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Effects of spatial scale on the perception and assessment of risk of natural disturbance in forested ecosystems: Examples from Northeastern Oregon

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Abstract

The perception and measurement of the risk of natural disturbances often varies depending on the spatial and temporal scales over which information is collected or analyzed. This can lead to conflicting conclusions about severity of current or past disturbances or the risk of future ones. Failure to look across scales also complicates local implementation of policies developed from broad-scale perceptions of risk because perception of risk is relative and depends on context. Methods that help policymakers, managers, and the public look across spatial and temporal scales can improve their understanding of the long-term dynamics of disturbances like wildfire and insect outbreaks. This capability provides a foundation for prioritizing restoration management activities, especially in forest types prone to frequent or severe disturbances. Although techniques for estimating risk over increasingly large spatial scales are becoming more widespread, the connection of risk assessments from broad to fine scales is not well established. We use a synthesis of five existing analyses to illustrate how scale affects the perception and interpretation of risk as information, models, and findings are stepped down from broad scale (interior Columbia basin) to mid scale (parts of a river basins) to fine scale (watersheds). We present results from the Interior Columbia Basin Ecosystem Management Project (ICBEMP) and the Interior Northwest Landscape Analysis System (INLAS) efforts that compare wildfire risk and other resource attributes. Our findings compare action and no-action alternatives to illustrate the use of multiple-scale "step-down" analysis for understanding the relation of broad-scale policy to the feasibility and impact of local management.

Keywords: Landscape analysis; Risk; Forest management; Wildlife; Wildfire; Wood products

1. Introduction

Ecologists are increasingly aware of the importance of conducting analyses that match the spatial and temporal scales of the ecological processes they are considering (Liu and Taylor, 2002). It is also important

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to look across scales as management plans are developed. Allen and Hoekstra (1992) suggested that examination of ecological processes at any one scale provides information and understanding that may not be apparent at coarser or finer scales. Haynes et al. (1996) discussed the partitioning of risk across scales. We contend that conducting multiscale analyses improves policymakers' and managers' ability to identify and understand various sources and types of risk.

In the case of wildfire risk, analysis at broad scales may provide a regional understanding of fire regimes, fuel patterns, and human habitation that can be used for broad-scale prioritization. Mid-scale analyses often reveal that the conditions in a particular area do not fit generalized broad-scale patterns, requiring adjustment of proposed broad-scale management approaches. Fine-scale analyses may emphasize spatially explicit factors such as the juxtaposition of ownership patterns and the spread characteristics of wildfire as it relates to topography, local weather, and site-specific fuels. Analyses at mid and fine scales may or may not require modification of proposed broad-scale approaches to achieve desired fire risk reduction objectives. In any case, mid- and fine-scale analyses help community leaders and agency officials evaluate alternative treatments and compare actual hazards in landscapes surrounding communities.

In the United States, federal government legislation such as the Endangered Species Act of 1973 (ESA, 1973) and the Healthy Forest Restoration Act of 2003 (HFRA, 2003) are based on a broad-scale perception of risk. A growing problem for policymakers and natural resource managers is that these laws do not provide explicit guidance about how to connect the outcomes of specific management activities at the "project scale" (a few hectares to tens of thousands of hectares) to the perception of risk across vast spatial expanses (e.g., states, United States Forest Service Regions, large ecological units like the Columbia Basin or Sierra Nevada region, etc.). Nor are they explicit about how to consider changes in conditions that occur over the decades or even centuries required for ecological processes to "play out."

In recent years, substantial progress has been made in developing methods to consider conditions and the consequences of management across large landscapes. Two good examples are Interior Columbia Basin Ecosystem Management Project (ICBEMP; Quigley and Arbelbide, 1997), which provides context (but not policy direction) for management over a large part of the US Pacific Northwest, and the Northwest Forest Plan (USDA and USDI, 1994), which provides policy direction for management on most federal land within the range of the northern spotted owl (*Strix occidentalis caurina*) and marbled murrelet (*Brachyramphus marmoratus*) in Washington, Oregon, and California. Even though policies like the Northwest Forest Plan provide guidance to managers and regulators about the goals and appropriate uses of management, they are not completely successful in helping people make the connections between actions in one place or time and the outcomes in another. These assessments make it clear that existing laws and policies do not preclude multiscale analyses.

Federal land managers may use the analyses of environmental consequences required under the National Environmental Policy Act of 1969 (NEPA, 1969) to reveal connections between fine-scale management actions and conditions on the broader landscape across both space and time. In practice, however, this is rarely done and most analysis of management actions still occurs at relatively fine scales. Insufficient understanding of basic ecological processes as well as the lack of well-defined methods, tools, and protocols for conducting cross-scale analyses often make it difficult for planners to consider environmental or socioeconomic consequences beyond a narrowly defined analysis area and short time period.

We illustrate how stepping down analysis through several spatial scales to provide different perceptions of management priority and effectiveness can facilitate prioritizing management strategies at the fine scale. We compare several previous analyses that were not part of an organized step-down process, but that nonetheless demonstrate how step-down can illustrate tradeoffs between reduction of fire risk and protection of forest-dependent resources. To accomplish this, we use information from previously published assessments and analytical frameworks including the Interior Columbia Basin Ecosystem Management Project (Quigley and Arbelbide, 1997), the Blue Mountains Vegetation Assessment (BMVA; Rainville, 2002) and the Interior Northwest Landscape Analysis System (INLAS; Hayes et al., 2004).

2. Methods

2.1. Broad scale

We used maps and geographic information systems (GIS) analyses generated during ICBEMP that depict historical fire regime and potential vegetation, current fire regime and current vegetation, and the intersection of areas with both high fire risk and rural populations to identify a set of high-hazard areas (Hann et al., 1997; Quigley and Arbelbide, 1997). From this information, we selected the Blue Mountains in Northeastern Oregon, USA, as a mid-scale landscape where current fire regimes have departed from those historically present, potential fire hazards to human property and life are high, and consistent mid- and fine-scale data are available.

2.2. Mid scale

Two mid-scale analyses provide examples of step-down processes that could refine understanding of fire risks and prioritization of treatments designed to reduce risks to various resources. The Blue Mountains Vegetation Assessment focused primarily on potential treatment areas and the financial aspects of fire hazard reduction treatments (Rainville, 2002). The Interior Northwest Landscape Analysis System is an ongoing mid-scale disturbance and vegetation modeling effort that examines mid-scale conditions in a subbasin within the Blue Mountains (Barbour et al., 2004, Hayes et al., 2004).

