

The Challenge of Human–Environment Interactions Research

During the past decade there has been rapid development of research on the human dimensions of global environmental change. This growth has been a result of several factors. Evidence for climate change, loss of biodiversity, rapid deforestation in the tropics, and an impending crisis in availability of potable water have made scholars and policy makers aware of the need to address the causes and consequences of these global processes. Moreover, it is widely recognized that these cumulative processes vary in their severity from region to region, and from place to place. In order to understand these processes, research for the past decade has supported the breakdown of traditional disciplinary boundaries in order to understand in more systematic fashion the complexities of the current human–environment nexus. While interdisciplinary research is nothing new, there has been considerable progress in identifying some of the dimensions that speak to these contemporary environmental problems.

The chapter begins by examining the mounting evidence for the cumulative nature of global environmental change, and the requirements to begin to scientifically understand it. Scientists working on this issue have come to a nearly unanimous conclusion that we cannot begin to understand global environmental change without a concerted and unified effort that integrates both biophysical and social sciences (NRC 1997a; NSF 2003). Human agency (i.e. actions of individuals) is implicated in most of our current dilemmas, and must play a part in solving them. However, integrating the social sciences and the natural sciences has not been easy, nor has the cacophony of competing theories and paradigms helped to promote collaboration between the social sciences and the natural sciences. This chapter reviews the evidence for the nature of the changes, considers the difficulties in understanding these complex biogeophysical and social processes, provides some history of the development of this interdisciplinary area of study and of global environmental change, and lays the basis for the organization of the rest of the book.

The Evolution of Social Ecological Systems¹

As a species we have relied on our capacity for sociality and communication in order to surpass our physical limitations (Richerson 1977). Our success as a species in spreading and colonizing the planet was through operating as relatively small groups of hunter-gatherers (HG). HGs' advantages were their behavioral flexibility, based on small-group trust and reciprocity, in response to opportunities and their highly mobile strategy of resource harvesting. This strategy served our species well for most of our time on the planet. However, as we grew in population size this strategy began to demonstrate its limitations in providing for an ever larger population. Hunter-gatherers knew about plant reproduction and carried out light management of plants of interest to them long before they began to sedentarize and turn into farmers (Smith 1989).

This first major transformation in social ecological systems, from hunter-gathering to farming, was a result of population increase, growing confrontation of HG bands over resources, and of rising costs and risks of moving into marginal environments. It took a couple of millennia for the transformation from a mostly HG landscape to one increasingly occupied by farming groups (i.e. in North America at least, Smith 1989). Whether famine played a role is not clear from the archeological record. Like many other transformations in social ecological systems, it probably had the shape of the diffusion of innovations (Rogers 1969) with a few adopting the change early, followed by a very slow adoption by others, and finally substantive adoption when the benefits were absolutely clear to most (and the price of nonadoption was dear). The greater density of farming communities allowed them to occupy preferred territories, and HGs increasingly were pushed into marginal areas which could not be cultivated. The keystone features of this new farming mode of production were the evolution of community institutions, shifts in the scope of reciprocity and trust, domestication of plants and animals, and sedentarization. The shift in reciprocity and trust led to features of social cooperation being associated at first with the settlement, and as settlements grew in size to kin-based groupings such as lineages, clans, and moieties. This reduced flexibility in HG systems since the common form of descent was bilateral, meaning that individuals traced their descent from either the paternal or maternal sides, and band membership was highly flexible.

In settled farming communities, control over land through inheritance grew over the years. In order to ensure control over the better land, and eventually over investments such as irrigation and homes, lineal descent

¹ This section is based on an earlier discussion to be found in *People and Nature* (Moran 2006).

(through either father or mother) came into play in order to provide clear forms of inheritance, along with the development of rules of preferred marriage, and even endogamy, to ensure control over resources. Whereas exogamy had been preferred before, and indeed it is a preferable evolutionary strategy from a biological perspective, with the growing importance of land, and accumulated wealth, interest in keeping wealth intact among those already well-off favored intermarriage among favored families. This resulted in extreme cases in caste endogamy, and class consciousness in marriage choice. The deleterious biological impact of this strategy is well known in the genetic aberrations found in some European royal families in the past.

The evolution towards kin-based lineal systems also provided a more rigid form of passing on cultural values, identities, norms, and religious preferences. This process took hundreds of years to occur as groups developed their own combination of workable ways of controlling resources as a function of population density, competition, and resource availability. In areas with great resource patchiness, where control over favorable patches was key to success, the development of sophisticated forms of kin-based control was more rapid given the stakes, whereas in areas with widely distributed resources and patches it was often easier for resource competitors to just move elsewhere and maintain a more flexible and less restrictive set of community rules.

Over time, as agriculture moved from extensive production systems to more intensive systems based on irrigation and eventual mechanization, social stratification, ethnicity, and complex rules for resource use and exclusion came into being. Whereas in the former extensive systems it was a value to share accumulated resources with other less fortunate members of the community, thereby acquiring social capital and prestige, in the latter the amount of shared resources declines, prestige still goes to those capable of concentrating resources but those resources are more sporadically redistributed, thereby increasingly rewarding those who already have more resources and productive capacity or wealth. Control over land becomes the greatest source of wealth, and by extension this provides greater control over labor, as more and more people are not able to control access to land – especially in patchy environments such as semi-arid landscapes.

Boserup (1965) and others (Netting 1968, 1981, 1993) have shown that the most important driver of the intensification implied by the shift from HG to agriculture has been population growth leading to greater applications of technology to production in order to stave off famine and meet the basic needs of growing populations. It is associated with greater competition over resources and the growing need to store supplies for times of scarce resources. The need to store provisions, rather than move to find them, resulted in a shift in how labor was invested, and in the settlement pattern of peoples worldwide.

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As these populations grew more numerous, chronic warfare ensued as groups competed for the best soils and the prime spots along the river or mountain, and sought ways to recruit more members to their communities. In a world of hand-to-hand combat, having strong and numerous men to field was the top determinant of success in holding onto territory. Over time, some groups developed from single village communities into networks of communities, and chiefdoms emerged that provided some capacity to mobilize larger social units when any of their member communities was threatened. The evidence is quite substantial that, as human communities grew more successful in production, the temptation was great for other communities to take away their accumulated wealth (often in the form of grain or animals). As in the shift from HG to extensive cultivation, the shift from extensive cultivation to intensive cultivation appears to have been driven by population growth putting too much pressure on resources (Boserup 1965; Netting 1993). One study showed that a given area of irrigated land could support 14 times as many families as it could under shifting cultivation (Palerm 1968; Spooner 1972). However, another explanation offered by scholars has been that this intensification was forced upon people either by external domination and colonialism (cf. Geertz 1963) or by internal domination brought about by elites wishing to control land resources for their own political and military objectives (Demarest 2004).

