Opportunities for Systematically Valuing Ecosystem Service Benefits Produced by Federal Conservation Programs

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Federal agencies invest taxpayer dollars every year in conservation programs that are focused on improving a suite of ecosystem services produced on private lands. A better understanding of the public benefits generated by federal conservation programs could help improve governmental efficiency and economic welfare by providing science-based evidence for use in policy decision-making regarding targeting of federal conservation investments. Of specific concern here are conservation investments made by the U.S. Department of Agriculture (USDA). While previous research has shown that efficiency gains are possible using cost-benefit analysis for targeting conservation investments, agency-wide implementation of this approach by policy makers has been constrained by the limited availability of location-specific information regarding conservation benefits. Cost-effective opportunities for integrating location-specific ecosystem service valuation research with USDA conservation decision-making include: (1) institutionalizing funding of comparable studies suitable for benefit transfer, (2) utilizing non-traditional data sources for research complementing benefit transfer, and (3) creating a state-of-the-art program for developing and communicating research in ecosystem service valuation exemplifying the highest standards of scientific conduct.

Keywords: Anthropocene, benefit transfer, conservation, efficiency, working landscapes, publication bias, replication, resilience, targeting

Introduction

During the early years of the 20th century, as biologists strove to discover the processes governing plant succession, it was argued that a fundamental understanding would emerge not only by considering the suite of dynamic interactions among organisms but by expanding the conceptualization to include the influence of non-living factors contributed by climatic and soil complexes. This broader, integrative framework was described as an ecosystem (Tansley 1935). Nearly a century later, the ecosystem concept is

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recognized as an essential framework for assessing the long-run sustainability of natural capital within the United States (Anon. 2008) and around the world (Millennium Ecosystem Assessment 2005). While the past decade has seen an increase in the supply of ecosystem service research, implementation of research findings has been more limited. This is due in part to a lack of research linking ecological and social systems in a manner that informs decision-makers about how ecosystem policy or management actions affect the benefits received by identifiable groups of stakeholders (Olander et al. 2017; Polasky, Tallis, and Reyers 2015).

There is growing scientific consensus that the list of factors influencing the varied dynamic interactions occurring within ecosystems must now include the increasingly dominant roles played by people. Humans and many other organisms are ecosystem engineers, having developed the ability to modify ecosystems for their own benefit while altering the flow of resources available for use by other species (Jones, Lawton, and Shachak 1994). However, the speed and scale of physical and functional changes in global biomes wrought by the nearly 7.5 billion people on Earth has ushered in a sense of urgent need to limit human impacts on ecosystems.

The concept of the Anthropocene, introduced near the beginning of the current millennium, captures the idea of a quantitative shift between humans and the global environment by equating the scale and degree of changes in the biosphere since the beginning of the Industrial Revolution with massive changes that occurred during the five previous geological epochs of the Earth's history (Steffen et al. 2011; Steffen et al. 2018).[1] Unintended consequences (negative externalities) imposed upon nature by economic activity are now thought to threaten the survival of perhaps 1 million species worldwide and are likely to significantly degrade the functioning of vital ecosystem services on which human life and well-being depends (IPBES 2019). Not only has the rate of accumulation of CO_2 in the atmosphere rapidly accelerated since the mid-20th century, raising concerns about the dangers of global warming, but indicators of a wide variety of human activities that, in aggregate, alter essential ecosystem functions—such as the damming of rivers, land clearing for agriculture, and the application of fertilizers—have also grown at an increasing rate (Steffen et al. 2011).

Resulting from a widespread growth of environmental awareness within the United States during the last decades of the 20th century, agricultural and forest conservation programs have been initiated that provide incentives for private landowners to adopt conservation practices (Lichtenberg 2014; Ma et al. 2012). Examples include the Conservation Reserve Program (CRP), the Environmental Quality Incentives Program (EQIP), and the Forest Legacy

[1] At the global level, human-dominated ecosystems cover vastly more area than do wildlands, which account for less than one-quarter of the ice-free land area on Earth (Ellis and Ramakutty 2008).

Program (FLP). These programs support landowners by providing technical and financial assistance to facilitate implementation of management actions. Agricultural and forestry conservation programs generally address two objectives—income support and protection of the environment. Unfortunately, these dual objectives are not generally complementary and often result in the necessity of making trade-offs in policy implementation.[2]

Economic efficiency criteria suggest that investments in agricultural conservation programs should be cost-effective, that is, provide the greatest level of ecosystem service benefits for a given budget (Kurkalova 2015). Although indicators of ecosystem services, such as the Environmental Benefit Indicator (EBI), were designed to improve the environmental outcomes of conservation investments, evidence suggests that income support often dominates political decisions regarding where conservation programs are implemented (Lichtenberg 2019). For example, CRP enrollment has been historically high in areas with marginal cropland (e.g., the Plains, High Desert, and Mountain areas), providing little benefit to agricultural sustainability. Low population density in these regions also suggests that few people benefit from improvements in environmental quality or wildlife habitat. It appears that improved targeting of conservation funding could increase the ecosystem service benefits that people receive for given levels of conservation investment.

