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Integrated Land-Change Science and its Relevance to the Human Sciences

B.L. Turner II, E.F. Moran and R.R. Rindfuss

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Anthropological Center for Training and Research on Global Environmental Change
Indiana University, Student Building 331, 701 E. Kirkwood Ave., 47405-7100, U.S.A.
Phone: (812) 855-6181, Fax: (812) 855-3000, Email: act@indiana.edu, internet: www.indiana.edu/~a

REMOTE SENSING AND DIGITAL IMAGE PROCESSING

Land Change Science

Observing, Monitoring and Understanding Trajectories of Change on the Earth's Surface

Edited by
Garik Gutman,
Anthony C. Janetos,
Christopher O. Justice,
Emilio F. Moran,
John F. Mustard,
Ronald R. Rindfuss,
David Skole,
Billy Lee Turner II and
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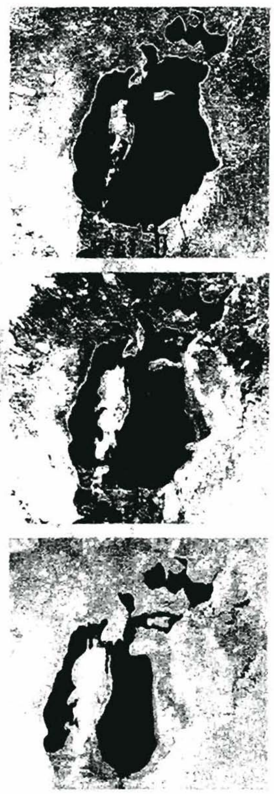

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LAND CHANGE SCIENCE

Observing, Monitoring and Understanding Trajectories of Change on the Earth's Surface

Edited by

GARIK GUTMAN
NASA Headquarters, Washington DC, U.S.A.

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BILLY LEE TURNER II
Clark University, Graduate School of Geography, Worcester, Massachusetts, U.S.A.

and

MARK A. COCHRANE
Michigan State University, Center for Global Change and Earth Observation and Department of Geography, East Lansing, U.S.A.

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Technical Editing:
LYNN H.J. HEDLUND
University of Virginia, College of Arts & Sciences, Charlottesville, U.S.A.

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CHAPTER 25

INTEGRATED LAND-CHANGE SCIENCE AND ITS RELEVANCE TO THE HUMAN SCIENCES

B. L. TURNER II[1], EMILIO MORAN[2], RONALD RINDFUSS[3]

[1]*Graduate School of Geography and George Perkins Marsh Institute, Clark University Worcester, MA 01610*
[2]*Center for the Study of Institutions, Population and Environmental Change Indiana University, Bloomington, IN 47405*
[3]*Department of Sociology, University of North Carolina, Chapel Hill, NC 27599*

1 The Programmatic Origins of Integrated Land-Change Science

What is and ought to be humankind's relationship with nature? This question has stood the test of time as an overarching intellectual and moral query confronting society and to which much research and pedagogy has been directed. The question can be traced to antiquity in western society (Glacken 1967), and has had no less profound thinkers in eastern societies. It has been recrafted in many forms following the Enlightenment, traced through such landmark concepts as noösphere and biosphere (Vernadsky 1945; Lapenis 2002), human modification of the earth (Thomas 1956; Marsh 1965), and ecosystem and biosphere function (Worster 1977; Lovelock 1988; Moran 2000; Golley 1992). These questions moved to the forefront of public concern in the 1960's American environmental movement, inspired in no small part by Rachel Carson's *Silent Spring* (1962), and led such initiatives as the International Biological Programme (IBP), which took advantage of the growing capabilities of computing to carry out large-scale ecosystem studies, including a "human adaptability" component examining the genetic, physiological, and behavioral adaptations that made it possible for human populations to thrive in environments considered to be extreme (Baker and Weiner, 1966; Odumi and Pigeon, 1970; Odum 1971; Baker and Little, 1976; Jamison et al., 1978). UNESCO's Man and the Biosphere Programme gave an even stronger role to the human dimensions of environmental concerns, especially as it has evolved today towards themes of sustainable development (www.unesco.org/mab).

Subsequent concern with global environmental change elevated questions to the structure and function of the biosphere,[1] spurred in part by the incipient recognition of potential human-induced climate warming in the 1980s (e.g., Schneider 1989;

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[1] Global change science does not necessarily imply that all questions and analyses take place at the global or earth system scale. As Turner and colleagues (1990) noted, early in its development this science addressed both biogeochemical cycles operating in a globally fluid system and state changes, operating locally, that cumulatively reached a global magnitude. In either case, the critical causes and consequences are often highly localized and must be addressed accordingly. Subsequently, the global change and sustainability communities have amplified this last theme, seeking ways to insert "place-based" and other spatio-temporal scales of assessment onto the research agenda (e.g., NRC 1999a).

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Houghton et al., 1990) and various assessments and stock takings demonstrating that the human impact on the biophysical systems of the earth had reached unprecedented conditions with profound implications for society worldwide (Turner et al., 1990; Steffen et al., 2003); humankind had entered the "anthropocene" (Crutzen and Stoermer, 2001) and a no analogue state (Steffen et al., 2002). This recognition not only stimulated the Intergovernmental Panel on Climate Change (IPCC) to examine the reality and causes of human-induced climate change, but also its societal impacts (Tegart et al., 1990). In 1986, the International Council for Science created the International Geosphere-Biosphere Programme (IGBP) to examine the systemic dynamics between the land, oceans, and atmosphere (Steffen et al., 2002). In its early development, the IGBP focused overwhelmingly on questions and issues of earth system science, with scant attention to the role of human behavior. Other organizations sought to create a human dimensions of global environmental program: internationally, the International Social Science Council (ISSC) which in 1990 created the forerunner of the Human Dimensions Programme (www.ihdp.uni-bonn.de), and in the US, the Social Science Research Council's Committee for Research on Global Change and the National Research Council's Committee on the Human Dimensions of Global Environmental Change which issued *Global Environmental Change: Understanding the Human Dimensions* in 1992 (Stern et al., 1992). It subsequently became clear to the IGBP, especially to its land components, that understanding the "human drivers" of land change was a critical but missing element of its science, and the IGBP and ISSC determined in 1991 to develop a joint effort on Land-Use/Cover Change (Turner et al., 1991). This decision had profound implications for the social sciences because it inserted basic research on the human causes and consequences of land change into the global change agenda (IGBP-IHDP 1999) paving the way for subsequent coupled human-environment studies of various kinds, including NASA's Land Cover and Land Use Change (LCLUC) program,[2] which taken together mark the emergence of integrated land-change science (Turner 2002).[3]

Such integrative interests continue to enlarge as global change science matures and expands to issues beyond climate change, including questions of ecosystem services and health, biotic diversity, land degradation, and coupled human-environment consequences (e.g., Daily 2000; NRC 2001; Balmford et al., 2002). This last theme, captured under the label of sustainability science, garners increasing attention as the science, policy, and public communities turn to the "so what" issue (Raven 1997; Schellnhuber and Wenzel, 1998; NRC 1999a; 2002; Kates et al., 2001). Sustainability promises to engender research attention on coupled human-environment systems, promoting multi- and interdisciplinary programs and activities to the array of themes and issues dealing with the human-environment condition, its change and consequences (e.g., NRC 1999b; NRC 2001). As a concept, sustainability also extends beyond science per se, raising questions relating to values, policies, and competing interests, thus enlarging the sociological research side of sustainability.

