

Perspective Essay

Forest landscapes as social-ecological systems and implications for management

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ABSTRACT

Many of the most pressing threats to forests result from complex interactions between multiple stressors and require management on large spatial and temporal scales. For this reason, many ecosystem managers have begun to recognize the need to consider the broader context of decisions, and how outcomes of past, present and future decisions in one location may interact with outcomes of such decisions in other locations nearby. The landscape has been put forth as an appropriate unit for such holistic approaches to management. However, as there are differing definitions of landscapes, it can be difficult to develop frameworks for management. Moreover, many definitions do not fully account for the many ways social and ecological conditions and processes interact within landscapes. Building on emerging theoretical and empirical literature, I offer a perspective on temperate forest landscapes as social-ecological systems: nested sets of coevolving social and natural subsystems connected through feedbacks, time lags, and cross-scale interactions. This interdisciplinary framing emphasizes the biogeophysical and socio-cultural influences on landscapes and the need to consider these influences – and the interactions among them – in management. I discuss challenges to managing forest landscapes as social-ecological systems that stem from mismatches in the temporal and spatial scales on which ecological and social systems typically function, as well as opportunities for policies, formal organizations, and governance networks.

1. Introduction

Many of the most pressing threats to forests today require management on large spatial and temporal scales. Wildfires, invasive species, and plant diseases, for example, do not observe administrative boundaries; rather, their behavior is a function of ecological patterns and processes across large areas. Moreover, land management practices influence ecological patterns and processes well into the future with impacts that often go unobserved for long periods of time. For these reasons, the forest management literature has begun to recognize the need to consider the broader context of decisions, and how the outcomes of present and future decisions in one location may interact with environmental conditions and processes, which are themselves outcomes of past decisions, and decisions made in other locations nearby (Filotas et al., 2014; Messier et al., 2015; Nocentini et al., 2017; Rist and Moen, 2013; Stephens et al., 2013). In other words, emerging paradigms of forest management emphasize the need to consider the many ways social and ecological conditions and processes (i.e., systems) interact to shape landscapes across space and time.

The landscape has been recognized as one of the most suitable spatial units for managing forests and other ecological systems (Brunckhorst, 2011; Forman, 1995; Forman and Godron, 1986; Phillips,

1998; Wu, 2012). Indeed, many of the social and ecological processes that affect trees and the forests they comprise occur on spatial and temporal scales typical of visible areas of land commonly referred to as landscapes. These processes unfold over geographic extents larger than the patch yet smaller than the region, and over time horizons on the order of decades and centuries (Fig. 1). However, as there are differing definitions of landscapes, it can be difficult to develop frameworks for landscape management (Antrop, 2006). On the one hand, landscapes have been defined on the basis of the ecological processes that shape them, that is, as diverse combinations of ecosystems at intermediate scales that affect each other across space and time within hierarchies of interdependent ecological processes (Nassauer, 1997; Wiens, 1999). Landscapes have also been defined on the basis of the social processes that shape them. In this view, landscapes, which have been modified by human activity, reflect cultural values and conventions and can therefore be viewed as social phenomena (Nassauer, 1995; Sauer, 1925). Some definitions integrate these two elements, social and ecological, describing landscapes as a nexus of nature and culture, encompassing environmental, economic, and social processes (Antrop, 1997; Brunckhorst et al., 2006; Jacobs, 1991; Nassauer, 2012; Pinto-Correia and Kristensen, 2013; Tress and Tress, 2001). More recently, a number of scholars (e.g., Angelstam et al., 2013; De Aranzabal et al., 2008;

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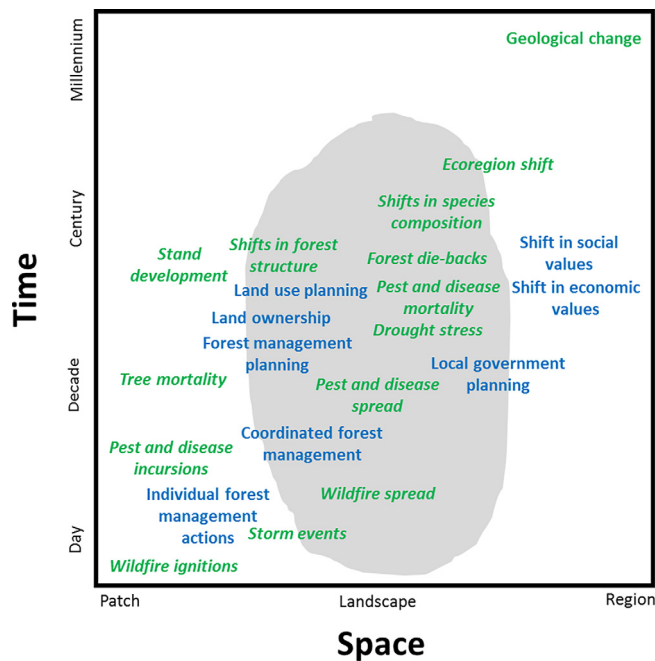


Fig. 1. Spatial and temporal scales of social processes (bold blue font) and ecological processes (italicized green font) that affect forests, many of which occur on the landscape scale (grey oval). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Gobster and Xiang, 2012; Matthews and Selman, 2006; Spies et al., 2014) have come to think of landscapes as spatial units in which many fundamental processes of social and ecological systems unfold, and thus have conceptualized landscapes as social-ecological systems (SESs) in and of themselves: interacting sets of interdependent bio-geophysical components and associated social actors (Liu, Dietz, Carpenter, Alberti, et al., 2007a; Ostrom, 2009).

