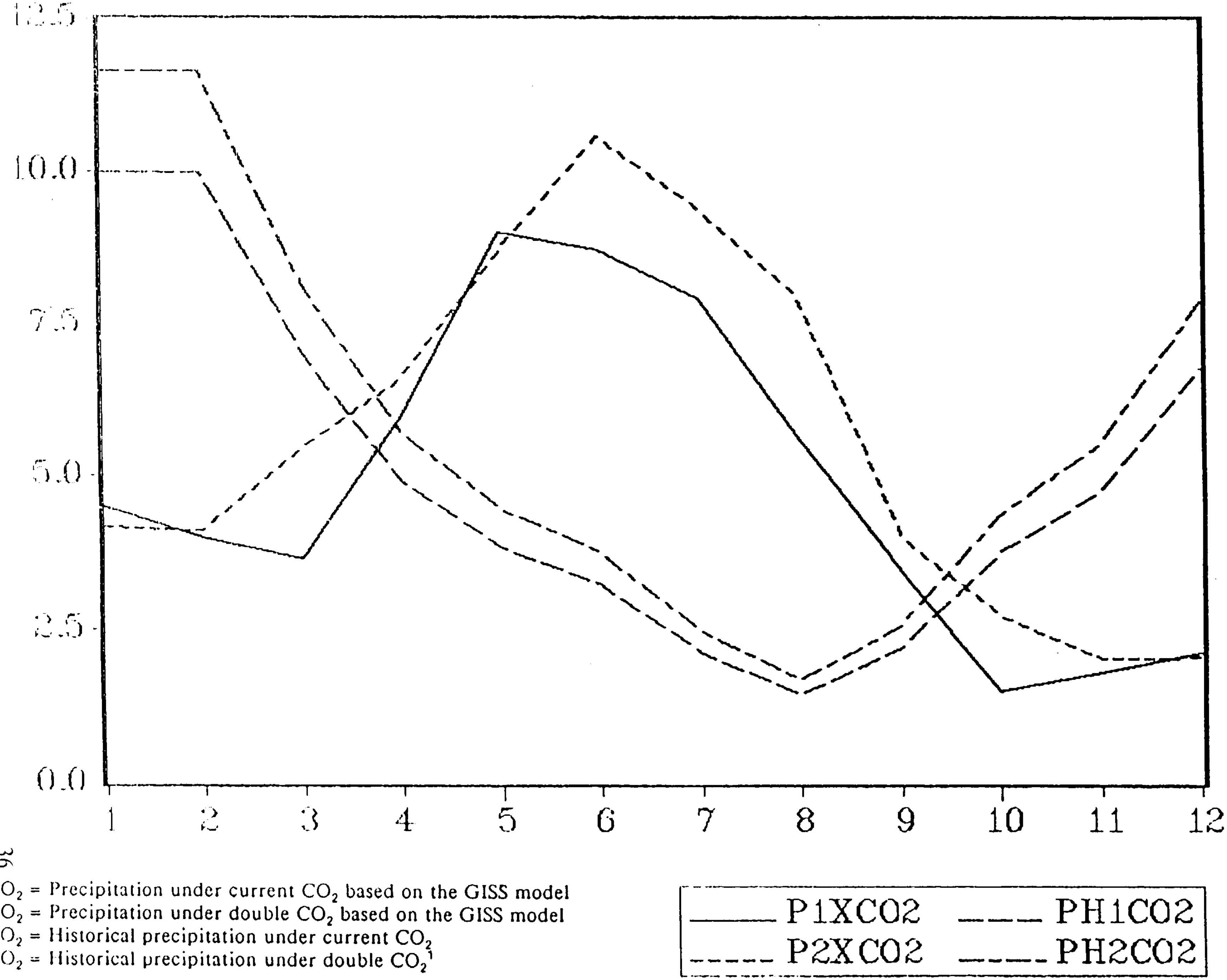
III. LIKELY IMPACTS OF CLIMATE CHANGE ON SOUTHEAST ASIA

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

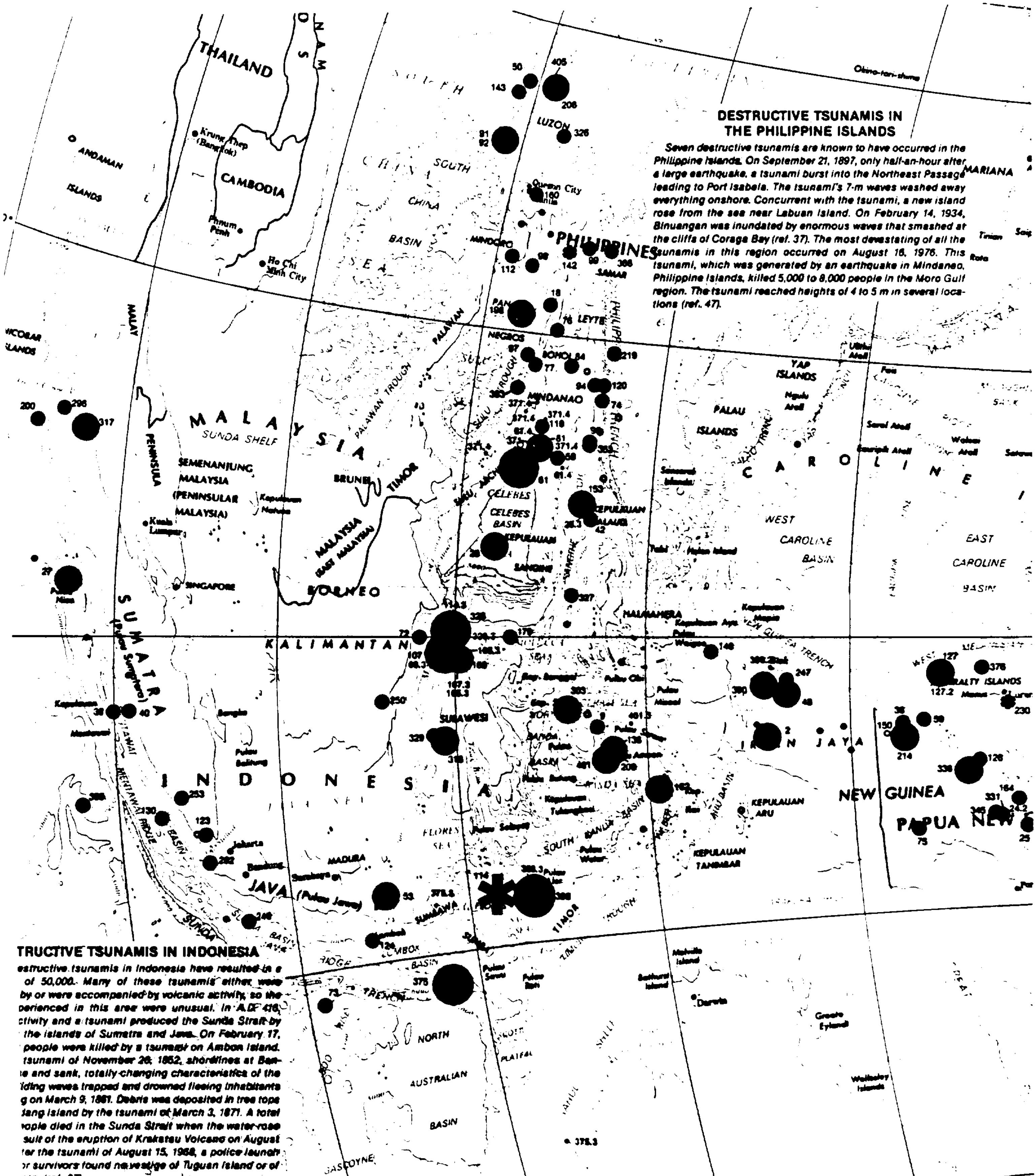
SECTORS:	Agriculture	Fisheries	Forestry	Energy	Water Systems	Direct Human Impacts
CLIMATE CHANGES: Sea Level Rise	Loss of coastal rice paddy Loss of floating rice in estuaries Increased storm surge damages Loss of coastal irrigation systems	Loss of wetland breeding areas Loss of mangrove swamps in nutrient 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

ORIGINAL PAGE IS
OF POOR QUALITY

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 1
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]

---

[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.

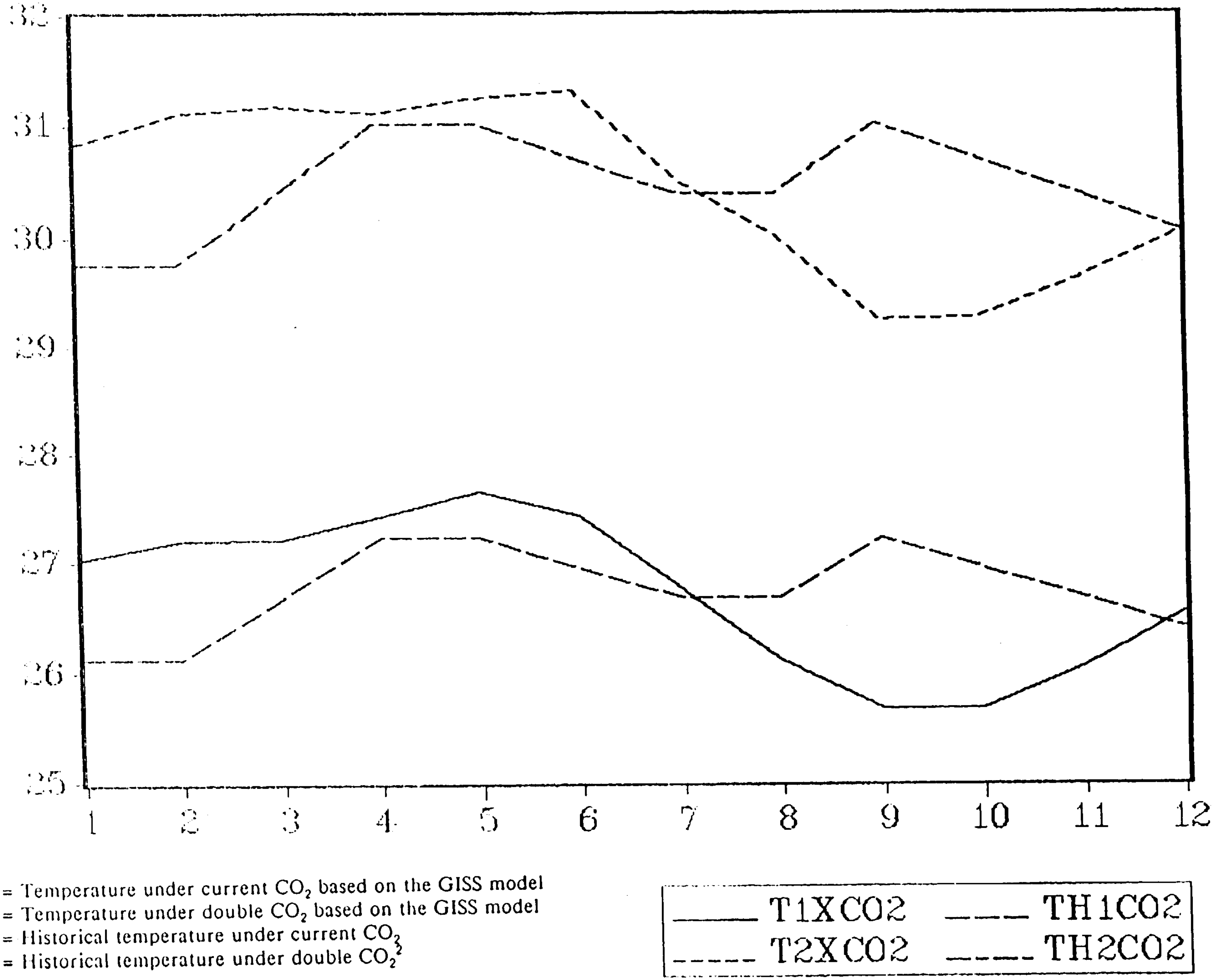
The lack of agreement between model calculations and historical data raises a question: How can one make policy based on models that are patently suspect? There are two answers to this question. First, in the present study we have made some bold assumptions about how the climate will change, and have 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

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

---

[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).

<u>Philippines</u>

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.

REFERENCES

The 1990 Almanac, Houghton Mifflin Company, Boston, 1990.

Biro Pusat Statistik, Statistical Year Book of Indonesia 1987.

Conway, H. Mc Kinley and Liston, Linda L., eds., The Weather Handbook, Conway Research, Inc., Atlanta, 1974.

Crosson, Pierre R., 1989, "Climate Change: Problems of Limits and Policy Responses," in N.J. Rosenberg, et al, eds., Greenhouse Warming: Abatement and Adaptation, Resources For The Future, pp. 69-82.

Darmstadter, Joel and Edmonds, Jae, 1989, "Human Development and Carbon Dioxide Emission: The Current Picture and The Long-term Prospects," in N.J. Rosenberg, et al, eds., Greenhouse Warming: Abatement and Adaptation, Resources For The Future, pp. 35-51.

De Datta, Surajit K., 1981, *Principles and Practices of Rice Production*, New York & Brisbane: John Wiley & Sons.

Easterling, William E. III, Parry, Martin L. and Crosson, Pierre R., 1989, "Adapting Future Agriculture to Changes in Climate," in N.J. Rosenberg, et al, eds., Greenhouse Warming: Abatement and Adaptation, Resources For The Future, pp. 91-104.

Frederick, Kenneth D. and Gleick, Peter H., 1989, "Water Resources and Climate Change," in N.J. Rosenberg, et al, eds., Greenhouse Warming: Abatement and Adaptation, Resources For The Future, pp. 133-143.

Glantz, Michael, ed., Forecasting by Analogy: Societal Responses to Regional Climate Change, Environmental and Societal Impacts Group, National Center For Atmospheric Research, August 1989.

Gornitz, V., S. Lebedeff, and J. Hansen, 1982, "Global Sea Level Trend in the Past Century," Science, 215 (1612-1614).

Hamilton, Lawrence S. and Snedaker, Samuel C., eds., Handbook for Mangrove Area Management , United Nations Environment Programme and East West Center, Environment and Policy Institute, Honolulu, 1984.

Hansen, et al., 1983, "Efficient Three-Dimensional Global Models for Climate Studies: Models I and II", *Monthly Weather Review* 111, p. 609-662.

Hansen, et al., 1988, "Global Climate Changes as Forecast by Goddard Institute for Space Studies Three-Dimensional Model", *Journal of Geophysical Research* 93, p. 9341-9364.

Hekstra, Gjerrit P., 1989, "Sea Level Rise: Regional Consequences and Responses," in N.J. Rosenberg, et al, eds., Greenhouse Warming: Abatement and Adaptation, Resources For The Future, pp. 53-67.

