Using Ecological Models to Coordinate Valuation of Ecological Change on Western Rangelands for ex post Application to Policy Analysis

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Introduction

The economic valuation of landscape-scale ecological change is increasingly considered necessary for policy-making. In the United States, ecosystem-level management goals have been formally adopted in federal and state land management policy for a variety of ecosystems (Malone 2000). Valuation of ecosystem services has had important impacts on policy decisions involving ecosystem management (Barbier 2012). Indeed, two of the six summary recommendations in the 2011 Presidents' Council of Advisors on Science and Technology report to President Obama relate specifically to the need for valuation of ecosystems and ecosystem services for policy decisions (PCAST 2011). Despite the recognition of the need for economic valuation of landscape-scale ecological change, there continues to be a perception among scientists and public lands decision-makers that economic theory and methods are not up to the task of providing accurate, timely, and policy-relevant estimates of the values associated with ecosystem change for use in policy-making (Nelson 2006).[2]

In this article, we argue that several practical steps can be taken to counter this criticism and to coordinate research output from independent non-market valuation studies to facilitate their routine ex-post application to ecosystem management policy on public and private lands.[3] Our focus is on facilitating the application of economic analysis to policies that target landscape-scale ecological change – changes that typically influence multiple ecosystem goods and services, over large areas, and over long periods of time, rather than policies that target changes in the quality or quantity of a specific good or service (i.e., hunting days, miles of trail, and congestion). Our primary point of reference in this article is ecological change on sagebrush rangelands in the western United States. We focus on rangelands, in part, because rangeland management policy in the western United States has increasingly targeted landscape scale ecological change (Havstad et al 2007; McIver et al 2010; Menke and Bradford 1992). While this article provides suggestions and insights from our work valuing ecological change on western rangelands, we argue that the obstacles to coordinating the results from valuation studies to performing policy-relevant, ex-post benefit-cost analysis that we identify are broadly shared by all ecosystems.

We argue that the most important step to promoting the ex-post application of valuation studies to policy-making is to ensure that the change in the ecological good or service being valued

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[2] Nelson (2006) goes as far as to argue that where science-based ecosystem management objectives have replaced the traditional multiple-use management paradigm in national public lands policy, "in place of economic benefits, ecosystem management substitutes biological goals that cannot effectively be captured by economic methods."

[3] Numerous studies that have integrated ecological and economic modeling to value ecological change (e.g., Polasky et al 2011; Eichner and Tschirhart 2007; Tschirhart 2012; Taylor et al 2012; Bockstael et al 1995) attest to the fact that this perception is not due to a fundamental inability of economic theory and methods to measure the cost and benefits of ecosystem change.

corresponds to the ecological change that policy-makers hope to influence through management. The primary advantage of including policy-relevant assumptions about ecological change into primary valuation studies is that it removes the onus on policy-makers to translate the ecological outcome they are attempting to achieve into units of the environmental good or service that has previously been valued in relevant primary valuation studies..[4] In addition to ex-post policy relevance, we argue that scientific accuracy and congruence with available data are important criteria for selecting an ecological framework for a valuation study. Furthermore, we propose that the state-and-transition model (STM) framework from rangeland ecology is the appropriate ecological framework for economic analysis of ecosystem change on western rangelands given these considerations (Stringham, Krueger, and Shaver 2003).

The ex-post application of valuation studies to ecosystem management policy on public and private lands is further complicated by the fact that landscape-scale changes often influence multiple ecological goods and services resulting in welfare changes for numerous groups in society. Valuing each ecological good or service often requires separate estimation methods, data needs, and expertise on the part of the researcher, and is typically accomplished in separate studies. Combining the results of separate studies ex-post to get a complete picture of the welfare consequences of landscape-scale ecological change can be difficult, if not impossible. This is particularly the case if there are differences in the component studies regarding spatial and temporal scales, explanatory variables, and assumptions about the underlying ecological change. We argue that in addition to sharing a common, policy-relevant ecological framework, the data collection and analysis in each component study (i) must be broad enough regarding biophysical context, and socio-demographic information, to encompass a range of potential policy sites within the ecosystem, (ii) be capable of addressing the uncertainty inherent in any ex-ante benefit-cost analysis of ecosystem management policy, and (iii) should consider the fact that the spatial and temporal scales of any ex-post cost-benefit analysis is determined by the component study with the broadest spatial and temporal scales.

