Landscape and Urban Planning 147 (2016) 18–27

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

A network approach to assessing social capacity for landscape planning: The case of fire-prone forests in Oregon, USA

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HIGHLIGHTS

- We analyzed the social network structure for ecoregion-scale planning.
- Despite shared concern about wildfire, organizations comprised distinct networks.
- Organizations with different goals and geographic foci comprised distinct networks.
- Social network ties among organizations were stronger at the sub-ecoregion scale.
- Network analysis can quantify social capacity for landscape planning.

ARTICLE INFO

Article history:
Received 1 October 2014
Received in revised form 13 October 2015
Accepted 27 October 2015
Available online 11 December 2015

Keywords:
Organizational networks
Social network analysis
Social capital
Landscape planning
Wildfire management
Forest restoration

ABSTRACT

Management of ecological conditions and processes in multiownership landscapes requires cooperation by diverse stakeholder groups. The structure of organizational networks – the extent to which networks allow for interaction among organizations within and across ideological and geographic boundaries – can indicate potential opportunities for cooperation on landscape-scale problems. In the arid landscapes of the western United States, where increasingly large wildfires burn irrespective of property boundaries and land designations, organizations involved in the restoration of forests and the protection of property from wildfire could benefit from working together to share information and coordinate strategies. We investigated patterns of interaction among organizations concerned with increasingly uncharacteristic wildfire risk in the Eastern Cascades Ecoregion of Oregon for evidence of structural conditions that create opportunity for cooperation. Through social network analysis of interview data, we found that despite sharing concern about wildfire risk in an area with a common set of ecological conditions, organizations with forest restoration and fire protection goals comprised distinct networks, as did organizations that focused on different geographic areas of the ecoregion. When interpreted through the lens of social capital and organizational theory these findings raise questions about the extent to which the structure of the organizational network reflects capacity to address wildfire risk in fire-prone forests on the ecoregion-scale. This study provides insights on the utility of a structural approach for investigating social capacity for landscape-scale planning.

1. Introduction

The need to plan natural resources management at the landscape scale is well-recognized because many environmental processes occur across large areas (Knight & Landres, 1998). The probability and potential severity of a wildfire, for example, is a function of the composition and distribution of flammable vegetation sometimes quite distant from the location of a forested stand

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http://dx.doi.org/10.1016/j.landurbplan.2015.10.006

(Ager, Vaillant, Finney, & Preisler, 2012). In many cases, however, planning at landscape scales is difficult because administrative boundaries established by society do not conform to ecological boundaries (Landres, Knight, Pickett, & Cadenasso, 1998). This is especially true with large landscapes such as ecoregions, which are composed of many public and private land ownerships (Powell, 2010). Around the world, organizations, agencies, and academic scholars seek to increase understanding of cooperation across ownerships on natural resource management to improve natural resource management (Brunckhorst, 2011).

In lieu of agencies or organizations equipped to manage multi-ownership landscapes, organizational networks can potentially play an important role in natural resource planning on large spatial scales. Organizational networks are defined as sets of interacting organizations and the ties among them. Ties refer to relationships and interactions between organizations, such as for the purpose of working together or sharing information. Organizational networks generally form when capabilities of existing organizations are insufficient to complete a given task on their own, and costs prohibit adding to those capabilities internally, and when there are functional gains associated with connecting to others (Benjamin, Brechin, & Thoms, 2011; Wolf, 2011). Organizational networks can serve as collaborative institutional structures uniting stakeholders into both formal and informal arrangements that can help facilitate flows of information and resources, and fulfill functions necessary for dealing with cross-boundary issues that traditional ownership-focused organizations cannot. Because networks are not bound to a specific structure, they can operate across multiple jurisdictions and geographies (multiscalar), have many centers of authority (polycentric), and consist of local to national stakeholders and organizations (multi-level) (Powell, 2010). This flexible structure allows networks to address large-scale, multi-jurisdictional problems beyond a single organization's capacity (Butler & Goldstein, 2010).

By bringing organizations with different goals, geographic foci and land management preferences into contact with each other, networks can help create conditions for cooperation across ownership boundaries on landscape planning. Cross-boundary cooperation refers to communication, coordination and joint-implementation by multiple parties of plans and actions on scales larger than single ownerships (Yaffee, 1998). The theory of cooperation is based on the benefits of reciprocity to participating parties when combined efforts can achieve more than individual efforts. For cooperation to be possible, several social conditions must be met: parties must share a common understanding of a problem (shared cognition) and sense of belonging to a common group (shared identity), and view other parties as fair, capable and entitled to play a role (perceived legitimacy) (Bouas & Komorita, 1996; Gass, Rickenbach, Schulte, & Zeuli, 2009; Rickenbach & Reed, 2002; Swaab, Postmes, van Beest, & Spears, 2007; Tyler, 2006; Tyler & Degoey, 1995). Opportunities for exchanging information and ideas, such as through formal and informal networks, are important for building social conditions that foster cooperation among diverse stakeholders (Ostrom, 1990; Yaffee, 1998). However, the natural social tendency to interact with others who are geographically or socially near (i.e., homophily) (McPherson, Smith-Lovin, & Cook, 2001) conceivably could impede social cohesion among diverse stakeholders across large areas. Little is known about the extent to which shared concern about natural resource problems can counter this tendency.