Intergovernmental Panel on Climate Change (IPCC), Working Group II, 1990, Potential Impacts of Climate Change, UNEP & WMO

Lander, James F. and Lockridge, Patricia A., United States Tsunamis (Including U.S. Possessions) 1690-1988, National Geophysical Data Center, Boulder, 1989.

Meehl, G., 1984, "Modeling the Earth's Climate", *Climatic Change* 6, p. 259-286.

Portney, Paul R., 1989, "Assessing and Managing the Risks of Climate Change," in N.J. Rosenberg, et al, eds., Greenhouse Warming: Abatement and Adaptation, Resources For The future, pp. 83-88.

Research Directorate of the National Defense University, eds., Crop Yields and Climate Change to the Year 2000, vol. 1, Superintendent of Documents, Fort Lesley J. McNair, Washington D.C., 1980.

Riebsame, William E., Jacobs, Jeffrey W., "Climate Change and Water Resources in the Sacramento-San Joaquin Region of California", Natural Hazards Center Working Paper #64, University of Colorado, December 1988.

Rosenberg, Norman J., Easterling, William E. III, Crosson, Pierre R., and Darmstadter, Joel (eds.), *Greenhouse Warming: Abatement and Adaptation*, Washington, D.C.: Resources for the Future, Inc., 1989.

Ruffner, James A. and Blair, Frank E., eds, The Weather Almanac, 4th ed., Gale Research Co., Detroit, 1984.

Schneider, Stephen H. and Rosenberg, Norman J., 1989, "Greenhouse Effect: Its Causes, Possible Impacts, and Associated Uncertainties," in N.J. Rosenberg, et al, eds., Greenhouse Warming: Abatement and Adaptation, Resources For The Future, pp. 7-34.

Soysa, Chandra, Chia, Lin Sien and Coller, William L., eds., Man, Land and Sea, Agriculture Development Council, Bangkok, 1982.

Taylor, Donald C., The Economics of Malaysian Paddy Production and Irrigation, The Agricultural Development Council, Bangkok, 1981.

Titus, James G., 1988, "Can Costal Communities Adapt to a Rise in Sea Level?" in D. Abrahamson and P. Ciborowski, eds., The Greenhouse Effect: Policy Implications of a Global Warming, Center For Urban Regional Affairs, pp. 241-259.

Titus, James G., Hoffman, John S. and Keyes, Dale, Projecting Future Sea Level Rise: Methodology, Estimates to the Year 2100, and Research Needs, 2nd edition, United States Environmental Protection Agency, Washington D.C., October 1983.

Wernstedt, Frederick L., World Climatic Data, Climatic Data Press, 1972.

World Bank, Trends in Developing Economies 1989, The World Bank Publications, Washington D.C., 1989

GLOBAL CHANGE AND BIODIVERSITY LOSS: SOME IMPEDIMENTS TO RESPONSE

Karen Borza and Dale Jamieson

for the
Center for Values and Social Policy
Department of Philosophy

in cooperation with the
Center for Space and Geosciences Policy

University of Colorado
Boulder, Colorado

October 1990

Preface

The authors would like to acknowledge Sally McVey and Radford Byerly of the Center for Space and Geosciences Policy for their guidance and comments. This work was primarily supported by a grant from the National Aeronautics and Space Administration and partially funded by a grant from the Ethics and Values Studies Program of The National Science Foundation.

Table of Contents

GLOBAL CHANGE AND BIODIVERSITY LOSS: SOME IMPEDIMENTS TO RESPONSE

EXECUTIVE SUMMARY

Many scientists believe that Earth's physical and biological systems are undergoing fundamental change. Although much is uncertain, changes in important biosphere-atmosphere feedback mechanisms may affect basic biological processes resulting in shifts in agricultural growing belts, reduction and poleward shifts of northern hemisphere forests, and possibly even mass extinctions. An effect of these changes may be a loss of biological diversity ("biodiversity"). This paper discusses the value of biodiversity and identifies some societal impediments to responding to its loss. We also offer some policy recommendations which may help us to better respond.

The concept of biodiversity is intuitively simple but surprisingly difficult to define. Generally, biodiversity refers to the variety and variability among and within living organisms and the ecological systems in which they occur (U.S.OTA 1987). However, there is no general agreement on the exact definition nor on why we should value biodiversity. There is also much debate about economic, cultural, scientific, and philosophical arguments for establishing the value of biodiversity. These conceptual problems are in part responsible for the difficulties we encounter recognizing biodiversity loss, and explain why we have largely failed to respond to it.

Sound policy must be based on relevant and useful information. However, the transfer of such information among the societal groups involved in the decision process, the scientific community, policy makers, and the general public, has been slow and inconclusive. In addition, the ecological consequences of present actions and policies may be long-term and spread out over vast geographical areas, making these consequences difficult to grasp. As

a result, government institutions, multilateral organizations, and nongovernmental organizations experience trouble knowing how to respond.

Recent policy attempts to deal with biodiversity loss have been fragmented. For example, legislation such as the Endangered Species Act mandates a reactive and atomistic approach to saving species and is thereby limited in its usefulness. This paper concludes with a discussion of some general elements we think are necessary to create effective biodiversity policy, as well as a few specific recommendations. For example, increased awareness that biodiversity loss is a problem, a renewed effort to determine the status of biodiversity, and suggestions for proactive rather than reactive policy could help us better manage threats to biodiversity loss.

I. INTRODUCTION

Many scientists believe that Earth's physical and biological systems are undergoing fundamental change (*e.g.* IPCC 1990). While natural systemic change has always been a part of our planet's history, many current changes appear to be caused largely by humans, and to be much faster than natural changes. Although these changes are not always readily apparent, they are potentially of great consequence. An increasing human population and rate of consumption place unprecedented strains on limited natural resources. Pollution, increasing as technological development outpaces our ability to dispose of the waste it produces, threatens critical land, water, and air resources. Even if nuclear, chemical, and biological weapons are not used, they pose threats to life because of dangers associated with their production processes. Ozone depletion, caused by the injection of chlorofluorocarbons into the atmosphere, threatens both human health and biological productivity. Perhaps most ominously, climate change, influenced by deforestation and the injection of carbon dioxide and other "greenhouse" gases into the atmosphere, may result in a climate regime unprecedented in the last 100,000 years.

In this paper we discuss the effects of anthropogenic global climate change on biodiversity, and we focus on human responses to this problem. Greenhouse warming-induced climate change may shift agricultural growing belts, reduce forests of the northern hemisphere and drive many species to extinction among other effects. If these changes occur together with the mass extinctions already occurring we may suffer a profound loss of biological diversity.

The concept of biological diversity ("biodiversity") is intuitively simple but surprisingly difficult to define precisely. Generally, biodiversity refers to the variety and variability within and among living organisms and the ecological systems in which they occur (U.S.OTA 1987; HR1268). However, because life is organized on many different levels ranging from the genetic to the ecosystemic, several different dimensions of biodiversity can be identified.

Genetic diversity refers to variety and variability at the cellular level, as in a specific gene pool. Genetic diversity allows a species to adapt to changing conditions, and it increases the range of possibilities for the future evolution of the organism. *Species diversity* refers to the number and variety of existing species. Although this is the aspect of biodiversity which is most familiar, it is problematic in that there is no universally accepted definition of "species" (Ruse 1988). Despite this difficulty, about 1.4 million species of plants, animals and insects have been identified, and between 5 million and 30 million species are estimated to exist (Wilson 1988). Although the exact number of species is unknown it is clear that extinction rates are increasing (Myers 1988; Lugo 1988). *Ecosystem diversity* refers to variety and variability at a higher level of organization, that of the ecosystem, which is a combination of plant and animal communities functioning holistically. Ecosystem diversity "embraces the whole collection of properties peculiar to renewable biological resources and it can, conversely, itself be regarded as a resource" (Ramade 1984, p. 15).

A comprehensive definition of biodiversity is difficult to formulate, both because there are so many levels at which biodiversity may exist and because it is difficult to distinguish between definitions and measures of biodiversity. It is important to note, however, that the holistic nature of biodiversity is of paramount importance. As Bryan Norton remarks, "Biological diversity is a much broader concept than genetic diversity. Biological diversity is not just constituted by the number of species, subspecies, and populations extant; it is also constituted by the varied associations in which they exist" (Norton 1987, p. 260).

In recent years concern about biodiversity loss has begun to move from the scientific literature to popular consciousness. Many reasons for this concern have been identified, including loss of resources, diminished opportunities for recreation, tourism, and research, and erosion of cultural heritage (U.S.OTA 1987). Scientists have been particularly concerned about the critical role that plant and animal life (the "biota") plays in maintaining the complex balance of life on Earth. Biodiversity loss at any level may affect the physical and biological processes we so greatly depend upon.

Global change threatens biodiversity because life is utterly dependent on its physical environment, and most life forms exist only within a narrow range of ecological conditions. Our concern in this paper will be to identify societal impediments to responding to biodiversity loss. We will begin by discussing the potential impacts of climate change on biodiversity, and the effects of biodiversity loss itself. Next we will address some problems in valuing biodiversity. Difficulties in recognizing biodiversity loss will then be considered. We will go on to evaluate the responsiveness of existing institutions to the problems we have identified, and, finally to draw conclusions and make recommendations.

II. POTENTIAL IMPACTS OF GLOBAL CHANGE ON BIODIVERSITY AND BIODIVERSITY LOSS

Systemic change has occurred throughout the history of the Earth, but many believe that change is now taking place at an unprecedented rate (Myers 1988; Lugo 1988). Many of these changes in Earth's physical systems can be attributed to human activity. Although there are many uncertainties about the magnitude and velocity of these anthropogenic changes, there is little doubt that they are occurring now and that they will have a profound effect on biodiversity.

Impacts of Global Climate Change on Biodiversity

Most scientists believe that we are already committed to a 1.5 to 4 degree centigrade warming of the Earth's mean surface temperature (IPCC 1990). Although the overall effect will be global warming, regional precipitation patterns, temperatures, and the likelihood of extreme events will impact different regions in different ways. Though these regional effects are not well understood, it has been suggested that on the North American continent there may be northward shifts of up to 300 km in agricultural growing belts (R.L. Peters 1989). Crop yields are expected to decrease in the Great Lakes region, the Southeast, and the Great Plains due to an increase in temperature, while an increase in crop yields is projected for the northernmost latitudes of Minnesota. Globally, an expansion of grasslands and deserts is expected to occur at the expense of forest and tundra. (UNEP/GEMS 1987).

Many factors can adversely affect the response of ecosystems and their constituents to climate change. Reduction in populations can reduce genetic diversity and consequently the ability of a species to adapt to changed environmental conditions. Temperature means and extremes, precipitation, soil type, soil moisture, and regional isolation affect both the actual distribution of species and their distributional limits (U.S.EPA 1988).

It is during the transition period from one climate regime to another that many species will be most vulnerable. In order to cope with changing climate, they will have to adapt or "migrate" to new areas. Climate change may often be too rapid to permit successful adaptation. Migration can be inhibited by species' lack of mobility as well as by physical barriers such as mountains, bodies of water, roads, cities, agricultural land, inappropriate soil type, and habitat heterogeneity (U.S.EPA 1988). In most areas migration corridors are not available for many species of plants and animals. Moreover, because of differing migration rates among species, ecosystems are unlikely to migrate intact. This disintegration of ecosystems may endanger species which otherwise could adapt to climate change.

Northern boreal forests are expected to shift poleward due to climate change. In the Eastern U.S., forests may migrate approximately 600-700 km within the next 100 years, while the southern range may die back due to increasing temperatures and drier soil conditions (U.S.EPA 1988). Because of the interdependency among species in an ecosystem, extirpation of a single tree species may adversely impact the rest of the organisms (birds, insects, plants, microorganisms, and mammals) in a forest ecosystem that depend on the tree species for food or habitat.

The pressure of climate change is likely to increase the already high rate of species extinction. Tropical deforestation, resulting from slash-and-burn agricultural practices, logging, and other human encroachment (Wilson 1988; Myers 1988) seems to be causing the destruction of about 17,000 species each year. In the world's rainforests approximately 375,000 to 1.25 million species are estimated to be threatened (deLama 1989). Although mass extinctions have occurred previously in Earth's history (Raup 1988), rarely have they approached the current rate and never before has human activity had such catastrophic effects.

Effects of Biodiversity Loss

Biodiversity cannot be equated with numbers of existing species; nevertheless, when species are driven to extinction, biodiversity declines. The impacts of biodiversity loss are wide-ranging. Some of these effects include changes in the composition of ecosystems. A reduction in the diversity of an ecosystem may result in both genetic and species loss as well as damage to the ecological processes that characterize the ecosystem (U.S.OTA 1987). For example, loss of soil fertility due to deforestation or desertification can reduce the kinds of crops that can be grown in a particular region. Soil erosion due to deforestation and desertification may reduce reliable water supplies by increasing runoff, thus decreasing water storage (U.S.OTA 1987; U.S.EPA 1988).

Changes in geochemical cycles may occur due to extinction or migration of plant and animal species responsible for cycling carbon, oxygen, nitrogen, and sulfur. The amount and availability of food sources as well as pharmaceuticals and fibers may be greatly reduced as the ecosystems, species, and genes which provide these resources are diminished (U.S.OTA 1987). Natural crop pollinators, pest predators, and weed control organisms may be lost as well. Declines in "resistance genes" (those which contribute to the resistance of crops to pests and pathogens), species that promote natural pest predators, and wild habitats that support pollinators, will make it difficult to protect crop species (U.S. OTA 1987).

Finally, changes or alterations in the food web could result from the deterioration of biodiversity. The removal of an organism at the top of the food web may have devastating effects throughout the web. (U.S.OTA 1987). An example is provided by the effects of ozone depletion on aquatic ecosystems. Depletion of the stratospheric ozone layer, as a result of man-made chlorofluorocarbons (CFCs) could lead to an increase in UV-B, ultraviolet radiation from the sun that is normally absorbed by stratospheric ozone. UV-B is able to penetrate clear water to a depth of a few meters, where it can damage algal chlorophyll, the chemical responsible in large part for photosynthesis. Single-celled algae occupy an important position at the top of the aquatic food web, and UV-B induced damage among algae would have repercussions throughout aquatic ecosystems (Smith et al 1980).

III. THE VALUE OF BIODIVERSITY

One of the most important impediments to preserving biodiversity is the difficulty of establishing and measuring its value. It has been argued that biodiversity should be preserved because such preservation is in our economic interests, because it contributes to scientific knowledge, because our cultural values demand it, and because a diverse world is better than a uniform one. In this section we discuss these reasons to value biodiversity and we note some of the difficulties which characterize the different values. In addition, we discuss some difficulties in making quantitative assessments of the value of biodiversity.

