FOREWORD
The Economics of Rural and Agricultural Ecosystem Services: Purism versus Practicality

Dana Marie Bauer and Robert J. Johnston

Ecosystem goods and services (we henceforth refer to these solely as "services") have been defined in general terms as the outputs of natural systems that benefit society (Daily 1997, Millennium Ecosystem Assessment 2005) or, more precisely, as "the flows from an ecosystem that are of relatively immediate benefit to humans and occur naturally" (Brown et al. 2007, p. 334). Economists have long recognized the capacity of natural systems to provide market and nonmarket benefits. Models to quantify these benefits have existed for decades (Krutilla 1967). The more recent concept of ecosystem services provides an alternative framework through which these values may be conceptualized and communicated. Among the factors that distinguish an ecosystem service framework from traditional economic analysis, at least in principle, is a more fundamental multidisciplinary focus, including an emphasis on both ecological production and economic value (Johnston et al. *forthcoming*, Wainger and Mazzotta 2011). The ecosystem service perspective also seeks to distinguish benefits provided by natural ecosystems from those provided by human capital, labor, and technology, thereby providing a more direct perspective on the benefits provided by natural systems (Bateman et al. 2011, Brown et al. 2007, Johnston and Russell 2011).

One advantage of the ecosystem service framework is its resonance with noneconomists, including ecologists and others who study the biophysical processes through which ecosystems produce outcomes that are valued by society (Brown et al. 2007, Carpenter et al. 2009, Daily 1997). The framework provides a means by which to link changes in ecosystem processes and outputs to effects on social welfare, thereby facilitating cost-benefit analysis of policies and projects affecting natural systems (Wainger and Mazzotta 2011). Research in this area typically seeks to quantify tradeoffs and promote more efficient

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or socially beneficial policy outcomes. In part due to these attractive features, there has been an exponential rise in the number of published papers on ecosystem services and related topics (Fisher et al. 2009) and numerous calls to incorporate ecosystem service information in policy analyses (e.g., Millennium Ecosystem Assessment 2005, President's Council of Advisors on Science and Technology 2011, Environmental Protection Agency 2009).

Rural and Agricultural Ecosystem Services

Much of the recent emphasis on ecosystem services has targeted services linked in some way to rural and agricultural ecosystems. These ecosystems both provide and rely upon a broad array of services (Dale and Polasky 2007, Swinton et al. 2007). Bergstrom and Ready (2009) reviewed two decades of research estimating the value of agricultural amenity benefits in the United States, many related to ecosystem services. Parallel themes appear in research related to the economics and preservation of nonagricultural rural lands (Johnston and Swallow 2006). The multifunctional agriculture movement in the United States and Europe similarly recognizes that agriculture provides benefits beyond traditional food, fiber, and fuel, including those related to the ecological functions of agro-ecosystems (Batie 2003, Boody et al. 2005, Duke and Johnston 2010). Examples include the provision of nutrient cycling, wildlife habitat, carbon sequestration, and recreational opportunities. As a heavily managed land use, agriculture is also the source and recipient of numerous ecosystem disservices—effects on or of agriculture that directly or indirectly diminish human welfare.[1]

Because many services and disservices of rural and agricultural ecosystems are realized outside organized markets, the value of these services is often unrecognized or underappreciated (Swinton et al. 2007). Lack of recognition of these values in markets and policy is among the primary causes of market failure in rural and agricultural systems and threats to agricultural sustainability (e.g., Dale and Polasky 2007, Kroeger and Casey 2007, Swinton et al. 2007, Zhang et al. 2007). As a result, the National Research Council (2010) identified research into the value of rural and agricultural ecosystem services and development of related markets as an area of high-priority research for U.S. agricultural sustainability.

The papers in this special issue of *Agricultural and Resource Economics Review* are the culmination of a workshop addressing the economics of rural and agricultural ecosystem services held on June 12 and 13, 2012, in Lowell, Massachusetts, immediately following the annual meeting of the Northeastern Agricultural and Resource Economics Association. Financial support for the

[1] Ecosystem services provided to agriculture by surrounding rural landscapes include water provision and purification (e.g., Eldridge and Freudenberger 2005, Vitousek et al. 2002), genetic biodiversity (e.g., Ruto et al. 2008), crop pollination (e.g., Bauer and Sue Wing 2010, Gallai et al. 2009), seed dispersal (e.g., Hougner et al. 2006), and natural pest control (e.g., Cleveland et al. 2006, Kellermann et al. 2008), among others. In addition to the direct provisioning services of food, fiber, and fuel, ecosystem services provided by agricultural landscapes include resources used for hunting and recreation (e.g., Hansen et al. 1999, Knoche and Lupi 2007), wildlife habitat (e.g., Uchida et al. 2007), water storage (e.g., Bohlen et al. 2009), groundwater recharge (e.g., Acharya and Barbier 2000), climate regulation through soil carbon sequestration (e.g., Antle and Diagana 2003, Colombo et al. 2006), and biodiversity (e.g., Jackson et al. 2007, Smukler et al. 2010). Agriculture also generates a number of disservices that include habitat loss, groundwater depletion, and fertilizer/pesticide runoff (Zhang et al. 2007).

workshop was provided by the U.S. Department of Agriculture's National Institute of Food and Agriculture (Award 2011-67023-30913).

