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A Grand Challenge for SBE:

Unlocking a New Cycle of Research for Human-Landscape Interactions

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Abstract

The grand challenge is to more fully utilize the social, behavioral, and economic sciences to develop predictive capacity for integrated human-landscape systems, and to re-frame the complex interactions of these systems in new ways, in which feedbacks can be better understood, represented, and predicted. Historical approaches, which treated humans as external drivers of change, have not sufficiently captured interrelationships involving the effects of landscape change on societies and individuals and the effects of multiple human-caused stressors on landscapes. Meeting this grand challenge presents infrastructural as well as thematic and intellectual challenges. This paper summarizes key questions for the science of human-landscape systems, developed first from the perspectives of disciplines that may contribute, then presents potential research themes linking these disciplines, and outlines urgent research needs for advancing the science. These findings were developed at an NSF interdisciplinary workshop in March 2010. Better integrating social-scientific as well as environmental components of human-landscape systems offers the potential to transform our thinking and to unlock a new cycle of research for human-landscape systems that fully engages the SBE sciences. Enhanced understanding of human-landscape systems also promises novel solutions for mitigating and even reversing environmental degradation and its societal consequences.

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Introduction

Humans have drastically altered Earth's landscapes, and in turn, these changes have affected human conditions, behavior, and decision-making choices. Although a complex web of interactions clearly exists, many of the connections and potential feedbacks between Earth's surface systems and human individuals and societies are largely unexplored and poorly understood. **The grand challenge is to more fully utilize the social, behavioral, and economic sciences to develop predictive capacity for integrated human-landscape systems, and to re-frame the complex interactions of these systems in new ways, in which feedbacks can be better understood, represented, and predicted.** Meeting this challenge will require developing new intellectual, virtual, and institutional spaces and collaborations to facilitate the emergence of new theories and tools through interdisciplinary efforts.

In March, 2010, the authors were among an interdisciplinary group of 50 scholars who met in Eugene, OR, at the NSF-sponsored workshop, Landscapes in the "Anthropocene": Exploring the Human Connections. Workshop participants identified fundamental disciplinary research questions related to human-landscape systems, and explored conceptual frameworks for integrative, interdisciplinary research and areas of interaction between their disciplines. Here, we review the broader context and significance of the grand challenge stated above, and summarize questions, themes, and research needs related to this challenge that emerged from the Eugene workshop [See http://geography.uoregon.edu/landscapes].

Context and Significance

Historically, Earth scientists (including physical geographers) have studied human impacts to the environment primarily from the perspective of humans as external drivers of change. This approach is insufficient to capture the interrelationships of landscapes increasingly affected by multiple human-caused stressors and people affected by landscape change. A more complete and useful treatment of integrated human-landscape systems requires consideration of human actions, decision making, and economic and political factors because they influence the potential responses and feedbacks within the human-landscape system. Human responses include mitigation and adaptation strategies, and the use of policy and technology, as well as media, education, and communication tools. These feedbacks are critical to slowing or reversing environmental degradation, with policy being a key instrument with which society facilitates the necessary feedbacks.

Humans have altered Earth's surfaces throughout history, and the environmental impacts of human population growth, accompanied by resource consumption and disposal, have intensified over time. Humans have modified land cover through agriculture and urban development, promoting soil erosion and changing hydrologic and biologic processes. Industrial and agricultural practices have released chemicals into water and soil. Dams and levees, built for flood control, water supply, and hydroelectric power, interrupt sediment movement along rivers, and change landscapes and human activities. Human activity is also linked to our recently warming climate, which, in turn, affects social and biophysical processes on Earth. These effects will likely increase with a growing global population that may reach 10.5 billion inhabitants by the end of the

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century. Understanding, predicting, and responding to rapidly changing processes on Earth's surface is among the most pressing challenges of our time.