Economic Arguments for Valuing Biodiversity

Some have argued that biodiversity should be preserved because it returns economic benefits (Randall 1988, Farnsworth 1988, Iltis 1988, Wilson 1988). Economic literature describes several types of value including use-value, option-value, and quasi-option-value. Use-value is the extractive value of a resource, and is based on its market price. Option-value is the value of having the option to use something as a resource (Norton 1987). Quasi-option-value is the value of preserving options, given the expectation that growth in knowledge will produce new uses for species (Randall 1986; Norton 1987). For example, it is assumed that over time the number of species useful to the pharmaceutical industry will grow as advances in medical science occur, and as knowledge of how to use these species increases.

Economic arguments for preserving biological diversity are not altogether convincing. Few economists specifically address the value of biodiversity. Rather their concern is with the economic value of natural resources and even in this context some questions may be raised. While use-values of natural resources are fairly clear, option-values and quasi-option values are not. Indeed the assertion that there are such values may imply substantive ethical commitments (Norton 1988, Randall 1988). It can also be argued that economic considerations favor reductions in biodiversity, and that it is economics that is driving current biodiversity loss. Clark (1973, 1989) has shown in detail that in some sense it is economical to drive blue whales to extinction and invest the benefits in other productive enterprises, rather than manage blue whale populations in a sustainable way. From the point of view of economic theory, it is rational to drive species to extinction if present benefits are greater than discounted future benefits. Of course some may see this argument as indicative of a flaw in economic theory, rather than a comment on the value of biodiversity.

Critics of economic approaches to species preservation have argued against the use of a discount rate for future benefits (Parfit 1983). The notion guiding the discount rate is that a present dollar has greater value than a future dollar because it can now be invested and in the future it will be worth more than a dollar. Thus, when resources are treated as capital their future value must be discounted, and the value of the resource depreciated exponentially as the time period used in the calculation increases (Krutilla and Fisher 1975). On this approach, benefits spread out over the next century often turn out to be worth very little at present.

Cultural Arguments for Valuing Biodiversity

One influential argument for preserving the natural environment appeals to the cultural values of Americans (Sagoff 1974) and might be extended in such a way as to provide a reason for preserving biodiversity. On this view, Americans value the environment because our own national experience was shaped by confrontation with nature. Immigrants left the teeming urban centers of the "old world" to live in the unspoiled nature of the "new world". Indeed, the migration from the eastern to the western U.S. of the 1880s might be explained the same way. On this view the destruction of nature involves the destruction of our own cultural ideals.

Some may doubt whether environmental preservation really is an American cultural value. Even if it is, this argument would not provide a reason for preserving biodiversity on a global scale. Other societies may have different cultural ideals, and thus may have no reason to preserve biodiversity. However, if biodiversity is to be preserved it will take a global effort. Ecosystems do not admit of national or cultural boundaries, and any attempt at preservation must respect the boundaries of ecosystems, even if these conflict with political or cultural boundaries.

Scientific Arguments for Valuing Biodiversity

The scientific reason for valuing biodiversity lies in its value as the potential subject of knowledge. Due to human activity, genetic resources, species, and whole ecosystems are being destroyed before they can be cataloged and identified, much less studied. There are forms of life about which we will never have knowledge. With their extinction, opportunities for knowledge are lost forever. Yet, while this consideration has some force, its power can be denied. Some would flatly deny that knowledge is intrinsically valuable. Such an attitude, although not common in the scientific community, is very common in society at large. Many people believe that knowledge is valuable only insofar as it serves human ends.

This argument differs from the economic argument in that it makes no appeal to the economic benefits that knowledge may produce. On this view knowledge is intrinsically good, and biodiversity loss is bad because it reduces the opportunities for knowledge acquisition. This reason for preserving biodiversity is often given by scientists whose research is most directly affected by biodiversity loss (Ehrlich and Ehrlich, 1981). For someone who investigates tropical rainforests, the destruction of the forests may seem morally equivalent to the wanton destruction of a chemist's laboratory.

Even if it is agreed that knowledge has intrinsic value, this does not lead directly to recommending policies for preserving biodiversity. If such preservation were costless, then strong measures would be in order. But preserving biodiversity is not costless. People benefit from activities that result in the reduction of biodiversity. Its scientific value is a reason to preserve biodiversity, but it is not easy to say how strong a reason it is, and what weight it should have compared to other reasons.

Philosophical Arguments for Valuing Biodiversity

Two sorts of philosophical arguments have been given for valuing biodiversity. One argument, at least as old as the Aristotelian tradition, and highly developed during the medieval period, is that a richer, more complex world is better than a simpler, more uniform one. A second argument holds that it is wrong to kill many forms of nonhuman life.

There are at least two possible bases for the claim that a more complex world is better than a simpler one. One basis would be that complex worlds are objectively better than simpler ones, and that this in no way depends on the interests or purposes of valuers: it is an irreducible fact about value. A second basis for such a view would be to say that people place greater value on complex worlds than on simpler ones. On this view complex worlds are more valuable than simpler ones because people value them more highly. People may value them more highly because of their aesthetic value, or because of other interests that humans take in them.

Even if the view that more complex worlds are better than simpler worlds is correct, there is still a question about how much value complex worlds have in relation to simple ones. In order to "operationalize" such a view we would need a way of measuring degrees of complexity, and we would have to be able to map degrees of complexity onto degrees of value. Only in this way could we trade off the value of complexity against other values, such as those of economic development.

A second philosophical argument claims that it is wrong to kill many forms of nonhuman life. Taylor (1986) argues that killing a wildflower is just as wrong as killing a human. Stone (1974) holds that forests, oceans, and rivers should be granted legal rights. Callicott (1989) and Rolston (1988) argue that biological entities such as ecosystems and species have priority over individuals, and that in some cases the moral obligation to save plankton and bacteria is more stringent than the obligation to save human lives. On these views the destruction of biodiversity violates moral obligations that we have, and perhaps even the fundamental rights of other life forms. While such views are becoming more prominent in the intellectual community, they have been severely criticized (see *e.g.*, Regan 1981). However a modest variant of this view reaches similar conclusions in an indirect way. In recent years some philosophers (*e.g.* Singer 1986, Regan 1986) have argued that the same reasons we have for considering humans to be members of our moral community also apply to many non-human animals as well. If we were to accept such a view, we would perhaps acknowledge an obligation to respect the habitats of these animals, and this would lead to the protection of many plants and animals, and therefore the preservation of biodiversity.

Biodiversity may be valuable for a variety of reasons. We believe that the scientific and philosophical arguments for preserving biodiversity are persuasive and can be rationally defended. Although the arguments are complex and the scientific and philosophical values are difficult to quantify, this does not make biodiversity less important.

Measurement Problems

As a society we have a difficult time recognizing and respecting values that are difficult to quantify. This has led economists and others to try to quantify non-economic values so they may be represented in our decision processes. This is difficult because economics relies on the market or demand value of a resource as an indicator of its value. Biodiversity is not traded in a market, and therefore has no demand value. Moreover the most significant dimensions of biodiversity's value (the scientific and philosophical), are not related to its use as a resource.

In order to represent such values, economists have developed the notion of existence value. Existence value is the value attached to knowledge of something's existence, and is independent of any potential uses (Randall 1986). Economists measure existence value by creating a "shadow market", and thus a demand value, through the method of contingent valuation. Consumers are asked what they would be willing to pay to have the option to use a resource or to know that it exists. Contingent valuation allows the economist to assign dollar figures to values traditionally not measured in monetary terms. An abundance of literature exists which discusses the validity of this method. Although there are many different views, this literature suggests that contingent valuation does not accurately measure the value of non-resource goods (Boyle 1989, Brown 1984, Ehrenfeld 1988, Fisher and Hanemann 1985, Goodman 1989, Gregory 1986, Hanemann 1988, Knetsch and Sinden 1989, Norton 1986, 1987, 1988, Swartzman 1982, Tversky and Kahneman 1981, Weisbrod 1964). We doubt whether such studies could ever accurately measure the value of non-resource goods because it is far from clear that people value such goods in economic terms. For this reason there may be no right answer to many of the questions that are asked in contingent evaluation studies. At best, such studies may create economic values for non-resource goods, rather than discovering the values of the respondents. The values that are created may be an artifact of our techniques and have no validity. Sagoff (1981, 1984) has argued that the value that we place on goods such as biodiversity flows from our ideals and principles, and that it makes no sense to measure ideals and values in economic terms.

The problem of measurement, then, is that the considerations that make biodiversity important are not open to simple quantification. For this reason it is difficult to determine acceptable tradeoffs between biodiversity and other goods, or even to represent the value of biodiversity in the decision-making process. Although biodiversity is important, it is difficult to respect its value in the public arena.

IV. PROBLEMS RECOGNIZING LOSS OF BIODIVERSITY

We have claimed that loss of biodiversity is an important problem. We are already losing species at a very high rate, and climate change threatens to make this problem even worse. We have identified one problem in responding to biodiversity loss: the value of biodiversity is difficult to quantify and to trade off against other values. There are other problems as well. If we are to make adequate policy with respect to biodiversity loss, relevant information must be made available in a usable form. However, information is differentially generated and consumed among various societal audiences. In this section we discuss some issues about information transfer among these audiences, including scientists, the general public, and policy-makers.

Scientific Community

The issue of biodiversity was first raised by a small group of specialists including some members of the scientific community, as well as advocates from research organizations, universities, multilateral governmental organizations, and non-governmental organizations (NGOs) as well. Within this group, there is a high level of awareness about biodiversity issues. However, despite efforts to quantify biodiversity loss, even biologists and ecologists lack some very basic information. As Jenkins (1988) points out, the following information, at least, is needed in order to address the problem of biodiversity loss:

> . . . existence, identity, characteristics, numbers, condition, status, location, distribution, and ecological relationships between biotic species and biological communities or assemblages . . . (p. 231)

We will argue that most of the information available to biologists and ecologists concerns *numbers* of species, and that despite the high level of awareness of biodiversity issues, the scientific basis for thorough discussion is not yet secure. What follows is a discussion of some of the disputes among biologists and ecologists. Among the major sources of disagreement are the difficult and controversial quantitative assessments which concentrate on species rather than on ecosystems.

One example concerns species and gene counting: various investigations have yielded a wide range of results. While taxonomists have catalogued about 1.4 million species, it is estimated that between 5 million and 30 million exist (Wilson 1988), and some estimate the upper end of the range at 80 million (Brower 1990). However, an exact number has not yet been agreed upon.

Another example of controversial quantification is the calculation of potential rates of species extinction. Although he acknowledges that there is no way to know the exact rate of extinction, Myers (1988) suggests we can arrive at an estimate by applying the techniques of island biogeography to the number of species present in a habitat before deforestation. Such a calculation suggests that when 90% of a habitat is destroyed, 50% of the species will eventually be lost. Myers estimates that in the last 35 years 50,000 species have disappeared in Brazil and Madagascar, an extinction rate of about 1500 species per year. Wilson (1987) estimates that in tropical forests world-wide, a total of 10,000 species becomes extinct each year. And, according to Simberloff (1986), if deforestation continues at the present rate, 15% of all plant species and about the same number of animals species will be gone by the year 2000 (as cited in Myers 1988 and Lugo 1988). However Lugo (1988) argues that these estimates are not accurate:

> It is necessary to consider the effect of forest types on species abundance, the spatially selective (life zone) intensity of human activity, the role of secondary forests as species refugia, and the role of natural disturbances in maintaining regional species richness. At a regional level, one also has to consider the importance of exotic species in the maintenance of species richness, particularly in ecosystems subjected to the impact of human activity. This approach seeks balance by considering factors that maintain species richness as well as those that decrease it. Considerable research is required to provide sound estimates based on this

approach, because critical data concerning ecosystem function are not available in enough breadth to support enlightened management or policy making (Lugo 1988, p. 65).

There are other criticisms of extinction rate calculations. Because an extinction rate is expressed as a percentage one must have a base from which to calculate an absolute rate. However, as we have noted, scientists do not know the total number of existing species. The usual estimate given (Myers, Wilson 1988) is a range of 5 million to 30 million species. The high end of this estimate was derived by Erwin (1983, see also May 1988) who counted beetle species in a tropical forest. An assumption is made here that nature is uniform, and that one can generalize extinction rates across ecosystems. However, the biota are discontinuous in general, so there is no reason to believe that extinction rates are geographically uniform.

In addition to being inaccurate over geographic areas, calculation of an average extinction rate averages periods of high and low extinction, a process which may provide misleading information along the temporal dimension. David Raup writes:

> If . . . the Cretaceous-Tertiary extinctions took place over a time as short as a single year, then calculations of long-term rates become meaningless: during short intervals of extreme physical environmental stress, extinction rates were nearly infinite, whereas between these events, extinction rates may have been virtually zero . . . extinctions are point events rather than the result of a time-continuous process (Raup 1988, p. 54).

Rates of extinction among species also ignore a fundamental problem of taxonomy. There is as we have noted, a debate in the scientific community over what a species is (Ruse 1988). If it is not clear what constitutes a species, then it becomes even more difficult to estimate loss.

Finally, the ecosystem focus becomes lost in the process of counting species. Even if we know about the destruction of a particular ecosystem, we cannot identify which species have become extinct. Without a basic knowledge of the species composition of an ecosystem, quantifying loss of biodiversity based merely on the loss of an ecosystem is a difficult and perhaps impossible task.

Despite the lack of basic knowledge about extinction rates and species, it is apparent to the scientific community that human-caused biodiversity loss is occurring. Although lacking exact numbers, ecologists do possess a qualitative understanding of many issues involved in species extinction, and they recognize that a problem exists. However, the disputes within this community on the quantitative issues are passed on to the public and policy makers by the media and interest groups, resulting in an inconclusive public discussion in part because the underlying scientific understanding is weak. Finally, other than biologists and ecologists, most scientists may not differ greatly from the general public in their lack of understanding of biodiversity issues.

Policy Makers

Those in charge of developing and implementing policy face many of the same problems recognizing biodiversity loss as do ordinary citizens, and those similarities will be discussed in a later section. This section describes the unique problems policy makers encounter in recognizing biodiversity loss.

First, while the general public can take its time and choose whether and how to participate in the issue, policy makers are quickly forced to take a side when an issue arises (*e.g.* through a political initiative or increasing public interest). This means that a policy maker may have to take a public position on an issue without having had the time to study it thoroughly.

Second, biodiversity issues are likely to have a relatively low priority because they are perceived by policy makers as international issues rather than domestic ones, and therefore far from the concerns of the electorate. Elections do not turn on a candidate's position on biodiversity loss.

Third, biodiversity loss is a long-term issue whose consequences are remote. Our political system emphasizes short-term, domestic issues that correspond to election cycles. Problems that require long-term thinking are unlikely to rise to the top of the political agenda.