While alternative criteria have been suggested for the targeting of agricultural conservation programs (Claassen, Cattaneo, and Johansson 2008; Kurkalova 2015), attention is focused here on emerging opportunities for targeting conservation investments using science-based information on the value that agricultural and forest ecosystem services provide to the American public (Feather, Hellerstein, and Hansen 1999; Hansen et al. 2015). This is accomplished by, first, briefly reviewing the application of non-market valuation studies for assessing changes in land use and land cover on the value of ecosystem services. This is followed by a summary of the major agricultural and forestry conservation programs within the U.S. Department of Agriculture. A rationale is presented for how meta-analysis and benefit transfer methods could help inform decisions regarding the targeting of agricultural conservation investments in the United States. This is followed by a discussion of how economic research studies supporting benefit transfer of ecosystem service values might be prioritized. Next, the use of nontraditional data sources that can be used in "exploratory studies" to explore the validity and robustness of "best-practice" benefit transfer studies is discussed. The possible design of a state-of-the-art program for developing

[2] In some cases, conservation practices such as increasing agricultural biodiversity can increase agricultural productivity and lower risk exposure for farmers while improving a suite of ecosystem services related to soil fertility, pest control, pollination, and reduced soil and nutrient losses (Bommarco, Vico, and Hallin 2018; Di Falco 2012; Dominati et al. 2019).

and communicating ecosystem service benefit research is presented in the following section. Finally, conclusions are presented.

Nonmarket Valuation Methods Contribute to Ecosystem Service Assessments

It has been argued that economic assessments are particularly well suited to providing policy makers with information describing trade-offs between the costs and benefits of various policy alternatives while avoiding double-counting of underlying ecosystem processes (Bateman et al. 2011). Many of the ecosystem services provided by agricultural and forested landscapes are not traded in markets, and the possibility for including the economic value of nonmarket goods and services in policy assessments has greatly advanced over the past five decades (Champ, Boyle, and Brown 2017). Nonmarket valuation methods are now recommended for valuing a suite of ecosystem services provided by agricultural and forested landscapes (Binder et al. 2017; Feather, Hellerstein, and Hansen 1999; Hansen et al. 2015; Sills et al. 2017). Further, the increasing availability of geospatial data and modeling tools has enhanced the ability of researchers to integrate models of ecosystem service production with models of ecosystem service values (Tallis and Polasky 2009). While it is recognized that not all ecosystem services (such as the spiritual value of a place) can be monetized given the current state-of-the-art in nonmarket valuation, the use of benefit-relevant indicators (Olander et al. 2017; Olander et al. 2015) or other metrics, such as those provided by the Montreal process (https://www.montrealprocess.org/), can provide alternative, complementary approaches that account for non-economic values held by stakeholders.

An example of how cost-benefit-analysis can be used to structure ecosystem assessments across broad geographical areas is provided by the United Kingdom National Ecosystem Assessment (Bateman et al. 2014). This research effort examined the economic consequences of various land-use change scenarios on agricultural food production, carbon storage, open-access recreation, urban greenspace amenities, and biological diversity. Including both the market and nonmarket impacts of future land-use change scenarios on the supply of ecosystem services led to the primary conclusion that “a restricted analysis focusing solely upon market priced goods yields a very different view of which scenario is superior, in contrast to a broader assessment which also considers non-market values” (p. 292). As the authors note, meta-analyses of primary data collection studies allowed the estimated economic benefits of alternative scenarios to be transferred across landscapes in the UK.

Advancing the Science of Ecosystem Service Valuation by the USDA

While it would be advantageous for every federal land management agency to develop a better understanding of the ecosystem service benefits that their programs deliver to the American public, attention is focused here on a single agency for practical reasons. The 2018 farm bill (Agriculture Improvement Act of 2018, P.L. 115–334, Title II) provides roughly $60 billion in conservation funding for the forthcoming ten-year period (CRS 2019). During the past two decades, mandatory funding in the farm bill for conservation programs on working lands (including EQIP, Conservation Stewardship Program, and Agricultural Management Assistance) increased rapidly from less than $500 million in 2002 to nearly $3.5 billion in 2020. During the same period, mandatory funding for land retirement programs (the CRP), has remained relatively constant at around $2 billion. Other programs (including the Agricultural Conservation Easement Program and the Regional Conservation Partnership Program) make up the remainder of the mandatory conservation spending program. Within the USDA Forest Service, the primary conservation programs targeted at private landowners are the Forest Legacy Program, providing incentives for the protection of private forest land through conservation easements and purchases, and the Working Forest Lands Program, providing landowners with information and tools needed to manage their forest land. In the year 2019, appropriations for these programs were roughly $20.5 million and $64 million, respectively (USDA 2020).

