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Research article

Land ownership and landscape structure: a spatial analysis of sixty-six Oregon (USA) Coast Range watersheds

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Abstract

Patterns of land ownership and forest cover are related in complex and ecologically significant ways. Using a Geographic Information System and regression analysis, we tested for spatial relationships between the structure of land ownership and forest cover across 66 watersheds in the state of Oregon (USA), Coast Range mountains. We found that in these watersheds (1) forest cover diversity increased with land ownership diversity, (2) size of forest patches increased with size of land ownership patches, and (3) connectivity of forest cover increased with connectivity of land ownership. Land ownership structure explained between 29% and 40% of the variability of forest cover structure across these watersheds. Driving this relationship are unique associations among particular ownership classes and various forest cover classes. The USDA Forest Service and the USDI Bureau of Land Management were associated with mature forest cover; private industry was associated with young forest cover; nonindustrial private forest owners were associated with a wide diversity of cover classes. Watersheds with mixed ownership appear to provide greater forest cover diversity, whereas watersheds with concentrated ownership provide less diverse but more connected forest cover. Results suggest that land ownership patterns are strongly correlated with forest cover patterns. Therefore, understanding landscape structure requires consideration of land ownership institutions, dynamics, and patterns.

Introduction

Land ownership is a critical natural resource policy issue in the state of Oregon (USA). As in many western states, Oregon's forested landscapes are characterized by a complex mosaic of public, forest industry, and nonindustrial private ownerships, complicating land use and environmental protection policy and resulting in ongoing debate over the benefits of land trades to consolidate tracts and connect habitat. Moreover, land ownership patterns are dynamic. The area in nonindustrial private forest (NIPF) in western Oregon declined by roughly 750,000 acres between 1961 and 1986; one-third of this land was converted to nonforest land uses while two-thirds were acquired by forest industry (MacLean 1990). Gaining a better understanding of the social and ecological implications of changes in land ownership and use is critical to linking landscape ecology to natural resource policy.

Although many researchers recognize the importance of interactions between social institutions (e.g., land tenure) and ecosystems, few studies have explicitly incorporated such recognition. Several recent landscape ecology studies have linked landscape structure to land ownership (Spies et al. 1994; Turner et al. 1996; Crow et al. 1999; Garman et al. 1999). Environmental historians over the past two decades have sought to tie social institutions such as markets, policies, and human ideology to environmental change (White 1980; Cronon 1983; Robbins 1988; Langston 1995). Social scientists have examined the management behavior of individual landowners (Straka et al. 1984; Romm et al. 1987; Bliss and Martin 1988) and the influence of land ownership patterns, particularly ownership concentration, on rural well-being (Geisler 1993; Bliss et al. 1998; Gaventa 1998; Sisock 1998). Nevertheless, although the importance of place to social behavior has gained currency among social scientists, most social research in the field of human-forest interactions has lacked spatial specificity. The dynamic nature of land ownership, a dearth of reliable spatial data, a focus on human values, beliefs, and behaviors and the inherent difficulty of spatially locating such intangibles; these and other factors have discouraged spatially-explicit social science research. Although natural scientists have made use of large, spatially explicit land cover and ownership data sets, they have begun to recognize that they lack explanations for the social-ecological spatial relationships they describe (Turner et al. 1996; Crow et al. 1999).

In the northwestern United States, there has been considerable interest in the structure of managed forest landscapes over the past two decades. Franklin and Forman (1987) used spatial models to simulate the degree to which conifer forests can become fragmented in response to different methods of timber harvesting. Forest fragmentation from disturbances such as forest cutting affects the amount and spatial arrangement of large trees and large dead wood, soil conditions, and microclimates on forest landscapes—all attributes that affect habitat quality at relatively broad spatial scales (McComb et al. 1993). In an empirical study, McGarigal and McComb (1995) found associations between the amount and spatial configuration of forest habitat and the abundance of breeding birds on managed forest landscapes in the Oregon Coast Range.

Focusing on the role of land ownership in shaping the structure of forest landscapes in Oregon, Spies et al. (1994) compared forest cutting patterns on private and federally owned forest land in the western Oregon Cascades. Although fragmentation of mature forests was found to be increasing in both private and public ownership classes as a result of forest cutting, significantly higher rates of fragmentation were found on private land. Garman et al. (1999) found significant differences in the composition and size of forest patches between several different land ownership classes in the Oregon Coast Range.

This study adds to previous research linking land ownership and landscape characteristics (Spies et al. 1994; Turner et al. 1996; Crow et al. 1999; Garman et al. 1999) by testing the hypothesis that ownership patterns are directly associated with the structure of forest cover (i.e., diversity, patch size, and connectivity) across landscapes. For this study, we used 66 watersheds ranging from 4,288 to 78,901 ha in size to represent a population of landscapes. We defined landscape structure in terms of both the composition and spatial configuration of patches in watersheds (McGarigal and Marks 1995). This study's two-dimensional definition of forest structure is pattern-based and does not include structural elements, such as large trees and dead wood, which are critical habitat components in North American Pacific Northwest forests (McComb et al. 1993).