History may provide a clue as to why policy makers have trouble recognizing biodiversity loss. Previous attempts to focus attention on similar environmental issues have often dealt with individual species such as bald eagles, blue whales, and furbish louse-worts, resulting in legislation such as the Endangered Species Act. Such species do not serve as proxies for entire ecosystems, nor were they intended to do so by the legislation. While the Endangered Species Act addressed an important problem, and although the use of species as symbols (*e.g.*, owl vs. jobs) captures public attention, over the long term this approach has proven to be too narrow to address current problems of biodiversity loss. Focusing attention exclusively on single species can blur the very important issue of complex ecosystems as an embodiment of biodiversity. While the Endangered Species Act was important as a first step, there is now a need to focus on ecosystem issues.

General Public

In their role as citizens, policy makers and scientists experience many of the same problems recognizing biodiversity loss as does the general public. These groups have several problems in common.

First is the high rate of scientific, and particularly biological, illiteracy among the general public. While few people grasp the concept of "species", even fewer understand the relative importance of different species. It is known that bacteria and fungi are essential to the maintenance of ecological and evolutionary processes on earth (Odum 1983; Ricklefs 1979). Therefore, decomposers and other plant life situated at the end and beginning of the food chain are equally, if not more important than the few conspicuous species (*i.e.*, condors, rhinos, and pandas), which tend to receive most of our attention. However, because the public is highly ignorant of these relationships (and as a result of the legislative approach embodied in the Endangered Species Act), it continues to place great emphasis on saving a very narrow range of species.

A second problem, issue competition, can draw the public's attention away from biodiversity loss issues. The American public relies in large part on the popular media for information about issues such as biodiversity loss. In particular, the media is quite adept at providing America's large television audience with front row seats for the latest natural disaster, coup attempt, or airplane crash. Such sensational, short-lived stories often draw interest away from long-term problems such as biodiversity loss.

The American public is also less likely to pay attention because biodiversity loss resulting from global change is an abstract idea. However, integrating biodiversity loss with more tangible and familiar issues, may provide the public with a clearer message. One way in which this might be accomplished is to link deforestation and biodiversity loss to encroachment on the natural resources of a developing country by a multinational corporation. An example might be the destruction of tropical rainforest ecosystems in Central America by American fast food chains in order to raise cattle for consumption in the U.S. as hamburgers (Myers 1981; Uhl and Parker 1986). Such examples provide a way for the public to focus on an otherwise long-term, abstract problem.

Finally, while biodiversity loss may directly and immediately affect the lives of the general public, it does so invisibly. There are two reasons why it is difficult for the general public to recognize biodiversity loss as it is taking place. One is that the consequences may not be evident in the short term. For example, the gradual loss of natural crop pollinators, pest predators, and weed controlling organisms eventually results in crop destruction, but such losses may take several years to recognize and even longer to be felt by the public. The second reason we don't recognize biodiversity loss is that the American public has at its disposal a wide range of resources. So many, in fact, that the disappearance of one is rarely alarming because there are many readily available substitutes at present.

Loss of biodiversity is a problem spanning geographical and cultural boundaries, as well as time and value systems. It is a problem without easy solutions, and certainly without the quick fixes which capture the public's attention. There may be some partial solutions that appear easy in principle, however, these solutions are difficult to implement and to sustain, and it appears to the American public that there is little they can contribute to help alleviate the loss. This sense of helplessness in itself may prevent individuals from taking action.

In order for our political institutions to respond successfully, loss of biodiversity must first be recognized as a problem caused by anthropogenic global change as well as by damaging local activities. Information about biodiversity loss is not clearly understood or transmitted by the scientific community, the general public, or policy makers, and without a clear understanding of the problems, finding solutions is much more difficult. Problems with biodiversity issues are not restricted to societal groups mentioned earlier.

V. INSTITUTIONAL RESPONSIVENESS

Problems with biodiversity issues are not restricted to the societal groups mentioned earlier. For several reasons institutions also have difficulty responding constructively to biodiversity loss. First, as noted above, the ability to respond depends somewhat on the ability to recognize biodiversity loss. Second, because a constructive response might well involve fundamental changes, the flexibility required to address biodiversity loss is lacking in many institutions. Third, an effective response typically involves many institutions. Finally, solutions to biodiversity loss may be in direct conflict with other policies. For example, by vetoing legislation that would have provided the United Nations Family

Planning Agency with $15 million in U.S. support, the Bush administration has indicated that it does not support population control, although one possible cause of biodiversity loss is the increasing number of people dependent upon a shrinking natural resource base. Thus, encouraging population control, a potential partial solution to biodiversity loss, is in direct conflict with current administration policy.

The problems of institutional responsiveness are aptly summarized in the following comments.

> The objective of sustainable development and the integrated nature of the global environment/development challenges pose problems for institutions, national and international, that were established on the basis of narrow preoccupations and compartmentalized concerns. Governments' general response to the speed and scale of global changes has been a reluctance to recognize sufficiently the need to change themselves. The challenges are both interdependent and integrated, requiring comprehensive approaches and popular participation (WCED 1987, p. 9).

Although this paper is geared toward United States policy, some brief observations about the way other countries respond to biodiversity loss are illuminating. Not only has the United States failed to act on biodiversity issues, most other countries lack comprehensive plans to deal with these issues as well. A further distinction can be drawn between the reactions of developed and developing countries. In developed countries such as the United States the resources are available for attacking biodiversity loss, but as discussed above a variety of factors keep them from recognizing and understanding the loss and coordinating programs to address it. Like developed countries, developing countries haven't responded to long-term issues such as biodiversity loss, but for different reasons. Developing countries depend to a greater extent on their native biodiversity, and in the long run ought to be very sensitive to its loss. However, developing countries with short-term pressures to provide food and shelter are not likely to respond to a long-term issue such as biodiversity loss. They do not have the resources of the developed countries with which to address it. Finally, developing countries experiencing foreign debt crises may exploit natural resources at much higher levels than countries without debt (NSB 1989).

The problems that we have identified differentially affect government institutions, multilateral organizations, and nongovernmental organizations. We will discuss each in turn.

Government Institutions. U.S. government institutions have only recently been forced to consider global change issues such as biodiversity loss. Currently there is no Federal mandate for the maintenance of biological diversity. However, many government institutions have some responsibility for Federal ecosystem conservation programs, although most of these programs address and protect only those species recognized under the Endangered Species Act. In addition, Federal agencies interpret terms such as "biological resources", "wildlife", "animals", and "natural resources" in different ways. "Wildlife", for example, has a number of definitions including:

- mammals that are hunted or trapped
- all mammals; used interchangeably with "animal"
- all animals, both vertebrates and invertebrates, excluding fish
- all animals, both vertebrates and invertebrates, including fish (U.S.OTA, 1987)

Federal agencies may have dichotomous missions (Clarke and McCool 1985), or conflicting mandates. An example is the Department of the Interior under which the National Park Service and the Bureau of Land Management (BLM) operate with almost diametrically opposed mandates. The Park Service was established to conserve, while the U.S. BLM has shifted toward development and production of natural resources (Clarke and McCool 1985).

In addition, the mandate of the Park Service is itself dichotomous, encompassing both preservation and use. The mandate is to:

> regulate the use of . . . national parks and monuments . . . conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations (as cited in Clarke and McCool 1985, p. 49).

In addition, the missions of agencies such as the Fish and Wildlife Service and the Bureau of Land Management are to conserve for economic, rather than preservationist ends. For the Fish and Wildlife Service this means that game fish and animals are of highest priority. For the Bureau of Land Management, it means that land will be leased for oil and gas exploration or to graze cattle, rather than for ecosystem protection. The result is an uncoordinated, noncomprehensive, and sometimes even counter-productive collection of programs.

Multilateral Organizations. Multilateral organizations, such as the World Bank, are also potential respondents to global change issues such as biodiversity loss; they act most often in developing countries. However, it is difficult for them to address the issue for a number of reasons. First, multilaterals are affected by the vagaries of international politics which can affect the funding and implementation of programs. For example, according to World Bank consultant George Honadle (1989), countries may be ranked for aid on the basis of their ability to spend money "productively" - their "absorptive capacity". However, absorptive capacity does not consider the environmental effects of those expenditures (Honadle 1989). In addition, difficulties are encountered when multilaterals try to impose institutional frameworks on developing countries.

Second, transnational problems also occur. For example, the efforts of a multilateral organization to address loss of biological diversity may be adversely affected because the multilateral usually works alone. Single organizations have difficulty influencing all the actors necessary to effect significant changes (Honadle 1989). This means that often little is accomplished toward solving transnational problems by multilateral organizations that operate alone.

Third, the exchange of scientific information occurs largely among developed nations, rather than between developed and developing nations (NSB 1989). In addition, on an international scale, politics may push science, including research on biodiversity, to a lower priority level.

Finally, multilateral organizations may have dichotomous missions, as in the case of development agencies which fund projects both to develop (build dams and roads) and to conserve, thus creating conflict and ultimately hampering the preservation of biodiversity.

Non-Governmental Organizations (NGOs). NGOs such as World Wildlife Fund, World Resources Institute, Conservation Foundation, Environmental Defense Fund, Friends of the Earth, National Resources Defense Council, National Wildlife Federation, The Nature Conservancy, and the Sierra Club are advocacy groups. Such groups are most attuned to global change and the problem of biodiversity loss, and have had the most success responding to the loss. Unlike government and multilateral organizations, NGOs have the flexibility to administer their programs most effectively. NGOs are also able to launch demonstration projects which governments can later administer. In the United States, advocacy groups have the power to litigate on biodiversity issues.

Despite these advantages NGOs are limited by their own economic constraints because they are dependent upon grants and donations. In addition, issue selection tends to drive programs and issues may be selected on the basis of their appeal to donors. Although the public may respond to the plight of the appealing panda, it is less likely to take an interest in and contribute to projects directed to ecosystems.

VI. RECOMMENDATIONS

The previous discussion indicated that the preservation and maintenance of biological diversity are important, and that a comprehensive policy for preserving biodiversity should be developed. The fact that the most important reasons for valuing biodiversity are scientific and philosophical, and therefore difficult to quantify, does not make biodiversity less important. Indeed, arguably it makes biodiversity more important. For biodiversity, rather than gaining its value from its impact on our standard of living, is in a domain that transcends economics. Future generations may forgive us for bequeathing them a large national debt but they may never forgive us for destroying Earth's irreplaceable stock of biological resources.

The biodiversity loss that is now occurring and may accelerate in the future is largely anthropogenic in origin. It can be attributed to increasing population, pollution, production of nuclear and biological weapons, exploitative economic development, and climate change. For this reason policies responsive to biodiversity loss must be directed toward controlling human behavior. Furthermore, such policies must specifically be directed towards preserving particular gene pools, species, and ecosystems, but they must also respond to the facts of systemic anthropogenic global change. Otherwise immediate successes in preserving biodiversity in dedicated parks and wilderness areas may be wiped out when climate change makes it impossible for the organisms that we are trying to protect to survive in their designated areas.

Any recommendation must recognize that policy takes place on different levels in both national and international arenas. We describe first some general elements of a policy addressing loss of biodiversity. Next we discuss more specifically the kinds of programs and improvements that can be established at the levels of federal institutions, multilateral organizations, and NGOs.

General Policy Elements

There are four general elements necessary for creating an effective biodiversity policy. The first element advocates an increased awareness of the sources of the problem. The second addresses technical issues of definition and information gathering. The third and fourth concern changes of approach to the problem of biodiversity loss.

Identify the Source of the Problem. As we have already suggested, it is important for us to identify the exact problem our policies are supposed to address. This is especially crucial with respect to biodiversity loss, because this issue is entwined with other important issues, including sustainable development and global change. Preserving biodiversity is not the same as preserving endangered species, and given the facts about global change, atomistic policies directed toward species preservation are not likely to be sufficient for preserving biodiversity. Before we can design policies that are adequate for preserving biodiversity, we must be clear about exactly which problems we are trying to solve.

Develop Better Definitions and Data. The second element of our policy recommendations concerns the efforts to determine the status of biodiversity. We have pointed out difficulties in defining key concepts, such as "biodiversity" and even "species". We have also shown that, despite qualitative and anecdotal data, our quantitative database about biodiversity loss is surprisingly weak. These problems suggest that both empirical and theoretical research must continue. We need to develop better theories, concepts, and vocabularies with which to address this problem. We also need more information about what is occurring on the ground. Because biodiversity levels are always changing, we must continue to monitor its status.

One way to do this is to establish global bioinventory databases for plants, animals, and microorganisms on both national and international levels. Monitoring and collecting programs such as UNEP's Global Environmental Monitoring System (GEMS), the

International Board for Plant Genetic Resources Program (IBPGR), and the Nature Conservancy's Natural Heritage Data Centers already exist, and these programs need to be continued and improved.

Transcend the Species Approach. The traditional approach to species loss is an individualistic one, exemplified by the Endangered Species Act. We suggest that while such an approach is useful for dealing with individual species, it does not address the holistic nature of biodiversity, "the varied associations in which [species, subspecies, and populations] exist" (Norton 1987, p. 260). As U.S. AID administrator Nyle Brady writes,

> . . . habitat conservation is the key to the effective conservation of the world's biological diversity. The utility or necessity of a species from the standpoint of humans is not necessarily a corollary of a species' adaptability. Therefore, conserving biological diversity for human benefit means conserving sufficient natural habitat for those species incapable of surviving elsewhere (1988, p. 410).

It is necessary to move beyond the individualistic, single species approach to one based on the ecosystem because,

> . . . attempts at snatching individuals from the jaws of extinction are analogous to treating the symptoms of a disease without curing the disease itself (Hunt 1989).

While her language may be harsh Hunt's point is well taken; the only way to ensure that organisms can continue their evolutionary processes is to ensure the protection of the ecosystems in which they live.

Become Proactive. Another characteristic of the traditional approach to species loss is that it is reactive. Under the ESA, the first step is to list a species. A species is listed as endangered when enough information is gathered to suggest that there is a significant decline in the population or range of the species, and after public review has been completed (U.S.OTA 1987, p. 228). The next step is the development of a formal recovery plan that outlines the responsibilities of all parties involved in protection of the species and management of its habitat. The recovery plan, which is not a binding agreement but simply an advisory document to the Secretary of the Interior, must then be approved.

The problem is that implementation of recovery plans is slow (Drabelle 1985, as cited in U.S.OTA 1987), and some animals may become extinct in the time period between their proposal as candidates and their review by the Fish and Wildlife Service (Bean 1985; Fitzgerald and Meese 1986, as cited in U.S.OTA 1987). The problem is inherent in the nature of the policy which is applied only after a problem is recognized.

This reactive approach should be modified in favor of a more proactive approach to preserving and maintaining biodiversity. A proactive approach would identify ecosystems that might become endangered in the future, and it would insist that preventive efforts be taken to ensure that none become endangered.