Associated with farming populations one often found pastoralists, occupying land unsuitable for cultivation. In some cases, they represented segments of ethnic farming populations, in other cases they represented other ethnic groups. Pastoralist social organization shows much greater flexibility than other forms of subsistence because of the flexible nature of managing animals. Sometimes it is possible to gather people and animals in areas when rain is abundant and pasture is rich, but for at least half of the year or more, the drying of the savannas results in scattering of people and animals. This scattering would put these populations at risk if it were not for mechanisms such as segmentary lineages that allow segments of large lineages to call upon others to come to their assistance in times of trouble. Thus, pastoral societies have developed an impressive capacity to field armed men to defend their animals and people – and then to return to a very scattered and apparently disorganized pattern of moving to find the best forage (McCabe 2004). It is a remarkable example of social self-organization that results in politically sophisticated outcomes. Farmers and pastoralists maintained an uneasy truce and trade relationship over the years, and there are well-documented cases of pastoralists becoming farmers and vice versa under favorable conditions.

It was just a matter of time, and opportunity, for people to have their growing villages develop into larger and more complex entities that we have

come to call cities. Urban areas provided a site for trade, for the exchange of information, for specialists in a large number of skills to meet the needs of a more technologically intensive society, and for redefining the nature of social ecological interactions. The rise of urban centers is most commonly associated with irrigation and the rise of complex water control. As these systems grew in size and complexity, breakdown became more common and more costly. In time, when they had grown to pharaonic proportions, the systems could collapse when either information or climate, or both, were beyond the capacity of managers (Butzer 1976).

If the rise of cities and a growing network of linked villages into states proved to be a considerable source of disturbance in social ecological interactions, imagine what happened with the rise of that technological wonder that is the industrial revolution. Cities are symptomatic of human transformation of social ecological systems: they are creative centers where some of the best and brightest of every society are concentrated to develop the arts, technology, education, science, and commerce. Yet, they are also often chaotic, with erosion of social controls, and distant enough from day-to-day realities of environment to ignore environmental feedbacks for a very long time. That is because urban areas have too many layers of information between the environment and the decisions managers take – who are motivated by many other incentives than just ensuring good environmental management: political pressures, mis-valuation of the resources, self-interest, and corruption (see discussion of urban ecology in Moran 2007, ch. 10).

The industrial mode of production² is accompanied by major technical innovations that also result in a reorganization of the division of labor (Schnaiberg 1980). The industrial revolution's larger environmental impact is the product of discovering the use of fossil fuels. First, and for a very long time, this involved only the use of coal. Oil and natural gas came much later. In using fossil fuels humans did not have to compete with any other animal species to use the resource, as we had often had to do with the use of plants (herbivores) and animals (carnivores). This would seem to be a win–win situation, and it certainly allowed for an enormous increase in the amount of energy that humans could harness for productive purposes. Unfortunately, the exploitation of the huge amounts of fossil fuel materials stowed away for geologic periods of time in subterrestrial sinks and the launching of the by-products from their use into the biosphere, kicked off biogeochemical changes in the atmosphere that took a couple of centuries to be felt and which now threaten our planet. But these changes were not entirely surprising. Local and regional consequences of the use of

² Mode of production is used in the anthropological meaning of the term, rather than Marx's usage.

fossil fuels were felt early on: the nineteenth century fogs of industrial cities like London, with serious health consequences for people living in these locations being the most recognized. While the rich could escape to their rural estates to breathe fresh air, the poor in the cities grew sick from the constant exposure to foul air. Social stratification, along with the use of police and power to maintain this mode of production with its high human and environmental costs, took place then and continues into the present, as developing countries industrialize with similar consequences (e.g. the current urban pollution in China's industrial centers). The result has been a growing loss of trust and the virtual extinction of reciprocity except in the bosom of families, growing disparities between people in wealth and access to resources, an increase in the amount of time spent working, and a growing emphasis on consumption to support the productive capacity unleashed on the planet (see Moran 2006 for an extended examination of this issue).

In short, over a period of 400 generations, or 10,000 years, the human population has grown from a few million to more than 6 billion. This growth has taken place quickly in recent decades, and has changed the nature of how we deal with each other (Raven 2002). The biggest shift has been since World War II and is connected to rising living standards and rising consumption levels for materials and energy. This compounding of population and consumption is recent and without precedent. Human populations do not respond in homogeneous ways to the environment, or anything else. Human society and culture is characterized by high diversity, and in the past this has gone along with biological diversity. The number of people who live by hunting-gathering today is shrinking, and most of them are connected to the global economy to some degree. Horticultural populations (i.e. extensive farmers using slash-and-burn methods mostly) still constitute significant populations in rural areas of developing countries – and among those in developed countries who seek to return our food production system to more organic methods. The latter is a fast and expanding movement that questions the industrial mode of food production and seeks to return to more organic ways to take care of the land and produce the food we need. Pastoral peoples have been under pressure for decades to abandon their migratory ways, but they still constitute an important component of how grasslands are managed, despite efforts to block the routes of their movements. Intensive farming is growing ever more intensive, now including genetic modification to a degree that has not been seen before. These shifts in the relationship of people to the environment constitute the fundamental questions that drive environmental social science and human–environment interactions research. With the growing recognition of the human dimensions of contemporary global environmental change this area of study has grown rapidly.

Characterization of Contemporary Global Environmental Changes³

The present condition of our planet is worrisome to those who pay close attention to the evidence. More and more species are becoming endangered or going extinct. Wetlands are disappearing at a rapid rate, endangering the migration routes of birds, and the maintenance of local and even intercontinental biodiversity. Unprecedented levels of CO₂ threaten our climate system, coral reefs, and the Greenland and Antarctic ice sheets. Pollution levels in a growing number of cities can only be called toxic for human health. The story goes on, giving cause for considerable alarm. There is very little evidence that governments are succeeding in implementing concrete strategic policies which ensure a sustainable earth system. Everyone talks about sustainability, but fails to implement measures to reduce our downward spiral, and we fail to even define what sustainability means or how we can begin to get on a sustainable path.

What is not widely recognized is that we have in the past 60 years changed nearly every aspect of our relationship with the environment. The Industrial Revolution began some 300 years ago, and since then, the impact and the pace of our impacts on the earth have been gradually increasing (Turner et al. 1990). Yet, the impact in the past 300 years pales by comparison with our impact in the past 60 years. We have no equivalent experience in our entire history or prehistory as a species.