[2] Various parallel and complementary programs internally and in the US also place land change high on their research agenda (e.g., NRC 2001). Examples include Millennium Ecosystem Assessment (www.millenniumassessment.org), PLEC (Population, Land Management and Environmental Change, www.unu.edu/env/plec/), National Science Foundation (US) program on Biocomplexity (www.nsf.gov), and the National Institute of Child Health and Human Development (NICHD) program on population and environment (http://grants1.nih.gov/grants/guide/rfa-files/RFA-HD-95-002.html).

[3] This science is not unidirectional in orientation. In addition to human influences on biophysical systems, biophysical impacts on human systems are also considered. These multidirectional orientations are variously termed "reciprocal relationships" by social scientists and "feedbacks" by biophysical scientists. Language aside, the important point to remember is that an integrated land-change science needs to encompass the effects of land-use change on human behavior. While mounting evidence exists that land-use changes contribute significantly to global warming, the ultimate effects of global warming on humans will take some time to sort out.

1.1 THE COUPLED SYSTEM

Global environmental change science has improved our understanding of the dynamics of the biosphere and the consequences of human activity on the earth's functions.[4] Integrated environmental science or sustainability science is rapidly expanding the research agenda to questions of human impacts and policy (Lee 1993; Raskin et al., 1996; NRC 1999a; Buttimer 2001; Kates et al., 2001; Raven 2002). This expansion of the problem demands that the synergies between the human and biophysical worlds, or the coupled human-environment system, not only be considered but actually frame the research approach. This approach, in turn, fosters another kind of coupling, that of the heretofore largely discrete, if networked research domains (i.e., biophysical, social, and policy sciences) into explicit integrative and synthesis activities akin to "integrated assessments" (Smil 1993; Risby et al., 1996; Ehlers and Krafft, 2001; Rotmans and van Asselt, 2001).

Understanding the coupled system has long been recognized as a goal, if treated differently by different research communities. System-wide analysis has been hampered by various problems, however, ranging from the way in which research-pedagogy is organized to the paucity of coupled data to the inadequacies of computational and analytical techniques and tools. Improvements facilitating integrated research notwithstanding, an increasingly large community of researchers and decision makers realize that analysis of "coupled human-environment systems" cannot wait (Raven 2002), and considerable attention is being directed to the study of them (Moran 2000; NRC 1999a; 2000).

[4] It is also important to remember that few social science data are truly global, and certainly not enough in terms of quality and concept-appropriate to sustain human-biophysical analyses and modeling at the global level. The availability of data on a country-by-country basis is related to factors that themselves are likely to affect global human-biophysical relationships. For example, more affluent countries tend to have more and better quality social science data than poorer countries. Countries with smaller populations (e.g. Norway) tend to have better data than those with larger populations. Countries whose political regimes that are outside mainstream international politics (e.g., North Korea) are likely to have poorer quality data, at least so far as it is available to the international research community.

Further, the data that do exist at the global level commonly have severe comparability problems. Much of this problem can be attributed to the paucity of global groups responsible and paying for the collection and compilation of the data. Instead the hundreds of units at the country and sub-national level who are responsible for collecting data do so with no or at best, modest coordination across data collecting units. Even when there is an elaborate and intensive effort to coordinate across countries, such as in the European Family and Fertility Survey project, critics complain about the lack of comparability (Festy and Prioux 2002).

"Coupling" connotes several intersections and linkages that are not always so obvious. For example, the LCLUC program and other human-environment coupling efforts have focused overwhelmingly on immediate or proximate linkages between cause and impact, fostering research on those systems in which these linkages are most obvious. While tropical deforestation is significant to global change, land degradation, loss in biodiversity and ecosystem well being are more tangible dimensions of this process. Tropical deforestation is commonly generated at the proximate level by semi-subsistence agriculturalists in which production and consumption decisions are intertwined within the same social unit (e.g., household) and in which the responses to community institutions (rules) and state policies can be readily observed. Yet, a dominant socioeconomic trend globally has been the decoupling of production and consumption decisions, both hierarchically and spatially. This process, commonly labeled "globalization" (e.g., Dicken 1992), is not only the subject of large interest in the social sciences, with roots extending back to Marx and Durkheim (see Axin and Barber, 2003), it commands that part of the economy worldwide that engender the most environmental changes. The coupled system addressed in land change and beyond, therefore, needs to account better for these more obscure and distal linkages, and it must develop techniques and models that can handle them (Kasperson et al., 1995; Schellnhuber et al., 1997; Wilbanks and Kates, 1999; Kasperson and Kasperson, 2001a).

1.2 INTEGRATED LAND-CHANGE SCIENCE

Integrated land-change science is pivotal to most, if not all, of the enlargement of global change and sustainability science. It seeks to understand the causes and consequence of land-change processes on the coupled system and subsystems through multiple ways of knowing (e.g., Buttimer 2001), but ultimately capable of understanding through modeling and other templates that speak to science and policy (Lee 1993; Schellnhuber and Wenzel, 1998). To achieve this goal requires a coupling of the biophysical, social, and GIS sciences into a common or integrative research framework.[5]

The social sciences have long maintained various small-sized communities engaged in questions of the human-environment condition, ranging from resource economics and environmental policy to prehistory, and various subfields have claimed human-environment relationships are their subject of study (Turner 2002b). Despite this tradition, at least two facets of integrated land-change science have posed modest impediments to a larger social science entry into integrated land-change science. By definition, land-change science takes on problems that are enhanced by interdisciplinary, team-based research, whereas the social sciences commonly draw upon traditions promoting individual intellectual achievements; and but for a few exceptions, the social sciences have lagged behind the biophysical sciences in the use of satellite imagery and geographical information systems (GIS) for problem solving (see reviews in de Sherbinin et al., 2002; Liverman et al., 1998).[6] These circumstances appear to be changing, however. Large numbers of integrated research and teaching programs, both internationally within the US, are providing venues for social scientists and human-environment scientists to join biophysical and policy scientists in team-based, integrative studies, much of it land-change in kind (Turner 2002b). Moreover, junior social scientists are increasingly attracted to the use of GIS and remotely sensed data to assist in the problem solving, be it econometricians, demographers, political scientists, or agent-based modelers (Irwin and Geoghegan, 2002; Parker et al., 2002; Walsh and Crews-Meyers, 2002). For example, social scientists collaborated with biophysical and remote sensing/GIS scientists in generating the only official science documented presented by the United States to the Earth Summit in Johannesburg, South Africa, 2002, which was intimately linked to integrated land-change science (NRC 2002).

These developments notwithstanding, the usefulness of remote sensing data, especially that from satellite sensors, for the social sciences, especially in regard to their historic core concerns, remains problematic (e.g., Liverman et al., 1998; de Sherbinin et al., 2002; Rindfuss et al., 2003). This circumstance follows because the data in question reveal only some of the consequences of human decisions or socioeconomic structures, intentional or not, and their applicability for understanding the decision or structure in the first place has not been well demonstrated—not surprising given how recently these connections have been made between the data and tools provided by geospatial approaches and core questions of the social sciences.

In the remainder of this chapter we attempt to categorize the classical core concerns of the social sciences and consider their links to land-change studies and the likelihood that they might be addressed, in part, through remotely sensed data. This assessment is undertaken through an examination of process-pattern linkages that illustrate some of the possibilities of LCLUC and integrated land-change research to inform social science concerns. We conclude with comments on the future of the LCLUC program to serve more fully the human component of the coupled human-environment system of study.

