PREINDUSTRIAL HUMAN ENVIRONMENTAL IMPACTS:
ARE THERE LESSONS FOR GLOBAL CHANGE SCIENCE AND POLICY?

INTRODUCTION

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Time present and time past
Are both perhaps present in time future,
And time future contained in time past.

—T. S. Eliot, Four Quartets

Predicting global change requires contributions from many of the physical and social sciences, including physics and chemistry applied to the atmosphere; biology applied to agricultural and natural systems that are sources and sinks of greenhouse gases; and political, economic, and social-psychological investigations applied to potential growth of emissions and their mitigation. Such diverse elements are equally important in attempts to know the past, i.e., to understand how human actions have shaped the environment even before the industrial revolution, and vice versa. In the literature, notable efforts have been made in this regard (Thomas, 1956; Goudie, 1990; Turner et al., 1990; Jacobsen and Firor, 1992).

To further unravel past human activity and environmental change with special attention to the climate, a conference was held at the East-West Center (September 17–19, 1993) that brought together historians, anthropologists, economists, and physical scientists to see what they could learn from each other and begin to lay down a foundation for evaluating environmental changes from human activities during the past 500–1,000 years. Most of these changes were not global in extent, although some global signals are detectable in ice core records and other proxy data. The signals are more clearly detectable on regional scales and tell us a great deal about how environmental changes were
caused and how they affected human life at those times. The global change expected in the future also ultimately translates to regional effects, since social organization is on this scale, which includes countries and provinces within the countries. The changes of the past, if they can be documented and understood, are therefore a measure of the effect of regional environmental change on human life. These studies may tell us about what can happen on regional scales if human activities bring about global environmental change.

Finding a place for interdisciplinary studies such as those reported here is difficult. *Chemosphere*’s Atmospheric Chemistry and Global Change section, however, is new and still experimenting with its scope and coverage. More important, the section is committed to new ideas and avenues that point toward a deeper understanding of global change. While some of the studies reported here may not fit into the normal physical-science ethos of this section, or any other journal confined to applying physical science to the environment, we feel that there are so many new ideas in this collection of papers that it is important to publish all that survived the peer review process. Here then is a unique collection of papers that looks backward to times before the chlorofluorocarbons, before the unusually high levels of carbon dioxide and methane, and asks whether the preindustrial atmosphere was pristine or polluted, and what feedbacks can we detect between natural and anthropogenic dynamics. Recent concern for future global environment has focused on understanding and, if possible, mitigating anthropogenic disruption of the natural biogeochemical cycles. Implicit in much of this research are the assumptions that previous to the widespread diffusion of industrial technology in the mid-nineteenth century, human activity did not significantly impact atmospheric or terrestrial chemistry and earlier concentrations of greenhouse gases reflected only natural processes (Siegenthaler and Sarmiento, 1993). This perception of a pristine preindustrial environment has persisted despite dramatic anthropological, archaeological, and paleoclimatic evidence that humans have long played an active role in environmental management and change. Well-documented examples of the interactive cycle of human environmental manipulation, environmental change, and the feedbacks that lead to social and cultural change span temperate and tropical ecosystems, and extend back many centuries.

Acceptance of this evidence has been inhibited by the widely held belief that preindustrial peoples always and everywhere lived in harmony with nature (Rambo, 1985). Arising out of the earlier Western conviction that technologically "backward" native peoples lived short and miserable lives as victims of powerful natural forces, this view has been transmuted in the postcolonial era into an ideologically potent claim of moral superiority for non-Western cultures (Quinn, 1992). Heated debate over the extent to which Native Americans modified the environment of the New World before European contact was, as an example, perhaps the most common element in the wave of publications triggered by the recent quincentenary of Columbus’ voyage (e.g., Greenblatt, 1991; Denevan, 1991).