The rationale for the workshop was grounded in two areas of increasing consensus related to rural and agricultural ecosystem services. First, progress toward sustainable agricultural and rural systems, including policies that address externalities and other market failures in agricultural production, requires insight into the provision and value of these services. Second, available research methods and data are often "stretched to their limits" when seeking to quantify and value ecosystem services, particularly when faced with the complexities of interacting natural and human systems (Wainger and Mazzotta 2011, p. 711). Among the contributions of the workshop was a critical review of ongoing research into rural and agricultural ecosystem services, emphasizing methodological coordination across economics, ecology, and other disciplines. Workshop presentations and discussions emphasized ways in which ecosystem service research could provide information required by decision-makers and interdisciplinary research collaborators considering both the state of the science and policy needs. Of particular emphasis was the level of quality and precision required of ecosystem service analyses used for different types of policy guidance—the tradeoff between purism and practicality in research targeting rural and agricultural ecosystems.

Purism versus Practicality in Research Addressing Rural and Agricultural Ecosystem Services

The dichotomy of purism versus practicality in empirical ecosystem service research raises two central questions. First, how good is good enough? Recognizing the empirical challenges of ecosystem service research and repeated calls for ecosystem service information and values, to what degree can and should precision and validity be sacrificed to provide needed information? What is the appropriate balance between purism and practicality? This tradeoff is driven in part by the limited availability of time and financial resources for ecosystem service research. Second, considering these challenges, when and how is an ecosystem service framework most useful compared to other analytical perspectives that might be used to inform policy and management?

Regardless of whether ecosystem service analyses seek to quantify economic values, evaluate tradeoffs, or quantify/optimize ecosystem service provision, all analyses require a formal structure that combines natural and social science elements. Beyond this underlying structure, lower resolution goals such as environmental advocacy typically require less precise typologies and empirical estimates than higher resolution goals such as cost-benefit analysis and green accounting (Kline and Mazzotta 2012). Yet this general observation does not account for the different ways that precision and relevance vary across ecosystem service research. To formalize these issues, we present a four-dimensional methodological assessment framework within which the precision and relevance of ecosystem service analyses may be evaluated: (i) the level of quality, precision, and validity in the economic or social science components, (ii) the level of quality, precision, and validity in the ecological or natural science components, (iii) the degree of integration between the social science and natural science components, and (iv) the degree of direct policy relevance. This framework allows one to address more directly the purism versus practicality tradeoff that arises so frequently in ecosystem service dialogs. It also provides an informative lens through which to view the contributions to this special issue.

Papers in the Special Issue on Rural and Agricultural Ecosystem Services

The first two dimensions of the four-dimensional framework are based on the level of detail and clarity in the definition of the good or service being valued, the robustness and precision of the empirical methods, and the strength of adherence to theoretical foundations. Ecosystem service valuation requires the same rigorous welfare-theoretic structure that defines all economic welfare analysis, allows monetized value estimates to be linked formally to human welfare, and enables meaningful comparison and aggregation of benefits and costs (Just et al. 2004). Ecosystem service analysis also imposes requirements that typically are not encountered in cost-benefit analyses or other forms of economic modeling. Among the requirements are the need to distinguish between "human" and "natural" production so that the benefits of ecosystem services can be disentangled from the benefits of human capital and labor (Bateman et al. 2011, Brown et al. 2007, Johnston and Russell 2011).[2]

Two papers in this special issue, Boyd and Krupnick (2013) and Johnston et al. (2013), focus on the importance of clear and comprehensive definitions of ecosystem services to avoid issues such as double-counting, omissions, and other problems with interpretation and aggregation of economic values. Boyd and Krupnick propose a systems-based approach to defining environmental commodities or the final endpoints (i.e., outputs) of the ecological production process, highlighting distinctions between intermediate and final ecosystem services. Their paper extends and clarifies prior contributions to the literature that sought to differentiate intermediate ecosystem functions from final ecosystem services so that the benefit of each ecosystem condition or process is counted once and only once (e.g., Boyd and Banzhaf 2007, Brown et al. 2007, Fisher et al. 2009, Johnston and Russell 2011, Wallace 2007). Boyd and Krupnick examine the implications of commodity definitions and ecosystem service specificity for both stated and revealed preference valuations. Attention to such details is particularly important when ecosystem services are valued using benefit transfer as avoiding transfer errors depends on commodity consistency across study and policy site (Johnston and Rosenberger 2010, Loomis and Rosenberger 2006). This is an important issue for ecosystem service research because an increasing number of analyses, including three in this issue (Liu et al. 2013, Timmons 2013, Wainger et al. 2013), rely on value estimates transferred from prior studies.