We used landscape metrics to measure the structure of land ownership and forest cover in each of the 66 watersheds, and linear regression to test for general, spatial relationships between the two factors across the watersheds. Landscape metrics, such as indices of landscape diversity and fragmentation, have been used in previous land ownership studies (Medley et al. 1995; Crow et al. 1999) and can be helpful in identifying general patterns of landscape structure (O'Neill et al. 1988; McGarigal and Marks 1995). However, this study is the first we know of to apply landscape metrics to both vegetation cover and land ownership data in order to compare the two across a series of landscapes at this scale.

We discuss the ecological and policy implications of current trends in land ownership change, with emphasis on ownership concentration. Concentration of forest ownership is taking place in several regions throughout the country (MacLean 1990; Bliss et al. 1998). While concentrated ownership has been shown to be related to several indicators of social well-being (Gaventa 1998; Sisock 1998), little is known about the ecological implications of such changes in ownership. By linking forests to land ownership, we explore empirical relationships between social systems and forest landscape structure, in order to better understand the effects of social forces manifested in land ownership.

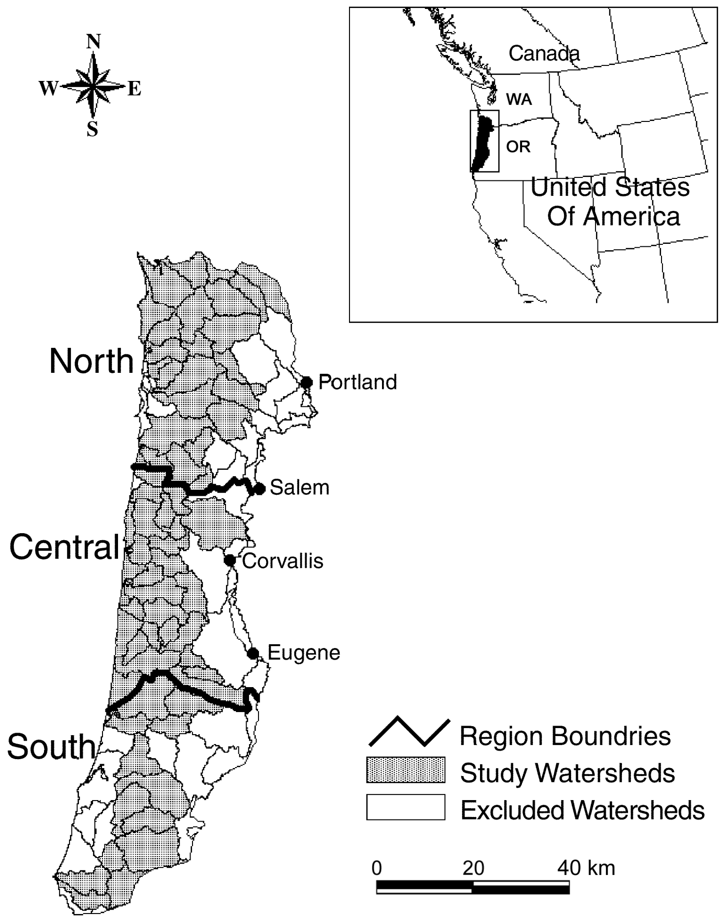


Figure 1. Study area showing the US Pacific Coast states of Oregon (OR) and Washington (WA), and Oregon Coast Range.

Study area

Our study area was the Coast Range mountains Physiographic Province; making up the westernmost portion of the state of Oregon, USA (Figure 1). Well known for its productive conifer forests, the province extends from the Columbia River basin at Oregon's northern border southward to the Klamath Mountains Province. The Pacific Ocean is the western border of this physiographic region. The Sitka spruce (*Picea sitchensis*) vegetation region is found at lower elevations along the coast, while the western hemlock (*Tsuga heterophylla*) vegetation region dominates the uplands. These species, along with Douglas-fir (*Pseudotsuga menziesii*), western redcedar (*Thuja plicata*), Pacific silver fir (*Abies lasiocarpa*), and various hardwoods, characterize much of the western slope and uplands (Franklin and Dyrness 1973). Oregon white oak (*Quercus garryanna*) woodlands dominate the Willamette Valley vegetation region throughout the interior foothills and lowlands along the eastern edge of the Coast Range. Because significant portions of the interior valley and coastal lowlands of this province have been developed for residential and agricultural land uses, these ecoregions were excluded from this analysis.

We selected the Oregon Coast Range because of the diversity of landowners and heterogeneous patchwork of land ownership patterns that characterize it. Landowners include the US Department of Agriculture (USDA) Forest Service (USFS), the US Department of Interior (USDI) Bureau of Land Management (BLM), the State of Oregon, and numerous private industrial and NIPF owners. Because of the province's ecological, economic, and recreational importance, the Coast Range has been the focus of much research, resulting in the availability of extensive data on land ownership and forest cover (Figure 1).

Table 1. Description of forest cover classes.

Class Name	Description
Regeneration Forest	Areas with 0–70% canopy cover AND not designated as non-forest or mixed woodland.
Young Forest	Areas with canopies that are dominated either by conifers or by a mixture of conifers and broadleaf trees AND are composed mainly of individuals that are 0–50 cm in diameter.
Mature Forest	Areas with canopies that are dominated either by conifers or by a mixture of conifers and broadleaf trees AND are composed mainly of individuals that are >50 cm in diameter.
Broadleaf	Areas with >70% of canopy cover represented by broadleaf trees or shrubs.
Non-forest/Mixed Woodland	Areas within an urban growth boundary that were harvested between 1972 and 1995 OR any non-industry land classified as 'open' or 'semi-closed' by Cohen et al. (1995), but not harvested between 1972 and 1995. This class generally includes land maintained as pasture or having widely spaced trees (Bettinger et al. 2000).

