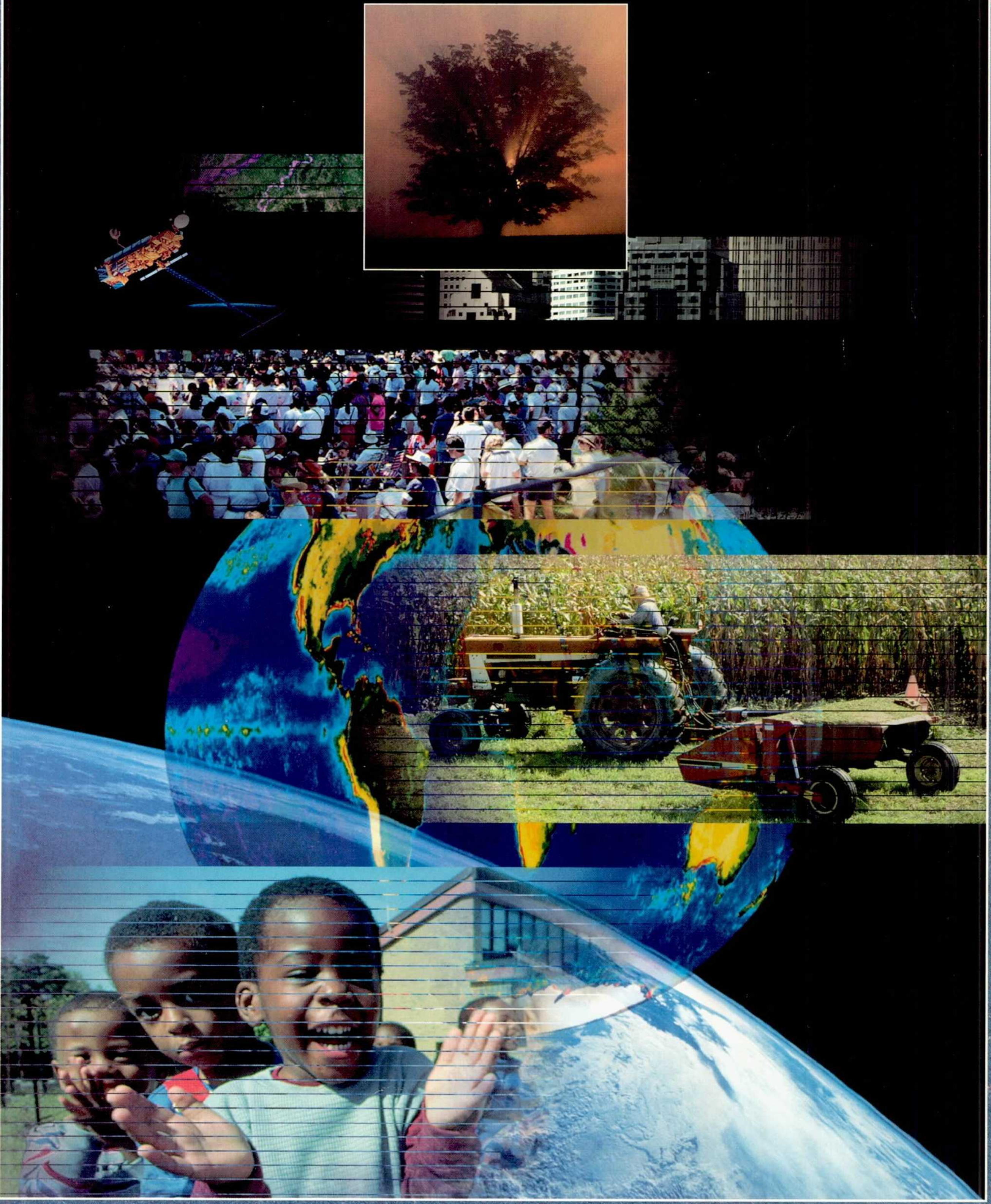
Consortium for International Earth Science Information Network

Pathways of Understanding

The Interactions of Humanity and Global Environmental Change



CIESIN

The Consortium for International Earth Science Information Network (CIESIN)
2250 Pierce Road
University Center, MI 48710 USA

CIESIN is a non-profit corporation founded in 1989 to facilitate access to, use and understanding of global change information worldwide. As a consortium, CIESIN draws upon the expertise of universities, non-profit research organizations, government agencies, foundations and private corporations to meet the challenges of understanding environmental issues and advancing information technology and scientific research involving the human dimensions of global change.

CIESIN is one of nine distributed data centers forming the data and information management component of the National Aeronautics and Space Administration's (NASA) Earth Observing System (EOS). EOS is a network of remote sensing satellites and instruments dedicated to collecting essential data for studying Earth and its changing natural systems. EOS is part of the United States Global Change Research Program, which has been established to coordinate global change research efforts across all participating federal agencies. CIESIN has been commissioned by NASA to extend the benefits of EOS to a broad array of both international research and non-research users including policy makers, federal agencies, educators, resource managers and the general public.

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Pathways of Understanding

The Interactions of Humanity
and Global Environmental Change

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CIESIN

Consortium for International Earth Science Information Network

About the Consortium for International Earth Science Information Network

In 1990, the National Aeronautics and Space Administration (NASA) granted funds to the Consortium for International Earth Science Information Network (CIESIN) to bring the benefits of Earth monitoring systems, such as the Earth Observing System (EOS), to policy makers and applied users worldwide. To achieve this task, CIESIN is working with current and potential users to outline ways to interact with both the scientific and policy making communities, and is studying the need for a computer network powerful enough to store and disseminate data gathered from a wide range of scientific disciplines.

Initially, NASA asked CIESIN to serve the EOS Data and Information System and the United States Global Change Research Program (USGCRP) as an Affiliated Data Center. Recently, CIESIN's role has expanded into that of a distributed data center. This designation means CIESIN will be a "gateway" to global change information, bringing data and research on the human dimensions of global change into the EOS and USGCRP.

In its first two years alone, CIESIN has made great strides by beginning to understand user needs; conducting workshops and convening conferences; sponsoring interdisciplinary science programs and pilot projects; and consulting with the scientific community and numerous agencies, institutes and organizations. The Consortium's success hinges on accounting for the growing interdisciplinary nature of global change research and understanding the rapid evolution of technology.

To fulfill its mission, CIESIN draws upon the expertise within universities, research organizations, federal agencies and, potentially, that of foundations and industrial partners. Consortium members include the Environmental Research Institute of Michigan, Michigan State University, New York's Polytechnic University, Saginaw Valley State University, the University of California at Santa Barbara, and the University of Michigan.

A major CIESIN goal is to cooperate and coordinate with organizations and researchers in the global change community in order to ensure that every country around the globe benefits from the most advanced technology, the latest scientific research and the best information available for critical decision making.

A Word to Our Readers

This document is aimed at a broad audience, from the general public to scientists who have an interest in global environmental change.

The Working Group that developed the Social Process Diagram recognizes that people actively engaged in studying global change will be familiar with some of the material presented here. We encourage this audience to focus on the sections that describe the Social Process Diagram. For those not as familiar with global change issues, it is hoped that the background information presented will stimulate your curiosity for further study.

It is also hoped that educators, resource managers and policy makers will gain valuable information from this document, using its principles to study, teach or make decisions. Educators, for example, may find the information presented will assist with curriculum development, while policy makers may find this document useful when evaluating recommendations from the research community. The Social Process Diagram can help determine whether a particular course of study or recommendation reflects an understanding of related issues.

Members of the Human Interactions Working Group

The scientists listed below developed the Social Process Diagram at the Aspen Global Change Institute, Aspen, Colorado in August 1991. The results of this Working Group's efforts are detailed in this document. This document was written and reviewed by the Working Group members.

Dr. William Kuhn, *Department of Atmospheric, Oceanic and Space Sciences, University of Michigan, Ann Arbor, Michigan (Working Group Organizer and Chair)*

Dr. Urs Luterbacher, *Graduate Institute of International Studies, Geneva, Switzerland (Working Group Co-Moderator)*

Dr. Ellen Wiegandt, *University of Geneva, Geneva, Switzerland (Working Group Co-Moderator)*

Dr. Christopher Achen, *Political Science Department, University of Michigan, Ann Arbor, Michigan*

Dr. Bruce Bueno de Mesquita, *Hoover Institution, Stanford University, Palo Alto, California and University of Rochester, New York*

Dr. Paul Demeny, *Population Council, New York, New York*

Dr. Allan M. Din, *International Academy of the Environment, Geneva, Switzerland*

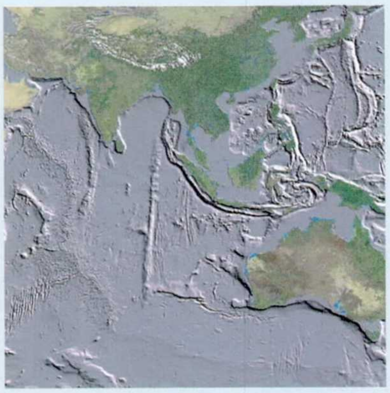
Dr. Jae Edmonds, *Economic Programs, Battelle Pacific Northwest Laboratory, and Policy Programs, Pacific Northwest Laboratory's Global Studies Program, Washington, D.C.*

Dr. Frank Hole, *Department of Anthropology, Yale University, New Haven, Connecticut*

Dr. Stephen Kowalewski, *Department of Anthropology, University of Georgia, Athens, Georgia*

Dr. Frederic L. Pryor, *Economics Department, Swarthmore College, Swarthmore, Pennsylvania*

Dr. Gary Yohe, *Department of Economics, Wesleyan University, Middletown, Connecticut*



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Preface

Science and technology have provided us with a new view of Planet Earth, first through the electronic eyes of sensor systems on spacecraft whirling around the globe, and then through human eyes, fascinated by its vast range of features and colors.

From space, we can see all the colors of Earth: the blues of its oceans, the white of its clouds and snow on its mountains, the green and brown patchwork of farm fields, and the painted deserts in all their living hues of red and brown and purple. From space, the world looks like a map or a globe that might sit atop one's desk—but with one major difference. It is without the lines or boundaries that divide us socially, politically or economically.

When looking back at Earth from space, we realize how much we care for this place, the place where our relationships, memories, hopes, dreams and ambitions reside. We wish we could convey the wonder, the marvel, the awe of this exquisitely beautiful blue and white sphere, suspended in its sea of blackness, with its appearance of unity and tranquillity. Seeing Earth from space is a powerful, expansive experience that often makes us impatient with the relative pettiness that so often preoccupies and confounds us in more traditional surroundings.

This experience also makes us realize that Earth itself is a kind of spacecraft, and we are all astronauts upon it, hurtling along at amazing speed. Just as the inhabitants of a spacecraft must conserve supplies, keep their ship clean and strive to work together in harmony, we must do the same on Spacecraft Earth. If we are to enjoy a safe and successful mission, we must use our resources wisely, be good stewards of our environment and strive to improve our relationships.

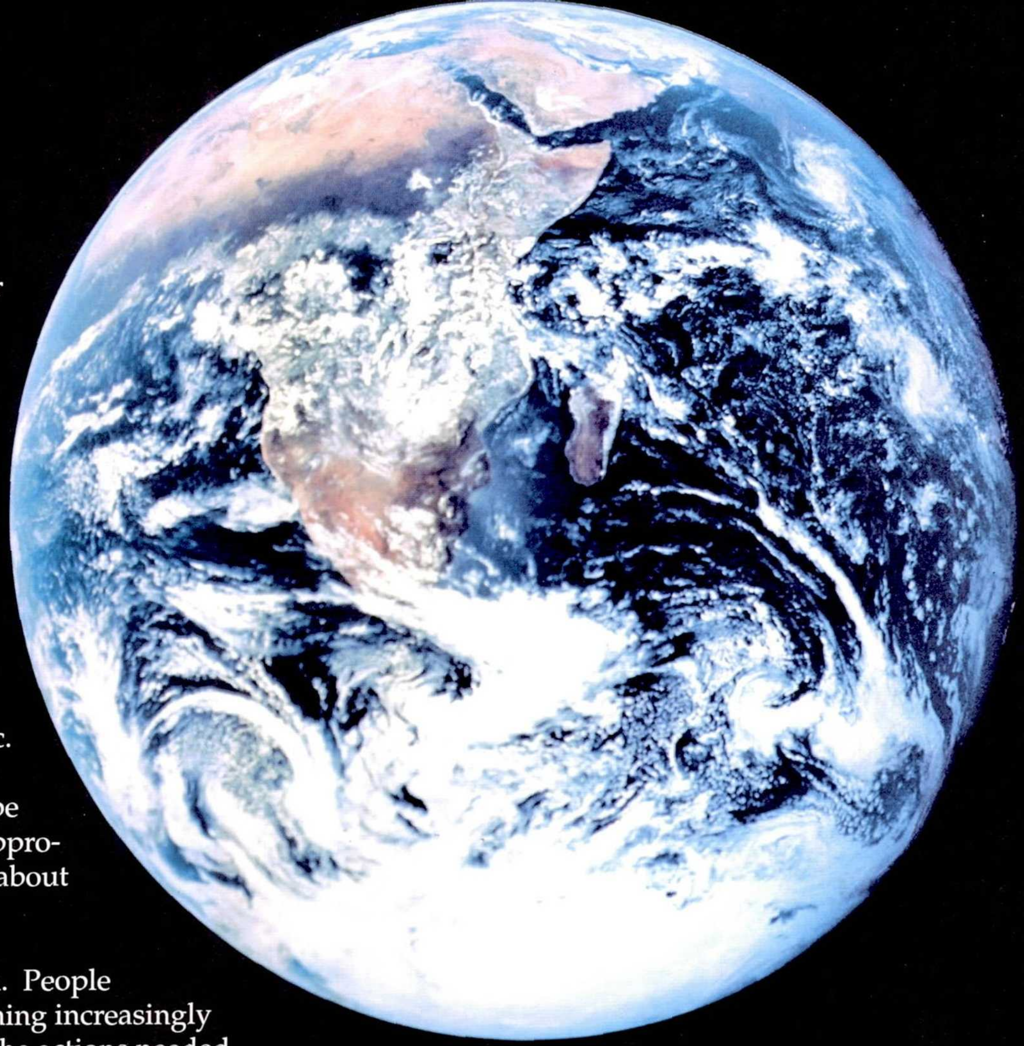
The great disparity between the rapidly advancing technology that allows us to fly in space, and the seemingly changeless way many people live on Earth, is brought into sharp focus from the space shuttle. As it orbits Earth every hour and a half, one of the most sophisticated creations ever conceived and built by human minds and hands passes over millions of people suffering from wars, hunger and disease—conditions that have persisted for generations. It seems that so few have benefited from all that we know and can do. Somehow, we must use technological advances to make the world a better place to live—for everyone.

We now have that opportunity.

We are living at a special time in history in which we can make a global contribution of lasting value. The convergence of three key factors is helping to create this opportunity: the recognition that more responsible and aggressive environmental action is needed; the development of the requisite sensor and data system technologies; and the public and political will to attack the environmental problems we now face.

Threats to our environment and the need for better management of Earth systems are reported and debated widely and vigorously. Although we sense the need to take action, there are conflicting views on how much or what kind of action to take, since problems are not well quantified or understood. The need to balance conflicting demands for economic progress with responsible and effective environmental management further complicates the issues, exciting a multitude of special interests in the process.

And, while space-based technology for remote sensing of Earth and its environment has been used for many years, the Earth-based use and application of the acquired data has not kept pace. The technology now exists, however, to catalogue and store tremendous quantities of data and to distribute it at high speeds via international electronic networks. This will give natural and social scientists access, for the



first time, to data needed for research and analyses leading to understanding and predicting environmental change. Integrating technologies are also available to translate complex information into products useful to a broad spectrum of applied users, including policy makers, resource managers, educators, students and the general public. At last, quantifiable, understandable information will be available to help us make appropriate and timely decisions about global change.

And not a moment too soon. People around the world are becoming increasingly sensitized and vocal about the actions needed to preserve our planet. The people are speaking and the politicians are reacting. Federal agencies have worked together to create the U. S. Global Change Research Program, and NASA is developing sensors, satellites and data systems to respond to the challenge. Our international partners are joining the action with multinational conferences, science programs, and collaborative activities that clearly demonstrate the resolve needed to attack the problems of global environmental change.

In response to these dramatic developments, CIESIN was created to fill identified niches within the global change research community and to contribute significantly to a complete and meaningful international program—without duplicating the efforts of other entities. CIESIN's charter is evolving rapidly through an expanding membership, as well as through collaborative efforts with both public and private sectors.

The Social Process Diagram is a step toward forging the link between the natural and human sciences. And, it is a step toward striking a balance between economic development and environmental management to improve the quality of life on Earth for all its inhabitants and future generations.

Our opportunity is here. The recognition of the threat, the demonstration of the capabilities and the generation of the will have converged to create a unique moment in the history of Spacecraft Earth.

We must seize this opportunity. We must work together. And we must succeed.

Jack Lousma
President and CEO,
Consortium for International
Earth Science Information Network

Executive Summary

Earth is a place of change, first and continually by natural forces, and increasingly by a myriad of human activities. Humans naturally organize into social groups, and our inclination to question, explore and learn has caused and continues to cause much of the environmental change we experience today. Critical global change issues—including loss of biodiversity, climate change and ozone depletion—will all remain center stage as we enter the 21st century. A growing realization surrounding research into these and other areas is how human activities combine with naturally occurring events to contribute to global change. This new facet of global change research is called the "human dimensions" of global change.

This document explores how humans, interacting within social systems, affect and are affected by global change. The causes and consequences of human activities need to be factored into the discussions, research, predictions, policies and actions surrounding global change. When the links between the natural and human domains are identified and quantified, we will begin to understand more fully the direction of global change. Achieving this goal requires that social and natural scientists work together to identify and understand global change and to recommend courses of action to ensure the long-term well-being of Earth and all its inhabitants.

Recognizing the impact human activities have on the environment and responding to the need to document the interactions among human activities, the Consortium for International Earth Science Information Network (CIESIN) commissioned a group of 12 scientists to develop a framework illustrating the key human systems that contribute to global change. This framework, called the Social Process Diagram, will help natural and social scientists, educators, resource managers and policy makers envision and analyze how human systems interact among themselves and with the natural system.

The Social Process Diagram is, in part, an expansion of several preceding global change research efforts. In the mid-1980s, a group of natural scientists constructed a diagram picturing the interactions among natural processes that influence global change. This diagram has become widely known as the Bretherton Diagram. While "Human Activities" are noted on the Bretherton Diagram, the relationships among these activities were not developed. The Social Process Diagram, explained in this document, gives us a framework to begin analyzing these human dimensions.

The Social Process Diagram consists of seven building blocks that constitute the Diagram's structural framework:

Fund of Knowledge and Experience. This refers to the formal and informal understanding people have of their natural and social environments, and to the technology that their culture defines as relevant.

Preferences and Expectations. From the Fund of Knowledge people define their preferences and expectations, which reflect the culturally defined constraints and opportunities that confront individual actions.

Factors of Production and Technology, including resources consisting of Labor, Land, Capital, Raw Material and Energy. The resources and technology people use to produce goods and services constitute this category. This category helps us trace what elements enter a system, how they are modified and what emerges at the end of the process.

Population and Social Structure. The world's growing population is perhaps one of the most important factors of global environmental change. Population helps determine the demands placed on resources and the associated wastes generated, and thus whether a region will sufficiently support these demands. Population can be defined statically (size and distribution); in terms of social structure (ethnicity, class, caste or clan); or dynamically (marriage, birth and death rates).

Economic Systems. Economic systems determine how people produce and consume goods and how wealth is distributed and evolves.

Political Systems and Institutions. Institutions and organizations ranging from governments to the family unit influence policy formation and the way society is organized.

Global Scale Environmental Processes. The physical, chemical, and biological processes and their interactions that affect global change are represented by the Bretherton Diagram. On the Social Process Diagram, this is called "Global Scale Environmental Processes." Thus, the six human dimension building blocks will not only interact among themselves, but will also link to Global Scale Environmental Processes (i.e., the Bretherton Diagram) through various driving forces.

