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An integrated approach to valuation and tradeoff analysis of ecosystem services for national forest decision-making

Christopher A. Armatas[a,*], Robert M. Campbell[b], Alan E. Watson[c], William T. Borrie[a], Neal Christensen[d], Tyron J. Venn[e]

[a] Department of Society and Conservation, College of Forestry and Conservation, University of Montana, Missoula, MT 59812, USA
[b] Economics Department, College of Humanities and Sciences, University of Montana, Missoula, MT 59812, USA
[c] USDA Forest Service, Rocky Mountain Research Station, Aldo Leopold Wilderness Research Institute, Missoula, MT 59801, USA
[d] Christensen Research, Missoula, MT 59801, USA
[e] School of Agricultural and Food Sciences, The University of Queensland, St Lucia 4072, QLD, Australia

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ABSTRACT

An integrated approach to understanding ecosystem service values in Wyoming and Montana, USA is presented. The assessment encompasses a major river basin, and includes a synthesis of existing data and research related to the natural system and separate data collection efforts regarding the social and economic importance of ecosystem services. A holistic look at the social-ecological system provides nuanced information about ecosystem service values and tradeoffs for the purpose of public land decision-making.

The initial ecological assessment concluded that water resources were particularly vulnerable, which guided the social and economic assessments. The social assessment applied Q-methodology, ultimately identifying and exploring four archetypes regarding views on the importance of 34 ecosystem services, which were dubbed "environmental", "agricultural", "Native American", and "recreation". The economic assessment applied choice modeling to understand non-market values of ecosystem services (i.e., agricultural community, aquatic biodiversity, river angling, and motorized winter recreation), and latent class analysis provided insight into preference heterogeneity previously indicated in the social assessment. The structured approach can inform natural resource decision-making by including several different perspectives, integrating multiple spatial scales, highlighting particular ecosystem services as relevant within the context of many ecosystem services, and facilitating relations between the public and natural resource stewards.

1. Introduction

The burgeoning ecosystem services concept aligns with contemporary natural resource management and planning in the United States with its broad focus on sustaining the environment and its ability to provide a myriad of benefits. This is a daunting task, which policy guidelines, such as the 2012 Planning Rule for the United States Forest Service (USFS), formalize with an aim to provide for social, economic, and ecological sustainability (U.S. Department of Agriculture Forest Service, 2012). According to the Planning Rule, providing such broad ranging sustainability can be achieved in part by maintaining the flow of services and benefits derived from public forests for both surrounding communities and on-site users.

In pursuit of these goals, both in the context of USFS planning, and natural resource stewardship more generally, management and policy decision-makers increasingly require information about ecosystem services and their tradeoffs that is understandable both to the decision-makers and the public (Deal et al., 2017; Kline et al., 2013). This complicates the decision-making process, as there are a diverse range of ecosystem services that support human well-being (MEA, 2005), and a diverse range of perspectives as to what ecosystem services are valuable (Kenter, 2016). In addition, the 'value' of ecosystem services is expansive. According to de Groot et al. (2002, p. 394), the value of ecosystem services can be categorized into different dimensions related to ecological value, social (or socio-cultural) value, and economic value, which are based on "ecological sustainability", "equity and cultural perceptions", and "efficiency and cost-effectiveness", respectively.

The valuation of ecosystem services, defined broadly herein as the act of 'assigning importance' (or lack thereof), has long been recognized as integral to the decision-making process (Dendoncker et al., 2014;

* Corresponding author.
E-mail address: christopher.armatas@umontana.edu (C.A. Armatas).

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Jacobs et al., 2016). However, more recently, there has been increasing recognition that decision-makers should consider diverse stakeholder values and perspectives about what (and why) ecosystem services are important. Specifically, it has been argued that the three value dimensions of ecosystem services (i.e., ecological, economic, and social) should all be considered in ecosystem service assessments, because it increases the potential that research will inform applied decision-making in an equitable and more sustainable way (Dendoncker et al., 2014; Díaz et al., 2015; Jacobs et al., 2016; Langemeyer et al., 2016). Martín-López et al. (2014) called for integration of multiple methods in a way that provides "information about irreducible and incommensurable value dimensions." Scholte et al. (2015, p. 74) added that to achieve such approaches, "the integration of monetary valuations and ecological assessments with socio-cultural valuations does not only entail adding the different parts, but also entails capturing the interactions between them." In addition to incorporating the three value dimensions and understanding how knowledge of one dimension may inform another, it has been suggested that focusing on a broad range of ecosystem services across spatial scales, and effectively communicating results with a broad audience, can also increase the potential that research will best inform applied decision-making (Chan et al., 2012; de Groot et al., 2010; Deal et al., 2017).

