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Assessing the ecological consequences of forest policies in a multi-ownership province in Oregon

7.1 Introduction

Advances in landscape ecology, ecosystem management, geographic information systems, and remote sensing have led us from the stand, to the landscape, and to broader scales in natural resources planning and management. As science and management have expanded to these scales, they frequently encompass multi-ownership landscapes. The management and scientific challenges posed by multi-ownership landscapes are especially complex. Species and ecosystems do not recognize legal boundaries between ownerships (Forman, 1995; Landres *et al.*, 1998), and the landscape dynamics of individual ownerships is controlled by a complex of economic, social, political, and biophysical forces. The aggregate ecological conditions of landscapes are controlled by the spatial pattern and dynamics of individual owners and ecological interactions among those ownerships. Solutions to problems of conservation policy and practices for multi-ownership landscapes do not lie in isolated owner-by-owner planning and management. Broader scale approaches are needed. Work in multi-ownership landscapes also reveals the need for increased integration among ecological and social sciences. In most contemporary landscapes, the dominant disturbance regimes are directly or indirectly controlled by human activities. In this chapter we will present a case study to demonstrate the importance of taking a multi-ownership view of landscapes and describe an approach we are developing to assess the effects of different forest management policies on ecological components of a province (i.e., subregion) in coastal Oregon.

7.2 Overview of multi-ownership landscape assessments and management

Interest in conservation planning, policy, and management in multi-ownership landscapes is increasing rapidly (Kreutzwiser and Wright, 1990;

Davis and Liu, 1991; Keiter and Boyce, 1991; O'Connell and Noss, 1992; Schonewald-Cox *et al.*, 1992; Turner *et al.*, 1996; Wear *et al.*, 1996; Maltamo *et al.*, 1997; Landres *et al.*, 1998). Several large regional assessments, most notably, the Southern California Natural Community Conservation Planning effort (Ogden, 1999) and the Northern Forest Lands Assessment (Hagenstein, 1999) have addressed multi-ownership regional issues. In one of the first published research studies focusing on dynamics of a multi-ownership landscape, Wear *et al.* (1996) found recent changes in social forces could result in a convergence of land cover types in a multi-ownership watershed in North Carolina. They found that forest cover increased over time across ownerships as timber management activities decreased on public and private lands. This study also found that overall landscape condition was most sensitive to land-use decisions on private lands rather than those on public lands. They concluded that the spatial arrangement of public and private lands will control ecosystem pattern and function at landscape scale.

Evaluation of these and other landscape and ecosystem management efforts indicates that the greatest obstacles for continued integration of landscape ecology into multi-ownership planning and management are not scientific and technological, but social. Yaffee *et al.* (1996) found that social opposition, institutional barriers, and inadequate stakeholder involvement were far greater impediments to progress at implementing ecosystem management than was scientific uncertainty. Often opposition to new approaches comes from misperceptions about the problem and its solutions, mistrust about whether land managers will do what they say they will do, or concerns about private property rights.

Different stakeholders often see differences in the state and direction of ecosystems and the feasibility of new approaches. However, it is questionable just how well we can really see the dimensions of large landscape issues (Lee, 1993). Our current capacity to visualize and understand the function of ecosystems over large areas and long time periods and to grasp the interdisciplinary linkages is typically inadequate. Although barriers may be primarily social, landscape ecology and new technologies can facilitate shared learning about multi-ownership landscapes and thereby foster the integration of landscape concepts into planning and management (McLain and Lee, 1996). Many significant ecological research problems remain to be solved, including understanding the effects of spatial pattern on ecological processes such as movement of disturbances and dispersal of organisms, developing ways to characterize species viability when population parameters are poorly known, finding the appropriate scale of information needed to evaluate landscape effects, and identifying landscape-scale ecological goals and criteria and indicators.

Policy-makers and managers are struggling with many kinds of cross-boundary landscape problems. Organisms such as the wolf (*Canis lupus*) in Yellowstone National Park and the upper Midwest (Mech, 1991; Mladenoff *et al.*, 1995), and whitetail deer (*Odocoileus virginianus*) in the eastern USA (Alverson *et al.*, 1994) move across ownerships and create problems when they prey on livestock or browse on crops on private lands or browse native herbaceous species in natural areas. Organisms such as salmon (*Oncorhynchus* spp.) in the Pacific Northwest, that spend their life cycle in different ownerships in a watershed, require conservation actions that can have economic impacts on private lands, e.g. leaving streamside buffers in agricultural lands and removing dams that supply irrigation water to farmers (Lee, 1997). Disturbances such as fires and floods may promote diversity and productivity of natural and semi-natural ecosystems but can cause economic losses and social upheaval in human-dominated ecosystems. Conversely, actions in human-dominated landscapes can affect natural ecosystems. Examples include the fires in Yellowstone and National Forests in the West (Knight, 1991), floods and debris flows in Oregon (Robison *et al.*, 1999), and water withdrawals for urban and agricultural uses which have affected the functioning of the Everglades in southern Florida (Ogden, 1999).

Solving multi-ownership management problems frequently comes down to finding ways to get different owners and agencies to modify or coordinate their individual behaviors to achieve some aggregate values for the landscape as a whole. This can be done through regulatory approaches (e.g., laws and policies), incentive-based approaches (e.g., subsidies or tax relief) and information-based approaches (i.e., appeals to voluntary change in behavior based on information about negative or positive effects of behavior) (Sample, 1994; Lee, 1997). Although these approaches may differ in their instruments, they all require some assessment of the ecological conditions of a landscape and the ecological and socioeconomic consequences of different courses of future action. Landscape ecology can make a significant contribution to solving complex natural resource problems by identifying the various ways in which ownerships interact in a landscape and using tools to help policy-makers and stakeholders visualize the ecological and socioeconomic consequences of their actions.

7.3 Case study: The Oregon Coast Range

We will use the Oregon Coast Range as a case study to illustrate: (1) the potential for landscape ownership pattern to have a strong effect on ecosystem goods and services within and across ownerships, (2) how integrated research can help visualize and project ecological consequences of different land management policies, and (3) the many challenges to conduct interdisciplinary research and management in multi-ownership landscapes.

7.3.1 Background

The Oregon Coast Range is an ecologically complex region of low, but highly dissected mountains, steep slopes, high stream densities and orographically related climatic zones. Forests are dominated by relatively few species: Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), Sitka spruce (*Picea sitchensis*), red alder (*Alnus rubra*), and bigleaf maple (*Acer macrophyllum*). However, physiognomic forest diversity is high because of strong differences between the structure of conifer forests and deciduous forests, and because of the large amount of structural differentiation that occurs as forests develop from young forests to 400+-year-old forests (Spies and Franklin, 1991). Extensive logging and wildfires since the mid-1800s have created a forest matrix of young and mature conifer forests interspersed with patches of hardwoods (primarily red alder and bigleaf maple) and remnant patches of old growth (structurally diverse forests typically older than 200 years) (Spies and Franklin, 1991). Current amounts of old growth are well below levels that probably occurred historically (Ripple, 1994; Wimberly *et al.*, 2000). The steep slopes, and extensive stream networks, create strong interactions between stream habitats and up-slope forest dynamics (Reeves *et al.*, 1995). Stream habitat structure is controlled by inputs of water, sediment, and large woody debris from adjacent stream banks, slopes, and small tributaries.