Because output from one building block acts as the input to another, none of these can be evaluated in isolation. Elements from one category influence the evolution of elements in another. These linkages, represented by arrows, are the processes that constitute the "driving forces" of global change.

Once the building blocks are dynamically linked by various processes, the Diagram can be used in two ways. First, on a general level, it can help clarify how researchers from different disciplines can work together on a particular issue. Second, on a more specific level, the linkages among building blocks can be defined as types of data sets needed to analyze a global change scenario.

The Diagram also accounts for the fact that human phenomena occur within a certain geographic location and over a certain time period. Adding the elements of space (where a change is taking place) and time (how quickly a process is occurring) to an issue being investigated extends the value of the Diagram and helps pinpoint our understanding of the issue.

To demonstrate potential ways the Diagram can be used, this document includes three hypothetical scenarios of global change issues: global warming and sea level rise; the environmental impact of human population migration; and energy and the environment. These scenarios demonstrate the Diagram's usefulness for visualizing specific processes that might be studied to evaluate a particular global change issue. The scenarios also show that interesting and unanticipated questions may emerge as links are explored between categories on the Diagram.

The effort to develop the Social Process Diagram is an important step in understanding the human dimensions of global change. The next step is to join the categories in the Bretherton Diagram with those in the Social Process Diagram into a more complete picture of global change. With this road map, scientists, policy makers, resource managers and others will have a tool to comprehend Earth system science and how the complex interactions among the atmosphere, biosphere, cryosphere, hydrosphere and human activities form the dynamic Earth system.

It is hoped that the Social Process Diagram will serve as a cornerstone for furthering existing research efforts and will initiate new efforts. The information presented in this document is consistent with the research agendas proposed by other national and international groups, including the United States Global Change Research Program, the International Geosphere-Biosphere Programme, the National Research Council, the Human Dimensions of Global Environmental Change Programme and the World Climate Research Programme.

The Call to Explore

the Human Dimensions of Global Change

Planet Earth has been modified continually since its infancy some 4.5 billion years ago. Many believe that early in Earth's history, the planet was covered by water, with an atmosphere dominated by carbon dioxide. Slowly, Earth began to give birth to volcanic islands, the cores of our present continents. As plant life developed, photosynthesis caused oxygen to increase in the atmosphere, while large amounts of carbon dioxide were removed by reaction with continental rock material. More recently, massive snow and ice fields have covered much of the planet at various times to sculpt and shape Earth's surface. Natural forces have caused global change throughout the history of our planet. Why, then, the present concern?

Our own species, *Homo sapiens*, and our ancestors have also drastically changed the face of the planet. Humans naturally organize into social groups, and our inclination to question, explore and learn has caused and continues to cause much of the environmental change we experience today. In fact, as thinking beings, humans have the potential to cause environmental changes within a shorter time period and of greater magnitude than many naturally occurring events.

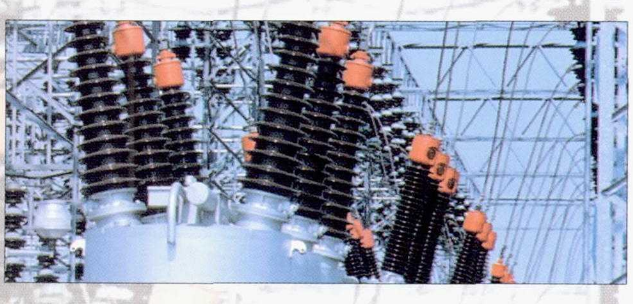
Clearly, humans are a potent and complex element within Earth's system of spheres—the atmosphere, biosphere, cryosphere and hydrosphere—that support a broad diversity of life. Consider some specific examples:

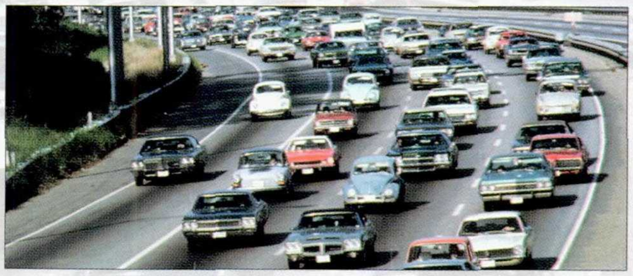
Population: Human ability to control disease, reproduce and feed continually growing numbers of people has caused our population to mushroom: from about one billion in the 1830s to more than five billion today. Burgeoning populations raise questions about how natural resources can be stretched to meet increasing human needs.

Economics: An evolutionary corner was turned when humans shifted from hunting and gathering to agriculture, because this activity dramatically changes the natural environment. This shift began about 10,000 years ago in Mesopotamia, and about 7,000 years ago in China and Mesoamerica (PreColumbian Mexico and Central America).

Energy: A half-million years ago, humans learned to ignite fire. Since then, humans have steadily increased their abilities to extract energy from the environment and exploit these sources through the use of tools and social organization. Energy production and consumption are major contributors to changes in the natural environment through effects such as depletion of natural resources and pollution.

Government Policy: The highway construction policies Congress passed in the 1950s created many of today's interstate highways. But the highway system spurred a huge expansion in interstate trucking at the expense of the railroad industry. In addition, the new highways created an increase in truck and automobile exhaust gases, a leading source of fossil fuel emission.





The coupling of natural and human systems, as shown in these examples, has led scientists to acknowledge that complex interrelationships exist between humans and their natural environment. Everything we do affects the system that supports us, and changes to the environment, in turn, cause changes in us. In this living cycle, one change leads to another, then another, as output from one activity becomes input to another.

This document describes an initial step toward exploring how humans, interacting within social systems, affect and are affected by global change. The causes and consequences of human activities—the human dimensions—must begin to be factored into the discussions, research, predictions, policies and actions surrounding global change. Achieving this goal requires social and natural scientists to work together to understand global change and to recommend courses of action to ensure the long-term well-being of Earth and all its inhabitants. When the links between the natural and human domains are identified and quantified, we will begin to understand more fully the direction and consequences of global environmental change.

The Need for Human Dimensions Research

Until recently, most global change studies focused on understanding the interactions among natural processes. For example, if carbon dioxide in the atmosphere increases, the Earth's surface and air temperature will rise. This, in turn, affects the wind and where and how much it rains. Clouds and atmospheric water vapor also change, and they, in turn, further affect the temperature. Temperature and rainfall affect the type and amount of vegetation on Earth. Vegetation and the oceans remove carbon dioxide from the atmosphere. Further, vegetation and clouds help determine the amount of sunlight available to heat the Earth.

While studying natural processes like these is crucial to understanding global change, it is not enough. For global change is more than drought in the African Sahel region or the record-breaking high temperatures of the 1980s. Increasingly, global change must include human dimensions such as the movement of human populations, urbanization, changing land use patterns, the consumption and production of energy, pollution, depletion of resources, evolution and extinction of species, changes in international economies, the balance of economic power, changes in the political orientation of world powers and disease.

The call for research in these human dimensions of global change has been heralded by numerous scientific groups, including the United States Committee on Global Change Research (the U.S. national committee for the International Geosphere-Biosphere Programme). In a 1990 report, *Research Strategies for the U.S. Global Change Research Program*, (National Academy Press, 1991), the Committee asserted:

The global change program has benefited tremendously from the early efforts of the Earth Systems Sciences Committee (ESSC) to create a "wiring diagram" of key processes and information flows among the climatic, biogeochemical and ecological components of the Earth system. . . .Scholarship on the human dimensions of global change is now sufficiently advanced that the diagram should be revised to reflect our conceptual understanding of the interactions between people and environment that constitute the Earth system.

Responding to this identified need, the Consortium for International Earth Science Information Network (CIESIN) defined an intermediate step to accomplish before we can conceptually understand the interactions between people and the environment. This step is to document the interactions among human activities themselves and subsequently how these interactions affect and are affected by global change.

To accomplish this task, CIESIN commissioned 12 scientists, called the Human Interactions Working Group, to meet at the Aspen Global Change Institute in Aspen, Colorado for six days in August 1991.

Dr. William Kuhn, active in CIESIN since its inception, initiated and orchestrated the effort to convene these social scientists. During their meeting, group members produced a diagram—called the Social Process Diagram—showing the relationships among social systems and how these affect and are affected by global change.

The Social Process Diagram illustrated in this document is the initial stage of developing this type of research tool. The Working Group anticipates that the Diagram will continue to develop and change as global change programs evolve. Today, with the ongoing input of the Working Group members, Kuhn and others are continuing to share ideas about the Diagram and describe how it can be applied.

Building on the Bretherton Diagram

The Social Process Diagram is, in part, an extension of several preceding global change research efforts. In the mid-1980s, a group of natural scientists assembled at Jackson Hole, Wyoming, to construct a diagram showing the interactions among natural processes that influence global change. This diagram, known as the Bretherton Diagram, was named after Dr. Francis Bretherton, who participated in this effort and chaired the Earth System Sciences Committee of the NASA Advisory Council.

The group that developed the Bretherton Diagram realized that understanding the relationships among their disciplines was crucial to studying the natural aspects of global change. The two major components of that Diagram, the Physical Climate System and Biogeochemical Processes, have several subcomponents. The Bretherton Diagram shows that information and data from one system or discipline is needed to evaluate processes in another system. By consulting that diagram, scientists can determine whether the relevant processes needed to evaluate and understand a particular global change phenomenon have been considered.

While "Human Activities" are noted on the Bretherton Diagram, the relationships within that category were not developed. Human systems cannot be studied independently, but are interrelated in a fashion similar to processes within the natural science system. Thus, there was a concrete need to develop a "social process" diagram to begin exploring how social science processes—the human dimensions of global change—contribute to and are affected by changes in the environment.

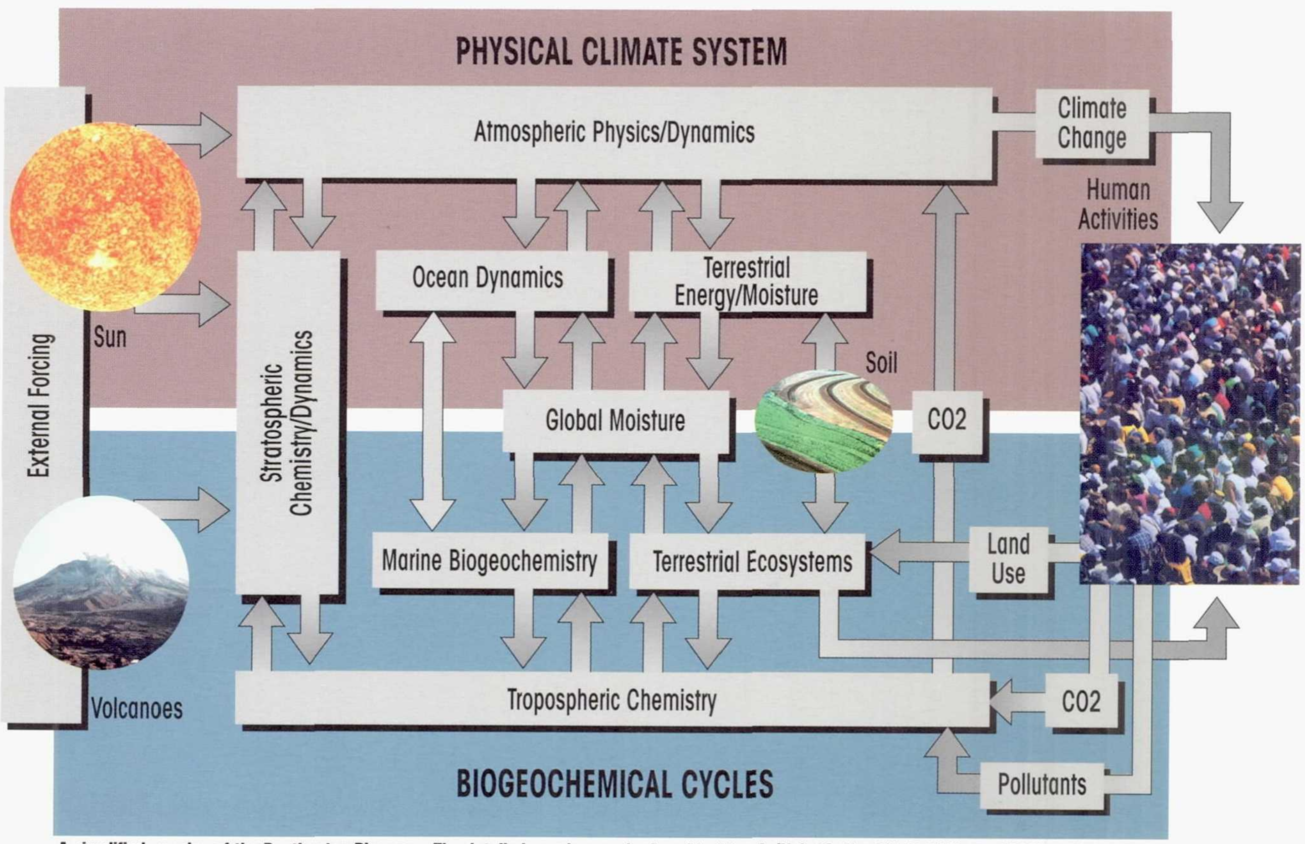
With continued development, the Social Process Diagram has the potential to be to the social sciences what the Bretherton Diagram is to the natural sciences. The Diagram gives us a framework to begin analyzing the human interactions that contribute to global change.

Forging a Link Between the Natural and Social Sciences

Using the Social Process Diagram and the Bretherton Diagram, researchers can take additional steps to comprehend more fully the causes and consequences of global environmental change. First, the Diagrams have the potential to be joined. In the same way the Bretherton Diagram factored in "Human Activities," the Social Process Diagram factors in "Global Scale Environmental Processes." Ultimately, these provisions will allow the diagrams to be joined into a complete picture of global change.

Second, scientists need to continue focusing on interdisciplinary research programs. As global environmental change becomes more complex, projecting courses of action will require an interdisciplinary approach. It is important to learn how research and findings in the social sciences relate to global change research and findings in the natural sciences. To do this, professionals must study issues individually, but also work together to study issues as related parts of the global system. Diagrams and models will be especially useful when researchers do not share a common technical language, yet rely on one another for data and information crucial to advancing research.

Armed with tools such as the Social Process Diagram and the Bretherton Diagram, scientists, policy makers, resource managers and others will be able to comprehend how the interactions among natural and human activities form the dynamic Earth system that supports 5.5 billion humans, more than a million species of invertebrates, 320,000 species of plant life, 22,000 fishes, 10,500 reptiles and amphibians, 9,000 birds, 5,800 microorganisms, 4,000 mammals and millions of other plant and animal species yet to be identified.

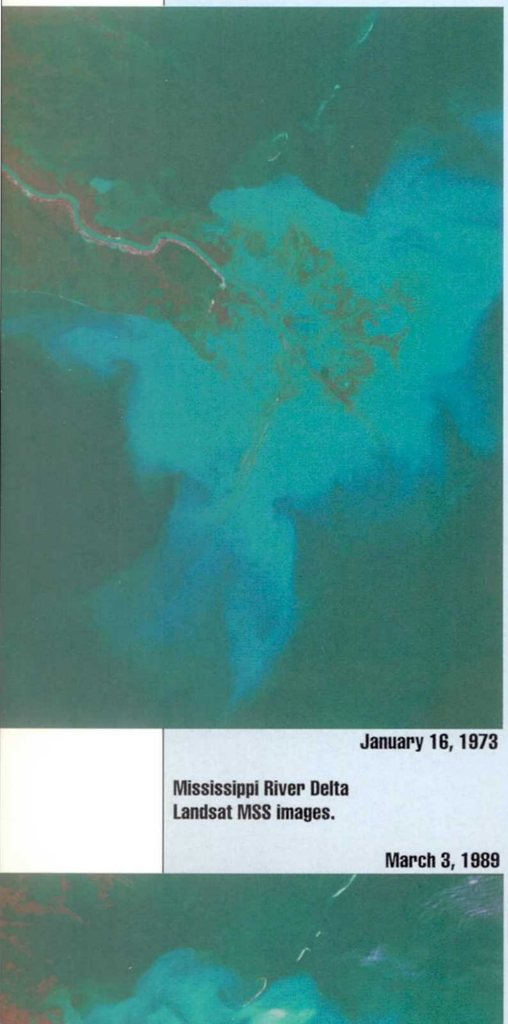


A simplified version of the Bretherton Diagram. The detailed version can be found in *Mosaic* (Vol. 19, No. 3/4, Fall/Winter 1988) published by the National Science Foundation.

The Social Process Diagram: A Fundamental Contribution to Human Dimensions Research

By Dr. Harold K. Jacobson, Chair, Scientific Committee of the Human Dimensions of Global Environmental Change Programme, International Social Science Council, and Director, Center for Political Studies, University of Michigan

The Social Process Diagram is a fundamental contribution to research on the human dimensions of global environmental change. It ties together efforts of the scientific community to develop and refine a research agenda and provides a broad orientation for future work.



January 16, 1973

Mississippi River Delta Landsat MSS images.

March 3, 1989

The process of defining a research agenda for the human dimensions of global change began in 1986. By 1991, consensus had been achieved on the topics that should be included. This consensus can be reviewed in *A Framework for Research on the Human Dimensions of Global Environmental Change* (Jacobson, Price 1990), which the International Social Science Council adopted in November 1990 as the broad orientation for its Human Dimensions of Global Environmental Change Programme, and in the report of the U.S. National Research Council Committee, *Global Environmental Change: Understanding the Human Dimensions*.

Although there is consensus among these and other agenda-setting documents on the topics that must be included in human dimensions research, none of the documents shows how the topics fit together. The scientific community had identified the natural science components of the Bretherton Diagram, but had not taken the next step.

In producing the Social Process Diagram, CIESIN's Human Interactions Working Group accomplished this next step. The Diagram, however, does more than show the linkages among the major categories within the social sciences. By indicating the direction and time scale of interactions among these categories, it provides the elements of a rudimentary comprehensive model.

The Social Process Diagram will play a critically important role in human dimensions research. The research will involve thousands of individuals all over the world from several disciplines working alone or in teams on discrete subjects. The natural and essential tendency is to orient one's research primarily in terms of previous work on the same topic. But to deepen the understanding of the human dimensions of global environmental change, the results of a wide variety of studies will have to be fitted together. This can be accomplished only if these studies are shaped from their inception by an awareness of connections and interactions with other topics. The Social Process Diagram provides the overarching framework that will facilitate these interactions.

Projecting the consequences of likely and possible future human activities will be essential to dealing with global environmental change in as rational a manner as possible. Existing projections extrapolate current activities or introduce assumptions about changes that are chosen more or less arbitrarily. To improve these projections, an operating model of social processes will be required and this will have to be linked with a model of natural processes.

Much data needs to be collected and many studies and modeling efforts need to be accomplished before it would be possible to even hope that this goal could be attained. The Social Process Diagram will orient this work and point the way toward the goal. Its importance to human dimensions research is fundamental.

Reestablishing a Unified Approach to the Sciences

By Dr. Urs Luterbacher, Professor of Political Science,
Graduate Institute of International Studies, Geneva, Switzerland

Science in the 17th and 18th centuries made little distinction between natural and social processes. In both areas, scientists believed that the "natural" order of the world could be discovered by either examining natural phenomena or by studying essential human interactions and arrangements such as social contracts. In the 17th and 18th centuries, these were defined as the constitutional framework, which was the foundation for social relations everywhere.

Scientists and mathematicians such as Pascal, Euler, Daniel Bernoulli, d'Alembert and Condorcet tried to solve problems that intersected the boundaries we currently draw between natural and social domains. For these scientists, the search for a "perfectable" social order was as important as the search for an understanding of laws in the natural sciences.

This unitary view of science was restated in the Encyclopedia Movement of the late 18th century in which d'Alembert played a significant role. This integrated approach was also adopted by the 18th century physiocrats (mostly French) who tried to define the interrelations among agricultural studies, biology, demography, economics and politics. Condorcet, the French mathematician and political figure who analyzed political problems in mathematical terms, also believed in this unitary concept. Condorcet stated his complete agreement with a concept proclaimed by the French economist and statesman Turgot that "the truths of moral and political sciences can be established with the same certainty as those that form the system of the physical sciences." (Condorcet 1785:i). This thought was important for Condorcet because it led him to "the consoling expectation that humanity will necessarily progress toward happiness and perfection as it has already progressed toward better knowledge of truth." (Condorcet 1785:i).