Given the potential role networks can play in landscape planning, and the fact that increasingly large and intense wildfires are a pressing challenge in many countries (Williams, 2013), we investigated a network of organizations concerned about wildfire risk for evidence of social ties that promote cooperation on landscape-scale planning. Our goal was to investigate whether shared concern about landscape-scale problems could counter homophily as an influence on the structure of an organizational network. Our research questions were: (1) To what extent are organizations with different management goals and geographic foci interacting with each other around the problem of wildfire risk, and (2) What do these patterns of interaction suggest about opportunities for cooperation on landscape planning?

We hypothesized that organizations concerned with wildfire risk would interact more with organizations that shared the same goals and geographic focus than with organizations that did not. According to social capital and social network theories, this tendency would suggest that while subnetworks of like-organizations may be in a position to communicate about, coordinate, and jointly-implement plans, the network as a whole would not exhibit a structure that promotes cooperation.

Our geographic focus was the Eastern Cascades Ecoregion (ECE) in Oregon, USA (Omernik, 1987) (Fig. 1), where wildfires are becoming increasingly large and difficult to control. Ecoregions are large landscapes with distinct assemblages of natural communities that share species dynamics and environmental conditions. Cooperation on planning at the ecoregion scale can be helpful because it can facilitate management of a common problem in a common set of environmental conditions (Powell, 2010). For example, in the case of wildfire, cooperative planning could facilitate agreement on circumstances under which management techniques such as thinning and prescribed burning are appropriate for reducing flammable vegetation and restoring forest conditions to lessen the risk of large wildfires, and strategic use of these techniques.

Social network analysis (Wasserman & Faust, 1994) served as the basis of our methodological approach. Social network analysis assumes that the structure of networks – the extent to which networks allow for interaction among organizations within and across social and geographic boundaries – can indicate potential to build the mutual understanding, group identity, and perceived legitimacy needed for cooperation on landscape planning. Network analysis has been used in sociology and organizational studies to quantify structural conditions for cooperation (Borgatti, Jones, & Everett, 1998; Burt, 2000; Lin, 1999), including in natural resource management contexts (Bodin & Crona, 2009; Bodin, Crona, & Ernstson, 2006; Newig, Günther, & Pahl-Wostl, 2010). In ecology, studies have used network analysis to understand ecological structures and processes for landscape planning purposes (Cook, 2002; Cumming, Bodin, Ernstson, & Elmqvist, 2010; Jongman, Külvik, & Kristiansen, 2004; Kong, Yin, Nakagoshi, & Zong, 2010; Minor & Urban, 2008; Rhodes, Wardell-Johnson, Rhodes, & Raymond, 2006; Saura & Pascual-Hortal, 2007). Some scholars have proposed social network analysis as a useful approach to examining social capacity for planning and management at landscape scales (Bodin & Tengö, 2012; Cumming et al., 2010; Guerrero, McAllister, Corcoran, & Wilson, 2013; Mills et al., 2014; Opdam, Steingröver, & Rooij, 2006), although empirical studies are limited.

We interpreted our findings about network structure through the lens of social capital and social network theory to identify opportunities for cooperation on landscape planning. These theories suggest that bonding social capital structure (i.e., interactions among actors in the same social group) promotes communication and collective action (Borgatti et al., 1998), transfer of knowledge (Reagans & McEvily, 2003), creation of common norms, and development of trust and mutual understanding (Burt, 2000; Coleman, 1990). Bridging social capital structure (i.e., interaction between actors from different groups), on the other hand, promotes access to new information and resources needed for complex problem-solving (Burt, 2000; Granovetter, 1973; Lin, 1999; Reagans & McEvily, 2003; Reagans & Zuckerman, 2001; Rogers, 1983; Ruef, 2002). We investigate the extent to which the network of organizations concerned with wildfire risk in the ECE exhibit a balance

