Integrating the biophysical and social sciences

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It is no longer tenable to study ecological and social systems in isolation of one another (Redman, 1999; Kinzig et al., 2001; Gunderson and Holling, 2002). Humans are an integral part of virtually all ecosystems (McDonnell and Pickett, 1993; Vitousek et al., 1997); almost all human activity has potential relevance to global environments (National Research Council, 1999); and biogeophysical contexts strongly condition human decisions (Diamond, 1997). Recently, the National Science Foundation underscored this when it released a 20-year review of the Long-Term Ecological Research (LTER) program. One of the main charges to the network was a recommendation for more collaboration with social scientists to increase the understanding of the reciprocal impacts of natural ecosystems and human systems. The review concluded that this was an essential next step in order to better inform environmental policy (National Science Foundation, 2002).

Agronomy, hydrology, and soil science have investigated human impacts, management, and cultural methods for much longer than ecology. But as ecology begins to play catch up, the discipline not only shares the agricultural sciences emphasis on place-based research and the analysis of complex systems, but adds an important dimension. By paying attention to long cycles of change, there is much more emphasis in ecology on structural change over time and space, types and rates of change, scales of phenomena, strengths of linkages, boundary conditions, and threshold values (Carpenter, 1999). In short, it is the adaptive dimension of human and natural systems that ecology seems well-positioned to confront, even if the integrative frameworks are short on specifics. But the implications of thinking in terms of generational change or life-cycle change are important for monitoring and managing agricultural landscapes.

Monitoring

Let us briefly review the program of monitoring put forward in the foregoing section of this book by Peter Groffman and colleagues. Those authors make the case that monitoring is a necessary first step to convince policymakers and farmers that sustainability is not illusory—that it can be documented. They offer concepts from ecosystem services and landscape ecology as a framework from which to build monitoring tools—an iterative process of goal-setting, monitoring, modelling, assessment, and re-evaluation. To tell the story to the public, there must be benchmarks.

The first organizing idea for this monitoring framework is that it must pay attention to spatial location because the physical structure of landscapes regulates ecosystem process. Variance will be strongly related to location. Few practitioners in the environmental sciences would dispute the need for a place-based approach.

But they raise the stakes with the second idea that a monitoring system needs to be organized hierarchically. More than simply monitoring ecosystem processes at scales considered most appropriate—the field, the farm, the watershed, the landscape, the region—an effective framework will monitor the processes of interest at several scales simultaneously.

The third organizing idea is subtle and less obvious, but no less important. Making a distinction between the content and context of landscapes, the authors recommend that land managers remain flexible about the boundaries of systems. It is a different way of expressing the need for hierchical monitoring. The boundaries of systems need to be elastic in order to monitor trophic structure. When rapidly changing processes—nutrient cycles, organic matter accumulation, patterns of disturbance—alter landscape-scale processes, the evidence is not often visible at the field level. Monitoring needs coarse scales of observation to know when spillovers begin to affect landscape- or regional-scale structures. And those studies need time depth to understand the longevity of processes and their tipping points.

The fourth organizing idea is that historical trajectories are important. But here it is worth cautioning against frameworks that tend to treat trajectories as preordained. The language used to describe the effect of past land use suggests that trajectories are based on self-organized landscapes and governing processes. This language is probably too deterministic to begin the process of convincing policymakers and farmers that there are genuine alternatives to current forms of organization and that a program of social and ecological monitoring will help to uncover the scope for change. Yes, the room for variation is strongly constrained by environmental context. But self-organization implies a limited range of outcomes. It also takes us away from the surprises of history, the paths not taken but possible, the unanticipated collapses, or just from the tremendous complexity that led to the current dynamics of environmental change.

Scale

Part way into the paper in a section on the challenges of ecosystem services to watershed analysis, Groffman and his coauthors suggest that the private benefits of better land stewardship are often much smaller than the public benefits. The returns that a farm might see from conservation tillage or riparian buffers are not as great as the wider benefits to society of water quality and carbon sequestration. The asymmetry of benefit helps to explain why conservation programs like the Conservation Reserve Program in the United States and the Greencover Program in Canada are necessary for implementation to occur.

Yet, the authors subsequently acknowledge the vastness of the problem. Two-thirds of the earth's terrestrial surface is in agricultural land use. Fifty percent of the coterminous United States is cropped or grazed. How can public remediation schemes possibly make a dent in the implementation of better management practices when the funds available for those programs are limited? Public schemes are important policy tools and especially useful in targeting sensitive ecosystem processes and locations. But in seeking broad implementation, it is essential that farmers themselves see the connections between practices and broader outcomes. Conservation science should not underestimate the potential for farm management to keep an eye on the long term. Farms are succession-minded institutions. To the extent that incentives for better management enhance the longevity of farm enterprises, they enhance the conservation of natural resources for future generations.

