CHAPTER 9

Human Contributions and Responses to Environmental Change

CHAPTER CONTENTS

Human activities play an important part in virtually all natural systems and are forces for change in the environment at local, regional, and even global scales. Social, economic, and cultural systems are changing in a world that is more populated, urban, and interconnected than ever. Such large-scale changes increase the resilience of some groups while increasing the vulnerability of others. A more integrated understanding of the complex interactions of human societies and the Earth system is essential if we are to identify vulnerable systems and pursue options that take advantage of opportunities and enhance resilience. Basic social science research into human-environment interactions provides a foundation for applied analyses and modeling of human behavior at its interface with global environmental change.

The need for understanding human contributions and responses—sometimes referred to as "human dimensions" of global change—motivates the research questions in this chapter and elsewhere in this plan. Human dimensions research includes studies of potential technological, social, economic, and cultural drivers of global change, and how these and other aspects of human systems may affect adaptation and the consequences of change for society. Much of this research is "cross-cutting"—integral to explorations of causes and impacts of changes in atmospheric composition, climate, the water cycle, the carbon cycle, ecosystems, land use and land cover, and other global systems. Research on human contributions and responses integrates information from different research elements to establish baseline characterizations of man acting in and reacting to his environment. The complex interactions of multiple environmental stressors on human activities must be examined. It is widely acknowledged that human dimensions research has special challenges associated with the cross-disciplinary nature of its topics and with the mix of qualitative and quantitative data and analyses employed in its pursuit.

Across the range of human dimensions research there is a particularly strong need for the integration of social, economic, and health data with environmental data. Such integration requires data from physical, biological, social, and health disciplines on compatible temporal and spatial scales, to support the synthesis of data for research and to support decisionmaking. There is an especially critical need for geo-referenced data.

A broad research agenda for human contributions and responses has been identified in a series of national and international reports, including the assessment reports of the Intergovernmental Panel on Climate Change (IPCC, 2001a,b,c,d) and a series of focused reports and monographs from the National Research Council (NRC, 1999a,e, 2001c,e). The NRC report *Climate Change Science: An Analysis of Some Key Questions* concluded that: "In order to address the consequences of climate change and better serve the Nation's decisionmakers, the research enterprise dealing with environmental change and environment-society interactions must be enhanced." Such an enterprise should include, "…support of interdisciplinary research that couples physical, chemical, biological, and human systems" (NRC, 2001a). This chapter draws from these reports and from priority areas identified by the research community through federal research programs.

Two overarching questions for research on the human contributions and responses to global change are:

- How do humans and human societies drive changes in the global environment?
- How do humans prepare for and respond to global environmental change?

These questions frame the human dimensions research outlined in the four key questions that follow.

Question 9.1: What are the magnitudes, interrelationships, and significance of primary human drivers of and their potential impact on global environmental change?

State of Knowledge

Human drivers of global environmental change include consumption of energy and natural resources, technological and economic choices, culture, and institutions. The effects of these drivers are seen in population growth and movement, changes in consumption, de- or reforestation, land-use change, and toleration or regulation of pollution. The IPCC (IPCC, 2000 a,b, 2001a,b,c,d), the NRC (NRC, 1999a, 2001a), and additional U.S. studies have summarized social science research on these drivers in the specific context of climate change, and the International Human Dimensions Programme has contributed to this body of knowledge. For example, research has pointed to population changes (including an aging population in the United States with rapid growth of human settlements, especially in the South, West, and coastal areas) that have affected consumption patterns and other drivers of global environmental change.

Research into the human drivers of global change has focused on changes in land use and energy use. But there is also a growing body of work on fundamental socioeconomic processes that drive human use of the environment (e.g., changes in population densities, advances in technology, the emergence of new institutional structures). Furthermore, current research on sustainability emphasizes the roles played by societies in driving global environmental change. Recent research has also improved our understanding of many of the factors that affect environmentally significant consumption at the household level. Important advances have been made in understanding the effects of economic transformation—for instance, how the growth of the service sector in urban areas contributes both to social wealth and vulnerability of human settlements. Similarly, research on technological change has helped to identify trends in innovation, efficiency, and expanded living standards, and their implications for natural and depletable resources.

