USING THE FOREST, PEOPLE, FIRE AGENT-BASED SOCIAL NETWORK MODEL TO INVESTIGATE INTERACTIONS IN SOCIAL-ECOLOGICAL SYSTEMS

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Introduction

Wildfire links social and ecological systems in dry-forest landscapes of the United States. The management of these landscapes, however, is bifurcated by two institutional cultures that have different sets of beliefs about wildfire, motivations for managing wildfire risk, and approaches to administering policy. Fire protection, preparedness, and response agencies often view wildfire as a threat to be mitigated or extinguished to protect things that humans value (e.g., houses, and timber), whereas land management agencies and conservation organizations often view wildfire as an essential ecological process for sustaining biodiversity and resilient forests. A lack of coordinated action between these two types of organizations raises the possibility of several management challenges in fire-prone socioecological systems: (1) maladaptive management behaviors (e.g., suppressing wildfires, which then allows fuels to accumulate further) resulting from lack of recognition of interdependencies between fire protection and forest restoration or a sole focus on minimizing property damage; (2) limited opportunities for problem-solving, innovation and collective action resulting from lack of communication among the two types of organizations; and (3) impediments to management at politically and ecologically efficient scales due to lack of coordination across cultural and geographic boundaries.

Photo by Emily Platt

Figure 1. Black Butte from a Lodgepole Pine Stand in the B & B Complex Fires

Participants in a set of April 2012 stakeholder workshops called attention to the disconnect between fire protection and forest restoration in the context of central and south central Oregon (Figure 1). The workshops were organized by the Forest, People, Fire project, a National Science Foundation-funded United States Department of Agriculture Forest Service-Oregon State University partnership (Forests, People, Fire 2012). The goal of the workshops was to bring representatives of public land management agencies, tribes, groups of private landowners, and organizations that seek to influence the management of land together to discuss future scenarios of landscape change in central and south central Oregon. Workshop participants were concerned that preoccupations with fire suppression and hazardous forest fuel reduction were compromising goals for forest restoration, and that unyielding advocacy for protection of old growth forest and endangered species was undermining the rural timber economy and local capacity to thin forests. Workshop participants called for more cohesive strategies for addressing wildfire across the landscape, not just near communities, and for restoring forests for the benefit of communities that depend on forests as well as wildlife species. Collaboration in particular was put forth as a means for achieving more cohesive strategies. Some participants asserted that collaboration would result in healthier, more fire-adapted forests.

Our team of social and natural scientists sought to understand the extent to which interaction occurs between fire protection and forest restoration organizations and how this interaction (or lack thereof) plays out on fire-prone landscapes such as central and south central Oregon. In addition to increasing our understanding of these interactions, we wanted to develop a tool that land management agencies and stakeholders could use to investigate how human behavior and ecological conditions and processes might interact in ways that produce intended and unintended consequences over time. We also wanted to consider new policy strategies and institutional arrangements for management in fire-prone landscapes. The tool we developed is an agent-based model that represents how networks of land managers (private owners, public agencies, and tribes) and organizations that influence management respond to changes in landscape conditions by exchanging

information and resources. These interactions alter the forest and fire management behaviors of the land managers and, thus, landscape conditions. We designed the social network model to operate within a broader framework of multiple interacting landscape-based models that address wildfire risk and spread, timber production, population change, and other variables.

Our rationale for integrating social networks into our modeling approach was to investigate sociocultural influences on the adaptation behaviors of land managers and organizations and, thus, landscape conditions and processes. We drew on social capital theory to design the model; the two main rules for social interaction in the model reflect (1) the natural tendency for people to interact with members of their same sociocultural group, which fosters bonding social capital, and (2) the strategy to reach beyond one's sociocultural group in times of stress or scarcity for information or resources, which builds bridging social capital (Figure 2). In this paper, we describe the conceptual design of the social network model, explain its usefulness as a tool for thinking about future landscape change, and reflect on the process we went through as an interdisciplinary group to develop it, including the challenges of incorporating information about social systems into computational models.