The BMVA examined approximately 2.25 million ha (5.5 million acres) of federally administered land in the Grand Ronde and John Day subbasins in Northeastern Oregon. The project used Forest Inventory and Analysis (FIA; on National Forests in Washington and Oregon formally known as the Continuous Vegetation Survey) plots, which are permanent forest inventory plots located on a systematic grid that covers all forested ownerships throughout the United States. Plots are located at various intervals depending on a variety of factors, but in the Blue Mountains they represent about 1215 ha (3000 acres; Max et al., 1996). For this analysis, plots were stratified by plant association group (Johnson and Simon, 1987) and administrative land use designation (reserves, restricted timber harvest, lynx (*Lynx canadensis*) habitat, and active timber harvest; Rainville, 2002). Administrative land use designations were used to identify areas where active timber management was allowed, e.g., to exclude plots in designated wilderness or other congressionally withdrawn areas, those identified as habitat for Canadian lynx (a federally listed species), nonforest areas, and areas where timber harvest is otherwise administratively restricted. Analyses were conducted for strata where timber harvest was allowed and that were represented by 10 or more inventory plots. The same average values were assigned to all of the area in each stratum. This method did not remove lands allocated to riparian buffers because these buffers or other fine-scale restrictions on management are not mapped so there was no cost effective way to include them in the analysis. The net result was that the process probably overstated available timber. In all, about 30% of the federally administered land was available for timber management, which amounted to 630 000 ha (1.6 million acres).

Each FIA plot in the active timber management category was evaluated for possible treatment by using one of two standardized treatments. First, plots were screened to determine if their stand density index (SDI; Reineke, 1933) was greater than 45% of the maximum for that plant association group (Cochran et al., 1994). If so, the plot was thinned "from below," i.e., removing the smallest trees first until SDI reached 30% of the maximum. Tree species that were not the preferred species for that site were removed first. Generally preferred species were white pine (*Pinus monticola* Dougl. ex D. Don), western larch (*Larix occidentalis* Nutt.), and ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.). Higher elevation spruce-fir (*Picea* spp.–*Abies* spp.) and lodgepole pine (*Pinus contorta* Dougl. ex Loud.) types usually fell into one of the land use categories where timber harvest was limited or not allowed. If the plot SDI was not greater than 45% of the maximum but there were more than 740 trees/ha (300 trees per acre) with diameters between 0.25 and 18 cm (0.1–7 in.) at breast height, then the plot was thinned from below to 330 trees/ha (135 trees per acre). These initial conditions are considered densely stocked for this area (Powell, 1999).

Costs for treatments were based on two harvesting systems: a conventional ground-based system for plots with slopes of less than 40%, and an aerial (cable) system for plots with slopes greater than 40%. The ground-based system consisted of a mechanical whole-tree harvesting system (feller buncher) for trees less than 45 cm (18 in.) diameter at breast height (dbh), hand falling (chainsaw) of larger trees followed by grapple skidding, then delimbing and bucking to length at the landing. The aerial system consisted of manual felling and cable yarding. Harvesting costs were estimated by using the STHarvest software package (Hartsough et al., 2001).

Transportation costs including hauling, contractual arrangements, road maintenance, and temporary roads were estimated at US$ 16 per cubic meter (US$ 44 per hundred cubic feet) of logs. Revenues were based on log prices. Product prices for the fourth quarter of 1999 and the fourth quarter of 2001 were averaged to estimate the value per cubic meter for each log species group (Warren, 2003). Individual product values were determined for each species group and small-end diameter of the log. Financial analyses were performed by using the Financial Evaluation of Ecosystem Management Activities (FEEMA) software package (Fight and Chmelik, 1998).

The INLAS project is an ongoing effort to model vegetation, management, and disturbance interactions in a study area of approximately 194 000 ha (480,000 acres) of mixed forest and rangelands in the upper Grande Ronde subbasin (Hayes et al., 2004). About 122 000 ha (302,000 acres) are administered by the La Grande Ranger District of the Wallowa-Whitman National Forest. The remainder is divided among nonindustrial private lands, 53 000 ha (132,000 acres); Native American tribal lands, 14 000 ha (34,000 acres); corporate industrial, 4900 ha (12,000 acres); and State of Oregon lands, 900 ha (2000 acres). Vegetation ranges from xeric bunchgrass communities at the lowest elevations (820 m, 2700 ft) of the project area to mixed conifer and subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.) at the highest elevations (2100 m; 7000 ft). Fuel loadings are highly heterogeneous and large wildfires have burned about 8100 ha (20,000 acres) since 1993 (La Grande Ranger District unpublished records). Outbreaks of western spruce budworm (*Choristoneura occidentalis*) and bark beetles (*Dendroctonus* spp.) occurred over the past few decades causing extensive mortality in Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco) and grand fir (*Abies grandis* (Dougl.) Forbes) (Gast et al., 1991; Filip et al., 1996; Hayes and Daterman, 2001; Torgersen, 2001).

We characterized fire threat to evaluate the effects of no management over two time intervals (100 and 500 years). The techniques for conducting this evaluation are described elsewhere (Hemstrom et al., 2004). They used a state and transition modeling system known as the Vegetation Dynamics Decision Tool (VDDT; Beukema et al., 2003) and the Tool for Exploratory Landscape Analyses (TELSA; Kurz et al., 2003). The VDDT states and transitions were used to develop models of forest vegetation in the Blue Mountains and project vegetation for 500 years without management. Our intention was to understand how vegetative succession and natural disturbance might progress in the absence of management so that we could provide policymakers with baseline conditions against which to compare proposed policies. We also used an analysis conducted by Wales and Suring (2004) that aggregated 650-ha (1605-acre) mapping units to illustrate the potential change in the abundance of patches of old forest over a 100-year period under two alternative management policies. The first policy suppressed wildfire with no other management. The second policy thinned eligible stands on a 10-year cycle following criteria and management prescriptions similar to those used in the BMVA.