The need for new integrating concepts and approaches for understanding human-dominated environmental systems is clear and has been increasingly articulated in the interdisciplinary sciences. Integration of human dimensions is necessary to address societal and environmental impacts of climate change and management responses. NSF has previously supported efforts to incorporate social sciences in studies of human-environmental systems, from Biocomplexity in the Environment (later, the Dynamics of Coupled Natural and Human Systems) to the Urban Long-Term Research Areas program. Those programs elicited new concepts for social-ecological systems that explicitly incorporate human decisions, governance, and economic systems.

What is needed now is the development of new approaches for exploring human-landscape systems, in which geomorphic and societal processes are central. Whereas ecological systems involve organisms, organic matter, and nutrients, geomorphic systems involve physical changes to Earth's surfaces, including landslides, soil erosion, and flooding. Thresholds for geomorphic systems may trigger policy and institutional responses that differ from those for ecological systems. Therefore, distinct questions, datasets, and frameworks are required for developing an understanding of integrated human-landscape systems that emphasize geomorphic phenomena and the consequent interactions, responses, and feedbacks among social, physical, and biological systems.

Recognizing the importance and urgency for accelerating understanding of human-landscape systems, the National Research Council (NRC, 2010a) recently recommended to the NSF the development of a high-priority research initiative, The Future of Landscapes in the "Anthropocene." This initiative requires full participation from the SBE sciences collaborating with the geosciences, biological sciences, and engineering to advance understanding of human-landscape interactions. Another 2010 NRC report (NRC, 2010b) called for large-scale collaborations between researchers with diverse areas of expertise, including the SBE sciences, to increase understanding of the human role in environmental change, along with other important challenges of the 21st century.

Key Questions

For interdisciplinary collaboration to be successful from the onset, research questions need to advance fundamental theory within existing disciplines as well as build new theory linking across disciplines. During the Eugene workshop, discussion of key questions from individual disciplines served as a basis for developing integrative research themes and identifying immediate research needs. The box below lists example key disciplinary questions in the SBE sciences related to human-landscape systems. They illustrate potential contributions from a range of disciplines and areas of overlap among them, and exemplify the need for interdisciplinary, integrated research:

Anthropology: How do societies adapt to changes on Earth's surface, such as to land eroding due to agricultural activity? What cultural variables affect how people value their natural resources and environment, and underlie decision making?

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Economics: How can valuation of ecosystem goods and services be improved to quantify costs of externalities? How do people respond to altered incentives and changes in landscape function created by environmental changes?

Human Geography: What are the effects of connectivity/networks and associated spatial autocorrelation issues on understanding management regimes and response options? What integrative techniques and approaches can spatial sciences contribute to understanding and predicting human-landscape systems?

Physical Geography/ geomorphology: What are the relevant timescales for addressing particular human-landscape interactions, when problems can occur over a geologic period or in a single flash flood? How can we separate human from natural signals in landscapes?

Policy science: What are the constraints—social, economic, and bio-physical landscape processes—on human behavior, and how do we understand them to promote change in individuals, communities, and institutions? How best can adaptive capacity be built and supported in human-landscape systems?

Sociology: What are the broader social and political consequences of landscape change, such as the installation or removal of dams, especially when the magnitude of causes and effects are asymmetric (i.e., small change in landscape processes can produce large social change, and vice versa)? How are the risks and benefits distributed among people?

Themes for Interdisciplinary Collaboration

Developed from the questions above, the following themes serve as potential focal points for interdisciplinary collaboration, around which new theory can be built for integrated human-landscape systems:

- *Thresholds/tipping points:* What are they, and how do they rise from interactions among hydro-geomorphologic, ecologic, and human systems? Given multiple and cumulative drivers of change, how can we infer the exact cause and effect relationships? Are thresholds predictable—i.e., are signals of irreversible change identifiable, especially where the path of response differs from the trajectory of impact?

- *Time scales and time lags:* How do time scales of geomorphological, hydrological, and ecological processes relate to those of behavioral and institutional processes? How do time lags within physical, biological, cultural, political, and economic systems interact to influence observed and predicted system states?