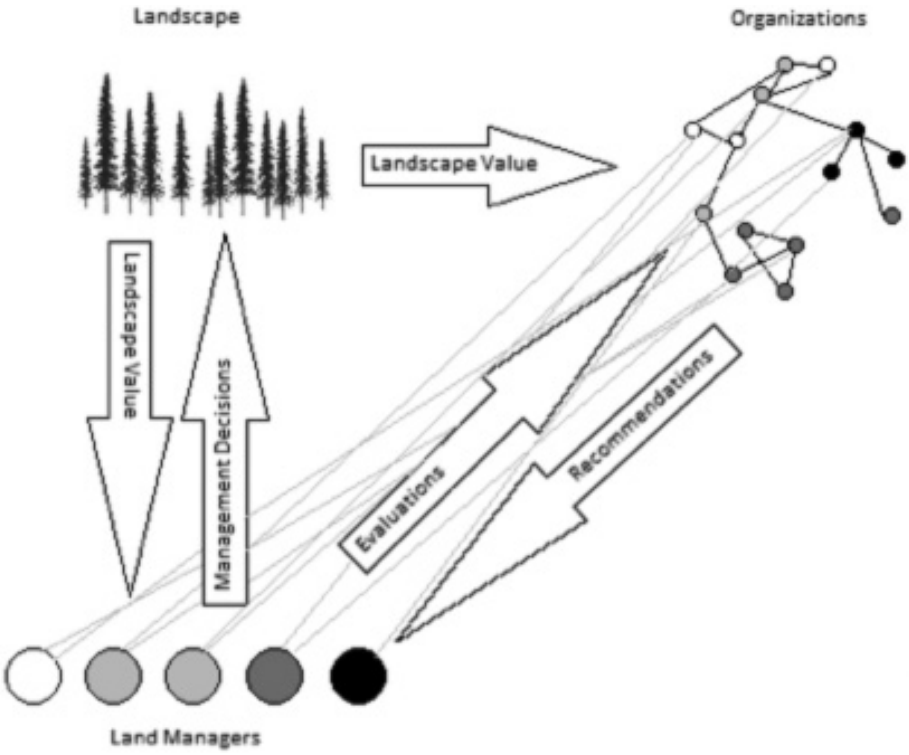


Figure 2. Conceptual Design of the Social Network Model

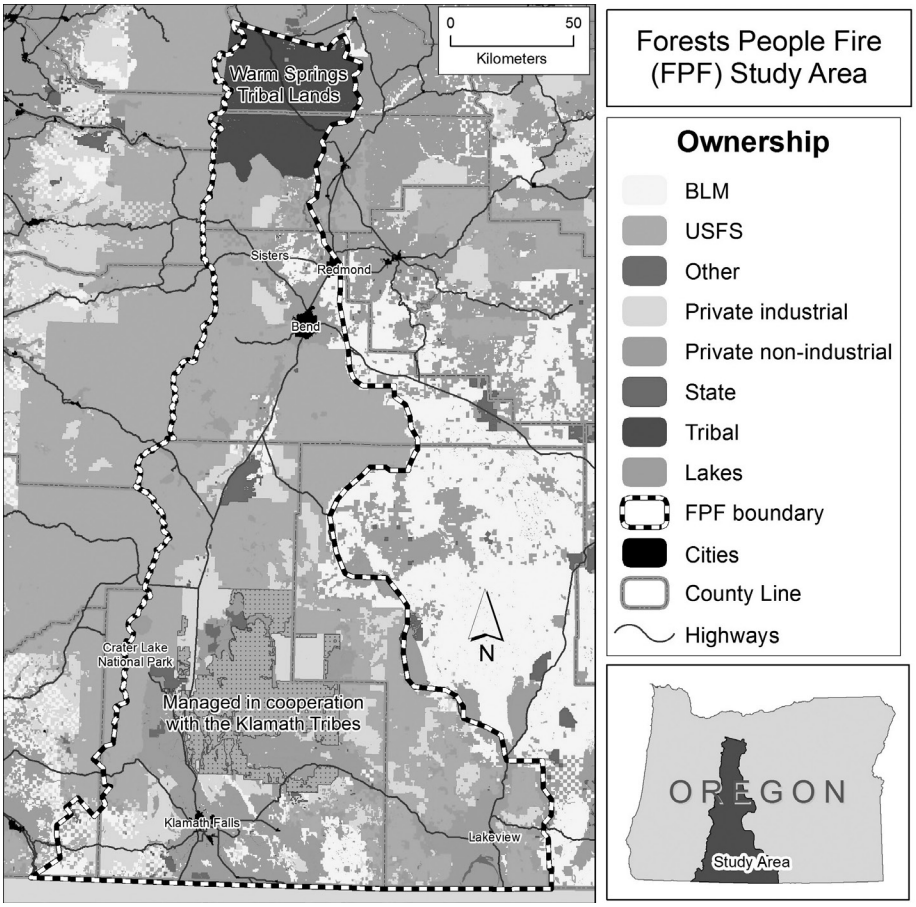
1. Representing Social Systems in Models of Landscape Change

