NEON

A TRANSFORMATIONAL ECOLOGICAL RESEARCH PROGRAM TO INTERPRET AND FORECAST DYNAMICS IN THE COUPLED HUMAN-ENVIRONMENT SYSTEM

Report of the NSF-Sponsored Workshop -- January 10-11, 2006
Harvard Forest, Harvard University

David Foster, Billie Turner, Morgan Grove, and Workshop Participants[1]

Executive Summary

- NEON has two broad goals: (i) understanding how land-use change and climate variation affect ecological systems and (ii) forecasting future dynamics;
- Achieving the first goal will require the engagement of social scientists and new sensor networks, data acquisition systems, and cyberinfrastructure to collect, integrate, synthesize, and interpret the required land-use and land-cover data;
- Forecasting demands credible models of the mechanisms by which land-use changes; this will require integrated research by social and ecological scientists on the interactions within coupled human-environment systems;
- Development of the requisite data, infrastructure, science programs, and sustained funding to undertake these tasks provide NEON with the opportunity to transform ecological and social science and the quality of ecological forecasting, while contributing to sustainability and global change science.

Overview – The Role of the Human Dimensions in NEON

The broad mission of NEON is "*to provide the capacity to forecast future states of ecological systems for the advancement of science and the benefit of society*" (NEON 2005). NEON seeks to build this capacity through coordinated research addressing two overarching questions about the effects of climate variation and land-use change on ecosystems and the patterns and movements of organisms. **Both the forecasting mission and the land change science of NEON involve important reciprocal or feedback relationships between human systems and environmental systems, and thus require a strong and focused social science component.**

Addressing these relationships and integrating social science into NEON would make NEON transformative for the ecological sciences and would complement the international consensus among ecologists and environmental scientists that **significant progress in addressing the Grand Challenges requires research addressing the coupled human-environment system** (Kates et al 2001; Lubchenco 1998; Raven 2002; Steffen et al. 2004, Turner et al. 2003, Foster et al. 2005; or social-ecological system (Berkes, Colding, Folke 2003))**.** For much of the ecological sciences, including NEON and LTER, this "coupling" may be best pursued through land-change analyses in conjunction with studies of climate interactions and ecological responses and feedbacks (NRC 2001, GLP 2005; Gutman et al. 2004; MEA 2003).

[1] See Workshop Participants in Appendix 1.

The current design of NEON explicitly incorporates social science in its principal research questions by drawing on social data to identify the land-use drivers of ecosystem dynamics. In order to address the stated questions NEON will need to engage preeminent social scientists working with land change data and analyses. However, even with these data in hand, omissions in the current NEON design will serve as barriers to fulfilling NEON's overall mission. The NEON design does not explicitly recognize that an understanding of the **social drivers** of land-cover change as well as the **feedbacks** between social and ecological systems is essential for a mechanistic interpretation of ecological responses and the development of reliable forecasts of future conditions. **Addressing these omissions is critical for NEON to achieve its stated goals and to attract the social science community needed for the land-change science. It will also provide key opportunities for NEON to transform the nature of ecological science and the quality of ecological forecasting, while contributing to sustainability and global change science** (MEA 2003, GLP 2005, Hobbie et al. 2005).

Challenges and Opportunities for the Objectives of NEON

Understanding and documenting changes in land use require sensor networks and data acquisition and analysis systems that capture information beyond the immediately observable characteristics of the landscape. Land-use systems encompass human dynamics that include historical, political, economic, social, behavioral, and psychological aspects of individuals and institutions. **To serve NEON's objectives** of (a) understanding how land-use changes affect ecological systems and (b) forecasting future dynamics, **sensor networks and data acquisition and analysis systems must be developed to characterize critical dynamics in social and ecological systems.** The requirements for both detailed resolution and regional to national coverage will challenge existing technology and cyberinfrastructure, from data collection - whether in existing digital archives, historical archives, or in the field - through the storage and integration of heterogeneous spatial and temporal data, to their analysis and modeling.

