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Informing Decision Making for Agricultural Watersheds

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This paper traces the development, outcomes and impacts of our Water and Watersheds project as a pioneering example of interdisciplinary, systems-level research (Santelmann et al. 2001). The first section sets the background and academic environment in which the project developed, the period in which interdisciplinary ecosystems research came of age. This section is followed by a description of project development and outcomes at three levels: 1) advances in the field of landscape ecology and ecosystems research, 2) impacts on the collaborators themselves, and 3) application of our approach by others. Finally, we discuss connections between our research and decision making and education, as well as the ongoing impact and influence of this research to inform policy-makers and guide relevant policy and action in agricultural regions.

Interdisciplinary Ecosystems Research

The end of the 20th century marked a turning point for ecosystems research. Ecology had struggled for decades to carve an identity for itself. Publications in top-tier ecological journals in the 60's and 70's focused on establishing the theoretical basis for ecological research and rigorous methods for investigation of the diversity and abundances of living organisms, and interactions among organisms and their environment. The desire to define ecology as a science and to counter the popular notion of ecology as environmentalism led to a near aversion to applied ecological research. In the 1980's, this attitude began to change. The Sustainable Biosphere Initiative, launched in 1988, represented both a response to "the need to ameliorate the rapidly deteriorating state of the environment to enhance its capacity to sustain the needs of the world's population…" and an effort "…to define research priorities for ecology in the closing decade of the 20th Century" (Lubchenco et al.1991). It also helped establish the legitimacy of applied ecological research, as evidenced by new journals and new professional societies devoted to applied ecological research. In the 1990's, the Ecological Society of America began publication of *Ecological Applications*, a prestigious journal dedicated to publication of applied ecological research. Newly-formed societies promoting interdisciplinary ecological research launched their own journals, such as *Landscape Ecology*, *Restoration Ecology*, and *Conservation Biology*. Funding agencies, too, began to recognize the need for interdisciplinary ecosystems research, and in the mid-90's, the U.S. National Science Foundation and the U.S. Environmental Protection Agency put out a call for systems-level environmental research on Water and Watersheds (US EPA 2006), funding (among others) the project whose results and impacts are described here.

Project Development

Involvement of collaborators from multiple disciplines on a common research project does not ensure interdisciplinarity. The research design and processes must include interactions to foster development of a common vocabulary and understanding. Interdisciplinary discussions and interactions were critically important in helping to develop our understanding of what should and could be included in the alternative future landscapes. We had initial project meetings to hammer out the details of the research plans, set up a listserve for email discussions of potential alternative future scenarios, and involved the local research

community and colleagues at Iowa State University and the University of Iowa. The work we were able to do could not have been accomplished without the strong foundation of research at these institutions (e.g., Best et al. 1995, Hatfield et al. 1999, Isenhart and Schultz 2003) and the help and assistance of many colleagues who shared their time, local knowledge, and long term data with us.

Annual program meetings helped keep us on track in several ways. They provided an opportunity to interact with the program directors and other teams who were striving to accomplish the same kind of interdisciplinary work that we were, and encountering similar challenges. We realized that we were not alone in having occasional difficulties in understanding and working with colleagues from different disciplines. We were all learning new vocabularies and encountering perspectives and research methods that differed substantially from our own. We were all being nudged outside our comfort zones, and all of us had underestimated the additional time that the interdisciplinary process would take. The annual meetings pushed us to keep to our timetable, and provided a way to measure our progress against similar projects.

Project Outcomes

Advances in the Field

Our Water and Watersheds project advanced the field of landscape ecology by linking high-resolution representations of alternative future landscapes to spatially-explicit modeling and evaluation tools for comparison across multiple endpoints. The project was featured as a case study in both Dale and Haeuber's Applying Ecological Principles to Land Management and in Landscape Ecology in Theory and Practice–Pattern and Process (Turner et al. 2001). Our work has been cited as an example of cutting edge research in environmental economics and landscape ecology (Davis et al. 2006)[1] and the approach has been adapted for use in other regions, not only in the U.S., but in other countries as well, including Canada and Australia. In addition, this work has informed numerous other projects involving future landscape generation and evaluation (e.g., Lamy et al. 2002).

This study was among the first in the U.S. to integrate interdisciplinary research on economic profitability, cultural acceptance, water quality, and native biodiversity (see also Brezonik et al. 1999, Hulse et al. 2000, and Steinitz and McDowell 2001) using a scenario design and evaluation approach for agricultural ecosystems, though similar studies have been completed since then (e.g., Baker et al. 2004, Boody et al. 2005, Millenium Assessment 2005). As a critical means to accomplish multi-objective goals, our project incorporated consideration of policy drivers and landscape planning as essential from its conception, and coupled a highly interdisciplinary, intentionally speculative scenario design process (Nassauer et al. 2002, Nassauer and Corry 2004) with the use of an array of spatially-specific evaluation methods to compare future landscapes (Santelmann et al. 2004).

