RESEARCH EDITORIAL

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How do we identify opportunities to apply new knowledge and improve conservation effectiveness?

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Abstract: Current approaches to conservation planning have an established and successful track record. However, as our knowledge of resource sciences and goals for conservation expand, review and improvement of planning protocols could help improve conservation effectiveness, even though we may be satisfied with the status quo. This is easy to suggest, but we do not readily know how and when standard planning protocols can be adapted to incorporate new information. Resource conservation is a transdisciplinary science involving multiple resources, contexts of landscape and time, and sociocultural dynamics. Yet technology and human experience are progressing, and our capacity to become more site-specific in devising conservation systems and adapting practices to each situation is expanding. This editorial presents a conceptual model that may help frame debate over adoption of new technologies in conservation planning. The model is based on the system of knowledge that every conservation planner must consider in doing his/her job, which involves knowledge of natural resources, landscapes, temporal dynamics of weather and management, and sociocultural constraints of the landowner. Research and testing of new approaches are advancing in all four arenas. It is argued that progress in landscape-specific planning and sociocultural (community-feedback) approaches are the two areas where standard procedures lag the most. This coincidence might provide a way to enable local communities to become more involved in identifying conservation priorities in watersheds and to adopt site-specific approaches that target locally identified resource concerns.

Key words: conservation effects assessment—conservation planning—precision conservation—integrated resource management

Each situation a conservation planner encounters is unique. This is because resource goals, landscape setting, the landowner, and dynamics of weather and management logistics combine to create an individual set of circumstances the planner must consider. Perhaps the greatest challenge in conservation planning is to address these site-specific conditions while ensuring consistency in implementation of practices that ensure minimum standards can be met. The USDA Natural Resources Conservation Service (NRCS) technical standards are written to allow flexibility by allowing each state to revise practice standards. This approach has a history of success and allows for improvements in conservation practices to become part of standard practice. Yet our capacity to devise conservation systems that are adapted to each set of landscape and management circumstances is rapidly expanding (Walter et al. 2007; Delgado and Berry 2008). Our knowledge about resource issues is also changing. We are beginning to recognize how farm and watershed scales are linked (Sharpley et al. 2009) and are seeking how to integrate the management of multiple resources (Schulte et al. 2008). New technical capabilities are driving research to develop new conservation planning tools (Berry et al. 2005; Pike et al. 2009). In the meantime, our agricultural land base is under increasing pressure to raise production of food, fiber, and now biofuels (Cassman 2007) and to provide greater supportive capacities (i.e., ecosystem services) that can ensure quality of life (Brauman et al. 2007).

Given these advances in conservation and challenges for agriculture, there are new questions to address if we are to improve conservation effectiveness. How can our planning structures incorporate new information as it becomes useful and new approaches as they become viable? When do new tools enable an update of planning processes? How should technical application keep up with new science on resource conservation? While each of us would answer these questions differently based on our own individual and professional perspectives, there is a vital need for the conservation community to open discussion on how these questions should be addressed.

This editorial considers these questions based on the task of conservation planning, one which involves the trained application of information to many different and site-specific situations. A conceptual model is proposed that views the transdisciplinary information applied in site-specific conservation planning as a system of knowledge. The model is intended to identify gaps between knowledge and application and opportunities to bring new tools and approaches into conservation planning. Ultimately, if new tools and technologies can be introduced as needs to better manage our resources become evident, then conservation efforts can adapt to address those needs, leading to greater resilience in our agricultural ecosystems.