2 Dominant Social Science Interests

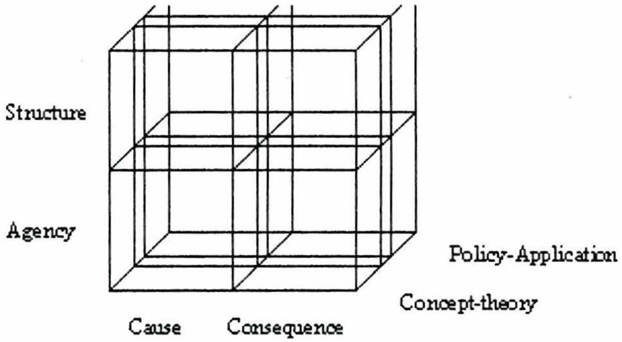
Integrated land-change science stands outside or on the edges of the dominant or core concerns of the social sciences as they have emerged over the past century. The coupled human-environment system—a center piece of this science in which environment refers to the biophysical world—has not been addressed consistently throughout the social sciences for various reasons, including the negative impacts of late nineteenth and early twentieth century "environmental determinism" (see discussions in Moran 2000; Turner 2002b) and the attempts by the social sciences to free themselves from explanatory templates with origins in or strong connections to the natural sciences. This last effort is attested by the many challenges to post-positivism as an adequate explanatory framework for the social sciences (Guba 1990). To be sure, the coupled system has been addressed by the human-environment subfields (i.e., human ecology) as practiced in geography and anthropology (Moran 2000; Turner 2002), and various elements of the coupled system are examined in resource and environmental economics, especially among those subfields examining the human responses to natural hazards (White 1974 for work on natural hazards). The collective research of these

[5] GIScience refers to the use and development of spatial analysis through geographical information systems (GIS), including remotely sensed data (Goodchild 1992).

[6] The NSF felt so strongly about this last issue that it supports the National Center for Geographic Information Analysis, and the Center for Spatially Explicit Social Science (U.C. Santa Barbara), to enhance the use of GIS, and to a lesser extent, remotely sensed data, among the social sciences.

interests is substantial (e.g., Rayner and Malone, 1998), yet even a cursory examination of compendium of basic social science interests (e.g., *International Encyclopedia of the Social and Behavioral Sciences*) reveals this research comprises only a small portion of the overall attention. The overwhelming attention, of course, is cast to questions that resonate within and among such broad issues as agency-behavior, societal structures, and meaning.

Figure 1. Framework of Land-Change Dimensions Relevant to Social Sciences
(Note: overlapping quadrants represent various research efforts that fuse or cut across the binary labels employed here.)



Such core "human components" relevant to integrated land-change science can be framed in various ways. One way is captured in a three-dimensional matrix (Fig. 1) defined by the categories of cause-consequence (subject) on the X-axis, agency-structure (explanatory emphasis) on the Y-axis, and concept-application (orientation of contribution) on the Z-axis, the definitions of which are found in Table 1. Most social sciences enter environmental questions through concerns about the ways in which culture, economy, and political organization shape the perception and use of nature and the social consequences of interactions with nature. Land use and its human consequences are commonly explained by way of individual decision making and behavior (i.e., rational choice), political economic structures creating entitlements, opportunities, and constraints affecting decisions, or some combination of the two. A further division involves those practitioners focused on the origins of system properties or structures, and those concerned with functions of those structures. Regardless of which focus is taken, the underlying causes of land use—the factors affecting agency-behavior and structure—tended to mark the initial entry of the social science into land-change studies (e.g., Angelsen and Kaimowitz, 1999; Lambin et al., 2001; Ostrom et al., 2001; Geist and Lambin, 2002).[7] With the enlargement of sustainability and integrated assessment themes, however, social science directed to the consequences of land change has enlarged to incorporate themes of natural hazards and vulnerability

[7] Poststructuralist and postmodern perspectives largely deny a "metanarrative" that elevates the usefulness for agency-decision making or structures. Few practitioners of land-change science, however, adhere to these perspectives or attempt to incorporate them into modified "metanarratives" involving structures.

(Dow and Downing, 1995; Kasperson et al., 1995; Burby 1998; Kasperson and Kasperson, 2001b; Turner et al., 2003a; 2003b). The combination of subject and explanatory emphasis may be directed to concepts, themes, and theories of basic social science research or to real-world application, as in shaping land-use policies, although this distinction may be dissolving somewhat given the fusing of these orientations in sustainability science and integrated assessment.

Table 1: Description of Categories in Framework

Category	Definition
Cause	Social, political and economic factors and processes influencing activities relevant to the use of land and its resources
Consequence	Social, political and economic outcomes of the land uses in question
Agency	Land-relevant behavior of and decisions made by manager of the land
Structure	Land-relevant rules and entitlements of opportunities and constraints on land manager
Concept-theory	Contribution to basic themes, theories, concepts of social science
Policy-application	Contribution to applied work and linked policy

Satellite data reveal much more about the consequences of land change than its causes, and speak less well to the questions of explanatory frameworks and concept-theory, than to various aspects of application. Recognizing these qualities, international agendas focused on land-change studies (e.g., IGBP-IHDP 1999) have reopened the pattern-process question: Are patterns of land change related to specific social processes and thus serve as indicators or measures of issues that strike to the core of social science interests (as noted above), either in regard to cause or consequence? Studies directed to this question under the label of "spatial geography" in the 1960s revealed that the same process could give rise to significant varieties of patterns, a not dissimilar outcome from the still earlier efforts of the culture-area approach in anthropology that found few correlations between biogeography and material culture (Kroeber 1939). With this caveat in mind, recent work hints that pattern-process relationships for certain bounded spatio-temporal land units exist (e.g., Brondizio et al., 2002; Evans and Moran, 2002; Moran et al., 2002), and the search is underway to uncover the implications of these relationships for theory and models (Irwin and Geoghegan, 2002; Parker et al., 2002; 2003). It is noteworthy that these findings point to one of the important contributions of the social sciences to an integrative land-use science: the significant variation in the combinations of biophysical and human processes operating in different locales and regions that give rise to land-use and land-cover change and the different response capacities of the coupled human-environment system in those locales and regions. For example, a recent meta-analysis of 152 case studies of tropical deforestation concluded that distinctive but different regional patterns exist in the causes and consequences of tropical deforestation (Geist and Lambin, 2002). While it is possible to extract some broad, general lessons about land-use transitions across the world and across land-use systems (Lambin et al., 2001), the local to regional variations are sufficiently large that models miss their mark if the differences are not considered. The social sciences have led the way in global change science in demonstrating the need to scale down from global to regional and local if the causes and consequences of environmental changes are to be understood (NRC 1999b).

3 Pattern-Process and Satellite Data

Remotely sensed data derived from satellite are a powerful source of information about the biophysical conditions of the biosphere, ranging from trace gas emissions to deforestation to urban expansion to the pathways that ENSO events take across Africa (Steffen et al., 2002). The abundance of information involved and the explosion of spatial analysis software (GIS) that permit the integration and analysis of this information with other data (Liverman et al., 1998) have rejuvenated the assessment of biophysical factors in human activities and outcomes (Rindfuss and Stern, 1998; Moran and Brondizio, 2001; Fox et al., 2002). The distinctive patterns in land change found at local and regional scales, and the power added to explanations and projections of land change by incorporating environmental variables into analysis have resulted in approaches that characterize human-environment relationships as interactive and that no matter the agency and structure involved in land management strategies, biophysical variables often play a profound role in shaping decisions and outcomes of land uses. This realization is not new and has been part of the centerpiece of long-standing research endeavors that cut across different explanatory perspectives. For the most part, however, they have not been accorded "core" status within the social sciences, and have been variously labeled the human-environment sciences (Kates 1987; Moran 2000; Turner 2002b).[8] The significance of biophysical processes for understanding the coupled human-environment system notwithstanding, in the remainder we focus on those themes that have attracted the core attention of the social sciences, as noted above.