High quality land-use data, and the supporting social science that facilitate inference of past and projection of future land use, exist in an array of different formats (i.e., digital and analog) at different spatial and temporal resolutions, with disparate category and variable definitions, and following a variety of disciplinary standards (e.g., legal, economic, demographic, etc.). Consequently, NEON sensor arrays will require the following infrastructure:

- Moderate to high-resolution multi- and hyper-spectral satellite sensors;
- Large-format, high-resolution, and high-capacity scanners for converting archived analog documents (e.g., parcel maps, aerial photographs) to high resolution digital formats;
- High-performance database systems, user-directed web crawlers and internet search engines;
- Software tools for large-scale text and image data integration and mining;
- Interactive web-based survey form generators with community input portals;
- Integrated *in situ* social-data collection devices (e.g., integrating palmtop computers with GPS, GIS software and data, digital survey forms, and back-end database and analysis servers); and
- Site safe data services (platform) that permits access to data that are open to researchers but under federal and state rules of use and security. The safe computer sites would be linked to the counter part data of the Census and Agriculture Census.

Data will need to be maintained at the level of individual parcels, landowners, users, and managers. Sensor data will need to be integrated on a network of distributed spatially and temporally explicit data bases that address scalability, semantic and format translation, and maintain appropriate licensing and privacy protection standards. The size and complexity of these data bases challenge existing hardware and software technology, and put demands on system administration and management functions. Data integration, mining, and modeling components of the NEON information infrastructure will require the integration of spatial, social, and ecological data sets for the purposes of understanding and forecasting land-use changes by integrated teams of natural and social scientists.

The information infrastructure required to meet NEON's goals has numerous reciprocal benefits for the social sciences and other science communities that are not currently articulated in the NEON science execution plan. If seized, these benefits could yield a transformation in the social sciences beyond those components dedicated to understanding of coupled human-environment systems. Land-use forecasts will need to be based on credible models of the mechanisms by which land-use changes. Such mechanisms are based on interactions within a coupled human-environment system with bi-directional causal effects. **To be credible, NEON land-use forecasts will need to engage a broad group of social science experts, who can collect, interpret, and model the appropriate data from within the NEON information infrastructure.** In order to attract this cadre of experts, NEON must articulate the opportunities for new data, new scientific environments, and new understanding that will be possible given the infrastructure, funding, and scientific challenges presented by this program. NEON should advertise and capitalize on its potential to facilitate a new generation of social scientists cooperating with ecological scientists and generating new opportunities to inform concepts and theory in the social sciences.

The Research in Review

The forecasting mission of NEON is informed by the following science questions:

1. How are ecosystems affected by variations in climate and changes in land use?
   a. How will ecosystems respond to these changes across a range of spatial and temporal scales? And, are the responses gradual or abrupt?
   b. How do changes in land use and climate influence the movement of water and materials from terrestrial to aquatic ecosystems? And, how does this affect nutrient dynamics and ecosystem metabolism?

2. How will the patterns and movements of organisms be affected by variations in climate and changes in land use?
   a. How will plant and animal biodiversity respond to these changes? And, do changes in biodiversity have a ***reciprocal effect*** [emphasis added] on land use and climate?
   b. How do these changes affect the spread of infectious diseases and invasive species? And, what are the ecological implications?

NEON couples the human dimensions of land change with ecological issues in a unidirectional way in three of its four sub-questions. Given appropriate data, social science experts can develop an empirical understanding of the human forcing functions on land change and ecosystems. **The forecasting mission of NEON, however,**

requires two modest elaborations: [1] a bi-directional (reciprocal, interactive, or feedback) research effort for each question, as identified in 2a (above), in which the ecosystem feedbacks on land use and other human activities are addressed; and [2] an examination of the mechanisms that drive land-use change.

With these modest elaborations, NEON would enlarge its contributions beyond ecological relationship to resolve dynamic coupled human-environmental interrelationships that provide the basis for generalization and forecasting. Such changes would engage international, sustainability and global change research agendas addressing coupled human-environment questions. Examples of these integrated and more comprehensive questions include:

- How does the maintenance of different ecosystem services affect extant land uses and land-use decision making?

- What are the dynamics of land use systems that affect the cycling of energy, water, nutrients and biota over various time scales and at continental, as well as local, regional, national and global scales?

- How do global and national changes in political economy, such as globalization, international treaties and market liberalisation, affect decisions about resources and land use at local, regional and continental levels with consequent impacts on ecological functioning of landscapes?