The approach discussed in this article has many parallels with benefit transfer, defined by Rosenberger and Loomis (2000, p 1097) as "the application of values and other information from a 'study site' where data are collected to a 'policy site' with little or no data." Indeed, we consider the approach discussed in this article as a special case of benefit transfer where the study and policy sites are in the same ecological setting, and where the analysis at the study sites is coordinated ex-ante to facilitate the development of a "site-to-site transfer function" capable of addressing spatial, temporal and other ecological details that are specific to the ecosystem. Unlike standard benefit transfer, however, each component study under our approach is performed with the express goal of ex-post application to valuing ecological change in a specific ecosystem. That is, primacy is given to maintaining a common ecological framework across studies that target specific ecosystems. The importance of similarity between the policy and study sites for the validity and reliability of the benefit transfer approach is widely recognized (Rosenberger and Johnston, 2010). We suggest that many of the barriers to ex-post application to policy sites can be overcome if additional steps are taken (i) to insure that the ecological good or service being valued corresponds to the ecological change that policy-makers hope to influence through their management and (ii) that given the fact that most landscape-scale ecosystem management policies will involve multiple ecosystem goods and

[4] Several previous authors have suggested that fundamental differences in spatial, temporal, and conceptual frameworks between ecology and economics create challenges to the use of economic information in environmental management (Lunney et al 1997; Drechsler et al 2007; Barbier 2012).

service, researchers are cognizant of the fact the ecological framework, spatial scale, and temporal scale of each component study places constraints on their joint ex-post application.[5]

Ecological Change on Western Rangelands and the Objectives of Land Management

Sagebrush rangelands occupy over 100 million acres of high desert in the western United States. These rangelands provide habitat for more than 300 species of wildlife, are an important forage base for the western livestock industry, and support one of the fastest growing human populations in the country (Knick et al., 2003). Sagebrush rangelands are undergoing rapid ecological change as a result of invasive annual grasses, such as cheatgrass (*Bromus tectorum*), from the expansion of native conifers, such as junipers and pinyon pine (*Juniperus occidentalis, Juniperus osteosperma*; *Pinus monophylla, Pinus edulis*), and from the acceleration of rangeland fire cycles to increasingly severe and more frequent wildfire. This ecological change threatens to permanently impair the ability of these rangelands to support native wildlife and plants, increase wildfire suppression costs, degrade hydrologic function, and may undermine the ecological and economic stability of the entire region (Devine 1993; BLM 1999, 2000; Pellant, Abbey, and Karl 2004). The Nature Conservancy ranked the sagebrush steppe as the third most endangered ecosystem in the United States (Noss et al. 1995; Stein et al. 2000).

A main objective of rangeland management policy in the western U.S. is to prevent further landscape-level ecological change and to rehabilitate lands that have undergone change to undesirable ecological states. These strategies necessarily target large areas, often at watershed scales, and are intended to alter ecological conditions over long time horizons. Relevant policy decisions include whether or not to treat, how large an area to treat, timing of treatment, and type of treatment to use in a given situation taking into account differences in treatment costs and success rates.

Ecological Framework

For economic valuation studies to be most useful for ex-post application to ecosystem management policy each primary valuation study would ideally share a common ecological framework, and value ecological changes that correspond to the framework of ecological change that natural scientists and policy-makers ascribe to. In this section, we discuss several factors that should be considered when selecting a common ecological framework to be used across valuation studies, and that the state-and-transition model (STM) framework from rangeland ecology is the appropriate ecological framework for economic studies valuing ecological change on sagebrush rangelands.

The STM framework divides an ecosystem into a series of “ecological sites” based on characteristic plant communities (Briske et al. 2003; Stringham, Krueger, and Shaver 2003; Bestelmeyer et al. 2009).[6] Each ecological site has a corresponding STM. An STM describes