The social dynamics that affect land use and its change (e.g., land rents, zoning, globalization) and the societal consequences of land change (e.g., food shortages and security, land degradation and desertification, land tenure and concentration, and social unrest and justice) have long captured the attention of the social sciences, if not necessarily focused on the land-change question per se. What is more recent, and evident in the cases presented in this book and related work, is that some of these social dynamics and societal consequences can be inferred from the pattern-process connections revealed in satellite data (particularly when linked to appropriate social science data) and have been employed variously in research analysis and policy assessment (e.g., NRC 2002). Robust linkages require strong coupling to ground information, rigorous analytical assessment, and regular monitoring to confirm that the linkages in question remain operative or have changed. These caveats notwithstanding, the pattern-process understanding gained provides a powerful mechanism to address the spatial extent, magnitude, and rates at which certain social process are operating and societal consequences experienced. This knowledge, in turns, informs concepts and theories, models and projections, and integrated assessment and policy. Below we provide various examples, partitioned by cause and consequence, in which "core" social science interests are addressed by way of linked ground and satellite data and analysis.

[8] Human-environment relationships are dynamic, changing as much for reasons that rest in shifts in social organization, political economy, technology, and wealth-poverty as in climate or other biophysical factors. Caution is raised among the social sciences in regard to those formulations of the relationship that focus only on the environmental factor or imply that stasis in this factor promotes stasis in the human consequences.

3.1 SOCIAL DYNAMICS AFFECTING LAND CHANGE

[1] Why do sheep and game "farms" in parts of the Karoo of South Africa display such disparities in the quality of their land cover (biomass), given the relative uniformity of soils there? Archer (forthcoming) employs various statistical techniques to separate the climate and land-use signals in fine-tuned temporal AVHRR for lands dominated by white large-holders who have lost government subsidies in the post-apartheid government. This output is linked to farm survey data, revealing that lower quality vegetative cover (determined by NDVI measures) is strongly associated with those stockers following holistic range management strategies and that these strategies tend to be followed by those stockers of Afrikaner ancestry and those with debt load inhibiting experimentation with alternative strategies that are less reliant on cash flow from livestock itself. In this way, not only the regional impacts of stocking strategies are determined, but some of the "root" socioeconomic determinants land-use decisions are linked to these impacts.

[2] Various changes in the political economic structures of Mexico have significantly altered land uses and cover in the southern Yucatán, with potential impacts on the Calakmul Biosphere Reserve and associated programs. The Southern Yucatán Peninsular Region project (Turner et al., 2001; Turner, Geoghegan and Foster, 2003) links detailed imagery classification (Landsat TM) to reveal, among other factors, the patterning of lands under differing levels of use intensity. This information is linked to extensive and detailed household and other data to reveal the role of household land access on market involvement, and ultimately, on agricultural intensification and landscape consequences. For the most part, those communities with lower amounts of land per household are most strongly engaged in commercial cultivation, switching land-use strategies in which low-level capital inputs are attempting to follow a more permanent form of cultivation. The subtle landscape patterns detected from imagery analysis indicate where this economic orientation is taking place and its magnitude. Similar results have been demonstrated elsewhere in Yucatán (Sohn et al., 1999; Gurri et al., 2001; Gurri and Moran, 2002).

[3] Do households in Amazonia maintain constant rates of deforestation throughout their history? Studies of household lifecycles (demographic composition) in the Brazilian Amazon have been linked to satellite data revealing the role of gender and age structure of households in deforestation trajectories (McCracken et al., 1999; Moran et al., 2000; Brondizio et al., 2002; Evans and Moran, 2002; McCracken et al., 2002; Walker et al., 2002). Young households rapidly deforest their property (6%/annum) in their first five years of forest occupation as they seek to establish their farms and provide subsistence for the household. They steadily reduce the annual rates of deforestation with length of occupation, shifting land uses to more permanent crops

(e.g., cocoa, sugar cane) and pasture. As the households progress in their life cycle, deforestation briefly increases as farms are consolidated in preparation for production systems that will characterize their later years as an aging household (20-25 yrs in residence)—managing their fallows rather than undertaking new deforestation. This trajectory is affected by the biophysical conditions on the property. Households with fertile soils developed a more diverse portfolio of crops than those with infertile soils who appear to be forced into a mostly planted pasture strategy (Moran et al., 2002).

[4] Policy is invoked as the distal driver of land change, especially for tropical deforestation. Anderson (2000) demonstrates how the role of policy can be linked to Amazonian deforestation, determined by satellite data and ground surveys. In this region, policy directed to road building, credit, and fiscal incentives leads to initial deforestation—pushing the frontier—but subsequent, sustained deforestation is generated by local economic factors, including population growth on which policy has minimal impact. In short, the distal factor of state policy initiates deforestation but the control of policy vis-à-vis deforestation is soon lost to other, more local factors, such as community road building (also Walker et al., 1999).

[5] What role might "globalization" play in land change? This question has been addressed in regard to foreign direct investment and the spread of urban land uses in southern China. Proxies for this investment, coupled with other data, indicate a strong correlation with urban expansion as observed through satellite imagery, but this relationship is mediated by the local or proximate conditions of agricultural land productivity (Seto and Kaufmann, 2003). Given that some of the agricultural-to-urban land conversions involve some of the potentially most productive crop lands in China, identification of those conditions that give rise to conversion sheds light on policy options that would amplify or attenuate the loss of crop lands.

[6] Scalar relationships profoundly affect most assessments of land change. Modeling remote sensing and other data relevant to tropical deforestation in the southern Cameroon reveal the role of spatial inertia of change processes in which deforestation is amplified in lands adjacent to recent deforestation, giving rise to spatial spread effect and permitting assessments of the trajectories (magnitude and direction) of change (Mertens et al., 1997; Mertens and Lambin, 2000). As well, examinations in Nang Rong, northeast Thailand, have shown that relationships between population and environment depend on the scale of analysis (Walsh et al., 1999; 2001). Using remotely sensed data to measure land cover and plant biomass, GIS derived measures of elevation, slope-angle, and soil moisture potential, and social survey data for demographic data, it was found that at small-scales or fine resolutions, the relationships between social variables and land cover are strong. When coarser scales/resolutions were used, biophysical variables tend to maintain a strong relationship.

3.2 SOCIETAL CONSEQUENCES OF LAND CHANGE

[1] Southern Quintana Roo and Campeche, Mexico, constitute a hot spot of tropical deforestation, a land change process that threatens the Calakmul Biosphere Reserve (Turner et al., 2001). Owing to this threat and the aim to modernize production on communal lands throughout the country, shifts to neoliberal economic policies seek to

intensify extant cultivation and reduce the expansion of deforestation in the area. A state-sponsored, PROCAMPO provides direct payments to participating households based on existing cultivated lands maintained in crops and not permitted to return to forest. Household and community surveys, however, reveal that significant amounts of these payments are invested in clearing forest for pasture, in most cases absent livestock (Klepeis and Vance, 2003), and the total amount of land cleared for this purpose can be tracked by satellite data (Turner et al., 2001; Turner et al., 2003). The combined information suggests that this unintended, even perverse, consequence is prevalent among households and communities with "surplus" land, and appears to be undertaken as a means to lay claim to lands under conditions of tenure uncertainty and in hopes that state-led livestock programs will follow (Klepeis and Vance, 2003).

