The Human Ecology of Global Change: Unresolved Questions

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ABSTRACT: The need to view human activity as an integral component of the geosphere-biosphere system has been emphasized since the earliest writings on global environmental change. In recent years, however, the long-term, large-scale interactions between human activities and the world's environment have become the focus of increasing practical and scholarly attention. Several national and international programs are beginning to plan systematic research strategies for better understanding those interactions. This paper attempts to review and summarize the major conclusions of these early planning efforts through a discussion of the major unresolved questions relating to the human ecology of global change.

The challenge of defining a research program on the interactions among the human, ecological, and physical systems involved in global environmental change has been explored over the past several years by a growing number of scholars and institutions. This paper seeks to review and summarize their findings, with a view towards identifying the questions that merit central attention in studies of the human ecology of global change. In attempting to cover this broad area, I focus on the interactions of social and environmental systems - in particular the human sources, consequences, and management of global change. Related and equally important questions that arise within the social or environmental sciences per se, or primarily in connection with specific policy decisions, I leave for others to explore.

Human Sources of Global Change

An early target of research on global change should be documentation and understanding of the most important ways in which human processes drive or force changes in the environmental system. Experience with study of the greenhouse problem and stratospheric ozone depletion shows that accurate histories of emissions resulting from human processes can seriously misdirect the attention of the research community. Finally, more informed social choices regarding environmental management require better understanding of not only how, but also why, the human forcing of global change varies with time, space, and culture. Such understanding will require better answers to the three related groups of questions discussed below.

Identifying Human Activities that Drive Global Change

Which anthropogenic alterations to material and energy flows within the geosphere-biosphere system play significant roles in forcing global change? Which human processes are significant sources of such alterations? How do answers to these questions vary across space, time, and culture?

The first requirement is for a more systematic identification of which human-induced changes in energy and chemical flows, water use, habitat extent, or other variables constitute the most significant "inputs" to climatic, biogeochemical, or biotic dynamics. For a few aspects of global change like the greenhouse effect or stratospheric ozone depletion, this preliminary identification of "input" linkages between the human and other components of global change is relatively well in hand: research can confidently focus on a specific list of radiatively active trace gases and halocarbons. For most other
aspects of global change, however, much basic research on human forcing of interactions with the environment needs to be done. A preliminary effort to set priorities for linkage information is sketched in the NASA report Earth System Science: A Closer View\(^2\).

Once a priority list of linkage variables has been defined, there remains the question of which specific human activities are capable of changing the fluxes of those variables. Even in relatively simple cases, this analysis is not trivial (e.g., Wuebbles and Edmonds 1988). Establishing the required knowledge base will require close collaboration between scientists studying the relevant nonhuman components of global change and specialists in the workings of relevant technologies and land use practices (especially chemical, water, mechanical, and agricultural engineers). Darmstadter et al. (1987) provide an example of the kind of collaborative effort that is needed.

Input-Output Relationships in Human Activities

How much alteration of the relevant material or energy flows is created per unit of human source activity? How do these “intensive” relationships between human processes and material and energy flows vary across space, time, and culture? Answering such questions will require basic quantitative process studies on the transformation of human activity “inputs” such as coke production or rice paddy cultivation into “outputs” such as methane flux to the atmosphere. Typical of the most complete work on individual inputs and outputs is the analysis of quantities of carbon dioxide produced per unit energy derived from various fossil fuels (Marland and Rotty 1983). But the relative simplicity of the I/O structure for the case of carbon dioxide emissions is potentially misleading as a guide to research requirements in this complex area. In the more general situation, a given pollutant flow will be altered through several human activities. Complex sequences of reaction, deposition, and remobilization may be involved within the human system en route to a final measured “output” into the environment. At each stage, process understanding is usually imperfect, as is monitoring data for estimating fluxes and pools. An important methodological advance in dealing with such complexities in I/O assessments has therefore been “materials/energy balance accounting” (Ayres 1978 and 1989). This approach takes advantage of conservation principles to balance amounts of energy and materials drawn into the human system with amounts exported or stored at any given time. It has helped in the “discovery” of unsuspected pollutant sources in seemingly innocuous or irrelevant human activities (Ayres and Rod 1986; Ayres et al. 1988). More systematic use of balance accounting, especially in historical context (e.g., Darmstadter et al. 1987), would almost certainly be useful in future efforts to answer questions concerning the I/O relations between human and other components of the geosphere-biosphere system.

The Changing Magnitude of Human Forcing

What are the total amounts or strengths of the relevant human source activities? How do these “extensive” measures of the human ecology of global change vary across space, time, and culture?

Ultimately, the need is for something approaching a theory of world development, cast in terms appropriate to produce relevant human forcing functions needed for the understanding of global environmental change. The underlying research questions were summarized in a recent Social Science Research Council (SSRC) meeting on changes in the global environment:

What are the persistent, broad-scale social structures and processes that underlie these changes? In particular, what are the relative roles of the amount and concentration of human population, the character and use of technology, the changing relation between places of production and consumption, and the “reach” and power of state and other institutional structures? How does the relative importance of these roles for environmental change vary across cultures, and through history? (SSRC 1988)?

Among the earliest efforts to address such questions at the global scale were the various world systems modeling efforts of the 1970s (e.g., CEQ 1980; Meadows et al. 1972). The shortcomings of these efforts are well known and can be traced to weaknesses in data, methodology, and conceptual foundations (Brewer 1986; Greenberger et al. 1983; Meadows and Robinson 1985; OTA 1982). A number of more modest efforts, focused on particular sectors of the human system, have since been carried out. Several of these, specifically in the fields of population, agriculture, forestry, and energy modeling, are relevant to studies of global change\(^3\). As pointed out in a recent review by the International Institute for Applied Systems Analysis, however, the assumptions underlying the best of these sectoral studies are often contradictory in ways that can only partially be resolved through subsequent reanalysis (Toth et al. 1989). No credible integrated and dynamic model yet exists of long-term global changes in human activities that force environmental change. Prospects for such a model, while still distant, are nonetheless improving and need to be pursued as part of a research program on global change.

As regards data, many of the most important contemporary human releases of materials and energy relevant to global change are monitored through national and international environmental networks. A careful review is needed, however, of the adequacy of this contemporary monitoring for the specific purposes of global change research. On the methodological side, another recent SSRC study has illustrated how much the social