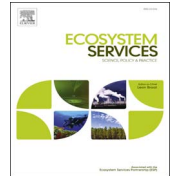


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Analyzing land-use change scenarios for trade-offs among cultural ecosystem services in the Southern Rocky Mountains

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ABSTRACT

Significant increases in outdoor recreation participants are projected over the next 50 years for national forests across the United States, with even larger increases possible for forests located in the Southern Rocky Mountains. Forest managers will be challenged to balance increasing demand for outdoor recreation with other ecosystem services. Future management needs could be better anticipated with information describing how and where stakeholders value these forests' cultural ecosystem services, as well as how management might impact these values. We analyzed land-use change scenarios to quantify changes in aesthetic and recreational ecosystem service values and assessed trade-offs between these values relative to forest stakeholder groups defined by their attitudes regarding motorized recreation. We adapted the GIS tool, Social Values for Ecosystem Services (SolVES), for scenario analysis and applied it to two national forests in the Southern Rocky Mountains to examine impacts of road-network expansion on stakeholder values. Our approach allowed us to quantify changes in the spatial distribution and intensity of aesthetic and recreation values. Trade-off assessments between the two values indicated that areas of conflicting value changes were limited, even when accounting for different user groups. However, this approach could be an important means of conflict resolution for multi-use management.

1. Introduction

Outdoor recreation participants are projected to increase approximately 60% across all national forests and recreational activity types by 2060 (Bowker et al., 2012). Forests in the Southern Rocky Mountain region, with the allure of popular activities such as downhill skiing and snowboarding, are expected to see an even larger increase in visitation. Resource managers and planners will be challenged to maintain the availability of recreational opportunities while also preserving other ecosystem services provided by these forests—cultural and otherwise—as they face the increased use of public lands and associated land-use changes. To better anticipate future management needs, it is important to consider information that develops our understanding of how, where, and why different user groups perceive the values of cultural ecosystem services within these forests. With such an understanding, trade-offs among these values resulting from land-use changes can be assessed and communicated to stakeholders through scenario analysis (Hauck et al., 2013; Martinez-Harms et al., 2015). To facilitate such analyses, more tools that include information describing these perceived values are required for valuing and modeling ecosystem services

(Turner et al., 2016).

1.1. Cultural ecosystem services and social values

The difficulties that arise in quantitatively evaluating cultural ecosystem services, often because they are viewed as subjective or intangible, result in them not being adequately represented within existing ecosystem service frameworks and assessments (Chan et al., 2016; Daniel et al., 2012). One way in which cultural ecosystem services can be more fully integrated into assessments is through the explicit consideration of social values. We have previously defined social values to represent nonmarket values of ecosystem services (particularly cultural services) perceived by ecosystem stakeholders (Sherrouse et al., 2011, 2014; Sherrouse and Semmens, 2014). These social values evolved from what was originally a typology of forest values proposed by Rolston and Coufal (1991). This typology was later modified and validated by Brown and Reed (2000) and subsequently included in surveys of various forms to elicit information describing and measuring stakeholder values in relation to landscapes (e.g., Alessa et al., 2008; Brown, 2005; Brown et al., 2002, 2004; Clement and

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Table 1

Definitions of social-value types frequently included in typologies to elicit information from stakeholders regarding values they assign to landscapes. This typology was included in value and preference surveys to collect data used in this study.

Social-value type	Social-value definition
Aesthetic	I value these forests because I enjoy the scenery, sights, sounds, smells, etc.
Biodiversity	I value these forests because they provide a variety of fish, wildlife, plant life, etc.
Cultural	I value these forests because they are a place for me to continue and pass down the wisdom and knowledge, traditions, and way of life of my ancestors.
Economic	I value these forests because they provide timber, fisheries, minerals, and/or tourism opportunities such as outfitting and guiding.
Future	I value these forests because they allow future generations to know and experience the forests as they are now.
Historic	I value these forests because they have places and things of natural and human history that matter to me, others, or the nation.
Intrinsic	I value these forests in and of themselves, whether people are present or not.
Learning	I value these forests because we can learn about the environment through scientific observation or experimentation.
Life sustaining	I value these forests because they help produce, preserve, clean, and renew air, soil, and water.
Recreation	I value these forests because they provide a place for my favorite outdoor recreation activities.
Spiritual	I value these forests because they are a sacred, religious, or spiritually special place to me or because I feel reverence and respect for nature there.
Subsistence	I value these forests because they provide necessary food and supplies to sustain my life.
Therapeutic	I value these forests because they make me feel better, physically and/or mentally.