Classes were derived by combining the 'Major Coast Range Vegetation Cover Types, 1995' layer (Cohen et al. 1995) and the 'Forest/Non-forest' layer (Bettinger et al. 2000). Urban growth boundaries used to designate non-forest/mixed woodland cover are land use planning boundaries established by each county in Oregon that attempt to protect forest and agricultural lands from urban development (OSDLCD 1999).

Methods

Spatial data

Forest cover data used in this study came from the Coastal Landscape Analysis and Modeling Study (CLAMS), a multidisciplinary study conducted by partners from Oregon State University and several public agencies (Bettinger et al. 2000). The study analyzes the aggregate social, economic, and ecological consequences of forest policies across different ownerships in the Oregon Coast Range (Spies et al. in press). CLAMS spatial vegetation models were created at 25-m resolution using Landsat TM imagery from 1988. Both unsupervised classification and regression modeling approaches were used to estimate vegetation cover, conifer cover, broadleaf cover, and conifer tree size, based on the methods of Cohen et al. (1995). Forest data for model building came from over 200 aerial photo points on which vegetation cover, conifer cover, broadleaf cover, and crown diameter were measured with a zoom stereoscope. Conifer diameter at breast height was estimated from crown diameter using equations from Dilworth (1956). These estimated variables were then sorted into classes (regeneration forest, young forest, mature forest, and broadleaf) (Table 1). The 1988 vegetation layer was updated to 1995 for cutting and growth of early successional stands using a stand replacement disturbance map, which was generated from a change analysis (Warren Cohen, personal communication). Accuracy assessment was conducted by measuring cover and crown diameter on 155 independent, random aerial photo points distributed across the study area. Overall accuracy for the four classes was 89%. Areas that were nonforest or mixed woodland were defined according to the method described in Table 1.

Land ownership data also came from CLAMS (Atterbury Consultants Inc. 1994). This 1:25,000 polygon coverage was converted to a 25-m grid prior to analysis for consistency. The original map was created from a combination of federal agency, private company, and county tax plat maps and assigns landowners to general classes (i.e. government agency or by size of land holdings for private companies) throughout the Coast Range for 1990–1991. (Table 2). The map contains nine ownership classes (USFS, BLM, miscellaneous public, state, private nonincorporated, small industry, medium industry, large industry, and very large industry) (Table 2). We separated private industrial owners based on total area owned. A preliminary comparison of several ownership and forest cover classification schemes suggested that splitting the forest industry into the four classes listed in Table 2 might improve the statistical association of land ownership with forest cover on these landscapes (Stanfield 2001). All private non-incorporated landowners were retained in a single class dominated by NIPF owners, but also including farmers and residential homeowners.

Regression analysis

We conducted two analyses to examine spatial relationships between land ownership and forest cover in 66 fifth-field watersheds in the Coast Range (Fig-

Table 2. Description of land ownership classes

Class Name	Class Abbreviation	Description
USDA Forest Service	USFS	Siuslaw and Siskiyou national forests
USDI Bureau of Land Management	BLM	US public domain lands; O&C Railroad lands
State of Oregon	State	Board of Forestry lands; State Land Board lands
Miscellaneous Public	Misc.	National, state, county, and municipal parks and other small public holdings
Non-industrial Private	NIPF	All non-public land not owned by a corporate entity
Small Private Industry	Sm. Ind.	Land owned by corporate entity that owns <10,000 ha
Medium Private Industry	Md. Ind.	Land owned by corporate entity that owns 10,000–50,000 ha
Large Private Industry	Lg. Ind.	Land owned by corporate entity that owns 50,000–100,000 ha
Very Large Private Industry	V. Lg. Ind.	Land owned by corporate entity that owns >100,000 ha

Classes were derived from the 'Western Oregon Industrial Forest Land Ownership' layer (Atterbury Consultants Inc. 1994).

ure 1). Fifth-field refers to the fifth level within a stream system hierarchy (e.g., the Columbia River watershed represents a first-field watershed). Ownership maps of this province show that fifth-field watersheds host a range of ownership patterns from mixed to concentrated and thus present a good opportunity for testing hypotheses. Due to data limitations in distinguishing nonforested urban lands from recently disturbed forest stands, we excluded from this analysis regions dominated by nonforest land uses, specifically, the Willamette Valley and Coastal Lowland ecoregions. We further disqualified watersheds in which more than 20% of the land area had been so excluded. Following these criteria, we disqualified 36 of 102 possible watersheds from analysis (Figure 1).