Illustrative Research Questions

Research questions related to human drivers span a range of topics, including: What are the key processes and trends associated with population growth and demographic change, management of natural resources (including land and water), the development of advanced technologies, and trade and global economic activity? How can improved understanding of these issues be used to improve scenarios and projections of global change? Who are the principal actors, both individuals and institutions, and what are the key factors, such as households, markets, property and land tenure, and government policies and practices? How can researchers develop appropriate scenarios and link them to decisionmaking frameworks? How can stakeholder involvement be used to help determine the research agenda? In addition, questions specific to population and technological change and the role of trade and economic activity include:

- **Population growth and demographic change**
  - How do population growth, composition, distribution, and dynamics (fertility, mortality, migration, and household change) affect the sustainability of energy and land use, economic activity, land cover, the climate system, and other global environmental systems?
  - How is the relationship between population dynamics and environmental change affected by the scale at which population-environmental linkages are measured (e.g., the plot, the community, the state, the region, the nation)?
  - How do people use information and form perceptions about potential or actual global environmental changes, along with other social, economic, and political considerations, to make decisions about production, consumption (including use of natural resources), and mobility (including migration)?
  - What are the roles played by institutions in structuring the activities that drive global environmental change?
- **Technological change**
  - What are the drivers, especially institutional factors that induce technological innovation and adoption of new technologies? What influences the transfer of technology from region to region or country to country? How does technological innovation and transfer impact systemic environmental change and figure in adaptation and mitigation strategies?
  - How can research that identifies viable technology options be modeled as policy options?
  - What can be projected about the effectiveness, cost, and environmental and health effects of alternative energy and mitigation technologies, including sequestration options?
  - How can this research contribute to efforts to develop mitigation technology options by, for example, placing values on such items as temporary carbon storage and the availability of limited resources such as land and water?

- **Trade and global economic activity**
  - What influences the movement of goods and services domestically and from one country to another? How does movement of goods and services impact global environmental change?
  - How do operational and technological changes affect economic productivity and energy use?

Research Needs

Key needs have been identified, including:

- Development of a connection to decision support capabilities by improving the scientific information that helps to inform the policy process.
- Development of more coherent and plausible scenarios with projections of social, economic, and technology variables. Here, linkages to outputs from the Climate Change Technology Program (CCTP) will be made.
- Development of integrated assessment models with the ability to better analyze the effects (social, economic, and health) of measures directed at reducing greenhouse gas emissions and that include non-market submodels for the analysis of quantitative and qualitative data related to human health and well-being.
- Development of integrated assessment models that introduce new energy and carbon sequestration technologies (including technologies under consideration in the CCTP) and incorporate new knowledge about innovation and diffusion.
- Development of the capability to study the economic and trade effects of various mitigation options that differ in complex ways, both within and among countries, including broad policy approaches (e.g., emissions targets, technology subsidies, voluntary national goals) and means of implementation (e.g., voluntary programs, incentives, taxes, cap and trade systems, and quantity constraints).
- Assessment of the full costs and benefits (including productivity impacts) of environmental policy and technology choices (mitigation and adaptation) that affect human well-being at different scales, including the individual or household level.

Milestones, Products, and Payoffs

- Research in this area is expected to improve our understanding of how human societies drive global environmental change. Inputs on potential future human drivers of change are required for Ecosystems, Water Cycle, and Carbon Cycle research. Available information will be reassessed for its relevance and contribution to interdisciplinary studies of human-induced environmental change [less than 2 years].
- Scenarios will be strengthened by an improved understanding of the interdependence among economic growth; population growth, composition, distribution, and dynamics (including migration); energy consumption in different sectors (e.g., electric power generation, transportation, residential heating and cooling); advancements in technologies; and pollutant emissions [less than 4 years] (a benefit to the Carbon Cycle research element).
- Evaluations will be developed of the economic opportunities to reduce greenhouse gas emissions or increase sequestration in the agricultural and forestry sectors [2-4 years].
- Structured methods will be developed to define the connections and tradeoffs among economic development, technological change, and human well-being at multiple scales and at the intersection of complex institutional arrangements [beyond 4 years].