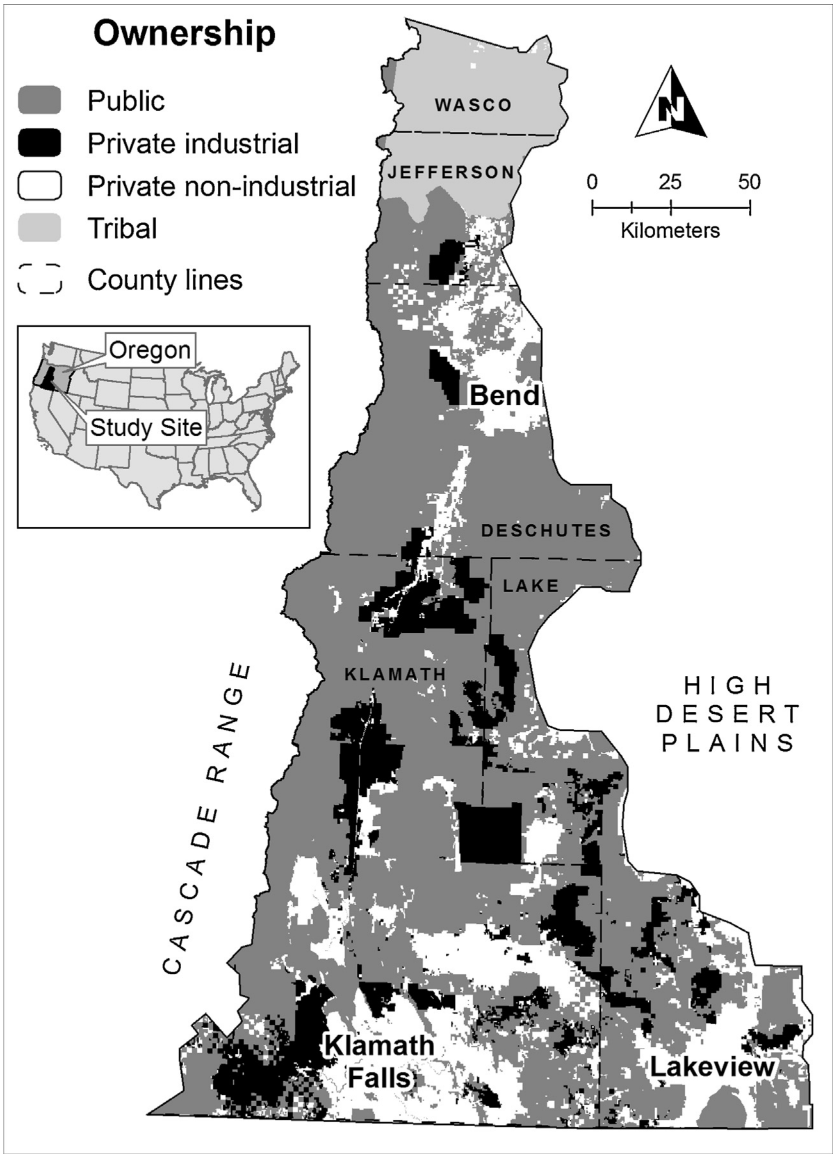

Fig. 1. The Eastern Cascades Ecoregion (ECE) of Oregon, USA.

between bonding and bridging capital such that cooperation on the complex problem of increasing wildfire risk is not only possible but likely.

2. Methods

2.1. Study area

The ECE (Fig. 1) is a 3.3 million hectare landscape that crosses five counties and includes several small cities and large expanses of ponderosa pine (*Pinus ponderosa*) and mixed-conifer forest inhabited by species of federal and state policy interest such as the northern spotted owl (*Strix occidentalis caurina*) and mule deer (*Odocoileus hemionus*). Two-thirds of the land area is in public ownership (mostly federal), one-sixth is held by tribes and corporate forestry entities, and the remaining one-sixth is owned by non-corporate private landowners (e.g., individuals, families, trusts). Our social network analysis included all but the northern-most portion of the ecoregion – the eastern flanks of Mount Hood – which is tied to the expansive networks of organizations in the large urban area of Portland, Oregon.

Fire is a natural and ecologically important process in the ECE and throughout the inland Northwest. However, the past century of fire suppression, commercial logging, and livestock grazing, combined with drought and incursions by invasive plants, insects and diseases, has led to an accumulation of flammable forest vegetation (Hessburg, Agee, & Franklin, 2005; USDA Forest Service, 2009). This vegetation now fuels "mega-fires" (Williams, 2013), which are atypical in size and severity even for the fire-adapted ecosystems where they occur. Alteration of the historical fire regime is also changing the distinct assemblages of natural communities in the ECE (Hessburg et al., 2005).

Organizations in the ECE have made substantial investments in collaborating on forest and fire management issues (Davis et al., 2012; Oregon & Solutions, 2013; Summers, 2014). For example, The Nature Conservancy, with funding from the Forest Service, administers two Fire Learning Networks, which engage land management organizations in the restoration of fire-dependent ecosystems through landscape-scale collaborative planning (Butler & Goldstein, 2010). The Forest Service and the Bureau of Land Management have formed formal partnerships around wildfire response. In addition, the Collaborative Forest Landscape

Restoration Program, which was established under Title IV of the Omnibus Public Land Management Act of 2009 on Forest Landscape Restoration, has funded projects that engage local public land managers and stakeholder groups in planning for management of landscapes on national forests.