The ability to provide comprehensive valuation of ecosystem service benefits received by the American public resulting from federal investments in conservation programs is necessary to provide critical feedback to policy makers regarding the efficiency of conservation investments (Wainger and Erwin 2017). In the interest of exploring the possibilities for advancing the science of ecosystem service valuation for use by the USDA, academic and federal scientists and administrators were convened at a workshop held in Washington, DC, on April 23–24, 2019. In what follows, ideas presented at the workshop are summarized and, in some cases, extended.

Identifying Priorities for Economic Research Funding Supporting Benefit Transfer

While guidelines have been recently recommended for the collection of stated and revealed preference data (Champ, Boyle, and Brown 2017; Johnston et al. 2017), primary data collection studies following best practices are expensive. This constraint has led to the development of benefit transfer studies for use in quantifying the nonmarket benefits associated with outdoor recreation, environmental regulations, natural resource damage assessments, and production of ecosystem services (Johnston et al. 2018; Richardson et al. 2015). However, the efficiency gains realized through the application of meta-analysis methods to summarize information contained in primary valuation studies is limited by the fact that underlying studies have generally been developed and implemented in isolation. The use of multiple research protocols in primary studies often leads to the exclusion of information from potentially useful studies due to the use of disparate units of measurement, variables of interest, and underlying modeling frameworks. Further, the uneven geographic dispersion of primary studies and the focus on iconic or otherwise important natural resources fails to provide a sample that can be readily generalized across a gradient of very rare to more common ecosystems.

In lieu of piecemeal funding of studies by federal and state agencies concerned with the management of landscapes and natural resources, a more efficient approach to creating a body of knowledge that can inform conservation targeting across a wide diversity of landscapes and ecosystems might proceed by dedicating funding to a defined research effort with the goal of designing comparable primary research studies specifically for use in benefit transfer. A focus on comparable study design could benefit from well-known strategies such as stratified sampling to assure that critical ecosystem services and human populations are represented. Further, a key criterion for study funding would emphasize that best science practices need be utilized. Although stated preference methods remain controversial, convergent validity of studies could be enhanced by matching stated and revealed preference studies (Champ, Boyle, and Brown 2017). In some cases, actual cash payments could be elicited as an element of experimental protocols, thus allowing assessments of criterion validity.

At least initially, priorities for economic research funding could be coordinated with the suite of land management efforts currently funded by federal conservation programs. The formation of partnerships between researchers (e.g., governmental and academic), conservation program managers (e.g., governmental and non-governmental), and the stakeholders (e.g., farmers, forest landowners, rural populations) could strengthen communication within governmental agencies and improve the delivery of ecosystem service benefits to defined populations. Further, such institutional changes are more likely to lead to actionable conservation science than "ivory tower" approaches (Gerber and Raik 2018).

Utilize Available Nontraditional Data Sources

In addition to the prospects for initiating a structured suite of new research studies that would facilitate benefit transfers at the landscape scale, it is helpful to consider the possibility for economists to utilize existing, nontraditional data sources that could complement the knowledge gained from benefit transfer. In contrast to the "best practices" approach to benefit transfer suggested earlier, alternative data sources could be used in "exploratory studies" that could be used to test the validity and robustness of "best practice" studies. A few examples of "exploratory studies" are summarized next. These studies use four types of nontraditional data for benefit evaluation: (1) time allocation data contained in the American Time Use Survey, (2) locational data contained in social media, (3) data on individual well-being contained in life satisfaction data, and (4) high-resolution spatial environmental data.

American time use survey data

If future changes in the provision of ecosystem services are thought to elicit a meaningful public response in terms of ex ante willingness to pay, then a pragmatic strategy for evaluating the validity of transfers is to ask whether ex post behavioral evidence may be found that is consistent with transferred values. The possible utility of this research approach was recently explored by considering behavioral changes, as measured by time allocated to different outdoor activities, related to the Deepwater Horizon Gulf Oil Spill and to variation in common measures of air pollution (McConnell and Siikamäki 2018). Using data provided by the American Time Use Survey (ATUS), the authors found evidence that PM2.5 concentrations at unhealthy levels influence time spent in resource-based outdoor recreation and work. Data analysis also indicated that people living in the Gulf region spent more time at work during the weeks and months following the oil spill. It is unclear whether this response reflected an increase in labor demand brought about by the cleanup efforts or whether people spent more time at work because outdoor recreation opportunities were limited by the oil spill. In both cases, the authors note challenges resulting from the limited number of observations available in the ATUS data that are specific to the locations and times of the environmental events being evaluated.