Johnston et al. (2013) address the same issue from an empirical perspective, illustrating the consequences of ambiguous treatment of intermediate and final ecosystem services within stated preference valuation. They develop a structural model that clarifies distinctions between intermediate and final ecosystem services and illustrates the consequences of casual or imprecise

[2] While these distinctions are sometimes clear, they also can require sometimes controversial judgments. For example, waterfowl or fish may use constructed drainage ponds as habitat. Are these organisms an ecosystem service or results of human production? Does the restoration of a wetland using human capital and labor disqualify the resulting ecological outputs as ecosystem services? Such distinctions are immaterial within traditional cost-benefit analyses and nonmarket valuations, which seek to quantify benefits and costs regardless of their source in human versus natural processes. However, they are directly relevant within ecosystem service analyses, which emphasize the production and value of natural systems alone.

treatment of these distinctions within survey scenarios (e.g., simultaneous exclusion of final services and inclusion of intermediate services within stated preference scenarios). They illustrate the model and its implications through a choice experiment applied to fish habitat restoration with results providing clear evidence that omission of a final ecosystem service from survey scenarios leads to speculation by respondents. This speculation has quantifiable impacts on resulting welfare estimates. Combined, the papers of Boyd and Krupnick and Johnston et al. set a high bar for theoretical and empirical precision, demonstrating both conceptually and empirically that significant biases can occur when these are sacrificed.

The third dimension of methodological assessment—socio-economic and biophysical integration—is discussed by Hart and Bell (2013). A fully integrated process begins with integration in problem definition, continues through integration in the methodological approach (e.g., integration can vary from linkages over only a few key variables to a single, fully integrated model), and culminates with integration in policy or program implementation and evaluation. Based on their experience working on a large-scale sustainability project, Hart and Bell propose a three-part strategy for addressing complex problems such as those involving ecosystem services: (i) focus on problem-driven, solution-oriented science, (ii) concentrate on human and natural system interactions and feedbacks (including fostering greater and more productive interactions among natural and social scientists), and (iii) engage stakeholders throughout the process. An important contribution of their paper is identification of key roles for economists in the emerging field of sustainability science.

The fourth dimension of methodological assessment—policy relevance—is a continuum that is contingent on both the outputs and uses of the analysis. Some analyses seek to increase general knowledge or provide broadly applicable guidance while others target a specific problem and/or decision-maker. Two papers in this special issue (Kline et al. 2013, Smith 2013) directly address the challenges and requirements for achieving policy relevance.

Kline et al. (2013) focus on the need of public land managers to make decisions that produce the collection of ecosystem services that provides the greatest benefit to the public. At the same time, managers must account for uncertainties in natural disturbances (e.g., wildfires) and adhere to a variety of regulatory and institutional constraints (e.g., the Endangered Species Act). Although federal agencies have "enthusiastically adopted the concept and language of ecosystem services" (p. 139), economic principles and methods are not routinely incorporated into decisions. Reflecting the ways that federal agencies do (and do not) use information on ecosystem services, the authors develop a conceptual model of public land management that defines the informational needs of public land managers. Based on this model, they discuss the methodological challenges and institutional barriers of applying an ecosystem service approach within the U.S. Department of Agriculture Forest Service. Key among these is a lack of financial resources for conducting robust and in-depth assessments in a timely manner. They also note a lack of economic fluency among many in the Forest Service. In summary, they emphasize that purpose and policy context are key factors in the precision and type of analysis that is required. For example, despite an emphasis on monetized values by economics, "dollar values may not always be necessary for evaluating management plans" (p. 153). They conclude with the admonition that "economists must seek ways to communicate more effectively with managers, ecologists, stakeholders, and the public. This objective includes presenting policy-relevant research using nontechnical language and occasionally publishing in industry-related outlets to build a broader audience for economics" (p. 154).

Smith's (2013) paper also highlights the critical need for economists to better communicate and coordinate with those outside the discipline. She articulates two key points of importance to policy-relevant ecosystem service assessments. First, Smith identifies the need for researchers to engage policymakers and other stakeholders early in the research process to facilitate delivery of policy-relevant outcomes. Second, she encourages researchers to recognize that the policymaking process will not wait for the results of the "perfect study" to become available, thus creating the necessity to make purism versus practicality tradeoffs. Like Kline et al. (2013), Smith provides important messages for economists who seek to inform the policy process.

Several papers in this special issue offer empirical case studies that vary in methodological approach and in their position along the four dimensions of our methodological assessment framework. These papers echo the discussions by Kline et al. (2013), Smith (2013), and Hart and Bell (2013). Empirical analyses often reflect the needs of the policy context within which each analysis was conducted.

Moore (2013), for example, illustrates an analysis that determines relative values among various ecosystem services rather than estimating specific cardinal values for each one. She applies a valuation approach that combines land cover maps with a choice experiment to inform priorities for a publicly funded PES program that would provide payments to private landowners in the Red Hills region of the southeastern United States for conserving ecosystem services most highly valued by the public. The choice questions were framed in terms of targeting program priorities rather than specific outcomes, reflecting the common needs of policymakers and stakeholders.[3]

Tuttle and Heintzelman (2013) use a hedonic approach to investigate the impact of land use restrictions within the boundary of the Adirondack Park and compare the effects on private property values both within and outside the park. Their research informs an ongoing debate among local residents, some of whom desire more economic development and employment opportunities while others want greater preservation of wilderness. Their results show that, on average, residents prefer medium-density development to low-density development and value higher biotic integrity. In addition, parcels outside but near the border of the park have higher values than those inside the park, presumably due to fewer land use restrictions.

