Editorial

Biocomplexity in coupled human-natural systems: The study of population and environment interactions

1. Introduction

The commonality in the papers invited to this Special Issue is the complexity theory context, the integrative nature of the studies, their inclusion in the Biocomplexity and/or Coupled Natural-Human Systems Programs of the US National Science Foundation (NSF), representation of scholars from the social, natural, and spatial sciences, and emphasis in linking patterns to processes in complex settings in which systems are dynamic, nonlinear, and adaptive. The study of coupled natural-human systems moves beyond normal nature-society concepts as it looks at emergence and other complexity theory contributions (An et al., 2005). Too often, physical geographers have isolated nature without human contexts. Human geographers, too, have had difficulty in merging their theories into computer models and physical systems thinking. The authors in this issue strive to overcome these problems as the funding agency challenged grant recipients to specifically address systems thinking and to analyze the feedback mechanisms inherent in coupled systems. The combination of human and physical geography interests and paradigms became a focal point for many of these investigations. While many of the findings reported in this issue relate more to changes in physical systems, the concomitant changes in human systems are also documented. The geographic aspects of complexity theory, social dynamics, and coupled natural-human systems are emerging as a fundamental component of our ability to describe how the natural and human environments intersect (Evans and Kelly, 2004; Messina and Walsh, 2005).

In this Special Issue, we seek to examine the nature of coupled human-natural systems by emphasizing biocomplexity, i.e., the interdisciplinary and integrated study of coupled human-natural systems, often approached from the perspective of LULC or systematic change, to address the causes and consequences of landscape dynamics. Biocomplexity often views landscapes as complex systems, consisting of interactions of human and natural processes, in which landscape patterns are important emergent properties of complex dynamics, and encompass the complex interactions within and among ecological systems, the physical systems on which they depend, and the human systems with which they interact (Michener et al., 2003).

2. Biocomplexity and land use/land cover dynamics

Several case studies are described in this Special Issue that have a pronounced connection between population and the environment. The general goals of the Special Issue are to (a) describe the theories and practices that contextualize the study of coupled human-natural systems, (b) examine pattern–process relations important in the behavior of systems in the various geographic settings and for the various research aims, (c) describe the modeling approaches used and the various forces and factor represented to assess system parameters and dynamics, (d) assess what we have learned and the impediments to our understanding, and (e) contribute to the synthesis of findings of case studies, and point to new challenges and opportunities in biocomplexity of coupled human-natural systems. The dominant theme in the Special Issue is our emphasis on pattern–process relationships, with explicit comment on feedback mechanisms that involve the interactions between people and environment within a coupled human-natural systems context (Henrickson and Mc Kelvey, 2002).

Further, individual papers address elements of case studies that comment on a selected set of “fundamental issues” in complexity theory, space-time scales, pattern–process relations, links between population and the environment, and spatial simulation models. We have also labored to make the Special Issue accessible to a broad geographic audience, but not exclusively to that community. We also asked authors to pay particular attention to “big issues” in biocomplexity and not solely on the local-regional issues that relate to their particular case study. Also, we sought to describe theories and practices germane to the study of coupled human-natural systems, as well as the geographic and spatial analytical perspectives and approaches of inquiry, and the cross-cutting nature of
integration and synthesis across the social, geographical, and biophysical domains.

The Special Issue reports on important research being conducted by social, natural, and spatial scientists who rely upon multidisciplinary and interdisciplinary theories, perspectives, and practices to examine population–environment interactions. Mostly supported by the US National Science Foundation, the US National Aeronautics and Space Administration, and the US National Institutes of Health, the invited researchers use dynamic systems modeling and nonlinear relationships to link people and the environment through multi-scale, pattern–process relations, and to examine complex systems that involve multiple agents and a dynamic environment. Explicit emphasis is on feedback mechanisms, emergent behavior, and self-organization (Freeman et al., 2000).

The Special Issue also describes how complexity theory is being used by a group of diverse scholars who are engaged in a host of settings in which people and the environment are explicitly linked within a dynamic systems approach. Emergent behavior is seen at a regional scale as an outcome of actions and patterns at local settings (Manson, 2001; Parker et al., 2003). Spatially-extended systems can self-organize to generate order as seen in frontier environments (Malanson et al., 2006a). Complexity emerges as a result of the patterns of interactions between elements (Luhman, 1985). For example, the complex structure of social inequalities in a number of frontier settings emerges from unstructured interactions of households, resource endowments of the land, and land uses at local scales (Malanson et al., 2006b; Walsh et al., 2006).