Human Contributions and Responses products will provide needed inputs to the Carbon Cycle and Land-Use/Land-Cover Change research elements related to changes in energy consumption, technology utilization, and adaptation policies (see also Question 9.2).

Question 9.2: What are the current and potential future impacts of global environmental variability and change on human welfare, what factors influence the capacity of human societies to respond to change, and how can resilience be increased and vulnerability reduced?

State of Knowledge

For the purpose of this question, "global environmental variability and change" includes climate variability and change and related sea-level rise. These environmental changes need to be analyzed in the context of other natural and social system stresses, such as land-use and land-cover change, population changes and migrations, and global economic restructuring. There has been significant progress in analyzing and modeling regional vulnerabilities and possibilities for adaptation, including in the context of multiple stresses. Progress has been made in understanding how society adapts to seasonal climate variability and, by extension, how it may adapt to potential longer term climate change (IPCC, 2001b).

The state of global change impact and adaptation research varies, depending on the nature of the impact, the scale of the analysis, and the region of the world. For most types of impacts, this field of inquiry has advanced from modeling direct impacts on natural and human systems (e.g., crops, forests, water flows, coastal infrastructure) to analyses of how people might alter specific activities in reaction to changing climate, and for several types of impacts, anticipatory responses have been investigated as well. For example, with respect to sea-level rise, the direct impacts and possible responses are fairly well established for the United States. However, a high priority for research concerns the environmental impacts of adaptive responses in the future.

On a global scale, considerable gaps exist in understanding, modeling, and quantifying the sensitivity and vulnerability of human systems to global change and measuring the capacity of human systems to adapt. For instance, little is known about the effectiveness of applying adaptation experiences with past and current climate variability and extreme events to the realm of climate change adaptation; nor about how this information could be used to improve estimates of the feasibility, effectiveness, and costs and benefits of adaptation to long-term change. Gaps also exist in understanding differences in adaptive capacity across regions of the world and different socioeconomic groups (IPCC, 2001b). Also less well known are the roles that institutional change and consumption patterns in the

future will play in the capacity of society to prepare for and respond to global changes.

Illustrative Research Questions

- What factors determine the vulnerability of human systems to climate variability and change, and how can vulnerability be reduced?
- What factors determine the vulnerability of natural systems to the adaptive measures that people may implement in response to global change?
- How are climate variability, trends in climate, and sea-level rise likely to affect resource management (e.g., water, fish, agriculture, forestry, transportation, energy supplies), urban planning, coastal zone management, and the effectiveness of federal environmental and infrastructure programs?
- What are the economic and social costs and benefits of current climate variability and longer term climate change and what are the market and non-market tradeoffs, feasibility, and effectiveness of potential adaptation and/or mitigation options?
- To what extent will consumption patterns (e.g., per capita water consumption) and/or land-use changes influence the vulnerability of human systems to the impacts of climate variability and change?
- How may methods be refined to accurately assess the combined impacts of the full range of potential climate change, water quality and availability, land use, sea-level rise, and ecosystems on human welfare?

Research Needs

Research needs include empirical studies and model-based simulation studies of the influence of social and economic factors on vulnerability and adaptive capacity in households, organizations, and communities; assessments and economic analyses of the potential impacts of climate variability and change (including using products from the Ecosystems research element); retrospective analyses of the consequences of surprising shifts in climate and the ability of society to respond to negative impacts and potential opportunities; and studies analyzing the factors that affect adaptive capacity in the context of multiple social and natural system stresses (climate change, land-use change, population change and movements, sea-level rise, changes in political institutions, technology gains, and economic restructuring).