2.3. Fine scale

As an example of a fine-scale analysis, we used the Mt. Emily wildland–urban interface located immediately north of La Grande, Oregon (Ager et al., 2004). This area is located within the upper Grande Ronde subbasin. The forests and adjacent rural community in this area were identified by the USDA Forest Service as ‘‘high risk’’ owing to the intermingling of homes and vegetation, potential fire behavior, and existing fire protection capabilities. The forests have accumulated high loadings of live and dead fuels after decades of fire exclusion and insect outbreaks (including spruce budworm, bark beetles, and balsam woolly adelgid [*Adelges piceae* (Ratzeburg)]) in the 1980s and 1990s that have resulted in extensive mortality (Barbour et al., 2004). A number of state, federal, and local agencies and organizations are coordinating efforts to reduce stand density, ladder fuels, and surface fuels (Graham et al., 2004) with the goal of reducing flame heights, spotting, and crown fire potential, as well as to provide defensible space for fire-fighting crews. We examined a number of strategic questions related to fine-scale analysis of fuel treatments including (1) How often are treatments needed to maintain desired vegetation conditions? (2) What is the long-term effect of intensive fuels treatments on fire behavior, fuels, forest structure and composition, and other resources? We used pre-existing stand boundaries obtained from the La Grande Ranger District's forest vegetation layer and digitized adjacent private lands by using the same USDA Forest Service mapping standards. We developed a vegetation database consisting of trees per hectare by species and 2.5-cm (1-in.) diameter classes for each stand. Data were obtained from stand exams, photo-interpretation, and extensive field reconnaissance over 80% of the area. Detailed fuels data were obtained from stand exams and line transects (Hilbruner and Wordell, 1992) taken on a representative set of stands. We simulated stand dynamics with the Parallel Processing Extension (PPE) to the Forest Vegetation Simulator (FVS; Crookston and Stage, 1991), and modeled potential fire behavior with the Fire and Fuels Extension (Reinhardt and Crookston, 2003). We used a forest regeneration model that was developed with data from the upper Grande Ronde subbasin. When thinning was only allowed on forest service lands the reduction in acres with potential crown fires was considerably less, due to the fact that only about half of the urban interface and surrounding lands are national forest. This situation is true of many wildland–urban interfaces.

We modeled site removal of fuels and, depending on the scenario, underburning. Stands were managed to stand density targets based on potential vegetation types (Rainville, 2002) except that we used slightly higher thinning thresholds (65% instead of 45% of maximum stand density index) based on input from La Grande Ranger District staff. We used the crowning index and torching index to measure potential fire behavior (Scott and Reinhardt, 2002). Weather conditions for simulating potential wildfire effects were derived from the J Ridge (Station 351414), Black Mountain (Station 351314), and Black Mountain 2 (Station 351317) remote automated weather stations located near Mt. Emily. Weather data for June to September from the years 1986 to 2002 were analyzed to determine the 97th percentile temperature, wind speed, and fuel moisture values. We measured forest structure (Keyes and O'Hara, 2002) for the scenarios by using the cover extension to FVS (Crookston and Stage, 1999). Additional details on the study area and methods can be found elsewhere (Ager et al., 2004).

3. Results and discussion

3.1. Broad-scale analysis

Nonlethal fire regimes (those where low-intensity fires typically do not kill overstory trees) dominated most landscapes in the interior Columbia Basin under historical conditions (Fig. 1; Hann et al., 1997). Historically, stand replacement or lethal wildfires, where most or all of the trees in the stand are killed by a high-intensity fire, were generally restricted to higher elevation forests of Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), subalpine, and lodgepole pine forest types with relatively long fire-return intervals. At lower elevations, frequent low-intensity fires helped to maintain more open stands of ponderosa pine and mixed conifers dominated by Douglas-fir, grand fir, and western larch. Regeneration in these forest types typically occurs in irregularly spaced clumps following underburns (low-intensity fires that only rarely reach the crowns of dominant trees; see Graham et al., 2004) or other patchy disturbances that create microsites with light levels and moisture conditions that allow seed sprouting and survival of young shade-intolerant trees. Fire suppression and increased grazing by wild and domestic ungulate herbivores (principally cattle, deer, and elk) tended to increase tree densities and fuels in these forest types, especially densities of shade-tolerant tree species, like grand fir, with low resistance to fire (Madany and West, 1983; Zimmerman and Neueschwander, 1984; Belsky and Blumenthal, 1997). Consequently, most of these dry forests now experience lethal fire regimes that are similar to those formerly restricted to moist and cold forests (Fig. 1).

This finding, if taken alone, could lead policy-makers to conclude that the general shift in fire regime means it makes little difference where fuel reduction

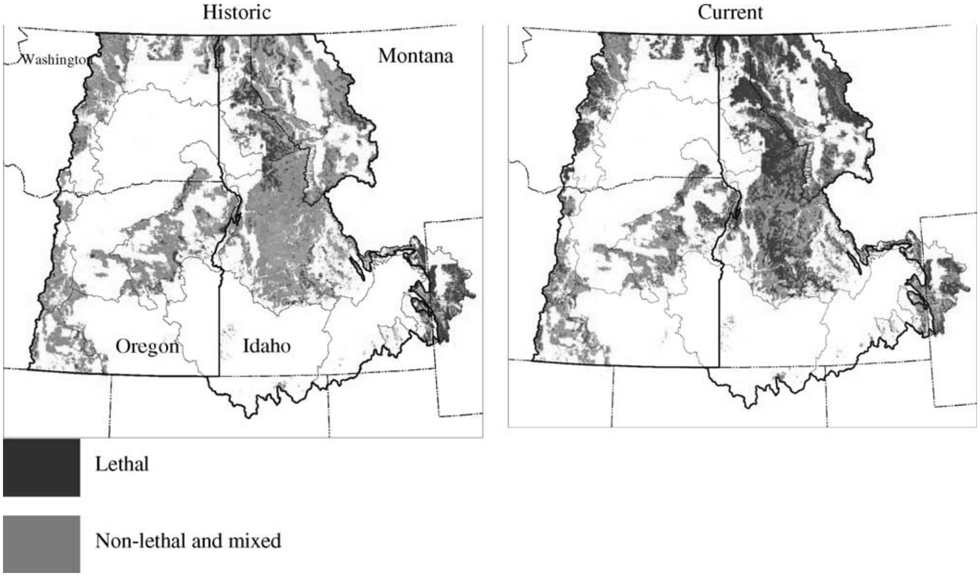

Fig. 1. Fire regimes under current and historical conditions in the interior Columbia basin.

treatments are applied. The intersection of fire threat, rural populations, and limited resources, however, presents a much different picture. There are far fewer places where high fire threat (Fig. 1) and human populations (Fig. 2) coincide. Because the intent of the HFRA policy is to focus restoration efforts in places where human habitations or the infrastructure that supports them are at risk, it might make more sense to prioritize limited funding and other resources by the coincidence of high fire risks and human habitation. A different policy goal, such as minimizing fire risk to habitat for threatened and endangered species from uncharacteristically large or severe fires would generate a different set of high-priority areas.