2.2. Data collection

We conducted semi-structured interviews with representatives of organizations concerned with increasing wildfire risk in the fire-prone forests in the ECE to collect network data for this study. Network data are defined by (1) information about ties (i.e., relationships, interactions) among actors (i.e., organizations) through which information and resources are shared, and (2) actor attributes (e.g., type of organization). We used a snowball sampling approach to identify the individuals we would interview (Doreian & Woodard, 1992), beginning with 45 individuals members the research team considered key actors in the area of forest and wildfire management in the study area. We asked interview informants with whom in other organizations they had interacted in the past five years to: (1) plan, fund, or implement work; (2) obtain information or expertise; (3) give advice; (4) gain exposure to new ideas, and (5) influence planning and management regarding wildfire risk and fire-prone forest management. We conducted second and third waves of snowball sampling by contacting additional individuals who were mentioned in response to these questions by at least three interviewees in the preceding wave. The third wave of snowball sampling did not identify any additional interview informants, therefore reaching saturation.

In total, we interviewed 154 individuals representing 87 organizations. In the interviews we first asked informants about their organizations' institutional concerns about wildfire risk, beliefs about the role fire should play in the forest landscape, and how wildfire and fire-prone forests should be managed. Then we asked informants to name individuals in other organizations with whom they have had the five types of interactions listed above in the past five years to address wildfire risk in the ECE. To ensure confidentiality and create the desired unit of analysis (the organization), we combined responses from individuals within the same organization for each of these questions. This process yielded a multi-relational data set of ties among organizations concerned with increasing wildfire risk in the ECE. In total, 476 organizations were identified through the interviews. In most cases, we considered local government agencies, private businesses, and non-profit groups as organizations. For complex organizations, such as universities, state and federal agencies, and non-profit groups operating at state and national levels, we treated local and regional offices and departments as unique organizations. For example, we considered US Forest Service (USFS) national forest supervisor offices and ranger district offices as separate organizations.

We drew on qualitative interview data to classify the 87 organizations represented by interview informants as either forest restoration or fire protection organizations on the basis of their institutional beliefs about wildfire risk and how wildfire and fire-prone forests should be managed. We used secondary data (i.e., organizations' web pages and policy documents) to classify the organizations identified by less than three informants and therefore not interviewed. Forest restoration organizations included conservation groups, sustainability groups, US Forest Service national forests and ranger districts, watershed councils, Natural Resource Conservation Service districts and other organizations fundamentally motivated to conserve or return ecological conditions and processes to their historic range of variability. Fire protection organizations included rural and suburban fire departments, US Forest Service fire and aviation units, Oregon Department of Forestry units, timber companies, forestry and rangeland interest groups and other organizations fundamentally motivated to protect homes, property and other assets from loss to wildfire. We also classified organizations by their primary geographic focus: central Oregon (CO), the northern portion of the ecoregion, which includes Deschutes, Jefferson and Wasco Counties; south central Oregon (SCO), the southern portion of the ecoregion, which includes Klamath and Lake Counties; and the area that includes both central and south central Oregon (COSCO), i.e., the entire ecoregion. We were unable to classify some organizations for which we did not interview representatives by their primary goals and geographic focus. We treated these organizations as missing data and did not include them in the analysis.

2.3. Data analysis

We used social network analysis (Wasserman & Faust, 1994) to quantify the composition and distribution of ties among organizations. We limited our analysis to the sets of organizations that reported interacting for the purpose of (1) planning, funding, or implementing work (hereafter referred to as the "works with" network) and (2) obtaining information or expertise (hereafter referred to as the "info from" network), since cooperation and resource-seeking are two primary types of interactions among organizations. For each of these two networks we divided the organizations into separate groups, or subnetworks, according to their goals and geographic focus. We compared the size (number of organizations) and average indegree (average number of times an organization was named) of the subnetworks to each other and to the full network. We used average indegree as an indicator of bonding social capital (Borgatti et al., 1998); a denser, more interactive community has greater potential for communication and coordination and thus, the production of bonding social capital (Borgatti et al., 1998). We used indegree instead of outdegree (i.e., average number of times the organizations named other organizations) to control for potential bias caused by interviewees who were able to recall large numbers of contacts.

To examine how differences in organizations' goals and geographic focus structured the ties among them, we compared the number of ties within and between the subnetworks to the average number of expected ties derived from 1000 simulations of the network structure controlling for the number of times an organization named (outdegree) and was named (indegree) by other organizations. This method is referred to as blockmodeling in the social network analysis literature (Wasserman & Faust, 1994). We used ties among organizations of the same type (within-group) to indicate bonding social, and ties between actors of different types (between-group) to indicate bridging social capital. We calculated all social network measures and produced their graphic representations with UCINET (Borgatti, Everett, & Freeman, 2002), and conducted permutation tests with the SNA package of R (Butts, 2008; R.Development Core & Team, 2013).

3. Results

We identified 1270 ties among the 396 organizations in the "works with" network and 335 ties among 158 organizations in the "info from" network. Fig. 2a and b provides graphic depictions of the reported relationships among the organizations in these networks.