Any proactive program should have at least the following dimensions:

First, we should pursue a "tie-in" strategy with various approaches to limit or slow climate change (Jamieson 1990). Many of the policies that should be implemented in response to the possibility of global warming would help preserve biodiversity in two ways. First, they would help preserve biodiversity by slowing or inhibiting climate change and, as we have seen, climate change is a major threat to the preservation of biodiversity. Second, many of these policies would also have indirect effects that would contribute toward biodiversity preservation. For example, policies to slow greenhouse warming would reduce the use of fossil fuels. The cycle of fossil fuel development and use is extremely damaging to biological resources. For example, the transport of oil can lead to cataclysmic accidents of the sort that occurred in Prince Edward Sound in 1989. The use of coal has lead to an epidemic of acid rain in Europe and increasingly in North America, with catastrophic effects on lakes and boreal ecosystems.

A second dimension of a proactive approach is an educational one. As we have seen, issues about biodiversity loss are complex and often ill-understood. Regulation, legislation, and court decisions are certainly needed in this area, but ultimately the protection of biodiversity rests on a well-informed, well-educated citizenry. Science education must be improved, and people must also learn to think more rigorously about the long-term effects of many small actions. In addition to this we need to educate people to think more clearly about values, and we need more research about the nature of values and how they change.

Specific Programs and Improvements

As discussed in Section V, government institutions, multilateral organizations, and nongovernmental organizations all have the potential to respond to loss of biodiversity, but they face a number of difficulties in doing so. Despite the uncertainties and questions it is important to begin to formulate some ideas about how these institutions might better respond to biodiversity issues.

Government Institutions. While there is interest in funding biodiversity research, institutions of the United States government lack a federal mandate for the protection and maintenance of biodiversity. H.R. 1268, National Biological Diversity Conservation and Environmental Research Act, offered by Representative Scheuer would provide such a mandate,

> It is the public policy of the United States that conservation of biological diversity is a national goal, and conservation efforts are a national priority (sec. 5(a)) . . . The actions, policies, and programs of all Federal agencies shall be consistent with the goal of conservation of biological diversity, to the maximum extent practicable (sec. 5(c)).

In addition H.R. 1268 would

1) amend the National Environmental Policy Act of 1969 to require that environmental impact statements include the impacts on biological diversity;

2) establish a National Center for Biological Diversity and Conservation Research;
3) establish an Interagency Working Committee on Biological Diversity responsible for coordinating the Federal strategy for conserving biological diversity;
4) authorize agencies on the interagency committee to provide grants for projects to maintain and restore biological diversity; and
5) establish a permanent National Scientific Advisory Committee on Biological Diversity to oversee the programs mentioned above and to serve as a general reference and advisory resource for biological diversity issues.

We believe that passage of the Scheuer bill would be an important step in addressing problems that we have identified.

Multilateral Organizations. Like governments, multilaterals typically have apparently conflicting missions of conservation and development. However, current thinking reflects the idea that development and conservation are not necessarily mutually exclusive goals, and may actually depend upon each other (Benbrook 1989; DESFIL 1988; Gow 1989; Honadle 1989; WCED 1987; Martin 1988). For example, the World Commission on Environment and Development states that:

> . . . it is impossible to separate economic development issues from environmental issues; many forms of development erode the environmental resources upon which they must be based, and environmental degradation can undermine economic development (WCED 1987, p. 3).

In many cases a degraded environment is more difficult to develop than one that is in good shape. For example, Ethiopia seems to be cycling between drought and flood. Much of the agricultural land in Ethiopia is so eroded that rainfall only contributes to further erosion. Preserving biodiversity is part of environmental quality, and environmental quality is part of a larger network of values which includes economic development.

Ecology and economy are becoming ever more interwoven — locally, regionally, nationally, globally — into a seamless net of causes and effects (WCED 1987, p. 5).

Second, multilaterals are best equipped to support and orchestrate exchanges of information about biodiversity loss between developing and developed countries. The international data collection programs run by UNEP as well as the Man and Biosphere Program of UNESCO (implemented by the Department of State), the Tropical Forest Action Plan of the FAO, and the international convention sponsored by IUCN and UNEP are examples of programs through which information can be exchanged among nations (Miller et al 1989).

Finally, multilaterals must work together as well as with NGOs and government institutions in order to broaden the impact of their biodiversity loss programs.

Nongovernmental Organizations. NGOs have had the most success with biodiversity-loss issues and must continue their important work in this area. They should continue to be the voice for biodiversity loss issues by using their high profile to send the message to other institutions as well as the general public. Moreover, NGOs should continue their pilot programs and litigation on biodiversity issues.

A recent study by the World Resources Institute (Abramovitz 1989) surveyed U.S-based organizations on biodiversity research and conservation activities in developing countries. In 1987 $37.5 million dollars were spent on 873 projects in 86 developing countries. NGOs implemented the most projects, 40%, and were the second largest funder of projects, 24% (the U.S. government funded 53%). Some examples of projects include: the planning and establishment of protected areas in Peru by The Nature Conservancy; ethnobotanical studies carried out in Madagascar, Peru, Thailand, and Cameroon to document the cultural values of biodiversity, as well as the management of buffer zones around protected areas by the World Wildlife Fund, and research in plant systemics to increase the knowledge of plant species by the Missouri Botanical Garden (Abramovitz 1989).

The fact that NGOs are doing a relatively good job does not relieve governments of their responsibilities, however. Any effort to address biodiversity-loss issues must be an effort that includes governments, NGOs, and multilaterals. What we need is major structural change in the way that the world approaches biodiversity issues and thus requires the cooperation of all major players.

VII. CONCLUSION

In this paper we have discussed the problem of biodiversity loss, and identified some of the difficulties involved in our attempts to respond to it. We have also tried to show how this problem is related to that of anthropogenic global change, and have argued that these problems must be approached in concert. We have also made recommendations for responding to biodiversity loss, ranging from new legislation to educational initiatives.

One point that should not be lost in this discussion is that biodiversity loss is occurring now, probably at an unprecedented rate, and unless concerted action is taken in the near future biodiversity loss will cease to be an issue. It is likely that sometime in the twenty-first century, if present trends continue, we will have transformed the Earth, in all of its beauty and richness, into a domesticated monoculture. The plants and animals that persist will be those which are resources for humans, or are able to live on the margins of human activity. As we have tried to show, there are good reasons for wanting to avoid such an outcome. In order to do so, however, we will have to act now.

REFERENCES

Abrahamson, D.E., (ed.), *The Challenge of Global Warming*, Island Press, Washington, D.C. (1989).

Abramovitz, J.N., *A Survey of U.S.-Based Efforts to Research and Conserve Biological Diversity in Developing Countries*, World Resources Institute, Washington, D.C. (1989).

Arrow, K.J., and A.C. Fisher, "Environmental Preservation, Uncertainty, and Irreversibility," *Quarterly Journal of Economics 88*: 312-319 (1974).

Baxter, W.F., *People or Penguins: The Case for Optimal Pollution*, Columbia University Press, New York (1974).

Bean, M.J., *Federal Laws and Policies Pertaining to the Maintenance of Biological Diversity on Federal and Private Lands*, OTA Commissioned Paper (1985).

Benbrook, C., Lecture at George Washington University, 2/14/89

Berner, E.K., and Berner, R.A., *The Global Water Cycle: Geochemistry and Environment*, Prentice-Hall Inc., Englewood Cliffs (1987).

Bolin, B., J. Jager, B.R. Doos, and R.A. Warwick (eds.), *The Greenhouse Effect, Climatic Change, and Ecosystems: SCOPE 29*, John Wiley and Sons, New York (1986).

Boyle, K.J., "Commodity Specification and the Framing of Contingent-Valuation Questions," *Land Economics 65*:57-63 (1989).

Brady, N.C., "International Development and the Protection of Biological Diversity," in Wilson, E.O. (ed.), *Biodiversity*, National Academy Press, Washington, D.C. (1988).

Brennan, A., *Thinking About Nature*, University of Georgia Press, Athens (1988).

Brower, D. Comments at a lecture given at the University of Colorado, Boulder (1990).

Brown, G.M. Jr., and J. Swierzbinski, "Endangered Species, Genetic Capital and Cost-Reducing R & D," in *Economics of Ecosystem Management*, D. Hall, N. Myers, and N.S. Margaris (eds.), Dr. W. Junk Publishers, Boston (1985).

Brown, T.C., "The Concept of Value in Resource Allocation," *Land Economics 60* (3):233-246 (1984).

Brown, W.L., "Genetic Diversity and Genetic Vulnerability: An Appraisal," *Economic Botany 37* (1):4-12 (1983).

Burley, F.W., "The Tropical Forestry Action Plan: Recent Progress and New Initiatives," Wilson, E.O. (ed.), *Biodiversity*, National Academy Press, Washington, D.C. (1988).

Callahan, J.C., *Ethical Issues in Professional Ethics*, Oxford University Press, New York (1988).

Callicot, J.B., *In Defense of the Land Ethic: Essays in Environmental Philosophy*, State University of New York Press, Albany (1989).

Clark, C.W., "Clear Cut Economies: Should We Harvest Everything Now?" *The Sciences*, Jan/Feb: 17-19 (1989).

"Profit Maximization and the Extinction of Animal Species," *Journal of Political Economy 81*:950-961 (1973).

Clarke, J.N., and D. McCool, *Staking Out The Terrain: Power Differentials Among Natural Resource Management Agencies*, SUNY Press, Albany (1985).

de Lama, George, Chicago Tribune, *Centre Daily Times*, "Man Pokes Holes in Jungle's Green Carpet," F:1, April 30, 1989.

DESFIL, *The DESFIL Newsletter 2*(1), 1988.

Drabelle, D., "The Endangered Species Program," *Audubon Wildlife Report*, 1985, New York, National Audubon Society (1985).

Ehrenfeld, D., "Thirty Million Cheers for Diversity," *New Scientist 110* (1512): 38-93 (1986).

"Why Put a Value on Biodiversity?" in E.O. Wilson (ed.), *Biodiversity*, National Academy Press, Washington, D.C. (1988).

Ehrlich, P., and A. Ehrlich, *Extinction: The Causes and Consequences of The Disappearance of Species*, Random House, New York (1981).

Ehrlich, P. "The Loss of Diversity: Causes and Consequences," in E.O. Wilson (ed.), *Biodiversity*, National Academy Press, Washington, D.C. (1988).

Elliot, R., and A. Gare (eds.), *Environmental Philosophy*, Pennsylvania State University Press, University Park (1983).

Erwin, "Tropical Forest Canopies: The Last Biotic Frontier," *Bulletin of the Entomological Society of America*, Spring: 14-19 (1983).

Farnsworth, N.R. "Screening Plants for New Medicines," in E.O. Wilson (ed.), *Biodiversity*, National Academy Press, Washington DC (1988)

Fisher, A.C. and W.M. Hanemann, "Endangered Species: The Economics of Irreversible Damage," in *Economics of Ecosystem Management*, D. Hall, N. Myers, and N.S. Margaris (eds.), Dr. W. Junk Publishers, Boston (1985).

Fitzgerald, J., and G.M. Meese, *Saving Endangered Species*, Washington, D.C., Defenders of Wildlife (1986).

Frankena, W.K., *Ethics*, Prentice-Hall, Inc., Englewood Cliffs (1963).

Freeman, A.M. III, "The Ethical Basis of the Economic View of the Environment," prepared for the Morris Colloquium "Environmental Policy: Ethics and Economics," Department of Philosophy, University of Colorado, Boulder, CO, April 1-3 (1982).

Goodman, A.C., "Identifying Willingness-to-pay for Heterogeneous Goods with Factorial Survey Methods," *Journal of Environmental Economics and Management 16*: 58-79 (1989).

Gow, D., Lecture at George Washington University, 3/21/89

Gregory, R., "Interpreting Measures of Economic Loss: Evidence from Contingent-Valuation and Experimental Studies," *Journal of Environmental Economics and Management, 13* :325-337 (1986).

Gunn, A.S., "Preserving Rare Species," in T. Regan (ed.), *Earthbound: New Introductory Essays in Environmental Ethics*, Random House, New York (1984).

H.R. 1268 U.S. House of Representatives, 101st Congress "National Biological Diversity Conservation and Environmental Research Act."

Hanemann, W.M., "Economics and the Preservation of Biodiversity", in E.O. Wilson (ed.), *Biodiversity*, National Academy Press, Washington, D.C. (1988).

"Information and the Concept of Option Value," *Journal of Environmental Economics and Management 16*:23-37 (1989).

Hardin, G. (ed), *Managing the Commons*, W.H. Freeman and Company, San Francisco (1977).

Honadle, George, Lecture at George Washington University, April 1989

Hunt, C.E., "Creating an Endangered Ecosystems Act," *Endangered Species UPDATE* 6(3/4): 1 (1989).

Hunt, C.E., *Down By the River: The Impact of Federal Water Projects and Policies on Biological Diversity*, Island Press, Washington, D.C. (1988).

Iltis, H.H., "Serendipity In The Exploration of Biodiversity: What Good are Weedy Tomatoes?" in E.O. Wilson (ed.), *Biodiversity*, National Academy Press, Washington, DC (1988).

IPCC (International Panel on Climate Change), *Scientific Assessment of Climate Change: Report Prepared by Working Group 1* (draft), World Meteorological Organization, U.N. Environment Programme.

Jamieson, D. "Managing the Future: Public Policy, Scientific Uncertainty, and Global Warming," in D. Scherer (ed.) *Upstream/Downstream: Essays in Environment/Ethics*, Temple University Press, Philadelphia (1990).

Jenkins, R.E., Jr., "Information Management for the Conservation of Biodiversity," in E.O. Wilson (ed.), *Biodiversity*, National Academy Press, Washington, D.C. (1988).

Kelman, S., "Cost-benefit Analysis: An Ethical Critique," *Regulation*, Jan.- Feb.: 74-82 (1981).

Knetsch, J.L. and J.A. Sinden, "Willingness To Pay and Compensation Demanded: Experimental Evidence of Unexpected Disparity in Measurer of Value", *The Quarterly Journal of Economics*, 99:507-521 (1989).

Krutilla, J.V. and A.C. Fisher, *The Economics of Natural Environments: Studies in the Valuation of Commodity and Amenity Resources*, Johns Hopkins University Press, Baltimore (1975).

Landres, P., Personal Communication (1990).

Leonard, H.B. and R.J. Zeckhauser, "Cost-benefit Analysis Defended," *QQ: Report from the Center for Philosophy and Public Policy*, University of Maryland 3(3): 6-9 (1983).

Leopold, Aldo, "The Land Ethic," in Pierce, C. and D. Van Deveer (eds.) *People, Penguins, and Plastic Trees: Basic Issues in Environmental Ethics*, Wadsworth Publishing Company, Belmont (1986).