Polyakov et al. (2013) use the percent of native vegetation as a proxy for natural landscape amenities within a hedonic property model. They show that rural lifestyle landowners in Victoria, Australia have positive values for on-parcel and in-neighborhood amenities and that these values vary according to the size of the parcel. Given a transition away from commercial agriculture and forestry and toward rural lifestyle land ownership, this research provides information on ecosystem services necessary to target conservation efforts to maximize public benefits.

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[3] For example, policymakers may request public values associated with programmatic priorities rather than specific ecosystem service outcomes, particularly when the data required to predict ecosystem outcomes are sparse.

In both of the hedonic studies (Tuttle and Heintzelman 2013, Polyakov et al. 2013), relatively simple proxies for open space ecosystem services are used. This highlights the common challenge in merging hedonic property value analysis with rural ecosystem service models noted by Boyd and Krupnick (2013); the degree of ecological specificity expected in the latter often far exceeds available data, leading to use of broad ecological proxies rather than specific measures of ecosystem services. However, one could argue in these two cases that the policy setting recognizes the broad-based decision land unit and that the "open space good" is defined such that policymakers and local residents are sufficiently familiar with its conservation benefits. This highlights the relevance of the policy context, as articulated by Smith (2013) and by Kline et al. (2013), when selecting and evaluating the methodological approach for ecosystem service valuation. That is, in some cases, improvement along the fourth dimension of methodological assessment (policy relevance) may justify limitations along other dimensions. This exemplifies the purity versus practicality challenge.

As noted previously, three papers in this special issue use benefit transfer to estimate values for ecosystem services rather than primary valuation studies. This represents an increasing trend in ecosystem service research. It is well known that benefit transfers are most often used when process constraints (e.g., time, funding, or information) prevent primary valuation research and require reliance on prior estimates. Although the use of primary research is generally preferred, benefit transfer is often the only feasible option for quantifying needed values (Johnston and Rosenberger 2010). Because the validity and reliability of benefit transfer depends on the methods applied (Rosenberger and Stanley 2006), transparency in the transfer approach is crucial. Papers in this special issue stand out for their transparent and clear discussion of the advantages and disadvantages of the applied transfer methods along with the reasons why particular approaches were applied. Such clarity is uncommon in the ecosystem service literature. In all three papers, moreover, the transfers are underpinned by rigorous biophysical analysis (the second dimension of our four-dimensional methodological assessment framework).

Liu et al. (2013) illustrate a method for conducting spatially explicit tradeoff analysis of watershed-scale ecosystem services under different land use and land management scenarios. Their approach integrates a detailed process-based hydrological model with ecosystem service values transferred from other primary valuation studies. They demonstrate the method with a case study of a watershed in southern Rhode Island, showing how stressors such as land use intensity (e.g., urbanization) and climate change can force tradeoffs among the provisioning of multiple ecosystem services and that spatial modeling is necessary to elucidate these tradeoffs fully.

Timmons (2013) uses benefit-transfer estimates of values for multiple rural ecosystem services in his comparison of switchgrass versus forest bioenergy production in western Massachusetts. A detailed agricultural production model indicates that switchgrass provides higher yields of biomass but also has greater social costs related to fertilizer externalities and foregone ecosystem services. Through extensive sensitivity analysis, Timmons shows that use of transferred benefits provides rough but "good enough" estimates to identify the range of biofuel benefits that make switchgrass the better alternative. This allows reframing of the policy question to one that precludes the need to estimate fully the values of all forest ecosystem services.

Similarly, Wainger et al. (2013) use benefit transfer to estimate ecosystem service values provided jointly with water quality improvements in their comparison of the cost-effectiveness of various TMDL (Total Maximum Daily Load) program designs with and without co-benefits in the Potomac River, a Chesapeake Bay sub-basin. Sensitivity analysis on the estimated value of carbon sequestration, one of the transferred ecosystem service values, does result in a change in the mix of TMDL program practices. Their results suggest that policies that inhibit nutrient trading or offsets between point and nonpoint sources increase compliance costs and reduce ecosystem service benefits. While their analysis is illustrative rather than policy prescriptive, it highlights the importance of high-quality valuations in the original studies as promoted by Boyd and Krupnick (2013) and by Johnston et al. (2013) and in the broader benefit-transfer literature by Johnston and Rosenberger (2010).

Markets for Ecosystem Services

In addition to examining the tradeoffs between purism and practicality in ecosystem service analyses, one of the primary goals of the workshop and this special issue was to investigate potential market mechanisms for providing ecosystem services. The theoretical benefits of markets over traditional regulatory approaches include gains in economic efficiency. Market creation has been successful in resolving natural resource allocation issues (e.g., individual transferrable quotas in fisheries) by assigning transferable property rights to rival but nonexclusive open-access resources and allowing firms to bid for those rights (Andersen et al. 2010, Tveteras et al. 2011). PES programs are touted as having similar potential for establishing markets for ecosystem services (Kroeger and Casey 2007).