Forest restoration organizations were identified more often on average as working partners and sources of information by other forest restoration organizations (i.e., had a higher average indegree) than fire protection organizations were named by other fire protection organizations (Table 1). CO and SCO organizations were named as working partners and information sources by a similar number of other organizations in their respective subnetworks

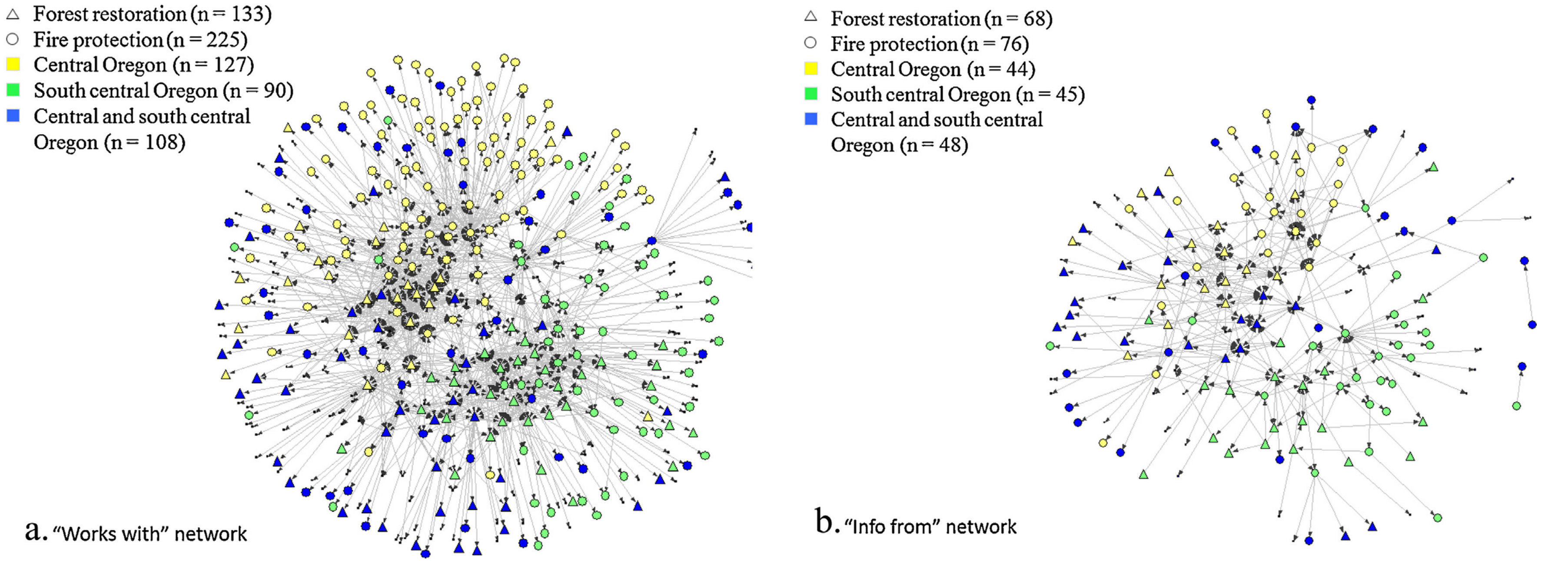

Fig. 2. Organizations (nodes) and reported interactions between them (lines with arrows) for the purposes of planning, paying for or conducting work (a) and seeking information and expertise (b) regarding wildfire risk planning and management in fire-prone forests.

Table 1
Descriptive network statistics.

Variables	Number of organizations		Number of reported ties		Average indegree	
Networks	Works with	Info from	Works with	Info from	Works with	Info from
Total	396	158	1270	355	3.2	2.1
Forest restoration	133	68	417	126	3.1	1.9
Fire protection	225	76	374	105	1.7	1.4
Central Oregon (CO)	127	44	429	100	3.4	2.3
South central Oregon (SCO)	90	45	287	67	3.2	1.5
Central and south central Oregon (COSCO)	108	48	74	23	0.7	0.5

on average, while COSCO organizations were named as working partners and information sources less often by other COSCO organizations (Table 1). These findings indicate that the subnetwork of forest restoration organizations was more densely interconnected than the subnetwork of fire organizations, as were the subnetworks of CO and SCO organizations in comparison to the subnetwork of COSCO organizations. In other words, there was more bonding social capital structure to foster communication and coordination in the forest restoration network than in the fire protection network, there were similar levels of bonding social capital structure in the CO and SCO networks, and there was more bonding social capital structure in these subregional networks than in the subnetwork of COSCO organizations that focused on the larger geographic area.

While bonding social capital is important for cooperation within groups of similar actors, bridging social capital creates opportunity for communication, coordination and joint-implementation of plans across geographic and social boundaries. Results from the blockmodel permutation tests indicate that in all cases organizations reported working with and seeking information from organizations with the same goals and geographic focus more often than expected by chance (Table 2). In contrast, organizations reported working with and seeking information from organizations with different goals and geographic foci less often or with a frequency no different than expected based on chance (Table 2).