Computational models provide the opportunity to represent complex relationships between people and their environments. Agent-based models in particular have proven useful for exploring the unintended ecological effects of land use as well as the social impacts of environmental change. A wide variety of agent-based models have been developed to explore the influence of human decision making on land use and landscape change (see Parker et al. 2003 for a review). However, progress towards models that directly link human behavior with landscape conditions and processes has been more limited (Matthews et al. 2007). Most commonly, models have represented social systems as an aggregation of the boundedly rational behaviors of individuals. Broader social phenomena such as culture and social structure also have been addressed in agent-based social network models, but not related to land use. These models use simple, predictable rules about social interaction to generate social patterns such as the diffusion of information, emergence of norms, and participation in collective action (Macy and Willer 2002). One of our goals was to expand the application of agent-based models by designing a model that interacts directly with landscape conditions and processes and allows culture and social structure to mediate these interactions.

2. Central and South Central Oregon's Fire-Prone Landscape

Our modeling effort focused on 3.3 million forested, fire-prone hectares on the east side of the Cascade Range in central and south central Oregon (Figure 3). This area is home to several small cities and large expanses of forested wildlands inhabited by several socially important species (e.g., Northern spotted owl, mule deer). Two-thirds of the land area is publically owned; the rest is in the hands of tribes, private industrial companies, and other private landowners. Wildfire has historically been important in this area; frequent low-severity fires were characteristic in the lower elevation ponderosa pine forests, mixed severity fires were typical of mid-elevation mixed conifer forests, and high-severity fire periodically burned in the higher elevation mountain hemlock and fir forests. Fire suppression, commercial logging, livestock grazing, and climate change has led to an uncharacteristic accumulation of flammable forest fuels, raising concerns about increased risks due to high severity fire. In the last decade, several large wildfires have burned in this landscape, challenging the traditional ownership-by-ownership approach to fire suppression and fuel management.

In response, United States federal forest fire policy has emphasized fire suppression and fuel reduction in the



Cartographic Image by Ketih Olsen

Figure 3. Forests, People Fire (FPF) Study Area

wildland-urban interface (WUI) to protect communities. WUI areas (3% of land area in Central Oregon) have been the site of the majority of fuel reduction activities in many places (Steelman and Burke 2007). In addition to directing resources away from wildland areas, emphasis on the WUI may have other consequences: fuels may accumulate in the wildlands causing an increase in risk of large high severity fire, and reduced fuels in the WUI may alter important wildlife habitat. Recognition of such policy tradeoffs has compelled some land managers and organizations to adopt new strategies for adapting to wildfire, including forming collaborative groups to plan forest management.

Photo by Christine Olsen

Figure 4. Regrowth near Santiam Pass, Oregon

However, it is unclear the extent to which the broader population of fire protection and forest restoration organizations communicate and collaborate and whether collaboration engenders different management behaviors and landscape conditions.

3. Social Networks, Social Capital, and Adaptation

A challenge of natural hazard systems is that events such as wildfires may be infrequent from an individual perspective. Consequently, the ability to learn through direct experience with fire can be limited. Social interaction can act to amplify weak feedback "signals" from the environment to individuals and organizations making decisions about how to reduce their vulnerability to risks (e.g., wildfire) or produce more things they value (e.g., wildlife habitat, scenic beauty). In our model design, we assumed that land managers and organizations are constrained or motivated in their pursuit of their values, goals, beliefs, and norms by initial social and ecological conditions (Macy and Willer 2002). In response to changes in the environment, land managers and organizations interact to exchange information and resources, generating and distributing knowledge that they then act on individually or collectively. Through social interaction, the land managers and organizations update their beliefs and behavioral intentions, in turn influencing how social groups adapt to their environment. As a result, their choices aggregate to form new patterns that are more than the sum of their parts, an idea that Macy and Willer (2002) note is rooted in the critical realist epistemology of Coleman (1990) and Durkheim's (1901) concept of emergence.