Threats to native biological diversity in this province are exemplified through five species that are listed as threatened or endangered by the US Government: Northern spotted owl (*Strix occidentalis caurina*), marbled murrelet (*Brachyramphus marmoratus*), coho salmon (*Oncorhynchus kisutch*), chum salmon (*O. keta*), and the Oregon silverspot butterfly (*Speyeria zerene hippolyta*). Of these five, the first four are at risk because of loss of forest and stream habitat associated with logging, forest conversion to agriculture and other threats such as predation from humans and other species. The Oregon silverspot butterfly is listed as threatened because of loss of coastal grassland habitat from development and forest encroachment. Changes in forest structure and dynamics, most notably the decline of old-growth forests with their large live and dead trees, are thought to be the major causes of risk to the populations of the four vertebrate species listed above as well as many other plants, animals, and fungi (FEMAT, 1993). Other threats to biological diversity in the province include decline in the area and quality of oak (*Quercus garryana*) woodland habitat resulting from fire loss (conifer encroachment) and development on eastern slopes of the Coast Range (Defenders of Wildlife, 1998).

The Coast Range is also a socially diverse region with a mosaic of landowner classes that operate under policies that reflect their general goals, which range from industrial commodity production to wilderness protection (Table 7.1). Of the five major landowner classes, private non-industrial landowners have the most diverse goals but they still operate under the same forest practices rules (Oregon Department of Forestry, 1996) as the industrial owners. As with industrial owners, they may choose to exceed those protection rules or not to harvest trees as all. However, non-industrial private owners have about the same propensity to harvest as industrial owners but have a greater tendency toward partial cutting (Lettman and Campbell, 1997) than industrial owners. The province is dominated by private ownership with significant blocks of public lands (Fig. 7.1, color plate). In 1993, the Northwest Forest Plan (FEMAT, 1993) brought sweeping changes to forest management on the federal forests in this province, dramatically shifting the focus of these forests toward protection of biodiversity through the creation of an extensive network of late-successional reserves and riparian management zones. This shift resulted in an 80–90% reduction of timber harvest from federal lands in the Coast Range compared to the 1980s. In the future over 75% of the harvest in the Coast Range is expected to come from forest industry lands which operate under the regulations defined by the State of Oregon Forest Practices Act (Oregon Department of Forestry, 1996). By and large, the forest policies now in effect in the Coast Range were put in place owner-by-owner with little effort to understand their aggregate effects across ownerships. These policies are based on very different approaches to management: intensive management for commodity production on private industrial lands and some non-industrial private lands; active management for multiple objectives on state forest lands and some private industrial lands; and passive, reserve-based approaches for biodiversity protection on federal lands.

7.3.2 The Coastal Landscape Analysis and Modeling Study (CLAMS)

We are currently involved in a research program that is designed to test and evaluate the effects of policies in a multi-ownership province. The Coastal Landscape Analysis and Modeling Study (CLAMS) is a large interdisciplinary effort to evaluate aggregate effects of different forest policies on the ecological and socioeconomic conditions of the Coast Range province as a whole (T. A. Spies *et al.*, unpublished data). The mosaic of different management practices creates potential spatial interactions that can affect the aggregate ecological and social conditions of the entire province. In addition, the management outcomes within individual ownerships potentially can be altered by management activities on neighboring ownerships. These spatial effects occur in two

Table 7.1. *Forest policies, goals assumed under policies, and management strategies dealing with biological diversity in the Oregon Coast Range by major ownership categories*[a]

Ownership	Policies	Goals[a]	Strategies
US Forest Service	1. Northwest Forest Plan 2. Individual National Forest Plans	To protect or produce: 1. Late succesional/old-growth Forests 2. Threatened and Endangered species 3. Aquatic ecosystems 4. Commodities	1. Reserves 2. Matrix management[b] 3. Green-tree retention 4. Stream buffers 5. Adaptive Management Areas
Bureau of Land Management	Same as above	Same as above	Same as above but with different matrix prescriptions
State Forests of Oregon	Forest Plans	To protect or produce: 1. Healthy forests 2. Indigenous species 3. Abundant Timber 4. Threatened & Endangered species protection	1. "Structure-based" management[c] 2. Habitat Conservation Plans[d]
Private industrial	State Forest Practices Act	To maintain and protect: 1. Priority to growth and harvest of trees 2. Protection of environment and fish/wildlife	1. Limited retention of individual trees 2. Limited streamside protection for fish-bearing streams
Private non-industrial	Same as above	More diverse than above but typically some level of revenue from forest land	Minimums are same as above but with greater tendency to use partial harvesting

Notes:

[a] Goals are listed in approximate order of priorities. Goals may have more than one strategy.

[b] Matrix management involves use of special silvicultural practices in areas surrounding the reserves.

[c] Structure-based management uses silviculture rather than reserves to achieve stand structure goals. This involves long rotations (120–150 years) and green tree retention.

[d] Habitat Conservation Plans are landscape management plans for Threatened and Endangered species developed in conjunction with the US Fish and Wildlife Service.

general forms: (1) Uneven representation of biotic communities, physical environments, and disturbance regimes (both managed and natural) and (2) spatial interactions of ecological processes such as organism dispersal and disturbance which move across ownership boundaries.

In the following sections, we briefly describe our general approach and present an example of a simulation model of forest landscape conditions over 100 years. We follow this with some simple analyses and a discussion of the potential ecological consequences of the mosaic of different ownership policies. Although CLAMS is an integrated ecological and socioeconomic assessment, we limit our focus to ecological effects in this chapter. We conduct our analysis directly on patterns of land ownership classes (keeping all ownership classes including the Bureau of Land Management [BLM] and the US Forestry Service [USFS] separate), which we use as a surrogate for landscape structure until more sophisticated models of landscape dynamics and ecological responses are developed. Under this assumption we will underestimate actual edge and overestimate interior habitat. However, given the extreme differences in management activities among the major ownership classes (e.g., about 90% of the federal land in the Coast Range is in an ecological reserve or special management area of some kind where cutting of trees is intended to meet restoration goals) we feel that this simple analysis can give us insights into future landscape potential.

The goal of CLAMS is to develop and evaluate concepts and tools to understand patterns and dynamics of ecosystems at province scales and to analyze the aggregate ecological and socioeconomic consequences of forest policies for different owners (Table 7.1). Our approach is based on the assumption that by knowing landscape structure and dynamics of vegetation we can project consequences of different forest policies on ecological outputs such as biological diversity and socioeconomic outputs, such as employment and recreational opportunities (Fig. 7.2). The major steps in our approach are:

(1) Build high-resolution spatial models (grain size of 0.1 to 10 ha) of current biophysical conditions (e.g., vegetation, ownership patterns, topography, streams) across all ownerships using Landsat satellite imagery, forest inventory plots, and other geographic information systems (GIS) layers.
(2) Conduct surveys and interviews of forest landowners to determine their management intentions (e.g., rotation ages, thinning regimes, riparian management intensity) under current policies and develop spatial land use change models based on retrospective studies.
(3) Simulate expected successional changes in forest structure and composition under different management regimes using stand dynamics models.

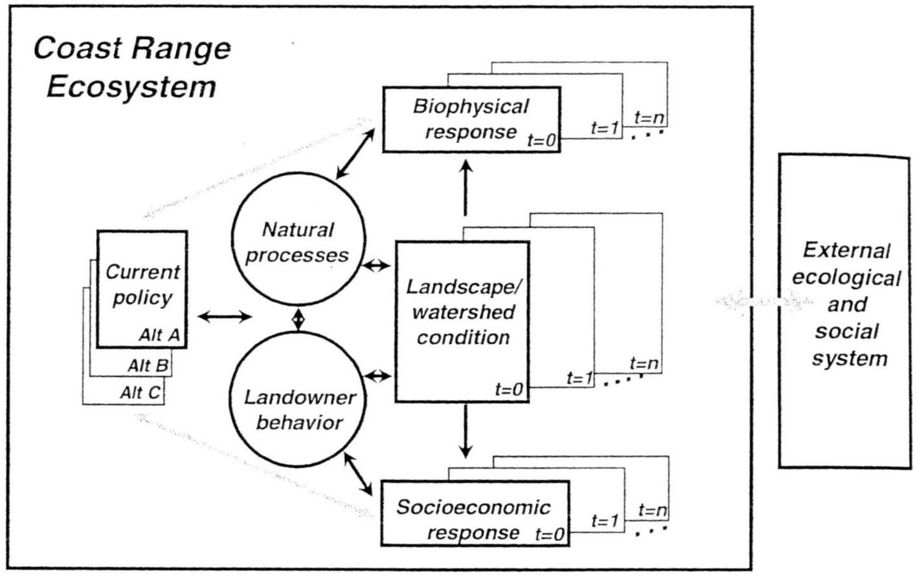

FIGURE 7.2
Coastal Landscape Analysis and Modeling Study (CLAMS) conceptual model for linking policy, ecological and social processes, landscape condition and ecological and socioeconomic outcomes to evaluate alternative forest policies.