We found several exceptions that could provide evidence of opportunities for ecoregion-scale planning. CO forest restoration organizations reported that they both worked with and received information from SCO forest restoration organizations at a rate not significantly different from what would be expected by chance. This finding simply indicates that the proportion of cross-geography ties between forest restoration and fire protection organizations is similar to that expected by chance given the distribution of the different types of organizations in the total network and the in- and outdegree of each organization. More notable, CO fire protection organizations named COSCO fire protection organizations, and CO forest restoration organizations named COSCO forest restoration organizations, as sources of information more often than expected by chance (Table 2). Most of the COSCO organizations were departments or divisions within institutions that hold a statewide or national focus (e.g., the state office of the Oregon Department of Forestry, Oregon State University's College of Forestry, The Nature Conservancy's Pacific Northwest Regional Office). The positioning of some of these organizations as brokers is evident in their location between the clusters of CO and SCO organizations and forest restoration and fire protection organizations in the "works with" and "info from" network diagrams (Fig. 2a and b).

We found only one instance in which organizations reported working with or seeking information from organizations that held different goals more often than expected by chance: SCO fire protection organizations named SCO forest restoration organizations as working partners and information sources more often than expected (Table 2). We found no examples in which organizations with different goals and different geographic foci interacted more frequently than expected by chance.

On the whole, the blockmodel permutation tests provide statistical indication that organizations concerned with wildfire risk in the forested landscape of the ECE do not comprise one cohesive network. At smaller sub-regional landscape scales, however, (i.e., CO and SCO) organizations displayed stronger network ties (Table 2). Overall, organizations demonstrated preferences for interacting with organizations that share similar goals and geographies.

4. Discussion

Organizations that share concern about a common landscape-scale natural resource problem in a common area arguably could benefit from cooperating on landscape planning. In the ECE, however, we found that in most cases, as we hypothesized, organizations with the same goals and geographic focus interacted more frequently among themselves than with others to get work done and to obtain information and expertise on the problem of wildfire risk. These findings indicate that bonding social capital was not as strong across the network as a whole as it was within subnetworks of similar organizations, especially subnetworks of similar organization types, particularly forest restoration organizations. In other words, we did not find evidence that shared concern about landscape-scale problems could counter homophily as an influence on the structure of a large organizational network.

Our finding of homophily among forest restoration and fire protection organizations is not surprising. Only since 2000 has US federal wildfire policy-historically focused on fire suppression-broadened to include goals for restoration of forest structure and species composition (Dombeck, Williams, & Wood, 2004; Steelman & Burke, 2007). The less-than-frequent interaction between forest restoration and fire protection organizations reflects the social distance between organizations with these different goals. Despite recent US policy initiatives and a growing advocacy movement to integrate protection and restoration goals and strategies (Butler & Goldstein, 2010; DellaSala et al., 2003; Wildland Fire Leadership Council, 2011), it appears that the institutional cultures of fire protection and forest restoration remain distinct, even in the ECE where great progress has been made in collaboration on forest and, separately, fire management (Davis et al., 2012; Oregon & Solutions, 2013; Summers, 2014). Some organizations appeared to be bridging this cultural divide. For example, in SCO, fire protection organizations named forest restoration organizations as working partners and information sources more often than expected by chance. Most often this took the form of state and local fire departments and fire-fighting agencies working with and seeking information and advice from federal or state natural resource management agencies, perhaps demonstrating attempts to communicate about and coordinate or jointly-implement wildfire mitigation and response efforts. In CO, forest restoration and fire protection organizations interacted as frequently as expected by chance, providing no indication that these two types of organizations were reluctant to interact with each other.

Our finding of geographic homophily is also not surprising. Ecoregions, due to their size, contain multiple overlapping and competing geographic, ecological and social territories. People, on

Table 2
Observed vs. expected ties among and between organizations by goal and geographic emphasis.

	CO-Fire protection		CO-Forest restoration		COSCO-Fire protection		COSCO-Forest restoration		SCO-Fire protection		SCO-Forest restoration	
	Works With	Info From	Works With	Info From	Works With	Info From	Works With	Info From	Works With	Info From	Works With	Info From
CO-Fire protection	>**	>**	NSD	NSD	NSD	>**	<**	<**	<**	<**	<*	<*
CO-Forest restoration	NSD	NSD	>*	>*	NSD	NSD	NSD	>*	<*	<*	NSD	NSD
COSCO-Fire protection	NSD	NSD	<*	<*	>*	>*	NSD	NSD	NSD	NSD	NSD	NSD
COSCO-Forest restoration	NSD	NSD	NSD	NSD	NSD	NSD	>**	>**	<*	<*	<*	<*
SCO-Fire protection	<**	<**	<*	<*	NSD	NSD	NSD	NSD	>**	>**	>*	>*
SCO-Forest restoration	<*	<*	<*	<*	NSD	NSD	NSD	NSD	NSD	NSD	>*	>*