Much of this research will need to be place-based analysis at regional and local scales in order to capture the complexities of the human-environment interface and the adaptive strategies of individuals, industries, institutions, and communities (requiring connection to the place-based research planned through the Decision Support element). Comparative studies at different locations and in different socioeconomic contexts are critical. Longitudinal data sets need to be developed, as do data sets that track adaptation strategies across time (linkage to the Observing and Monitoring working group is key).

More extensive research crossing social science disciplines as well as research integrating social and natural system components is needed for improved understanding and modeling of impacts and adaptation and their feedback to possible mitigation efforts. Integrating across these connections is complex and will require methods for integrating qualitative and quantitative data and analyses as well as improvements in linking component models. Use of qualitative and quantitative approaches is critical if we are to make progress at a range of scales. Specifically, attention needs to be paid to the associated costs and benefits of adaptation strategies, strategies for mitigating the impacts of global change on different economic sectors and people in different locations and economic brackets, market and non-market valuation of positive and negative impacts, the possibility of new economic instruments for responding to global change, and the role of public and private institutions and public policies in influencing adaptive capacity (IPCC, 2001b). Research could include input from studies of mitigation and adaptation measures undertaken by the Ecosystems research element.

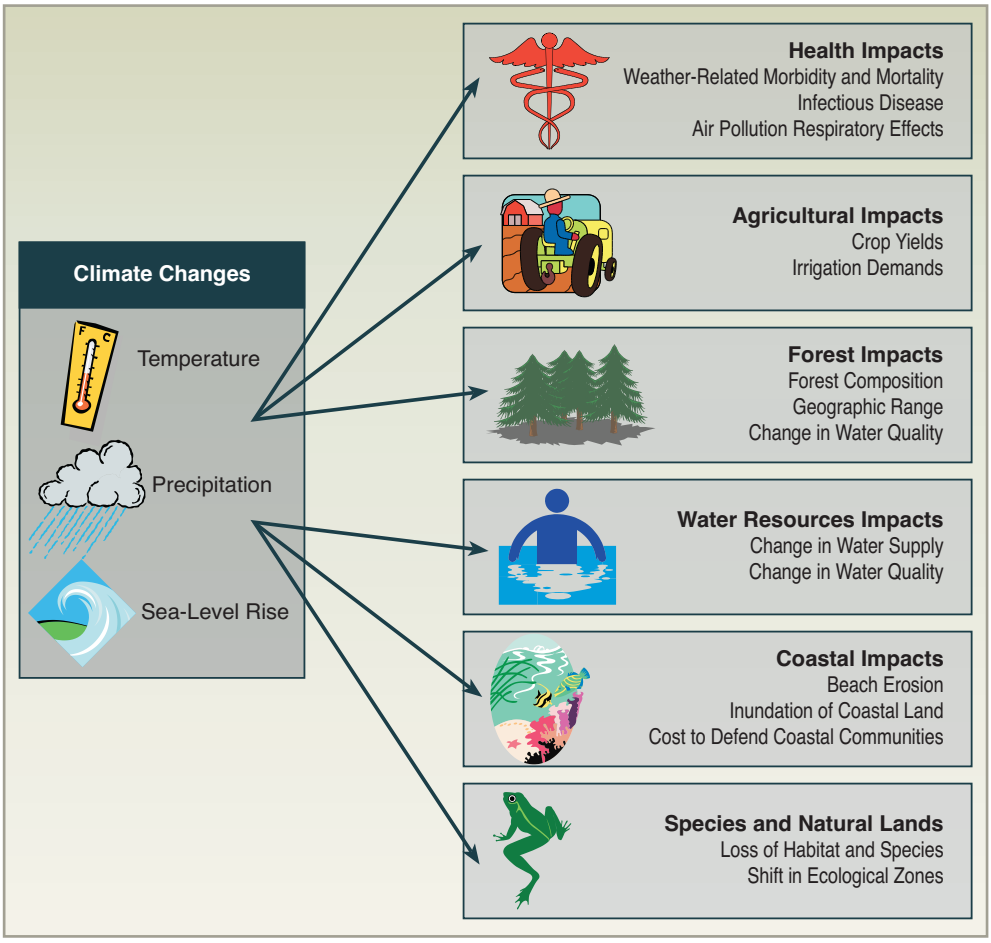

Figure 9-1: Potential climate variability and change impacts.