(4) Build a landscape change simulation system based on forest management intentions and forest stand models to project future landscape structure for 100–200 years.
(5) Develop biophysical response models for habitat quality for selected terrestrial and aquatic vertebrate species, viability of selected vertebrate species, coarse-filter measures of community and landscape conditions, historical range of natural variation of forest successional stages, and landslide and debris flow potential.
(6) Develop socioeconomic response models for measures of employment and income by economic sector, timber value and production, recreational opportunities, and contingent value of biological diversity to the public.
(7) Estimate ecological and socioeconomic consequences of current forest policies using the landscape simulator and the various response models.
(8) Include outside influences such as effects of population growth on land-use change.
(9) Evaluate, test, and revise overall simulator system and sub-models.
(10) Provide policy-makers, landowners, and the public with results of spatial projections of consequences and interact with them to help inform debate and facilitate collaborative learning.

At this point in the project we are simulating only forest management-related disturbances (e.g., clear-cutting, partial cutting, thinning) and landslide and debris flow disturbances. We focus on these because they are among the most frequent in the region, potentially have large impact on measures of biological diversity, and are of great interest in policy debates. We are not simulating stochastic disturbances such as wildfire, wind, insects, and disease. Studies in the region indicate that wildfire occurs infrequently (150 to 400 years) and its spatial pattern is only weakly controlled by topography, especially for large fire events (Impara, 1997). Also, these events are likely to be even less frequent in the future because of aggressive fire suppression policies. Smaller wind and pathogen disturbances are quite frequent but they are difficult to predict and typically occur at patch sizes below our level of spatial resolution for this provincial study. We may incorporate these stochastic disturbances in future modeling efforts, either directly in the simulation model or as scenarios (e.g., effects of a large fire) for comparative analysis.

7.3.3 Projection of future landscape conditions: An example

We have developed a prototype of our landscape simulator for the Coast Range province and run it for a 100-year scenario under current policies (Table 7.1) (Fig. 7.3, color plate). Patterns of current forest condition are not uniformly distributed across ownerships. Current vegetation patterns in the province are characterized by a predominance of early and mid-sized (0–50 cm diameter at breast height [dbh] of dominants and codominants) conifer forests. Forests dominated by trees of the largest size classes (>50 cm diameter at breast height) are rare and restricted primarily to public lands. Broadleaf forests are less common than coniferous forests and tend to be concentrated in riparian areas. Old-growth forest conditions (approximately equivalent to the very large conifer class) (Fig. 7.3, color plate) are currently a small percentage of the total area and what is remaining is concentrated on BLM and USFS lands in the southwestern portion of the province. Little old growth occurs on private land, but some small remnant patches do occur and form the basis of Habitat Conservation Plans for the northern spotted owl. Conversely, open (pasturelands, meadows, agricultural lands and recent clear-cuts) and early successional stages of forest (typically forests less than 15–20 years old) occupy almost 40% of the province but are concentrated on private lands. By 50 years into the simulation of future conditions, the pattern of vegetation classes has changed dramatically. Amounts of large-dbh classes have increased, especially on federal lands, and the spatial pattern of vegetation has begun to resemble the underlying ownership pattern. Young plantations (10–30 years old) on federal lands have matured and are beginning to blend into the matrix of large conifer size classes. On private lands, intensive forest management (45–50 year rotations) keeps these landscapes cycling between early successional stages and harvest-age timber plantations. By 100 years the contrasting patterns of vegetation across ownerships are even stronger.

While total amounts of late successional forest have increased dramatically in the Coast Range in this simulation, the spatial pattern of these forests creates considerable potential edge effects and spatial pattern interactions. The simulations suggest that large watersheds of the Coast Range will develop into a mosaic of very different landscape types based on the amount and spatial pattern of forest conditions. These landscapes range from watersheds dominated by late succesional forest to watersheds dominated by early successional and mature forest plantations. Between these extremes is a wide range of mixtures of successional dominance and dispersed or blocked spatial patterns. Consequently, we hypothesize that a new landscape pattern is emerging in this province in which ownership patterns and boundaries will control patterns of biophysical processes more than in the past. The ecological and socioeconomic consequences of changing diversity and spatial pattern are the primary focus of our ongoing research efforts.

7.3.4 Spatial variation and pattern of ecosystems and ownerships

Policies and ownerships in the province are not uniformly distributed across environmental gradients and patterns of biotic communities. Different classes of ownership represent different strategies and levels of environmental protection and disturbance regimes. Consequently, in some environmental settings certain forest developmental stages and stand conditions are not well represented or could disappear. For example, in the moist coastal zone and the drier foothills ecoregions where federal ownership is 15% and 8% of the area, respectively, ecosystem conservation especially for old-growth and natural watershed processes (e.g., debris flows that deliver large woody debris to streams) is not a major management objective. However, in the interior ecoregion, federal conservation strategies cover over 30% of the area and levels of old growth may reach historical levels in this area (Wimberly *et al.*, 2000) (Fig. 7.4a). Perhaps the most important imbalance occurs in riparian areas around large lowland coastal river valleys (Fig. 7.4b). These areas were historically sites of meandering rivers with well-developed floodplains, complex aquatic habitats, and distinctive riparian forests, that were probably characterized by especially large western redcedars (*Thuja plicata*), bigleaf maples and Oregon myrtle (*Umbellularia californica*) (Robbins, 1997). They would have been highly productive habitat for many salmonid species including: Chinook (*O. tshawytscha*), coho, and chum salmon. Today nearly 70% of these lands are held by private non-industrial landowners.