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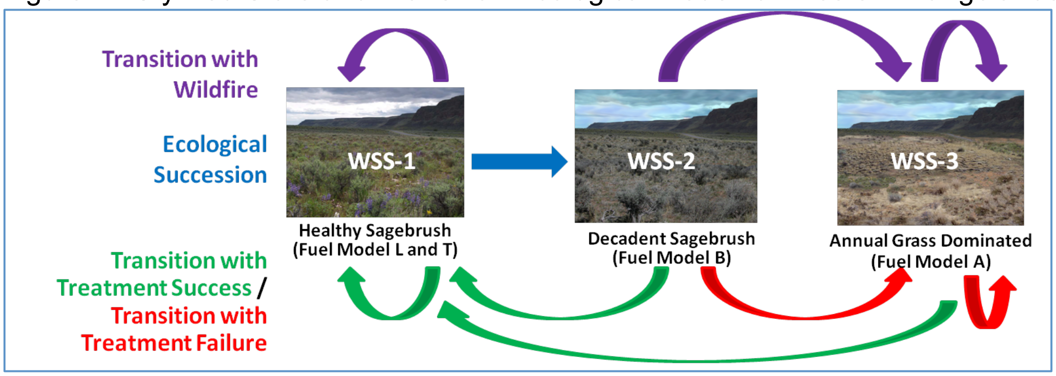
[5] Rosenberger and Loomis (2006) identify the lack of incentive for individual scholars engaging in valuation studies to design their studies to be of greater practical use for policy as a major problem for benefit transfer. This problem may be even more acute in our approach, as it requires that primary valuation studies within an ecosystem use parallel ecological frameworks.

[6] The Society for Range Management (SRM, 1989) defines an ecological site as, “an area of land with the potential to produce and sustain distinctive kinds and amounts of vegetation under its particular combination or environmental factors, particularly climate, soils, and associate native biota.” The USDA

the alternative “ecological states” that could characterize a given site, depending on vegetation, soils, and other factors, as well as potential transitions between states. In rangeland ecosystems, transitions between ecological states can be triggered by natural events such as drought, wildfire, and invasive plants, or by human activities such as excessive livestock grazing, and transitions can only be reversed with active (and often expensive) management effort (Briske et al., 2006; McIver et al., 2010). A stylized version of an STM that we developed in collaboration with ecologists for the purposes of economic valuation of sagebrush rangeland ecological change accommodates many specific STMs (through different parameterizations), and is illustrated in Figure 1.

Figure 1: Stylized State and Transition Ecological Model for Western Rangelands



The scientific validity of the STM framework for western rangeland has been established in the scientific literature (Briske et al. 2003; Stringham, Krueger, and Shaver 2003; Bestelmeyer et al. 2009). Concerning the generality of welfare estimates based on the state-and-transition framework, it would not be feasible to conduct economic analysis of the welfare impacts of ecological change on each ecological site in western rangeland ecosystems. There are over 1,000 sagebrush ecological sites in the State of Nevada alone (Stringham and Freese, 2011). For this reason, when valuing the benefits of pre-fire vegetation management treatments in terms of wildfire suppression costs avoided, Taylor et al. (2011) consider stylized STMs for two rangeland ecosystems – the Wyoming Sagebrush Steppe and Mountain Big Sagebrush ecosystems – rather than presenting results for hundreds of specific ecological sites within each system. The stylized STMs that are intended to be broadly representative of ecological sites found in the two ecosystems. While analyzing stylized STMs involves a loss in scientific accuracy, using groupings of similar ecological sites has the advantage that the estimated models can be applied to estimate the welfare implications of ecosystem change for each ecological site described by the aggregate grouping of sites described by the stylized STMs.

In addition to having defined an ecological framework that corresponds to that used in decision-making, the ecological change being valued in each component empirical study – i.e., the “good” being valued – should correspond to the ranges of ecological change that policy-makers generally expect to influence through management. The STM framework is an appropriate framework for western rangelands according to this criterion because management activities on western rangelands are generally aimed at either rehabilitating rangeland from degraded ecological states dominated by invasive plants and noxious weeds, or at preventing healthy rangeland from transitioning to degraded ecological states. For example, a management objective on western rangelands may be to rehabilitate a site from the annual grass dominated ecological state (WSS-3 in Figure 1) to the healthy sagebrush state (WSS-1 in Figure 1). An

Natural Resources Conservation Service uses a land classification system based on the ecological site concept to organize information for the purposes of monitoring, assessment and management.

estimate of the benefits from achieving this management objective can then be obtained and compared against the management costs if the relevant primary valuation studies estimate the value of the change in ecosystem goods and services associated with the movement from WSS-3 to WSS-1.