Milestones, Products, and Payoffs

Research on these questions can be expected to improve analytical methods and models of how climate variability and change and sea-level rise combined with socioeconomic changes are likely to affect decisionmaking in water management, agriculture, forest management, transportation infrastructure, urban areas, coastal areas, public health, and other climate-sensitive sectors in the United States and developing countries. The research will enable decisionmakers in both the public and private sectors to make more enlightened choices regarding the nature and timing of actions to undertake in response to the challenges and opportunities associated with anticipated climate variability, potential climate change, and sea-level rise.

Some expected products/milestones include:

- Improved characterization and understanding of vulnerability and adaptation based on analyses of societal adjustment to climate variability and seasonal-to-interannual forecasts [2-4 years].
- Identification of adaptation strategies effective for managing the impacts of seasonal and year-to-year climate variability that could prove useful for adaptation to projected longer term climate change [beyond 4 years].
- Elevation maps depicting areas vulnerable to sea-level rise and planning maps depicting how state and local governments could respond to sea-level rise [less than 2 years].
- Assessments of the potential economic impacts of climate change on the producers and consumers of food and fiber products [2-4 years].
- Estimates of the value of the ancillary benefits (e.g., enhanced wildlife habitat and improved water quality) that could result from implementing various mitigation activities within the forestry sector [2-4 years].
- Assessments of how coastal environmental programs can be improved to adapt to sea-level rise while enhancing economic growth [2-4 years].

Question 9.3: How can the methods and capabilities for societal decisionmaking under conditions of complexity and uncertainty about global environmental variability and change be enhanced?

State of Knowledge

Decisionmaking is rife with uncertainties including risks of irreversible and/or non-linear changes that may be met with insufficient or excessive responses whose consequences may cascade across generations. The difficulties associated with characterizing and explaining uncertainty have become increasingly salient given the interest of policymakers in addressing global environmental change. Uncertainties arise from a number of factors, including problems with data, problems with models, lack of knowledge of important underlying relationships, imprecise representation of uncertainty, statistical variation and measurement error, and subjective judgment (IPCC, 2001b,d).

BOX 9-1

HUMAN CONTRIBUTIONS AND RESPONSES TO ENVIRONMENTAL CHANGE

FY04 CCRI Priority - Decisionmaking Under Uncertainty

The Climate Change Research Initiative (CCRI) will leverage existing U.S. Global Change Research Program (USGCRP) efforts to provide structured information to inform national, regional, and local discussions about possible global change causes, impacts, and mitigation and adaptation strategies.

The CCRI will provide continuing support for a set of interdisciplinary centers focusing on *Decisionmaking Under Uncertainty* associated with climate change and variability. These centers, which should be established in FY04 following a special competition, will conduct fundamental research on decisionmaking associated with climate change and variability. The centers are expected to advance basic understanding about decision processes dealing with issues such as inter-temporal choice, risk perception, hazards and disaster reduction, opportunities, trade-offs, equity, framing, and probabilistic reasoning associated with uncertainty.

The centers will develop tools that people, organizations, and governments can use to better understand the risks and uncertainties associated with climate variability and change and the options they have to address them. In order to do this, they will develop and disseminate tangible products for researchers, decisionmakers and other relevant stakeholders and make them readily accessible through a range of media.

Illustrative Research Questions

How can methods or approaches be improved:

- For representing, analyzing, describing, and communicating uncertainties and for evaluating and addressing scientific disagreements about the nature and extent of risks?
- For understanding the costs (market and non-market) and opportunities (societal, organizational, and individual) associated with global climatic variability and change?
- For representing how individuals, organizations, and societies make choices regarding risks whose consequences are long-term and uncertain?
- For evaluating and comparing the effectiveness of different approaches to modeling decisionmaking?
- For understanding how public and private decisionmaking impacts human health and the natural environment?