Each research team modeled or measured a dimension of the performance of the landscape futures, and drew from a disciplinary tradition and methodology appropriate to those disciplines to evaluate the futures for their response with respect to water quality (Vaché et al. 2002), farmer perceptions (Nassauer and Corry, forthcoming), economic return to farmers (Coiner et al. 2001), and plant and animal biodiversity (Rustigian et al. 2003, Santelmann et al. 2005, Clark et al. forthcoming, Debinski et al. forthcoming, Santelmann et al. forthcoming). The results of these approaches were also combined in an integrated assessment (Santelmann et al. 2004).

Some approaches (such as modeling the response of native plants and animals to landscape change) have a higher uncertainty associated with their modeled response than others (such as modeling the response of crop yields to different agricultural practices). We believed it was important to use an array of methods to help quantify the response of the system for endpoints (such as response of native plant and animal species) in which the uncertainty of response was relatively high. We used several methods for estimating the response of plant and animal species to changes in land use and management. These ranged from empirical estimates of how changes in habitat area would lead to changes in abundances of species found in those habitats (Santelmann et al. 2005) to spatially-explicit simulations of population dynamics for selected species (Rustigian et al. 2003), landscape pattern metrics (Corry 2005) and even a model in which species interactions were modeled as part of

species' response to landscape change (Clark et al. forthcoming)

In our Water and Watersheds project, we envisioned, evaluated, and compared three alternative futures for agricultural landscapes in the U.S. Corn Belt that could result in 2025 from different sets of policy choices (Scenario 1: Production, Scenario 2: Water Quality, and Scenario 3: Biodiversity) with the landscape that existed in 1994 (Santelmann et al. 2001, Nassauer et al. 2002, Nassauer and Corry 2004, Santelmann et al. 2004). The production scenario was perceived as the future most likely to emerge if agricultural production and profit remained the dominant objectives in land management. In this scenario, more land was converted to cultivation, woodlands nearly disappeared, riparian areas had narrow (3-6 m) grass buffers, corn and soybeans were grown with limited crop rotations, and there was little land area in pasture or alfalfa. The Water Quality scenario assumed that land cover patterns in both watersheds would change to enable landowners to meet enforced water quality standards. In this scenario, woodlands were maintained, riparian buffers widened from 3-6 to 15-60 m, small wetlands were created to process flow from tile drains, and substantial areas were in pasture and alfalfa production. The Biodiversity scenario assumed that policy and the public would support land use change to increase habitat for indigenous wildlife and to improve water quality. In this scenario, permanent, indigenous ecosystem reserves of at least 260 ha were established in each watershed. Riparian buffers were expanded to 30-90 m wide, and innovative agricultural practices such as agroforestry and native strip intercropping were developed in which native perennial species are interspersed with corn and soybeans.

Although the modeled results consistently found Scenario 3 (designed to enhance native biodiversity) best for achieving biodiversity goals, our results also indicated that different sets of species (for example, mammals and amphibians) can respond differently to landscape change. In both study watersheds, results indicated that if water quality improvement were the primary goal, Scenario 2 would out-perform both the current landscape and all other alternative futures. Finally, it was interesting to see that very little increase in production of agricultural commodities and profitability could be accomplished even in Scenario 1, which had agricultural commodity production and profitability as the top priority of agricultural policy, and the increase came at a significant cost of increased nitrate and sediment export from the watershed and further loss of habitat for most native species.

Impacts on Collaborators

Nearly all of our eighteen collaborators (including postdoctoral fellows and graduate students) have been extremely positive about their own involvement as part of an interdisciplinary team as well as about project outcomes. Many faced obstacles in participation in and completion of their research over the course of the project, and yet chose to carry it through to completion, in part because of their own enthusiasm for the research and in part because of their professional engagement and sense of connection with the rest of the group. There were no overwhelming egos on this project. There were occasional delays in progress, disappointments, disagreements, and a few "lively discussions," but we always came back to the table to work things out. I was grateful for the opportunity to work with so many gifted colleagues, and I think most of the collaborators felt the same way. I include here some excerpts from my colleagues' responses when I asked them to reflect on the project and their experiences to include in this article:

> … the … [approach] was what was so cool. The devil is in the details but in addition to getting a lot of interdisciplinary expertise - in practice in the real world - it gives folks ownership and a real tangible voice in the outcome.

> I came away from my part in the project thinking that there is still a tremendous amount of the basic ecology of vertebrates that we don't understand… this project brought together many diverse talents in recognition of the complexity involved in assessing land management at large scales…

> The Iowa futures project … was instrumental in me winning a Loeb Fellowship from Harvard Graduate School of Design for a program of self directed study during for the 1998-99 academic year. I was the first International Fellow to receive an award through the competitive process.