- *Spatial scales and boundaries*: How do physical boundaries compare with cultural and political boundaries? Do human-made boundaries produce environmental signals, and vice versa?

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- *Feedback loops*: In human-landscape systems, how can feedback loops be identified and tightened to slow or reverse degradation, especially when coupling is weak, or when coupling is driven by a threshold response? How can coupling be managed to promote greater resilience in desired system states toward a sustainable Earth?

In discussing how to implement new research on these themes, the following needs were identified:

1. *Common metrics* are needed for describing and quantifying human, geomorphological, and biological systems. Such metrics are critical for linking interconnected processes and for quantifying the conditions of bio-physical and human systems in ways that are comparable. Examples include (i) how resilience might be quantified and compared for human and hydro-geomorphological systems and (ii) how "functionality," including ways to quantify the loss of "functionality" in geomorphological, ecological, and human systems could be a common parameter. Much work is needed to develop and test the effectiveness and utility of these and other potential metrics. Developing and testing usable common metrics is an urgent first step toward interdisciplinary advances for human-landscape systems.

2. A critical need exists for *integrating data* and developing *integrative methodologies*. Particularly important is the need to merge spatially extensive data from remote sensing with field-based data. Developing systematic methodologies to analyze relationships across disciplines will also require integrating qualitative methods and conceptual models with quantitative ones.

3. As individual studies continue to accumulate, an urgent need has emerged for *synthesis, generalization, and meta-analyses*. How can individual studies, which commonly document single small impacts, be aggregated in meaningful ways to quantify cumulative impacts? Each removal of a small dam along a river may exert a small impact, but how do they collectively affect the river and the lives and livelihoods of local populations? How can individual studies of local-scale issues be scaled up to regional and global scales, such as to document the global sum of small diffuse human impacts or of environmental stressors on human responses? Are studies from one area applicable to other areas? Clearly, major advances will require much synthetic work ahead.

The challenges are institutional as well as thematic. Identifying common metrics, integrating data and ways of data collection, and synthesizing across studies require effective communication and collaboration among multiple communities: among a range of natural scientists and social scientists, among scientists from different traditions, and between modelers and field-based researchers. The enthusiastic response of a diverse group of researchers to one workshop highlighted differences between disciplinary approaches and perspectives, but also demonstrated tremendous potential for advancing integrative, interdisciplinary research. A main infrastructural challenge, therefore, is to develop venues and mechanisms for supporting broad interdisciplinary work focused on human-landscape interactions. The long-term challenge is to build capacity—to push the frontiers in developing the science, to nurture graduate students, and to translate the science toward public good.

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Further, the intellectual and practical challenges of interdisciplinary research are especially heightened when working across the bio-physical and social science divide. Differences in methodological approaches often pose real and perceived gaps that must be bridged in order to forge scientific advances. In the case of research on Earth's surface processes, identification of colleagues across the 'divide' for potential collaboration has also been difficult, because researchers in these fields have historically worked in isolation from each other. Yet, the time has come to engage in dispassionate conversation about the future of Earth's changing surfaces and the societal effects of these changes to create a focused effort across disciplines to anticipate and mitigate future impacts, as well as to factor the changes that have already occurred into human decision processes. Because increasing human impacts are changing Earth's surface at unprecedented rates, and because human society depends on Earth's surface for resources and ecosystem services, such efforts are critical for transforming our approach to producing the new knowledge required for mitigation, environmental restoration, and social adaptation.

Integrated human-landscape systems require social-scientific as well as environmental components, thereby offering the potential to transform our thinking about the role of human agency in landscapes, and to unlock a new cycle of research that fully engages the SBE sciences. Enhanced understanding of such systems also promises novel solutions for mitigating and even reversing environmental degradation in human-landscapes, as well as promoting socially fair and acceptable adaptation to landscape changes that cannot be avoided. Collaboration between physical geographers, geoscientists, and social, behavioral and economic scientists is not only possible, but stimulating and transformative. We believe this is the way forward.

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