Cheng, 2011; Cole, 2012; van Riper et al., 2012). The definitions of individual values composing the social-value typology (Table 1) provide a basis for relating values held by stakeholders to the benefits provided by ecosystems. The consideration of social values in relation to cultural ecosystem services responds to ongoing calls from various research perspectives for the inclusion of social information in ecosystem service assessments (e.g., Carpenter et al., 2006; Chan et al., 2012; Fontaine et al., 2014; Kumar and Kumar, 2008; Millennium Ecosystem Assessment, 2005; Raymond et al., 2009; Schmidt et al., 2016; Turner et al., 2016; Whitehead et al., 2014). When the ecological and economic information that is typically included in ecosystem service assessments is augmented by social information—particularly that obtained by responding to stakeholder needs at the outset of the planning process (Fürst et al., 2014)—the valuation and modeling of ecosystem services can be improved (Turner et al., 2016), non-monetary values can be better accounted for (Schmidt et al., 2016), and varying perceptions of ecosystem service values held by different stakeholder groups can be considered (Hauck et al., 2013).

1.2. Maps, scenarios, and trade-offs

Social values have been repeatedly examined through surveys using public participation geographic information systems (PPGIS) to provide spatially explicit information describing how and where landscapes are valued by stakeholders (e.g., Alessa et al., 2008; Ancona et al., 2016; Brown et al., 2011; Raymond et al., 2009; Reed and Brown, 2003; van Riper et al., 2012). These methods enable stakeholders to explicitly identify locations on a landscape with which they associate certain values or ecosystem services. Other methods, such as valuing cultural ecosystem services like aesthetics through the evaluation of photos taken at various locations across a landscape (e.g., Schirpke et al., 2016; van Berkel and Verburg, 2014), can be similarly applied. The spatial information that can be derived from these methods offers opportunities for integrating socio-cultural values and their connections to the landscape into planning processes (Zoderer et al., 2016). Furthermore, a spatially integrated view of social values and biophysical data describing the cultural ecosystem services with which they are associated can be instrumental in identifying potential conflicts or synergies between stakeholder values or between these values and management actions (Bagstad et al., 2016a; De Vreese et al., 2016; Whitehead et al., 2014).

Once mapped, cultural ecosystem service values are available for inclusion in spatially explicit scenarios that can be beneficial for assessing future management actions and communicating their potential outcomes to stakeholders. Among other things, scenarios can be used to model potential changes in ecosystem service provision (e.g., Bagstad et al., 2013), estimate changes in ecosystem service values both monetarily (e.g., Baral et al., 2014) and non-monetarily (e.g.,

Schirpke et al., 2016), identify trade-offs between ecosystem services (e.g., Reed et al., 2013), and anticipate land-use changes (e.g., Hamilton et al., 2013; Hansen et al., 2014) that are major drivers of change in the provisioning and spatial pattern of ecosystem services (Lawler et al., 2014).

In this study, we develop and apply spatially explicit scenarios based on the expansion of existing road networks within two national forests in the Southern Rocky Mountains. Between 1944 and 2000, total road mileage under U.S. Forest Service (USFS) jurisdiction increased from approximately 100,000 miles to 386,000 miles with much of that road construction supporting timber harvesting (Krause, 2000). The rate of increase slowed in the 1990s with much of the increase coming from results of inventory and classification efforts of existing USFS roads (Krause, 2000). An estimated 90% of daily traffic on USFS roads is related to recreational activities (Krause, 2000). An additional 77,000 miles of non-USFS roads exist on USFS lands including state, county, and private roads (Krause, 2000). Although the rate of USFS road construction has decreased in more recent decades, given the significant presence of non-USFS roads on USFS lands accompanied by demand generated by projected increases in visitation, local development, and other factors, some level of future road network expansion can be anticipated.

Simulating future land-use changes (scenarios) by modifying the spatial data representing existing road networks permits an assessment of impacts on the intensity and spatial distribution of social values. In particular, these scenarios enable us to evaluate trade-offs between aesthetic and recreation values according to the spatial coincidence of relative changes in their value intensity resulting from changes in the road network. The trade-offs between the two values can be characterized according to whether the relative changes were conflicting as one value increased and the other decreased, a synergistic situation in which both values increased, a mutually negative impact in which both values decreased, or some other combination in which one value increased or decreased while the other did not change.

Given the various recreational activities available to national forest users and the differing value orientations of distinct user groups, for example those with a more biocentric orientation versus those with a more anthropocentric orientation (e.g., Clement and Cheng, 2011), it is important to assess trade-offs that also account for these differences. In this study, we include an analysis of trade-offs between aesthetic and recreation values that are assigned to the forest by two distinct user groups defined by their attitudes towards motorized recreation. Based on the relationship between attitudes and value orientations reported for survey respondents by Clement and Cheng (2011), it could be assumed that for those with more favorable attitudes towards motorized recreation the scenario results would indicate an increase in recreation value in response to new roads. Conversely, for those with less favorable attitudes towards motorized recreation the scenario

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