Social and ecological systems

Groffman and his colleagues take a somewhat pessimistic view of farm management. They are not specific about the social science variables needed to monitor the adoption of best management practices. So let us suggest some ways to conceptualize the interaction between social and ecological systems.

The current national-scale monitoring effort by the U.S. Department of Agriculture, for instance, will produce a benchmark study with unprecedented geographic breadth. But the Conservation Effects Assessment Project (CEAP) (Makuch et al., 2004) will not monitor social conditions that might be relevant to land use decisions. Nor are any return visits to the 30,000 cropping sample points [fields or land segments that vary in size from 16 to 256 hectares (40 to 640 acres)] currently planned. Data will be gathered on more than 200 attributes, including land use and land cover, soil type, cropping history, conservation practices, soil erosion potential, water and wind erosion estimates, wetlands, wildlife habitat, vegetative cover, and irrigation methods, and the four waves of data collection in 2003, 2004, 2005, and 2006 will produce a pooled data set that will drive hydrological models.

CEAP is an important study that will provide exhaustive background information. By not monitoring social change and not pursuing follow-up farm surveys, however, the benchmarking exercise may foreclose discussion about trajectories or the complexity of coupled human and natural systems. Ultimately, we want to be able to measure growth or decline and apportion variance to the scales at which change happens; that will allow us to see how much context shapes outcomes and how much room exists for adaptation and change.

There are many examples of longitudinal, multilevel, or agent-based analysis in the social sciences. For example, one of the longest running repeat surveys in the United States, the Panel Study on Income Dynamics, has been conducted at the University of Michigan since 1968. The original design consisted of two independent samples: A cross-sectional national sample (3,000) and a national sample of low-income families (2,000). From 1968 to 1996, the study interviewed and re-interviewed individuals from the families in the core sample every year. The study collected data on family composition changes, housing and food expenditures, marriage and fertility histories, employment, income, time spent in housework, health, consumption, wealth and more. The core sample grew to 8,500 families in 1996. One kind of analysis the data allow for is the intergenerational transfer of earning status. Think of what such a design could tell us about farm practices and landscapes. Of course, respondent identities would have to be protected and the landscape information presented in a nonidentifying way. But if nested in an informed way within a larger cross-sectional database that posed similar questions about farm practice, we would have the basic data needed to model how and when micro-level processes begin to affect macro-level structures and trends.

Integrated research

What are the aspects of human change that we need to monitor? Redman is a participant in the deliberations of the Resilience Alliance, which has established some first principles for researching integrated socioecological systems and identifying adaptive capacity in them (www.resalliance.org). The alliance has proposed an integrated framework that parses natural and human spheres, but conceptualizes those spheres as components of a single, complex socialecological system (Levin, 1999; Gunderson and Holling, 2002). The ecological patterns and processes are all things familiar to those involved with the LTER network: Primary production, trophic structure, organic matter accumulation, inorganic nutrient flow, and disturbance. In the social realm, the proposed patterns and processes also focus on long-term dynamics. Cultural phenomena, framed by economic incentives, play a large role. Those cultural phenomena include, but are not limited to:

- *Demography*: The growth, size, composition, distribution, and movement of human populations.
- *Technological change*: The accumulated store of cultural knowledge about how to adapt to, use, and act upon the biophysical environment and its material resources to satisfy human needs and wants.
- *Economic growth*: The sets of institutional arrangements through which goods and services are produced and distributed.
- *Political and social institutions*: The enduring sets of ideas of how to accomplish goals recognized as important in a society. Family, religious, economic, educational, health, and political institutions that characterize its way of life.
- *Culture*: Culturally determined attitudes, beliefs, and values that purport to characterize aspects of collective reality, sentiments, and preferences of various groups at different scales, times, and places.
- *Knowledge and information exchange*: The genetic and cultural communication of instructions, data, ideas, and so on.

Many of these phenomena are straight out of the National Research Council's 1992 report on Global Environmental Change (1992:2-3), with one important exception—knowledge and information exchange (Berkes and Folke, 1998). Institutions, culture, and knowledge are difficult for physical scientists to incorporate into their research, but they are vital. All choices are not equally available to decision-makers—decisions are always conditioned by what we "know" and "value" (Ostrom, 1999; Berkes et al., 2003).

The bottom line is that we will not get closer to an integrated framework unless we treat practices as something more than a stylized component in our models—in which the human dimension is a black box where the behavior and the cultures and contexts that sustain farm practice are assumed rather than measured and modelled. Only when we can relate changes in practice and outcome more directly will farmers and policymakers begin to see how alternative practices can achieve similar levels of productivity with less environmental impact. This argues for more intensive place-based research to flesh out the time-varying nature of social and ecological change. There will still be a need for the geographic breadth of CEAP-like surveys. But to understand adaptive change, we must understand the reciprocation between human and natural systems over time. Groffman and colleagues provide us with a good starting framework. If we could add one important dimension to what they propose, it is that we need to make room for the analysis of adaptive behavior in this enterprise. Culture and time dimensions are essential.

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