[2] May land preservation policies have adverse consequences for people and the land? Yes, according to work undertaken in the "woodland" landscapes of Rajasthan, India. Linking Landsat data with discourse assessment, Robbins (2001) shows that the woodlands are transforming to hybrid or "quasiforests" complete with exogenous species that have proven difficult to control and which have significant production consequences for the local occupants-land users. The hybrid woodlands follow from state planners holding the view that reduced herding and other activities would reduce woodland degradation, when in fact the qualities of the woodlands that the state sought to preserve required land use. Absent an understanding of the coupled system dynamics but holding the capacity to regulate land use (Robbins 1998), state policy has apparently had negative consequences for the woodlands and the people.

[3] As part of its international responsibilities to preserve endangered biota, China has established a Panda Reserve with the explicit aim of preserving the critical habitats that support this endangered species. Using Landsat data, Liu and his colleagues (1999) have demonstrated that the type of settlement pattern adjacent to or within the preserve has significant consequences for these habitats and, hence, the social aim of preservation. Surprising, even to some experts, was the finding that areas with the less dense but spatially dispersed settlements has a greater negative impact on panda habitat than areas of dense, concentrated settlement. This relationship appears to be related to the distances that local occupants are willing to travel to their fields and to collect wood fuel. This distance does not vary by settlement pattern, such that a dispersed pattern affects more of the critical panda habitat, while the dense pattern reduces the total habitat affected, even if its effect is more profound for the use area. The use of remote sensing data permitted an important, broad generalization that other methods would have been inadequate to grasp as quickly and as convincingly.

[4] Can land-change agendas affect the well being of locale people? A strong case can be made that policies aimed at regulating landscape burning in Mali are linked in this way. Despite the antiquity of human-controlled landscape burning there and elsewhere in western Africa, desertification and related land degradation themes have resulted in policies attempting to reduce the activity. Laris (2002) links interviews and study of those actually setting fires with remote sensing data to examine the human-environment rationale for the activity and policy impacts in Mali. Intentionally set fires tend to be small scale and follow a seasonal rhythm that creates a landscape mosaic of biomass that is less likely to trigger a large-scale burn that threatens homes and fields alike.

State policy is seen as reversing this circumstance, endangering the well being of the occupants.

[5] Various examples from the health fields illustrate human consequences linked to land change and other environmental considerations. Seto and colleagues (2002), for example, join biophysical and remote sensing data to project the change in the magnitude and location of schistosomiasis in southern China that will follow from the Three Gorges dam on the Yangtze River. Linthicum and colleagues (1999) advance such assessments by linking historical records of precipitation and Rift Valley Fever in Kenya, linking outbreaks of the fever to abnormally high rainfall. They then link ocean warming with such rainfall fluxes and, with remote sensing techniques, to map its spatial dimensions across the country. These same techniques permit a five-month advanced forecast of the epidemic. Similarly, Landsat Thematic Mapper data have been used to identify human risk to hantavirus pulmonary syndrome by estimating the location and expansion of sites favoring the deer mouse in 1998, following an ENSO event (Glass et al., 2002). These cases, illustrate how satellite data are combined with other information to create forecasts and projections that guide policy and planners in regard to potential health hazards.

4 Integrative Land-Use Science and Its Future with Remote Sensing

Integrated land-change science seeks to forge a union among biophysical, socioeconomic, and remote sensing information and understanding to address the coupled human-environment system. Here we have focused on the socioeconomic-societal and remote sensing coupling as it contributes to the long-held interests of the social sciences. We have attempted to illustrate that these linkages help to reveal various characteristics of both the causes and consequences of land change as they are understood through both agency and structure to address conceptual themes and application.

A frequently stated claim and concern speaks to the potential of remote sensing techniques generating and thus replacing traditional social science data, such as found in censuses, surveys, and face-to-face encounters with the people in question. Unless there are some startling breakthroughs in remote sensing technology, satellite data (and aerial photography) will never replace the data in question. Remotely sensed data can detect the physical characteristics of the landscape and the objects that comprise that landscape as well as various attributes of the objects (e.g., their dimensions and physical properties). It is obviously unlikely that remotely sensed data alone would ever be able to determine the number of people occupying that landscape, including their age, sex, race, education, occupation or other standard demographic variables, nor will it provide information about their attitudes, decision-making rationales, and the guiding political economic structures and policies for the observed land unit. The data needs of integrated land-change science will never be fully met by remotely sensed data.

Even though remotely sensed data will never provide the complete data needs of the land-use research community, the time is ripe to query the extent to which remotely sensed data can provide some variables that might be considered "social." Examples include indexing the land context around human settlements and using night-

lights as a proxy of the measure of human occupational density. Judith Lessler once observed that in the early history of brick-making technology, bricks were made in the shape of stones – which is about where we are in using remotely sensed data to measure social science concepts. Just as brick technology advanced, however, we anticipate more creative uses of remotely sensed data to measure social science variables, but we suspect that these refinements will address the "physical" dimensions of those variables. While important, these dimensions and variables will be insufficient to address the coupled system of integrated land-change science. It is worth noting that, to date, a very small portion of global change research funds has been devoted to the collection and analysis of social science data linked directly to remotely sensed data. One result is that the proportion of projects in LCLUC and similar programs with a distinct and strong social science component remains regrettably small. Greater advances might be expected if investments commensurate with the importance of the human dimensions of global change were made.

The data linkages notwithstanding, a truly integrative land-change science requires improvement in the way students are trained so that they are given the experience and excitement of engaging integrative research in the lab and the field. Those who have led in this domain need to ensure that the benefits of this integrative science fertilizes the social sciences and leads them more fully into critical local to global concerns captured in integrated land-change science. The burden of our current community is to demonstrate that the coupled human-environment system is of fundamental importance to understanding the human condition on this planet. The burden of the social sciences at large is to realize that beyond their traditional cores, the broader science communities have elevated the significance of understanding the coupled human-environment system in integrative ways, reinvigorating the "great" question with which we began this chapter and portending to change the partitioning of knowledge, otherwise known as the academy (Kates et al., 2001; Turner 2002b).

5 References

Anderson, L. E. 2000. The causes of deforestation in the Brazilian Amazon. *Journal of Environment and Development* 5: 309-328.

Angelsen, A., and Kaimowitz, D. 1999. Rethinking the Causes of Deforestation: Lessons from Economic Models. *The World Bank Research Observer* 14: 73-98.

Archer, E. R. M. nd. Beyond the climate versus grazing impasse: Using remote sensing to investigate the effects of grazing system choice on vegetation cover in eastern Karoo. *Journal of Arid Environments* (forthcoming).

Axin, W., and Barber, J. 2003. Linking people and land use: a sociological perspective. *People and the Environment: Approaches for Linking Household and Community Surveys to Remote Sensing and GIS*, J. Fox, R. R. Rindfuss, S. J. Walsh, and V. Mishra, eds. Kluwer: Boston, MA, 285-313.

Baker, P. T., and Little, M. 1976. *Man and the Andes.* US/IBP Synthesis Volume No. 1. Dowden, Hutchinson, and Ross: Stroudsburg, PA.

Baker, P. T. and J. S. Weiner, eds. 1966. *The Biology of Human Adaptability*. Oxford, UK: Clarendon Press.

Balmford, A., Bruner, A., Cooper, P., Costanza, R., Farber, S., Green, R., Jenkins, M., Jefferies, P., Jessamy, V., Madden, J., Munro, K., Myers, N., Naeem, S., Paavola, J., Rayment, M., Rsendo, S., Roughgarden, J., Trumper, K., and K., T. R. 2002. Economic reasons for conserving wild nature. *Science* 297: 950-953.