Lovejoy, "Diverse Consideration" in E.O. Wilson (ed.), *Biodiversity,* National Academy Press, Washington, D.C. (1988).

Lovelock, J.E., "The Earth as a Living Organism," in E.O. Wilson (ed.), *Biodiversity,* National Academy Press, Washington, D.C. (1988).

Lugo, A.E., "Estimating Reductions in the Diversity of Tropical Forest Species," in E.O. Wilson (ed.), *Biodiversity,* National Academy Press, Washington, D.C. (1988).

Magurran, A.E., *Ecological Diversity and Its Measurement*, Princeton University Press, Princeton (1988).

Manahan, S.E., *Environmental Chemistry* (4th edition), Williard Grant Press, Boston (1984).

Martin, V. (ed)., *For the Conservation of the Earth*, Golden, Fulcrum (1988).

May, R.M., "How Many Species Are There on Earth?" *Science 241*:1441-1449 (1988).

McNeely, Jeffrey A., *Economics and Biological Diversity: Developing and Using economic Incentives to Conserve Biological Resources*, International Union for Conservation of Nature and Natural Resources (IUCN), Gland Switzerland (1988).

Mill, J.S., *Utilitarianism*, O. Prest (ed.), Bobbs-Merrill Inc., New York (1957).

Miller, K., Reid, W., and McNeely, J., "A Global Strategy for Conserving Biodiversity," *Endangered Species UPDATE*, 6(8) 1989.

Myers, N., "Tropical Forests and Their Species: Going, Going . . .?" in E.O. Wilson (ed.), *Biodiversity,* National Academy Press, Washington, D.C. (1988).

"The Hamburger Connection: How Central America's Forests Become North America's Hamburgers," *Ambio* 10:3 (1981).

The Sinking Ark: A New Look At The Problem Of Disappearing Species, Pergamon Press, New York (1979).

Nash, R.F., *The Rights of Nature: A History of Environmental Ethics*, University of Wisconsin Press, Madison (1989).

Norton, B., "On The Inherent Danger of Undervaluing Species," in *The Preservation of Species*, B.G. Norton (ed.), Princeton University Press, Princeton (1986).

Why Preserve Natural Variety?, Princeton University Press, Princeton (1987).

"Commodity, Amenity, and Morality: The Limits of Quantification in Valuing Biodiversity," in E.O. Wilson (ed.), *Biodiversity*, National Academy Press, Washington, D.C. (1988).

NSB (National Science Board), *Loss of Biological Diversity: A Global Crisis Requiring International Solutions*, National Science Foundation, Washington, D.C. (1989).

Odum, E.P., *Basic Ecology*, W.B. Saunders, Philadelphia, (1983)

Oldfield, M.L., *The Value of Conserving Genetic Resources*, Sinauer Associated Inc., Sunderland, MA (1989).

Parfit, D., "Energy Policy and the Further Future: The Social Discount Rate," in *Energy and the Future*, D. Marlen and P. Brown (eds.), Rowman and Littlefield, Totowa, NJ (1983).

Peters, C.M., A.H. Gentry, and R.O. Mendelsohn, "Valuation of an Amazonian Rainforest," *Nature* 339: 655 (1989).

Peters, R.L., "Effects of Global Warming on Biodiversity," in *The Challenge of Global Warming*, D.E. Abrahamson (ed.), Island Press, Washington, D.C. (1989).

Pierce, C. and D. Van Derveer (eds.) *People, Penguins, and Plastic Trees: Basic Issues in Environmental Ethics*, Wadsworth Publishing Company, Belmont (1986).

Public Law 93-205, "Endangered Species Act of 1973."

Rachels, J., *The Elements of Moral Philosophy*, Random House, New York (1986).

The Right Thing To Do, Random House, New York (1989).

Ramade, F., *Ecology of Natural Resources*, John Wiley and Sons, New York (1984).

Randall, A., "Human Preferences, Economics, and the Preservation of Species," in *The Preservation of Species*, B. Norton (ed.) Princeton University Press, Princeton (1986).

"What Mainstream Economists Have to Say About the Value of Biodiversity," in E.O. Wilson (ed.), *Biodiversity*, National Academy Press, Washington D.C. (1988).

Raup, D.M., "Diversity Crises in the Geological Past," in E.O. Wilson (ed.), *Biodiversity*, National Academy Press, Washington, D.C. (1988).

Regan, T. (ed.), *Earthbound: New Introductory Essays in Environmental Ethics*, Random House, New York (1984).

"The Nature and Possibility of an Environmental Ethic," *Environmental Ethics*, 3: 19-34 (1981).

"The Rights View," in Pierce, C. and D. Van Derveer (eds.) *People, Penguins, and Plastic Trees: Basic Issues in Environmental Ethics*, Wadsworth Publishing Company, Belmont (1986).

Ricklefs, R.E., *Ecology*, Chiron Press, New York (1979).

Rolston, H. III, *Environmental Ethics: Duties to and Values In the Natural World*, Philadelphia, Temple University Press (1988)

Ruse, M., *Philosophy of Biology Today*, State University of New York Press, Albany (1988)

Sagoff, M., "At The Shrine of Our Lady Fatima, Or Why Political Questions Are Not All Economic," *Arizona Law Review 23*: 1282-1298 (1981).

"Ethics and Economics in Environmental Law," in *Earthbound: New Introductory Essays in Environmental Ethics*, T. Regan (ed.), Random House, New York (1984).

The Economy of The Earth: Philosophy, Law, and the Environment, Cambridge University Press, New York (1988).

On Preserving the Natural Environment, The Yale Law Journal 84,2, pp 205-267 (1974).

Schneider, S., *Global Warming: Are We Entering the Greenhouse Century?*, Sierra Club Books, San Francisco (1989).

Simberloff, D., "Are We On The Verge of a Mass Extinction in Tropical Rain Forests?" in D.K. Elliot (ed) *Dynamics of Extinction*, John Wiley & Sons, New York (1986).

Singer, P., "Animal Liberation," in Pierce, C. and D. Van Deveer (eds.) *People, Penguins, and Plastic Trees: Basic Issues in Environmental Ethics*, Wadsworth Publishing Company, Belmont (1986).

Practical Ethics, Press Syndicate, Cambridge (1979).

Slovic, P. and S. Lichtenstein, "Preference Reversals: a Broader Perspective", *The American Economic Review 73*(4):596-605 (1983).

Smith, V.K., and J.V. Krutilla, "Resource and Environmental Constraints to Growth," *American Journal of Agricultural Economics* 395-407 (August 1979).

Smith, R.C., K.S. Baker, O. Holm-Hanson and R. Olson (1980) "Photoinhibition of Photosynthesis in Natural Waters," Photochemical Photobiology, 31:585-592.

Stone, C. D., *Earth and Other Ethics: The Case for Moral Pluralism*, Harper and Row, New York (1987).

Should Trees have Standing? Toward Legal Rights for Natural Objects, Los Altos, CA: William Kaufmann, Inc. (1974).

Swartzman, D., "Cost-benefit Analysis in Environmental Regulation: Sources of the Controversy," in *Cost-Benefit Analysis and Environmental Regulations: Politics, Ethics, and Methods*, D. Swartzman, R.A. Liroff, and K.G. Croke (eds.), The Conservation Foundation, Washington, D.C. (1982).

Taylor, P., *Respect for Nature*, Princeton University Press, Princeton (1986).

Titenberg, *Environmental and Natural Resource Economics*, Scott Foresman and Company, New York (1988).

Tribe, L.H., "Ways Not to Think About Plastic Trees: New Foundations for Environmental Law," *Yale Law Journal 83*(7): 1315-1346 (1974).

Tversky, A., and D. Kahnemna, "The Framing of Decisions and the Psychology of Choice," *Science*, 211: 453-458 (1981).

Uhl, C., and G. Parker, "Our Steak in the Jungle," *BioScience 26*:642 (1986).

UNEP/GEMS (United Nations Environment Programme), *The Greenhouse Gases*, UNEP, Nairobi (1987).

U.S.EPA (U.S. Environmental Protection Agency), *The Potential Effects of Global Climate Change on the United States*, draft report to Congress, Eds. Joel B. Smith and Dennis A. Tirpak, Volume II, Chapter 12, "Biological Diversity," Washington, D.C. 1988

U.S.OTA (U.S. Office of Technology Assessment), *Technologies to Maintain Biological Diversity*, Government Printing Office, Washington, DC (1987).

Weisbrod, B.A., "Collective-consumption Services of Individual-consumption Goods," *Quarterly Journal of Economics 78*:471-478 (1964).

Wilson, E.O., "The Current State of Biological Diversity," in E.O. Wilson (ed.), *Biodiversity*, National Academy Press, Washington, D.C. (1988).

"Biological Diversity as a Scientific and Ethical Issue", in Papers Read at a Joint Meeting of the Royal Society and the American Philosophical Society, Volume 1. Meeting held April 24, 1986 in Philadelphia. American Philosophical Society, Philadelphia (1987).

WCED (World Commission on Environment and Development), *Our Common Future*, Oxford University Press, New York (1987).

N91-22623

A REMOTE SENSING APPLICATIONS UPDATE

RESULTS OF INTERVIEWS WITH EARTH OBSERVATIONS COMMERCIALIZATION PROGRAM (EOCAP) PARTICIPANTS

Sally McVey

Center For Space and Geosciences Policy

University of Colorado

Boulder, Colorado

Submitted in partial fulfillment of NASA Grant NAGW-1415

December, 1990

TABLE OF CONTENTS

PREFACE

This study has been undertaken by the Center for Space and Geosciences Policy at the University of Colorado, Boulder, as part of our research in geosciences policy supported by NASA Grant NAGW-1415. The Center proposed to build on the investment NASA has made in the remote sensing applications community by reporting on the needs of applications users. The original proposal focused on user involvement in an Applications Information System design, one of the key recommendations of the 1987 NASA report, "Linking Remote-Sensing Technology and Global Needs: a Strategic Vision. A Report to NASA by the Applications Working Group", L.R. Greenwood, Chair. The proposed plan was modified to look at user needs more generally, i.e., without specific reference to a dedicated applications information system.

Applications investigators and users in the Earth Observations Commercialization Applications Program (EOCAP) were chosen as the study population. EOCAP began in 1987 as a NASA program jointly administered by the Earth Science and Applications Division of the Office of Space Science and Applications, and the Science and Technology Laboratory of the Office of Commercial Programs. Twenty-one applications projects were selected for EOCAP participation in response to the 1987 NASA Research Announcement (NRA). The projects are now entering the final year of a three-year program. The Center was interested in the EOCAP population because the projects included a variety of organizational participants and many different kinds of applications.

The Center's study was neither conceived nor carried out as an evaluation of EOCAP or its participants, but rather as an inquiry into the current status and needs of the applications user community, in light of the changes in remote sensing capabilities and applications that will likely follow from implementation of NASA's Earth Observing System (EOS).

This work was carried out by Sally McVey under the direction of Radford Byerly, Jr.

Summary of Results

The principal findings of the study of EOCAP users are as follows:

1. Essentially all EOCAP projects are working on problems associated with managing large-scale natural-resource holdings.

2. Resource management information needs are being driven by a pervasive renewed interest in the environment and the need for more detailed information.

3. Synoptic coverage offers unique possibilities for cost-effective resource management operations.

4. Recent advances in geographic information system (GIS) technology and digital data and image processing technology are putting remote sensing tools within reach of more resource managers. Training operating personnel to use technology developed in the project is among the highest priorities for EOCAP users.

5. Most EOCAP end-users want to continue using Landsat data, but data costs, delivery problems, and the uncertainty over Landsat's future constrain the development of applications.

6. Essentially all participants find collaboration with NASA Centers, universities, other agencies, and commercial firms to be valuable. Most end-users would participate in a project like EOCAP again, in spite of start-up problems.

7. End-users will gauge EOCAP success by their ability to use technology developed during the project in their own operations. In this regard data continuity is seen as a necessary prerequisite for continuing end-user interest in remote sensing.

8. Most EOCAP investigators and many end-users are aware of the Earth Observing System (EOS) program. However, few now see the program as benefiting applications. Many investigators and some agency end-users are interested in working on global change problems. Global change and responses to it will further impact their operations and responsibilities in much the same way that environmental concerns have already impacted them.

Our conclusions are as follows:

o General conclusion:

Earth remote sensing is a uniquely valuable tool for large-scale resource management, a task whose importance will likely increase world-wide through the foreseeable future.

NASA research and engineering have virtually created the existing U.S. system, and will continue to push the frontiers, primarily through the EOS instruments, research, and data and information system. In our view, the near-term health of remote sensing applications also deserves attention; it seems important not to abandon the system or its clients.

This study suggests that like its Landsat predecessor a successful Earth Observing System program (as part of the U.S. Global Change Research Program), is likely to reinforce pressure to "manage" natural resources, and consequently, to create more pressure for EOCAP-type applications. The current applications programs, though small, are valuable because of their technical and commercial results, and also because they support a community whose contributions will increase along with our ability to observe the earth from space.

o Specific conclusions:

1. Resource Management users in industry and all levels of government constitute a potential market for remote sensing data and technology. Maintaining remote sensing applications programs will provide another dimension of use for EOS data, and accordingly additional support for EOS.

2. Little has changed in amelioration of the systemic problems that continue to undermine U.S. earth remote sensing operations; the overarching issues seem intractable, but progress is being made in small-scale applications projects as exemplified by the EOCAP program, which is making an important contribution in this area.

3. In proper accord with its charter, NASA's interest in earth remote sensing is focused on earth science. The agency's role in remote sensing applications is limited but still important. EOS data will ultimately offer enormous opportunity for operational management of earth resources, but in the meantime, EOCAP results will likely advance the state of the practice, and the program is building public-private and inter-agency collaborations that have great potential for further advances in the future.

4. The issues of Landsat commercialization and applications interact to complicate the situation with respect to the use of EOS data outside the global change research program. On the one hand the primary purpose of EOS might be undercut politically if a large number of applications users felt excluded from EOS data. On the other hand, the reason for EOS is scientific, and science users and uses must be given top priority: Given limited and strained resources, if EOS is operated in part to serve applications users, its primary users and purpose will be compromised. It is possible that the Land Remote Sensing Commercialization Act of 1984 might offer a solution to this potential problem. That is, it is possible that "commercialization" could provide the needed separation between the scientific purposes of EOS and the potentially broader, practical usefulness of its data. An approach worth studying would be to offer one or (better) two "ports" into EOS/DIS to

commercial data providers. The exact definition of a "port" would have to be negotiated, but basically NASA through the commercial entities would offer EOS data at cost plus a fee or royalty. Having two competing offerors should keep data prices to users down to reasonable levels. A competitive selection would award the ports to the two bidders proposing the best deal to the government and to applications users. It would be clear that in doing so NASA's purpose would be to make EOS data available cheaply and fairly to existing commercial and other applications users; not to promote or generate an applications community. Such an approach could benefit the EOS program: EOS could concentrate on Earth systems science and leave applications to other relevant organizations.