ATUS data were used to explore the impacts of increasing temperature that may be induced by future climate change on the amount of time allocated to outdoor and indoor leisure (Zivin and Neidell 2014). The climate data used in this study included the 2006 heat wave that produced high temperatures across much of the United States, allowing more reliable estimates of behavioral responses at the high end of the temperature distribution. The authors found large reductions in time allocated to labor in industries with greater exposure to climatic factors as temperatures exceeded 85°F, with corresponding decreases in the marginal productivity of labor and reallocation of time to indoor leisure. Further, the authors also discovered an inverted U-shaped relationship for outdoor leisure activities in which more time was allocated to outdoor leisure at the lower end of the temperature gradient up to a point after which higher temperatures decreased the time spent in outdoor leisure activities.

As ATUS data contain demographic information, they are useful for investigating impacts of exogenous changes in climate, ecosystem services, or environmental effects on different segments of the U.S. population. Where significant linkages are found, projections of demographic changes can then be used to forecast time allocations under a variety of future scenarios incorporating exogenous variables of interest. In situations where outdoor recreation or leisure can be assigned a monetary cost, it may then be possible to estimate willingness to pay for changes in exogenous levels of ecosystem services (McConnell and Siikamäki 2018).

Social media data

In addition to time allocation data, a second, publicly available, data source that is increasingly being used to investigate behavioral decisions regarding the availability and quality of ecosystem services is provided by social media (Wood et al. 2013). While traditional travel-cost models of recreation demand typically utilize some form of registration or permit data, it is now recognized that geotagged photographs that are uploaded to photo-sharing websites such as Flickr can be used to identify both the destination and origin of recreational trips. These data sources have been used to estimate the value of changes in water quality at lakes in the Midwestern United States (Keeler et al. 2015).

Life satisfaction data

Research interest in the economic aspects of subjective well-being (SWB; happiness, life satisfaction) is rapidly growing, and “experienced” utility is now being (re)considered as an alternative method, in juxtaposition with “decision” utility, for use in economic analysis of welfare (Kahneman, Wakker, and Sarin 1997). SWB data have been used in studies seeking to estimate nonmarket values associated with changes in environmental variables and have been principally applied to problems concerned with understanding the impacts of air pollution on human well-being (Frey, Luechinger, and Stutzer 2010). Further, it has been suggested that SWB data can augment hedonic property value studies used to estimate welfare impacts of environmental changes and can provide missing shadow costs in cases where housing markets are not in equilibrium (van Praag and Baarsma 2005; Ferreira and Mouro 2010). In the forestry sector, SWB data have been used to estimate the impacts of nonnative and native forest pests on the well-being of people residing within forest ecosystems (Jones 2017; Holmes and Koch 2019). As with other nontraditional sources of data for conducting economic evaluations, the temporal and spatial scope of SWB data may limit analyses in specific applications to ecosystem service valuation.

High-resolution spatial environmental data

The U.S. EPA is developing a nationwide database, known as Enviro-Atlas, describing a suite of environmental variables at relatively high-resolution spatial scales. These data include over 300 data layers. The richness of these data provide economic researchers with opportunities for innovative analyses related to the value of ecosystem services. For example, tree cover data provided at the 1m^2 resolution for a select set of urban areas in the United States, combined with real estate data on housing characteristics, sales prices, and other environmental attributes, was used to estimate the value of urban tree cover across several ecological regions in the United States (Siriwardena

2016). The availability of housing price and characteristic data from sources such as Zillow, in combination with data layers available from Enviro-Atlas, will presumably expand the opportunities for conducting hedonic price studies related to various ecosystem services across broad regions of the United States.

Create a State-of-the-Art Program for Developing and Communicating Ecosystem Service Research

Current publication pressures emphasize the production of novel research methods and results, providing information that is distant from the day-to-day needs of policy makers and, in some cases, lead to questionable research practices. Within the social sciences, questionable practices such as deciding whether to exclude data after looking at the impact of doing so on results have been found to be surprisingly prevalent (John, Lowenstein, and Pralec 2012). Further, attempts to replicate findings of social science experiments recently reported in *Nature* and *Science*, with sample sizes about five times larger than original experiments, found a significant effect in the same direction as the original study in only about 63 percent of the cases (Camerer et al. 2018).[3] More generally, concerns over replicability, HARKing (hypothesizing after results are known), P-hacking (searching model specifications for significant results), and publication bias (the proclivity to publish studies with positive and novel results) has advanced calls for research methodologies that increase the transparency, reproducibility, and efficiency of scientific research (Munafò et al. 2017).