The singular approach to natural and social science was not just an intellectual phenomenon, but was conditioned by technological and political changes taking place during that time. The discovery of physical laws, the extension of mathematical knowledge, the invention of machines that could be used in industrial processes, the exploration of the globe, the constitutional developments in England, and the political changes leading to the American and French Revolutions all contributed to developing this vision.

During the 19th century, however, partially because of major advances in the natural sciences, this unified approach began to unravel. This process did not result only from the success of the natural sciences, but also because natural science began to specialize into various disciplines. At the same time, the social upheavals of the 19th century spawned separate social sciences whose aims became more and more diversified. As a result, the unitary perspective of the 18th century was abandoned and the social and natural sciences mostly went their separate ways.

Concern for the interaction between social and physical processes and the use of common methodologies was never completely lost. Great scientific minds such as Emile Borel and John Von Neumann addressed problems in the social as well as in the natural sciences in the 20th century. The fact that both Borel and Von Neumann played a significant role in developing game theory, and that Von Neumann did important work in economics and in mathematics and theoretical physics demonstrates their ability to contribute to several disciplines.

The challenges posed by the processes of global environmental change that result from immense social, political and technological changes (as occurred in the 18th century) again require a unitary approach by social and natural scientists. Global environmental change can only be understood if perspectives developed by both the social and natural sciences are adopted and linked together. This union is necessary because human activities cause many of the changes occurring in the global natural environment and humans are, in turn, affected by the consequences of the processes they help create.

Global Change Research
Occurring Worldwide

With a wide range of complex issues contributing to global change, addressing the problems that are arising at an ever-accelerating pace requires the combined efforts and expertise of natural scientists, social scientists, resource managers, administrators, policy makers and the general public. To further understand the foundation upon which the Social Process Diagram was developed, it is helpful to describe some of the major global change research programs.

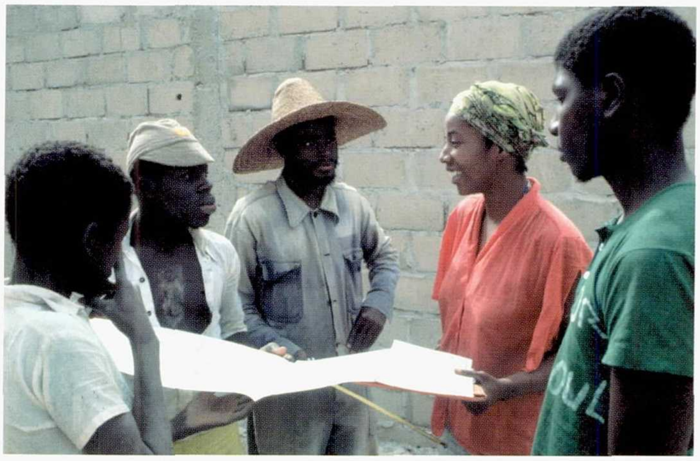
The world's scientific community has been coordinating its efforts to understand global change, realizing that both beneficial and detrimental environmental actions by any nation will impact other nations as surely as the atmosphere and the oceans forever bind them together. As Dr. Mooney notes in the accompanying article, the evolution of studying Earth system science has been a difficult process, but one that is now advancing along a well-defined path. Similar efforts are underway to combine the expertise of social scientists to study the human dimensions.

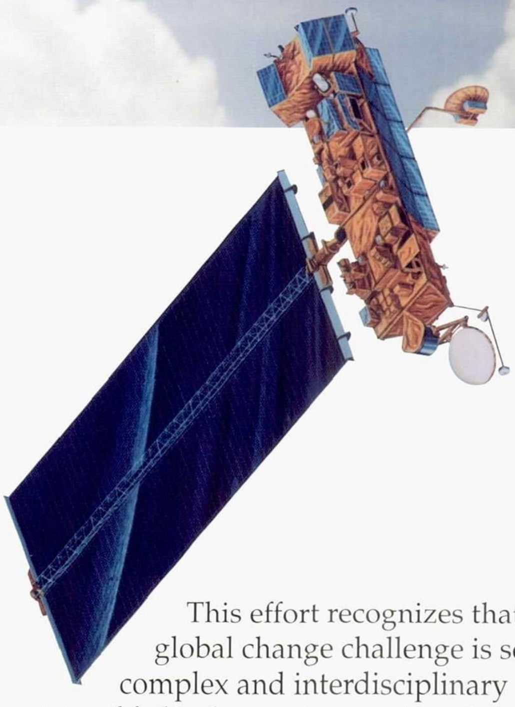
The International Council of Scientific Unions (ICSU) is an international, non-governmental scientific organization whose principal objective is to encourage international scientific activity for the benefit of humankind. Among the international global change research programs administered by ICSU is the International Geosphere-Biosphere Programme (IGBP).

The IGBP is an alliance of interdisciplinary, interlinked projects, each aimed at scientific questions that address the most critical unknowns about the Earth system. Fifty-one nations now have national IGBP committees and programs.

The IGBP has been working since 1986 to identify the key unknowns about the functioning of the Earth system. These unknowns, formulated in seven questions, are the basis for developing the IGBP core projects, and concern issues such as how biological and other processes regulate atmospheric chemical composition; how processes in the open oceans and the coastal zones influence global cycles and may respond to global change; how vegetation controls fluxes of energy and water in the soil-vegetation-atmosphere system; how global changes will affect terrestrial ecosystems; and the causes and consequences of past global changes. Detailed scientific plans to address these unknowns have been or are being developed.

In addition to participating in international programs, individual countries are mounting their own global change research efforts. In the United States, the U.S. Global Change Research Program (USGCRP) was established in the late 1980s by the Committee on Earth and Environmental Sciences (CEES). The CEES, which includes representatives of 11 federal agencies and departments, coordinates the federal research plan for global change.





This effort recognizes that the global change challenge is so complex and interdisciplinary that a variety of federal agencies must work together to advance knowledge.

CEES has established seven priorities for U.S. global change research. Heading the list is "Climate and Hydrologic Systems;" the water cycle—clouds in particular—is fundamental to understanding climate change. At the bottom of the priority list is "Solar Influences;" while the sun does vary in intensity, it is not clear what effect this has on climate. Fifth in this list of priorities are the "Human Dimensions." While six of the seven priority areas in the USGCRP can be studied by those in the physical, chemical, geological and biological sciences, the human dimensions, especially, require the expertise of the social scientist.

Another significant national program is the United Kingdom Global Environmental Research Office (UK GER). The UK GER was established in 1990 by the five UK Research Councils. The UK GER Office acts as a focal point for flow and exchange of information on UK and international science and policy developments, and acts as a contact point for equivalent offices in other countries. The involvement of all the Research Councils in establishing and funding this initiative reflects the UK's commitment to interdisciplinary approaches to global change, and the extent to which the issues cross traditional scientific disciplines within the natural and social sciences.

Focusing on the Human Dimensions

A deficiency in both national and international global change programs has been the lack of effort in the area of human dimensions. This deficiency is not due to a lack of interest; rather, most initiatives have been led by natural scientists and most funding has been appropriated to their disciplines.

In recent years, however, several agencies addressing the human dimensions of global change have been established. The International Social Science Council (ISSC), consists of representatives from 15 international associations. ISSC addresses such issues as economics, political science, psychological studies, public opinion research and mental health. Recently, the Human Dimensions of Global Environmental Change Programme (HDGECP) was formed within the ISSC. The Scientific Committee for the HDGECP is chaired by Dr. Harold K. Jacobson, one of the long-time advocates for including the human dimensions in global change research efforts. This committee includes representatives from numerous social science disciplines worldwide, and complements the IGBP.

Another organization with a strong focus on the human dimensions of global change is the National Research Council (NRC), an agency of the U.S. National Academy of Sciences and National Academy of Engineering. The NRC recently proposed an aggressive human dimensions program for the United States in the recently published book *Global Environmental Change: Understanding the Human Dimensions* (Stern, et al., 1992).

Non-governmental efforts to address global change issues are also operating worldwide. The Social Science Research Council (SSRC), an independent, international association composed of and directed by social scientists, is one example. The SSRC helps scientists and scholars from different disciplines work together to advance interdisciplinary research. Through its Committee for Research on Global Environmental Change, SSRC sponsors research not only among social scientists, but also between social and natural scientists. This committee is fostering interdisciplinary research in six major areas of large-scale, long-term change in the human environment.

Another program, Earth Transformed (ET), developed as a result of a symposium held at Clark University in October 1987 called "The Earth as Transformed by Human Action." This program sponsors research in the human dimensions of global environmental change and the development of tools such as geographic information systems. Dr. Billie Lee Turner II, professor of geography at Clark University, is ET's coordinator.

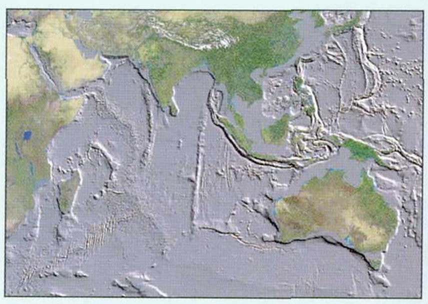
Shanghai, China Landsat MSS Image

Studying the Earth System

By Dr. Harold A. Mooney, Past Chair, U.S. Committee on Global Change Research, and Professor of Biological Sciences, Stanford University, Stanford, California

The need for a comprehensive approach to studying Earth as a system has become increasingly obvious as the unequivocal signs of major changes in the lands, oceans and the atmosphere have accumulated. The implications these changes have for the well being of society have created an urgency to understand the consequences of these changes.

This sense of urgency resulted in the development of an international program, through the mid-1980s to the present, for studying the consequences of global change. This international planning effort, the International Geosphere-Biosphere Programme (IGBP) has been augmented by comparable national programs. In essence, the original architects of the IGBP concept thought that melding information from physical and biological sciences would give us a quantitative understanding of what drives the global climate and biogeochemical systems. It was the perturbation and potential major alteration of these systems that spawned our concern for the consequences of global change. Although the links between biological and physical systems were easy to perceive, the quantitative linkages had not been made. Developing the Bretherton Diagram provided an important visualization of how the elements of the total natural system interact.



The efforts of the Bretherton group implied that attention had to be directed to the interfaces among the traditional natural science disciplines. Initially, this meant dialogue between, for example, terrestrial ecologists and climate modelers. This in itself was not easy in the beginning because these disciplines normally conduct studies using different spatial and temporal domains and traditionally use different tools as they progress in their work. During the past few years, though, increasing communication among these scientists and collaborative projects have evolved. New, integrated teaching programs and research centers have helped develop these collaborative efforts. This important transition has not been easy and is still an ongoing process.

Implicit in the Bretherton Diagram is that changes that occur to the Earth system are in part driven by human activities. No attention, however, was given to these drivers in the initial development of the formal IGBP research program. This omission is now being corrected by aggressive national programs in this area, namely by the Human Dimensions of Global Environmental Change Program (HDGECP) and by forging links between the HDGECP and the IGBP. The process of integrating research approaches between natural and social sciences will be even more difficult than is being experienced by scientists within the natural sciences. Nevertheless, there is now a strong consensus that we must understand, in detail, both human-induced and naturally-induced drivers and their impacts, if we are to understand how the Earth system operates and is changing.

The development of the Social Process Diagram will no doubt serve a similar role to that of the Bretherton Diagram. It will stimulate integrated, globally-oriented thinking within the social sciences. It will also help the natural sciences by clearly showing the links between the direct social drivers and environmental change as well as the complex indirect factors controlling these drivers.

Studying the Human Dimensions of Global Environmental Change

By Dr. Richard H. Moss, Deputy Executive Director, Human Dimensions of Global Environmental Change Programme and Programme Officer, International Geosphere-Biosphere Programme

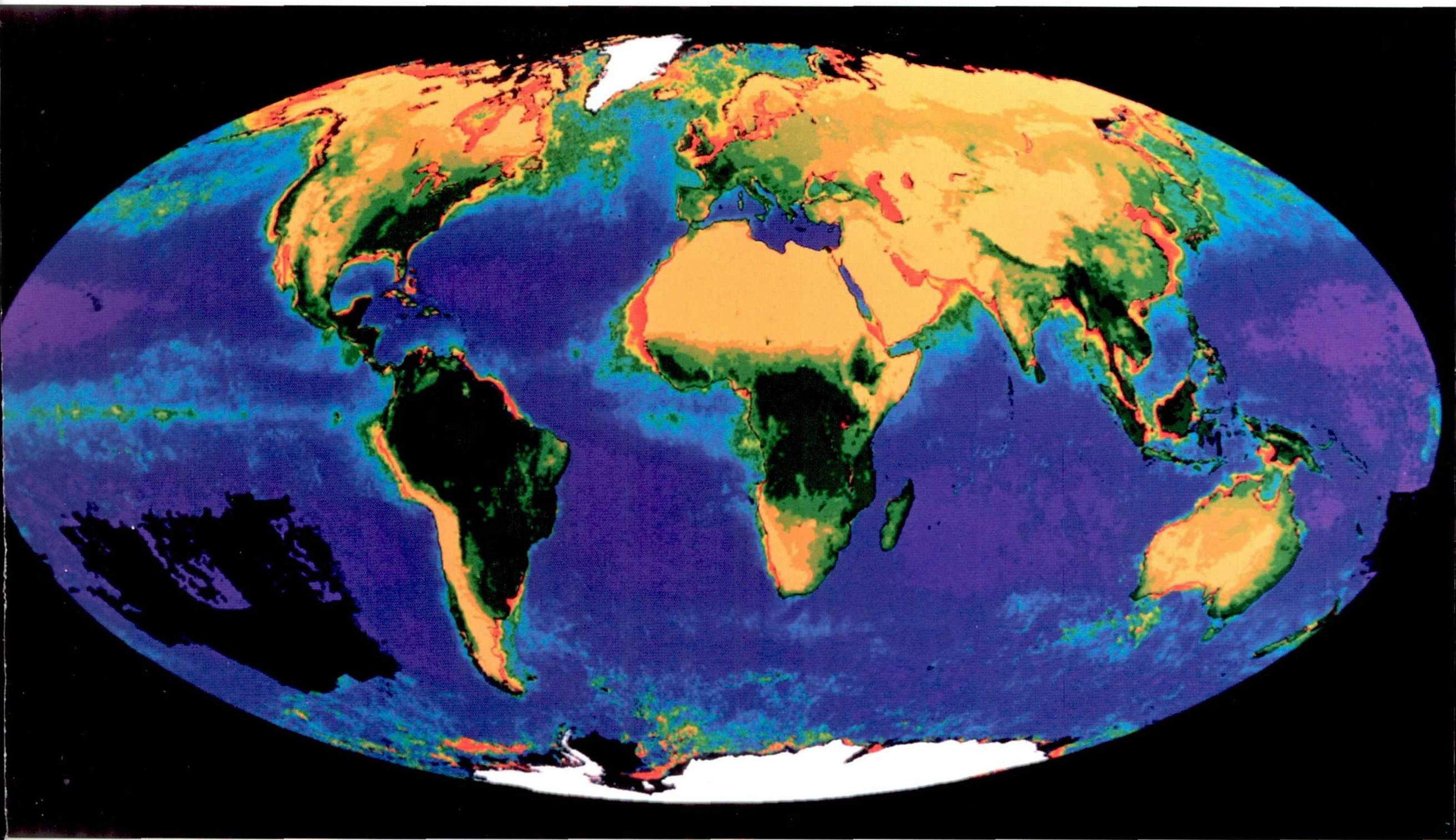
The International Geosphere-Biosphere Programme (IGBP) was established in order to describe and understand the interactive physical, chemical and biological processes that regulate the total Earth system, the changes that are occurring in this system and how these changes are influenced by human activities.

Detailed planning for the IGBP started in 1986. The first step in establishing the programme was to clarify the key scientific unknowns about the Earth system and changes to it. This task was launched by scientists within a range of natural science disciplines that are important to understanding the hydrological and biogeochemical cycles and their interaction with the physical aspects of the Earth system.

Now that this task is completed, it is necessary to begin incorporating information, data and research on the human dimensions of global change. There are several reasons why this is crucial. The most basic is that while natural forces have influenced and shaped the environment over the course of Earth's history, humankind is now expected to change the environment more rapidly than during any comparable period. The burning of fossil fuels, agriculture, forestry, changes in land use, industrial activities, waste disposal and other human activities have all helped alter natural cycles and systems. In order to understand natural and anthropogenic-induced changes in the functioning Earth system, it will be necessary to develop a full understanding of human use of natural resources, a task that requires close collaboration with the social sciences.

Because the IGBP seeks to develop a predictive understanding of changes that affect the functioning of the biosphere and the impact these changes have on natural systems, the programme will require information about how human activities currently force natural cycles, how socio-economic behaviours that affect natural systems may change and how human responses to global changes may create new feedbacks in natural systems. Natural scientists cannot develop these predictions on their own; they need information and data that can only be developed by researchers in the social sciences.

Some research into the human dimensions of global change will occur independently of research in the natural sciences. Projects focusing on issues such as discontinuities between human behaviour and human attitudes regarding environmental protection and global change; the impact of industrial heritage on innovation; the effects of institutions on resource use; the ways in which global changes could affect trading patterns and flows; the relationship between population pressures and land and resource degradation; and the process of diffusing new technologies will complement the research of programmes like the IGBP. Interdisciplinary research in


Global Biosphere

these and other areas is needed to advance the goal of both the natural and social sciences to improve our understanding of how humankind's relationship with the environment can be managed.

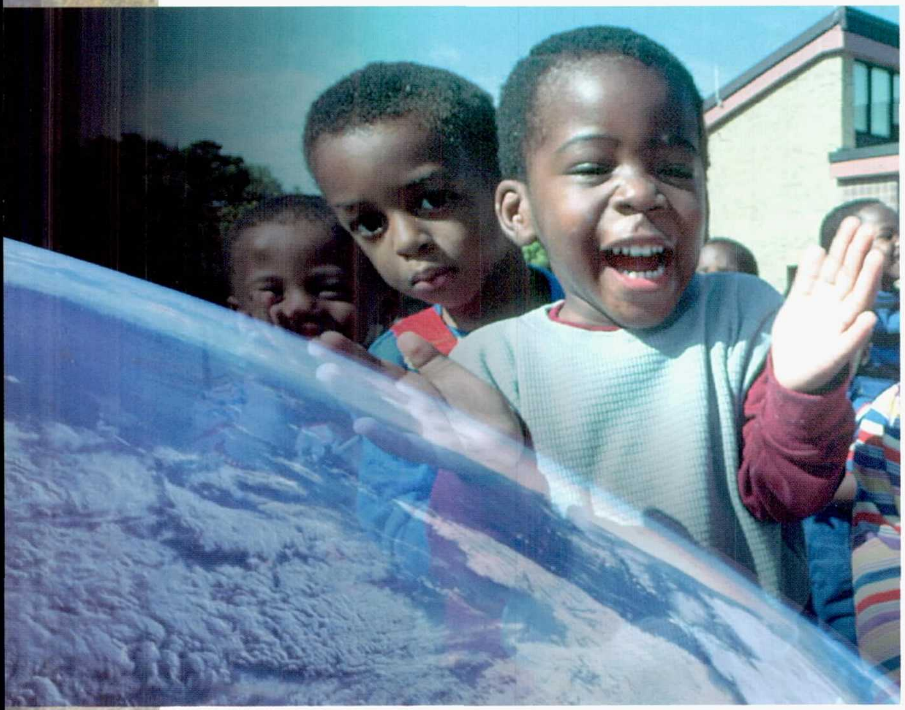
Other projects will require close collaboration between natural and social scientists. These will include projects that focus on changes in land cover due to changing land use practices and the use of coastal zones. Projects will also include developing models of the socio-economic impacts of meso-scale climate changes and improving current models of greenhouse gas emissions for activities such as logging and agriculture. These projects are beginning to be developed through the liaison between the IGBP and the HDGECP.