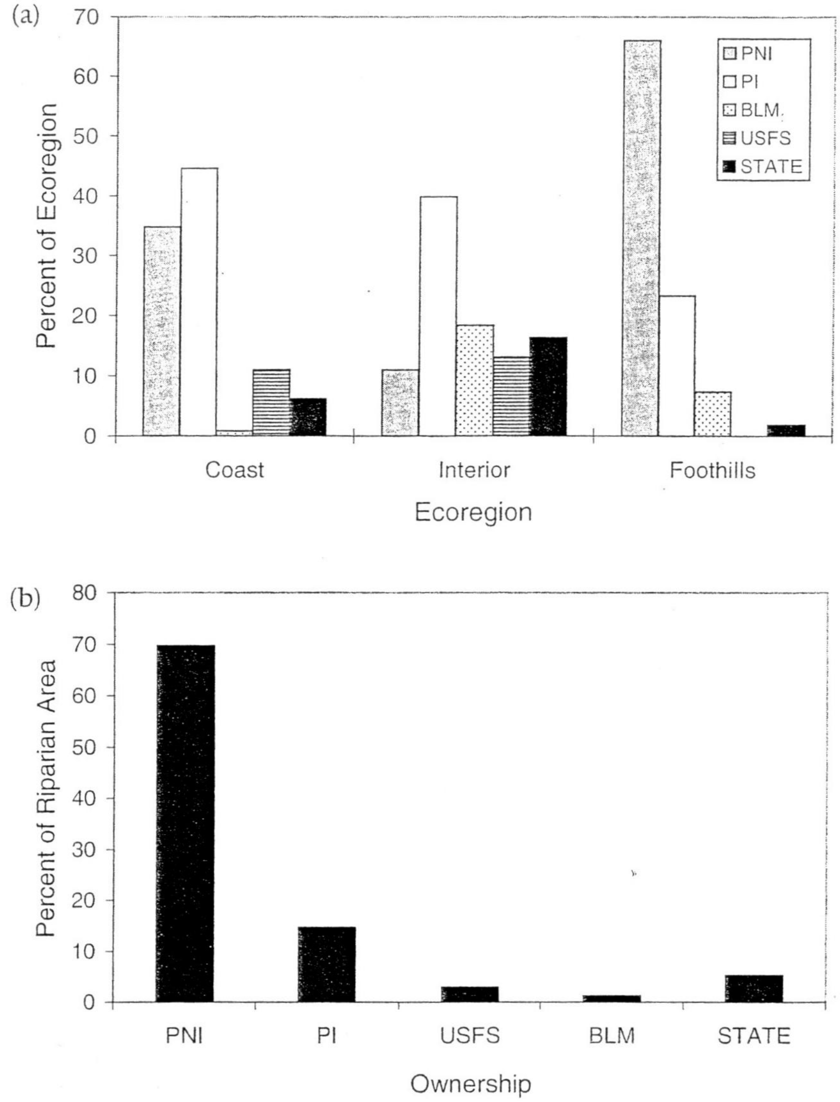

FIGURE 7.4
Frequency distribution of percentage ownership by: (a) ecoregion and (b) riparian zones along major river valleys (areas within 100 m of a river and less than 5% slope and less than 300 m elevation). PNI, private non-industrial; PI, private industrial; BLM, Bureau of Land Management; USFS, US Forestry Service.

Stream habitat here has been greatly simplified by activities related to agriculture, transportation, and urbanization that have straightened channels and removed riparian vegetation and large down wood. Consequently, the parts of the landscape that had the most diverse and productive fish habitats are among those that have been the most altered by human activity.

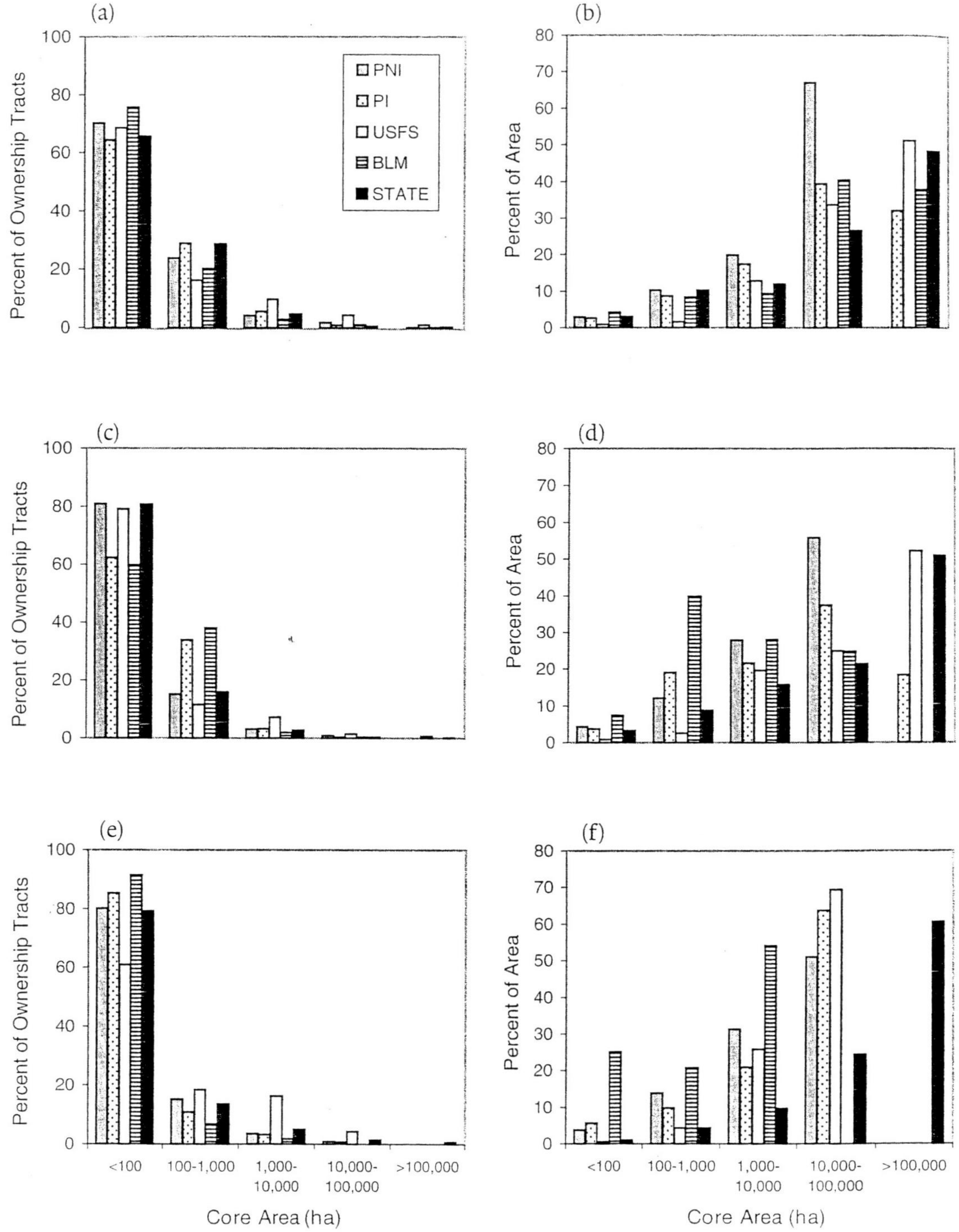

FIGURE 7.5
Size distribution of core areas for ownership classes (total area in tract and number of individual tracts) for different edge effect distances: (a, b) no edge effect; (c, d) 100 m; (e, f) 500 m. PNI, private non-industrial; PI, private industrial; BLM, Bureau of Land Management; USFS, US Forestry Service.

The individual tracts of land of ownership classes vary widely in spatial distribution and pattern. Industrial private and non-industrial private lands, which dominate in area, form the matrix which surrounds public lands. Federal lands are concentrated in the central and southwestern portions of the province. The current pattern of private and federal lands was established 70 to over 100 years ago when the now-federal lands were either recently burned-over and had low timber value or were revested to the US Government by the railroad companies following failure of federal land policies (Richardson, 1980). These revested lands now form the "checkerboard" pattern of mile-square alternating federal and private ownership that is characteristic of many BLM lands (Fig. 7.1, color plate). Large blocks of state lands occur in the north and the south. Most individual tracts of ownership classes are smaller than 100 ha (Fig. 7.5a). However, most of the area of ownership tracts occurs in large patches greater than 10 000 ha (Fig. 7.5b).

7.3.5 Spatial interactions among ownerships

A variety of landscape features and processes create potential spatial interactions among ownerships that affect the aggregate ecological conditions in the province. These spatial effects would be invisible in assessments based only on knowledge of the acreage of management actions and not their spatial distributions. The potential for neighboring ownership classes to influence conditions within a focal ownership varies by ecological process and ownership. Important landscape features and processes include edges, interior patches, roads, movement of organisms, and movement of wood and sediment. The ecological movements can be viewed as a source–sink process, a conceptual framework that helps to visualize the degree to which the ownership mosaic affects the ecological function of the province.