- For designing processes that combine scientific analyses with the policy deliberations and judgments of decisionmakers?
- For disseminating, communicating, and evaluating climate forecast information for use by decisionmakers?

Research Needs

Associated research needs include analysis of decision processes to identify what information on global environmental variability and change is most useful and at what stage in the decision process that the information is needed. This work will be done in collaboration with the Decision Support Resources development described in Chapter 11.

Milestones, Products, and Payoffs

- Research on these questions will enable the development of assessments of the kind of knowledge and information needed by different decisionmakers and stakeholders in order to enhance decisionmaking associated with climate change, and will produce decision support resources [beyond 4 years].
- Research centers will be expected to facilitate interactions among researchers and relevant decisionmakers and stakeholders [less than 2 years]; provide educational opportunities for U.S. students and faculty [less than 2 years]; increase understanding of the types of information needed by decisionmakers [less than 2 years]; develop tools that people, organizations, and governments can use to better understand the risks associated with climate variability and change and the options they have to address those risks [2-4 years]; and increase basic understanding of decisionmaking processes associated with climate change and variability [2-4 years].
- In addition to the advancement of basic understanding and modeling of decisionmaking, the program expects to develop improved modeling frameworks that better link general circulation, ecological, and economic models of the agricultural and forestry sectors [2-4 years].
- Recommendations will be developed for producing, communicating, and disseminating climate information and its associated uncertainties to resource managers (e.g., farmers, forest landowners, drought policy planners, water utilities) and urban planners at local to national levels. Integration with Decision Support efforts will be important as will drawing on communication and dissemination tools developed by the Water Cycle research element [2-4 years].

Question 9.4: What are the potential human health effects of global environmental change, and what climate, socioeconomic, and environmental information is needed to assess the cumulative risk to health from these effects?

State of Knowledge

It is well established that human health is linked to environmental conditions, and that changes in the natural environment may have subtle, or dramatic, effects on health. Timely knowledge of these effects may support our public health infrastructure in devising and implementing strategies to compensate or respond to these effects.

Over the past decade, several research and agenda-setting exercises have called for continued and expanded research and development of methods in this area (WAG, 1997; NRC, 1999a,d, 2001c; EHP, 2001; IPCC, 2001b). Given the complex interactions among physical, biological, and human systems, this research must be highly interdisciplinary, well integrated, and span the breadth from fundamental research to operations. A multi-agency interdisciplinary research effort to examine the linkages across these sectors is in place with research focusing on global and developing country impacts, and on the effects of simultaneous environmental and economic shifts on human health and well-being.

Federally supported research has thus far provided information on a broad range of health effects of global change, including the adverse effects of ozone, atmospheric particles and aeroallergens, ultraviolet (UV) radiation, vector- and water-borne diseases, and heat-related illnesses (see Figure 9-2). Research continues to improve understanding of the potential impact of climate variability on certain infectious diseases, and researchers are developing and evaluating tools and information products for anticipating and managing any such impacts that capitalize on the enormous protections afforded by wealth and the public health infrastructure. However, many questions remain unanswered.

Illustrative Research Questions

- What are the impacts of changes in water quantity and quality, temperature, ecosystems, land use, and climate on infectious disease and what is the relative importance of these impacts compared to other socioeconomic and technological factors?
- What are the impacts of atmospheric and climatic changes on the health effects associated with ambient air quality and UV radiation?
- What are the health effects and effective preparedness and response strategies associated with temperature extremes and with extreme weather events?
- What are the best methods for assessing known and potential climate-related health impacts and for developing and evaluating useful tools and information products to enhance public health and support decisionmaking?
- How can we improve the capacity of public health and societal infrastructure to prevent, detect, and effectively respond to health impacts that may be associated with climate change?
- How can the incorporation of health impacts and trends into climate change scenarios improve tools for decisionmaking at various time scales?