The practice of ecosystem service markets, however, has largely failed to live up to these expectations, and significant and often unavoidable implementation difficulties remain (Engel et al. 2008, Muradian et al. 2010). For example, many ecosystem services initiate on private lands with benefits spilling over to neighboring or downstream recipients. Thus, the property right to the land itself is established, but there is a positive, off-site spatial externality, typically in the form of a public or quasi-public good. Market mechanisms to compensate landowners for these externalities are difficult to establish. For example, the non-rival and nonexcludable aspect of many ecosystem services leads to free-ridership among beneficiaries. Rural and agricultural ecosystem services also frequently lack the characteristics necessary for markets to assign prices that reflect social benefits; such characteristics include measurability of service flows, enforceable liability rules and property rights, and low transaction costs (Kroeger and Casey 2007). Hence, while ecosystem service markets in some cases can ameliorate market failures, the design and application of these markets is not a trivial challenge and can be infeasible.

Two papers in this special issue offer complementary expositions on the challenges as well as optimism for designing and implementing markets for selected ecosystem services. Shortle (2013) examines the lessons learned from several innovative water-quality trading programs. Most of these programs exist at local or regional levels and were developed to complement rather than replace existing regulations. This latter feature is consistent with other successful PES programs, which rely on government intervention to create the initial incentive for market participation or do not reflect true markets as understood by economists (Kroeger and Casey 2007, Vatn 2010). Shortle identifies several challenges in developing water-quality trading markets and proposes two economic research needs: (i) research to increase our understanding of the factors that influence market participation, and (ii) research to reduce the level of uncertainty associated with predicted market outcomes. One observation from Shortle's assessment is that influential program parameters are not always based on scientific criteria; nonscientific stakeholder input is equally if not more important in policy success. Similar conclusions are drawn by Hart and Bell (2013) and by Smith (2013).

Swallow (2013), in contrast, challenges economists to be creative in designing market mechanisms for ecosystem services that move toward economic efficiency without being perfect in achieving it. Inspired by recent empirical work (Newell and Swallow 2013, Smith and Swallow 2013), Swallow uses graphical analysis to show how innovative auction mechanisms can be used to create private markets for public goods that are capable of minimizing some known problems (e.g., free-ridership) and can take advantage of positive willingness to pay and altruism values among some members of society while still recognizing that the result will not necessarily be a first-best optimum. Swallow makes a convincing argument that private funding of public goods need not be limited to philanthropic donations and advocates for economists to focus less on "pure" economic efficiency and more on "practical" policy-relevant research and market creation. He reminds economists that markets need not be perfect to be effective.

Research Needs and Next Steps

Although the primary focus of this special issue is on rural and agricultural ecosystems, the preceding discussion applies equally well to all ecosystem service analyses. The papers in this special issue illustrate both the potential insights provided by applied ecosystems research and the empirical challenges inherent to it. The four-dimensional methodological assessment framework presented here is an attempt to formalize the tradeoffs that can be necessary when seeking to implement relevant ecosystem service research. Papers in the special issue also highlight the need for economists to engage meaningfully with scientists from other disciplines and with decision-makers (Hart and Bell 2013, Smith 2013) and to recognize that different decision contexts call for different types of information (Kline et al. 2013).

The varying information needs of decision-makers, however, do not justify the methodological ambiguity and lack of scientific rigor that have pervaded ecosystem service research. The published literature is plagued by a lack of clarity and consistency, particularly with regard to underlying theory and implications for the ways that well-defined ecosystem services are linked (and not linked) to human welfare. As highlighted by Johnston et al. (2013) and Boyd and Krupnick (2013), lack of precise linkages between theory and methods can lead to severely biased or ambiguous empirical results. Current enthusiasm for the ecosystem service concept has led to numerous empirical applications that sacrifice scientific rigor in ways that provide imprecise or misleading information. The enthusiasm for ecosystem service markets also belies a general lack of evidence that these markets have enhanced rural and agricultural ecosystem service provision on a broad scale (Kroeger and Casey

2007) despite a small number of promising counter-examples (discussed in the papers by Shortle (2013) and Swallow (2013)).

Given these concerns, analysts must consider when and where an ecosystem service framework is appropriate and informative versus cases in which alternative means of policy analysis may provide superior guidance. Research grounded in the ecosystem service concept should be promoted when it can enhance the guidance that is provided to the policy process. Similarly, ecosystem service markets should be pursued in instances where theoretical and empirical evidence suggests that they can improve on regulatory approaches to address market failures. When these conditions do not apply, ecosystem service research and markets may be unnecessary, ineffective, or even counter-productive. The challenges moving forward are to (i) recognize and clarify current shortcomings of ecosystem service research and markets that can be ameliorated through future work, (ii) recognize other limitations and shortcomings that are (likely) unavoidable, and (iii) engage in the in-depth interdisciplinary work needed to elevate ecosystem service research and markets from proof of concept to useful approaches that directly or indirectly enhance human welfare. This special issue of *Agricultural and Resource Economics Review* showcases efforts toward addressing these challenges.