In our first of two watershed analyses, we examined general relationships between the structure of land ownership and the structure of forest cover in the 66 watersheds. We used four landscape structure metrics computed by FRAGSTATS 2.0 (McGarigal and Marks 1995) to measure the structure of both land ownership and forest cover in watersheds. The first metric, Shannon's Diversity Index (SHDI), calculates compositional diversity (or lack of concentration in any one class) as a combination of richness and evenness (Shannon and Weaver 1949). This aspatial metric provides a single value based on the number of classes on the landscape and the evenness of their distribution across the landscape. The Patch Size Standard Deviation (PSSD) metric calculates the absolute variability of patch sizes on the landscape, a large value indicating a population of patch sizes that is skewed toward the outer limits, and thus indicating the presence of relatively large and relatively small patches. The Largest Patch Index (LPI) metric calculates the largest patch on a landscape as a percentage of the total landscape area. These two patch size metrics together were chosen as indicators of large patches in watersheds. Lastly, the Contagion Index (CONTAG) calculates the spatial aggregation (or connectivity) of patches by measuring the probability that adjacent grid cells will be of the same cover class. Connectivity is defined in this study as the collective adjacency (or lack of edge) of cover classes in a watershed.

Because previous research in the Coast Range has indicated that habitat quality for forest birds is dependent on the type of forest patches present, as well as the size and physical orientation of the patches (McGarigal and Marks 1995), we specifically selected metrics that measured these particular aspects of landscape structure. Furthermore, SHDI, LPI, and CONTAG (or modified versions of these metrics) have all been used in one or more previous landscape studies focused on land ownership (Medley et al. 1995; Crow et al. 1999; Garman et al. 1999). To our knowledge PSSD has not been used in previous studies. It enabled us to validate relationships found using LPI, is easily interpreted, and does not display co-linearity with other metrics.

Statistical tests

For each landscape metric we performed a regression analysis of forest cover against land ownership, designating land ownership as the explanatory variable. Because of the potential for regional differences in such a large study area, we accounted for a regional effect (North, Central, and South) in all regression models (Figure 1). In addition, since only one metric (LPI) accounted for watershed size, we tested for an area effect when it was appropriate. Using multiple linear regression, we accounted for additive and interactive terms using a backward elimination stepwise procedure (Ramsey and Shafer 1997). We report all transformations, influential cases, and significant covariates. When influential cases were present, we performed the stepwise procedure both with and without influential cases and reported results from both.

Concentrated watersheds

We examined landscape structure in watersheds displaying highly concentrated ownership patterns. Because no watershed in the Coast Range is held entirely in a single ownership class, we selected those 5 of the original 66 watersheds in which each of the major ownership classes is most concentrated. The extent of single ownership class concentration varied from 59% to 90% in these watersheds. We included only 5 ownership classes in this analysis because 4 classes were never found to own more than 60% of the total area in any single watershed. The BLM, though owning only 59% of its watershed, was included because it owns a significant amount (13%) of the province.

For each watershed we calculated the percentage of watershed area in each forest cover class. We then compared the forest cover percentages in these 'concentrated' watersheds with the aggregated Coast Range-wide percentages. Finally, we used landscape metrics to compare the spatial configuration of forest patches in these 5 watersheds.

Results

Regression analysis

The four landscape metrics used to test for spatial relationships between land ownership and forest cover were found to be significant among the 66 watersheds. Using SHDI, we found that the diversity of forest cover types in these watersheds was positively correlated with land ownership diversity (Figure 2). Land ownership diversity explained approximately 40% of the variability of forest cover diversity in these watersheds. Using PSSD and LPI, we found that in these watersheds the size of forest cover patches was positively correlated with the size of land ownership patches and the size of land ownership patches explained approximately 41% of the variability of forest cover patch sizes. A significant additive regional effect (detected for both patch size metrics) reflected the small size of watersheds (and thus a lower limit to maximum patch sizes) in the Central Coast Range relative to the North and South regions. Using CONTAG, we found that connectivity of forest cover patches was positively correlated with the connectivity of land ownership patches (Figure 2), and that land ownership connectivity explained approximately 29% of the variability of forest cover connectivity. Overall, these watersheds exhibit strong relationships between land ownership and forest cover (Figure 3).

Concentrated watersheds

Our comparison of five watersheds with concentrated land ownership patterns revealed varying degrees of forest cover diversity and spatial aggregation at the watershed level. The watersheds concentrated in USFS, BLM, and very large industry ownership had low forest cover diversity (SHDI), large patches (PSSD and LPI), and high levels of connectivity (CONTAG) (Table 3). In contrast, the state-dominated watershed had moderate levels of forest cover diversity and connectivity and the NIPF-dominated watershed was associated with extremely diverse and spatially fragmented forest cover patterns (Table 3). Therefore, although concentrated ownership was generally associated with forest cover patterns that were low in diversity, had large patches, and showed high levels of connectivity, these associations varied, depending on the specific ownership class present.

Even where the spatial configurations of these watersheds were similar, the forest cover classes that occurred in these watersheds varied greatly (Table 3). Forty-one percent of the USFS-dominated watershed was mature forest, compared to 36% mature forest in the BLM-dominated watershed and only 15% mature forest in the very large industry-dominated watershed. Likewise, 29% of the large industry-dominated watershed was broadleaf, compared to 17% broadleaf in the BLM watershed and only 14% broadleaf in the USFS-dominated watershed. The patterns of forest composition in these watersheds were consistent with those seen throughout the Coast Range for these ownership classes (Figure 5).