Burning fossil fuels results in emissions of vast amounts of carbon dioxide and other earth-warming gases that are changing the atmosphere, the productivity of terrestrial vegetation, and are at the highest levels known over the past 400 millennia. More nitrogen fertilizer is applied in agriculture than is fixed naturally in all terrestrial ecosystems (Crutzen 2002). Fishing fleets have depleted the stock of many species, removing more than 25% of the primary production in upwelling ocean regions (Crutzen 2002), and the catches are collapsing. Irrigation and other alterations of surface and underground water are increasing the vulnerability of hydrologic systems and the people that depend on these precious water sources (Crutzen 2002). Agricultural activities have resulted in massive deforestation and alteration of land cover at huge scales – with the amount of land devoted to agriculture increasing fivefold over the past three centuries (Lambin and Geist 2006). In short, human activities are so pervasive that they are capable of altering the earth system in ways that could change the viability of the very processes upon which human and nonhuman species depend.

³ This section is based on an earlier discussion to be found in *People and Nature* (Moran 2006) and Steffen et al. (2003).

Both data and information at global scale are now abundant in alerting us to the magnitude and seriousness of the processes we have unleashed. This evidence tells us of exponential increase in carbon dioxide, exponential rates of ozone depletion and nitrous oxide concentrations in the atmosphere, rapid losses in tropical rainforests, increases in the frequency of natural disasters and in the rate of species extinctions. The same can be said for fertilizer consumption, damming of rivers, water use, paper consumption, the number of people living in cities, and the number of motor vehicles (Steffen et al. 2003). There has also been a steady increase in the last 60 years in the incidence of armed conflict worldwide (Kates and Parris 2003:8062). In 1992, one third of the world's countries were involved in such conflicts, and in that year 40 million refugees and displaced persons were affected by armed conflicts (ibid). These figures do not include the growing globalization of both terror and crime beyond state borders. Some have described this growing conflict in terms of “the coming anarchy” and as a “clash of civilizations” (ibid.). These numbers have increased severalfold since then.

The exponential increase in all these measurable phenomena is tied to the increase in the human population, and to our consumption habits. Indeed, one must think of these two factors in tandem. One Euro-American citizen consumes 25 times the resources that one average citizen from India, Guatemala, or other less developed countries does (Redclift 1996; Wernick 1997). While birth rates have steadily declined to replacement level or even below in developed countries, these populations continue to impact the earth's resources far more than the larger populations in developing countries. Both developed countries and developing countries have a huge impact on the environment, the former through consumption, and the latter through population increases. Some developing countries have now succeeded in reducing rates of growth (e.g. Brazil is now at, or below, replacement).

In all societies one sees conflicting cultural values. Europe has similar traditions to the USA in a number of regards (e.g. democratic institutions, capitalism) but it does not value individualism above the common good. This has made it possible for Europe to accept more quickly than the US the proposed reduction of carbon dioxide in the atmosphere to 1992 levels and thus to support the Kyoto Protocol on the emission of greenhouse gases. A profound rift between the more advanced nations of Western Europe and the USA has developed over the willingness of the former to set limits on carbon dioxide emissions, and the unwillingness of the US to do so. (Nevertheless, we must remember that even West European countries have had difficulty meeting the Kyoto greenhouse gas emission targets.) The use, and misuse, of the earth's resources is at the very center of international negotiations, the global political economy, and the fate of nations. These negotiations require an understanding of both environmental science, and social

science – and thus the need for integrative science that can address the biophysical and the social dimensions of human–environment interactions.

The Cartesian dichotomy between humans and nature is a peculiar notion in Western society. Most peoples in the world see humans as very much a part of nature. In its more extreme forms it takes the form of ideologies where we are reincarnated in forms other than human (i.e. plant, animal), and vice versa. Mythologies across the globe have always pointed to the close connection in both origin, and continuity, between animals in nature and us; between the plants in the landscape and our spiritual and material lives (Pretty 2002:13). Australian Aborigines' Dreamtime embodies these beliefs, for example, in how the land came to be, how closely they are still connected to these ancestors, and why the land must be respected – that it belongs to no one, but that it belongs to everyone. Today we even know that we are closely tied to our primate ancestors, with over 90 percent of our DNA shared with them, yet we insist in our philosophical stances, and behavior, to act as if we hold a place above the rules that govern the rest of the species on the planet.

One of the challenges we must face is rethinking how we view the environment. Dichotomous thinking led us to think of people as apart from nature, and charged with controlling nature for human purposes – and crucially, as distinct from the inherent dynamics of the earth system itself. It is from this error that a lot of our post-World War II spiral towards self-destruction comes. What happens to the air we breathe, the water we drink, and the land upon which we depend for our food matters. If we take care of it, it will nurture us – and if we damage its capacity to provide us with sustainable goods and services, and the comfort of aesthetic beauty, we will put ourselves at risk. We cannot do this alone, but it must be a partnership of trust in human communities bound by covenants that favor life over material accumulation, that favor dignity for members of the community and the pleasures of taking care of each other, and nature, as the highest good. We need to reconceptualize our relations with each other, and with nature – and to think of human agents as organic parts of nature (for more detailed discussion see Moran 2006).

Figure 1.1 illustrates what is happening in the realm of human process variables –and it raises a number of concerns. Population has been increasing rapidly since 1750 but it has gone exponential since 1950, and shows very little sign of leveling off in the next 30 to 40 years. In the past 60 years we have gone from 2.5 billion to 6 billion people. In less than 30 years the human population will be in excess of 10 billion. Total Gross Domestic Product, foreign direct investment, damming of rivers, water use, fertilizer consumption, urban population, paper consumption, and the number of motor vehicles, have all jumped exponentially since 1950, with no evidence of a turnaround in this upward increase. This increase would be enough