Connections Between Our Research and Decision Making

Our work has helped inform colleagues on many projects using the future scenario approach to explore issues surrounding human alteration or restoration of ecosystems. For example, Nassuaer and Santelmann presented project results and methods for evaluation of alternative future scenarios to the State of Illinois EPA and Department of Natural Resources (December 1999; Chicago, IL). This invited presentation assisted these agencies in the initiation of similar projects to develop alternative future scenarios for river basins in Illinois undergoing rapid development. The Blackberry Creek Alternative Futures Project is demonstrating how communities can design new development to prevent flooding. Kane County Dept. of Environmental Management is bringing the lessons learned to communities in other tributary watersheds to the Fox River.

Connections Between Our Research and Education

This work has been presented in lectures and seminars for our professional colleagues and to students in the courses we teach. The outcomes of our agricultural futures project have been the topic of invited sessions of symposia as well as contributed papers in professional meetings. We have presented workshops for technology transfer to assist others in development of a future scenario approach for land use and management planning; this type of activity falls along a continuum between educational aspects of the project and its ongoing impact. Project PI Santelmann participated in the meeting of a science advisory group on managing successful interdisciplinary projects (hosted by the EPA/NSF Partnership for Environmental Research STAR grants program in Washington, DC.) to help summarize the lessons learned concerning project management. In December of 2006, Santelmann was invited to Justus Liebig University in Geissen, Germany to present research results from this project and to conduct a workshop on normative scenario design in which 15 doctoral students (as well as several interested faculty and postdoctoral fellows) participated. Research teams at Liebig University are actively involved in international research projects that could incorporate elements from this approach.

Several project collaborators have used the approach and outcomes from this project as part of lectures in undergraduate courses and graduate seminars as an example of interdisciplinary research in landscape ecology. This project is cited most often by prospective students as the area of my research in which they would like to become involved.

Ongoing Impact and Influence of This Research

Many project collaborators have gone on to incorporate experiences and methodologies developed from this work on other projects. Co-investigator Denis White participated on a project to explore alternative futures for use in future planning for the Willamette River Basin (Baker et al. 2004) and has begun work on another project in the San Luis Valley in south central Colorado. Corry has a current research project that is informed by our normative scenarios approach, although it is not a replication of these methods. It deals with alternative future rehabilitation approaches to aggregate pits and quarries in Ontario.

Co-investigator Kate (Freemark) Lindsay built on our experience in the futures project to develop an integrated modeling approach for considering ecological, economic and social dimensions of delineating critical habitat under the new Species at Risk Act (SARA) in Canada, funded by the federal Interdepartmental Recovery Fund and involving 14 researchers in the academic, government and private sectors and two of the three federal departments (Parks Canada and Environment Canada) responsible for delivering on SARA. In 2005-2006, Lindsay became involved in the UNEP Global Environmental Outlook - 4 as part of the North American (Canada and the USA) Regional team to provide input on customizing the global scenarios in GEO-3 to better reflect regional differences. Lindsay, in collaboration with the International Institute of Sustainable Development in Winnipeg, plans to begin an alternative futures project for Canada over the next 3-5 years. Vaché is now working in Europe, and is involved in a large project in Inner Mongolia (MAGIM 2006). As part of the larger project, the team is proposing to develop a set of normative scenarios for the region.

Collaborator Nassauer and Santelmann (with

colleague Don Scavia from the University of Michigan) are editing a book entitled: *From the Corn Belt to the Gulf: Societal and Environmental Implications of Alternative Agricultural Futures*, due out in Spring 2007 linking the outcomes of this project to the environmental and economic impacts of agriculture in the Upper Mississippi River Basin and to the presence of an increasingly larger dead zone (hypoxia) in the Gulf of Mexico. This book integrates our work on small agricultural watersheds in Iowa with that of others in the Mississippi River Basin and beyond (Mitsch et al. 2001, Doering 2002) to inform decision makers and those who are working to make agricultural policy about the impacts of land use at multiple scales. Scheduled for publication in Spring 2007, this could be an important source of information for those crafting the next Farm Bill.

In summary, the Water and Watersheds project we began in 2006 continues to influence our own work, as well as that of others in the field. The approach for interdisciplinary design and evaluation of alternative future scenarios which we helped refine and advance for use in agricultural systems is being increasingly used for land use planning and management in regions around the world. We hope that the integration of our work with that of others who have been studying the causes of and solutions to hypoxia in the Gulf of Mexico and environmental issues in the Midwestern U.S. will eventually lead to improved and informed policy and to environmentally sound improvements in land use and management in the U.S. Corn Belt.

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Endnote

1. "Assessment and forecasting the multiple effects of land use & management change using a spatial interface for inter-disciplinary modeling tools lies at the cutting edge of research in environmental economics and landscape ecology see (Nilsson et al. 2003; Santelmann et al. 2004; Veldkamp and Verburg, 2004)." Davis et al. 2006.

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