The knowledge gained through programmes like the IGBP about the functioning of the Earth system will be interesting in their own right to natural scientists. Unless this knowledge is applied through collaborative research with social scientists to understand the impact of global changes on human systems, however, it will not be useful to the public or policy makers. Both natural and social science expertise and research need to be applied to what we learn about global change in order to develop effective policy responses. This will improve our prospects of meeting the challenges and capitalizing on the opportunities that global change creates.

Integrating the Social Sciences
to Address Global Change Issues

Researchers within the social sciences have a significant role to play in analyzing, understanding and mitigating global environmental change. While social scientists recognize that their expertise is crucial to a wide variety of initiatives, they have not yet formulated a comprehensive plan to organize and focus their efforts.

This section gives the layperson and scientists not yet involved in global change issues an introduction to the potential roles social scientists can play in global change. This section is not exhaustive, for other social science disciplines, such as sociology, geography and history, clearly have a role to play in understanding global change. Based upon the expertise represented in the Working Group, however, this section details how some of the social science disciplines can contribute.



Anthropology and Archaeology

Humans have 10,000 years of experience as farmers and 5,500 years as urban dwellers. The way humans have reacted to environmental change and how they have influenced and reshaped the environment are important aspects of studying the human dimensions of global change. Anthropology, the study of human populations throughout history and in diverse physical environments, can give a regional view of changes—a viewpoint that allows us to assess actual rather than theoretical impacts of global change.

Virtually all human experience lies in the past, whether considering *Homo habilis*, two million years ago, or our own species, *Homo sapiens*, present at least 35,000 years ago with cultural traits similar to today's. Archaeology, a specialty within anthropology, focuses on how people have interacted with their environment over thousands, even millions, of years. Human experiences with global environmental change have been encoded in written history, in archaeological remains and in the environmental record itself. At least since the advent of agriculture some 10,000 years ago, these records show that humans have been major players in changes to the physical environment on local and regional scales. The origin and spread of agriculture, for example, has transformed vegetation, soils and animal life.

By studying the past, we know that social systems change and we can document these changes. The larger a society's population, the more apparent the episodes of growth, consolidation or collapse. For example, every long-running, urbanized region that has been studied in detail—such as Mesoamerica, Mesopotamia and Europe—has undergone episodes of rapid demographic growth akin to those of today, and has experienced at least one dramatic collapse. Thus, over the very long term, we observe periods of growth, consolidation and decline and can unravel the complex interaction of social forces and environmental change. We can apply this knowledge to predicting what may happen in modern societies if events continue along a certain course.

Study of modern culture and cultures of the recent past gives insight into the diverse strategies humans have adopted to confront the uncertainty, depletion of resources, risk and catastrophes that often characterize global change. Anthropologists traditionally study people who are the basic producers of the world's food. These diverse cultures often use crops and techniques that are not seen in the industrialized world. Thus, the study of cultural diversity is analogous to biodiversity: it has given and will continue to give humans adaptive potential to meet a wide range of changing circumstances. Such studies document how humans exploit diverse environments using crops, foods and fuels that lie outside the domain of international trade and commerce. For example, analyzing the practices of cropping, herding and managing natural resources and the vastly different forms of social organization (particularly those of non-industrial peoples) may help us evaluate alternative strategies for dealing with environmental change. In this way, anthropology raises awareness of how human societies have survived and thrived in differing environments.

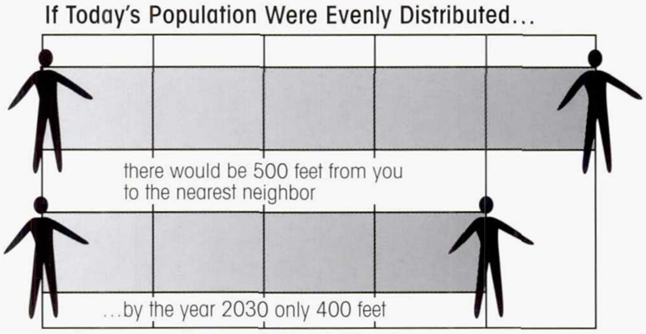
Anthropology, as well as other social science disciplines, reveal that potentially there are many, not few, solutions to global problems, and that solutions must be tailored to local conditions. Diversification, rather than specialization, has been the traditional mode of adaptation by successful non-industrial peoples. It is possible that, with a global approach to environmental issues, diversity will be recognized as an important strategy to deal with uncertainties introduced by global change and local circumstances.

Demography

A significant factor in the widening scope of global change is the world's growing human population. Increasing populations pose significant risks and challenges to the world's ecosystems, forcing settlement in new areas and raising the demand for resources. It has been estimated that 7,000 years ago, Earth's population totaled about five million, similar in size to today's Rio de Janeiro, Brazil. Demographers estimate that Earth supports 5.5 billion people, a thousand times more than 7,000 years ago. If today's population were distributed evenly over all the world's land area, your nearest neighbor would be about 500 feet from you. Demographers predict that by the year 2030, the world's population will expand to 8.3 billion (based on a 1.1 percent growth rate). Everyone's nearest neighbor would then be only 400 feet away.

Such predictions of human population derive from a combination of empirical data from census and registration records and from sophisticated models of population-related variables (fertility, mortality or migration). Although population is increasing worldwide, significant regional variations exist in the densities and rates of growth, and thus in the effect of population on local environments. Differential human migration and increasing population will lead to new demands for regional resources, produce new regional concentrations of pollutants and ultimately affect the global environment.

Demographers increasingly incorporate economic, political and cultural data to explain different patterns of population growth. The results of their analyses and predictions of population dynamics can help us understand the risks and challenges to local ecosystems. A thorough understanding of regional demographic patterns combined with comparisons among nations will expand analyses into problems of human population movement and consequences for global change.



Political Science

Governments, how they enact policies and the effects these policies have on global change provides an important focus for study. Political institutions and systems define the way individual interests are translated into social goals, laws and regulations. Political systems and policies can have a sudden impact on the spatial distribution of a population, as well as on its size and health. Oppressive government policies may lead people to seek relief, creating the conditions for mass exodus. More lenient policies, on the other hand, stimulate conditions that attract immigrants and refugees and that may foster wealth.

Political science also focuses on the processes and dynamics of how people and institutions seek to control the distribution of resources and wealth. Political systems affect these processes through differing definitions of property rights. In this way, some political systems promote equity, while others concentrate wealth. Political scientists also study international institutions and the process of achieving the sort of international cooperation that will be required to slow global change.

Economics

Because economic activity and the resulting political regulation are driving forces behind much of what human beings do as they inhabit the planet, these systems also drive many human-induced global change phenomena. Understanding economic activity involves investigating both the source of global change and the potential for abating the change.

For example, entrepreneurs focus their energies on features of the environment that offer a comparative advantage. Sometimes, this means using available inexpensive labor or exploiting certain characteristics of the surrounding environment, like arable land, minerals or water resources. The ensuing economic growth and opportunities can attract more people to the relevant area, eventually straining local resources. This demand for goods and services generates a stream of revenue, which is used to pay laborers and service providers.

Political authorities or regulatory agencies can decide on how to best control economic and social strains. If water is in short supply and drought conditions prevail, for example, a local governing body may introduce water conservation or rationing rules. Such regulations may help relieve the strains on water resources, but may exacerbate other problems, such as fire hazards.

Economic systems also act as a filter through which human preferences and expectations flow. Free market systems, for example, tend to reflect individual interests. The output of economic systems is partially driven by the market forces of supply and demand and partially by political regulation and taxation. The flow of capital and labor through an economy can be altered by policy choices; for example, by raising the price of particular commodities through taxation (i.e., tariffs and gas taxes), or by favoring certain forms of investment through regulation or tax breaks. For example, the provision to deduct mortgage interest payments can stimulate the demand for house construction and construction materials, and thus influence environmental conditions.

Economic systems that encourage individual choice (as distinct from the social choices of political systems) also attract populations. Prosperity stimulates demands on resources and on populations, but can also foster innovation and invention. These factors, in turn, change the mix of resources in an environment and the demand placed on them. Gradually, global environmental processes respond to political and economic dynamics, leading to stress in some areas and relief in others.

The Human Interactions Working Group

Christopher Achen (Ph.D., Political Science, Yale University, 1974), is a professor of political science at the University of Michigan. His research investigates how effectively government programs develop policies as they apply to issues of national security. He also studies how governments make decisions, form policies and cooperate on an international level on environmental matters.

Bruce Bueno de Mesquita (Ph.D., Political Science, University of Michigan, 1971), is a political scientist and senior fellow at the Hoover Institution at Stanford University and professor at the University of Rochester (New York). His research focuses on the design of rational choice models, decision making in the context of international relations, conflict/cooperation models and models to forecast policy choices.

Paul Demeny (Ph.D., Economics, Princeton University, 1961), is an economist and demographer. He is a distinguished scholar at the Population Council, an independent research and technical assistance organization in New York City. Dr. Demeny's scientific work centers on population dynamics, economic growth and the economic aspects of demographic change.

Allan M. Din (Ph.D., Theoretical Physics, University of Gothenburg, 1974), is a physicist and information system specialist at the International Academy of the Environment, Geneva, Switzerland. Dr. Din has been working in several interdisciplinary areas involving environment and security, environmental impacts of war, decision making and expert system technology, remote sensing and arms control. In recent years, Dr. Din has been involved in applications of remote sensing data and Geographic Information Systems (GIS) to global change research.

Jae Edmonds (Ph.D., Economics, Duke University, 1974) is technical leader of Economic Programs at the Battelle Pacific Northwest Laboratory, Washington, D.C. office, and the leader of the Policy Programs within the Pacific Northwest Laboratory's Global Studies Program. His current research focuses on energy and greenhouse gas emissions and the effects of climate change on human and natural systems. Dr. Edmonds is best known for his work, with Dr. John Reilly and others, on the "Edmonds/Reilly" model of long-term global energy and greenhouse gas emissions.

Frank Hole (Ph.D., Anthropology, University of Chicago, 1961), is a professor of anthropology at Yale University and curator of archaeology in the Peabody Museum. He has studied the origins, spread and development of agricultural societies. His research currently focuses on northeast Syria in the Middle East, investigating the interrelationships among climatic and environmental change and human culture and development.

Stephen Kowalewski (Ph.D., Anthropology, University of Arizona, 1976), is an anthropologist at the University of Georgia. He focuses his research on comparative human ecosystems, economic history and the evolution of social ecosystems on a regional scale. He currently conducts field studies in southern Mexico and the southeastern United States.

William Kuhn (Ph.D., Astrogeophysics, University of Colorado, 1966), is a professor of Atmospheric, Oceanic and Space Science at the University of Michigan. He is also the Science Manager for CIESIN and initiated and organized the efforts of the Human Interactions Working Group session in Aspen, Colorado. Dr. Kuhn's prior research has been devoted to studying Earth's climate and atmosphere and how it has changed over geologic time.

Urs Luterbacher (Ph.D., Political Science, Graduate Institute of International Studies, 1974), is a political scientist teaching at the Graduate Institute of International Studies, Geneva, Switzerland. His research includes global modeling of political processes, including the strategic interactions among powers. Dr. Luterbacher also studies scenarios of future energy consumption, substitution effects and government policies relating to this issue.

Frederic L. Pryor (Ph.D., Economics, Yale University, 1962), is a professor of economics at Swarthmore College. His research focuses on comparing the performance of economic systems, where performance includes environmental variables. Currently, Dr. Pryor is working on two projects: a study of the agricultural system in several formerly communist nations in the past two decades; and a study of the evolving institutional structure of all sectors of the American economy in the next few decades.

Ellen Wiegandt (Ph.D., Anthropology, University of Michigan, 1977), is an anthropologist at the University of Geneva, Geneva, Switzerland. Her research focuses on the relationships among demographics, land use patterns and cultural rules and the interrelationships of these social dimensions with important climate factors.

Gary Yohe (Ph.D., Economics, Yale University, 1975), is a professor of economics at Wesleyan University and chairs the Public Affairs Center there. He concentrates his research on applied microeconomic theory, environmental economics, climate change and adaptive decisions to changes in global warming that might be posed under uncertain conditions. Dr. Yohe currently chairs a working group on economic data applicable to environmental issues for the International Social Science Council's Human Dimensions of Global Environmental Change Programme.

The Social Process Diagram

The Human Interactions Working Group developed the Social Process Diagram during a six-day meeting at the Aspen Global Change Institute. To focus and guide the Working Group's efforts, Dr. Kuhn asked CIESIN researchers Drs. Urs Luterbacher and Ellen Wiegandt to prepare a white paper exploring the links between climate and society. This white paper helped the Working Group debate fundamental questions about humans and their relationship with global environmental change. These questions included:

How do people conceptualize what they choose and what they do?

Human values and behavior are conditioned by culture and cultural history. To understand present and future attitudes and decisions, it is important to consider cultural and historical factors that shape values and the preferences of individuals and social groups. These values and preferences help shape the choices we make.

How do people organize and implement their activities?

Within the domain defined by a culture's history and experience, societies must devise ways to achieve the goals set by their preferences. All societies have developed institutions. Some are society-wide and formal, like political institutions. Others organize people into smaller groups within society, such as families, churches, corporations and universities. Analyzing the structure of these institutions and evaluating the processes of decision-making within them can reveal how certain actions and policies are chosen over others.

How many people are there and what is the nature of their internal divisions?

People live in every habitable place on Earth. Populations can be described by the size of their groups and divided into subgroups according to age, sex or social divisions like class, ethnic group, tribe or caste. Absolute numbers of people as well as their distribution in space and into social groups affect the ways they organize and carry out their activities. Health parameters influence the differential size and growth of the various subgroups and are thus relevant to understanding the structure and development of different populations.

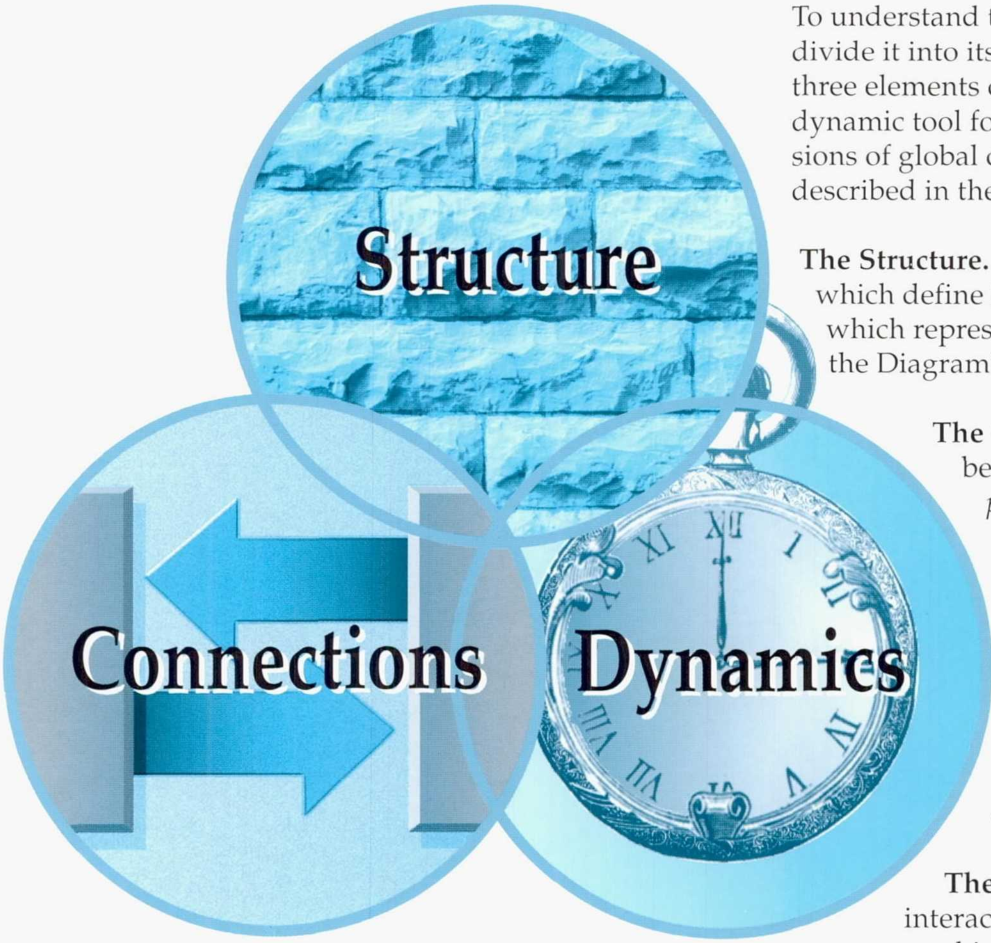
How do people make a living?

Producing goods and services assures that individuals and societies survive. The ways of organizing basic activities also affect how the environment is perceived and used. Understanding the economic domain, therefore, is fundamental to any study of the interactions between humans and their natural environment. In its broadest sense, the economy includes the distribution of factors of production; resources such as land, capital, labor and raw materials; and the types of technology available to exploit these resources. Analyzing the economic system also includes studying how goods and services are produced, distributed and consumed. Furthermore, changes in economic organization can only be evaluated with reference to how a society is growing and developing.

Where do people live? What is the physical nature of their habitat?

Local environments provide the physical context within which a society's activities occur. Some small-scale operations affect global scale environmental processes, and global changes also modify local conditions. Studying the links between human activities, where people live, the characteristics of these environments and how humans and their environments influence one another, are at the heart of the Social Process Diagram.

A Dynamic Tool for Understanding Global Change



As the Working Group discussed the previous questions and as participants shared their expertise, the Social Process Diagram took shape. The questions helped the group define the building blocks, and the links among them, that create the Social Process Diagram.

To understand the Diagram, it is helpful to divide it into its individual parts. Together, three elements constitute an integrated, dynamic tool for analyzing the human dimensions of global change. These three elements, described in the next three sections, are:

The Structure. The seven building blocks, six which define human social systems and one which represents natural systems, constitute the Diagram's structural framework.

The Connections. The links between building blocks create a *process diagram*, which defines fundamental driving forces of environmental change. Specific scenarios show how output from one category provides input to another. This form of the Diagram is used to launch discussions and research about the human dimensions of global change.

The Dynamics. Because human interactions occur within certain geographic locations and over certain time periods, the dimensions of space and time are important to understanding how the Diagram can be used.

The Structure: The Seven Building Blocks

The seven building blocks that create the Diagram's structural framework are:

Fund of Knowledge and Experience

Every society is the outcome of its history. Over millennia and generations, humans have developed techniques to adapt to their natural environment and have established rules to regulate relations among individuals and groups. The Fund of Knowledge and Experience refers to the understanding people have of their natural and social environments, and to the technology they have developed to exploit the resources their culture defines as relevant. The study of people in different places and at different times reveals the great diversity of strategies adopted to confront the challenges of an uncertain environment. Technologies, economies, political organizations and institutions, and social arrangements have varied through time and across space. These varying cultural histories have shaped the way people perceive and interact with their environment. Recognizing these long-term determinants is essential to predicting potential responses to current environmental changes. It is also a reminder that humans have always defined and perceived "nature" in cultural terms.

Preferences and Expectations

From the Fund of Knowledge people define their preferences and expectations, which reflect the culturally defined constraints and opportunities that shape individual actions. Expectations refer to an individual's assessment of how likely he or she will achieve

personal goals. This assessment can take various forms and will reflect the individual's attitude toward different kinds of uncertainty. A culture's history, reflected in the Fund of Knowledge and Experience, sets the boundaries of acceptable risk-taking behavior. Some cultures, for example, give more leeway than others to individuals to consume and transform natural resources. Overall, an individual's goals are expressed as preferences, which are defined within a particular cultural context and chosen by evaluating alternatives.

Factors of Production and Technology, including resources such as: Labor, Land, Capital, Raw Material and Energy

The resources and technology people use to produce goods and services make up this category. Production and consumption act as inputs and outputs to changes that may occur in the economic system. This category helps us trace what elements enter the system, how they are modified and what emerges at the end of the process. The production process is generally dependent on inputs such as: capital, land, labor, raw materials, energy, and the infrastructures of technology, communication and transportation.