I. THE EARTH OBSERVATIONS COMMERCIALIZATION APPLICATIONS PROGRAM (EOCAP) STUDY

Context and Methods

The Center for Space and Goesciences Policy has interviewed 45 EOCAP participants: twenty of twenty-one Principal Investigators (PIs) and twenty-four of sixty-seven Co-Investigators (CO-Is, end-users, or users) (See Appendix A). These interviews add an anecdotal update to a series of previous studies of the status of the U.S. remote sensing applications endeavor. Examples of such studies include:

o United States Civilian Space Programs: Volume II. Applications Satellites. Prepared for the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives by the Science Policy Research Division, Congressional Research Service, Library of Congress. May, 1983.

o Remote Sensing of the Earth from Space: A Program in Crisis. Space Applications Board, National Research Council. 1985.

o Space-Based Remote Sensing of the Earth from Space: A Report to the Congress. NOAA/NASA. September, 1987.

o Keystone Landsat Policy Dialogue. The Keystone Center. October, 1989.

o James V. Taranik. "Landsat, Privatization, Commercialization and the Public Good". Space Commerce, Vol.1, pp.67-80. 1990.

These reports describe the context in which U.S. Remote sensing applications work is taking place. Key remote sensing issues discussed in these and other publications include privatization of Landsat and continuity of operations and data, the market for applications, maintenance of U.S. pre-eminence and competitive position in earth observations, user needs, and evolution of remote sensing instrumentation and data processing techniques. Most of these issues remain alive and unresolved.

The present study was motivated by an interest in soliciting input from the applications user community. Among other recommendations, the report of an applications working group chaired by L. R. Greenwood in 1987 suggested that:

"NASA should develop mechanisms to involve users heavily in its R&D program and state this intention publicly; users should be involved at all stages from inception through implementation." [NASA, 1987, p. 13].

The 1987 EOCAP NRA reflected this recommendation in its program goal and objectives:

> "Initially emphasize a near-term remote sensing applications program, while gaining feedback from the user community as inputs into future NASA program planning." [NASA, NRA-87-OSSA-6, p. 1]

In our telephone interviews with EOCAP participants, separate sets of questions were asked of PI and User groups and ancillary lines of inquiry were followed in cases where interesting points arose. The questions are listed in Appendix B.

The EOCAP program was chosen as our sample because of the variety of institutions and participants involved, and because the common proposal requirements and selection processes were assumed to facilitate comparability. Although we have not determined whether the EOCAP sample is representative of the entire applications community, the possibility that EOCAP information can stand alone as an indicator of current applications issues is suggested by the involvement of eleven state universities, eight state and local agencies, nineteen for-profit and two private non-profit organizations, and twelve agencies or centers in four federal departments. These organizations are listed in Appendix C. Consideration of EOCAP applications issues may inform some aspects of the next generation of U.S earth observations: NASA's Earth Observing System (EOS). EOS will include two series of polar orbiting platforms with instruments that will provide coordinated, simultaneous measurements of earth system interactions. Launch of the first platform is currently scheduled for 1998. Among the proposed instruments of great interest to applications users are
the High Resolution Imaging Spectrometer (HIRIS), the Moderate Resolution Imaging Spectrometer (MODIS), and the Synthetic Aperature Radar (SAR). Other components of EOS include an advanced data and information system and interdisciplinary investigations of global change. (NASA, September 1988, p. 115-118. NASA, February, 1990, p. 1. Earthquest, 1990, p. 6.).

Characterizing the EOCAP sample

- Principal Investigators

Fourteen of the twenty EOCAP principal investigators interviewed are affiliated with publicly-funded institutions, either government agencies or universities (Table 1). Thirteen of the fourteen public sector Pis are involved with resource management projects; the other is working in climate analysis.

The remaining six PIs come from the private sector, and represent industrial firms, value-added companies, systems developers, and non-profit organizations. Three PIs are working on resource management projects, and the others are involved in resource exploration, and logistical support for exploration and commercial fishing operations.

- Users

Forty five of sixty-seven EOCAP users are affiliated with government agencies or public universities, and 22 with commercial organizations. Of these commercial participants, six are affiliated with major corporations, eleven with value-added firms*, three with computer systems development companies, and two with private non-profit companies.

- Projects

Most EOCAP projects are dealing directly with such resource management tasks as forest inventory, natural hazards assessment, or crop yield prediction, however some of the commercial projects are concerned with logistical support for resource exploration, extraction or harvest. For example, an EOCAP project with oil and gas company participants is looking at sea-ice forecasting for off-shore arctic drilling operations, and a commercial fisheries project is using remote sensing to track fish movement in the Gulf of Mexico.

If logistical support for natural resource operations is included in the definition of "resource management", nineteen of the twenty projects in the EOCAP study are resource management projects.

---

*i.e., firms that process and analyze remote-sensing data, thereby adding value to it.

II. FINDINGS

Finding 1:

o Essentially all of the EOCAP projects are solving problems associated with managing large-scale natural resource holdings.

> "The potential is there. This will be a useful product in 10 years. But in 10 years, we'll only have archival information to work with because there won't be any wetlands to look at in real time. We're being asked to manage a diminishing resource and the conclusion is right there in front of us."
> Dr. Doug Barnum, U.S. Fish and Wildlife Service, DOI

EOCAP users need remote sensing tools to help them survey, monitor, or otherwise manage large areas ranging in size from an Indiana county to the National Park Service holdings in Alaska and the lower forty-eight states. The budgets of resource management agencies at all levels of government are under pressure. As one participant noted, "Demands on the Department of Natural Resources for good, accurate, and timely information are increasing and the budgets for traditional methods of producing such information are decreasing with time, so that's why they're interested in satellite data."

The project "product" most commonly desired by both private and public sector resource managers is information to feed their management decision processes. Barnum pointed out that managers want to fine-tune their skills, "We've got intuition, but no real information. We deal on the microscale...everyone knows his own area, but we need to know how to manage water in California in toto...I can't overstate the importance that wetland agencies will attribute to this technology."

Finding 2:

o Resource management information needs are being driven by a pervasive renewed interest in the environment and the need for more detailed information.

According to EOCAP users, the combination of legislation and renewed public and political interest in the environment is magnifying needs for resource management information. The spotted owl controversy recently led to a Forest Service contract for a remote sensing survey of old growth forest in California, and the Yellowstone fire in the summer of 1988 influenced National Park Service interest in participating in an EOCAP satellite forest-fire alarm project.

Traditionally, when dealing with the environment the timber industry has taken the approach "tell us what to do". In spite of this, California's largest private timber landowner wants to show that it knows more than anybody else about the lands that it manages, according to Ed Murphy, Inventory Forester at Sierra Pacific Industries. "This puts us in a better position in managing the multitude of resources that originate in our forests." Sierra Pacific must submit the functional equivalent of an Environmental Impact Statement in the state's timber harvest planning process. Stewardship of the owners combined with state regulations are moving this company in the direction of more comprehensive management of all its resources.

Public agency managers have also been affected by public interest in the environment for some time. A paper co-authored by an EOCAP participant in the Oregon Department of Fish and Wildlife noted that today's "managed forest" is the product of 1) environmental legislation dating from the 1970's, and 2) government budget decisions that affect implementation of those laws (Thomas et al.). The current resurgence in environmental awareness is pushing resource managers in new directions. One user commented that "the Forest Service hasn't thought at all about the cumulative impact - the global impact of our actions...the impact of large-scale deforestation, but it may be forced on us. Some of the more resource-oriented people think about it, but the change won't come from inside. For example, concern for the spotted owl, which inhabits old growth forests, is an outside force that is now affecting us." Another Forest Service representative simply noted that "the public is turned off by the way we clear-cut."

Finding 3:

o Synoptic coverage offers unique possibilities for cost-effective resource management operations.

The combination of budget constraints and increasing emphasis on resource management operations in agencies and industry is promising for remote sensing applications because synoptic coverage offers large amounts of information at low cost. EOCAP users said that with traditional technology they cannot afford to monitor forests or update land-use files for tax assessment or growth prediction as often as regulations require. These users are interested in the capability of remote sensing data to increase their efficiency at costs which are the same or lower than those of traditional methods. The size of the areas managed by EOCAP participants precludes recourse to either ground surveys or aerial photography as alternate sources of data for inventory and change detection. Typically, users want more detailed information on shorter update cycles.

For example, nearly half of the state of Minnesota is forested, with much of the forested area in the public domain, and at the Minnesota Department of Natural Resources, the Supervisor of Resource Assessment and Analysis says "I need to know how many cords of birch I've got." Echoing the comments of other users, Mr. Michael Carroll describes his perspective on remote sensing benefits: "We are looking for a cost-effective method to reduce the dependence on the expensive traditional aerial photo interpretational mapping methods...it has to be cost-effective or do something better than the way we're doing it now. We're very pragmatic about it."

Commercial users are also looking for ways to improve operating efficiency. At the largest commercial fishing interest in the U.S., the Project Engineer told us, "there is only so much you can do in traditional ways to cut costs -- if this technology works, it's well worth the costs."

A major oil and gas company representative pointed out that seismic information needed for exploration costs his company millions of dollars each year, "another success would be if we could reduce the cost of seismic information...with this technology, we wouldn't spend less money, but we would spend it more effectively". Another oil and gas company representative in an EOCAP sea-ice forecasting project said that drilling-support operations in the arctic cost $200,000 to $300,000 per day. "Efficient forecasting can save money by reducing downtime." An EOCAP user representing the United States' largest food service business says, "we're in a competitive business -- if we can stay a quarter-step ahead of our competition, this technology will be useful. Information from this project won't reduce the cost as much as it will increase efficiency. With remote sensing information, our planes can know better where the fish are likely to be, and then the ships can go directly to the field instead of going somewhere else first."

Finding 4:

o Recent advances in geographic information systems (GIS) and digital data and image processing technology are putting remote sensing tools within reach of resource managers. Training personnel to use technology developed in the project is among the highest priorities for EOCAP participants.

Several earth remote sensing reports issued during the 1980s linked demand for satellite data to improvements in data processing technology.

In 1987, a NOAA/NASA report noted that "Because of the very high potential utility of satellite data, especially multi-spectral imagery, and the very broad spectrum of possible users, a significant increase in demand can be expected as the necessary skills and equipment become more widespread. Many programs project that the use of satellite data will double or triple within a few years." [NOAA/NASA, 1987]

In light of such comments it is interesting to note that nearly all of the EOCAP projects are developing digital data processing or GIS technology; some projects are using commercial systems and others have systems developers on the project team. EOCAP projects in both public and private sectors expect to produce systems that staff members without remote sensing backgrounds can be trained to use.

A user in a state department of natural resources summed up his ideas on changes in the field of remote sensing, "thinking about applications must take into account the tremendous explosion in the data processing capability of the average resource manager...the days when the data was intelligible only to specialists are gone forever."

An EOCAP PI and vice-president of a large resources consulting firm adds, "When NASA developed those airborne sensors five years ago, no one had the foresight to see where we'd be now with GIS, storing and analyzing digital data -- how it would change engineering and forestry."

With the prospect of having synoptic data, GIS, and image processing systems tailored to their operations, EOCAP resource managers are defining their needs. As one user put it, "I want my staff to be able to make forest inventory calls from the desk." As is the case with other users, training staff to use project technology is among this manager's requirements for EOCAP. A remote sensing specialist with a regional government land-use agency explains: "The University brought us up to speed fast on satellite imagery, but we ultimately have to do it ourselves. Seeing applications [demonstrated] is different from doing it ourselves."

Project PIs share the concern about transferring the technology. One agency investigator describes his current training role, "I teach resource managers in the field about what's available in remote sensing data and techniques. I'm not in technology development at the moment - I'm an extension type, educating others."

The increasing capability of remote sensing data processing technology to improve management operations is perhaps the most positive development in applications in recent years.

Finding 5:

o Most EOCAP end-users want to continue using Landsat data, but data costs, delivery problems, and the uncertainty over Landsat's future constrain applications development.

About half of the EOCAP projects are using Landsat as their primary source of data. Two are using the Advanced Very High Resolution Radiometer (AVHRR) (one in conjunction with Landsat); the High Resolution Interferometer Sounder (HIRS) and a Geostationary Operational Environmental Satellite (GOES) each supply data for one other project. The remaining projects primarily use airborne instrument data: the Thermal Infrared Multispectral Scanner (TIMS), the Calibrated Airborne Multispectral Scanner (CAMS), the Airborne Ocean Color Imager (AOCI), and radar. One airborne radar user intends to switch to the European Earth Remote-Sensing Satellite (ERS-1) Synthetic Aperature Radar (SAR) data as soon as it becomes available. Relatively more commercial projects are using aircraft data than are public sector projects. Nearly all projects use ancillary data sets including SPOT (8 of 20 projects), digital elevation data, and aerial photography.

In discussing their data needs, the investigators using Landsat data frequently mentioned that Landsat was best suited for their application, in spite of the enhanced spatial and temporal resolution and better service offered by SPOT. Several noted the cost advantage of Landsat data relative to Spot and aerial photography. However, as one university PI noted, "The uncertainty about Landsat has hampered applications development at the state level and in other agencies. Potential users ask, 'If I invest in Landsat, will it be up there next year, or 5 years from now?' "

Most EOCAP participants had data delivery problems due to negotiation delays in the NASA-EOSAT data grant or due to aircraft scheduling constraints. Data cost was a potential problem for many users because their applications required frequent coverage and/or coverage of very large areas.

Finding 6:

Essentially all participants find collaboration with NASA Centers, universities, other agencies, and commercial firms to be valuable. Most end-users would participate in a project like EOCAP again in spite of start-up problems.

Because the first EOCAP program has one more year to run and because of start-up delays, it is too early to evaluate technical, operational, and commercial success, according to users on most projects. However, Users and PIs alike described project collaborations as an outstanding benefit of participation. This result is particularly important because one of the specific objectives of the EOCAP program is to "emphasize private sector, university, and government partnerships, which require joint initiative and resources for high technology ventures while sharing risk."

Users commended Stennis Space Center and Ames Research Center team members for their contributions, including technical expertise and help in working with the NASA

system, which was especially problematic for commercial users. One Forest Service participant
commented that "this is an unusual project for the Forest Service -- it got support due to NASA's name."

Finding 7:

o End-users will gauge EOCAP success by their ability to use technology developed in the project operationally. In this regard, data continuity is seen as a necessary prerequisite for continuing end-user interest in remote sensing applications.

When asked how he would gauge the success of the EOCAP project, one state agency participant captured the sentiment expressed by most operational users, "When the technology is running in my shop!" A Department of the Interior user says "If our people have confidence in the project technology, they'll fund it down the line and use it. The measurement of confidence is whether people will use it in the dispatch or not dispatch decision [for firefighters]. But there are problems with allocations of resources...some people don't want to spend pick and shovel money on satellite systems."