Edge effects

Edge effects take a variety of forms (Forman, 1995). The most important and well-documented edge effects in this region occur when tall coniferous forest stands are positioned next to shorter conifer plantations, deciduous forests or agricultural lands. In these situations edge effects can penetrate from shorter stature vegetation 50 to over 200 meters into taller stature vegetation. Edge phenomena in the region include microclimatic effects (Chen *et al.*, 1993), habitat effects (McGarigal and McComb, 1995), and disturbance, especially blowdown where tall stands are adjacent to areas of low vegetation such as clear-cuts and agricultural land (Franklin and Forman, 1987). Edge effects can also move from taller stands into shorter stands such as when tall forests shade adjacent young forests, and when ungulates forage 200–300 m into early successional stands from areas of hiding cover in tall forests (Wisdom *et al.*, 1986).

Table 7.2. *Distribution of percentage of total edge by ownership combinations and total percentage edge by ownership in the Coast Range*

	Ownership						
Ownership	PI	PNI	State	Bureau of Land Management	US Forestry Service	Miscellaneous	Total
PI	—	32.6	8.6	25.9	5.2	2.3	74.6
PNI	—	—	5.5	6.9	6.1	2.1	53.2
State	—	—	—	2.1	0.6	0.6	17.4
Bureau of Land Management	—	—	—	—	0.8	0.5	36.2
US Forestry Service	—	—	—	—	—	0.3	13.0
Miscellaneous[a]	—	—	—	—	—	—	5.8

Notes:

[a] Miscellaneous owners such as Indian tribes and counties.

The edges created by disturbances to stands are dynamic and move around the landscape depending on the rate of disturbance and the rate of regrowth of the disturbance patches. Boundaries created by ownerships also form a type of edge whose ecological effects are dependent on the degree of differences in management regimes across the ownerships. Although individual management disturbances can shift around the landscape, over time ownership boundaries can be thought of as a long-term dynamic edge whose ecological effects reflect the differences in cumulative effects of activities on either side of the boundary. Given the highly contrasting management regimes of the ownerships (see section 7.3.3), the ownership class boundaries should be a good indicator of long-term edges. The potential for edge effects derived from ownership boundaries is large – there are 24161 km of boundary edges between ownership classes, not including the edges of the province itself. Of the total boundary edge the largest percentage (65.4%) occurs among three ownership classes: private industrial, private non-industrial, and BLM (Table 7.2). Of the total of all boundary edges, 74.6% includes private industrial boundaries, 53.2% includes non-industrial private boundaries and 36.2% includes BLM boundaries. USFS boundary edges form only 13% of the total edge among ownerships in the province. Not surprisingly, edges involving the matrix of private lands constitute the vast majority of potential edge in the province (62.6%). Of course, boundary edges underestimate the total edge in the province, since edges will form between individual ownerships within a class and between forest patches within an individual ownership.

Interior area patch sizes

Some species may be favored by large patches of interior coniferous forests in the region but it is not clear if the species are responding to the total amount of habitat patches or sizes of patches/amount of edge. These include species such as the northern spotted owl (Carey *et al.*, 1992; Ripple *et al.*, 1997) and brown creeper (*Certhia americana*) (McGarigal and McComb, 1995). The stability of large forest habitat patches is probably greater than small ones because edge effects from windthrow, fires, and microclimatic change are minimal. Just as with ownership boundary edges, the size of ownership tracts serves as a rough indicator of the potential for interior patch conditions to develop across the province. These can be either large patches of early-mid successional conditions or mid to late successional conditions, depending on the ownership and their management objectives. The size distributions of potential core areas of tracts of ownerships vary by the amount of edge effect that is assumed. BLM lands show the greatest impact of potential edge effects on core area size distributions (Fig. 7.5c–f). Assuming no ownership boundary edge effects, all ownerships have the majority of their total ownership areas in tracts of at least 10 000 ha (Fig. 7.5b). When potential edge effects are taken into account, the proportion of core areas shrinks on all ownerships but changes most drastically for BLM lands, which occur primarily as small blocks in the checkerboard landscape. USFS and State of Oregon lands, on the other hand, maintain large core area ownership blocks when ownership boundary edge effects are assumed.

Roads

Roads have widespread and poorly understood impacts on many ecological processes (Forman and Alexander, 1998). Roads create edge effects for animals and people. Road densities in watersheds of the province range from less than 1 km/km^2 to over 3 km/km^2. Elk and deer avoid roads and habitat quality for elk is estimated to be reduced by half when road densities exceed 1 km/km^2 (Wisdom *et al.*, 1986). Some human recreational experiences are also lost by proximity to roads. For example, according to recreational opportunity spectra (Driver *et al.*, 1987) the primitive recreational class of experiences requires a distance of at least 2.4 km from any road. Less than 0.05% of the Coast Range would meet this criterion. Of course, roads also provide the access benefits for other types of recreation.

Movement of organisms

Movement of organisms among ownerships and landscape elements in the Coast Range occurs in two primary forms: diffuse and directional. Terrestrial animals, propagules, forest pathogens, and fire move by diffuse or non-directional movements. Fish, landslides, debris flows, floods and spread of some non-native species exhibit movements constrained by landscape features (directional movement). In some cases organisms may also move in both ways and to some extent the distinction is scale-dependent. Individual movements of animals may be directional but aggregate movement of populations may appear diffuse.

Diffuse movement by animals occurs at different scales: within home ranges, by dispersal of subadults to new areas, and by migration in and out of the province. All three types of movement occur at scales that interact with the ownership patterns of the Coast Range. Terrestrial vertebrates in the Coast Range have a spectrum of home ranges from a small fraction of a hectare for Ensatina salamander (*Ensatina eschscholtzi*) to over 5000 ha for a black bear (*Ursus americanus*). Dispersal characteristics are not known for many species, although minimum distances are assumed to be several times the diameter of a home range (Forman, 1995). Home ranges of spotted owls in the province range from an average of 1500 ha for owls in relatively unfragmented landscapes to over 2900 ha in fragmented landscapes (Carey *et al.*, 1992). For juvenile owls, median dispersal distances range from 12 to 25 km in the Coast Range (Forsman *et al.*, in press). These movement areas and distances exceed the boundaries of most blocks of ownership in the province.

Relatively little is known about dispersal of vascular plant, lichen, and fungi propagules. For many of these organisms most dispersal is very local and would be contained within ownership blocks. For example, Schrader (1998) studied the distribution of western hemlock seedlings in closed canopy forests in the Coast Range and concluded that most hemlock seeds disperse within 20 m of a potential parent tree. While lichens can disperse great distances, some such as *Lobaria oregana* effectively disperse over short distances through fragmentation of tissues when broken thalli are blown by wind from source trees to adjacent trees (B. McCune, personal communication). Consequently, this species and several other lichen species are at risk in managed landscapes because they are very slow to recolonize clear-cuts from refugia in older tree canopies (FEMAT, 1993).

Pathogens such as Swiss needle cast (*Phaeocryptopus gaumannii*), a recent serious forest management problem, have spread across several ownerships in the northern Coast Range in recent years (Campbell and Liegel, 1996). This fungal disease, which causes needles to yellow and die, drastically reduces the growth rates of Douglas-fir stands and occurs primarily on the moist ecoregion of the Coast Range. A native organism, it appears to have reached outbreak levels as a result of a combination of factors including widespread planting of Douglas-fir stands in moist climatic sub-regions and a wetter climate cycle in recent years. The infestation began in young forest plantations of non-local stock and has spread to other plantations. Initially it occurred only in younger stands but recently it appears to be spreading to stands of old trees on public lands (G. Filip, personal communication). Spore loads may have built up on younger stands to the point that the fungus is overwhelming the resistance of older native stands in other parts of the landscape.