$^{*}p \leq 0.05$, $^{**}p \leq 0.01$, NSD: no significant difference.
Light shading indicates hypothesized patterns; dark shading indicates unexpected patterns.

the other hand, develop connections to place at local scales, to the spatial entities to which a group feels a sense of belonging and by which a group governs itself (Fall, 2003; Powell, 2010). In some cases these social boundaries may even seem arbitrary when considered in their ecological context (Fall, 2003). In the ECE, our findings suggest that the spatial territories that share similar ecological conditions and face similar threats (i.e., wildfire risk) were not strongly connected via social processes (i.e., communication, coordination, and joint-implementation of plans). Again, a notable exception was that COSCO organizations were named by CO organizations more often than expected by chance in some cases, suggesting that they may be in a position to link local organizations to discussions about wildfire planning at larger scales. Interestingly, however, COSCO organizations named SCO organizations as working partners and information sources less often than expected, indicating a lack of attention to SCO by COSCO organizations despite their broad spatial focus.

When interpreted using social capital and organizational theory, we found little evidence of structural conditions offering opportunity for cooperation on the shared problem of wildfire risk at the scale of the ECE. Social interaction can provide a mechanism for building shared cognition, group identity and perceived legitimacy necessary for collective action around a common problem (Ostrom, 1990; Yaffee, 1998). Bridging interactions, when frequent and sustained, can build bonding social capital among organizations with disparate goals and geographies. Our study did not reveal a cohesive, densely interconnected network of forest restoration and fire protection organizations that would reflect frequent and sustained interaction. Rather, we found a network largely bifurcated on ideological and geographic boundaries.

Although it makes sense that organizations would invest in relationships with organizations that share similar goals and geographic foci, this social structure is problematic for managing large landscapes to achieve broad, shared goals at the ecoregional scale. In fire-prone landscapes such as the ECE, some forest restoration activities (e.g., thinning to restore desired structure) can help reduce the risk of large wildfire, and some fire protection activities (e.g., thinning to reduce flammable vegetation) can help return forest structure and processes to their natural fire regimes. Despite the complementarity of forest restoration and fire protection, these two types of organizations did not appear to engage in a pattern of interaction that reflects frequent communication, coordination or joint problem-solving. The lack of apparent high-levels of cooperation among these organizations could hinder recognition of interdependencies between fire protection and forest restoration. It could also limit opportunities to develop mutually acceptable strategies for addressing the problem of large and intense wildfires burning across the jurisdictions of the multiple ownerships and stakeholder groups that comprise the ecoregion.

Moreover, despite wildfire's tendency to burn across administrative and ownership boundaries, fire protection organizations did not appear to be very interconnected at the scale of the ECE: they were named as working partners and information sources by less than two other fire protection organizations on average, whereas forest restoration organizations were named by more than three other forest restoration organizations on average (Table 1). Although we did not ask who they worked with and sought information from during fire events (which might have reflected stronger ties) the low average indegree of fire protection organizations may be a reflection of legal and policy barriers that prevent planning and implementing joint wildfire risk mitigation actions across their different jurisdictions (Fischer & Charnley, 2012; Knight & Landres, 1998; Landres et al., 1998).

Our finding of relatively little bridging social capital at local levels may reflect the logic of cooperation on natural resource management at smaller spatial scales than the ecoregion. Although the accumulation of flammable forest vegetation is an ecoregion-wide problem, wildfire events rarely if ever occur on the scale of an entire ecoregion. Thus, while collective ecoregion-wide problem solving and coordination of plans and actions would likely be fruitful, cooperation to conduct the work of thinning and prescribed burning to minimize potential movement of fire across the landscape makes more sense on smaller scales. The mismatch between the spatial scales on which landscapes and humans function, as suggested by our findings, arguably has led to a disconnect between the spatial scale of an ecological problem and the spatial scale of human response (Kondolf & Podolak, 2014). Despite increasing wildfire risk being an ecoregion-scale problem, we see little evidence of social organization for addressing the problem at this scale.

While it generally takes situations of stress or scarcity to compel different interests to forge alliances (Benjamin et al., 2011; Wolf, 2011), network governance institutions can create opportunities for building shared cognition, group membership, and legitimacy for landscape management (Powell, 2010). A variety of initiatives in recent years have promoted cooperation on landscape management in the U.S. (Butler & Goldstein, 2010; Knight & Landres, 1998; Laven, Jewiss, & Mitchell, 2012), including the aforementioned Fire Learning Network and Collaborative Forest Landscape Restoration Program. The networks formed through these initiatives plan natural resource management at scales much finer than ecoregions, however. The National Cohesive Wildland Fire Management Strategy, on the other hand, still in its early stages, aims to promote collaborative processes at multiple scales, involving government and non-governmental organizations and the public in an "all lands" approach to forest restoration and fire protection (Wildland Fire Leadership Council, 2011). These initiatives could play a bigger role in building connectivity among stakeholders in the management of large fire-prone landscapes and encouraging cooperation across geographic and ideological boundaries.