A novel method that is currently being used by some journals to address concerns regarding HARKing, P-hacking, and publication bias is known as Registered Reports (Nosek and Lakens 2014). This procedure relies upon a journal reviewing and accepting preregistered proposals prior to data collection as a means for encouraging replication studies and reporting results regardless of their statistical significance.[4] The practice of not publishing insignificant results can lead to substantial bias in meta-analysis studies, and various statistical methods and research guidelines have been developed to address this problem (Christiansen and Miguel 2018; Stanley et al . 2013). Concerns about replicability of research studies have been addressed in the economics profession following several initiatives promulgated by the American Economic Association. The *American Economic Review* began requesting data in 2003 and, under then-editor Ben Bernanke,

[3] In confirmatory cases, the replication size effect was about 71 percent of the effect in the original study, suggesting that meta-analyses conducted on true-positive findings will overestimate effect sizes, on average.

[4] As of November 2016, more than 40 journals had adopted Registered Reports (Munafò et al. 2017).

instituted a data- and code-sharing policy in 2004. Other journals published by the American Economic Association followed suit and the *Quarterly Journal of Economics* finally adopted a data-sharing requirement in 2016 (Christiansen and Miguel 2018).

Taken together, it appears timely for the USDA to consider linking the needs for: (1) institutionalizing a research system capable of providing a suite of primary studies designed for landscape-scale benefit transfer, (2) pursuing the possibilities of using available but unconventional data sources, and (3) a research development and communication system that addresses currently prevalent concerns about scientific data analysis and publication. It might be possible, for example, to develop a Registered Report system that would be required when applying for USDA grants supporting ecosystem service valuation. Review of submissions into this system, as well as publication of research (including non-significant) results could provide multiple benefits, such as: (1) making economists aware of other researchers with interest in similar topics[5], (2) reducing incentives for HARKing and P-hacking, and (3) avoiding publication bias. Further, requiring that data and computer code be made available after publication would likely enhance replicability of research findings.

While it might be possible to create a specialized publication outlet for ecosystem service production and valuation research, the USDA Forest Service currently maintains research reporting capacities such as the Resources Planning Act and General Technical Report systems. Likewise, the Economic Research Service provides a variety of reporting services, including Economic Research Reports and Technical Bulletins. Whether such an ambitious system for communicating the results of a dedicated research program in ecosystem service valuation could fit within existing research outlets or would require the institution of new format is a topic suggested for consideration.

Conclusions

The rate of change in the global provision of ecosystem services has caused alarm among many scientific communities. While individual citizens can do their part, it will be essential for governments and policy makers to address existing and emerging threats at state, regional, and national levels. The ability to protect and enhance the provision of ecosystem services to the greatest number of people at the lowest cost requires better information regarding the impact of policy and management actions on the benefits

[5] Consistent with these concerns, efforts within the USDA led, in 2012, to the rollout of VIVO, providing scientists with the capacity to locate others with a particular expertise and to more easily identify potential peers and collaborators. The VIVO database draws information about research being conducted by USDA scientists and makes it available to searching.

received by identifiable groups of stakeholders. This need may be fulfilled by economic valuation studies, non-economic benefit relevant indicators, or other metrics such as provided by the Montreal process.

The USDA can set an example of how ecosystem services can be targeted and delivered in the most efficient manner to the American public. As USDA funding for conservation programs currently exceeds $6 billion annually, opportunities exist for targeting these programs to locations where the ecosystem service benefits are maximized for given program costs. The resulting gains in governmental efficiency will require the development of an actionable-science program that integrates the research capabilities of the USDA with conservation program managers and a diverse array of stakeholders and beneficiaries, including farmers, forest landowners, and residents of rural communities.

Economists within the USDA have a key role to play in advancing this integrative process. Research funding specifically allocated to the development of a program focused on the provision of knowledge regarding the ecosystem service benefits of USDA conservation programs could help decision-makers better understand the linkages between program activities and benefits to the American public. At the same time, the expertise developed by USDA economists could facilitate the coproduction of similar efforts across other federal agencies and research organizations concerned with the protection and enhancement of critical ecosystem services to benefit the well-being of current and future generations.

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Conflicts of Interest

None.

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