Roads provide another mechanism for directional movement of organisms, especially non-native plant species. Distribution of invasive, non-native woody plant species such as Scotch broom (*Cytisus scoparius*) and Himalayan blackberry (*Rubus discolor*) is correlated with distance from roads and they appear to have spread through the province along major highways. Roads are also associated with the spread of *Phytophera lateralis*, a root fungus that kills Port Orford cedar (*Chamaecyparus lawsoniana*; Zobel *et al.*, 1985), a highly valuable species that occurs in the southern part of the province. The spores of the fungal disease are transported in flowing water and during the wet season can be transported on the hoofs of elk and cattle and on the tires of construction and logging machines.

Anadromous salmonids are good examples of organisms that exhibit directional movement since they migrate in and out of this province, between the Pacific Ocean and their spawning and juvenile rearing habitat. Salmonid species differ in the distance that adults swim up into a coastal stream network to spawn. Since cutthroat trout (*O. clarki*) and steelhead trout (*O. mykiss*) use smaller, steeper streams, these species generally migrate further inland. They frequently must cross non-industrial private (primarily agriculture) and private industrial forest ownerships to get to their spawning and rearing habitats, which are often concentrated, higher in watersheds on federal lands. The young spend one to two years in these streams before they move down into larger streams and rivers where they remain for up to a year before moving into the estuary and open ocean (Peterson, 1982). In contrast, chum and chinook salmon use habitats that are in the lower portions of rivers nearer the ocean where channels are usually larger and less steep, and are typically on private lands.

Movement of wood and sediment

One of the strongest spatial interactions and most important management issues in the Coast Range is the delivery of large wood and sediment from forested uplands to streams. These elements create stream channel complexity, which is important for salmonid spawning and rearing habitat. Large wood is especially important in creating channel heterogeneity in high gradient, high peak flow streams of the Coast Range. Wood gets into streams through two mechanisms: (1) the fall of streamside trees into streams, and (2) debris-flow-generating landslides. Although landslides and debris flows can reduce the quality of spawning gravels in the short term, inputs of large wood and coarse sediments to streams are important to maintaining habitat quality for species in the long term (Everest *et al.*, 1987; Reeves *et al.*, 1995).

Once a landslide occurs in these steep mountain landscapes it may become a debris flow of water, sediment, and wood moving down through stream channels. Its final resting place depends on stream gradient and stream junction angles among other factors (Benda and Cundy, 1990). Landslide-debris flows typically travel about 200–300 m with a maximum travel distance of about 2500 m (Robison *et al.*, 1999); consequently, a significant number could initiate in one ownership and be deposited in a different one.

Source–sink processes

Another way to conceptualize ecological movements in the Coast Range is as source–sink processes in which some parts of the landscape are net sources of organisms and matter and others are net sinks (Forman, 1995). In many cases these transfers will cross boundaries and some ownerships will be sources and some will be sinks, depending on the process and the intervening landscape structure.

Organisms such as deer or fungal pathogens have great potential to move out of private industrial and private non-industrial lands (source areas) and influence large areas on public lands (sinks) (Table 7.3). For example, 89% of BLM lands could be affected by organisms or processes that move 1000 m out from the margin of adjacent private industrial lands. Nearly 100% of BLM lands would fall within 5000-m movements out of private lands. Conversely, the federal lands have relatively little potential influence over private lands: only 7% and 36% of private industrial lands would be influenced by processes that move 1000 m out from the margin of USFS and BLM lands, respectively. Possible candidate organisms for these flows from private lands to federal lands include deer and elk, early successional and non-native plant species that might build up in areas of high road density and highly disturbed agricultural lands, genes from genetically altered commercial tree species and pathogens such as Swiss needle cast that could originate in relatively uniform plantations of Douglas-fir. Organisms that might move from source areas on federal lands to sink areas on private lands include the northern spotted owl and other species of late-successional forests.

Landslides and debris flows that carry large wood and sediment to streams are an example of directional source–sink phenomena that can cross ownership boundaries. Source areas for delivery of large conifer wood via landslides in coastal stream networks are steep concave headwall areas that fail periodically during high rainfall periods. These parts of the stream network are also

Table 7.3 *Estimate of percentage of sink ownerships influenced by hypothetical inputs from other organisms and processes from adjacent source ownerships for different distances of movement*

	Sink ownership				
Source ownership	Private non-industrial	Private industrial	Bureau of Land Management	US Forestry Service	State
100-m distance					
Private non-industrial	—	7	5	5	4
Private Industrial	11	—	17	5	6
Bureau of Land Management	2	6	—	1	2
US Forestry Service	2	1	1	—	0
State	2	2	1	0	—
1000-m distance					
Private non-industrial	—	46	36	47	29
Private Industrial	66	—	89	42	43
Bureau of Land Management	22	36	—	11	11
US Forestry Service	9	7	4	—	3
State	15	18	13	6	—
5000-m distance					
Private non-industrial	—	88	87	99	80
Private Industrial	96	—	100	100	93
Bureau of Land Management	60	64	—	60	37
US Forestry Service	17	18	17	—	10
State	55	60	45	48	—

places where the highest densities of large live conifers develop (Pabst and Spies, 1999) and where dead wood frequently accumulates from tree falls from steep adjoining hillslopes. It is possible, using information about topography and stream network patterns, to develop a prediction of which source will have sink areas for wood within fish-bearing stream channel segments. The degree to which source–sink processes for large wood delivery in streams interact with ownership can not be assessed without high-resolution digital elevation models (DEMs), stream network maps, and GIS models that identify potential landslide sources and debris-flow paths, and maps of forest structure. However, a simple analysis of ownership patterns of potential debris-flow source areas can be made by examining the distribution of ownership by slope class. In this analysis, areas likely to contain landslide prone sites (>30% slope) within the province are disproportionately owned by federal and state agencies (57% of steep areas vs. about 37% of all lands in the province). (This slope steepness analysis should be viewed with caution because the 30-m DEMs on which it is based will underestimate the area of steep slopes.) Conversely, topographically low areas which contain sites where debris flows would stop are disproportionately owned by private non-industrial and industrial landowners. It seems clear many sources of landslides reside on federal lands and many of the potential sinks occur on private lands. Additional important source areas of wood to streams occur in riparian areas immediately adjacent to all streams. Where large trees have been removed from these areas through harvesting, the potential source of large wood for streams will be absent.

Road networks can also be a source area for landslides that affect streams and define flow paths between uplands and stream networks. Analysis of erosion events in recent floods in the Oregon Cascades indicate that roads in midslope and ridge-top positions are net sources of sediment and debris flows while roads along valley floors tend to trap sediment and restrict the movement of debris flows before they reach streams (Wemple, 1998). Road networks may also act to expand the drainage network of a watershed, and increase the magnitude of peak flows after storm events (Jones and Grant, 1996).

7.4 Lessons learned

At this point in our effort we have learned as much about conducting integrated regional assessments as we have about the region we are studying. The lessons learned from conducting integrated assessments include both improved understanding of ecological issues at this spatial scale and the process of conducting interdisciplinary research.

7.4.1 Potential ecological effects

We have learned that recently enacted policies in the Oregon Coast Range have the potential to create novel landscape patterns of vegetation and dynamics. We hypothesize that in this emerging landscape, the complex ownership pattern, contrasting management regimes, and ecological processes create the spatial interactions that could not be predicted based on information from individual ownerships in isolation from each other. While the preceding simple analysis of the ownership patterns indicates a strong potential for aggregate effects in this province, more detailed analyses are needed to test the degree and distribution of these effects. The spatial interactions that we expect will have greatest impact on the ecological systems of this province are the following:

(1) Imbalances and gaps in seral stage distributions across environmental strata including sub-ecoregions, watersheds, and topographic positions.
(2) Gaps in distribution of habitat of relatively wide-ranging species (such as the northern spotted owl or salmonids) whose movement occurs at scales similar to that of ownership tracts and management allocations within ownerships.
(3) Decline in aquatic habitat quality in some stream reaches and watersheds where private lands occur upstream and sources of wood from debris flows are lost because of intensive forest management practices.