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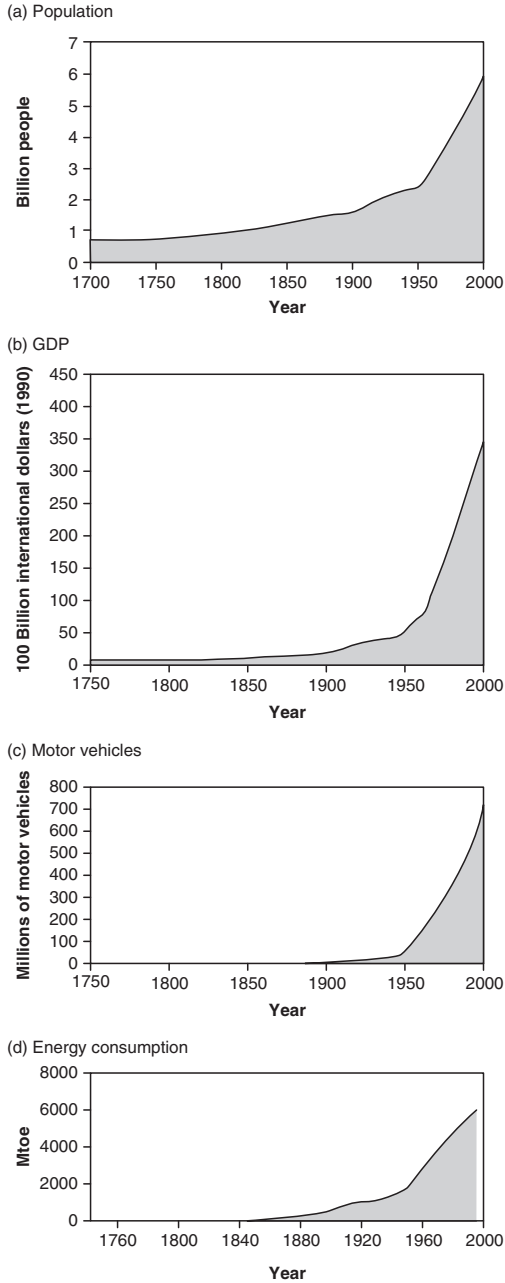


Figure 1.1 Rate of increase in several spheres of human activity for the past 300 years: a. population (US Census Bureau 2000); b. world economic GDP (Nordhaus 1997); c. motor vehicles (UNEP 2000); d. energy consumption (Klein Goldwijk and Battjes 1997)

Source: Steffen et al. 2003

cause for concern if it were happening in one or two of these measurable areas, but it is happening in all simultaneously.

As if this were not enough reason for concern, similar synchronous events are happening on the biophysical side (see Figure 1.2): CO₂ concentrations, N₂O concentrations, CH₄ concentrations (all three of them earth-warming gases), ozone depletion, Northern Hemisphere average surface temperatures, the number of natural disasters, the rate of loss of fisheries, the increase in nitrogen fluxes in coastal zones, the rapid loss of tropical rain forests and woodlands, and the number of species gone extinct have all gone exponential since 1950. While some might argue, for example, that there is evidence that CO₂ concentrations are actually beneficial to many plants and can result in enhanced productivity, experimental studies have shown that increases in productivity when CO₂ concentrations are up to a certain level (e.g. 56 Pa) can take place but that these gains are lost when concentrations go higher (e.g. to 70 Pa), at which time there is a steady decline in productivity (Granados and Korner 2002). There are also notable differences in how different species and types of forest vegetation respond to CO₂ enrichment (Norby et al. 2002). There is very little positive light that can be found in these measures going exponential. Are thresholds about to be crossed from which systemic collapses can ensue?

One of the most troubling changes in the planet has been the human alteration of the global nitrogen cycle. We know with a high degree of certainty based on available scientific evidence (a) that we have doubled the rate of nitrogen input into the terrestrial nitrogen cycle and that these rates are still increasing; (b) that increased concentrations of the greenhouse gas N₂O globally, and other oxides of nitrogen, drive the formation of photochemical smog; (c) that this nitrogen increase has caused losses of calcium and potassium from soils, essential for soil fertility; contributed to the acidification of soils, streams, and lakes; increased the quantity of organic carbon stored in terrestrial ecosystems; and accelerated losses of biodiversity, particularly plants adapted to efficient use of nitrogen (Vitousek et al. 1997).

Surface temperatures over the Northern Hemisphere at present are warmer than at any other time over the past millennium, and the rate of warming has been especially high in the past 60 years (Hurrell et al. 2001:603). Agricultural yields, water management, and fish inventories are affected by this warming – having as it does its origin in an upward trend in the North Atlantic Oscillation, dictating climate variability from the eastern seaboard of the US to Siberia and from the Arctic to the subtropical Atlantic. Changes in the North Atlantic Oscillation, in turn, affect the strength and character of the Atlantic THC. Climate changes can have profound effects on society as suggested by recent research suggesting that the lowland Maya collapse was associated with an increase in droughts in Yucatan resulting

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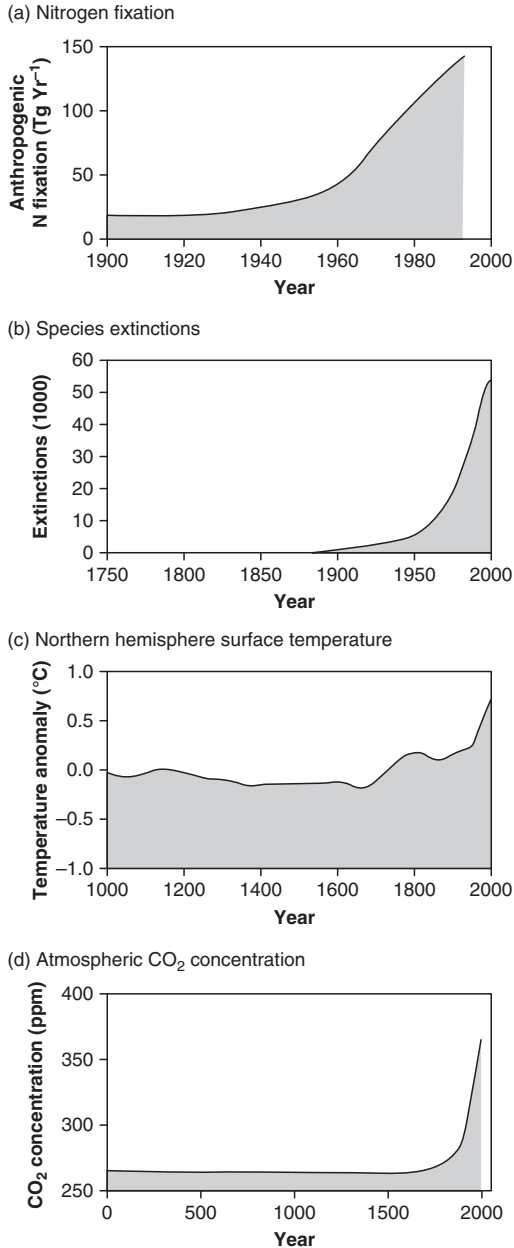


Figure 1.2 Rates of increase in several spheres of the earth system: a. nitrogen fixation (Vitousek 1994); b. species extinction (Smith 2002); c. northern hemisphere surface temperature (Mann, Bradley, and Hughes 1999); d. atmosphere CO_2 concentrations (adapted from Keeling and Whorf 2000)

Source: Steffen et al. 2003

from bicentennial oscillations in precipitation (Hodell et al. 2001). The Maya were dependent on rainfall and small water reservoirs for the sustainability of their agriculture, and these multidecadal and multicentury oscillations in precipitation probably exacerbated other challenges faced by the Classic Maya (Demarest 2004). One of the conclusions of recent climate change studies is not that it will be warmer everywhere but, rather, that we will see more extreme events more frequently, such as the occurrence of El Niño events – with drought in some places and flood in others (Caviedes 2001). In Brazilian Amazonia there is already serious concern with the increased frequency of devastating fires entering into Amazonian forests as a result of El Niño. In 1997 climate scientists and ecologists were in agreement that the droughts associated with that El Niño were responsible for a fire that consumed 13,000 square kilometers of forest in just one location. We know of similar vast fires during the 1982–3 El Niño over Borneo (Prance 1986:75–102) and of devastating fires in the Amazon 250–400 years ago (Sanford et al. 1985).