The high percentage of broadleaf cover in the watershed dominated by very large industry could reflect the establishment of hardwood trees and shrubs in recently harvested areas in which the planted species (typically Douglas-fir) has yet to dominate the canopy. It could also partially reflect classification bias toward the broadleaf cover class in northern portions of the Coast Range (J. Brooks, Oregon State Univer-

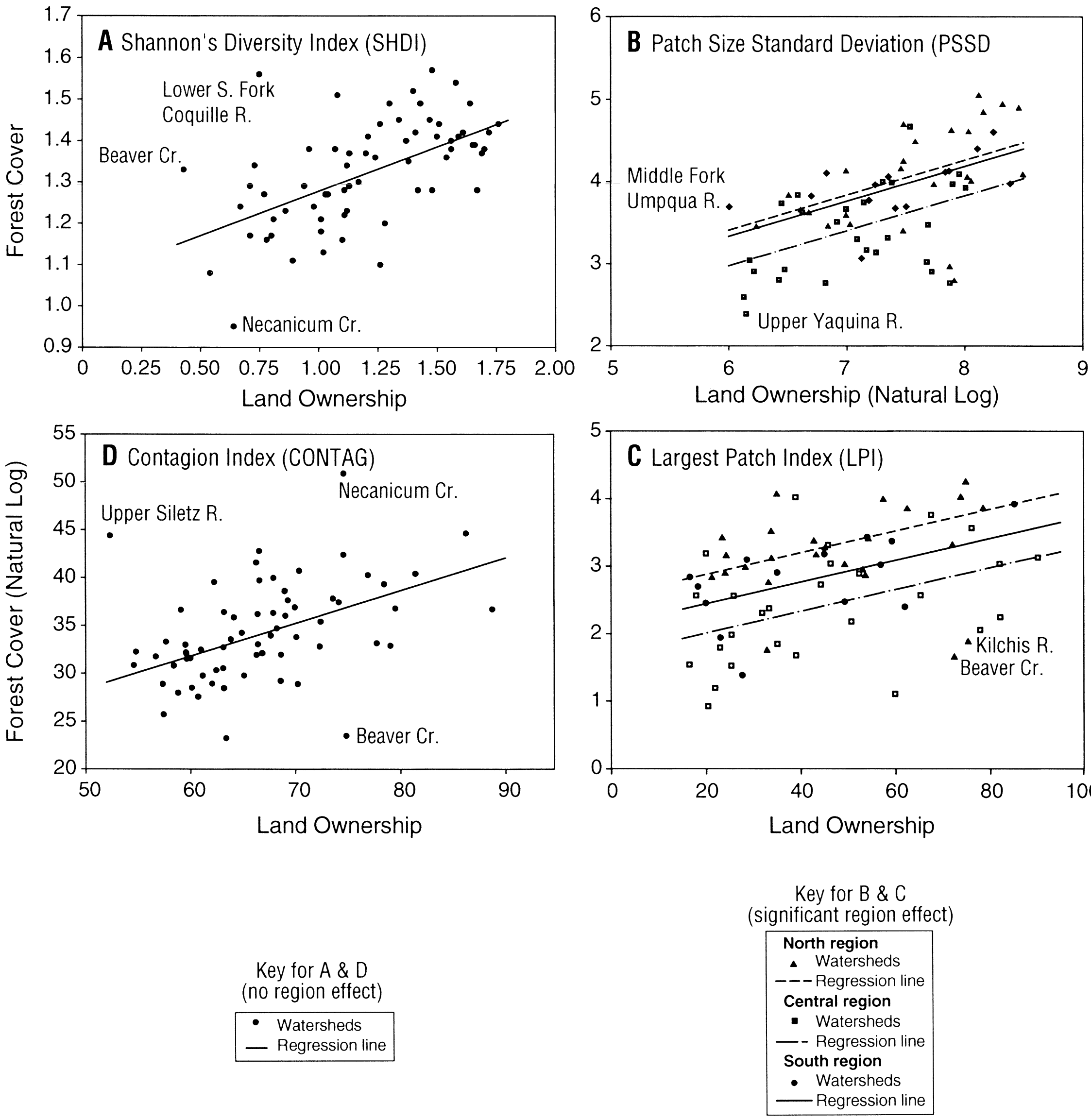


Figure 2. Linear relationships between land ownership and forest cover among 66 Oregon Coast Range watersheds. Summary statistics are listed with values in parentheses indicating tests with influential cases included: (a) $F = 40.29$ (30.03), $p = < 0.0001$ (< 0.0001), and $r^2 = 0.3978$ (0.3293) (b) $F = 16.96$ (19.39), $p = < 0.0001$ (< 0.0001), and $r^2 = 0.4012$ (0.4257) (c) $F = 17.68$ (8.77), $p = < 0.0001$ (0.0043), and $r^2 = 0.4012$ (0.4257) (d) $F = 29.27$ (13.77), $p = < 0.0001$ (0.0004), and $r^2 = 0.2927$ (0.1770)

sity, personal communication). Nonetheless, these comparisons illustrate how watersheds with similarly large and connected patches can promote very different ecological processes, depending on the existing forest cover and land ownership. Finally, the four different private industry classes exhibit few compositional differences (Figure 5).