All of these can be described as outputs of processes specified by other relationships on the Diagram. Furthermore, production systems are defined by the interaction among relevant factors at a given moment. For example, land is affected by climate, thus tying the category explicitly to Global Scale Environmental Processes; the way land is exploited is influenced by cultural tradition

and settlement patterns. Finally, the potential labor force is determined by the number of people considered employable and of appropriate age, and affected by processes such as marriage, birth, death, immigration and emigration.

Economic Systems

Economic systems determine how people produce and consume goods and how wealth is distributed and evolves. The Diagram's category of Economic Systems is not limited to market systems. It also encompasses peasant and traditional economies, where markets play a reduced role, as well as centrally planned and mixed-market arrangements.

In this context, it is useful to distinguish among three different systems of production and consumption. Industrial market economies, mixed market/centrally planned systems and economies of developing countries differ in the ways they use resources and how they organize consumption and production. An industrial market system embodies an economic sector in which decisions to produce and consume are made by individuals and industries. Although the government does not make most direct decisions regarding production and consumption, it may steer the process through various indirect measures, such as taxation, quality regulation and limits on wastes such as pollution.

In a mixed market/centrally planned system, significant segments of the economy are subject to government control. Governments directly determine levels and types of production and consumption of key goods and services. Decisions derive primarily from political goals rather than supply and demand. In recent years, nearly all centrally planned systems have come to include more and more sectors of the economy that are regulated by market forces. Thus, this type of system must now be defined as a split market/centrally planned economy.

The coexistence of different systems of production and consumption characterize a third type of economic organization. Developing countries have both a market-based industrial and agricultural sector and a peasant agricultural component. The market sector operates according to standard relations of supply and demand. The peasant agricultural sector is influenced by household decisions that may or may not be determined by market forces.

"Real world" countries and regions may combine different mixes of these broadly drawn economic categories. For example, developing countries can be compared according to the size of their peasant sectors. Mixed market/centrally planned countries may also contain traditional agricultural sectors, as well as different ratios of market to government-controlled sectors. The general concept of the Social Process Diagram accommodates all these forms of economic organization.

The characteristics of population at any given moment will also affect its evolution. Various techniques allow social scientists to view population dynamically so that by calculating marriage, birth and death rates, predictions can be made about the future size of populations by region or by subgroup. The different rates in these areas are often related to health factors, which constitute an important component of population.

Population and Social Structure

The world's growing population is one of the most important factors contributing to global environmental change. An assessment of global population as well as knowledge about its regional distribution and social structural divisions are crucial elements in determining the demands placed on resources and evaluating whether regions can fulfill these demands. Furthermore, the waste products generated from resource use can pollute the environment.

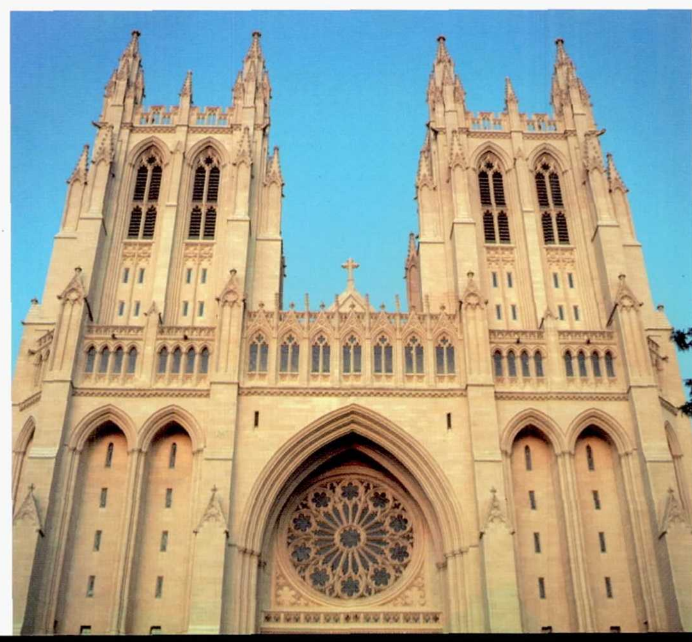
Population can be defined statically in terms of its size, distribution and the social categories that subdivide it. Theoretically, population counts can be made at any level of aggregation, but usually the accounting is done in relation to a political or geographic unit (commonly the nation). In this context, the overall count may be distinguished by age or sex, with these often attached to spatial criteria.

In addition to the breakdown according to demographic criteria, a population can be described in terms of its social structure. This allows researchers to assess the types of divisions that characterize particular societies. These would include distinctions among subgroups such as ethnicity, class, caste or clan. Both demographic and social structural categories are relevant to global change because they imply particular behavior. Regions with different age and sex distributions would likely have dissimilar birth rates, migration patterns and labor force participation, all of which would affect resource use and production.

Political Systems and Institutions

Institutions and organizations ranging from families to governments influence policy formation and the way society is organized. The Social Process Diagram accommodates a wide variety of institutions and organizations, as the descriptions of the Economic System and Population categories have shown. Political and other institutions have differed vastly through time and currently vary greatly from place to place. In the description of the economy it was suggested that there was a relationship between market systems and political openness. Within market systems, for example, if the political sectors are open or democratic, the government is more likely to respond to public opinion expressed through voting and lobbying. The role of other institutions and local political arrangements will be less dependent on the government and thus relatively effective.

Authoritarian systems tend to subordinate most other institutions—from the family to the economy—to the political options of the central government. Subordinate bureaucracies, such



as the ministries, the army, the police or the structure of the ruling political party, might be important in such systems because they influence the outcome of the authoritarian decision-making process. In developing countries, the political system, like the economic system, can often be split between a weak national level and a strong local level dominated by ethnic and kin-based loyalties.

Global Scale Environmental Processes

The physical, chemical and biological processes and their interactions that affect global change are represented by the Bretherton Diagram, as discussed previously. On the Diagram, this is labeled "Global Scale Environmental Processes." Thus, the six human dimension building blocks will not only interact among themselves, but will link to Global Scale Environmental Processes (i.e., the Bretherton Diagram) through the various driving forces. Driving forces originating from the six building blocks and leading to Global Scale Environmental Processes indicate human activities affecting global change. Driving forces originating from Global Scale Environmental Processes and leading to the social science building blocks express global change impacts on human activities.

The relationships among natural science processes for specific scenarios within Global Scale Environmental Processes are not included in this effort. A complete evaluation of a particular global change issue consisting of both natural and social processes would require analyzing driving forces *within* the Bretherton Diagram. Potential links between the Bretherton and the Social Process Diagrams and within the Social Process Diagram itself are presented in "The Diagram in Action: Three Potential Scenarios," later in this document.

The Connections:
The Processes Linking the Building Blocks

Taken together, the Diagram's building blocks define the Diagram's structural framework. Each of the six categories represents an area of human activity. To gain a complete picture of global change, however, none of these categories can be considered in isolation.

Building blocks are linked by *processes*, in which elements from one category influence the evolution of elements within another. By specifying the nature of relationships among the various categories, the Diagram becomes a process diagram, expressing the dynamic quality of these interactions. When applied to a specific global change issue, the Diagram highlights the complexity of the linkages among social processes and with the environment.

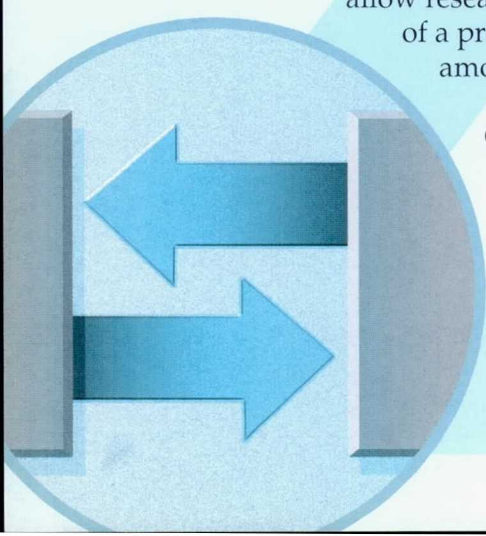
Population growth, for example, creates new demands for resources and more waste and pollutants. Economic growth and technological change will alter the nature of goods and services produced. The evolution of governmental and international policies and regulations will affect economic and social incentives and thus modify human-environment interactions. Over time, preferences and expectations will also influence behavior.

The labels on the Diagram's arrows (pages 32-33) are examples of driving forces that influence and are influenced by global environmental change. These labels will, in general, be different for each issue analyzed, and will depend upon the nature of the interactions that a particular issue creates. As the arrows indicate, the outputs of one category are the inputs to another. These inputs and outputs allow researchers to analyze the dynamics of a process and the relationships among categories.

Once the building blocks are dynamically linked by various processes, the Diagram can be used in two ways. First, on a general level, it can help clarify how researchers from different disciplines can work together on a particular issue. For example, demographers can provide demographic rates to economists to look at the evolution of the labor force; political scientists can share election data with anthropologists and sociologists analyzing the evolution of attitudes toward immigrants from environmentally stressed regions; or archaeologists can show how new technologies can lead to loss of knowledge about environmental diversity. Economists, political scientists and psychologists can incorporate these data into their study of how decisions about production and consumption are made. The Diagram is thus useful for presenting a map for inter-disciplinary research.

Second, on a more specific level, the linkages among building blocks can be defined as various types of data sets needed to analyze a global change scenario. For example, a population is linked to the economy through demographic rates, which provide quantifiable information. This permits the definition of present and future potential labor force size and composition. Thus, the process diagram acquires empirical content when a specific global change scenario is analyzed. How an issue is analyzed and what variables are introduced, create specific links that connect two or more categories. The Diagram can help reveal interactions among categories and suggest causal relationships among given phenomena.

In these ways, the Diagram can be as simple or complex as the researcher and the issue being investigated require. The next major section presents three detailed examples of specific global change scenarios that have been analyzed using the Social Process Diagram.



The Dynamics:
The Dimensions of Space and Time

To define the processes operating among the seven categories for a particular global change issue, we must understand both the issue being studied and whether it is being analyzed on a regional or global scale. Because human phenomena occur within a certain geographic location and over a certain time period, the dimensions of both space and time must be considered when using the Diagram.

The box surrounding the entire Diagram defines its spatial limits when a local or regional issue is being analyzed. Certain elements, represented by the arrows crossing into and out of the surrounding box, influence the issue from outside the region. A problem of coastal flooding, for example, would particularly affect a specific region. In this case, data could be required on regional population, local agricultural technology and practices, and regional governments. Thus, the system is an "open" one and the national or global influences would be represented as arrows entering the Diagram (such as trade flows), while the effect of the region on a nation or the world would be represented by arrows leaving the Diagram (such as emigration). If an issue is being analyzed on a truly global scale, the box surrounding the seven driving forces would not be present.

The Fund of Knowledge and Experience is outside the Diagram's spatial limits. This category incorporates a society's history and understanding of the world. Its beliefs and practices are derived from these past experiences, and current decisions and behavior become part of the history.

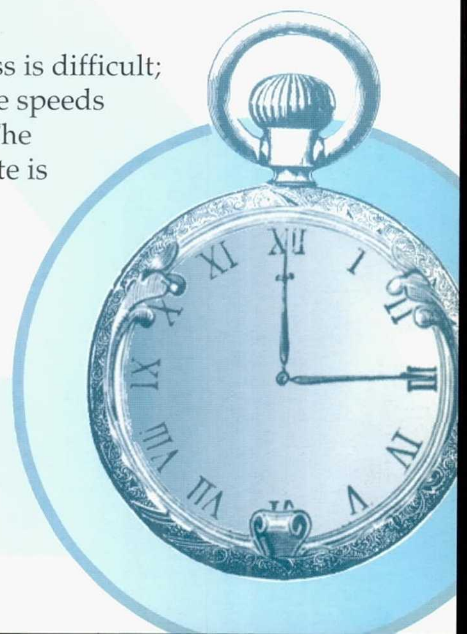
The speed at which various processes operate must also be taken into account. The impact of human-induced changes on the environment unfold over different time scales, depending on the particular path a process follows through the Diagram. Understanding a process also means understanding where the process is in its temporal cycle and the length of that cycle.

A way to define speed is in terms of human life cycles: a slow timescale is one longer than a human lifetime (more than 70 years); a fast timescale refers to a process occurring during less than a generation (about 25 years); and a moderate timescale refers to an interval between a generation and a human lifetime. Processes such as national industrial modernization, for example, can occur over 20-30 years, while others, such as human migration, can happen much faster.

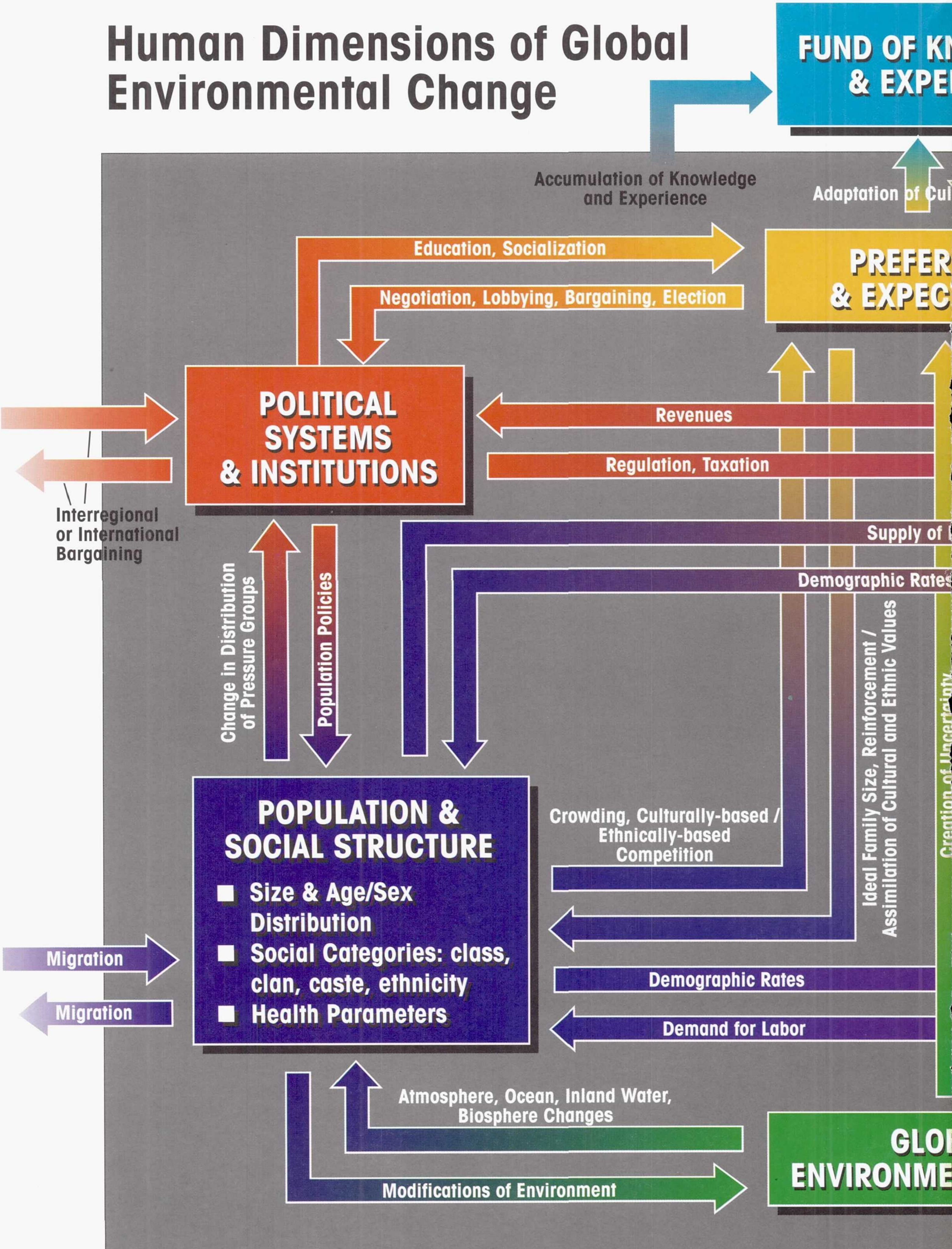
Timescale is a key element when the Diagram is put into action, because it helps define which areas will be most relevant when evaluating an issue. Analyzing the speed at which a process occurs can determine what moves so slowly that it is a "given" element (exogenous) of a problem, or what moves quickly enough to be considered integral to the problem (endogenous).

If a process occurs slowly enough, the output from that particular category may be negligible to the issue being considered if there are other, faster occurring processes from other categories. For example, the Fund of Knowledge and Experience changes slowly over the lifetime of an individual and over generations in a society. This Fund of Knowledge and Experience helps shape a society's Preferences and Expectations. The preferences or goals of individuals generally change slowly, but this change flows rapidly to the political and economic arenas. Expectations are shaped by such preferences, as well as the power competing groups possess to achieve their goals in the face of environmental, political and economic constraints.

Analyzing the speed of a process is difficult; driving forces can have multiple speeds or can even change direction. The speed at which processes operate is crucial to understanding global environmental change.



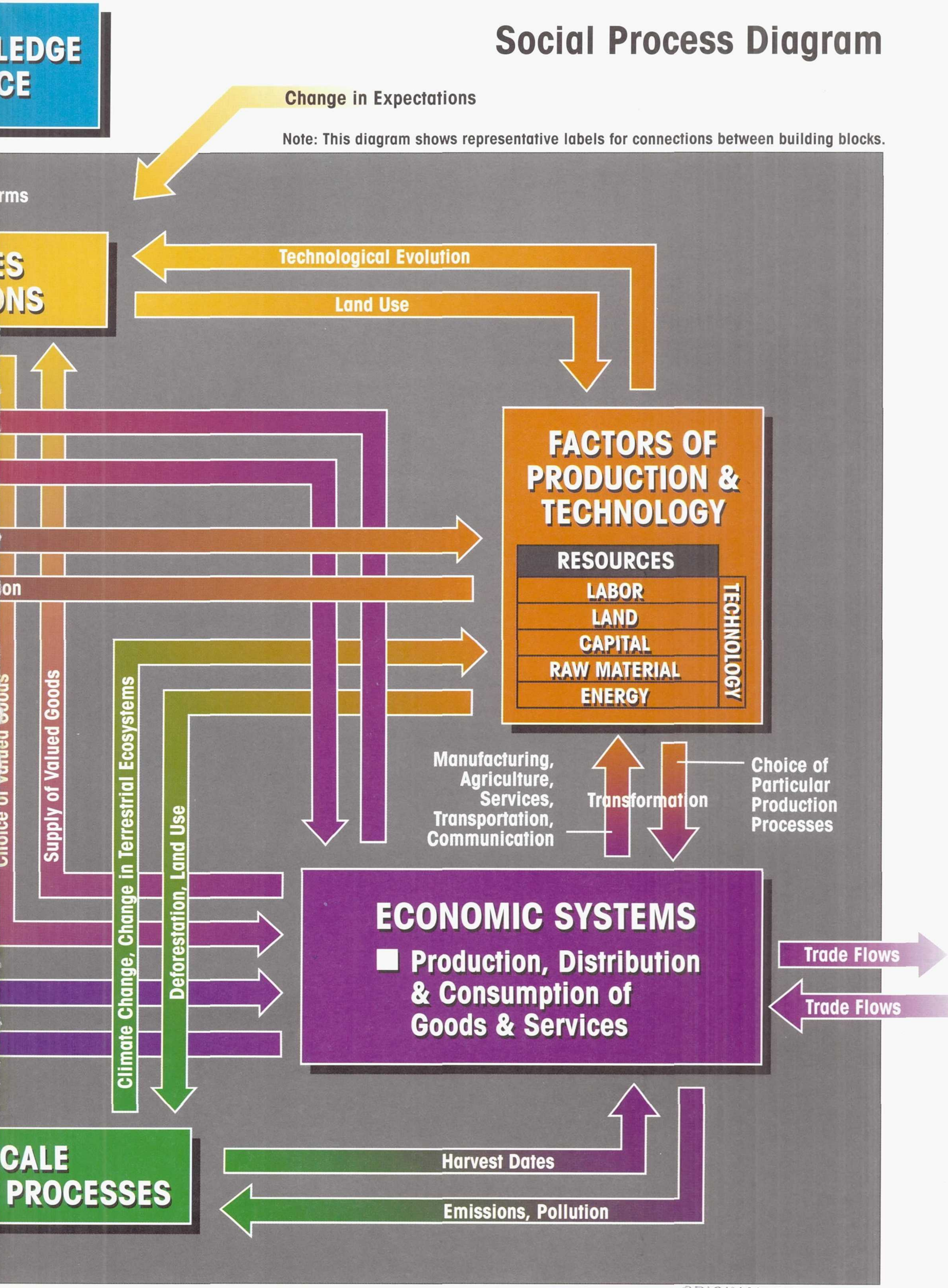
Human Dimensions of Global Environmental Change



ORIGINAL PAGE
COLOR PHOTOGRAPH

Social Process Diagram

Note: This diagram shows representative labels for connections between building blocks.