A Need for New Programs with Sustained Funding for Integrated Studies

Current funding is insufficient to analyze and interpret the human subsystem of coupled human-environment systems in terms of both consistency and duration of long-term data collection, infrastructure, and research. Quite simply, there is not enough funding overall, and **inadequate sustained, long-term funding in particular** to support land-use systems research that encompasses human dynamics. To transform the ecological and social sciences underpinning our capacity to understand and forecast the dynamics of coupled systems, three deficits will need to be addressed. First, NEON will need to develop **sensor networks and data acquisition and analysis systems to characterize critical dynamics in human and ecological systems** as described above**.** Second, research and mission-oriented agencies such as the NSF, NASA, USDA Forest Service, NRCS, EPA, USGS, US Park Service, and US Census will need to work individually and/or collaboratively to fund **short (3 years) and long term (6 year and longer) social science and interdisciplinary research programs** to support this effort. Currently, long-term social science funding occurs on only 4 of the 25 sites in the LTER program (Gragson and Grove, 2006), with co-support by NSF and US Forest Service occurring for social science on only one of those 4 sites. Lastly, in order to maximize benefits to society, NEON will need to work adaptively and incrementally with these and other mission-oriented agencies to **harness their existing infrastructure for technology exchange to disseminate data, knowledge, and tools to inform decision making at national, regional, and local levels.**

Conclusion

As a science program that captures, assembles, and analyzes new data to interpret the dynamics of the coupled human-environment system at regional (Domain) and continental scales, NEON has the capacity to transform ecological and social

sciences while providing a model for global change science. By providing the understanding of complex systems and a new level of forecasting abilities NEON can coordinate with its mission-oriented partners (e.g., USDA, USFS, NASA, NOAA, EPA, USDI, BLM, NPS, NRCS) to provide meaningful contributions to society, policy development and management approaches. One hallmark of success in these ventures will be realized when NEON scientists recognize the need to alter the assumptions underlying their models in order to incorporate fundamental changes in national, state, or local public policies (e.g., legal structures, regulations, etc.) that arise from observations originating in the NEON program. In essence, it is the understanding and anticipation of these dynamic feedbacks that provide the greatest challenge and opportunity for the NEON program, its ecological and social scientists, and its mission-oriented partners.

References

Berkes, F., J. Colding and C. Folke (editors). 2003. *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*. Cambridge University Press, Cambridge, UK.

Foster, D. R., R. Aspinall, J. Briggs, G. Brush, A. Hansen, W. Hargrove, F. Swanson, B. Turner, and D. Urban. 2005. Neon Land Use Subcommittee Report – Boston Meeting. HTTP://WWW.NEONINC.ORG/DOCUMENTS/LUC_BOSTON_REPORT.PDF

GLP (Global Land Project). 2005. *Science Plan and Implementation Strategy*. IGBP Report53/IHDP Report 19. IGBP Secretariat, Stockholm.

Gragson, T. and M. Grove. 2006. Social science in the context of the Long term Ecological research Program. Society and Natural research programs 19:93-100.

Gutman, G., A. Janetos, C. Justice, E. Moran, J. Mustard, R. Rindfuss, D. Skole and B. L. Turner, II (editors). 2004. *Land Change Science: Observing, Monitoring, and Understanding Trajectories of Change on the Earth's Surface*. Kluwer Academic Publ., New York, NY.

Hobbie, J. (chair), B. Bond, J. Melillo, W. Parton, D. Peters, G. Pontius, E. Rastetter, and D. Urban. *A Workshop on Modeling in NEON*. Proceedings of a workshop held July18-20, 2005 Woods Hole, MA. Sponsored by The National Science Foundation. http://www.neoninc.org/documents/NEON_modeling_18jul05.pdf

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

Lubchenco, L.. 1998. Entering the Century of the Environment: A New Social Contract for Science. *Science* 279:491-497.

MEA (Millenium Ecosystem Assessment). 2003.ECOSYSTEMS AND HUMAN WELL-BEING: A Framework for Assessment. Millennium Ecosystem Assessment Series. Washington D.C.: Island Press.

NEON 2005. (National Ecological Observation Network) http://www.neoninc.org/

NRC. 2001. Grand Challenges in the Environmental Sciences. Committee on the Grand Challenges in the Environmental Sciences. National Research Council. National Academy Press: Washington, D.C.

Raven, P. H. 2002. Science, Sustainability, and the Human Prospect. *Science* 297:954-958.

Richardson, H.-J. Schellnhuber, B. L. I. Turner and R. Wasson. 2004. *Global Change and the Earth System: A Planet Under Pressure*. IGBP Global Change Series. Springer-Verlag, Berlin, GR.