Brondizio, E., McCracken, S., Moran, E. F., Siqueira, A., Nelson, D., and Rodriguez-Pedraza, C. 2002. The colonist footprint: Towards a conceptual famework of land use and deforestation trajectories among small farmers in the Amazonian frontier. *Deforestation and Land Use in the Amazon*, C. Wood and R. Porro, eds. University of Florida Press: Gainesville, FL, 131-161.

Burby, R. J. 1998. *Cooperating with Nature: Confronting Natural Hazards with Land-Use Planning for Sustainable Communities*. John Henry Press: Washington, D. C.

Buttimer, A., ed. 2001. *Sustainable Landscapes and Lifeways: Scale and Appropriateness*. Cork University Press, Cork, IR.

Carson, R. 1962. *Silent Spring*. Houghton Mifflin: Boston, MA.

Crutzen, P. J. and Stoermer, E. 2001. The "Anthropocene". *Global Change Newsletter* (International Geosphere-Biosphere Programme) 41: 12-13.

Daily, G. C., Söderqvist, T., Aniyar, S., Arrow, K., Dasgupta, P., Ehrlich, P. R., Folke, C., Hansson, A., Jansson, B.-O., Kautsky, N., Levin, S., Lubchenco, J., Mäler, K.-G., Simpson, D., Starrett, D., Tilman, D., and Walker, B. 2000. The value of nature and nature of value. *Science* 289: 395-396.

de Sherbinin, A., Balk, D., Yaeger, Y., Jaiteh, M., Pozzi, F., and Giri, C. 2002. Center for International Earth Science Information Network (CIESIN) of Columbia University: Palisades, NY.

Dicken, P. 1992. *Global Shift: The Internationalization of Economics Activity*, Guilford Press, New York.

Dow, K., and Downing, T. E. 1995. Vulnerability research: Where things stand. *Human Dimensions Quarterly* 1: 3-5.

Ehlers, E., and Krafft, T., eds. 2001. *Understanding the Earth System: Compartments, processes and Interactions*. Springer: Berlin.

Evans, T., and Moran, E. F. 2020. Spatial integration of social and biophysical factors related to landcover change. *Population and Development Review* 28 (supplement): 156-186.

Festy, P., and Prioux, F. 2002. *An Evaluation of the Fertility and Family Surveys Project*, United Nations: New York, NY.

Fox, J., Mishar, V., Rindfus, R., and Walsh, S., eds. 2003. *People and the Environment: Approaches for Linking Household and Community Survey to Remote Sensing and GIS*. Kluwer (Forthcoming), Amsterdam.

Gesit, H., and Lambin, E. F. 2002. Direct causes and underlying driving forces of tropical deforestation. *Bioscience*, 52: 143-150.

Glacken, C. J. 1967. *Traces on the Rhodian Shore: Nature and Culture in Western Thought from Ancient Times to the End of the Eighteenth Century*. University of California Press: Berkeley, CA.

Glass, G. E., Yates, T. L., Fine, J. B., Shields, T. M., Kendall, J. B., Hope, A. G., Parmenter, C. A., Peters, C. J., Ksiazek, T. G., Li, C.-S., Patz, J. A., and Mills, J. N. 2002. Satellite imagery charaterizes local animal reservoir populations of nombre virus in the southwestern United States. *Proceedings of the National Academy of Sciences of the United States of America* 99: 16817-16822.

Golley, F.. 1992. *The Ecosystem Concept in Biology*. Yale University Press: New Haven, CN.

Goodchild, M. F. 1992. Geogrpahical information science. *International Journal of Geographical Information Systems* 6: 31-45.

Guba, E. G. (1990). *The Paradigm Dialog*, Sage. Newbury Park, CA.

Gurri, F., Pereira, G., and Moran, E. 2000. Well-being changes in response to 30 yearsr of regional integration in Maya Populations from Yucatan, Mexico. *American Journal of Human Biology* 13: 590-602.

Gurri, Y., and Moran, E. 2002. Who is interested in commercial agriculture? Subsistence agriculture and salaried work in the city among Yucatec Maya from the state of Yucatan. *Culture and Agriculture* 24: 41-47.

Houghton, J. T., Jenkins, G. J., and Ephraums, J. J. 1990. *Climate Change: The IPCC Scientific Assessment*. Intergovernmental Panel on Climate Change. Cambridge University Press: Cambridge, UK.

IGBP-IHDP. 1999. *Land-Use and Land-Cover Change, Implementation Strategy*. International Geosphere-Biosphere Programme and International Human Dimensions Programme: Stockholm and Bonn.

Irwin, E. G., and Geoghegan, J. 2002. Theory, data, methods: developing spatially-explicit economic models of land use change. *Agriculture, Ecosystems, and Environment* 84: 7-24.

Jamison, P., Zegura, S., and Milan, F. 1978. The Eskimo of northwestern Alaska: A biological perspective. US/IBP Synthesis Volume No. 8. Dowden, Hutchinson, and Ross: Stroudsburg, PA.

Kasperson, J. X., and Kasperson, R. E., eds. 2001a. *Global Environmental Risk*. United Nations University Press and Earthscan: Tokyo and London.

Kasperson, J. X., and Kasperson, R. E. 2001b. International Workshop on Vulnerability and Global Environmental Change, 17-19 May 2001. Stockholm Environment Institute (SEI). Stockholm, Sweden: A workshop summary SEI Risk and Vulnerability Programme Report 2001-01. Stockholm: SEI.

Kasperson, J. X., Kasperson, R. E., and Turner II, B. L., eds. 1995. *Regions at Risk: Comparisons of Threatened Environments*. United Nations University: Tokyo.

Kates, R. W. 1987. The human environment: The road not taken, the road still beckoning. *Annals of the Association of American Geographers* 77: 525-34.

Kates, R. W., Clark, W. C., Corell, R., Hall, J. M., Jaeger, C. C., Lowe, I., McCarthy, J. J., Schellenhuber, H. J., Bolin, B., Dickson, N. M., Faucheaux, S., Gallopin, G. C., Grübler, A., Huntley, B., Jäger, J., Jodha, N. S., Kasperson, R. E., Mabogunje, A., Matson, P., Mooney, H., Moore, B., III, O'Riordan, T., and Svedin, U. 2001. Sustainability science. *Science* 292: 641-642.

Klepeis, P., and Vance, C. nd. Neoliberal policy and deforestation in southeastern Mexico: An assessment of the PROCAMPO program. *Economic Geography* (forthcoming).

Kroeber, A. 1939. *Cultural and Natural Areas of Native North America*, University of California Press: Berkeley, CA.

Lambin, E. F., Geist, H. J., and Lepers, E. 2003. Dynamics of Land-use and Land-Cover Change in Tropical Regions. *Annual Review of Environment and Resources*, 28 (forthcoming).

Lambin, E. F., Turner II, B. L., Geist, H., Agbola, S., Angelsen, A., Bruce, J. W., Coomes, O., Dirzo, R., Fischer, G., Folke, C., George, P. S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E. F., Mortimore, M., Ramakrishnan , P. S., Richards, J. F., Skånes, H., Steffen, H., Stone, G. D., Svedin , U., Veldkamp, T., Vogel, C., and Xu, J. 2001. The causes of land-use and land-cover change-moving beyond the myths. *Global Environmental Change: Human and Policy Dimensions* 11: 2-13.

Lapenis, A. G. 2002. Directed evolution of the biosphere: Biogeochemical selection or Gaia? *Professional Geographer* 54: 379-391.

Laris, P. 2002. Burning the seasonal mosaic: Preventing burning strategies in the wooded savanna of southern Mali. *Human Ecology* 30: 155-186.

Lee, K. N. 1993. *Compass and Gyroscope: Integrating Science and Politics for the Environment*, Island Press: Washington, D. C.