Discussion

We found the structure of forest cover to be positively correlated with the structure of land ownership across 66 watersheds in the Oregon Coast Range (Figure 2). In general, we found that (1) forest cover diversity increased with land ownership diversity, (2) the size of forest cover patches in these watersheds increased with the size of land ownership patches, and (3) the connectivity of forest cover patches in these water-

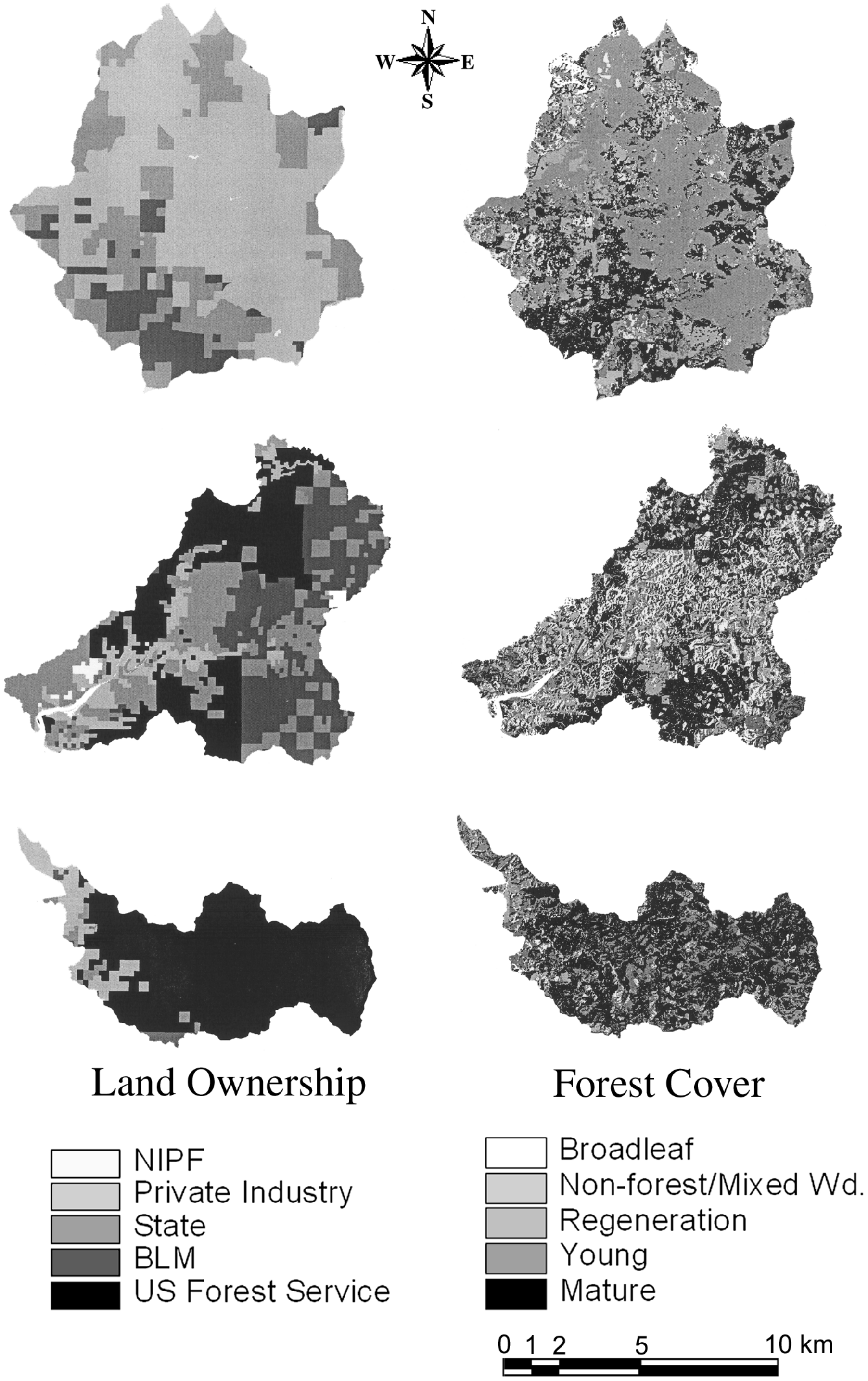
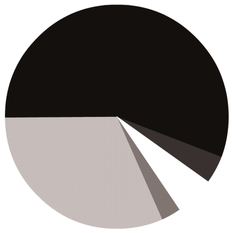
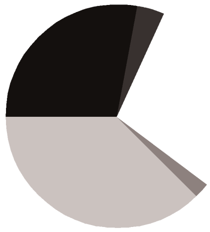
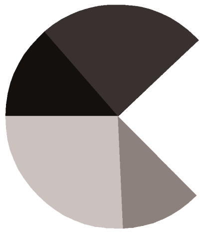
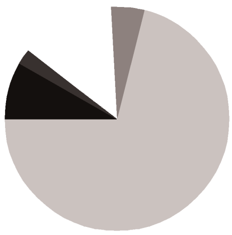


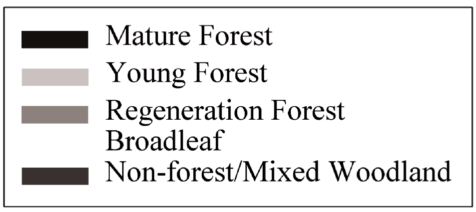
Figure 3. Land ownership and forest cover in three Oregon Coast Range watersheds; (Lower South Fork Coquille R. (top), Lower Smith R. (middle), Elk R. (bottom)).

sheds increased with the connectivity of land ownership patches.