The question remains, however: What is the appropriate balance between bonding and bridging structure for landscape-scale planning, and at what scale? Excessive bonding social capital can give rise to homogeneity, jeopardizing a network's ability to maintain a diverse knowledge base, and too much bridging social capital may make it difficult to build the trust and norms of reciprocity needed to efficiently communicate and act on new ideas (Borgatti & Cross, 2003; Burt, 2004; Reagans & McEvily, 2003; Reagans & Zuckerman, 2001; Ruef, 2002). To effectively address the problem of increasing wildfire risk policies must encourage sufficient interaction between forest restoration and fire protection organizations to foster complex problem-solving without compromising the social cohesion within these subnetworks that allows for communication and coordination. Moreover, policies should encourage interaction between organizations in different geographic subregions to the extent that it is practical and does not divert resources that could otherwise be invested in management at smaller landscape scales. At the spatial scale of ecoregions, which are composed of multiple, more coherent social territories, weak bridging structure may be sufficient for planning and joint problem-solving. Assuming the number of relationships organizations can enter into is limited, it may be more important for parties to invest in relationships at scales at which work (e.g., implementing fuels reduction treatments) can be coordinated.

5. Conclusions

Management of ecological conditions and processes in multi-ownership landscapes requires cooperative planning among diverse stakeholder groups. This is especially true in arid human-inhabited forested landscapes of the world, where increasingly large and intense wildfires burn irrespective of property boundaries and land designations. In these areas, organizations involved in the restoration of forests and the protection of property from wildfire could benefit from working together to share information and coordinate strategies. The structure of organizational networks can indicate potential opportunities for communication, coordination and joint implementation of landscape-scale natural resource management plans.

We investigated patterns of interaction among organizations concerned with increasing wildfire risk in Oregon's ECE for evidence of structural conditions that create opportunity for cooperation. Social network analysis enabled us to quantitatively characterize the bonding and bridging social capital among these organizations. We found that despite sharing concern about wildfire risk in an area with a common set of ecological conditions, organizations with forest restoration and fire protection goals comprised distinct homophilous networks, as did organizations that focused on different geographic areas of the ecoregion. At the subregional scale, however, we found that social network ties were stronger, suggesting that social structure may be in place locally for cooperative planning. When interpreted through the lens of social capital and network theory these findings raise questions about the extent to which the overall structure of the organizational network reflects capacity to address wildfire risk in fire-prone forests on the ecoregion scale.

For natural resource planning to occur on large spatial scales and across boundaries, the social organization for cooperation must be built. Our research results validate and suggest continued need for network governance institutions to provide connectivity across geographic and social boundaries. An important step for research on stakeholder networks and landscape planning is to better understand the implications of different network structures for accomplishing different types of objectives relating to natural resource planning. The appropriate scale at which to foster bridging and bonding social capital among organizations will vary depending on the goals and objectives for landscape management. We suggest that combining network analysis with qualitative data from stakeholder interviews may be a useful way to explore the relationship between network structure and social capacity for landscape planning and consider how to strengthen social networks at the ecoregion-scale.

Our study contributes to scholarly literature by investigating whether shared concern about a pressing landscape-scale problem such as wildfire could counter homophily as an influence on the structure of a large organizational network. We confirm that homophily is a powerful influence on social organization even in cases of shared concern about pressing natural resource problems. Our research also provides an empirical example of how network analysis can illuminate opportunities and constraints for cooperative natural resource planning among organizations operating in the same landscape or ecoregion. It provides a method for assessing capacity for landscape planning through quantification of the bonding and bridging social capital in a network. By testing the differences between observed bonding and bridging social capital and what would be expected by chance in a network of organizations concerned about wildfire, this study provides insights on the utility of a structural approach for investigating human capacity for landscape-scale planning. The social network analysis methods we use to assess social capacity for landscape planning in Oregon can be replicated in other regions of the USA and the world where diverse sets of stakeholder organizations seek to address natural resource problems that operate on large spatial scales and where recognition of the importance of cooperation across ownerships on management is growing; for example in Australia, where landscape-scale planning is gaining traction (Brunckhorst, 2011) including on the problem of wildfire.

Acknowledgements

National Science Foundation's Coupled Human and Natural Systems Program (NSF Grant CNH-1013296) and the USDA Forest Service PNW Research Station provided the funding for this research. The authors would like to acknowledge all the interview informants who generously gave their time to participate in the study. They authors would also like to acknowledge Orian Bodin for reviewing the study plan for the research, Emily Platt for assisting with data collection, and Maribel Vidrio for assisting with data management.

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