We know that climate change will increase the severity of population and species declines, especially for generalist pathogens infecting multiple host species. The most detectable effects relate to geographic expansion of pathogens such as Rift Valley fever, dengue fever, and Eastern oyster disease. While other factors are surely implicated, such as land-use change, there is very little doubt in the end that warming trends will affect crop and human diseases (e.g. potato late blight; rice blast; cholera, and Rift Valley fever) (Harvell et al. 2002). Climate warming is also expected to alter seasonal biological phenomena such as plant growth, flowering, and animal migration (Penuelas and Filella 2001). Some Canadian tree species (e.g. *Populus tremuloides*) show a 26-day shift to earlier blooming over the last century, and biological spring in Europe is about 8 days earlier from data for the period 1969–98 (ibid.). In the Mediterranean, leaves of deciduous plant species now unfold 16 days earlier and fall on average 13 days later than they did 60 years ago (ibid.).

In short, the simultaneous and interconnected nature of these changes in human and in environmental conditions since 1950 suggest that human activities could inadvertently trigger abrupt changes in the earth system with consequences that we can only faintly imagine. The most troubling of all is, of course, triggering a disruption in the “oceanic conveyor belt,” as it is called, which regulates world climate (Broecker 1991). The increases in greenhouse gases can trigger changes in the North Atlantic circulation and computer simulation results have most of the scenarios resulting in rather dramatic collapses. We know already that the Atlantic Thermohaline Circulation (THC) can have multiple equilibria and multiple thresholds, that THC reorganization can be triggered by changes in surface heat and in freshwater fluxes, and that crossing thresholds can result in irreversible

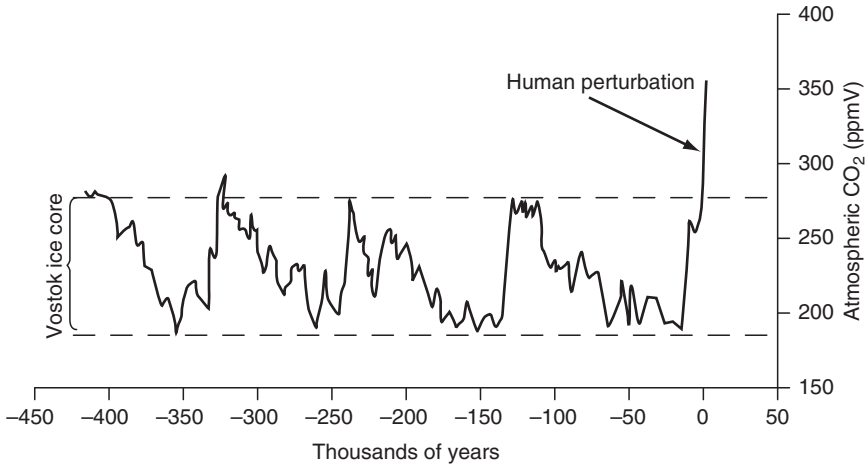


Figure 1.3 Vostok Ice Core provides the best current record of carbon dioxide changes for the past 420,000 years

Source: Petit, Jouzel, and Raynaud 1999 as modified by Steffen et al. 2003

changes of ocean circulation (Rahmstorf and Stocker 2003). Our current situation with regards to CO₂ alone, not to mention all the other earth-warming gases being emitted exponentially, is well above the experience of the past 420,000 years as recorded in the Vostok Ice Core (see Figure 1.3).

The evidence for the seriousness of climate change was affirmed at a meeting of members of 63 national academies of science from all parts of the world, affirming support for the work of the Intergovernmental Panel on Climate Change (IPCC) which says that it is at least 90 percent certain that temperatures will continue to rise by at least 5.8 degrees Celsius above 1990 levels by 2100, and urging prompt action to reduce emission of greenhouse gases (IPCC 2000). In their joint statement, the representatives of the 63 national academies of science concluded that “the balance of the scientific evidence demands effective steps now to avert damaging changes to Earth’s climate.” (Interacademies 2000).

The past 60 years have been devastating to the earth system’s functions. These changes have been of sufficient magnitude to rival climate change in both environmental and social terms (Vitousek et al. 1997; NRC 1999a, 1999b). During the first 50 years of the twenty-first century, demand for food and other commodities by a wealthier and larger global population will be a major driver of global environmental change (particularly from the BRIC countries, Brazil, Russia, India and China). While some of this change may come from more intensive and efficient agricultural production, much of it will come from converting further land areas and natural ecosystems

into agricultural fields. This will result, at least, in a 2.5 increase in the amount of nitrogen and phosphorus making its way into terrestrial freshwater and near-shore marine ecosystems resulting in unprecedented eutrophication and habitat destruction (Tilman 2001). Much of the nitrogen and phosphorus from fertilizers and animal wastes enters surface and groundwater untreated and unimpeded to any significant extent (Tilman et al. 2001). The result is eutrophication of estuaries and coastal seas, loss of biodiversity, changes in species composition, groundwater pollution, and tropospheric smog and ozone. The projected conversion of up to 1,000,000,000 hectares of natural habitat to meet our expected demand for food is viewed as conservative.

For most of the 400 generations that we have been farming, production and consumption of food has been intimately linked to social and cultural systems, to systems of beliefs, and respect for the environment. Foods were given special meaning, and were surrounded with ritual. First crops harvested were treated with deference and gratefulness. We still see some of these practices in some ethnic rural populations, and even in an industrial superpower such as Japan, particularly in relation to traditions regarding rice. Japan's rice paddy fields are carefully maintained, even by those who hold other employment as their main means of support, and all special occasions include rice dishes as ways of connecting people to this basic staple and giving it importance. Rivers and mountains embodied the divine and the forces of creative and destructive nature that were respected. Over the past three generations we have changed this respect for the environment in too many places. Industrial agriculture has steadily replaced family farms worldwide, and, while this seems to produce a lot more food in absolute terms, it does so at huge cost in terms of loss of soils, damage to biodiversity, pollution of the air and water, and negative impacts on human health through heavy use of chemicals (Pretty 2002:xii). Industrial agriculture, in an age of cheap fossil fuels, was able to ship produce across large distances and drive local producers out of business. In a future world, where fossil fuel will be increasingly dear, we will need to redesign whole systems of food production, more directly linking those who grow food to those who consume it, using methods that have a lighter impact on the environment, and in which the land takes on, once again, the nurturing value that it had for most of human history.