Knowledge Applied in Conservation Planning

Resource conservation presents a myriad of challenges, due to its transdisciplinary nature. To be completely effective, the conservation planner must understand and apply knowledge about (1) interactions between agricultural management practices and natural resources (soil, water, air, and biota); (2) landscape-scale processes and attributes of soil, terrain, and hydrology; (3) impacts of weather, climate, and seasonal variability on management choices and flexibilities; and (4) motivation, logistical and financial constraints, and social psychology of the agricultural producer. Inadequate information in any of these areas will lead to a loss of effectiveness in planning and implemen-

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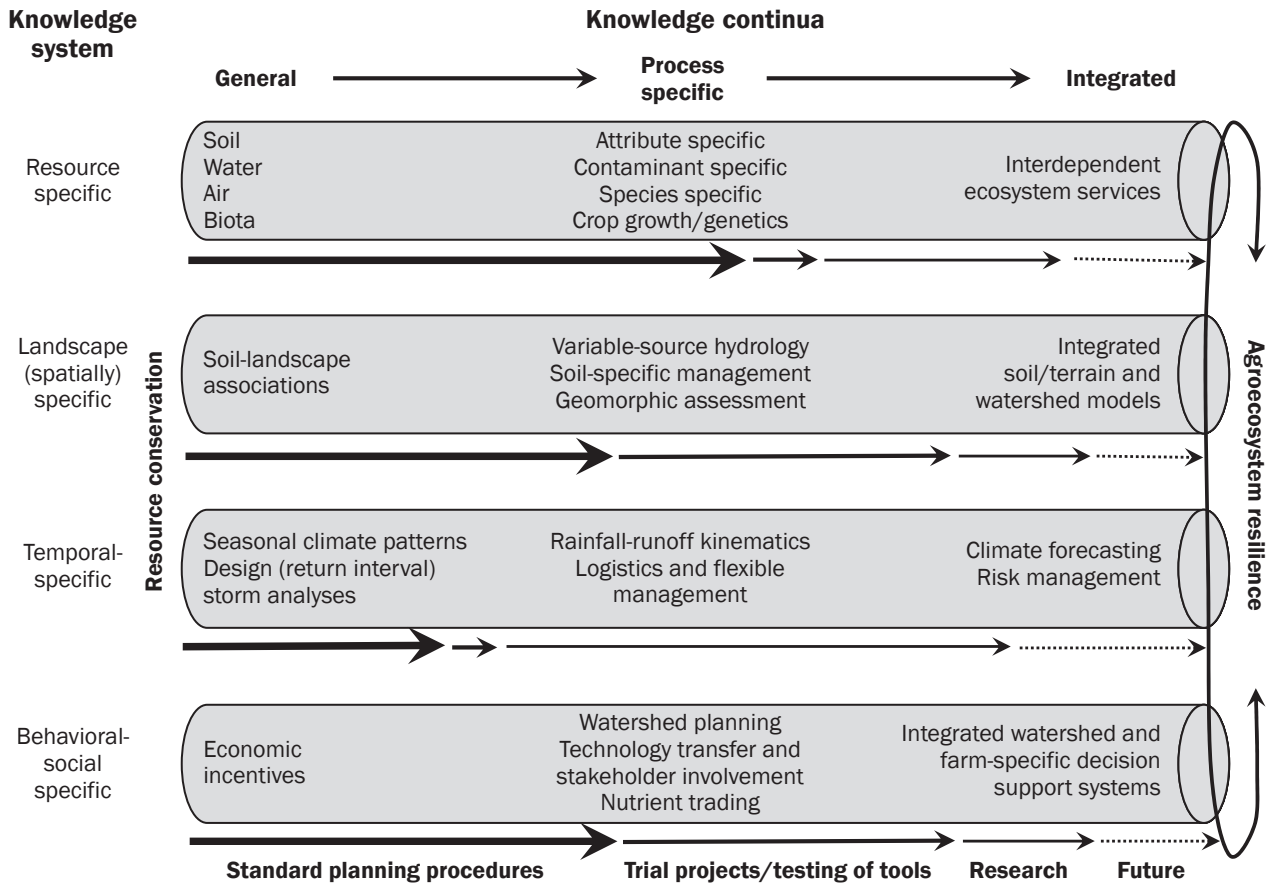
Figure 1

Conceptual model of knowledge system used in conservation planning. Planning requires application of specific knowledge about resources, landscape, timing, and the landowner. While knowledge in each area can be regarded as discrete, linkage among them provides leverage to develop integrated management systems and will lead to the most viable future. If conservation is to progress towards integrated management of agroecosystems, new knowledge must be developed among these four sets of disciplines. The development of this knowledge is a learning process that relies not only on integrative research but experience in application of new knowledge developed through testing and case studies that involve communities, watersheds, and new geospatial technologies.



tation. Moreover, the quality and specificity of knowledge that is applied in conservation planning varies along a continuum for each of these four areas. The approach to and effectiveness of a planning effort is impacted by the status and application of knowledge within each of these continua.