The Aspen Global Change Institute

By John Katzenberger, Director, Aspen Global Change Institute, Aspen, Colorado

The Aspen Global Change Institute (AGCI), located in Colorado's Rocky Mountains, provided a conducive intellectual and physical setting for the CIESIN-sponsored Human Interactions Working Group to discuss how people live and work within social systems and how these activities relate to global change.

Founded in 1990, the AGCI is a division of the Windstar Foundation, an environmental education program headquartered in Snowmass, Colorado. The AGCI is a coalition of public, private and nonprofit organizations, including the National Aeronautics and Space Administration (NASA), the United Nations Environment Programme and the Amway Corporation. This partnership illustrates how business, government, science and education can work together to benefit our understanding of the environment.

The AGCI is a place where scientists from around the world can study global change and environmental issues. The Institute bridges the gap between scientists and grassroots environmental activity by hosting summer conferences and developing educational materials. During the summer of 1991, the AGCI provided a forum for more than 100 scientists, researchers and educators from 13 countries.

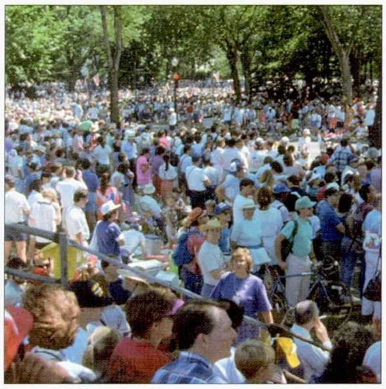
We at the AGCI were pleased to have the opportunity to host the Human Interactions Working Group, with the support and collaboration of CIESIN. The pathways for establishing alliances between a mixed group of social scientists and an equally diverse group of natural science researchers are not yet obvious. Much experimentation is needed to foster exchange. CIESIN's session at the AGCI was a crucial first step in a thrilling and vital journey.

The AGCI's interdisciplinary approach to studying global change is unique, making its goals consistent with CIESIN's. Increasingly, global change organizations are fostering more integration among natural science and social science disciplines and providing more time for it to occur. While this is not an easy integration to achieve, efforts by organizations such as CIESIN and AGCI will allow scientists time to explore and learn about other disciplines.

Our challenge in the next decade is to assemble the data, the ideas and the models that exceed the limits of separate, single-discipline research and forge new models of interdisciplinary research that equally embrace the natural and social sciences. CIESIN's effort to develop the Social Process Diagram is significant because it helps answer questions, such as "Where is the understanding and know-how to approach these challenges? Where are the models to guide us in the 21st century? What tools do we have to mitigate our global impacts, to approach who ecosystems wisely? What is required to approach these questions with confidence?"

Human activity is a collective in which all peoples of all nations participate. In our efforts to advance global change research, it is important to conceptualize that we, as a species, share the same air, water and ultimately the same land for our fundamental support. CIESIN and AGCI recognize the growing international need for a common set of values, principles and working models from which to practice of local, regional and global stewardship to Earth systems, including human systems and institutions, and to reach beyond our own species to others sharing the planet.

The Diagram in Action: Three Potential Scenarios


The Social Process Diagram can be applied to global change issues that occur on every scale from global to local. The hypothetical scenarios presented in this section demonstrate the Social Process Diagram's usefulness for representing and analyzing a particular global change issue.

Within each scenario, certain social science disciplines are called upon to provide the data and theory necessary to analyze the particular problem under study. The Diagram allows the researcher to highlight the relevant building blocks and define the interrelationships in terms of quantifiable data. The building blocks and linking arrows suggest the type of data necessary to evaluate relationships. The Diagram can be used to represent human activities that either respond to or initiate global environmental change, as demonstrated in the following scenarios.

The scenarios are presented only to represent what *might* occur, and are not meant to predict the specific effects of global change. Rather, the scenarios demonstrate how such a change, if it were to occur, could impact various social systems. The inputs and outputs are examples only and do not represent all the information that may be required. Each scenario also shows that interesting and perhaps unanticipated research questions may emerge as links are explored among the Diagram's categories.

Global Warming and Sea Level Rise

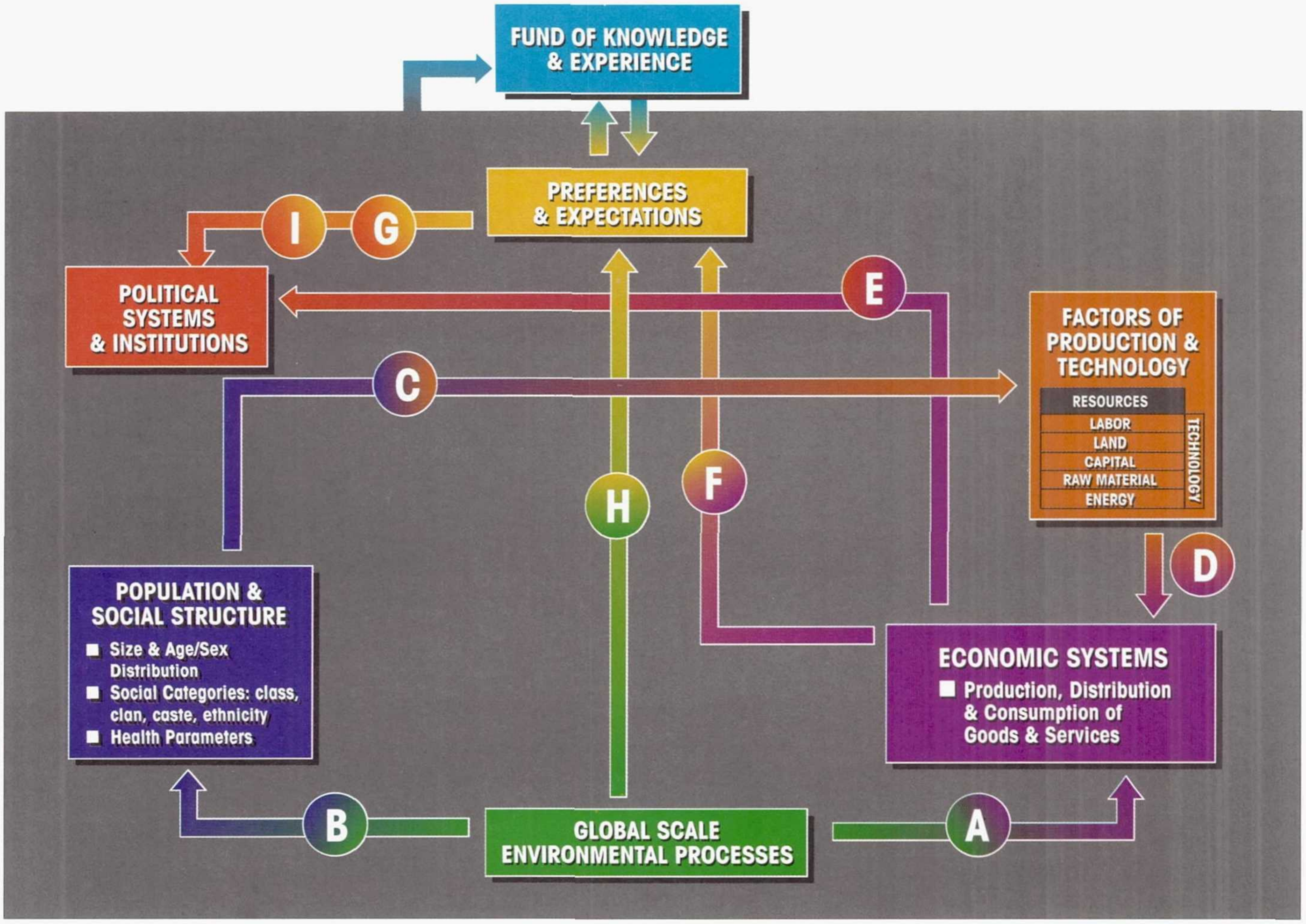
by Dr. Gary Yohe, Wesleyan University, Middletown, Connecticut

The Question

What effects could sea level rise potentially have on the human dimensions of global change?

The Analysis

Global warming could cause the seas that surround us to rise about six centimeters per decade. If Earth's air and surface temperatures rise, the water temperature of the seas would increase and the water would expand. In addition, warmer air and surface temperatures would stimulate melting of anchored glaciers, further adding to sea level rise. Because of these changes, shorelines and property could be threatened. This scenario explores the impact of sea level rise in a developed country such as the United States.



Labels for "Global Warming and Sea Level Rise" Pathways

Path A & Path B: Rate of increase in sea level and decrease in usable land.

Path C: Change in population distribution.

Path D: Substitution effects, for example, changes in compensation and levels of employment.

Path E: Distribution of benefits and costs.

Path F: Longer term (up to 20 years) distribution of benefits and costs.

Path G: Pressure for protection through economic caveats.

Path H: Decrease in land and changes in ecological distribution.

Path I: Political activism

Global Scale Environmental Processes → Economic Systems (Path A)

A rise in sea level could affect economic activity in vulnerable areas. Because the sea level will rise slowly, a developed country could anticipate the changes and move economic activities away from areas likely to be affected. Thus, the link between the environmental process of sea level rise and an impact on the economic system is minimal. For people who own land and buildings that may be flooded, however, complete adaptation would not be possible. In addition, there would be a change in relative prices of various types of properties. These changes would drive the adaptation.

The arrow associated with Path A is labeled "Rate of increase of sea level rise and decrease of usable land." This output from Global Scale Environmental Processes would be used to determine real estate market data within the Economic Systems. These would include

initial property and structure value gradients, anticipated rates of community growth, price elasticities of supply (development) and some measure of how the risk of sea level inundation would be internalized in markets.

Global Scale Environmental Processes → Population and Social Structure → Factors of Production and Technology → Economic Systems (Paths B, C and D)

A rise in sea level would decrease the quantity of land available. This process might have several effects. People occupying ocean-front land may shift inland, thus changing population distribution. This coupling occurs between Global Scale Environmental Processes and Population and Social Structure (Path B). The change in population distribution (Path C) would then be needed to determine the market response to this impact, which would occur before the property is actually affected, and may change the price of land. Land is a Factor of Production in many processes (agriculture, recreation, retailing, etc.) There is a possible direct effect of sea level rise on this supply that should be quantified by use. Path D brings sea level rise back into the Economic System through a second set of market reactions labeled "Substitution Effects," for example, changes in compensation and levels of employment." Price elasticities of demand and elasticities of substitutions would be required to measure these effects, taking the quantities and relative prices of other inputs into account.

Economic Systems → Political Systems and Institutions (Path E) and

Economic Systems → Preferences and Expectations → Political Systems and Institutions (Paths F and G)

Coastal lands overwhelmed by flooding would cause a change in the quantity of land available. People may therefore apply pressure to political systems to respond by either protecting property or stopping the rising seas. The pressure may be direct, as from the economic system to the political system, or indirect, as from the economic system, through preferences and expectations to the political system. The degree to which people expect policy protection by governments is important in modulating adaptation. Uncertainty about policy response would slow individual adaptation in this case.

The pressure to protect, a response to the "Distribution of benefits and costs" is the label for Path E. It would be quantified not only by the output of the Economic System through Path A and Paths B, C and D, but also by the "political distribution" of the dislocations noted there. Indirect pressure may also occur through changes in preferences and expectations, but driven by longer-term distribution of benefits and costs (Paths F and G). Sea level rise impacts will be unevenly distributed, depending upon random parameters like who lives where now and empowering parameters like who can process information best. If the potential losers have political clout, Path E will be strong; if not, it will be weak.

Global Scale Environmental Processes → Preferences and Expectations → Political Systems and Institutions (Paths H and I)

The changes caused by a rise in sea level may also mobilize an environmental movement. The issue of preserving coastal wetlands, which would migrate as seas rise, may also be presented to the political system. People may learn about the issue from the news media, for example, which is an element within the Fund of Knowledge and Experience. Because many wetlands are preserved for wildlife and public enjoyment, pressure on the political system would be quick and direct. This process is shown by the link from Global Scale Environmental Processes through Preferences and Expectations to the Political System. This political pressure would confront the pressure to preserve economic interests. For example, protecting wetlands may prevent migration to such areas.

A similar movement may spring into action when people begin to understand how coastal storms can damage sensitive areas. With all other things being equal, higher seas could mean higher and more frequent storm surges. The political system could address issues such as beach preservation, erosion control and replacement of damaged buildings.

Paths H and I, labeled "Decrease in land and changes in ecological distribution" and "Political activism" respectively, bring the whole range of non-economic impacts of sea level rise to bear on the political debate over how to respond. Protection of economic assets may run counter to other objectives, and these opposing forces should be quantified by physical impact: what ecological systems are threatened doubly by sea level rise on the one hand and economically motivated protection policies on the other?

Links for Developing Countries (Paths B and C)

The processes described above could also occur in a developing country. Populations in areas such as the mangrove forests along the Indian subcontinent, however, would not have the same ability to adapt by moving to less affected land. This would create additional economic, social and political links on the Diagram. The dangers of coastal flooding and destruction of natural resources would be a more vital issue for this group. A link from Global Scale Environmental Processes to Factors of Production and Technology (Paths B and C) would thus be strengthened. The link from Global Scale Environmental Processes to Population and Social Structure would also be a significant process (Path B).

The Environmental Impact of Human Population Migration

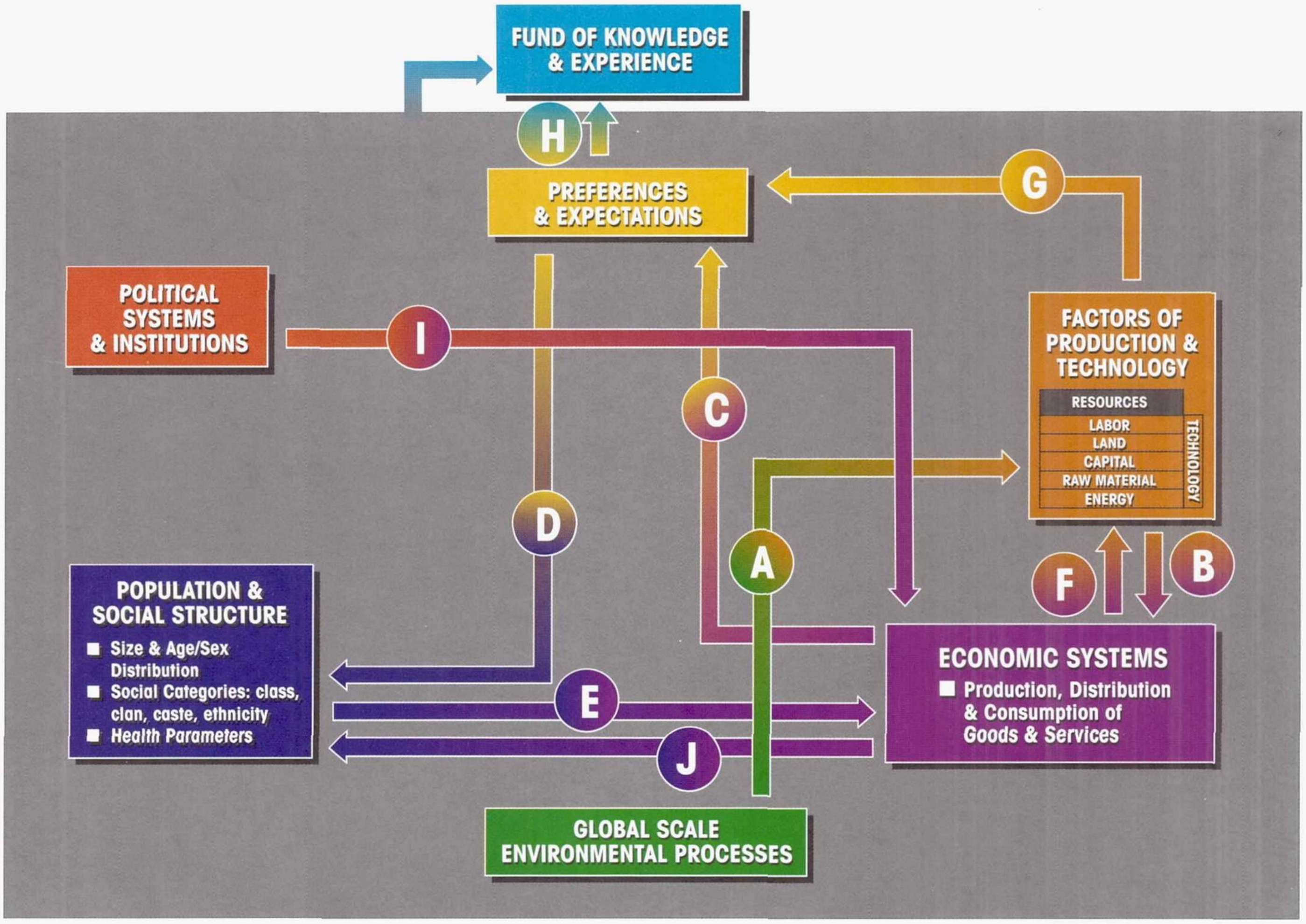
by Dr. Urs Luterbacher, Graduate Institute of International Studies, Geneva, Switzerland;
Dr. Ellen Wiegandt, University of Geneva, Geneva, Switzerland; and
Dr. Stephen Kowalewski, University of Georgia, Athens, Georgia

The Question

What effects could human migrations have on the environment and other elements of society?

The Analysis

Global warming could change the global distribution of agriculture through coastal flooding in some areas, desertification in others and general changes in the length of the growing season. This scenario uses the Social Process Diagram to examine the effects of global warming in regions with small-scale but intensive agriculture production. Very different initial conditions and processes prevail in large-scale agricultural enterprises, and the effects of climate change on market farmers in wealthy countries must therefore be studied in the context of a separate scenario.



Labels for "Human Population Migration" Pathways

Path A: Temperature and rainfall changes: influence on amount of cultivable land and water supplies.

Path B: Levels of production of agricultural products (by crop) in terms of yields per area and assessment of total area under cultivation.

Path C: Level of consumption of agricultural products and income derived from production, percent and age distribution of employment in agriculture.

Path D: Changes in ideal family size (survey data), migration patterns (empirical observation and survey for intention and motivation to migrate), changes in distribution of cultural, ethnic groups in rural versus urban areas.

Path E: Population size and age in sex distribution, urban/rural distribution, demographic rates, education levels, health statistics, income distribution.

Path F: Changing production and consumption patterns (measure of labor and capital investments), changes in land use, labor by sector, energy use, savings and investment rates, inventories of agricultural products.

Path G: Changes in distribution of land and agricultural labor and other resources, evolution of technology used in agriculture.

Path H: Folk knowledge, rate of adoption of new technologies, perception of future livelihood in agriculture.

Path I: Environmental policies affecting agricultural production: evolution of fertilizer use, mechanization, energy use, crop and animal types and varieties.

Path J: Labor force participation, distribution of population by economic sector.

Global Scale Environmental Process → Factors of Production and Technology (Path A)

Global warming could alter the global distribution of agricultural land. Its greatest impact could be in developing countries that are highly dependent on agriculture and do not have the resources to anticipate changes. The historical record suggests that subsistence agriculture, small holders and poor farmers are most sensitive to environmental change. From the Middle Ages to recent United States farm failures, hardships on family or small-scale exploitations were felt especially by people in marginal environments and operating under marginal economic conditions (the Alps, north-eastern Brazil, the Sahel and the United States Dust Bowl era, for example).