7.4.2 The process of building integrated provincial-scale models

The importance of problem definition and conceptual model

Without adequate problem definition and a conceptual framework, integrating landscape ecology and management issues (e.g., watershed management, old-growth forest conservation) can degenerate into separate studies that will ultimately fall short in meeting management needs. For example, in our early efforts at framing our conceptual model we discovered that we had no direct link between measures of biodiversity and socioeconomic values. Consequently, we initiated a survey of how the public valued different types and strategies of biodiversity conservation (e.g., salmon habitat protection, biodiversity reserves).

The importance of policy-makers and policy questions

Without incorporating policy-makers and specific policy questions into the research at the beginning, the potential for the research to be relevant to policy and management questions will be diminished. In dealing with multi-ownership landscapes it is extremely important to have the support of state and federal agencies. The research must also be very sensitive to private property issues and interagency institutional policies if the research is to be taken seriously and used. We have met repeatedly with representatives from forest industry to communicate our intentions, get information about their management practices, and build trust and understanding of the assessment model we are building.

The challenge of spatial information about landscapes and regions

Gathering spatial information about large landscapes and regions can be an enormous undertaking. Much of the resources for a project can be consumed in compiling spatial data bases with adequate quality to meet scientific standards and address relevant questions. In most cases, information about the accuracy of spatial information will not be available and if available, it is not always clear what level of accuracy is needed. Some spatial information such as road locations can require cooperation of private landowners.

The value of landscape projections

Spatial projections of future landscape patterns are a very powerful way to communicate landscape issues to policy-makers, managers and the public. Maps of possible future states create much interest in stakeholder groups and can foster communication and understanding. However, landscape projections should be viewed more as a simulation experiment or a type of sensitivity analysis of policy instruments than a real forecast of future conditions. Projecting the future of complex ecological and socioeconomic systems for 100 or more years requires many simplifying assumptions that should be made clear to any user.

The challenge of measuring ecological effects

Developing landscape- and regional-scale measures and models of ecological responses is a major challenge. Empirically based response models (e.g., based on logistic regression) may be useful for some areas and situations but are typically inadequate for large landscape or regional studies of multiple organisms or processes for which data do not exist. Ecologists will have to work as paleontologists do, with only a few "bones" of knowledge of an ecosystem and will have to fill in the pieces of the larger ecosystem "skeleton" without the benefit of field or experimental research. These gaps in our knowledge will be filled from theory, expert judgment, a few empirical studies, and simulation models (i.e., computer experiments). In some cases it might be possible to conduct field studies to fill in critical information needs or verify model performance, however, resources will typically not be adequate for extensive field studies over large areas.

The challenge and importance of scale

Integrated studies of large landscapes are fraught with scale problems. The spatial and temporal scales of ecological, policy, and socioeconomic processes and measures typically are not the same. The spatial scale and resolution of simulation models may not match that of data available to characterize the current or initial conditions of a landscape. For some processes, it may not be clear what scale and resolution are needed for adequate representation. Dealing with scale problems cannot be done in a single planning effort at the beginning of an assessment. Continuous attention to scale is needed to find ways to ensure that changes in one component will not create scale or resolution mismatches with other components.

Integration occurs at many levels and takes many forms

Integration is central to all aspects of landscape assessments, from developing the conceptual model to linking data bases to social interactions in a multidisciplinary team to working with different institutions. All scientists practice integration at some level, but not all scientists have the interest or time to attend to the integration needed to link landscape ecology and management in a significant way. Some scientists must pay attention to the broad-scale integration problems (ecological–social integration; institutional issues; dynamics of scientist–manager teams) if landscape ecology is to be useful in natural resources management and policy.

Conducting science in a public policy environment

Applying landscape ecology to large multi-ownership areas of the earth is not something that can be done solely within a research laboratory or an academic institution. If landscape ecology is to become relevant to natural resource issues, scientists must learn to interact with policy-makers, managers, and the public. In some cases these interactions simply may be keeping these groups informed of progress and results, in other cases the interaction can be much more involved. For example, stakeholder groups can be invited to suggest questions to address or even invited to participate in building the conceptual or computer models. These interactions can take a lot of time and be threatening to scientists and the normal process of science, but they can also help ensure the relevance and use of the results of the work. At the same time, there is a risk that segments of the public with a large stake in the outcome will attempt to manipulate the process. Consequently, engaging the public needs to be done carefully.

7.5 Implications to policy and management

Principles and empirical studies from landscape ecology indicate that policies and management actions within individual ownerships may not necessarily achieve their objectives because of effects of adjacent owners. As our simulations indicate, long-term effects of forest policies in multi-ownership landscapes can result in highly contrasting landscape patterns. The effects of this juxtaposition of habitats are not well known and require further research and monitoring. In our experience, monitoring should focus on factors such as environmental representation of ecosystems, edge effects, interior patch sizes and distributions, roads, movement of organisms, movement of energy and materials such as water, wood, and sediment, and disturbances such as fire. It appears that some organisms could occur on ownerships on which they would not otherwise be found because of the occurrence of source habitat on adjacent ownerships. These effects may be both desirable and undesirable depending on the effect and ownership. For example, spotted owls, nesting on federal lands, could use adjacent private industrial lands for foraging or dispersal of young. Thus, private lands may contribute to the overall viability of this and other species. On the other hand, actions on private lands might decrease quality of habitat on public lands and some pest organisms or disturbances that originate on one ownership may spread to adjacent ownerships. The condition of aquatic habitat within a multi-ownership basin will probably depend on the ownership patterns of key stream reaches (e.g., low gradient unconstrained streams) and woody debris source areas within a watershed. In watersheds with a diversity of owners, conservation practices will need to be based on involvement of many owners if watershed goals are to be met.

The recognition of the ecological effects of multi-ownership landscape mosaics places pressure on state and federal agencies to develop policies that take these cumulative landscape effects into account. No current policies specifically mandate multi-ownership planning and no public agencies have the broad authority over it. However, some limited multi-ownership planning activities are beginning. For example, the State of Oregon has developed a salmon recovery plan based on watershed councils that are charged to develop voluntary approaches to conserving salmon based on watershed management. This and other efforts pose a major challenge to government agencies and the public to balance competing values, mandates to protect biological diversity, and private property rights. Some policies and laws may work at cross-purposes. For example, anti-trust laws might prevent large timber companies in the Coast Range from coordinating their activities to achieve overall landscape goals.

It is difficult to identify specific practices that can mitigate negative effects within boundaries and enhance positive effects outside of boundaries. Much depends on the particular political, socioeconomic, and biophysical context of a multi-ownership landscape and of course, the goals and objectives of the particular landowners and management agencies. However, specific actions can be grouped into three major categories: (1) those that affect the underlying ownership pattern, (2) those that unilaterally change ecological conditions within a single focal ownership, and (3) those that involve changes of conditions on two or more ownerships. We will briefly describe some examples of these from the perspective of a public land agency whose goals include maintenance or restoration of natural and semi-natural ecological systems.

Land exchanges and purchases can be used to alter the fundamental pattern of ownership on a landscape. These may be done to block-up dispersed ownership units to create more core area or to obtain particular ecosystem types that are not well represented within the current ownership. Public land management agencies have been doing land exchanges for years but have typically not done so with specific landscape ecological concerns in mind.