While the physical landscape has been shown to influence land ownership patterns (Crow et al. 1999),

Table 3. Forest cover composition and connectivity in five concentrated watersheds.

Ownership Class (Watershed)	% Watershed Owned by Class	Contagion Index Rank		Forest Cover Composition
		Land Ownership	Forest Cover	
Forest Service (Elk R.)	86	Top 5%	Top 5%	
BLM (U. Smith R.)	59	Top 25%	Top 25%	
State (Kilchis R.)	83	Top 10%	Middle 50%	
Private Non-industrial (Beaver Cr.)	75	Top 25%	Bottom 5%	
Very Large Industry (Necanicum Cr.)	90	Top 25%	Top 5%	



spatial associations between land ownership and forest cover can be further explained by the distinctive contributions different ownership classes make to the overall composition of forest cover (Figure 5). Con-

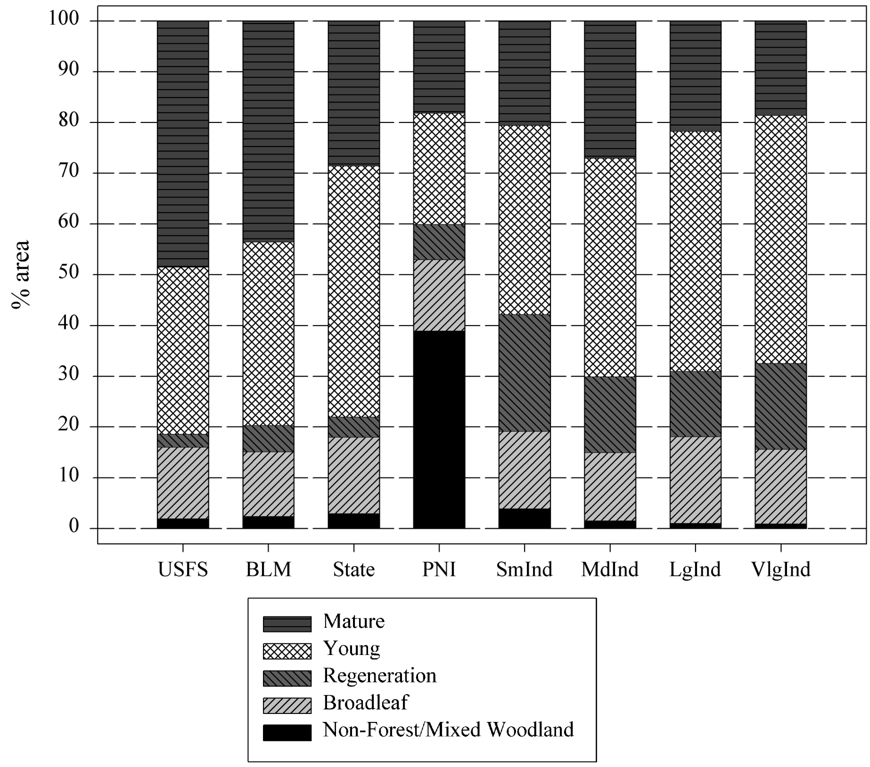


Figure 5. Forest cover composition in the Oregon Coast Range by ownership class (USFS = United States Forest Service, BLM = Bureau of Land Management, State = State of Oregon, PNI = Private Non-incorporated, Smind = Small Industry, Mdind = Medium Industry, Lgind = Large Industry, Vlgind = Very Large Industry).

sistent with previous land ownership studies in this region (Spies et al. 1994; Turner et al. 1996; Garman et al. 1999), we found lands in public (particularly federal) ownership to have the greatest abundance of mature forest cover. The four private industry classes had the greatest abundance of regeneration forest and young forest cover. Only the NIPF ownership class displayed large amounts of nonforest/mixed woodland cover. Thus different land ownership classes contribute to landscape structure by supporting different forest cover classes. The greater the mix of ownership classes in a watershed, the greater the probability that the watershed will contain a mixture of forest cover classes (Figure 3).

The contributions of different land ownership classes are also apparent where ownership is spatially concentrated. Our analysis of five concentrated watersheds showed that in three of the five watersheds forest cover patterns were low in diversity and high in connectivity (Table 3). The USFS-dominated watershed was composed of large contiguous patches of mature forest, whereas the very large industry-dominated watershed was composed of large contiguous patches of young forest. The BLM-dominated watershed was made up of a combination of young and mature forest patches. In contrast with the former three watersheds, the structure of forest cover in the state-dominated watershed showed moderate levels of diversity and connectivity, whereas forest cover in the NIPF–dominated watershed demonstrated extremely high diversity and spatial fragmentation (Table 3). The distinctively high degree of forest cover diversity and fragmentation associated with the NIPF-dominated watershed is related to the relatively small parcels held by landowners in this class and to the great diversity of management objectives, opportunities, and constraints associated with NIPF ownership (Birch 1996; Cleaves and Bennett 1995). Although watersheds dominated by the NIPF ownership class are consistently diverse and spatially fragmented throughout the Coast Range, it could be argued that the high degree of heterogeneity in these watersheds, when observed at a greater spatial scale, also forms a matrix of fairly uniform forest habitat. The key difference is that this matrix comprises forest edge.