Although all types of landscapes – terrestrial and marine – can be viewed through the lens of SESs, forest landscapes comprise a particularly intriguing type of SES because of their temporal and spatial dynamics. Trees can live for hundreds, sometimes thousands, of years, and many of the changes that affect them—disturbances such as wildfires and invasive plant, pest, and pathogen outbreaks, for example—are the result of former management practices and policies, as well as social and economic changes. Forest management actions can have unintended consequences that cause changes in distant locations at points far in the future (i.e., stages in forest succession), spanning decades, and in some cases, centuries. The process of coupled social-ecological change in forest landscapes can be relatively linear, or non-linear. Over time, as human populations and cultures shift and impose new pressures on landscapes, ecological conditions in landscapes change, imposing new limitations and opportunities for people (Gross and Blasius, 2008; Norgaard, 1994; Rammel et al., 2007); people, in turn, adjust their management systems to changing ecosystem characteristics (Bodin et al., 2016a; Liu, Dietz, Carpenter, Folke, et al., 2007b; Österblom et al., 2010; Reenberg et al., 2008; Sivapalan and Bloschl, 2015). Humans can also change entire forest landscapes with long-lasting impacts through disproportionately small actions at single points in time, for example, by lighting a fire, or bringing an invasive plant, pest or disease into an uncontaminated stand. This combination of linear and non-linear interactions between social and ecological components across space and time make forest landscapes worthy of study in their own right.

Drawing on emerging empirical and theoretical research literatures from social and natural science fields, I provide a perspective on forest landscapes as SESs, focusing on core processes that govern forest

landscapes, specifically feedbacks, time lags, and cross-scale interactions. This interdisciplinary framing emphasizes the biogeophysical and socio-cultural influences on landscapes and the need to consider these influences and the interactions among them over space and time. I identify challenges that can emerge in forest landscape management when these processes are not taken into account, resulting in mismatches in the spatial and temporal scales on which ecological processes occur and humans attempt to govern these processes, as well as opportunities to improve society's institutions for managing forest landscapes by treating them as SESs. Here, I focus in particular on temperate forests, which are undergoing dramatic change in North America and other regions. In offering this perspective on forest landscapes as socio-ecological systems, grounded in a synthesis of emerging literature, I aim to improve understanding of the interactions between people and forests and the implications of these interactions for landscape planning and management.

2. Key features: feedbacks, time lags, and cross-scale interactions

An emerging literature has framed forest ecosystems in terms of complex adaptive system properties (Filotas et al., 2014; Messier et al., 2015; Nocentini et al., 2017; Spies et al., 2014); specifically, heterogeneous conditions, hierarchical structure, ability to self-organize and adapt in response to changing external conditions, openness (not closed off from other systems), path dependency, non-linearity, and unpredictability (Levin, 1998). In addition, a growing body of empirical research has documented complex interactions between forest ecosystems, socio-economic changes, and land uses over space and time, specifically how new land uses can combine with legacies of past practices and ongoing climate change to give rise to large scale disturbance patterns (Allen, 2007; Barbier et al., 2010; Chapin et al., 2008; Lambin and Meyfroidt, 2010; Ravenscroft et al., 2010; Rudel et al., 2005; Spies et al., 2014; Stanfield et al., 2003; Vergara and Armesto, 2009; Zheng et al., 2010). These bodies of literature provide a foundation for framing forests as SESs. However, despite growing recognition of the complex social and ecological dimensions of forest landscapes, little attention has been paid specifically to core processes that govern forest landscapes as SESs: feedbacks, time lags, and cross-scale interactions. Here I distill and explain these three core processes, and illustrate how recognition of these processes can inform time horizons and spatial extents of management as well as consideration of unintended consequences of management actions (Virapongse et al., 2016).

2.1. Feedbacks

The modification or control of a process or system by its effects – or feedback – is a core SES process that features prominently in forest landscapes. Through feedbacks, forest landscapes self-organize (Filotas et al., 2014). As a type of SES, forest landscapes display feedbacks with both social and ecological dimensions. Many of the current ecological health crises in temperate forests are illustrative of SES feedbacks. Across the temperate forest biome, management activities intended to increase forest productivity for human benefit (thinning, harvesting, road building, fire suppression) have stressed, homogenized, and introduced invasive species into forest landscapes, resulting in large scale wildfires and insect and disease outbreaks that have, in fact, decreased productivity (Millar and Stephenson, 2015). In fire-prone temperate forests, in particular, wildfire risk mitigation activities have amplified the very processes that created risk in the first place; fire suppression has allowed more flammable vegetation to accumulate on forest landscapes, leading to larger and more intense wildfires (Adams, 2013; Calkin et al., 2015; Fischer et al., 2016) (Sidebar 1). On a global scale, forest mortality resulting from increasingly extensive and severe pest outbreaks has led to higher emissions of terrestrial carbon into the atmosphere, further exacerbating global warming (Flower and Gonzalez-Meler, 2015).

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