Spatially-explicit modeling methods that involve Cellular Automata and Agent-Based Models are highly suited to the exploration of pattern–process relations in land-use systems (Batty et al., 1997; Messina and Walsh, 2001). The models allow one to spatially simulate LULC patterns, assess likely future LULC states, and examine how social, demographic, geographic, and biophysical factors alter trajectories of LULC change, resulting in possible shifts in the composition and spatial structure of the landscape, and with it, pattern–process relations (Benenson, 1999; Deadman et al., 2004; Walsh et al., 2006). Research in complex systems attempts to identify corresponding morphology of patterns and processes in social and natural systems. Complex systems may be far from equilibrium, because there are constant interactions through feedback mechanisms that maintain the organization of the system (negative feedbacks) or alter subsequent alternatives in state space (positive feedbacks). A complex system does not only evolve through time, its past is co-responsible for its present behavior.

The science of biocomplexity and the associated modeling approaches and practices are rapidly evolving across the sciences. A case in point is the recent development of the Human and Social Dynamics research program led by social scientists at the US National Science Foundation, which followed on the heels of the Biocomplexity: Coupled Natural-Human Systems Program that originated at the National Institutes of Health that featured the development of tools and approaches for complex systems modeling.

The language of biocomplexity can be confusing to social, natural, and spatial scientists, and, therefore, this Special Issue, devoted to coupled human-natural systems, is diverse, describes cutting-edge applications and modeling activities, integrates the effects of people on the environment and visa versa in interesting ways, and describes some fundamental and advanced research applications and directions. The challenge of this Special Issue is to frame the papers for a broad audience, limit the jargon, explicitly define key concepts and “big picture” issues, extend the literature review to important and fundamental references as well as targeted citations, and reduce the emphasis of the papers to purely case study reports in favor of descriptions of important insights into wider sets of debates. In addition, the collective research experiences of the group of scholars are used to sculpt the Special Issue to meet our central goal of accessibility, representation across the sciences, and emphasis on methodological and theoretical concerns for linking people and the environment.

The Special Issue is organized to describe specific geographic settings, research questions, methods, and findings derived within a biocomplexity context and a coupled human-natural systems approach. In additional to the case studies being reported, two “fundamental issues” papers are also included. They were invited to the Special Issue to lay the foundation for the papers that follow by describing background material, context, and challenges that are important to the study of coupled human-natural systems.

In the first paper, Manson describes an epistemological scale continuum that arrays perspectives on scales that range from “realist” and “constructionist” views, as no single scale definition is sufficient in biocomplexity research. The next paper by Parker, Hessl, and Briden considers biocomplexity in land use systems moving from human decision-making to human interactions, and including the effects of space, time, and scale. Mismatches between human drivers and the scale of their impacts are identified as important factors. These papers are followed by two papers that are geographically positioned in the Upper Midwest of the United States. The paper by Brown and authors examines land use/land cover change in exurban environments in Southeastern Michigan, whereas Evans and Kelly explore historical dynamics of reforestation in South-Central Indiana. The papers rely upon a multi-disciplinary perspective, disparate data, and agent-based models to assess land use/land cover dynamics and to validate the structure of the derived spatial models and to assess the trajectories of land use change through time, respectively. Bennett and
McGinnis also examine human–environment interactions in the United States, but move West to the Greater Yellowstone Ecosystem of Montana and Wyoming. They use a coupled human-natural systems framework to study the winter range of elk within the context of sustainability, resilience, and predictability. The papers by Acevedo and authors and Walsh and colleagues move the study of biocomplexity to Latin American by conducting paired studies in Texas and Venezuela on protected areas and deforestation and agricultural extensification in the Ecuadorian Amazon, respectively. Acevedo and authors examine forest conversion by affluent individuals in Texas and by landless settlers in Venezuela. Agent based models are used to represent human stakeholders and feedbacks between agents, ecological habitats, and hydrological processes. Walsh and colleagues examine the effects of off-farm employment on deforestation patterns in the Ecuadorian Amazon through changes in household livelihood strategies. Cellular automata models are used to link the effects of population–environment interactions, and rely on diverse data types, including a longitudinal social survey, GIS coverages, and a remote sensing image time-series for developing spatial simulation models. Entwisle and colleagues also use cellular automata models to examine land use/land cover change in a frontier environment by considering the effects of alternate patterns of human settlement, where nuclear settlement patterns exist and land is distributed in an areal pattern that surrounds the villages. Finally, Olson and authors examine climate–land interactions at multiple space and time scales in East Africa by linking land use/land cover change and climate change.

In sum, the Special Issue brings together a number of topics, methods, findings, and comments on fundamental issues and new directions in the study of biocomplexity and coupled human-natural systems, with an emphasis on LULC change and population–environment interactions. We hope that the collection of papers inform those new to CA and ABM approaches for the study of dynamic systems, as well as those substantially engaged in the study of biocomplexity.

Finally, we sincerely thank the authors and the reviewers who have labored to generate interesting and important statements on biocomplexity and coupled human-natural systems. Further, we offer our deep appreciation to Paul Robbins, North American Editor of GeoForum for his energies, talents, and interests in the Special Issue, and to the other editors and staff of the Journal for their assistance and cooperation.

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