The continua of knowledge that a conservation planner uses can be conceptualized as shown in figure 1. Conservation planning concerns the multiple resources to be conserved, the landscape on which the resources are found, the temporal dynamics to be considered, and the social arena (client-landowner). Each of these four areas comprises a real system about which a conservation planner has given and limited knowledge. Knowledge in each area is depicted as a progression from general to process-specific to integrated. Progress towards expanded knowledge is motivated by a future vision and is initially facilitated by research. Research success leads to trials and testing of new tools, which if successful, may lead to broader application. These steps in progress are depicted as arrows within figure 1. Hopefully, research objectives are driven by a vision in which our future agricultural systems are holistically managed to provide for society's need for food, fiber, and fuel, and to enable agroecosystems to maintain their integrity, biodiversity, and supportive capacities. In figure 1, this vision is denoted "agroecosystem resilience" (see Walker and Salk 2006 for discussion of the term resilience); our paradigm of resource conservation is viewed as shifting towards this vision to achieve agroecosystem resilience through health and prosperity in both ecological and economic terms. While this resilience is difficult to define, a focus on this concept is consistent with an increased emphasis on "ecosystem services" in conservation research (Brauman et al. 2007; Schulte et al. 2007). Resilient systems can recover after disturbance, whether that disturbance occurs from economic or environmental impacts. Ensuring conservation effectiveness is critical to achieve resilience in our agricultural systems. Mechanisms to recognize when and how to incorporate new conservation tools and approaches into practice are needed if we are to progress towards this shared vision of agroecological resilience.

Three points can be made about these knowledge systems and their applications to conservation planning. First, our knowledge of these systems has been developed inde-

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pendently, and each is in a different stage of development (figure 1). This is a natural consequence of academic specialization and the scientific method. Because research approaches are traditionally aimed at isolating one (or a few) controlling variables that determine the effects of a management change on environmental or economic endpoints, science may discover linkages among these systems by accident as often as by design. Yet the amount and quality of information available within each of these four continua are changing with new technologies. Each system has a vast research literature describing it (consider the topics listed within figure 1).

Second, there are cross dependencies among and within these systems. We are only beginning to understand how management decisions and changes in land use can affect the interactions and functionalities of soil, water, and biotic resources into the future (Dale et al. 2000). Recognizing and accounting for these cross dependencies will become necessary if our resource conservation efforts are to become well-integrated from an ecosystem (multiresource) perspective. While a good conservation planner probably understands this intuitively, some capability to incorporate multiple criteria into decision making is being developed (Prato and Herath 2007).

Third, effective application of the best information available in each area is needed for optimal conservation planning outcomes. Clearly, the likelihood of planning success depends on the specificity and quality of information along all four continua. Any improvement in the specificity of information available in any of these four continua, or our capacity to integrate across these areas, could mean that a revision of planning approaches and/or tools might be advantageous. This is proposed as the basis of this model's utility. It is hypothesized that where new tools are available along two or more continua, new planning approaches and/or tools should be devised to ensure conservation effectiveness is optimized. The transition towards application of new knowledge requires successful technology transfer. As technology expands and provides tools that have been successfully tested in a real-world context, the opportunity exists to formally expand the toolbox of conservation planning approaches available. But to take advantage of these opportunities, both the scientist and the practitioner (planner) must interact to adapt science towards application, incorporating new information and feedback.