Ecological conditions within an ownership can be modified unilaterally to buffer against outside influences. For example, forest management activities can be zoned to create a gradient of management intensity that decreases from the edge to the interior of an ownership block (Harris, 1984). It may be more possible to mitigate and slow the spread of invading species or to stop the spread of wildfire into natural areas if they are positioned near the core of public ownership blocks than if they are on the margins. Effects of grazing wild and domestic animals can be mitigated through fencing; tree windbreaks can be used to reduce erosion or facilitate invasion of desirable species (Mitchell and Wallace, 1998; Harvey, 2000). The challenge of unilateral changes (in absence of coordination among owners) will be to determine how much policies and management actions within an ownership block should be modified based on conditions or management plans on adjacent lands. Since management goals and plans and owners are likely to change over time, one strategy may be to assume a worst-case effect of outside ownerships on resources within a focal ownership. This assumption was used in conservation planning for federal forest lands in the Pacific Northwest (FEMAT, 1993). This approach might result in a relatively low-risk strategy for sensitive resources within an ownership but it might not be the optimal strategy when a diversity of owners and resource goals are considered.

Ecological conditions outside a focal ownership can be modified through negotiations among two or more landowners. These kinds of efforts often include county, regional, or state-level planning and consensus groups such as watershed councils. In many cases effective cross-boundary resource management is in its infancy, even in places such as the Greater Yellowstone Ecosystem, where these types of efforts have been going on for over ten years (Glick and Clark, 1998). However, some successes have been reported (Propst *et al.*, 1998). For example, areas of private lands can be identified to help maintain natural and semi-natural conditions outside public lands and reduce contrasts in vegetation structure at borders of public and private lands. These actions require, of course, funds to purchase lands or conservation easements or incentives for voluntary actions on private lands. Flow of energy and matter through multi-ownership landscapes can be controlled through practices such as road closures and modification of riparian vegetation to increase shade and lower stream water temperatures in downstream reaches in a watershed. In Oregon, the Oregon Department of Forestry has imposed limitations on logging on steep slopes, which may reduce risk of landslide and debris flows across a drainage network (Oregon Department of Forestry, 1996).

7.6 Summary

Multi-ownership landscapes pose significant opportunities and challenges to the integration of landscape ecology into natural resource planning and management. Basic principles of landscape ecology can be used to demonstrate the importance of taking a multi-ownership perspective. For example, evaluation of patterns of environmental variation and ownership, edge effects, and spatial interactions, including source–sink phenomena in the Oregon Coast Range Physiographic Province, demonstrates how ownership patterns control the ecological potential of whole landscapes and regions. In this landscape, some ownerships such as the Bureau of Land Management are potentially quite sensitive to effects of activities on adjacent owners because of highly fragmented pattern of patches and high edge density. Recent changes in forest policy in this province will result in a divergence of landscape conditions among ownership blocks over time and an increase in the effects of ownership pattern on aggregate ecological conditions. Analysis of the dynamics and pattern of multi-ownership landscapes requires integration among ecological and social disciplines which is a major challenge to scientists and managers. Landscape ecology can play an important role in this social process through analyses and visualization that help policy-makers, managers, and the public understand the consequences of individual owner decisions across multi-ownership landscapes. We described an interdisciplinary research effort in Oregon, the Coastal Landscape Analysis and Modeling Study (CLAMS) that is attempting to meet this need.

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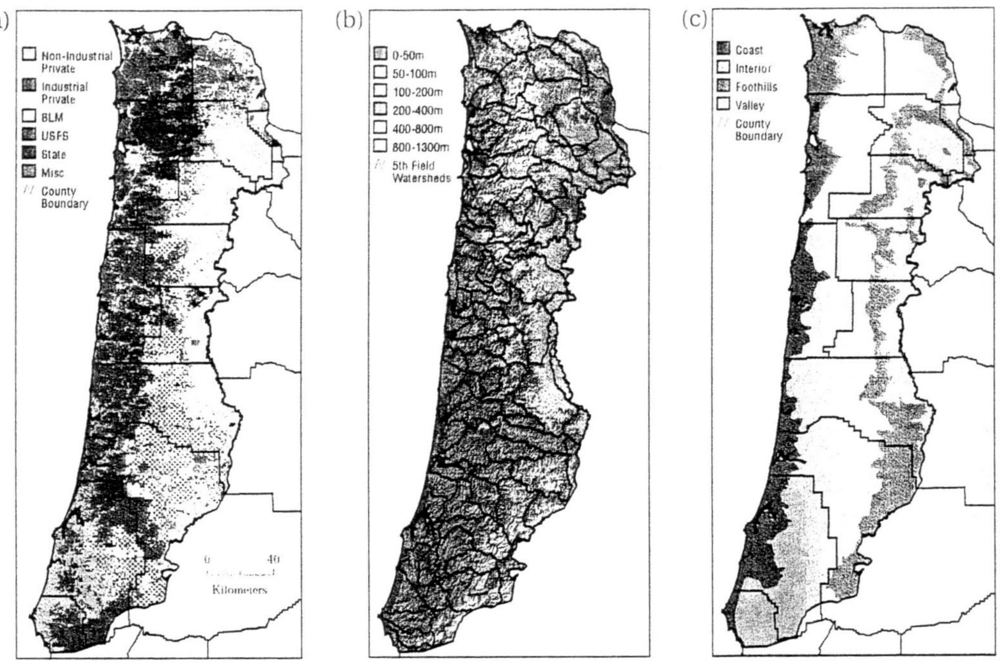

Fig. 7.1. Patterns of (a) major ownerships, (b) topography (elevation in meters), and (c) ecoregions in the Oregon Coast Range Province. Abbreviations: BLM, Bureau of Land Management; USFS, US Forest Service; Misc, miscellaneous owners. (Modified from Pater *et al.* 1998.)

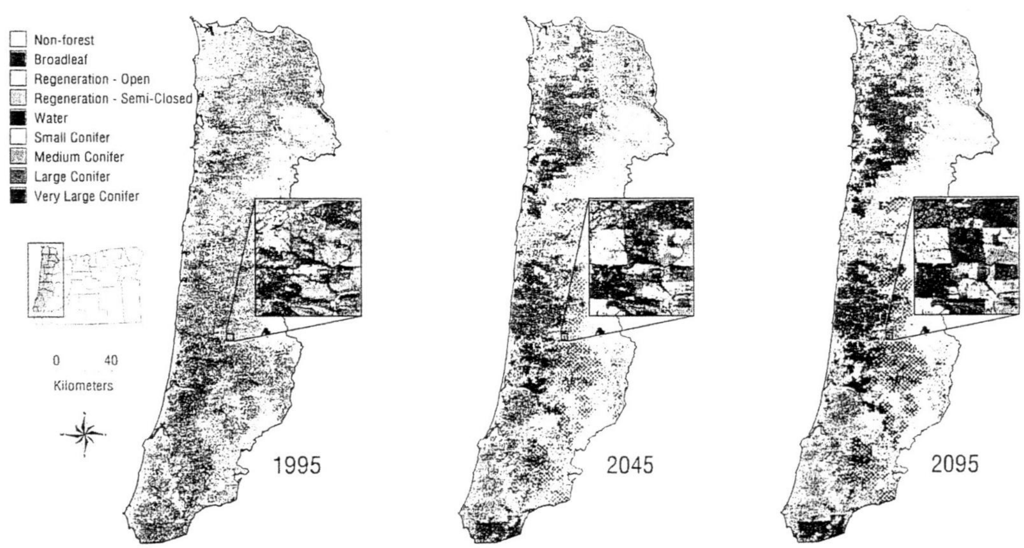

Fig. 7.3. Initial vegetation condition and simulation model projections of future conditions at 50 and 100 years into the future. Broadleaf is total vegetation cover >70% and >70% of which is broadleaf cover, Open is <40% total vegetation cover, Semi-closed is 40–70% vegetation cover, Conifer is >70% vegetation cover and at least 30% of which is conifer cover, Small is dominant and codominant trees <25 cm diameter at breast height (dbh), Medium is 25–50 cm dbh, Large is 50–75 cm dbh, and Very Large is >75 cm dbh.

CAMBRIDGE Studies in Landscape Ecology

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