Additionally, the common ecological framework selected for component empirical studies ideally would correspond to existing data available for policy making. This means that the ecological framework and the description of the ecological change used in the definition of the good for valuation purposes must correspond to the data collection protocols currently in place and used for policy and management decisions in the ecosystem being evaluated. The STM framework for western rangelands has been formally by the USDA Natural Resources Conservation Service, and is used as the basis for data collection and access (USDA, NRCS 2006; TNC 2009).

Finally, it is important to consider the constraints placed upon the scientific detail of the common ecological framework by the specific data needs for estimating non-market benefits measured in each component valuation study. For example, estimating the change in expected wildfire suppression costs resulting from annual grass invasion requires estimates of both the change in wildfire frequency due to the transition to an invasive annual grasses dominate state and the change in the expected cost of a wildfire given ignition. Either of these two steps can restrict the use of a common ecological framework. If the data on changes in wildfire frequency is only available at broad ecological classifications, then it will not be possible to estimate change in the costs of wildfire suppression for specific ecological sites, even if suppression costs data is available at this finer degree of ecological resolution. Taylor et al (2012) base their model for estimating benefits of landscape level fuel treatments on the STM framework for western rangelands, so that the estimates correspond with ecosystem shifts that are targeted by management efforts.

Spatial Scale

Coordination of the spatial scales from component valuation studies is necessary so that estimates can be combined in ex-post analysis of policies targeted at influencing landscape-scale ecological change. There are two factors to consider when selecting the appropriate spatial scale for component valuation studies. First, the goal of many policy applications is landscape scale assessment of the costs and benefits of ecological change. Evaluating ecological change at the landscape scale, however, is often problematic because the accuracy of ecological predictions of ecosystem function declines with increases in spatial scale (Stringham, Krueger, and Shaver 2003). This loss in predictive power imposes restrictions on the probabilities that any given management action will have the intended outcome. The use of the STM framework we advocate adopting for western rangelands incorporates probabilities of success and failure of management actions. These probabilities can be included as indicating risk into stated preference frameworks, so that the valuation of alternative outcomes corresponds with the ecological models used by land managers.

Second, the spatial scale of the most aggregate component study places constraints on the spatial scales of ex-post policy applications. These limitations imply that that analysis of costs and benefits that correspond to spatial scales smaller than those used in primary valuation studies will necessarily be incomplete.

Time Scale and Discounting

Coordination of the temporal scales of component studies is necessary so that estimates can be combined in an ex-post policy analysis of landscape-scale ecological change. As with spatial scale, the temporal scale of the most aggregate component study constrains the temporal scale of any ex post applications. For example, if a primary valuation study values a permanent ecological change where “non-use” or “existence” values for ecological change are relevant, then it may be incorrect to apply these results in an ex-post application to evaluate the costs and/or benefits of ecosystem change on a shorter time frame than in is described in the original definition of the good in the primary valuation study.

Uncertainty

Any evaluation of the benefits and costs of a proposed ecosystem management policy or program requires understanding how the ecosystem is expected to evolve with and without the policy in place, and how determining how these differences will influence the provision of ecosystem good and services. The change in the future provision of ecosystem goods and services resulting from an ecosystem management policy or programs is, of course, uncertain. In addition, there is uncertainty about whether and ecosystem management policy or program will succeed at meeting its objective. In rangeland ecosystems, this uncertainty is often related to stochastic factors such as wildfire and drought. For these reasons, each component valuation study must make provisions for the uncertainty inherent in any appraisal of the benefits and costs of a proposed ecosystem management policy or program by capturing the welfare consequences associated with the range ecological outcomes that could result from relevant policy applications

Conclusions

In this article, we discuss several practical steps that can be taken to coordinate research output from independent non-market valuation studies to facilitate their routine ex-post application to ecosystem management policy on public and private lands. We argue that in order to facilitate ex-post application to policy-making it is necessary to have the change in the ecological good or service being valued correspond to the ecological change that policy-makers hope to influence through management, and that the ecological framework in the primary valuation studies be both scientifically accurate and agree with the available data for the ecosystem. Our discussion emphasizes that decisions about the ecological framework, spatial scale, and temporal scale of each study valuing ecosystem change place constraints on their ex-post application to policy issues, and that the limitations imposed by these constraints can be mitigated if the design of each component valuation study is coordinated with the goal of joint ex-post application in mind. In light of the discussion, we argue that the state-and-transition from rangeland ecology is the appropriate ecological framework for studying the benefits and costs of ecological change and analyzing land management policy on western rangelands.

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