In the past 35 years, we were able to double food production but we did so with a sixfold increase in nitrogen fertilization, a threefold increase in phosphorus fertilization, and a substantial increase in the area under cultivation (Tilman 1999). Another doubling of food production would result in a threefold increase in nitrogen and phosphorus fertilization and an increase of 18 percent in cropland cultivated. These increases will further eutrophy fresh and marine ecosystems, leading to biodiversity losses, shifts in the structure of the food chains, and impairment of fisheries (Tilman 1999).

History of the Development of the Human Dimensions Agenda⁴

Until 1988, the study of global environmental change was carried out largely by earth science disciplines such as meteorology, atmospheric chemistry, atmospheric sciences, and geology. The focus of this work, under the aegis of the International Geosphere-Biosphere Programme (IGBP), was on documenting the extent of biosphere change and projecting at global scale the likely consequences of changing atmospheric conditions on the earth. Modeling, particularly global circulation models (GCMs), were heavily used given the absence of many important data points and the ambition of understanding the global environment – but scientists also identified, and lobbied for, research in areas needed to better run the GCMs. Among the many achievements of this effort, for example, was the creation of a vast network of buoys in the earth's oceans to measure changing temperatures. Over time they led to the current ability of atmospheric and marine scientists to forecast El Niño and La Niña events many months in advance of human populations feeling their terrestrial impact. Scientists accurately predicted the onset of the 2002–3 El Niño Southern Oscillation almost a year in advance, and farmers in many locations modified their planting behavior, thereby reducing economic losses and human misery. This is done by observing the warming or cooling of the waters over the northern Pacific and following its circulation around the globe. But something was missing. The coarse spatial scale of these early GCMs did not allow for any meaningful role for what human behavior does within the earth system, which ran at very coarse spatial (several degrees of latitude) and temporal (decades to centuries) scales with broad assumptions like what might happen if all tropical forest cover were removed and replaced by pasture. While the results of such models were informative, they rarely included adaptive behavior on the part of humans, who are likely to desist from the total elimination of tropical forest cover by information dissemination and feedback processes.

At the request of scientists associated with the International Geosphere Biosphere Programme (IGBP), the International Social Science Council (ISSC) was asked to consider assembling a working group to develop a human dimensions (social and economic sciences) agenda to parallel the ongoing work of atmospheric and climate scientists working on global environmental change. The ISSC met and recommended that it would be desirable to begin to create national panels to undertake such a discussion and write up research plans that would articulate well with the IGBP research. This led to the creation of a group parallel to the IGBP, named Human

⁴ This section is based on an earlier discussion in Moran (2005).

Dimensions Program (HDP), composed of a panel of social scientists from around the globe to discuss how best to proceed. In the USA, both the National Research Council (NRC) and the Social Science Research Council (SSRC) created expert panels of scientists to discuss research priorities for the human dimensions as well.

The obvious changes in our global environment led first to the creation of a network of scientists to address these globally scaled processes. The International Geosphere Biosphere Programme (IGBP) was started in 1987 because of the need for an international collaborative research endeavor on the phenomenon of global change. A Special Committee was appointed to guide the planning and initial implementation of the program. The planning phase ran from 1987 to 1990 and involved about 500 scientists worldwide. This community of climate and atmospheric scientists, in turn, turned to the social sciences in 1988 and asked them to join them in an effort to understand the human dimensions of global environmental change (NRC 1999a, 1999b). This agenda began to be formulated in 1992 with the National Research Council's book, *Global Environmental Change: Understanding the Human Dimensions* (NRC 1992), which set the early agenda for research in this area. The early research on global change had focused on climate change, biodiversity, pollution, and international environmental agreements driven by a growing awareness of global impacts such as accumulation of earth-warming gases, the appearance of an ozone hole changing the amount of ultraviolet (UV) radiation people receive, and documentation of glacier meltdowns. Current trends are expected to continue to have cumulative effects on the atmosphere and climate change (NRC 1998b; Hunter 1999; Potter 1999).

“Human dimensions research addresses the workings of social systems that manage environmental resources – markets, property rights regimes, treaties, legal and informal norms, and so forth – and the potential to modify those institutions through policy and thus to mitigate global change or increase adaptive capability” (NRC 1999b:5). The first issues identified in 1992 as needing urgent attention and research priority were: (1) understanding land-use and land-cover changes; (2) understanding the decision-making process; (3) designing policy instruments and institutions to address energy-related problems; (4) assessing impacts, vulnerability, and adaptation to global changes; and (5) understanding population-and-the-environment interactions.

A great deal was accomplished in the years that followed, focusing on the causes, consequences, and responses of human populations to global environmental change (NRC 1999b). Advances were particularly notable in the study of land-use and land-cover change which had been defined as the topic that the research community was most ready to undertake (see some of the syntheses produced from this effort in Gutman et al. 2004; Moran

and Ostrom 2005; NRC 2005a) to understand human responses to climate events (NRC 1999c; Moran et al. 2006; Galvin et al. 2001; M. Guttman 2000). Human dimensions of global change became an important priority at the National Science Foundation (NSF), the National Oceanic and Atmospheric Administration (NOAA), the National Aeronautics and Space Administration (NASA), and the Social Science and Population Program at the National Institute for Child Health and Human Development (NICHD).

New priorities have been identified that place human–environment research even more at the center of research on global change. One important reason is that there is growing evidence that socioeconomic uncertainties are greater than biophysical uncertainties, for example in the study of climate impacts (NRC 1999c:1). Major sources of changes in the global atmosphere come from human activities, such as deforestation and energy consumption. Studies showing that tragedies of the commons are not inevitable but are, rather, the product of how humans organize themselves to respond to perceived threats to their well-being further strengthen the case for the importance of human–environment interactions research. Since 1992, the field has evolved and a new set of research priorities have emerged. For the first decade of the twenty-first century several research questions have been identified:

- 1 Understanding the social determinants of environmentally significant consumption (NRC 1997a; Moran 2006);
- 2 Understanding the sources of technological change;
- 3 Making climate predictions more regionally relevant and accurate (NRC 1999c);
- 4 Improving how human populations can better respond to environmental surprises;
- 5 Understanding the conditions favoring institutional success or failure in resource management (Ostrom 1998, 2005);
- 6 Linking land-use and land-cover dynamics to population processes, especially the role of human migration (Moran and Ostrom 2005; NRC 2005a; Lambin and Geist. 2006);
- 7 Improving our understanding of human decision-making (Moran et al. 2006; Brondizio and Moran 2008);
- 8 Advancing capacity to make social science data spatially explicit (NRC 1998a; Goodchild and Janelle 2004).