Here we outline an emerging body of research on the interplay between human activity and the preindustrial environment. Case studies in this special issue include unmistakable evidence of environmental change during twenty-one centuries of human habitation of the Loess Plateau of China; a 40,000-year history of Aboriginal manipulation
of ecosystems and biodiversity by fire in Australia; agricultural and forest manipulation by the native peoples of North America extending over roughly one-third of the continent by the fifteenth century; erosion and environmental degradation from agricultural practices in the volcanic uplands of Mexico that date back over 3,000 years; dust deposits in the tropical glaciers of the Peruvian Andes resulting from activities of pre-Incan peoples on the shores of Lake Titicaca; and evidence from all cultures and civilizations of the central role of environmental manipulation by biomass combustion. Taken in sum, these cases paint a remarkable picture of not only a long history of significant human impact on the natural world, but also an awareness and response to environmental change.

Whereas human impact on local or regional environments can be clearly discerned from historical record, the possibility of impact on a global scale remains an intriguing but unproven speculation. The scientific and policy implications of a "preindustrial greenhouse signal," however, are significant. Current efforts to predict global change, notably the time scale and magnitude of global warming or sea-level rise, hinge on knowledge of the baseline greenhouse gas concentrations as well as on the dynamics of carbon and nitrogen exchange from both natural and anthropogenic reservoirs. Preindustrial human activity may have altered these assumed-pristine levels.

At first inspection, the possibility of human impacts on the global environment prior to the advent of industrial technology, with much lower populations than exist today, appears unlikely. It is sobering to recognize, however, that 30–40% of current anthropogenic carbon emissions results from biomass combustion in developing nations (Smith et al., 1993). This is partly from rural household biomass fuel use, which may exceed 1 ton/capita/year (Kammen and Marino, 1993), and open fires in savannas and agricultural fields. Tropical swidden (slash-and-burn) agriculture is also a major source of greenhouse gases today (Crutzen and Andreae, 1990). Such practices have a long history and a wide geographic distribution. Vast areas are today covered by intact forest (e.g., the Maya lowlands of Central America, Cambodia, northeastern North America), areas which were cultivated using fire technology long before Western contact.

Furthermore, expansions in fixed-field agriculture over the past several centuries resulted in dramatic and long-lasting changes in biomass diversity and density that in turn impacted atmospheric aerosol concentrations as well as albedo. Independent estimates of the greenhouse gas emissions for CO₂ and CH₄ in about 1500 A.D. reach 20% and 50% of current levels, respectively (Kammen and Marino, 1993; Khalil and Rasmussen, this volume; Subak, this volume). These calculations are consistent with the discrepancy between atmospheric trace gas concentrations as recorded in the palaeoclimatic record and the box-diffusion models that reconstruct historical concentrations from contemporary atmospheric measurements.

There is growing recognition of the potentially substantial impact of even modest changes in atmospheric chemistry on global environmental parameters, such as might be expected to accompany preindustrial human activity. A recent examination of new Greenland ice cores indicate a variation in CO₂ concentrations over 8–20 year time scales during
the Pleistocene that are correlated with changing atmospheric dust concentrations (Taylor et al., 1993). It is suggestive
that this proxy measure is able to resolve seasonal events, an accuracy that would be required to explore the
preindustrial anthropogenic hypothesis, notably due to agricultural practices. A second impetus comes from recent
reconstructions of temperatures and flood regimes in the period 1250–1450 A.D. from the sediment record along the
Mississippi River. In this record, large variations in flooding can apparently be tied to 1–2 °C temperature fluctuations
and, perhaps more ominously for the anthropogenic model, to 10–20% changes in annual precipitation (Knox, 1993).
Changes in rainfall on tropical islands are a documented result of agricultural expansion, deforestation, and other
human environmental impacts that clearly do not require advanced technology (Grove, 1992 and this volume).

None of this, of course, is roof of global preindustrial impact, but it does suggest a valuable line of research that at
least will clarify a number of useful regional case studies and help evaluate the significance of the "cold-start" or
pioneer effect in global climate models (Fichefet and Tricot, 1992; Robock and Graf, this volume). An improved
understanding of the sensitivity and feedbacks between the global carbon cycle and human activity could also shed
light on the fate of various premodern civilizations, as well as on the possibility that anthropogenic emissions
contributed to the end of the Little Ice Age.