Current Status

Let's briefly break down this conceptual model (figure 1) to describe recent progress in each arena of knowledge. The brevity of these remarks belies the depth of the scientific literature behind each area, with acknowledgment that a meaningful review of these four topics is not in the scope of this editorial.

Resource-Specific Concerns and Objectives. Addressing resource concerns today must be viewed in the context of multiresource planning, including soil, water, air, and biotic (plant and animal) resources. The USDA NRCS has embraced this concept, denoting it SWAPA (Soil, Water, Air, Plants, and Animals). However, in practice, and wittingly or not, each of these resource classes is prioritized, considered as ancillary, or ignored during the conservation-planning process. Each resource class can be further divided into discrete but interacting objectives that also, in turn, may or may not be prioritized:

- Soil: erosion control, nutrient management, soil-water use efficiency, soil quality, carbon cycling
- Water: surface and groundwater hydrology; water quality including nutrients and other specific contaminants
- Air: windblown particulates, odor, greenhouse gasses
- Biotic: conservation of specific types or species of plants and animals; conservation of upland, littoral, and aquatic habitats

As our view and knowledge of these resources grows, the cross dependencies among these resources become clearer and we view them as fully integrated ecosystems. An understanding of how to approach this integration may be taking shape as we study the landscape-scale processes involved in the dynamics of various ecosystem services (Brauman et al. 2007).

Landscape-Specific Processes. The scope and specificity of our knowledge about landscape processes varies by resource concern. That is, we are only beginning to appreciate how soil, water, air, and biotic resources interact at landscape scales, but linkages and interactions are becoming apparent. This is because the specificity of our knowledge about landscape processes influencing soil and water resources is becoming refined (e.g., see Lerch et al. 2005) and is improving rapidly for biotic (habitat) resources (Allan 2004; Walter et al. 2007). Computerized monitoring technologies (Rundel et al. 2009), remote sensing data (Hively et al. 2009), and our capacities to analyze spatial processes (Kampf and Burges 2007) have spurred this progress, in a large part by influencing the types of questions we can ask about spatial aspects of the many relationships and interactions that drive ecosystem dynamics. These questions have enabled various approaches to spatial analyses that have helped us learn about landscape processes. Indeed, the understanding to integrate management of multiple resources has often been acquired through landscape-scale investigations (Allan 2004; Dale et al. 2007). In short, the field of landscape ecology is beginning to influence the science of agricultural resources conservation.

Temporal-Specific Processes. In this arena, our best knowledge is actually at fine scales. Our focus on erosion and surface runoff in conservation has led to a good understanding of the impacts of storm dynamics. Also, we know what the weather will be tomorrow and can plan accordingly but are less confident of our ability to manage future risks as predictions extend further into the future. Our understanding of seasonal dynamics is reasonably well developed but can be better incorporated into conservation practice design (e.g., see Tomer et al. 1997). Development of multiyear predictions has been suggested based on oscillatory cycles in climate (Malone et al. 2009), but the utility of any predictive management tool has yet to be demonstrated, particularly in regard to conservation effectiveness. Impacts of climate change and climate oscillations could conceivably be incorporated into conservation planning at some point, focusing on those resources that may become most vulnerable under anticipated shifts in weather and climate.

Behavioral-Social Specific: The Landowner's Motivation, Capabilities, and Constraints. Success in utilizing improved knowledge about resources, landscapes, and changing conditions depends on social and economic acceptability. Clearly, this reality is being addressed, and the social science behind conservation planning and decision making is being improved. Community involvement in watershed planning, targeted economic tools (e.g., see Claassen 2007), better understanding of social psychology, and decision support software are all being

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brought to bear on expanding this area of knowledge (Hatfield 2005). The combination of risky behavior taking place on vulnerable landscapes has also been recognized as a key determinant of conservation effectiveness (Nowak and Cabot 2004). The advantages of engaging communities in conservation efforts are clear enough to be advocated for more widespread adoption (Walker and Salt 2006); however, we should be prepared for some trial and error in moving this direction with individual communities and watersheds (Bellamy and Johnson 2000; Moot et al. 1997).