References

Acharya, G., and E.B. Barbier. 2000. "Valuing Groundwater Recharge through Agricultural Production in the Hadejia-Nguru Wetlands in Northern Nigeria." *Agricultural Economics* 22(3): 247–259.

Andersen, P., J.L. Andersen, and H. Frost. 2010. "ITQ in Denmark and Resource Rent Gains." *Marine Resource Economics* 25(1): 11–22.

Antle, J.M., and B. Diagana. 2003. "Creating Incentives for the Adoption of Sustainable Agricultural Practices in Developing Countries: The Role of Carbon Sequestration." *American Journal of Agricultural Economics* 85(5): 1178–1184.

Bateman, I.J., G.M. Mace, C. Fezzi, G. Atkinson, and K. Turner. 2011. "Economic Analysis for Ecosystem Service Assessments." *Environmental and Resource Economics* 48(2): 177–218.

Batie, S.S. 2003. "The Multifunctional Attributes of Northeastern Agriculture: A Research Agenda." *Agricultural and Resource Economics Review* 32(1): 1–8.

Bauer, D.M., and I. Sue Wing. 2010. "Economic Consequences of Pollinator Declines: A Synthesis." *Agricultural and Resource Economics Review* 39(3): 368–383.

Bergstrom, J.C., and R.C. Ready. 2009. "What Have We Learned from Over 20 Years of Farmland Amenity Valuation Research in North America?" *Review of Agricultural Economics* 31(1): 21–49.

Bohlen, P.J., S. Lynch, L. Shabman, M. Clark, S. Shukla, and H. Swain. 2009. "Paying for Environmental Services from Agricultural Lands: An Example from the Northern Everglades." *Frontiers in Ecology and Environment* 7(1): 46–55.

Boody, G., B. Vondracek, D.A. Andow, M. Krinke, J. Westra, J. Zimmerman, and P. Welle. 2005. "Multifunctional Agriculture in the United States." *BioScience* 55(1): 27–38.

Boyd, J.W., and A. Krupnick. 2013. "Using Ecological Production Theory to Define and Select Environmental Commodities for Nonmarket Valuation." *Agricultural and Resource Economics Review* 42(1): 1–32.

Boyd, J., and S. Banzhaf. 2007. "What are Ecosystem Services? The Need for Standardized Environmental Accounting Units." *Ecological Economics* 63(2/3), 616–626.

Brown, T.C., J.C. Bergstrom, and J.B. Loomis. 2007. "Defining, Valuing and Providing Ecosystem Goods and Services." *Natural Resources Journal* 47(2): 329–376.

Carpenter, S.R., H.A. Mooney, J. Agard, D. Capistrano, R.S. DeFries, S. Diaz, T. Dietz, A.K. Duraiappah, S. Oteng-Yeboah, H.M. Pereira, C. Perrings, W.V. Reid, J. Sarukhan, R.J. Scholes, and A. Whyte. 2009. "Science for Managing Ecosystem Services: Beyond the Millennium Ecosystem Assessment." *PNAS* 106(5): 1305–1312.

Cleveland, C.G., M. Betke, P. Federico, J.D. Frank, T.G. Hallam, J. Horn, J.D. Lopez, G.F. McCracken, R.A. Medellin, A. Moreno-Valdez, C.G. Sansone, J.K Westbrook, and T.H. Kunz. 2006. "Economic Value of the Pest Control Service Provided by Brazilian Free-Tailed Bats in South-Central Texas." *Frontiers in Ecology and Environment* 4(5): 238–243.

Colombo, S., J. Calatrava-Requena, and N. Hanley. 2006. "Analyzing the Social Benefits of Soil Conservation Measures Using Stated Preference Methods." *Ecological Economics* 58(4): 850–861.

Daily, G.C. 1997. *Nature's Services*. Covelo, CA: Island Press.

Dale, V.H., and S. Polasky. 2007. "Measures of the Effects of Agricultural Practices on Ecosystem Services." *Ecological Economics* 64(2): 286–296.

Duke, J.M., and R.J. Johnston. 2010. "Nonmarket Valuation of Multifunctional Farm and Forest Preservation." In S.J. Goetz and F. Brouwer, eds., *New Perspectives on Agri-Environmental Policies: A Multidisciplinary and Transatlantic Approach*. Oxford, UK: Routledge.

Eldridge, D.J., and D. Freudenberger. 2005. "Ecosystem Wicks: Woodland Trees Enhance Water Infiltration in a Fragmented Agricultural Landscape in Eastern Australia." *Austral Ecology* 30(3): 336–347.

Engel, S., S. Pagiola, and S. Wunder. 2008. "Designing Payments for Environmental Services in Theory and Practice: An Overview of the Issues." *Ecological Economics* 65(4): 663–674.