Linthicum, K. J., Anayamba, A., Tucker, C. J., Kelley, P. W., Myers, M. F., and Peters, C. J. 1999. Climate and satellite indicators to forecast Rift Valley fever epidemics in Kenya. *Science* 285: 397-400.

Liu, J., Ouyang, Z., Taylor, W., Groop, R., Tan, Y., and Zhang, H. 1999. A framework for evaluating the effects of human factors on wildlife habitat: the case of giant panda. *Conservation Biology* 13: 1360-1370.

Liverman, D., Moran, E. F., Rindfuss, R. R., and Stern, P. C., eds. 1998. *People and Pixels: Linking Remote Sensing and Social Science*. National Academy Press: Washington, D.C.

Lovelock, J. E. 1988. *The Ages of Gaia: A Biography of Our Living Earth*. Norton: New York, NY.

Marsh, G. P. 1965 [1864]. *Man and Nature: or, The Earth as Modified by Human Action*. Belknap Press of Harvard University Press: Cambridge, MA.

McCracken , S., Siqueira, A., Moran, E. F., and Brondizio, E. 2002. Land use patterns on an agricultural frontier in Brazil: Insights and examples from a demographic perspective. deforestation and land use in the Amazon, C. Wood and R. Porro, eds. University of Florida Press: Gainseville, FL, 162-192.

McCracken, S., Brondizio, E., Neslon, D., Moran, E., Siqueira, A., and C., R.-P. 1999. Remote sensing and GIS at farm property level: Demography and deforestation in the Brazilian Amazon. *Photogrammetric Engineering and Remote Sensing* 65: 1311-1320.

Mertens, B., and Lambin, E. F. 2000. Land-cover-change trajectories in Southern Cameroon. *Annals of the Association of American Geographers* 90: 467-494.

Mertens, B., Sunderlin, W., Ndoye, O., and Lambin, E. 1997. Impacts on deforestation in South Cameroon: Integration of household and remotely sensed data. *World Development* 28: 983-1000.

Moran, E. 2000. *Human Adaptability: An Introduction to Ecological Anthropology*. Westview Press: Boulder, CO.

Moran, E., and E., Brondizio. 2001. Human ecology from space: Ecological anthropology engages the study of global environmetnal change. *Ecological and the Sacred: Engaging the Anthropological of Roy A. Rappaport*, E. Messer and M. Lambeck, eds. University of Michigan Press: Ann Arbor, 64-87.

Moran, E. F., Brondizio, E., and McCracken, S. 2002. Trajectories of land use: Soils, succession, and crop choice. *Deforestation and Land Use in the Amazon*, C. Wood and R. Porro, eds., University of Florida Press: Gainesville, FL, 133-161.

NRC (National Research Council). 1999a. *Our Common Journey: A Transition Toward Sustainability*, National Academy Press: Washington, D.C.

NRC (National Research Council). 1999b. *Human Dimensions of Global Environmental Change: Research Pathways for the Next Decade*. National Academies Press: Washington, D.C.

NRC (National Research Council). 2001. *Grand Challenges in the Environmental Sciences*. National Academy Press: Washington: D. C.

NRC (National Research Council). 2002. *Down to Earth: Geographical Information for Sustainable Development in Africa*. National Academies Press: Washington, D.C.

Odum, H. 1971. *Environment, Power, and Society*. Wiley-Interscience, New York, NY.

Odum, H., and Pigeon, F., eds. 1970. *A Tropical Rain Forest*. Department of Commerce and Atomic Energy Commission Springfield, VA.

Ostrom, E., Dietz, T., Dolšak, N., Stern, P. C., Stonich, S., and Weber, E. U., eds. 2002. *The Drama of the Commons*. National Academy Press. Washington, D. C.

Parker, D., Berger, T., Manson, S., and McConnell, W. J., eds. 2002. *Agent-Based Models of Land-Use and Land-Cover Change. LUCC Report Series No. 6*. LUCC International Project Office: Louvain-la-Neuve, Be.

Parker, D. C., Manson, S. M., Janssen, M. A., Hoffamn, M. J., and Deadman, P. 2003. Multi-agent systems for the simulation of land use and land cover change: A review. *Annals of the Association of American Geographers*, 93: forthcoming.

Raskin, P., Chadwick, M., Jackson, T., and Leach, G. 1996. *The Sustainability Transition: Beyond Conventional Development*. Stockholm Environment Institute: Stockholm, SW.

Raven, P. ed. 1997. *Nature and Human Society: The Quest for a Sustainable World*. National Academy Press: Washington, D.C.

Raven, P. H. 2002. Science, sustainability, and the human prospect. *Science* 297: 954-958.

Rayner, S., and Malone, E. L. eds. 1998. *Human Choice and Climate Change: An International Assessment*. Battelle Press: Columbus, OH.

Rindfuss, R., and Stern, P. 1998. Linking remote sensing and social science: The need and the challenges. *People and Pixels: Linking Remote Sensing and Social Science*, D. Liverman, E. Moran, R. Rindfuss, and P. Stern, eds. National Academy Press: Washington, D. C., 1-27.

Rindfuss, R. R., Walsh, S. J., Mishra, V., Fox, J., and Dolcemascolo, G. P. 2003. Linking household and remotely sensed data: methodological and practical problems. *People and the Environment: Approaches for Linking Household and Community Surveys to Remote Sensing and GIS*, J. Fox, R. R. Rindfuss, S. J. Walsh, and V. Mishra, eds. Kluwer: Boston, MA, 1-29.

Risby, J., Kandlikar, M., and Patwardhan, A. 1996. Assessing integrated assessments. *Climatic Change*, 34: 369-395.

Robbins, P. 1998. Authority and environment: Institutional landscapes in Rajasthan, India. *Annals of the Association of American Geographers 88: 410-35.*

Robbins, P. 2001. Tracking invasive land covers in India, or why our landscapes have never been modern. *Annals of the Association of American Geographers* 91: 637-659.

Rotmans, J., and van Asselt, M. 1996. Integrated assessment: A growing child on its way to maturity. *Climatic Change* 34: 327-336.

Schellnhuber, H. J., Black, A., Cassel-Gintz, M., Kropp, J., Lammel, G., Lass, W., Lienenkamp, R., Loose, C., Lüdeke, M. K. B., Moldenhauer, O., Petschel-Held, G., Plöchl, M., and Reusswig, F. 1997. Syndromes of global change. *GAIA* 6: 19-34.

Schellnhuber, H. J., and Wenzel, V., eds. 1998. *Earth System Analysis: Integrating Science for Sustainability*. Springer-Verlag, Berlin.

Schneider, S. 1989. *Global Warming: Are We Entering the Greenhouse Century?* Sierra Club Books: San Francisco, CA.

Seto, E., Xu, B., Liang, S., Gong, P., Wu, W., Davis, G., Qiu, D., Gu, X., and Spear, R. 2002. The use of remote sensing for predictive modeling of schistosomiasis in China. *Photogrammetric Engineering & Remote Sensing* 68: 167-174.

Seto, K., and Kaufmann, R. 2003. Modeling the dirvers of urban land use change in the Pearl River Delta, China: Integrating remote sensing with socioeconomic data. *Land Economics* (Forthcoming).

Smil, V. 1993. *Gobal Ecology: Environmental Change and Social Flexibility*, Routledge: New York.

Sohn, F., Moran, E. F., and Gurri, F. 1999. Deforestation in North-Central Yucatan (1985-1995): Mapping secondary succession of forest and agricultural land use in Sotuta using the cosine of the angle concept. *Photogrammetric Engineering and Remote Sensing* 65: 947-958.