Although users praised project commitments to training and the benefits of multi-institutional cooperation, many of them were concerned that NASA and university participants might not fully understand the realities of users' operational and business environments.

A user dealing with inter-jurisdictional resource management issues commented, "We are a real-life lab for this project. We want to know if what comes out will work in the real world. Our 1990 land-use inventory has to serve as a baseline for growth forecasts here and at the State level. This is a real schedule -- we're production oriented."

According to EOCAP participants, moving from technology development to operational capability requires collaboration, tools, training, and in some cases, creating specialized service providers.

One user noted that the Forest Service is a decentralized agency, and would most likely contract with value-added organizations for remote sensing application services. One of this participant's objectives is to create in-house remote sensing expertise in order to deal with specialized contractors. Participants in local government, regional offices of federal agencies, and industrial users also indicated that they would use the services of remote sensing value-added firms rather than develop and support in-house expertise. An industrial participant said, "In the upside scenario, the question is, 'How can we commercialize this technology?'. Our industry says that you can't hold exploration for more than two years. What is the value of that head-start? Do we want to commercialize it ourselves, or go to someone else and have them develop the instrument...We've done this successfully in the past."

A question remains about where these users will go for remote-sensing services after EOCAP projects are completed if the market is not yet able to support service providers.

In a different approach, the National Park Service, the Oregon Department of Fish and Wildlife, and the Departments of Natural Resources in Minnesota and Florida have in-house remote sensing departments, and expect to further develop their internal capability.

Finding 8:

o Most EOCAP investigators and many end-users are aware of the Earth Observing System (EOS) program, but few now see the program as benefiting applications in the near-term. Most PIs and many users are interested in working on global change problems. Global change and responses to it will further impact their operations and responsibilities in much the same way that environmental concerns have already impacted them.

A prominent characteristic of the EOCAP population is that nearly all users had training in remote sensing applications: several are remote sensing specialists and many others had courses in remote sensing in graduate school; both agency and commercial users had learned about applications potential from previous experience with NASA. As a consequence of their interest in remote sensing generally, or their contact with NASA centers through the EOCAP projects, most of the participants had heard of NASA's Earth Observing System program.

Many participants in federal agencies are interested in global data sets and want to work on global change problems, often in conjunction with their agency's participation in the federal Global Change Research Program.

In this connection, several EOCAP PIs are participating in EOS investigations, and others hope to do so. Among the users, several know about EOS because of the activities of their colleagues, or their own participation in remote sensing activities at the national level. Many others were aware at the "ordinary citizen" level, having seen or heard about the Mission to Planet Earth in news accounts of global change.

In commenting on NASA's science mission, participants with remote sensing expertise were concerned that applications do not appear to be a priority use for EOS data. One participant commented:

> "We need two things: continuity for historical and current data, and improved EOS data...we're interested in questions with global significance, but we want continuity. We want hyperspatial data to answer questions in forestry and ecology -- new sensors can answer some questions, but without continuity, we waste the work of the last twenty years. It is important not to have EOS just dumped on us, but to bring us along, for us to be part of the process during the next seven years, for us to be informed so we can make adjustments."

A representative from a value-added firm adds,

> "I am interested in EOS, but the infrastructure for providing data to users has to be examined. Users aren't involved in distribution plans. Data can't just be archived for posterity -- there has to be a day-to-day data stream available for users in the real world, they need current data. EOS has to be different than past projects. People in applications have a different mindset than people in R&D, [applications people] need a different process to support them. Science projects have exclusive use of a new sensor and data for a few years. That worked for new sensors, but we're not using any new sensors [on EOS], we are using improved versions of old sensors: altimeters, scatterometers...what we'll really be doing is more data collection, so the framework for data distribution needs to be different."

III. CONCLUSIONS

Our conclusions are as follows:

o General conclusion:

Earth remote sensing is a uniquely valuable tool for large-scale resource management, a task whose importance will likely increase world-wide through the foreseeable future. NASA research and engineering have virtually created the existing U.S. system, and will continue to push the frontiers, primarily through the EOS instruments, research, and data and information system. In our view, the near-term health of remote sensing applications also deserves attention; it seems important not to abandon the system or its clients.

This study suggests that like its Landsat predecessor a successful Earth Observing System program (as part of the U.S. Global Change Research Program), is likely to reinforce pressure to "manage" natural resources, and consequently, to create more pressure for EOCAP-type applications. The current applications programs, though small, are valuable because of their technical and commercial results, and also because they support a community whose contributions will increase along with our ability to observe the earth from space.

o Specific conclusions:

1. Resource Management users in industry and all levels of government constitute a potential market for remote sensing data and technology. Maintaining remote sensing applications programs will provide another dimension of use for EOS data, and accordingly additional support for EOS.

2. Little has changed in amelioration of the systemic problems that continue to undermine U.S. earth remote sensing operations; the overarching issues seem intractable, but progress is being made in small-scale applications projects as exemplified by the EOCAP program, which is making an important contribution in this area.

3. In proper accord with its charter, NASA's interest in earth remote sensing is focused on earth science. The agency's role in remote sensing applications is limited but still important. EOS data will ultimately offer enormous opportunity for operational management of earth resources, but in the meantime, EOCAP results will likely advance the state of the practice, and the program is building public-private and inter-agency collaborations that have great potential for further advances in the future.

4. The issues of Landsat commercialization and applications interact to complicate the situation with respect to the use of EOS data outside the global change research program. On the one hand the primary purpose of EOS might be undercut politically if a large

number of applications users felt excluded from EOS data. On the other hand, the reason for EOS is scientific, and science users and uses must be given top priority: Given limited and strained resources, if EOS is operated in part to serve applications users, its primary users and purpose will be compromised. It is possible that the Land Remote Sensing Commercialization Act of 1984 might offer a solution to this potential problem. That is, it is possible that "commercialization" could provide the needed separation between the scientific purposes of EOS and the potentially broader, practical usefulness of its data. An approach worth studying would be to offer one or (better) two "ports" into EOS/DIS to commercial data providers. The exact definition of a "port" would have to be negotiated, but basically NASA through the commercial entities would offer EOS data at cost plus a fee or royalty. Having two competing offerors should keep data prices to users down to reasonable levels. A competitive selection would award the ports to the two bidders proposing the best deal to the government and to applications users. It would be clear that in doing so NASA's purpose would be to make EOS data available cheaply and fairly to existing commercial and other applications users; <u>not</u> to promote or generate an applications community. Such an approach could benefit the EOS program: EOS could concentrate on Earth systems science and leave applications to other relevant organizations.

REFERENCES

Earthquest, Summer 1990, Vol.4, No.2, p. 6.

Keystone Center, Keystone Landsat Policy Dialogue. Keystone, Colorado, October, 1989.

NASA, The Earth Observing System: EOS, A Mission to Planet Earth, EOS Program Office, February, 1990.

NASA, NASA Earth Science and Applications Division: The Program and Plans for FY 1988-1989-1990, September, 1988.

NASA, Linking Remote-Sensing Technology and Global Needs: A Strategic Vision, A Report to NASA by the Applications Working Group, Washington, D.C., 1987.

NASA, NASA Research Announcement Soliciting Proposals for Commercial Applications Research and Development in Earth Observations, NRA 87-OSSA-6, Office of Space Science and Applications, 1987.

NOAA (National Oceanographic and Atmospheric Administration)/NASA, Space-Based Remote Sensing of the Earth from Space: A Report to the Congress. Government Printing Office, Washington, D.C., September, 1987.

Space Applications Board, Remote Sensing of the Earth from Space: A Program in Crisis, National Research Council, National Academy Press, Washington, D.C., 1985.

James V. Taranik. "Landsat, Privatization, Commercialization and the Public Good," Space Commerce, Vol.1, pp.67-80. 1990.

Thomas. J., Leckenby, D., Erickson, L., Thomas, S., Issaacson, L., and Murray, R., "Wildlife Habitat by Design: National Forests in the Blue Mountains of Oregon and Washington," Transactions of the 51st Wildlife and Natural Resources Conference. 1986.

U.S. House of Representatives, Subcommittee on Space Science and Applications of the Committee on Science and Technology, United States Civilian Space Programs: Volume II. Applications Satellites. Prepared for the U.S. House of Representatives by the Science Policy Research Division, Congressional Research Service, Library of Congress Serial-M (Committee Print), Government Printing Office, Washington: May, 1983.

APPENDIX A

INTERVIEW LIST

USERS

Douglas Barnum
Fish and Wildlife Service
U.S. Department of the Interior

William Befort
Division of Forestry
Minnesota Department of Natural Resources

Michael Carroll
Division of Forestry
Minnesota Department of Natural Resources

Yvonne Dodson
Statistical Research Branch
National Agricultural Statistics Service
U.S. Department of Agriculture

Ken Haddad
Florida Marine Research Institute
Florida Department of Natural Resources

Nancy Hardwick
Miami County, Indiana, Tax Assessor's Office

Jack Hart
Miami County, Indiana Extension Office

John Jett
Zapata Haynie Corporation

Richard Kempka
Ducks Unlimited

Keith Kerr
Agriculture Services
Lamb Weston

Donavin Leckenby
Oregon Department of Fish and Wildlife

A. James Miller
NOAA/Climate Analysis Center
National Weather Service

James McKean
Forest Service
U.S. Department of Agriculture

JoAnn Mossa
Louisiana Geological Survey

Edward Murphy
Sierra Pacific Industries

Maurice Nyquist
Geographic Information Systems Division
National Park Service
U.S. Department of the Interior

Dennis Orthmeyer
Fish and Wildlife Service
U.S. Department of the Interior

James Pace
Forest Service
U.S. Department of Agriculture

Robert Parrott
Research and Information Systems
SANDAG (San Diego Area Governments)

Jon Schneeberger
National Geographic Society

Mark Settle
Exploration and Production Research Center
ARCO Oil and Gas Company

Thomas Spies
Forest Sciences Laboratory
Oregon State University
U.S. Department of Agriculture

Walter Spring
Mobil Oil Research and Development Corp.

Lee F. Werth
Branch of Remote Sensing
Bureau of Land Management
U.S. Department of the Interior

PRINCIPAL INVESTIGATORS

Marvin E. Bauer
Remote Sensing Laboratory
University of Minnesota

Gregory S. Biging
Space Sciences Laboratory
University of California, Berkeley

Jim Cotter
National Agricultural Statistics Service
U.S. Department of Agriculture

Robert G. Ellingson
Department of Meteorology
University of Maryland

Leonard Gaydos
U.S. Geological Survey, and
NASA Ames Research Center

David S. Gilmer
Pacific States Ecology Section
Fish and Wildlife Service
U.S. Department of the Interior

David A. Hastings
Data Integration & Remote Sensing
National Geophysical Data Center
NOAA/NESDIS

Mark Jadkowski
James W. Sewall Company

Chris Johannsen
Laboratory for Applications of Remote Sensing
Purdue University

Frank G. Lamb
Eastern Oregon Farming Co.
Cropix, Inc.

Jacquiline Michel
RPI International, Inc.

George Mourad
Batelle Columbus Division

William J. Ripple
Environmental Remote Sensing Applications Laboratory
Oregon State University

Harry H. Roberts
Coastal Studies Institute
Louisiana State University

Kenneth W. Ruggles
Systems West, inc.

Douglas E. Scholen
Forest Service
U.S. Department Of Agriculture

Mark Settle
Exploration and Production Research Center
ARCO Oil and Gas Company

Tom Sever
NASA Stennis Space Center

Douglas A. Stow
Department of Geography
San Diego State University

Robert C. Wrigley
NASA Ames Research Center

APPENDIX B

Principal Investigator and User Discussion Questions

Principal Investigator Discussion Questions

1. What are the roles of each of the investigators in your project?

2. Which data sets are you using for your research, and how do you access them?

3. What will the final products of your work be?

4. Who will use them?

5. Have you worked with NASA, other federal agencies, or your co-investigators on related projects in the past?

6. What are your follow-on research plans?

7. What are your future data needs? Do you anticipate using Earth Observing System data?

8. What are the major impediments to your research?

User Discussion Questions

1. What is your role in the EOCAP Project?

2. What does your company or agency hope to get from the project?

3. What is your company or agency contributing to the project?

4. How will <u>you</u> gauge the success of this project?

5. What are the impediments to your work on this project? What are the successes?

6. Would you participate in a project like EOCAP again?

APPENDIX C

INSTITUTIONS AND ORGANIZATIONS PARTICIPATING IN EOCAP PROJECTS

UNIVERSITIES

University of California, Berkeley
University of Minnesota
University of Maryland
Purdue University
Oregon State University
Louisiana State University
San Diego State University
University of Maine
University of South Carolina
Ohio State University
Middle Tennessee State University

FEDERAL AGENCIES

- US Department of the Interior
  - Fish and Wildlife Service
  - National Park Service
  - Bureau of Land Management
  - Geological Survey
- US Department of Agriculture
  - Forest Service
  - Agricultural Statistics Service
- Department of Commerce
  - National Oceanographic and Atmospheric Administration
    - National Environmental Satellite Data and Information Service
    - National Weather Service
    - National Marine Fisheries Service
- National Aeronautics and Space Administration
  - Stennis Space Center
  - Ames Research Center

STATE AND LOCAL AGENCIES

California
- San Diego Area Governments

Florida
- Department of Natural Resources
  - Marine Research Institute

Indiana
- Miami County
  - Extension Office
  - Office of the Surveyor
  - Agriculture Stabilization Conservation Service
  - Tax assessor
  - Soil Conservation Service

Louisiana
- Geological Service

Minnesota
- Department of Natural Resources
  - Forestry Division

Oregon
- Coastal Oregon Productivity Enhancement Organization
- Cooperative Wildlife Research Unit
- Department of Fish and Wildlife

RESOURCE PRODUCTION COMPANIES

Amoco Production Co.
ARCO Oil and Gas Co.
Lamb Weston (Agriculture)
Mobil Research and Development Corp.
Sierra Pacific Industries (Timber)
Unocal

NON-PROFIT ORGANIZATIONS

Ducks Unlimited
National Geographic Society

SYSTEMS DEVELOPMENT COMPANIES

ERDAS
ESRI (ARCINFO)
User Systems, Inc.

VALUE-ADDED COMPANIES

James W. Sewall Company (Utilities, Land Use, Forestry)
Cropix (Agriculture)
RPI International (Oil Spill Response, Coastal Resources)
Systems West (Marine Transportation, Fisheries)
TGS Technology, Inc.
Weather Management Consultants (Forecasting)
Geoinformation Services, Inc. (Geographic Information Systems)
Vestra Resources
Pacific Meridian
Spectroscan