One way to look at these social patterns is in terms of adaptive capacity: the ability of a social-ecological system to recover from disturbance and be capable of responding to change. Adaptive capacity is highly dependent on the ability of diverse groups of individuals and institutions to learn, store knowledge and experiences, and engage in creative, flexible

decision making and problem-solving (Adger 2003). Thus, while the focus of our modeling is on identifying influences on human behavior at the level of individual people or organizations (methodological individualism), social interaction is the superstructure for the process of learning and, thus, the adaptive capacity of socioecological systems.

Patterns of social interaction contribute differently to adaptive capacity according to theories of social capital, which refers to the stock of social relationships necessary for cooperation (Adger 2003). Bonding social capital results from the natural sociological tendency to associate with others with similar beliefs, values, and assumptions, as captured in the adage "birds of a feather flock together" (McPherson, Smith-Lovin, and Cook 2001). This phenomenon encourages the development of strong social ties that foster efficient in-group communication and decision making, important for the spread of ideas and the development of collective adaptation strategies. However, strong bonding capital also reinforces preexisting behavior and ways of thinking. Bridging social capital, on the other hand, results from the drive to seek out information or resources that are scarce within a social group and can compel people or organizations to reach out across sociocultural boundaries (Lin 1999). This drive can result from exogenous conditions (resource scarcity, stress, risk) and events (disasters) as well as institutions and policies (e.g., that encourage communication or collaboration across disciplines or work units). The diffuse and heterogeneous social ties in networks with strong bridging capital create opportunity for people to air competing ideas, become exposed to new domains of knowledge, and access scarce resources, thereby enhancing innovation and the ability to solve complex problems (Burt 2005). A balance between bonding and bridging capital is important to adaptive capacity: bonding capital is needed to grasp the value of the information and resources offered by bridging capital (Burt 2005).

4. Conceptual Design of the Forest, People, Fire Social Network Model

We designed our social network model to (1) capture the patterns of interaction among organizations and actors with different beliefs and behavioral intentions regarding fire protection and forest restoration and (2) represent landscape changes that could contribute to and result from these patterns of interaction. The design of our social network model was grounded in theories of social capital and adaptive capacity. However, unlike many other agent-based models, it was also designed to incorporate empirical data. We used Envision (2012), a framework of agent-based models, to simulate the landscape change associated with the patterns of interaction in the social networks.

Social networks are sets of individuals or organizations (nodes) and the interdependencies (ties) between them. The nodes in our social network model represent land managers and organizations, and the ties represent interactions among them through which information and resources flow (Figure 2). The information that land managers receive through these interactions influences their land management behaviors; thus, we refer to this information as recommendations. Land managers' evaluations of past recommendations determine which organizations to sever or maintain ties with in the future. We represented land managers' evaluations of past recommendations from organizations with a measure of reliability loosely based on a concept described by Walter, Battiston, and Schweitzer (2008).

Land managers and organizations have value orientations regarding landscape values (e.g., biodiversity, scenery, reduced fire risk). Land managers and organizations receive signals about scarcities in the landscape values via the other models running in Envision. When landscape values important to land managers and organizations become scarce, interactions occur within the existing network as determined by empirical data. These interactions initially reinforce existing ties among land managers and organizations with similar value orientations. In the case that the scarcity of a landscape value of interest to a specific land manager is reduced, the land manager will maintain ties with the organizations they are already connected to. This process fosters bonding social capital, which promotes dissemination of existing knowledge and collective action within a network.

Photo by Christine Olsen

Figure 5. Burn Piles near Sunriver, Oregon

If the scarcity condition of a landscape value of interest to a specific land manager is not reduced and instead becomes chronic or severe, the land manager will sever some existing ties with organizations to make it possible to search out other organizations. Organizations that have many severed ties are considered to have low reliability; organizations with maintained ties are seen as having high reliability. Land managers looking to form new ties in the face of scarcity will search for organizations with high reliability, often reaching out beyond the immediate social circle. Because these new organizations have different value orientations, they may also hold different information and resources that could come in useful. Thus, these new interactions lead to the development of bridging social capital, which fosters innovation and complex problem-solving.

When the measure of reliability of an organization becomes very low (i.e., many land managers have severed ties with it), it also reaches out to other organizations that have high reliability with, implicitly, different value orientations. Organizations adjust their value orientations to become more similar to the organizations with which they develop new ties. Over time, this process of repeated communication fosters mutual understanding, cooperation, and learning among a diverse group of stakeholders.