These research needs nicely align with the requirements outlined in the 2012 Planning Rule (U.S. Department of Agriculture Forest Service, 2012), which is the guiding document for forest planners across the United States working on updating old forest plans. However, meeting these broad-reaching research needs requires integration across disciplines in both the natural and social sciences. As Jacobs et al. (2016, p. 215) asserted, "the complexity of real life application defy hopes for a methodological silver bullet." Although the importance of integrated approaches that address the above needs is well established, the development of such approaches is still in progress. As Hattam et al. (2015) noted, the majority of ecosystem services assessments focus only on a single value dimension (i.e. ecological, social, or economic), and even in situations where mixed-method approaches are employed, integration of the results from the assessment of all three value dimensions are rare.

This paper aims to contribute to the effort to develop ecosystem service assessments that integrate ecological, social, and economic valuations. The methodological approach presented herein is not unique in that it integrates all three value dimensions, as several others have performed such assessments (e.g., Bark et al., 2016; Berg et al., 2016; De Vreese et al., 2016b; Fontaine et al., 2014; Villegas-Palacio et al., 2016). The novel contribution of our stakeholder-driven approach is that it combines two important elements. First, the approach focuses on understanding different perspectives about the importance of ecosystem services and, as shown by Crouzat et al. (2016), investigating these different perspectives can highlight both tradeoffs and synergies. Second, the approach aims to ensure that the perspectives highlighted and thoroughly investigated are broadly representative of the population of interest. The context within which this approach was designed is USFS National Forest decision-making, but the approach is broadly applicable to natural resource management focused on providing a spectrum of ecosystem services (e.g., oil and natural gas extraction, non-motorized recreation, and biodiversity conservation). Specifically, the potential benefits yielded include:

- a focus on inclusiveness, whereby multiple disparate stakeholder perspectives about importance of, and tradeoffs between, ecosystem services ('preference heterogeneity' in economic parlance) are discovered and investigated;
- a holistic research process where the different 'valuations' (i.e. ecological, economic, and social) inform one another, both in process and results interpretation;
- a structured and replicable research process, which can potentially be adopted (partly or wholly) to support forest management and planning;
- the integration of multiple spatial scales;
- a prioritization of select ecosystem services while not losing sight of the holistic picture; and
- additional confidence in decision-making and development of a foundation of knowledge about agreement and disagreement regarding ecosystem services which may facilitate public relations.

It is important to stress that this approach is not necessarily superior to other high-quality and rigorous approaches (e.g., De Vreese et al., 2016a; Fontaine et al., 2014; Martín-López et al., 2014). Instead, we emphasize that this approach should be added to a repertoire of approaches, which may be more or less appropriate to others depending on the context. We agree with Martín-López et al. (2014, p. 227) that "ecosystem service research needs as much variety of methods as complexity and value plurality exists in the system we want to analyze."

In a natural resources planning context, considering and accommodating multiple disparate stakeholder perspectives about what is important and what should receive scarce management and planning attention is paramount. Our approach is designed to assist the USFS in fulfilling their mission of "caring for the land and serving people" through "listening to people and responding to their diverse needs in making decisions" (US Department of Agriculture Forest Service, 2017).

This paper proceeds as follows: section two describes the study area where this integrated approach was applied; section three explains the methods integral to this holistic approach; section four presents results; section five provides a discussion of the strengths and limitations of this approach within the context of National Forest decision-making and; section six concludes.

2. Study area

This integrated approach to understanding the importance and tradeoffs related to ecosystem services is based on research from the Wind-Bighorn River Basin (the Basin) in northwest Wyoming and southcentral Montana, USA. The Basin, illustrated in Fig. 1, is similar to many regions of the intermountain western United States as: the majority of the land is managed by federal, state, and local government agencies; local residents often rely economically on natural resources (both through extractive and tourist-based industries); it has a snow-driven hydrologic cycle; and topography, vegetation, and climate are variable.

The topography within the study area ranges from rugged high elevation mountains (maximum elevation of 4207 m) to sagebrush flats (minimum elevation of 819 m). Predominant vegetation zones include: the alpine vegetation zone, which is typically composed of rugged, rocky terrain supporting shrubs, grass and forb species; the sub-alpine vegetation zone, which supports a number of tree species, including whitebark pine (*Pinus albicaulis*), subalpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmannii*), and lodgepole pine (*Pinus contorta*) and; the montane vegetation characterized by Douglas fir (*Pseudotsuga menziesii)* (Rice et al., 2012; United States Department of Agriculture, 2009). The climate in the Basin can generally be described as a high-elevation semi-arid desert, with annual precipitation ranging from 13 cm on the valley floor to 180 cm in higher elevations (much of it in the form of snow) (MWH Americas Inc et al., 2010; Rice et al., 2012). The extensive system of rivers and lakes in the Basin support a diversity of aquatic species, including both native (Yellowstone cutthroat trout – *Oncorhynchus clarkii bouvieri*) and non-native (brown trout – *Salmo trutta*) trout species. The majority of higher elevation steams in the Basin, many of which lie within the Shoshone National Forest, are in good condition in terms of sedimentation and