Utility of Concept

If this conceptual model (figure 1) can help to evaluate opportunities to move our best research products and tools from testing towards standard practice, how might that be so? If figure 1 is essentially correct in depicting progress from research to testing to full-scale application of conservation planning tools, then tools related to landscape-specific and behavioral-social specific knowledge systems are being vetted and are most advanced. The figure indicates that integrated management of soil, water, air, and biotic resources (i.e., ecosystem services management), or use of future climate scenarios in conservation management remain as goals that we must progress towards through continuing research and technology transfer. The need to develop trading markets for ecosystem services may drive rapid research progress in these areas. This assessment of current status is based on opinion. Readers are encouraged to form their own critiques of figure 1, especially on the question of how well recent progress in each area is (and could be) translated into practice. If figure 1 is (at least roughly) correct, the possibility exists to expand our standard planning procedures to more formally include community feedback and advanced geospatial tools in the conservation planning process.

We seem well poised to move in these directions. Watershed modeling and resource conservation planning efforts that include communities as part of the process are becoming common. For example, the USDA NRCS watershed assessments include stakeholder input on resource issues of local concern and which practices that address those concerns are most socially acceptable (USDA NRCS 2009). We should ask how we could better leverage community feedback and its potential to expand and improve conservation efforts at the local scale.

Watershed-scale research on conservation effectiveness (Richardson et al. 2008) and field-scale research on precision conservation (Delgado and Berry 2009) both point to the potential gains from incorporating more precise geospatial information into conservation planning. Our capacity to quantitatively predict how well a given practice can address specific soil or water quality concerns remains limited, but we can make qualitative predictions of where given practices should have the greatest benefits based on landscape- and watershed-scale information, which is becoming more commonly available. Examples from the literature are well documented and for multiple resources (Delgado and Berry 2008; Walter et al. 2007). It seems appropriate, therefore, that where given resource concerns and acceptable practices to address those concerns are identified (e.g., through watershed assessments), site-specific analyses to place those practices and address those concerns as precisely as possible can be included within our operational toolbox of conservation practices.

Based on this assessment, site-specific (also known as precision or targeted) conservation is ready for prime-time wherever the economic and environmental benefits of site-specific practices are accepted within stakeholder communities. More efforts to demonstrate those benefits will be necessary. Also, some practice in adjusting technical standards towards encouraging site-specific analyses to address sensitive lands and specific resource concerns within watersheds and/or ecoregions is needed. Simple tools have been suggested for riparian buffer placements (Tomer et al. 2003), buffer widths (Dosskey et al. 2008), and placement of grassed waterways (Pike et al. 2009). We have the capability to develop new geospatial tools to support site-specific conservation planning, based on process modeling of remote-sensing and terrain data (Berry et al. 2003; Berry et al. 2005; Walter et al. 2007; Delgado and Berry 2008). Not only that, but we can use those same technologies to check our progress (e.g., Hively et al. 2009). Efforts to extend such tools across watersheds may not all prove to be successful, and many such tools may need to be adjusted for local conditions, but experience in applying these tools in watershed planning would provide for institutional learning towards applying new scientific knowledge in the conservation planning process. To contribute to this learning process, scientists working to assess conservation-practice effects need to consider how to convert new knowledge into planning tools that can be adapted across broader regions and river basins. We must also prepare current and future generations of conservation planners to use geospatial information and technologies.

Multiple challenges of expanding human population, changing climate, and the need for agricultural lands to meet increased demands to produce food, fiber, and (now) biomass-based fuels means that our institutions must adapt to meet the challenge to sustain and improve the productivity and resilience of our agroecosystems. Future generations are depending on us. Let's figure out how to bring every appropriate tool we have to bear on this task and involve conservation's most important customers as we do so.

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Disclaimer

Opinions expressed are the author's alone, and have been formed based on experience that has included work as a conservation planner and as research scientist working to evaluate conservation effectiveness.

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