Fisher, B., R.K. Turner, and P. Morling. 2009. "Defining and Classifying Ecosystem Services for Decision Making." *Ecological Economics* 68(3): 643–653.

Gallai, N., J.M. Salles, J. Settele, and B.E. Vaissière. 2009." Economic Valuation of the Vulnerability of World Agriculture Confronted with Pollinator Decline." *Ecological Economics* 68(3): 810–821.

Hansen, L., P. Feather, and D. Shank. 1999. "Valuation of Agriculture's Multi-site Environmental Impacts: An Application to Pheasant Hunting." *Agricultural and Resource Economics Review* 28(2): 199–207.

Hart, D.D., and K.P. Bell. 2013. "Sustainability Science: A Call to Collaborative Action." *Agricultural and Resource Economics Review* 42(1): 75–89.

Hougner, C., J. Colding, and T. Söderqvist. 2006. "Economic Valuation of a Seed Dispersal Service in the Stockholm National Urban Park, Sweden." *Ecological Economics* 59(3): 364–374.

Jackson, L.E., U. Pascual, and T. Hodgkin. 2007. "Utilizing and Conserving Agrobiodiversity in Agricultural Landscapes." *Agriculture, Ecosystems and Environment* 121(3): 196–210.

Johnston, R.J., and S.K. Swallow, eds. 2006. *Economics and Contemporary Land Use Policy: Development and Conservation at the Rural-Urban Fringe.* Washington, DC: RFF Press.

Johnston, R.J., and R.S. Rosenberger. 2010. "Methods, Trends, and Controversies in Contemporary Benefit Transfer." *Journal of Economic Surveys* 24(3): 479–510.

Johnston, R.J., and M. Russell. 2011. "An Operational Structure for Clarity in Ecosystem Service Values." *Ecological Economics* 70(12): 2243–2249.

Johnston, R.J., E.T. Schultz, K. Segerson, E.Y. Besedin, and M. Ramachandran. 2013. "Stated Preferences for Intermediate versus Final Ecosystem Services: Disentangling Willingness to Pay for Omitted Outcomes." *Agricultural and Resource Economics Review* 42(1): 98–118.

Johnston, R.J., S.K. Swallow, D.M. Bauer, and E. Uchida. Forthcoming. "Connecting Ecosystem Services to Land Use: Implications for Valuation and Policy." In J.M. Duke and J. Wu, eds., *The Oxford Handbook of Land Economics*. Oxford, UK: Oxford University Press.

Just, R.E., D.L. Hueth, and A. Schmitz. 2004. *The Welfare Economics of Public Policy: A Practical Approach to Project and Policy Evaluation*. Cheltenham, UK: Edward Elgar.

Kellermann, J.L., M.D. Johnson, A.M. Stercho, and S.C. Hackett. 2008. "Ecological and Economic Services Provided by Birds on Jamaican Blue Mountain Coffee Farms." *Conservation Biology* 22(5): 1177–1185.

Kline, J.D., and M.J. Mazzotta. 2012. *Evaluating Tradeoffs among Ecosystem Services in the Management of Public Lands*. General Technical Report PNW-GTR-865, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. Available at www.fs.fed.us/pnw/pubs/pnw_gtr865.pdf.

Kline, J., M. Mazzotta, T. Spies, and M. Harmon. 2013. "Applying the Ecosystem Services Concept to Public Land Management." *Agricultural and Resource Economics Review* 42(1): 139–158.

Knoche, S., and F. Lupi. 2007. "Valuing Deer Hunting Ecosystem Services from Farm Landscapes." *Ecological Economics* 64(2): 313–320.

Kroeger, T., and F. Casey. 2007. "An Assessment of Market-based Approaches to Providing Ecosystem Service on Agricultural Lands." *Ecological Economics* 64(2): 321–332.

Krutilla, John V. 1967. "Conservation Reconsidered." *American Economic Review* 57(4): 777–786.

Liu, T., N.H. Merrill, A.J. Gold, D.Q. Kellogg, and E. Uchida. 2013. "Modeling the Production of Multiple Ecosystem Services from Agricultural and Forest Landscapes in Rhode Island." *Agricultural and Resource Economics Review* 42(1): 251–274.

Loomis, J.B. and Rosenberger, R.S. 2006. "Reducing Barriers in Future Benefit Transfers: Needed Improvements in primary Study Design and Reporting." *Ecological Economics* 60(2): 343–350.

Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-being: Synthesis*. Washington, DC: Island Press.

Moore, R. 2013. "Prioritizing Ecosystem Service Protection and Conservation Efforts in the Forest Plantations of the Red Hills." *Agricultural and Resource Economics Review* 42(1): 225–250.

Muradian, R., E. Corbera, U. Pascual, N. Kosoy, and P.H. May. 2010. "Reconciling Theory and Practice: An Alternative Conceptual Framework for Understanding Payments for Environmental Services." *Ecological Economics* 69(6): 1202–1208.

National Research Council. 2010. *Toward Sustainable Agricultural Systems in the 21st Century*. National Academy Press, Washington, DC.