Research Needs

Research needs include:

- Work on improved understanding of the health effects of UV radiation, including exposure across regions and populations, risk awareness, and early detection.
- Initiation of a temporally and spatially compatible long-term field study, empirical analysis, and integrated modeling effort of the physical, biological, and social factors affecting the potential impact of climate variability and change on public health issues of national importance.
- Research on the climatic effects of temperature on air quality, particularly in urban heat islands and other regional settings, and the potential health consequences.

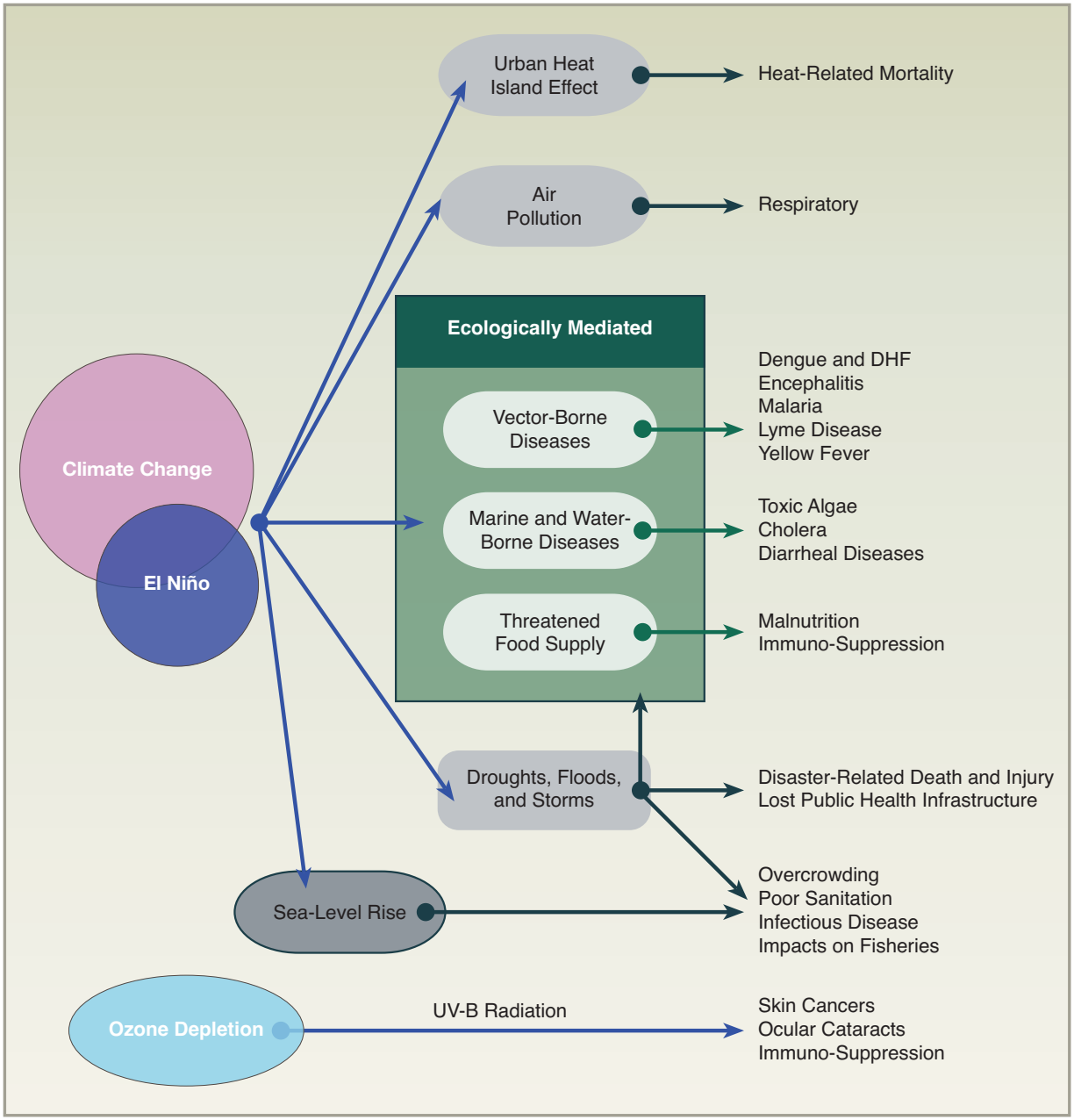

Figure 9-2: Possible pathways of public health impacts from climate change. For more information, see Annex C.