If the recommendations of organizations do not reduce the scarcity of

the landscape values of interest to the majority of actors and the reliability of recommendations across the entire network becomes low, the network model supports formation of new organizations with distinctly different values. Formation of ties to these organizations represents evolution of the network in attempt to adapt to a scarcity in a particular landscape value, which provides access to additional resources and different approaches to problem solving.

Ultimately, network dynamics influence the value orientations of land managers and, as such, their decisions about land management (e.g., vegetation manipulation, home fire risk reduction). The application of those decisions results in changes in the landscape, which, in the next time step, are captured by measures of scarcity of the landscape values and as such drive the dynamics of the network. This process captures societal adaptation to resource scarcities by forming a closed loop of human decision making, changes in the landscape, and social interaction.
At the time of the writing of this paper, empirical data collection was underway but not completed. Interviews and mail surveys were being used to collect information about the patterns of interaction and forest and fire-related value orientations and behavioral intentions of federal and state agencies, tribes, industrial timber companies, groups of other private land owners, and organizations that provide assistance and advice or advocate for views, practices, and policies.

We will use social network analysis (Wasserman and Faust 1994) to describe the patterns of interaction among the organizations and actors in the network. Social network analysis offers quantitative measures of the existence, directionality, and strength of ties among actors in a network and, thus, the opportunity for exchange of information or resources. By providing evidence of bonding and bridging capital among forest and wildfire-related organizations, social network measures can indicate conditions for communication, innovation, and, ultimately, adaptive capacity.

5. Contributions to Anthropology and Natural Resources Planning

Computational models provide a structured way of increasing scientific understanding of complex interactions in socioecological systems. They can also help identify key gaps in knowledge that require more focused studies. The Forest, People, Fire project hopes to contribute to this line of inquiry through a better understanding of the relationships between social networks, human behavior, and landscape change. At the broadest level, our agent-based social network model within the Envision modeling framework will shed light on the importance of social connections to how people shape landscapes. We also expect to shed light on the importance of bonding and bridging social capital to adaptive capacity in fire-prone socioecological systems. In terms of understanding people on the landscape, we hope to gain understanding about the role bridging capital may play in (1) actors' willingness to live with, rather than suppress, wildfire and (2) to plan across ownerships for addressing wildfire risk.

Integrated social and ecological modeling frameworks are especially useful tools for understanding the environmental causes and consequences of human behavior. Such frameworks can be used as decision support, particularly for land managers who need to look across ownerships and understand potential social and ecological effects of their decisions. The social network model in particular may be useful to land managers in public agencies who have relatively short tenures in a specific geographic location, making it difficult to engage with stakeholders. Integrated social and ecological modeling frameworks can also serve stakeholders by helping to foster discussion of complex landscapes. The opportunity for visualization provided by spatially-explicit modeling frameworks such as Envision can make it easier for stakeholders to understand how they fit in to complex landscapes and how these landscapes may change over time.

The Forest, People, Fire project plans to hold additional workshops to engage stakeholders in the development and interpretation of our agent-based models and the maps of potential future landscape change these models yield. Through social network analysis of our empirical data, we will provide insight into the extent of interaction among land managers and organizations focused on fire protection and forest restoration in central and southern Oregon. Through agent-based modeling, we will demonstrate the potential for cohesive strategies that the participants in our initial workshops called for to contribute to landscape change.

Despite the promises of computational models for exploring how people adapt to their environments, why different groups adapt differently, and the effects of human adaptation on the environment—all long-time concerns of anthropology—designing such models can be a challenge for some social scientists. Computational models require distillation of social theory into simple decision rules, and, while they can produce richly detailed output (e.g., Envision's simulation maps that extend across space and time), they do not allow for "thick description" as input. Rather, agent-based models are representations of the complex social reality with which many anthropologists and sociologists are concerned. Moreover, the often highly realistic maps that landscape models produce can be deceptive to clients who can mistake model output as predictive rather than speculative. Nevertheless, the promises of computational models outweigh the pitfalls in our view. The process of developing the models can be as valuable as the model outputs. It forces the interdisciplinary team to develop common language and understanding, and it identifies key information gaps. We expect the Forest, People, Fire project will contribute to efforts to better represent and understand interactions between social and ecological systems and how culture and social structure mediate these interactions to create landscapes with, for better or worse, enduring human imprints.

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