Steffen, W., Jäger, J., Carson, D., and Bradshaw, C. eds. 2002. *Challenges of a Changing Earth: Proceedings of the Global Change Open Science Conference, Amsterdam, NL, 10-13 July 200*. Springer-Verlag: Heidelberg, GR.

Steffen, W., Sanderson, A., Tyson, P., Jäger, J., Matson, P., Moore, B., III , Oldfield, F., Richardson, K., Schellnhuber, H.-J., Turner, B. L. II., and Wasson, R. 2003. *Global Change and the Earth System: A Planet under Pressure*. IGBP Global Series. Springer-Verlag: Berlin, GR.

Stern, P. C., Young, O. R., and Druckman, D. eds. 1992. *Global Environmental Change: Understanding the Human Dimensions*. National Academy Press: Washington, D.C.

Tegart, W. J. M., Sheldon, G. W., and Griffiths, D. C. 1990. *Impact Assessment of Climate Change: Report of Working Gouop II*. Australian Government Publ. Service: Canberra.

Thomas, W. L., Jr. ed. 1956. *Man's Role in Changing the Face of the Earth*. University of Chicago Press: Chicago.

Turner, B. L., II 2002a. Toward Integrated land-change science: Advances in 1.5 decades of sustained international research on land-use and land-cover change. *Challenges of a Changing Earth: Proceedings of the Global Change Open Science Conference, Amsterdam, NL, 10-13 July 200*, W. Steffan, J. Jäger, D. Carson, and C. Bradshaw, eds., Springer-Verlag: Heidelberg, GR., 21-26.

Turner, B. L., II 2002b. Contested identities: Human-environment geography and disciplinary implications in a restructuring academy. *Annals of the Association of American Geographers* 92: 52-74.

Turner, B. L., II, Clark, W. C., Kates, R. W., Richards, J. F., Mathews, J. T., and Meyer, W. B., eds. 1990. *The Earth as Transformed by Human Action: Global and Regional Changes in the Biosphere over the Past 300 Years*. Cambridge University Press: Cambridge, UK.

Turner, B. L., II, Cortina Villar, S., Foster, D., Geoghegan, J., Keys, E., Klepeis, P., Lawrence, D., Macario Mendoza, P., Manson, S.,Ogneva-Himmelberger, Y., Plotkin, A. B., Pérez Salicrup, D., Roy Chowdhury, R., Savitsky, B., Schneider, L., Schmook, B., Vance, C. 2001. Deforestation in the southern Yucatán peninsular region: An integrative approach. *Forest Ecology and Management*, 154, 343-370.

Turner II, B. L., Geoghegan, J., and Foster, D., eds. 2003. *Integrated Land-Change Science and Tropical Deforestation in the Southern Yucatán: Final Frontiers*. Clarendon Press of Oxford University Press, Oxford, UK.

Turner II, B. L., Kasperson, R. E., Meyer, W. B., Dow, K., Golding, D., Kasperson, J. X., Mitchell, R. C., and Ratick, S. J. (1990). Two Types of Global Environmental Change: Definitional and Spatial-Scale Issues in their Human Dimensions. *Global Environmental Change: Human and Policy Dimensions* 1: 14-22.

Turner, B. L., II, Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., Kasperson, J. X., Luers, L., Martello, M. L., Polsky, C., Pulsipher, A., and Schiller, A. 2003a. "A framework for vulnerability analysis in sustainability science." *Proceedings of the National Academy of Sciences, U. S. A.*, forthcoming.

Turner, B. L., II, Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., Eckley, N., Hovelsrud, G., Kasperson, J. X., Kasperson, R. E., Luers, L., Martello, M. L., Mathiesen, S., Naylor, R., Polsky, C., Pulsipher, A., Schiller, A., Selin, H., and Tyler, N. 2003b. "Illustrating the coupled human-environment system for vulnerability analysis: three case studies." *Proceedings of the National Academy of Sciences, U. S. A.*, forthoming.

Turner II, B. L., Moss, R. H., and Skole, D. L. 1993. Relating Land Use and Global Land Cover Change: A Proposal for an IGBP-HDP Core Project. IGBP Report No.24 & HDP Report No. 5, International Geosphere-Biosphere Programme and International Human Dimensions Programme: Stockholm and Geneva.

Vernadsky, W. I. 1945. The biosphere and the noösphere. *American Scientist* 33: 1-12.

Walker, R., Perz, S., Caldas, M., and Tiexeira Silva, L. G. 2002. Land use and land cover change in forest frontiers: The role of household life cycles. *International Regional Science Review* 25: 169-199.

Walsh, S. J., and Crews-Meyer, K. A. 2002. Linking people, place, and policy: A GIScience approach. Kluwer Academic Publ., Boston, MA.

Walsh, S. J., Evans, T. P., Welsh, W. F., Entwisle, B., and Rindfuss, R. R. 1999. Scale dependent relationships between population and environment in Northeast Thailand. *Photogrammetric Engineering and Remote Sensing* 65: 97-105.

Walsh, S. J., Evans, T. P., Welsh, W. F., Entwisle, B., and Rindfuss, R. R. 2001. A multiscale analysis of LULC and NDVI variation in Nang Rong District, northeast Thailand. *Agriculture Ecosystems and Environment* 85:47-64.

White, G. F. 1974. *Natural Hazards: Local, National, Global*. Oxford University Press, New York, NY

Wilbanks, T. J., and Kates, R. W. (1999). Global Change in local places. *Climatic Change* 43: 601-628.

Worster, D. 1977. *Nature's Economy: A History of Ecological Ideas*. Cambridge University Press: Cambridge, U.K.

ACT Publications 2003

No. 03-01
Moran, E., A. Siqueira and E. Brondizio. "Household Demographic Structure and it's Relationship to Deforestation in the Amazon Basin." *People and the Environment: Approaches to Linking Household and Community Surveys to Remote Sensing and GIS.* J. Fox, V. Mishra, R. Rindfuss, and S. Walsh (eds.) 2003. Kluwer Academic Press. Pp. 1-30.

No 03-02
Batistella, M., S. Robeson, E. Moran. "Settlement Design, Forest Fragmentation, and Landscape Change in Rodonia, Amazonia." *Photogrammetiric Engineering & Remote Sensing* Vol. 69(7), July 2003, pp. 805-812.

No 03-03
Lu, D., P. Mausel, E. Brondizio, E. Moran. "Classification of successional forest stages in the Brazilian Amazon basin." *Forest Ecology and Management* Vol. 181, pp. 301-312. (2003).

No 03-04
Futemma, C., E. Brondizio. "Land Reform and Land-Use Changes in the Lower Amazon: Implications for Agricultural Intensification." *Human Ecology* Vol. 31(3) September 2003. Pp. 369-402.

No 03-05
Siqueira, A., S. McCracken, E. Brondizio, E. Moran. "Women and Work in a Brazilian Agricultural Frontier." In: Gender at Work in Economic Life. Gracia Clark (editor). 2003. Altamira Press, New York, NY. Pp. 243-265.

No 03-06
Hurtt, G.; X. Xiao, M. Keller, M. Palace, G. Asner, R. Braswell Eduardo Brondizio, Scott Hetrick et al. "IKONOS imagery for the Large Scale Biosphere-Atmosphere Experiment in Amazonia (LBA)." ***Remote Sensing of Environment*** 88(2003). Pgs 111-127.

No 03-07
Lu, Densheng; Emilio Moran, and Mateus Batistella. "Linear mixture model applied to Amazonian vegetation classification." *Remote Sensing of Environment* 87(2003). Pgs 456-469.