3.2. Mid-scale analysis—Blue Mountains Vegetation Assessment

Stepping down to the subbasin scale can facilitate evaluating local consequences of different management approaches. The BMVA (Rainville, 2002) suggests that if treatments are restricted to areas where active timber management is generally allowed, strategies designed to reduce SDI by thinning from below on federally administered land in the Blue Mountains will usually produce negative net revenues (i.e., lose money). Under the economic assumptions used in the analysis, only about 8.5% of the accessible federal land in the Blue Mountains could be treated in this way without a subsidy (Fig. 3). This amounts to only about 3.4% of the forested land administered by the federal government. It is worth mentioning that 51% of the federally administered land in the Blue Mountains is either not forest (26%) or designated as wilderness or some other noncommodity use category. Of the remaining 49%, just over half (29% of federally administered land) was included in this analysis, and the remainder (20% of federally administered land) has been identified as potential Canadian lynx habitat or has other restrictions on its management for timber. Even so, the results presented by Rainville (2002) suggest that policies that restrict fire-hazard management to areas with positive net revenues will result in treatment of relatively few hectares in the Blue Mountains. Excluding riparian buffers would probably further reduce the amount of land on which fire risk could be managed by thinning. However, it is, possible that with strategic placement of treatments such as those suggested by Finney (2003) timber harvests could help to offset some costs of reducing fire hazard at the landscape scale.

Approximately 30% of the 650 000 ha (1.6 million acres) designated for active management could be treated with a subsidy of ≦US$ 615 ha^{-1} (US$ 250

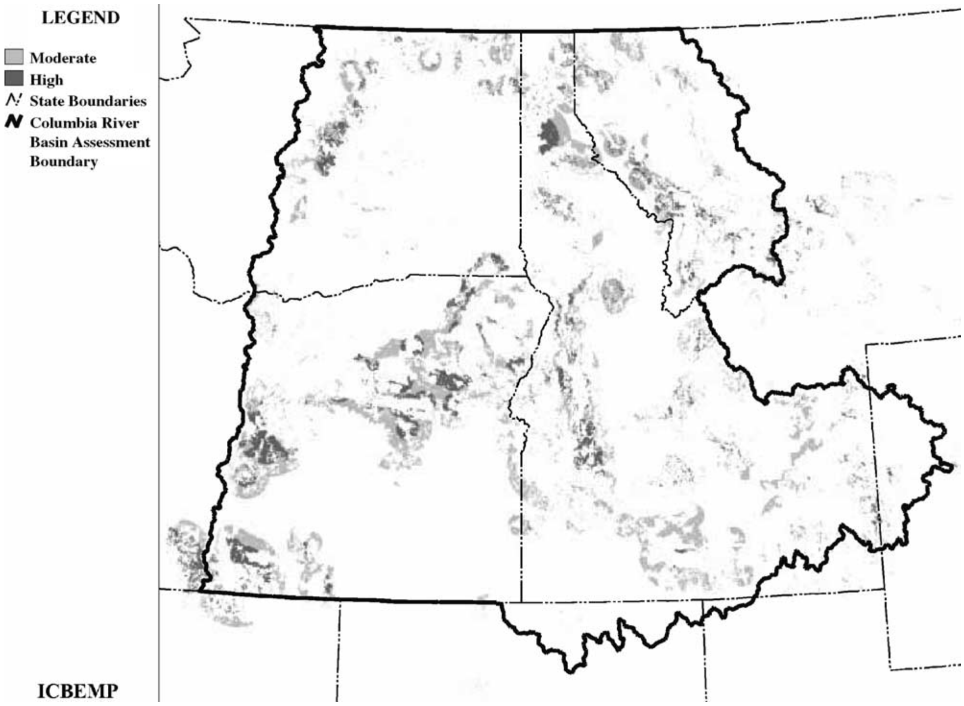

Fig. 2. Areas of high fire risk and high human population density in the interior Columbia basin.

per acre), and an additional 25–30% of the available land base could be treated with a subsidy of US$ 615–1230 ha^{-1} (US$ 500 per acre) (Fig. 3). This means that small changes in the cost criteria used to identify sites for treatment could result in relatively large gains in the number of hectares that could be thinned to reduce fire hazard.

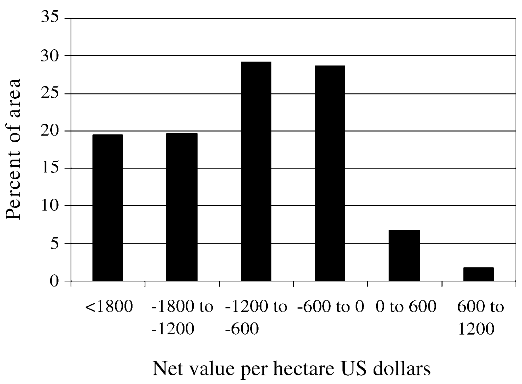

Fig. 3. Proportion of lands with negative, neutral, and positive net revenue for fuel treatment activities in the Blue Mountain Vegetation Assessment area, Northeastern Oregon.

The BMVA explored two potential changes in policy that could make timber harvest more effective at paying for fire hazard reduction treatments: (1) removing an existing restriction on harvesting any trees over 53 cm (21 in.) dbh and (2) allowing transfer of revenues from areas with positive net revenues to subsidize negative-revenue areas. Rainville (2002) found that the latter, i.e., internal subsidization, was more effective than allowing harvest of some of the larger trees. The BMVA assumed that achieving density objectives to reduce fire risk would involve thinning from below, i.e., removing the smallest trees first. Other thinning strategies might have generated more revenue by thinning across diameter classes (Fiedler et al., 2004), but in most cases stand density goals in the Blue Mountains were assumed to be achieved by removing only smaller trees.

3.3. Mid-scale analysis—upper Grande Ronde

Given scarce resources, federal managers will certainly want to know what locations provide highest benefit, lowest cost opportunities to manage disturbance processes on large landscapes. The BMVA suggested that a large-scale, fire-hazard-reduction program in the Blue Mountains will probably require financial subsidies, or other forms of investment in future stand conditions, to offset the initial costs of restoration activities. Without additional information about other resources, regional- or national-level federal administrators may question the long-term feasibility of active management. For instance, how will disturbances that might occur under passive management affect quality of human life (e.g., directly from fire or indirectly from increased smoke), and how might these disturbances affect other landscape values such as wildlife habitat or aquatic conditions?