Interestingly, the SSRC, the NRC, and the HDP quickly came to agreement that the research area which would best articulate with the work of IGBP, and to which social scientists could make the strongest contributions in the short term, would be the study of land-use and land-cover change. The logic was that there was a preexisting community in the social sciences concerned

with cultural ecology, agrarian studies, and agricultural and resource economics whose work approximated the likely areas of interest of a land-centric research program. This led to the creation of the Land-Use and Land-Cover Change core project (LUCC), a joint activity of IGBP and HDP, with support from groups such as SSRC and NRC. A panel of scientists began to meet that produced over the next several years a Science Plan to guide the work of the international community (Lambin et al. 1999). The Science Plan had several major science questions that they deemed central to the core project:

- How has land cover changed over the last 300 years as a result of human activities?
- What are the major human causes of land-cover change in different geographical and historical contexts?
- How will changes in land use affect land cover in the next 50 to 100 years?
- How do immediate human and biophysical dynamics affect the sustainability of specific types of land uses?
- How might changes in climate and biogeochemistry affect both land use and land cover?
- How do land uses and land covers affect the vulnerability of land users in the face of change and how do land-cover changes in turn impinge upon and enhance vulnerability and at-risk regions?

Similar but varying in some degree were research priorities defined by the NRC and SSRC. The first major guiding document to appear from these expert panels was the “rainbow book,” *Global Environmental Change: the Human Dimensions* (NRC 1992). This book defined a broad set of priorities that identified land-use and land-cover change as the top research priority but that listed in detail other important questions that deserved attention, such as environmental decision making, integrative modeling, environmental risk analysis, and studies of population and environment. Many of the recommendations of this book served as guidance to funding agencies, and have since that time been implemented – such as the creation of human dimensions centers of excellence by the National Science Foundation, land-use and land-cover change research programs at NASA; human dimensions of global change programs at NOAA; and population and environment programs at NICHD.

The following year, the NRC published a smaller and more accessible document entitled *Science Priorities for the Human Dimensions* (1993). This document reaffirmed the priorities of the 1992 book and a couple of new areas of interest: land-use and land-cover change, decision-making processes, energy-related policies and institutions, impact assessment, and

population dynamics. By 1995 the National Science Foundation announced a competition for national centers of excellence on the human dimensions of global environmental change.

Since that period considerable advances have taken place. These are summarized at some length in an NRC volume: *Global Environmental Change: Research Pathways for the Next Decade* (1999a). The Human Dimensions Programme became the International Human Dimensions Programme (IHDP) in 1996 when it moved from Geneva to Bonn, Germany. IHDP has played a growing role in coordinating the work of national human dimensions panels, and creating IHDP-based research groups on the Institutional Dimensions of Global Environmental Change, and the Environmental Security and Vulnerability group.

One of the important activities of the LUCC program has been to stimulate the generation of syntheses of what we know about LUCC processes, such as tropical deforestation (e.g. Geist and Lambin 2001, 2002; Lambin and Geist 2006), agricultural intensification (McConnell and Keys 2005), and urbanization, to provide input to a larger synthesis for earth system science (Steffen et al. 2003). These efforts at synthesis rely heavily upon the scholarly community working on issues of land-use and land-cover change.

Other interesting research areas in the human dimensions of global change agenda include: social dimensions of resource use; perception of environmental change; how people assess environmental changes and environmental risks; the impact of institutions; energy production and consumption; industrial ecology; environmental justice; and environmental security. In 2001 an expert panel from the National Research Council came up with eight *Grand Challenges in the Environmental Sciences* that defined key priorities (NRC 2001). The eight priorities share one common denominator: they require joint work by biophysical and social scientists. A similar recommendation came from the National Science Board which developed similar but not equivalent priorities and also gave multidisciplinary across the biophysical and social sciences a strong nod.

Characteristics of the Research on the Human Dimensions

Research on the human dimensions differs from disciplinary research in a number of ways. Global change research must be inherently multidisciplinary given the complexity of factors that must be taken into account. No discipline offers an adequate array of theories, methods, and concepts to provide integrative modeling (see Chapters 2 and 3, this volume). Because it is global, the work must be multinational in scale, otherwise one is likely to erroneously think that what one sees as processes in one country applies to the globe. This forces an agenda oriented towards comparative research

wherein one must collect comparable data in a number of nations and regions so as to sample the diversity of biophysical and social processes (Moran and Ostrom 2005). Because the earth is such a complex entity, this means that the work must be spatially explicit so as to be able to anchor the work precisely on the earth's surface and understand what is site specific from what is generalizable (see Chapter 4). Because the agenda is driven by a concern with changing dynamics, the work must be multi-temporal and have some historical depth. The depth will vary with the question and processes of interest, so that some scientists operate in temporal scales of millennia (paleoclimatologists and palynologists), while others work in terms of centuries and decades (e.g. historians, ecologists, social scientists). Because disciplines' methods vary, it is likely that processes examined vary not just in time and spatial scales but also in scale of analysis (from local to regional to national to global; see Chapter 5). It is well known but rarely analytically addressed that explanations for processes vary by the scale at which they are studied. Thus, specificity of what scale is being explained is essential, but also it is necessary for each analysis to make an effort to scale both up and down from the scale of interest so that the effort and investment is useful to other scientists in the community working at other scales. Finally, because the work is about an impending environmental crisis of global, and local, proportions, the work must keep in mind the relevance and importance of the research in informing policies which might reverse current negative outcomes and favor sustainability of human–environment interactions (see Chapters 6, 7, and 8).

Participation in human dimensions research offers a number of advantages to the advancement of theory, particularly theories on human–environment interactions. The questions posed by the human dimensions agenda are new questions that reach beyond traditional disciplinary concerns and thus extend the value of social science and natural science to all of society. The disciplines bring important theories to this kind of research: anthropology and geography have contributed cultural ecology and political ecology, which remain important paradigms in understand human use of resources. Biology and ecology have contributed ecosystem and evolutionary ecology. Political science has contributed theories about institutions and collective action. Unlike traditional disciplinary research, however, human dimensions research demands a multi-scaled approach. This is rarely the case with discipline-based research and is thus a broadening of the way the social sciences can contribute to the understanding of the world around us. The work on human dimensions links the biological, physical, and social sciences, thereby making social sciences centrally important not only to other social scientists but to the rest of the sciences. It is important to recall that it was the physical sciences that recognized the role of human actions and that felt the need to encourage the social science community to join

them in an effort to understand global environmental changes. While a lot remains to be done to achieve this integration, there has been progress.