A number of fascinating cultural, social, and political questions follow directly from a recognition that preindustrial
societies developed response strategies to environmental change. The use of fire as a means to shape the environment
was, and still is, practiced throughout the world, e.g., over thousands of years across much of Australia and North and
Central America (see the papers in this volume by Anderson; Lewis; O'Hara et al.; Pyne; and Woodcock and Wells).
In what ways was fire used as a tool to manage biodiversity to meet agricultural and political goals? Over what
geographic and temporal scales did this practice extend? Only very recently have the time scales of ecological change
and recovery become clear (Manabe and Stouffer, 1993). At the same time, the archaeo-environmental record is
expanding: the Chinese dynastic record of climatic events covers more than twenty-one centuries and records
thousands of climatic events (Fang and Xie, this volume), and even European environmentalism seems to have partly
stemmed from observations of deforestation and change in weather on tropical islands (Grove, 1992).

Case studies of preindustrial environmental change and of the feedbacks with social change present an ideal
interdisciplinary connection between climate research and archaeology—an extremely promising confluence of ideas
that is only beginning to be explored. Recognition that climate change occurred due to preindustrial human activity
would dramatically impact contemporary energy and environmental policy (Andrews; Dove; both this volume).
International agreements financing North-South technology transfer, or a "climate convention" to prevent global
warming, all necessitate accurate estimates of the relative national or regional contributions to the global greenhouse
budget. One hotly debated component of the scientific inputs to these discussions is the magnitude and dynamics of
the global sources and sinks of greenhouse gases (Smith, 1991; Hall et al., this volume). Only with an accurate picture
of the human capacity to impact these stocks and flows at numerous scales. Using a variety of technologies, can an equitable protocol to regulate future emissions be achieved.

For example, if emissions from portions of the biosphere, whether mostly managed or mostly natural, are to be included in a nation's greenhouse gas inventory for assigning responsibility in international agreements, it is necessary to establish a baseline from which each nation has deviated. For any one geographical location, however, at what point in history could such a baseline be established, given humanity's long-term and extensive interference with "natural" conditions (Kammen; Smith; both this volume)? Even knowing enough to go back to prehuman times to define such a baseline would not help much, since it would bear little relevance to today's political boundaries and probably reflect a different climate. Such 'accounting' choices are politically crucial because, as Table 1 illustrates, inclusion or omission of specific gases and the history of natural reservoirs of carbon can alter the assessment of pollution arising in the North versus the South from almost a 90/10 to a 50/50 split (Subak, 1993 and this volume).

<table>
<thead>
<tr>
<th>Emissions Category</th>
<th>Source, by nation (%) of total, CO₂ equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Industrialized</td>
</tr>
<tr>
<td>Cumulative CO₂, energy only</td>
<td>86</td>
</tr>
<tr>
<td>Cumulative CO₂, energy and biota</td>
<td>68–80</td>
</tr>
<tr>
<td>Current energy emissions, CO₂ only</td>
<td>72</td>
</tr>
<tr>
<td>Current, CO₂ and CH₄ only</td>
<td>57</td>
</tr>
<tr>
<td>Current, comprehensive</td>
<td>52–57</td>
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</tbody>
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Note: Estimates of greenhouse gas emissions as a percentage of the global total as CO₂ equivalent, from developed and developing nations under a variety of accounting schemes. The range for biota reflects various estimates of land use, while the range for the comprehensive emissions stems from assessments made for a number of different time scales as well as the inclusion/exclusion of CFCs (from Subak, 1993).

Improving our understanding of the impact of energy and, hence, biomass management in nonindustrial societies can also provide a number of critical lessons for development policy in poorer nations. The extent to which historical societies recognized environmental change as a consequence of anthropogenic alterations in regional biodiversity provides a critical landmark for sustainable development. Efforts to disseminate renewable energy technologies or to
couple water conservation and agricultural policy, both of which depend on awareness of environmental elasticity and limitations, can often be clearly discerned in the efforts of historical societies to cope with a changing environment.

REFERENCES


Turner, B. L., et al. (eds.) (1990), *Earth as Transformed by Human Action* (Cambridge Univ. Press, Cambridge UK).