Within today's developing countries, regions where farming is already at a subsistence level could be particularly vulnerable. Small land holders with labor- rather than capital-intensive operations might be especially affected. Populous, low-coastal areas without technology or capital means to oppose flooding might see a shrinking of their land, livelihood base and fresh water supplies.

Factors of Production and Technology → Economic Systems (Path B)

In affected agricultural areas, shifts in land and crop use may occur, altering patterns of production and consumption. Some previously untouched areas such as forests and pasture land might now be converted to land for agricultural production. Climate change could also shift cattle production away from some areas and introduce it into others. This shift would affect the demand for labor in both areas because of the differences in labor intensiveness of the two types of production. There would thus be secondary consequences of climate change in regions where changes in the production system would reduce opportunities for small land holders or wage laborers to make a sufficient living from the land.

Economic Systems → Preferences and Expectations → Population and Social Structure (Paths C and D)

When people's livelihood is threatened, one response may be to move to other locations where they hope conditions will be better. Rural populations may migrate to other rural areas less influenced by climate change. In these small-holder agricultural areas, birth and death rates may remain high as households diversify their strategies and try to counteract rising uncertainties by increasing their number of children. However, as the number of people needed for agricultural production declines, people may move to the nearest cities or to national or even international centers of activity. In this new urban environment, demographic patterns may change in response to different employment opportunities and constraints, changing the social structure of the migrant population. The presence of culturally different populations could increase labor market segmentation and ultimately exacerbate racial, national or ethnic tensions. The stability of the political system could be threatened as a result of confrontations among different social groups.

Population and Social Structure → Economic Systems (Path E)

In some instances, migration may improve rural conditions by increasing local income through remittances to areas from which people have migrated. Likewise, return migration may improve an area by an increase in educational level. On the other hand, urban problems could be aggravated as crowding and poverty impair health conditions and indirectly cause unemployment. Urban migration and its accompanying problems may also inhibit some technological expansion toward more capital intensive processes as resources are diverted to social services.

Economic Systems → Factors of Production and Technology → Preferences and Expectations → Fund of Knowledge and Experience (Paths F, G and H)

As previously farmed areas are abandoned or as systems of production change, knowledge about some specific crops and agricultural techniques may be lost, changing choices in methods of production. This may ultimately reduce the fund of knowledge and experience and restrict capacity for future adaptations.

Aerial view of Baltimore, Maryland USA

Political Systems and Institutions → Economic Systems → Population and Social Structure (Paths I and J)

As policies to decrease greenhouse gases are developed within the political arena, they may have an impact on the production system through potential restrictions on use of agricultural machinery and fertilizer. This may affect levels of production and therefore the livelihood of rural populations, possibly modifying demographic rates and health parameters.

Energy and the Environment:

The Effects of a Tax on Fossil Fuel Emissions

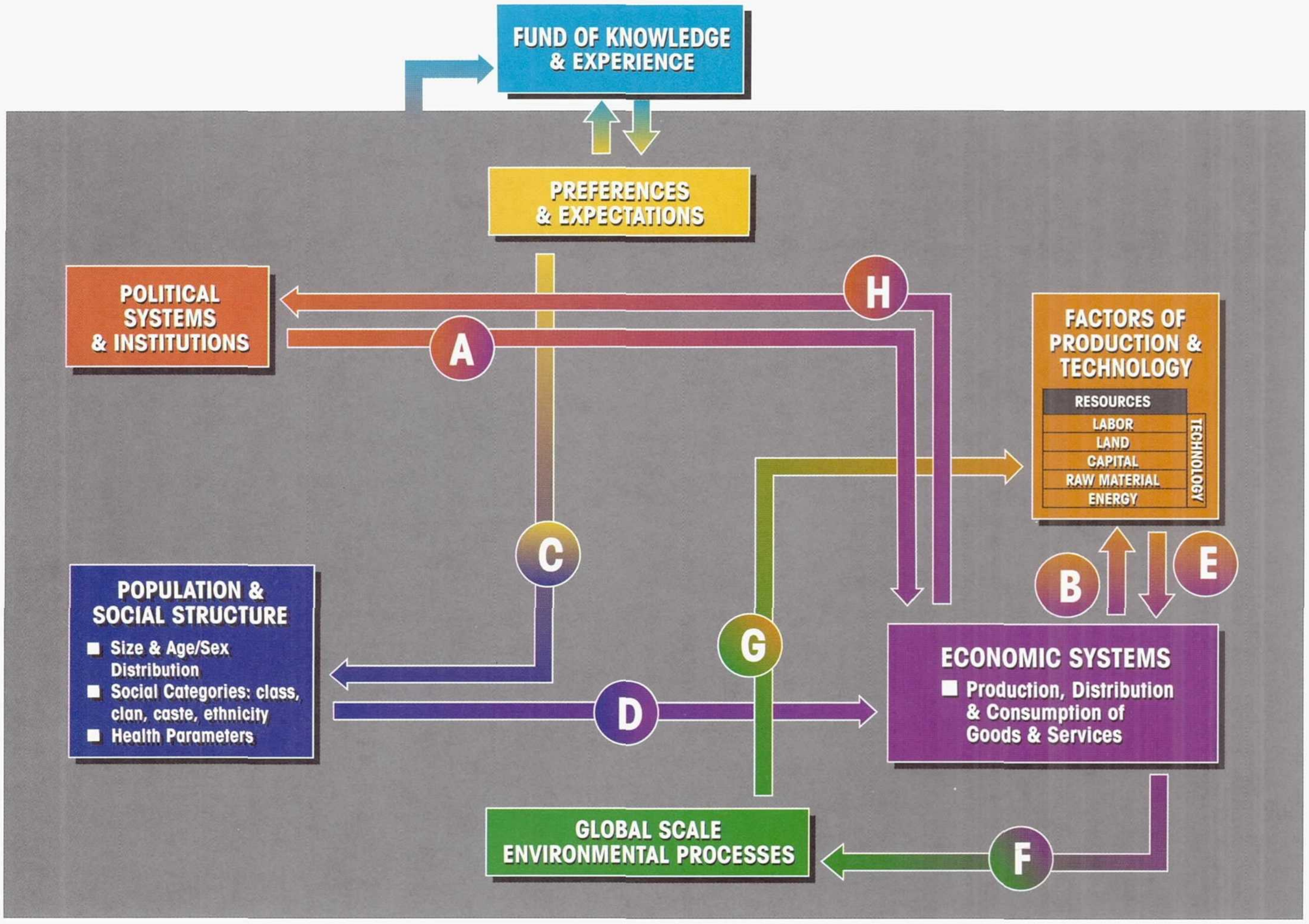
by Dr. Jae Edmonds, Battelle Pacific Northwest Laboratories, Washington, D.C.

The Question

What effect could a tax on fossil fuel carbon emissions have on the levels of emissions and thus the human dimensions of global change?

The Analysis

The analysis of this issue begins with the premise that a policy instrument has been chosen to reduce greenhouse gas emissions. This premise implies, among other things, that government has concluded that continuing to produce and consume energy as in the past would impose costs and warrant changes in the way society produces and uses energy. Varieties of other policy instruments are also available, including standards on energy related technologies, and limitations on the emissions of greenhouse gases.



Labels for "Energy and the Environment" Pathways

Path A: Subsidies and taxes, regulations and whether or not the economy under investigation is centrally-managed or free-market.

Path B: Wages, interest rates and rental rates on land.

Path C: Desired fertility rates.

Path D: Actual population by age, gender, education and in- and out-migration.

Path E: Investments, capital stocks and labor and land resources.

Path F: Rates of human emissions of, for example, carbon dioxide, methane, nitrous oxide, sulphur dioxide, CFCs and their substitutes.

Path G: Temperature and precipitation data, nitrogen deposition and saltwater intrusions.

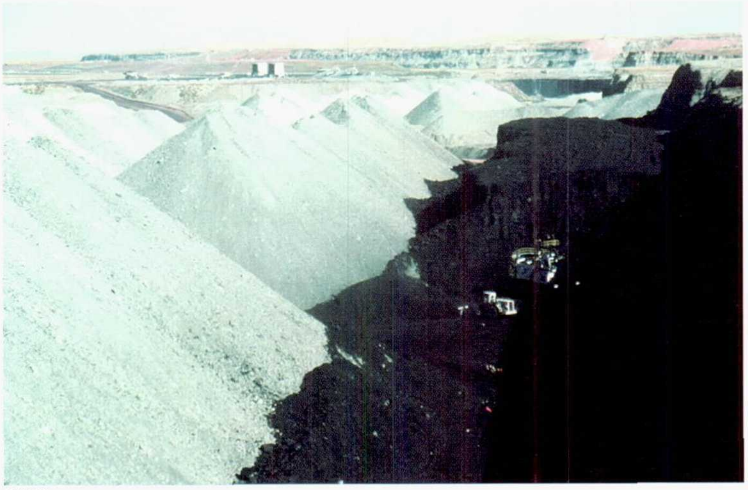
Path H: Tax revenues, changes in income, and international transfers of wealth from tradeable emissions permits.

Political Systems and Institutions → Economic Systems (Path A)

The initial step in the process is a political determination that a policy intervention is desired. A carbon tax would likely be the outcome of a political process grappling with an array of interrelated issues. The carbon tax could emerge from domestic deliberations or from international negotiations. The magnitude and timing of the tax would depend as much on near-term fiscal and political considerations as on a long-term concern for the global habitat. To implement a tax, institutional arrangements would be required to monitor compliance.

These arrangements could in themselves have costs and implications that range from trivial to major. A simple tax on energy, which was proportional to the carbon-to-energy ratio of fuels would require relatively little new infrastructure. On the other hand, if tree planting to absorb carbon was allowed as a mechanism for reducing net carbon release to the atmosphere, such a system could entail development of institutions to centrally monitor all land use in the entire region of implementation.

Coal Mine



Oil Rig

Wind Power

Examples of the output from Political Systems and Institutions required by the Economic System are subsidies and taxes, regulations and whether or not the economy is centrally-managed or free-market.

Economic Systems → Factors of Production and Technology (Path B)

The role of a tax in an economic system is to communicate the relative desirability of alternative actions. Since a tax on carbon means that coal is taxed more per unit of energy than either oil or natural gas, there is a clear incentive for economies to conserve taxed fuels and to substitute among various fossil fuels. Energy conservation, that is, using technologies to use energy efficiently in such activities as space conditioning, lighting and cooking, would generally be encouraged. So, too, would the introduction of sources of energy that release no carbon directly into the atmosphere.

In the short-term, existing conservation and non-carbon energy supply technologies would be encouraged. In addition, there would be a smaller substitution of other goods and services for energy services. That is, in colder climates, some rooms might no longer be heated, or transportation activities might be reduced. The existence of the tax would also stimulate the development of new conservation and non-carbon energy supply technologies.

To be effective, a carbon tax would have to be placed on the production, consumption and importation of fuels. If the tax were placed only on final consumption of fuels and fossil fuel production were not taxed, then fossil fuel use in the taxed region would fall, but fossil fuel production would not. This would lead to a decrease in the world price of fuels, and an increase in fossil fuel consumption in non-taxing regions. If, on the other hand, fossil fuel supplies were taxed, this would have the effect of driving production in the taxing region from the world market, but not necessarily reducing consumption.

If credits could be obtained for the capture and disposal of carbon from the use of fossil fuels, then technologies to use these fuels without releasing carbon into the atmosphere would also be encouraged. If the tax was not applied globally, there would be a tendency for participating countries to shift production of goods and services that released carbon to non-participating countries. In addition, the reduction in demand by participating countries would tend to reduce the world price of fossil fuels.

The Economic System would provide such information as wages, interest rates and rental rates on land.

Preferences and Expectations → Population and Social Structure → Economic Systems (Paths C and D)

The demographic character of the population affects the potency of a carbon tax in many subtle ways and should be considered in overall policy decisions. The demographic structure of the population will affect the total use of energy and fossil fuels. The scale of population alone, and in particular the scale of the working-age population and its level of education and health, affects the overall level of economic activity and thereby the scale of human activities. For example, the degree to which males and females participate in the workforce depends upon preferences and expectations, and in turn has a profound effect on the overall level and nature of human activity. Similarly, the age structure of the population affects the conduct of such fossil fuel using activities such as automobile and motorcycle use.

Desired fertility rates (Path C) would be an important input to Population and Social Structure, which would provide information on the actual population by age, gender, education and in- and out-migration to the Economic System (Path D).

Factors of Production and Technology → Economic Systems (Path E)

If there were no effects from the disposition of tax revenues and the economic system was efficient, the effect of a carbon tax would be to divert some resources from the production of final goods and services to produce non-fossil energy supplies and energy conserving technologies. Not all regions and productive sectors of the taxing society would be affected equally. Coal producing regions would experience greatest declines in employment and income. Other fossil fuel producing regions and sectors would also be affected, but to a lesser extent.

Some regions have imposed energy subsidies that result in general market inefficiencies. In such places, the imposition of a carbon tax might actually improve overall economic efficiency and increase production, while reducing fossil fuel carbon emissions.

One of the most important questions that arises in the analysis of carbon taxes is: what happens to the money collected? Carbon taxes that are high enough to stabilize net fossil fuel carbon emissions potentially generate large tax revenues. If the revenues are used to retire government debt, or are added to government savings, then the effect of the tax will be to encourage investment in the society. This, in turn, will lead to a higher future gross national product (GNP). The increase in societal savings would likely give future generations higher standards of consumption, but reduce present consumption of goods and services. The higher future GNP would generally imply that emissions and reductions in the long term would be less than expected. If, on the other hand, taxes were returned to consumers, the effect of the redistribution would be to temporarily increase consumption, but reduce savings. The resulting long-term decline of GNP would reduce emissions, but at the expense of a materially poorer society.

International transfers of revenues from carbon taxes from economically developed regions to developing regions have been discussed as a means to induce participation by developing countries in carbon reduction programs. Such transfers could be very large, particularly in relation to developing regions' current incomes, and substantially affect the level of material consumption in both donating and receiving regions.

Investments, capital stocks and labor and land resources are important inputs to the Economic System.

Economic Systems → Global Scale Environmental Processes (Path F)

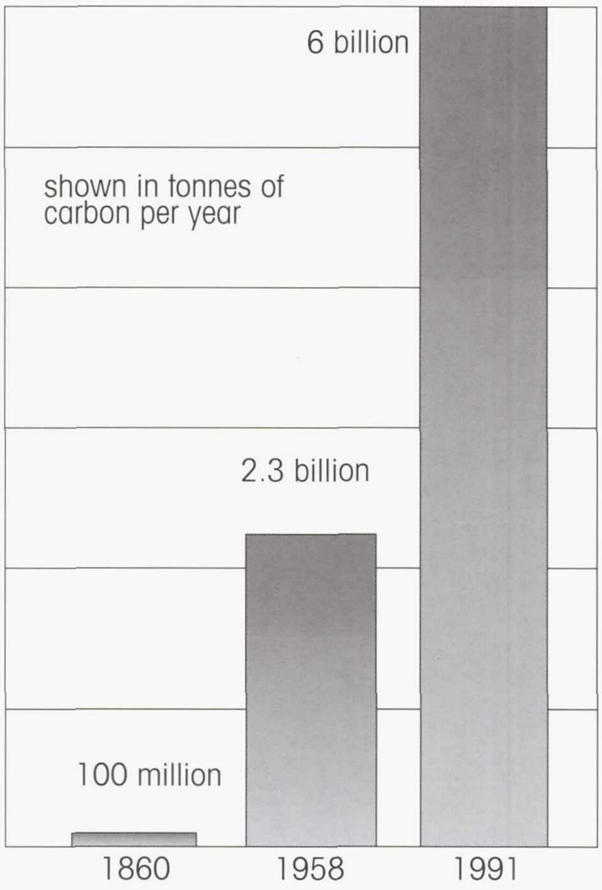
Production and use of fossil fuels is generally believed to be affecting the global concentration of atmospheric carbon dioxide (CO_2). Since accurate measurements were begun in 1958 in Mauna Loa in Hawaii, the concentration of atmospheric CO_2 has risen from 315 parts per million volume (ppmv) to about 350 ppmv (1990). Global fossil fuel carbon emissions have risen from less than an estimated 100 million tonnes of carbon per year in 1860, reached 2.3 billion tonnes per year in 1958, and are currently about 6.0 billion tonnes per year (1991). These emissions to the atmosphere, combined with emissions from deforestation and land use change of about 1.6 billion tonnes per year (+/- one billion tonnes per year) are considered to be the primary causes for the growth of CO_2 in the atmosphere. Introducing a carbon tax is motivated by a desire to reduce the rate and timing of changes to the concentration of greenhouse gases. Such a tax, therefore, could be expected to reduce the rate at which human activities introduce carbon into the atmosphere.

Economic Systems would provide rates of human emissions of, for example, carbon dioxide, methane, nitrous oxide, sulphur dioxide, CFCs and their substitutes to Global Scale Environmental Processes.

Global Scale Environmental Processes → Factors of Production and Technology (Path G)

Ironically, some of the options for reducing net carbon emission to the atmosphere, such as biomass and trees for carbon sequestration are sensitive to climate change. Depending upon the nature, rate and degree of climate change, forests planted to absorb carbon over the course of the next 50 to 100 years could find themselves growing in an inhospitable climate. It is possible, under some scenarios, that trees planted to remove carbon from the atmosphere could die, after a period of years, resulting in a secondary pulse of carbon from their decay. Biomass crops planted for their energy content could also suffer from changing climate, though the shorter crop rotations would prevent any significant release of carbon from

Global Fossil Fuel Carbon Emissions

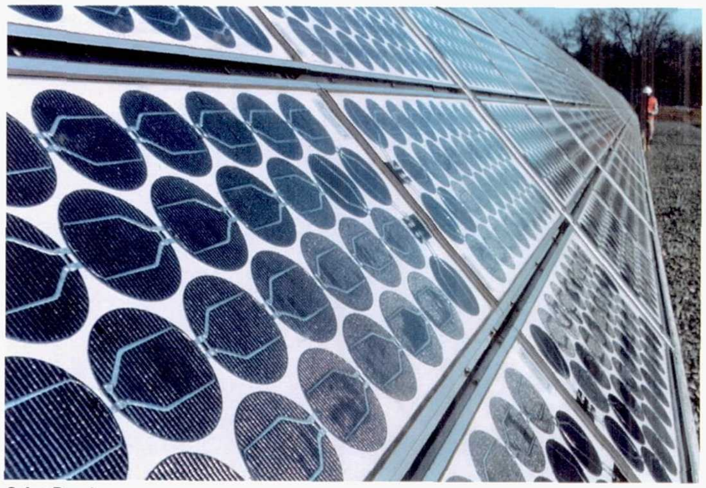


death and decay. The location and productivity of such crops, particularly in conjunction with adaptations by agriculture, could be affected.

Factors of Production and Technology would receive from Global Scale Environmental Processes, for example, temperature and precipitation data, nitrogen deposition and saltwater intrusions.


Hydropower


Nuclear Plant


Solar Panel

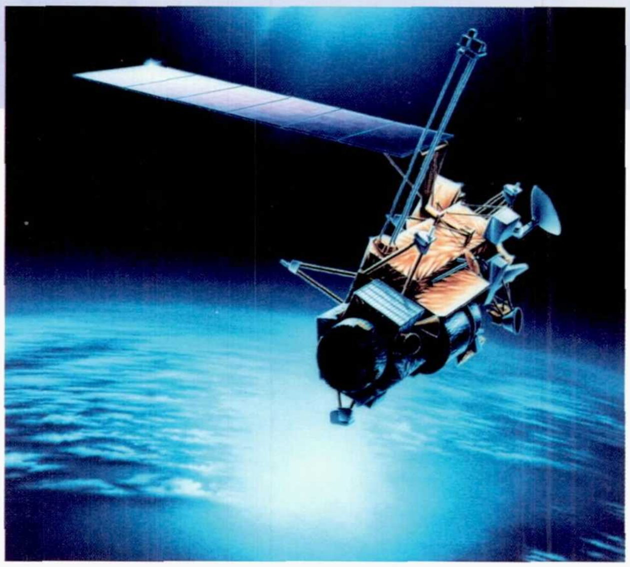
Economic Systems → Political Systems and Institutions (Path H)

The existence of large revenues from carbon taxes could lead to a general reassessment of government fiscal policy. There would be strong incentives to use the revenues for a wide variety of special interests. The unequal burdens of carbon taxes would also lead to political pressure to provide special assistance to regions and sectors whose populations were particularly affected. Regions with large concentrations of fossil fuel production and transformation activities would be most likely to apply pressure for assistance. Other groups might lobby for the allocation of tax proceeds to develop new, environmentally benign technologies.