- Research on the effect of seasonal-to-interannual climate variation on public health, especially at a regional scale, and the integration of this information into decisionmaking processes.
- Research on preventing and reducing the adverse health impacts of extreme weather events.
- Research on prevention and control of infectious diseases that might increase in incidence as a result of climate change.
- Research on the regional control and treatment of vector- and water-borne diseases (this work should be linked to the Ecosystems research element).
- Economic analysis of the prevention, control, and treatment strategies for potential public health impacts associated with climate variability and change.
- Studies on the costs and benefits to public health of mitigation strategies for greenhouse gas emissions.

A parallel need exists to develop additional appropriate tools and methods for assessing and adapting to potential health outcomes, and for evaluating the impact of research, the effectiveness of Earth science information and products, the methods for communicating that information, and the systematic identification of knowledge gaps and feedback to the research communities.

Milestones, Products, and Payoffs

Products from this area include operational tools, research to support innovative institutional arrangements and processes, and research results that may be used by decisionmakers. Expected milestones, products, and payoffs include:

- Additional tools for preventing and managing the public health threat of infectious diseases [2-4 years].
- Assessments of the potential health effects of combined exposures to climatic and other environmental factors (e.g., air pollution, and including input from the Atmospheric Composition research element) [beyond 4 years].
- A multi-agency joint award for competitive grants to support research on climate variability and health [2-4 years and beyond].

- The next phase of health sector assessments to understand the potential consequences of global change for human health in the United States, especially for at-risk demographic and geographic subpopulations [2-4 years].

National and International Partnerships

The study of human contributions and responses to global change within the Climate Change Science Program (CCSP) has ties to a number of national and international programs beyond those represented among the CCSP member agencies, including the International Human Dimensions Programme, the Intergovernmental Panel on Climate Change, the World Health Organization, the Pan American Health Organization, Environment Canada, Health Canada, the Climate Change Technology Program, the National Research Council, the Centers for Disease Control and Prevention, the National Institute of Environmental Health Sciences, the National Institute for Child Health and Human Development, the National Institute of Allergy and Infectious Diseases, the U.S. Census Bureau, the Bureau of Labor Statistics, and other federal agencies and programs, and to the International Research Institute for Climate Prediction and the Inter-American Institute for Global Change Research (see Chapter 15). Collaborations between the federal agencies involved in global change research and the abovementioned organizations include co-sponsorship of scientific workshops and conferences, efforts to set scientific agendas in research areas of mutual interest, and collaborative assessments of the state of knowledge.

Furthermore, numerous collaborative research projects between scientists in the United States and other countries are underway. As examples, U.S. scientists collaborate with developing country scientists to analyze coping strategies and the use of climate information in the face of year-to-year climate variability. In addition, U.S. researchers in the field of economics and other areas associated with creating decisionmaking frameworks collaborate through institutions such as Stanford University's Energy Modeling Forum (EMF). For example, an annual EMF meeting of specialists in integrated assessment modeling and related disciplines, such as climate science, biology, and health, has generated a great many successful research partnerships across both countries and disciplines.

The scientific community has called for strengthening international cooperation and coordination related to human contributions and responses research, particularly in the areas of the potential impacts of climate on human welfare and resource management, vulnerability assessments, and adaptation research. Progress depends on advances in these areas, as well as in improvements in climate modeling, observations, and our understanding of the integrated climate system and associated socioeconomic and environmental responses. Cooperation should include the collection and archiving of social and economic data, as well as exchanging methodologies and research insights.

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