Hemstrom et al. (2004) projected local effects of passive management in the upper Grande Ronde subbasin (Fig. 4). The three youngest categories, stand initiation, and stem exclusion (SE) forests currently dominate the forested areas in the subbasin, owing to an extensive recent history of fire, insect outbreaks, and management. Model projections suggest that 300–400 years might be required for the area to reach forest conditions in dynamic equilibrium with the current natural disturbance regime (Hemstrom et al., 2004). The resulting landscape would be dominated by nonstocked forest land, small-tree forests, and large-tree single-storied forests, and, to a lesser extent, old multistoried forests (Fig. 4). The long time required to reach dynamic equilibrium results from a combination of the time (150 years or more) needed to grow large, fire-tolerant trees and a continuing probability of fire and other natural disturbance events. During the first 200 years or so, wildfire and insect outbreaks preferentially remove dense stands of larger trees (Hemstrom et al., 2004). This happens because the currently abundant young forests and young stands that develop after fire are often densely stocked with a variety of conifer species, including relatively thin-barked species easily killed by fire or insects. Over decades, fires tend to kill smaller trees and thinner-barked species, while insects remove dense stands of larger trees, leading to a slow accumulation of widely spaced, larger, fire-tolerant trees, particularly at low elevations. Landscapes dominated by stands of these large, widely spaced, fire-tolerant trees become relatively stable but require two centuries or more to develop (Fig. 4). Until then, stand-replacement fires pose considerable risks to human and wildlife communities and undoubtedly produce abundant smoke.

Notably, this mid-scale analysis (Hemstrom et al., 2004) does not account for climatic change that could

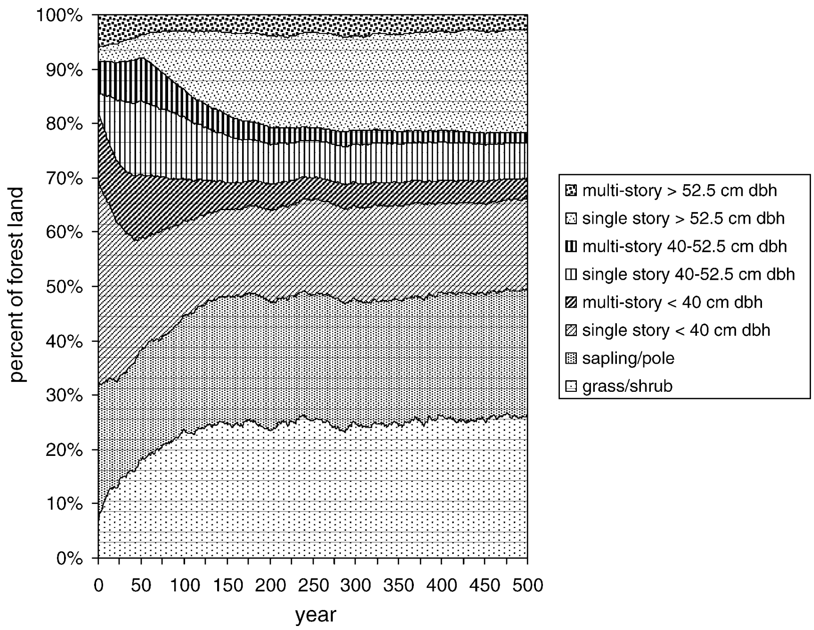

Fig. 4. Percentage of land in various vegetation structural conditions in a portion of the upper Grande Ronde subbasin, Northeastern Oregon.

easily occur within one or two centuries. The influence of climate change remains obscure at this spatial scale. In addition, the methods used by Hemstrom et al. (2004) to describe forest states and transitions are probabilistic. These methods permit projecting which parts of the subbasin are most likely to experience disturbances, but they do so without specifying exactly where or when disturbances will occur on the landscape.

The direct risks posed by fire to human habitation are not the only landscape characteristics of interest in the upper Grande Ronde subbasin. Wildlife habitat, especially for key species of conservation concern, is also important (Wisdom et al., 2000). For an illustration, we draw from an example developed by Wales and Suring (2004). They contrasted two management scenarios: one permits suppression of wildfires but no other management (a passive/reactionary approach), and the other suppresses wildfires and allows prescribed management (i.e., precommercial thinning, commercial thinning, prescribed burning, and limited regeneration harvests) to reduce risk over time (proactive approach).

Wales and Suring (2004) indicate that a passive approach will not create large blocks (650 ha [1605 acres] or more) of old-forest habitat as quickly as a proactive approach in this area (Fig. 5). This finding aligns well with the previous nonspatial analysis (Fig. 4), which suggested more than 100 years are required for natural disturbance processes to differentiate out the young and middle-aged stands that currently dominate this landscape. A proactive approach produces larger blocks of older forests more quickly by selecting large, widely spaced, fire-tolerant trees for retention across the landscape. Allowing the passive approach to play out for an additional 100 years or more might eventually generate large blocks of old-forest structure. This raises the question of how long society is willing to wait to reduce the risk of large-scale fire, and how many attendant changes in other forest attributes society is willing to accept in the process. Would public opinion favor passive management if we could predict with a fairly high degree of certainty that forest conditions in the Blue Mountains would return to something resembling presettlement conditions if we simply allowed ‘‘nature to

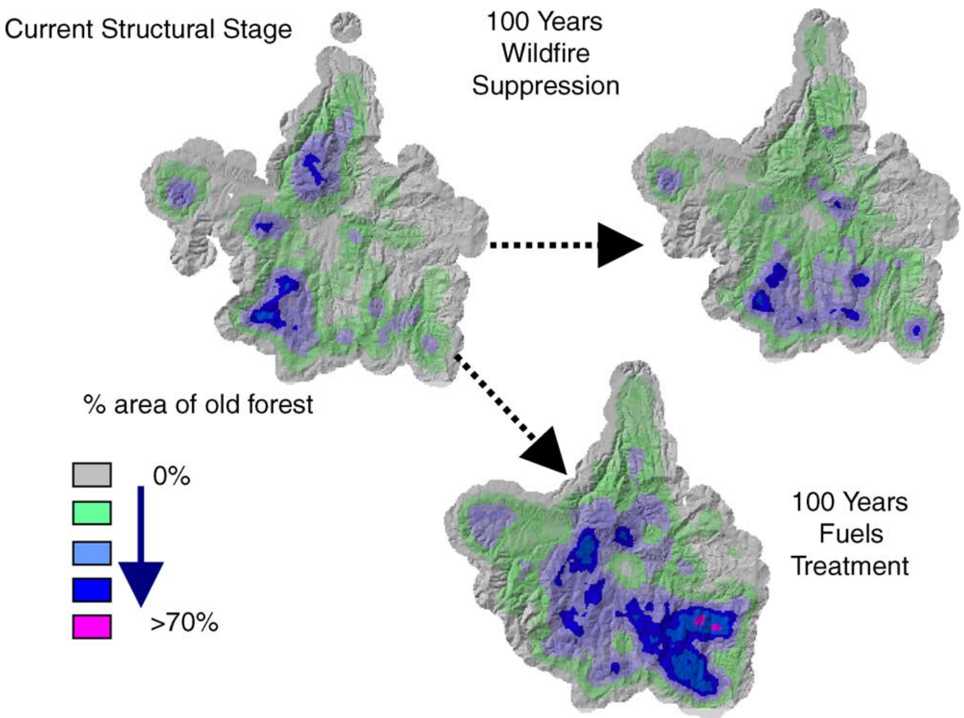

Fig. 5. Percentage of land in old forest structural conditions with and without fuels treatment in a portion of the upper Grande Ronde subbasin, Northeastern Oregon.