Steffen, W., A. Sanderson, P. Tyson, J. Jäger, P. Matson, B. Moore, III, F. Oldfield, K. Richardson, H.-J. Schellnhuber, B. L. I. Turner and R. Wasson. 2004. *Global Change and the Earth System: A Planet Under Pressure*. IGBP Global Change Series. Springer-Verlag, Berlin, GR.

APPENDIX 1. LIST OF PARTICIPANTS AND AUTHORS

Richard Aspinall, Department of Geography, Arizona State University
Kathleen Bell, Resource Economics and Policy, University of Maine.
Chris Boone, School of Human Evolution and Social Change/Global Institute of Sustainability, Arizona State University
Dan Brown, School of Natural Resources and the Environment, University of Michigan
Tom Evans, Department of Geography/CIPEC, Indiana University
David Foster, Harvard Forest, Harvard University
Jackie Geoghegan, Department of Economics, Clark University
Morgan Grove, Northeastern Research Station, U.S. Forest Service
David Kittredge, Department of Natural Resources Conservation; University of Massachusetts
Charlie Lord, Urban Ecology Institute, Boston College
Robert McDonald, Harvard Forest, Harvard University
Gil Pontius, Department of Geography, Clark University
Tom Prudhomme, National Center for Supercomputing Applications. University of Illinois
Mark Rickenbach, Forest Ecology and Management; University of Wisconsin
Eric Strauss, Urban Ecology Institute, Boston College
Billie Turner, Department of Geography, Clark University

Appendix 1. Table from the NEON Boston Land Use Report showing valuable data types for social science and land use studies.

Data	Content	Source
Socio-economic		
Historical Land Cover and Use	Historical land cover and land-use maps	Various
	Historical air photo and satellite images	NASA (EROS Data Center), DAACs
	Agricultural use, Fertilizer use etc	Farm, County and State records Agricultural Census
Land Tenure	Property and ownership data	County, City and National cadastral datasets Historical archives
Population/Demography	US Population Census	US Bureau of Census
	Historical Pop. Census (1790-2000)	National Historical GIS (U Minn.)
	Daytime population	Landscan (ORNL)
Employment and Economic Activity	Jobs, wages, unemployment, occupation, and prices data series	Bureau of Labor Statistics
	Gross State Product, Regional Economic Information System (REIS), foreign direct investment data, national income account data, Survey of Current Business	Bureau of Economic Analysis
	Annual income, financial, tax data	Statistics of Income (IRS)
Transportation	Transport networks, characteristics, use	National, State and County Highway, Transportation, and Engineering Departments
Human activity/preferences	Activity and Marketing databases	Commercial sources e.g. CACI
Biophysical		
Contemporary and Historical Climate records,	Includes both direct and indirect measurements e.g. Precipitation, temperature, hurricanes	NOAA, National Weather Service University of Arizona tree ring lab, Columbia University, International Tree Ring research community
Disease		Historical forest records; pollen records in sediments
Introduced species		Local records
Fire regimes	Fire scars, charcoal records in sediments, historical records	

Appendix 2. Additional kinds of socioeconomic data that would provide social scientists with an opportunity to examine human / social behavior in light of the biophysical results from NEON.

Data	Content	Source
	Population trends	Bureau of Census: US Census of Population, Industrial data, American Community Survey
	Land cover estimates	USDA: FIA, NRI, Common Land Unit
	Crime, disease incidents	Public health (CDC) and safety data (FBI)
	Zoning and other restrictions on use (easements)	Local town offices or regional planning agencies
	Parcel land ownership and attributes (prices, land tenure)	Local town offices or regional planning agencies
	Land cover data AND land-use data	Relevant State agencies
	Utilities infrastructure (Sewer, power, restrictions on septic)	Relevant local and state agencies
	Road infrastructure and related layers (Traffic Analysis data)	State departments of transportation
	Other: School districts	Municipal offices
	Value-added census data (Geolytics, PRIZM)	Commercially available
	Political voting patterns survey data	State data centers (e.g., MA Institute for Social and Economic Research)
	Business employment data (Dun and Bradstreet)	Commercially available, or from state department of employment
	State tax assessment	State bureau of revenue
	MLS real estate data	Real estate listings
	Text sources: legal decisions → parcel governance and restrictions??? Unpublished legal and regulatory documents (city ordinances, conservation easements, deed restrictions, neighborhood covenants)	Local offices
	Other: Newspapers and news feeds, Interviews	Libraries; original data from interviews and surveys