Costs imposed by carbon taxes might lead to attempts to reduce costs by increasing overall system efficiency. Institutional arrangements, such as allowing electric utilities to purchase energy conservation credits, have already been introduced in an attempt to improve energy market performance.

Examples of inputs to Political Systems and Institutions are tax revenues, changes in income and international transfers of wealth from tradeable emissions permits.

Advancing Global Change Research



As previously described, national and international programs have existed for several years to help us understand Earth as a system. Recently, many organizations have begun to develop a "human dimensions" research agenda that can be incorporated into existing global change efforts. While some might argue that the natural system should be better understood before trying to integrate efforts with the social sciences, it seems clear that the complexities of the social system are as great as those in the natural sciences, and that the two efforts must proceed synergistically.

The Working Group's effort to develop the Social Process Diagram can help integrate the social sciences with existing research programs and initiate new efforts. Working with the Social Process Diagram to identify and prioritize the data associated with the processes that occur for even a single scenario can be unsettling. It is easy to become overwhelmed by the amount of data that needs to be collected and analyzed. There is a need, therefore, to initially "divide and conquer," that is, to develop a research agenda that focuses on a priority list of critical data.

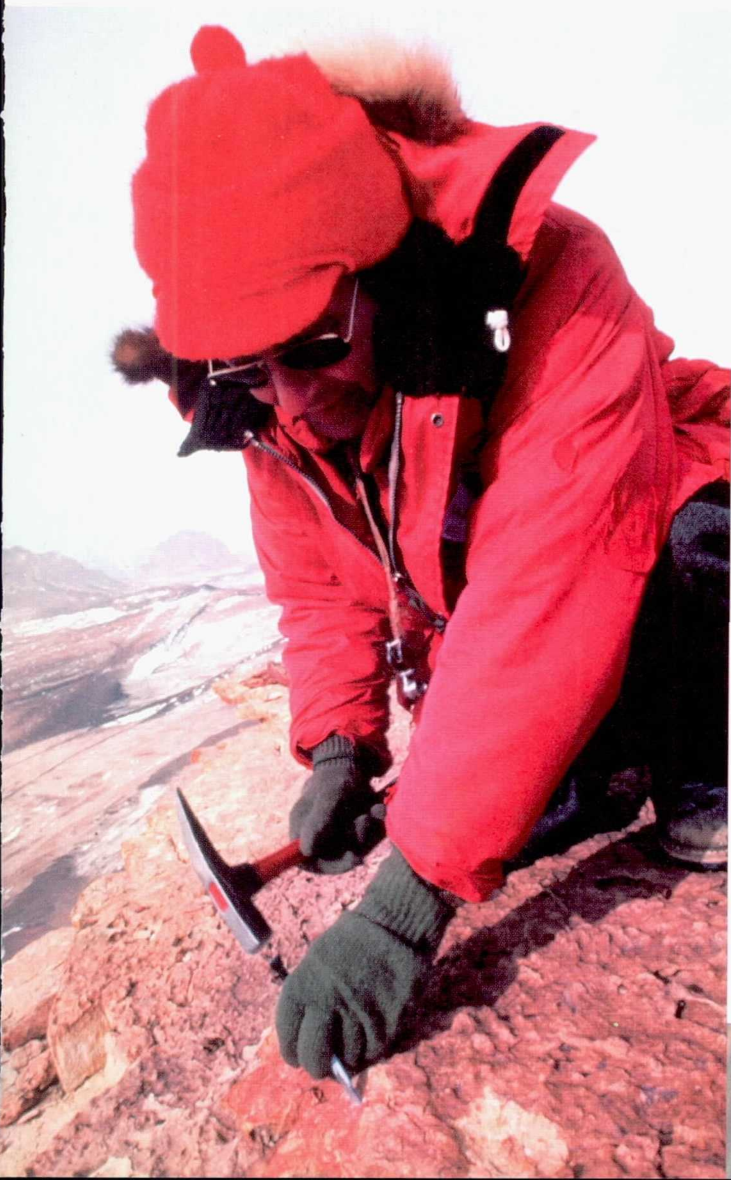
Social science research agendas for global climate change will differ depending upon whether the research is being directed toward understanding the processes that lead to global change or toward understanding the potential consequences of global change. Research agendas will differ for a variety of other reasons, including the fact that the natural science interface with social science will vary depending upon the type of issue being addressed. Although there will be no manageable, well-defined list of important data that will handle all possible global change phenomena, the Social Process Diagram can help identify the data needed on a case-by-case basis. There is also the need to begin to construct natural/human system models to predict change on timescales of decades to centuries.

It is important to emphasize that an integrated approach to studying global environmental change will challenge social and natural scientists to communicate with each other in new ways. Although the research methods and expectations of natural and social scientists differ, there is the need for collaborative, interdisciplinary research. This requires more than natural and social scientists coming together for a few days or a week in a workshop setting. Efforts must occur at the international and national levels, and also within academic institutions that can forge partnerships and encourage integrated research efforts. Unless global environmental change research transcends traditional disciplinary boundaries, only marginal success will be achieved.

Specific Directions for Research

With the Social Process Diagram in mind, the Human Interactions Working Group suggests a number of directions for research, detailed below. There is a significant correspondence among these and the research topics elaborated by Jacobson and Price (1991) in their *Framework for Research on the Human Dimensions of Global Environmental Change,* and in the National Research Council's *Global Environmental Change: Understanding the Human Dimensions.* The Social Process Diagram thus reflects the concerns of organizations in the social science community working on issues of global environmental change.

For example, the topics that Jacobson and Price propose for a concerted research effort are represented by the building blocks of the Social Process Diagram. Jacobson and Price's "Social Dimensions of Resource Use" are represented by the interactions among Factors of Production and Technology, Population and Social Structure, Economic Systems and Preferences and Expectations. The study of "Land Use" and "Energy Production and Consumption" are investigations focused on specific resources that appear in the Diagram's category of Factors of Production and Technology and are linked to the Diagram's other dimensions. "Perception and Assessment of Global Environmental Conditions and Change" correspond to the Fund of Knowledge and Experience and to Preferences and Expectations on the Diagram.



"Impacts of Local, National and International Social, Economic and Political Structures and Institutions" are primarily present within the category of Political Systems and Institutions, but also appear within the definition of Economic Systems and Population and Social Structure. "Environmental Security and Sustainable Development" appears implicitly in the Diagram's Political Systems and Institutions category in the form of policy choices that favor a particular form of interaction among social systems and between social systems and the environment.

There are also similarities between the National Research Council's recommendations and the Social Process Diagram. Although the NRC's research program focuses more on the process and funding for a comprehensive research program, they do assert that human responses to global change fall within seven systems. The systems they identify (and the corresponding Social Process Diagram building block) are: Individual perception, judgement and action (Preferences and Expectations); Markets (Economic Systems); Sociocultural systems (Population and Social Structure); Organized response at the subnational level, National policies and international cooperation (Political Systems and Institutions); and Global social change (Factors of Production and Technology, Fund of Knowledge and Experience, Preferences and Expectations, Population and Social Structure and Economic Systems).

Furthermore, the NRC proposes five social variables that affect global environmental change. These are Population Change, Economic Growth, Technological Change, Political-Economic Institutions and Attitudes and Beliefs. It is clear that these are all represented in the Social Process Diagram.

The Diagram can thus be used to develop research programs based on the recommendations elaborated by Jacobson and Price or others. It has, moreover, stimulated the Working Group's reflections on these and related issues that merit further study.

Health

Many of the questions people may ask regarding global change will relate to the quality of life. Health may be the major impacted sector for developing countries, and Earth's "vital signs" (air and water quality, etc.) relate directly to human life. Yet, if one looks at the priorities established by the various national and international agencies, there is little emphasis on how health will be affected by global change. Indeed, one finds in global change literature more discussion of changes in health of vegetation in the biosphere than animal health, particularly human health. Thus, there is a need to identify and provide a directory of national and international health data sets and conduct related research.

There must also be the capability for data transfer and integration with natural and socioeconomic data. The major health problems associated with global change, as identified by the medical community, include hyperthermia, infectious illness, respiratory disease, skin cancer and melanoma, immune suppression, malnutrition and starvation. Most of the scenarios that can be analyzed using the Social Process Diagram should consider these and other health-related issues.

Economics, Land Use and Population Dynamics

The study of agricultural systems and demographic regimes examines both the impact of global environmental processes on society and of human activities on the global environment. Production in agricultural systems is clearly affected by global environmental processes. The extent and intensity of this relationship, however, is not clear. Moreover, the possibilities and limits of substitution effects (the replacement of one form of production by another) are not well understood. These two areas should be prime targets for more intensive research.

In addition, the particular structure that agricultural production takes, both in terms of type of production and property arrangements, is important to understanding the consequences of global change on human activities. It matters a great deal if a region is characterized by a monoculture-type agriculture, such as cotton, or by a diversified crop or herding system. Each agricultural method will affect greenhouse gas emissions differently. Property ownership also influences land use and therefore, indirectly, climate.

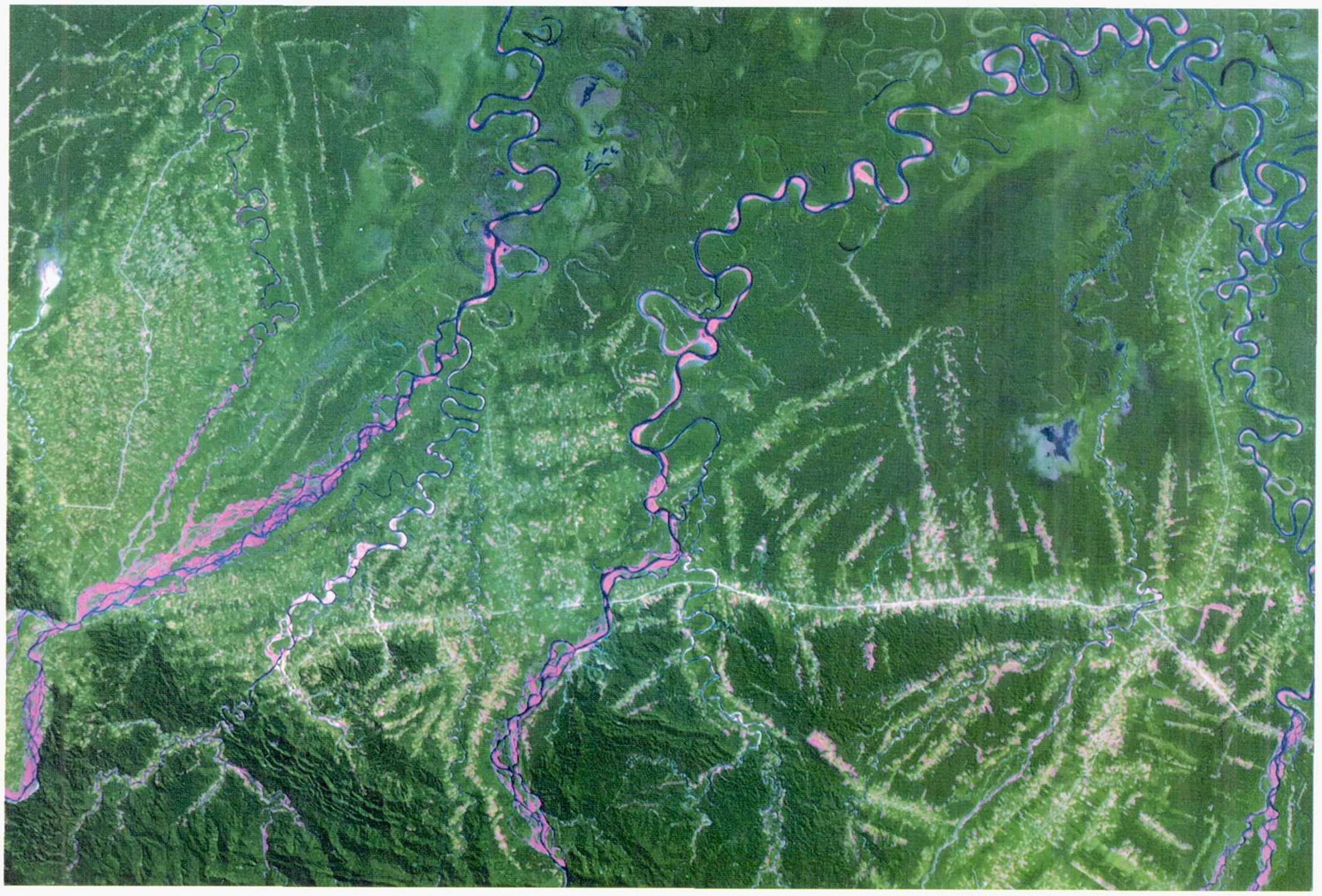
Various scholars have already discussed the possible inefficiencies of collective forms of property in arguing "the tragedy of the commons." Though some interpretations of the argument oversimplify the complex distinctions among forms of open access and carefully controlled common lands (distinctions which in some areas may vary for a single piece of land over the productive cycle), the debate calls to question the relative harm or benefit to the environment implicit in property arrangements. Resource mismanagement has been associated with uncontrolled or common access. Individual private forms of property may also lead individuals to fragment land or to clear forests solely to maximize profits rather than to enhance productivity. Such practices may or may not lead to more emissions. More research on these problems is needed.

Different demographic regimes determine each community's population structure and thus the size and composition of the labor force. This, in turn, influences how property is transferred. The complex interactions between demographic processes and patterns of inheritance must be examined to better understand the effects these have on land use and ultimately on climate and other environmental processes. High demographic density may contribute directly to greenhouse gas emissions through concentrated fuel use. A crucial component of demographic analyses in this context is to examine the forces that lead to human migration, especially from rural to urban regions. Research into the dynamics of demographic systems and their impact on other aspects of society and environment is thus central to understanding global change. It is equally important to examine the effects of climate on human health to determine the long-term effects of changes in the environment to population growth.

Another potential consequence of climate change with profound implications for international relations is increased emigration from developing to industrialized countries. This is already a sensitive issue and could become more so if the climate evolves unfavorably in marginal agricultural areas, or if important coastal regions are flooded. Massive migration might heighten tensions, as industrial nations face growing public opposition to an influx of newcomers. Negotiations among countries to share the burden created by such problems may prove complex and difficult. To understand population and political distribution problems in these cases, models that deal with emigration or emission reduction questions can prove useful analytical tools.

Energy

Another research focus involves substitutions of one form of energy for another, and how these ultimately affect total expenditures. Analyzing energy demand can give useful indications of more or less efficient uses of energy and how consumers substitute among them. Such a perspective can suggest ways in which greenhouse gas emissions will evolve and may or may not be easily modified. The possible effects of specific taxation policies in shaping these choices should also be studied, as is being done for carbon emissions.



Bolivian rainforest depletion, Landsat MSS Image

Political Systems

The numerous national and international political consequences of interactions between society and global environmental processes are important. Many of these are distribution problems between and within countries and regions. Taxation policies that attempt to ease negative impacts on climate due to human activities is one example. On the international level, agreements to limit greenhouse gas emissions would be another; the burden of reducing greenhouse gas emissions and the accompanying consequences on each country's income would have to be distributed. This could complicate relations between industrialized and developing countries.

Such issues and their complex interactions require interdisciplinary approaches. These can best be achieved with methodologies that are able to account for phenomena that depend on particular locations that vary in size, and that can include processes that evolve over relatively long periods of time (decades to centuries). The systems currently used by social scientists to describe how things change are usually not connected to geographical locations, which is crucial to studying the complex interactions outlined in the Social Process Diagram.

Taking the Next Steps

Studying the many aspects of environment-society interactions will require considerable amounts of data. A data management structure should allow data to be both spatially and temporally referenced. In addition, this structure should present data in a format that helps scientists understand how a problem changes with time and location. For example, using geographic information systems, one could imagine looking at a map of an area on a computer screen and then retrieving a set of databases with specific information for that region. These data could be of many different kinds, from both the natural and social sciences. Furthermore, the system should be capable of performing analyses and integrating data sets from different regions.

Data needs will evolve over time and continual review will be needed to ensure that the data collected appropriately addresses global issues.

This methodological structure, however, must be innovative enough to accommodate a wide variety of variables. There is strong need for a coordinated effort to provide directory assistance and data access for the purpose of integrating natural and social science information. Such a system would be useful to social, natural and health scientists, policy makers, resource managers and educators.

The interactions between human activities and global environmental processes outlined above lead to a research program which includes anthropologists, sociologists, economists, demographers, cultural geographers, political scientists, health scientists and natural scientists. In addition, computer scientists should be involved to design procedures that permit different types of data and different methodologies to be combined into a coherent, interrelated whole. Worldwide programs should be constructed so that results of the various studies can be presented to different audiences in clear and meaningful ways. To reach this goal and achieve significant, integrated research results, there must be a clear vision of the overarching framework and adherence to rigorous analytical standards.

Overall, these issues and their complex interactions suggest the need for creative interdisciplinary approaches. The global change community's agreement on a clear vision of how to advance global change research in the future could help facilitate further development of such approaches. The Social Process Diagram is a step toward shaping this vision and furthering research and understanding of human interactions and global environmental change.

Appendix A
For Further Reading

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Appendix B
Acronyms Used Within Text

ADC	Affiliated Data Center
AGCI	Aspen Global Change Institute, Aspen, Colorado
CEES	Committee on Earth and Environmental Sciences
CIESIN	Consortium for International Earth Science Information Network
DAAC	Distributed Active Archive Center
EOS	Earth Observing System
ESSC	Earth Systems Sciences Committee
ET	Earth Transformed program
GIS	Geographic Information Systems
HDGECP	Human Dimensions of Global Environmental Change Programme, a program established by the ISSC.
ICSU	International Council of Scientific Unions
IGBP	International Geosphere-Biosphere Programme
ISSC	International Social Science Council
MSS	Multi Spectral Scanner
NCAR	National Center for Atmospheric Research
NASA	National Aeronautics and Space Administration
SSRC	Social Science Research Council
UK GER	United Kingdom Global Environmental Research Office
USGCRP	United States Global Change Research Program

Appendix C
Acknowledgements

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This document was compiled through the efforts of:

Primary Authors: Draft material was submitted by members of the Working Group. Dr. William Kuhn, Dr. Urs Luterbacher and Dr. Ellen Wiegandt developed the text from these submissions.

Contributing Authors: Dr. Harold K. Jacobson, Mr. John Katzenberger, Mr. Jack Lousma, Dr. Harold A. Mooney and Dr. Richard H. Moss.

Text Development and Project Management: Leslie Wilhelm and Katie Wolf.

Content Review and Recommendations: Working Group Members, Mr. Robert Coullahan, Dr. Jack Eddy, Dr. Harold K. Jacobson, Mr. James Jordan, Mr. John Katzenberger, Dr. Richard H. Moss, Dr. Richard Rockwell, Dr. Michael Thomas, Dr. Billie Lee Turner II and Mr. William Wallace.

General Review and Editing: Norris McDowell, Leslie Wilhelm and Katie Wolf.

Editing and Assistance: Greta Bolger, Elaine Brown, Nancy Carroll, Carol Y. Swinehart and Karen E. Vigmostad.

Document Design and Production: Paul Grabhorn, Cindy Faber Smith and Melody Warford.

Organizational Support: Beth Lawson.

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CIESIN

Consortium for International
Earth Science Information Network

2250 Pierce Road
University Center, MI 48710 USA
Phone: 517/797-2700
Fax: 517/797-2622
E-Mail CIESIN.Info@ciesin.org

1825 K Street, N.W.
Suite 805
Washington, D.C. 20006 USA
Phone: 202/775-6600
Fax: 202/775-6622

1968 Green Road
P.O. Box 134003
Ann Arbor, MI 48113 USA
Phone: 313/663-5650
Fax: 313/663-6622