run its course'' for two to three centuries? If so, would this still be the case if letting nature run its course meant that during the first 150 years large, severe fires would be common across the landscape, with attendant effects on smoke and wildlife habitats?

To answer these types of questions people probably need more information than is provided by a mid-scale analysis. People who live in the area are certain to want to know more about how various policy scenarios might directly affect their lives within a few years or decades, especially within their favorite areas or around their homes. Fine-scale analyses can provide some of this more specific information.

3.4. Fine scale—Mt. Emily wildland–urban interface

The increasing number of wildland fire ignitions and growing size of wildfires in recent years has made fire a major concern for residents of much of the interior West. As a result, people generally want information that is as precise as possible about how management might or might not affect their living situation, and fine-scale analyses are best suited to answer questions where a high level of spatial specificity is necessary. Our analysis of the Mt. Emily wildland–urban interface suggested a number of

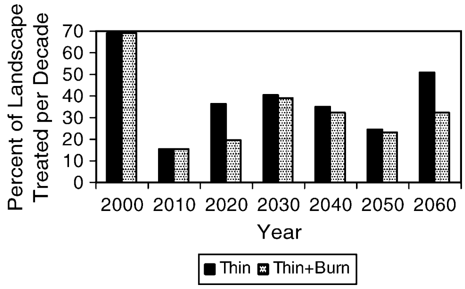

Fig. 6. Results of simulations for the Mt. Emily area showing the percentage of forested area treated by decade to maintain all stands under 65% of maximum stand density index.

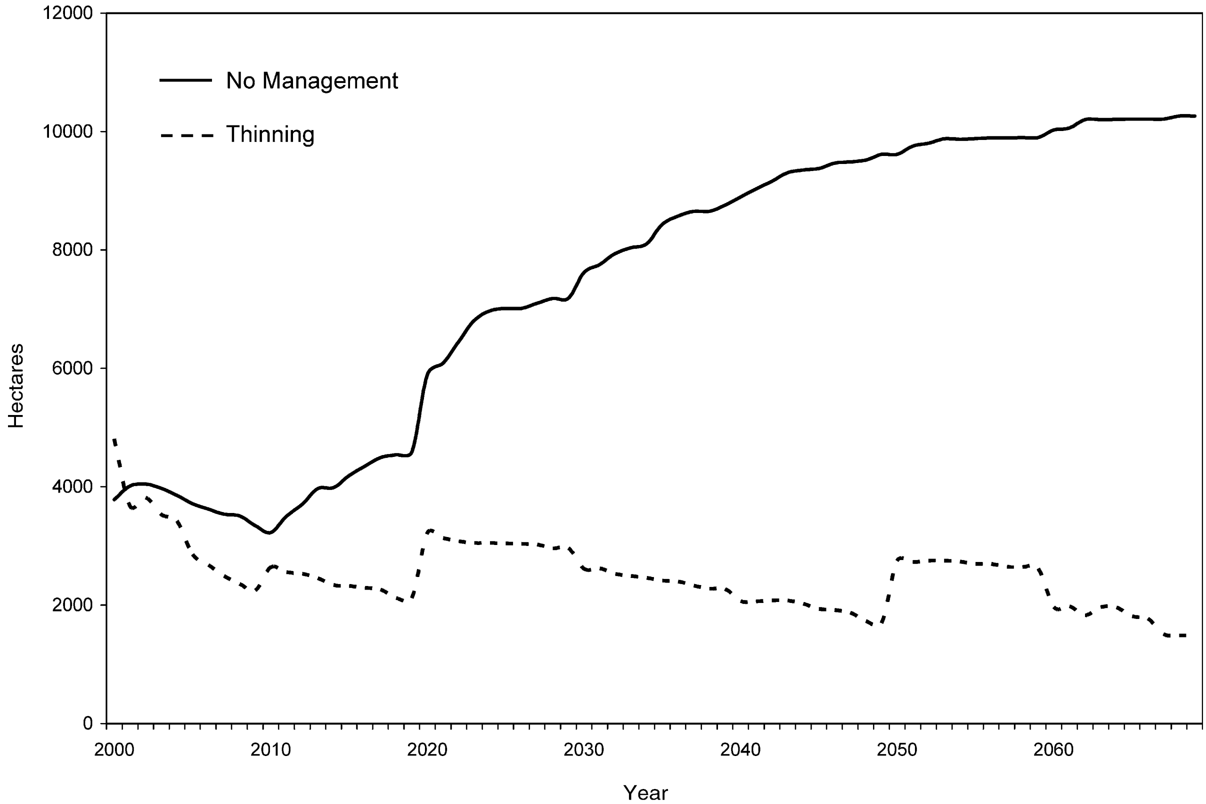

Fig. 7. Results of simulations for the Mt. Emily area showing acres of active crown fire for thinning and no-management scenarios.

interesting results in terms of wildfire risk assessment and perception.

When density management goals were modeled over time for the Mt. Emily area, the simulations showed that a large proportion (68%) of the landscape is overstocked by USDA Forest Service standards and that in order to meet stand density guidelines used by the Forest Service in the Blue Mountains, considerable areas need to be thinned over time (Fig. 6). The addition of underburning to the thinning treatments substantially reduced the area to be thinned in some of the future decades (Fig. 6). It is not clear how this landscape compares to others in the interior West because estimates of long-term treatment rates needed to achieve forest restoration targets in western US forests are absent from the literature.