Work on human dimensions requires comparison and multidisciplinary approaches. This offers the potential for more robust tests of the applicability of site-, region-, or nation-specific findings. By testing things cross-nationally, cross-regionally, and cross-locally, the results are more likely to be robust and theory strengthened. The human dimensions research agenda challenges most of the social sciences (except geography, which already is sensitive to this) to develop new spatially explicit ways to select cases for comparative analysis, to determine sampling frames in a spatial context, and to model results that are spatially informed. This is true as much for the social sciences as for ecology, which only now, too, is developing spatial ecology as a field of study and thereby revolutionizing the way we think about population ecology and community ecology (see Chapter 4).

Undertaking these challenges is an awesome task. It requires that we work in large teams of scientists, rather than work alone as is more common in the social sciences. As noted earlier, the work should be multinational, multidisciplinary, multi-scale, multi-temporal, spatially explicit, and policy relevant. To be successful, it requires that we leave our “weapons” at the door, that we choose the right tools, theories and methods for the question that is being asked (without regard for what discipline it comes from). The goal is to pick the right one for the job at hand, even if it means that team members will need to learn all sorts of new approaches that were not part of their earlier academic training. It is a challenging and exciting task, one that ensures continuous growth in one’s skills and perspectives, an open approach to research, without sacrificing rigor, and ensuring that the research speaks to the questions society needs answers to, and not just to the academic scientist.

The Way Forward: Integrative Science

In order to advance the state of the art, there is a need to engage all of the social sciences in multidisciplinary research, jointly with each other and with the biophysical sciences. In this enterprise, integrative science approaches have much to offer. Anthropologists and geographers bring to the analysis of global change two main contributions; first, both are committed to understanding local and regional differences. When looking at a satellite image, for instance, they search for land-use patterns associated with socioeconomic and cultural processes coming from local populations. Consequently, they strive to find the driving forces behind land-use differences and for land-use classifications that are meaningful in socioeconomic and cultural terms. Sociology and Economics bring a set of sophisticated skills to the study of

demography which is integratable with both bioecological and spatially explicit approaches. Political science contributes institutional and cross-national approaches that address a variety of scales of interactions. Biological scientists and ecologists bring robust theories about evolution by natural selection and how environmental change occurs at a variety of levels of organization.

A second important contribution is related to data collection and methods. Anthropologists, sociologists, and human geographers using satellite images want to reveal the living human reality behind land-cover classes. Such a perspective requires methods that link local environmental differences to human behavior (Moran and Brondizio 1998, 2001; Rindfuss et al. 2003). Environmental social scientists pride themselves on the emphasis given to fieldwork, and they should take advantage of this preference to make important contributions to advancing the state of spatially explicit social science (Walsh and Crews-Meyer 2002; Goodchild and Janelle 2004; Moran and Ostrom 2005). Ecologists and biologists, too, give a very high place to fieldwork, and this is a very positive thing as this can lead them to respect one another and work together. On the other hand, there are many issues that require discussion across the disciplinary traditions with regards to selecting sample areas and study sites, how much detail to capture at each location, and how best to scale up from the “patch” to the larger units of social and ecological organization.

In several disciplines, emphasis is placed on one dimension over another. History traditionally places more emphasis on time and less on spatial aspects. Geography, on the other hand, emphasizes the spatial dimensions over the temporal one. Other disciplines, such as geology and ecology, contain a mix of both dimensions. Certain social sciences (e.g. political science, sociology, and anthropology) traditionally emphasize space or time when needed. For example, political scientists do, at times, undertake research that emphasizes the temporal aspects in longitudinal studies. The emerging interdisciplinary field of human–environment interactions must give attention to both spatial and temporal variability.

With the diverse vocabularies of separate disciplines, it is no wonder that human–environment interactions can appear extremely complicated. Aggravating this is a sense of urgency often felt by researchers, students, policy makers, and land managers because the state of the earth calls for immediate action, and a feeling that our understanding lags severely behind the processes involved. If our collective monitoring and understanding of human–environment interactions continues to lag severely behind those changes, how can humanity mitigate any negative consequences and try to prevent avoidable future problems?

How can this synthesis be accomplished? What strategies can we use to help integrate all the varying analytical “lenses” used by scholars from a

variety of social and physical science disciplines? Can we make individual case studies more comparable and compatible with each other such that we can identify significant trends manifest across all cases? While each researcher moves forward in his or her individual research endeavors, the environmental research community as a collective group would probably benefit by becoming familiar with a common set of theories and methods that are mutually understood across the social and natural sciences. Studies that are well documented with respect to their spatial and temporal dimensions can inform and build on one another. Specific articulation of the spatial and temporal parameters in each study would significantly ease case-to-case integration and compatibility. While this proposition is simple, it is a collective action problem that may yield synergistic results that are critical for research to progress. Moreover, diverse spatial and temporal perspectives will help students and researchers understand how contrasting processes relate to each other and will help place a given case study in a broader context.

In order to have a robust interdisciplinary and multidisciplinary human–environment science it is essential that one consider how to overcome disciplinary biases, without losing rigor in theory and method. Theories and methods are developed to address specific questions, most commonly of broad scope but focused on specific scientific challenges, and on particular spatial and temporal scales of analysis. In Chapters 2 and 3, theories and methods that promise to aid the development of this new area, human–environment interactions research, are proposed. Clearly, no single set of theories and methods will address all questions posed by investigators in this broad and encompassing multidisciplinary field. The methods and theories are offered as a first approximation or baseline for multidisciplinary team participants. One of the challenges the area of human–environment research poses is that doctoral training is still largely disciplinary and thus, when investigators or students begin to work in teams, as they must to address complex socioenvironmental questions, they face a major obstacle in understanding the jargon from other disciplines present in the team. One response is simply to do one’s small bit in the large project and not worry about the approaches used by others. This is not always a productive way to work, as it will surely lead to disappointment over the definition of the focus of the work to be done, and about the conclusions and recommendations. Instead, it is proposed here that by becoming familiar with a baseline set of theories and methods from “across the aisle,” understanding and dialogue are facilitated, integrative questions rather than disciplinary ones can be asked, it becomes more possible to challenge one another in the field and in the lab, and to arrive at integrative analysis. It is in such a spirit that Chapters 2 and 3 present a set of theories and methods to facilitate a baseline dialogue across the social sciences and the natural sciences.