The relatively moderate levels of diversity and connectivity present in the state-dominated Kilchis River watershed reflect the history of fire disturbance and management practices on its lands. The state acquired land in the Kilchis River watershed following a devastating series of forest fires in mid-1900's (Wells 1999). This land was aerially seeded in the early 1950s but seeding was most successful on north slopes and at high elevations (Mike Newton, personal communication), and today this watershed has a distinctive heterogeneous forest structure that mirrors its variable topography.

More than half the variability of forest structure is unexplained by land ownership; we propose four possible explanations. First, heterogeneity exists within land ownership classes because landowners within a class differ in management objectives, opportunities, and capacities. Also, landowners frequently assign a variety of allocations to land within a single property, creating heterogeneity within a single tract. Second, these landscapes span a large geographic area with a wide range of physical and biological conditions. Third, the influence of cultural, economic, and historical factors such as fire disturbance, timber harvesting, and reforestation efforts have been significant in shaping Coast Range landscapes (Robbins 1988; Stanfield 2001). Lastly, land ownership patterns are dynamic, not static.

Indeed, land ownership has changed dramatically in parts of the Oregon Coast Range over the last century (Butler and Stanfield (in press)). As ownership of forestland in an area changes, so does forest management (Heasley and Guries 1995; Stanfield 2001). The acreage in nonindustrial private forest in western Oregon has been on the decline for several decades (MacLean 1990). Moreover, forest products companies have merged, purchased NIPF land, and traded land with other companies and with government agencies in order to consolidate their ownerships. If this trend toward consolidation continues, we can expect to see more watersheds in the Coast Range resembling the concentrated watersheds examined in this study, particularly those dominated by very large industry.

Landscapes of the scale discussed in this paper (i.e., 4,288 – 78,901 ha), which have larger, more connected ownership blocks, typically have larger forest patches with greater connectivity. Such landscapes might provide opportunities for habitat management at landscape spatial scales. However, although these forest industry landscapes display the greatest connectivity of forest cover, they also host the lowest levels of forest cover diversity.

Ownership consolidation is also an issue concerning public forest owners. In particular, the checkerboard pattern of BLM and industrial forestlands might present an opportunity to achieve both ecological and economic goals through ownership swaps. Trading fragmented BLM lands with private industrial counterparts to create larger ownership blocks might increase the potential for interior habitat in some areas, but from a regional perspective, it could result in further isolation of late successional habitat. Some researchers have suggested that conservation efforts should focus on the amount of forest habitat more than on the spatial configuration of patches (Fahrig 1999). Still, policy makers must determine the ecological benefits of increasing the amount of interior habitat by concentrating ownership at the expense of losing more diverse and fragmented habitat that spans a larger geographic range.

Conclusions

We found the structure of forest cover to be positively correlated with the structure of land ownership across 66 watersheds in the Oregon Coast Range. We attribute these spatial relationships primarily to unique associations among land ownership classes and different forest cover classes. In watersheds where a single ownership class dominated, we found less diverse, more spatially connected forest cover than in watersheds where ownership was mixed. The ecological implications of concentrated ownership varied, depending on the dominant ownership class and thus the dominant forest cover class.

Generalizations made in this study are limited by the coarse resolution of our forest data. Although we discuss relationships with respect to landscape-scale diversity and fragmentation, we may be unable to detect important differences that might exist within individual forest cover classes. For instance, habitat characteristics in areas of regeneration cover might differ dramatically based on the amount of snags, coarse woody debris, and shrubs that remain following harvesting. Furthermore, different classes of landowners may value such habitat characteristics unequally, resulting in further cover diversity. Despite these limitations, we believe the relationships we have described offer valuable information to about the influence of ownership on landscape structure.

Although landscapes with highly mixed ownership patterns have long been seen as an obstacle to broad-scale ecosystem planning, our results suggest that they may be beneficial to some ecosystem components by providing a diverse array of habitats and by supporting biological diversity at a watershed scale (McGarigal and McComb 1995). Furthermore, what is seen as fragmented habitat for some organisms could also act as a semi-permeable landscape for organisms traveling between larger, more contiguous tracts of forest habitat (Mladenoff et al. 1995). The degree of landscape diversity and fragmentation desired depends on both the specific ecological objectives and the scale at which the objectives are to be realized. Because society places value on a variety of ecological functions, it may be prudent to maintain some degree of diversity among the types of forest landscapes (from fragmented to concentrated), in addition to diversity within individual landscapes. These conclusions have direct implications for federal land in the Pacific Northwest, particularly for BLM's checkerboard lands.

Adding to the complexity of existing ownership and habitat patterns are land ownership changes over space and time. In Oregon, ownership patterns are becoming more fragmented along the urban-wildland interface (Azuma et al. 1999) and more concentrated elsewhere. As public values, policies, and markets adapt to global economic and technological changes, so do the composition and spatial configuration of land ownership (Heasley and Guries 1995; Sisock 1998). Moreover, socially-sanctioned rights in property also change over time, affecting patterns of land ownership, land use, and vegetative cover (Eckert 1998). Developing a more complete understanding of the relationships between social forces, land ownership dynamics, and landscape structure will be invaluable to making the difficult land use decisions of the future.

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