In terms of fire behavior, thinning treatments resulted in a dramatic reduction in the area of stands that were predicted to exhibit active crown fire behavior under a 97th percentile weather scenario (Fig. 7). Fire models also predicted more torching (Fig. 8) and higher surface flame lengths for many treated stands (Ager et al., 2004). Clearly, in a wildland–urban interface, the benefits of mitigating active crown fire far outweigh the potential adverse impacts of more extreme surface fire behavior, especially if surface flame lengths are less than the 1.2-m (4-ft) threshold for direct suppression activities. Much of the torching fire behavior reported by the FFE model occurs in saplings or small trees that develop after thinning treatments. This general result is consistent with the literature, and can result from drier surface fuels, higher canopy wind speeds, and higher surface fuel production after thinning (Martinson and Omi, 2002; Graham et al., 2004).

As expected, simulation of long-term thinning treatments resulted in dramatic changes in forest structure and composition (Ager et al., 2004). In the no-management scenario, simulations indicated large increases in the stem exclusion structural stage, and by

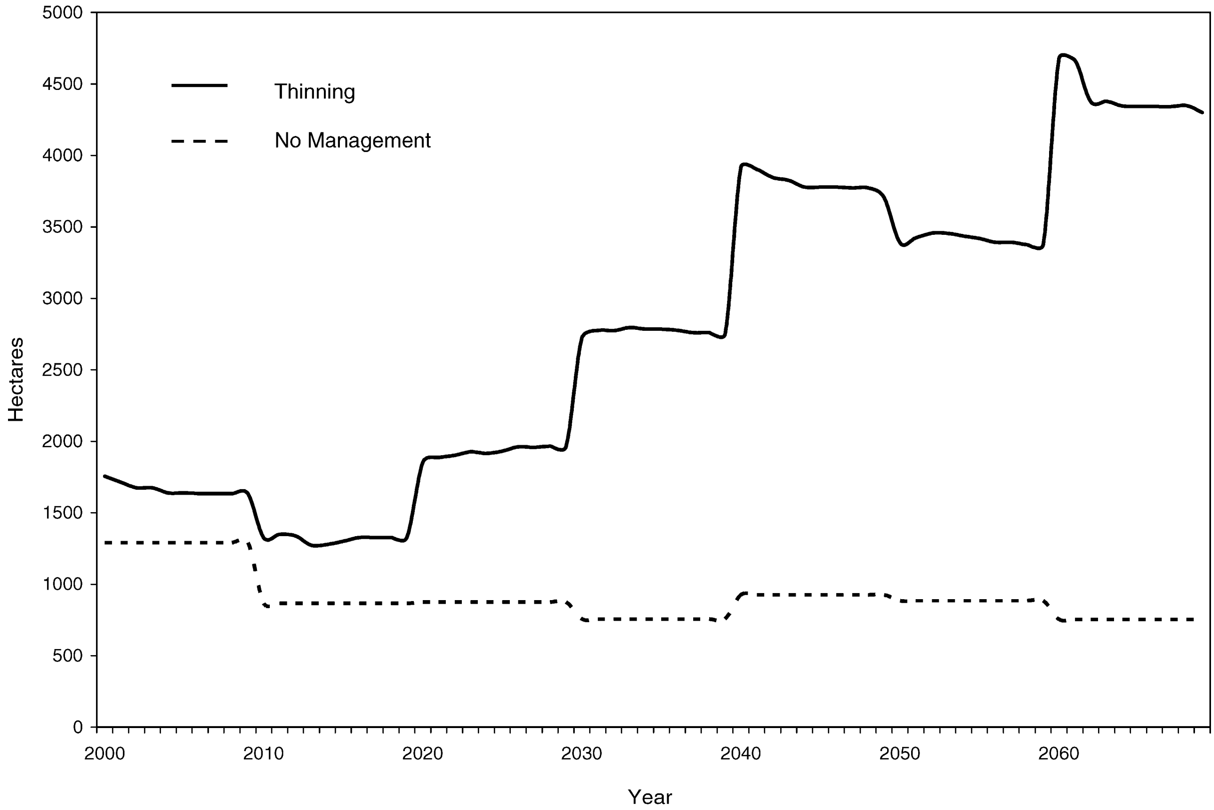

Fig. 8. Results of simulations for the Mt. Emily area showing acres of passive crown fire or torching for thinning and no-management scenarios.