Newell, L.W., and S.K. Swallow. 2013. "Real-Payment Choice Experiments: Valuing Forested Wetlands and Spatial Attributes within a Landscape Context." *Ecological Economics* in press.

Polyakov, M., D.J. Pannell, R. Pandit, S. Tapsuwan, and G. Park. 2013. "Valuing Environmental Assets on Rural Lifestyle Properties." *Agricultural and Resource Economics Review* 42(1): 159–175.

President's Council of Advisors on Science and Technology. 2011. *Sustaining Environmental Capital: Protecting Society and the Economy*. Executive Office of the President: Washington, DC.

Rosenberger, R.S., and T.D. Stanley. 2006. "Measurement, Generalization, and Publication: Sources of Error in Benefit Transfers and their Management." *Ecological Economics* 60(2): 372–378.

Ruto, E., G. Garrod, and R. Scarpa. 2008. "Valuing Animal Genetic Resources: A Choice Modeling Application to Indigenous Cattle in Kenya." *Agricultural Economics* 38(1): 89–98.

Shortle, J.S. 2013. "Economics and Environmental Markets: Lessons from Water-Quality Trading." *Agricultural and Resource Economics Review* 42(1): 57–74.

Smith, E.C., and S.K. Swallow. 2013. "Lindahl Pricing for Public Goods and Experimental Auctions for the Environment." In J. Shogren, ed., *Encyclopedia of Energy, Natural Resource, and Environmental Economics*. Oxford: Elsevier Science, *in press*.

Smith, K.R. 2013. "Economic Science and Public Policy." *Agricultural and Resource Economics Review* 42(1): 90–97.

Smukler, S.M., S. Sanchez-Moreno, S.J. Fonte, H. Ferris, K. Klonsky, A.T. O'Green, K.M. Scow, K.L. Steenwerth, and L.E. Jackson. 2010. "Biodiversity and Multiple Ecosystem Functions in an Organic Farmscape." *Agriculture, Ecosystems and Environment* 139(1/2): 80–97.

Swallow, S.K. 2013. "Demand-Side Value for Ecosystem Services and Implications for Innovative Markets: Experimental Perspectives on the Possibility of Private Markets for Public Goods." *Agricultural and Resource Economics Review* 42(1): 33–56.

Swinton, S.M., F. Lupi, G.P. Robertson, and S.K. Hamilton. 2007. "Ecosystem Services and Agriculture: Cultivating Agricultural Ecosystems for Diverse Benefits." *Ecological Economics* 64(2): 245–252.

Timmons, D. 2013. "Social Cost of Biomass Energy from Switchgrass in Western Massachusetts." *Agricultural and Resource Economics Review* 42(1): 176–195

Tuttle, C., and M. Heintzelman. 2013. "The Value of Forever Wild: An Economic Analysis of Land Use in the Adirondacks." *Agricultural and Resource Economics Review* 42(1): 119–138.

Tveteras, S., C. Paredes, and J. Pena-Torres. 2011. "Individual Vessel Quotas in Peru: Stopping the Race for Anchovies." Marine Resource Economics 26(3): 225–232.

Uchida, E., C. Anderson, and S. Swallow. 2007. "Marketing Ecosystem Services from Agricultural Land: Stated Preferences over Payment Mechanisms and Actual Sales of Farm-Wildlife Contracts." Presented to the *Annual Meeting of the American Agricultural*

Economics Association, July 29–August 1, Portland Oregon. Available at http://purl.umn.edu/9955.

U.S. Environmental Protection Agency (EPA). 2009. *Valuing the Protection of Ecological Systems and Services: A Report of the EPA Science Advisory Board*. Washington, DC.

Vatn, A. 2010. "An Institutional Analysis of Payments for Environmental Services." *Ecological Economics* 69(6): 1245–1252.

Vitousek, P.M., K. Cassman, C. Cleveland, T. Crews, C.B. Field, N.B. Grimm, R.W. Howarth, R. Marino, L. Martinelli, E.B. Rastetter, and J.I. Sprent. 2002. "Towards an Ecological Understanding of Biological Nitrogen Fixation." *Biogeochemistry* 57/58(1): 1–45.

Wainger, L., and M. Mazzotta. 2011. "Realizing the Potential of Ecosystem Services: A Framework for Relating Ecological Changes to Economic Benefits." *Environmental Management* 48(4): 710–733.

Wainger, L., G. Van Houtven, R. Loomis, J. Messer, and M. Deerhake. 2013. "Tradeoffs among Ecosystem Services, Performance Certainty, and Cost-efficiency in the Implementation of the Chesapeake Bay Total Maximum Daily Loads." *Agricultural and Resource Economics Review* 42(1): 196–224.

Wallace, K.J. 2007. "Classification of Ecosystem Services: Problems and Solutions." *Biological Conservation* 139(3/4): 235 –246.

Zhang, W., T.H. Ricketts, C. Kremen, K. Carney, and S.M. Swinton. 2007. "Ecosystem Services and Disservices to Agriculture." *Ecological Economics* 64(2): 253–260.