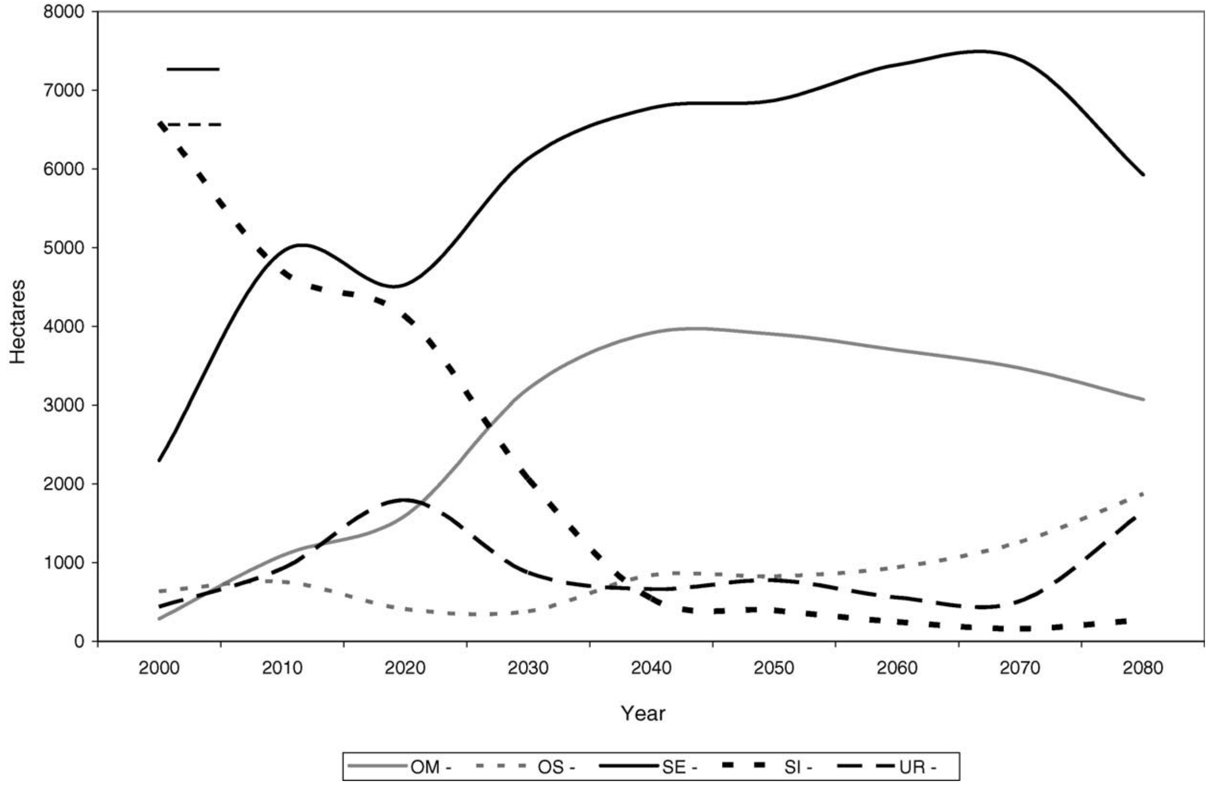

Fig. 9. Results of simulations for the Mt Emily area showing changes over time in forest structure for a no-management scenario. Structure classifications follow Keyes and O'Hara (2002) and were determined with the FVS cover extension (Crookston and Stage, 1999). OM, old forest multistory; OS, old forest single story; SI, stand initiation; UR, understory initiation; SE, stem exclusion.

2030, well over half of the forested lands were in this condition (Fig. 9). In contrast, thinning to maintain density targets converted the stem exclusion stage to single-stratum old forest (OS; Fig. 10). Thinning also reduced the proportion of stands in the understory reinitiation (UR) stage as well (Fig. 10). These large changes in forest structure have impacts on wildlife habitat considerations, visual aesthetics, and other resource concerns. In a wildland–urban interface, some residents might actually perceive an increase in older less dense forest structure as a negative outcome because it provides less screening, and therefore less privacy, than denser stem exclusion forests. Fine-scale analyses such as this one might help residents to ponder whether they prefer lower fire threat or a more secluded setting for their home. The need for all owners to participate in fire hazard reduction treatments is another aspect of the management of this landscape that was discussed by Ager et al. (2004). They showed that only treating the land administered by the federal government would not be nearly as effective as treating a combination of all ownerships.

Although the thinning scenario we simulated was hypothetical, it illustrated potential problems with managing wildfire risk in areas like wildland–urban interfaces and elsewhere. First, our modeling and Martinson and Omi (2002) both show that thinning can exacerbate surface fire intensity, which can adversely affect the perceived benefits of fuel treatments. Second, maintaining stand density targets and minimizing crown fire potential and insect and disease issues will require treating a significant proportion of the landscape through time (Fig. 6). Our modeling suggests that thinning densely stocked stands induces waves of regeneration and sets the stage for future development of ladder fuels and higher crown bulk densities. If recurring treatments do not

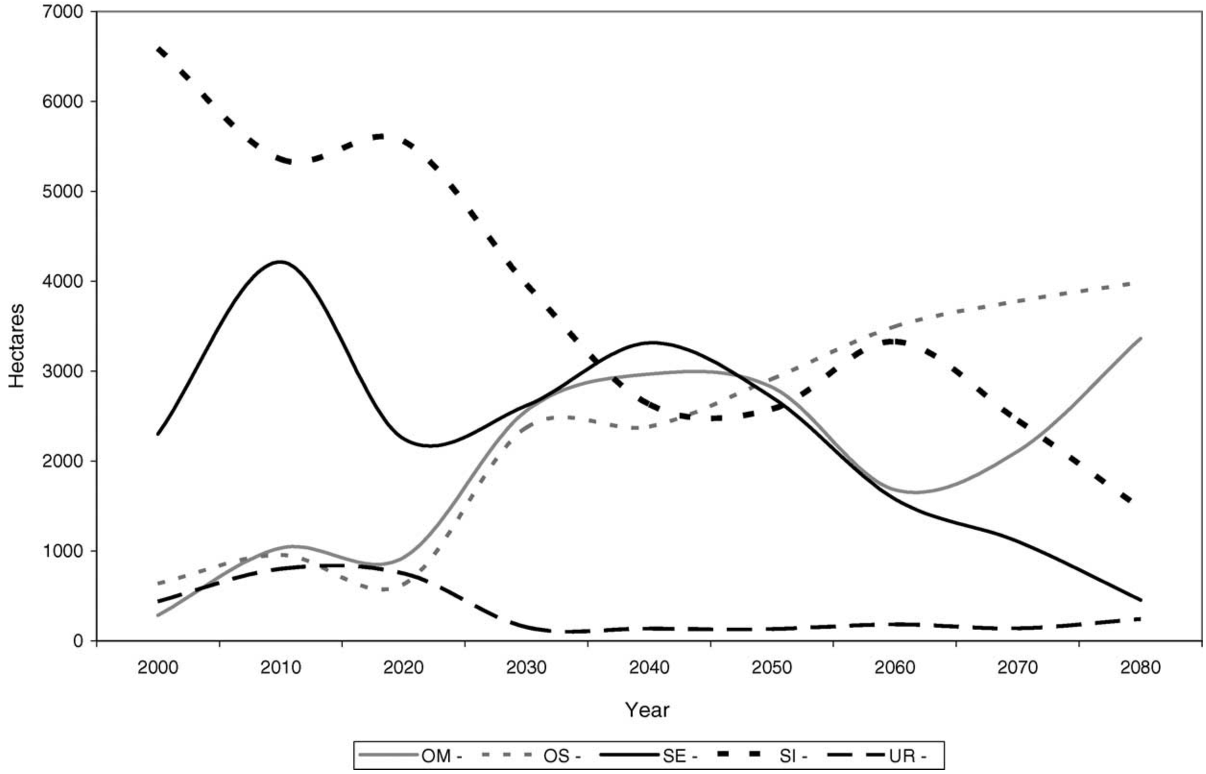

Fig. 10. Results of simulations for the Mt. Emily area showing changes over time in forest structure for an active fuel treatment scenario. Structure classifications follow Keyes and O'Hara (2002) and were determined with the FVS cover extension (Crookston and Stage, 1999). OM, old forest multistory; OS, old forest single story; SI, stand initiation; UR, understory initiation; SE, stem exclusion.

follow when needed, the initial treatments will be counter to long-term landscape goals (Keyes and O'Hara, 2002). The long-term treatment of fuels is made difficult by the finding that most restoration treatments in the Blue Mountains have negative net values under current economic conditions (Rainville, 2002) and the fact that a variety of resource values must be considered on the federal land base (NEPA, 1969). Additional questions about the impacts of bark beetles on landscapes managed with periodic frequent fire need to be addressed (Wallin et al., 2003). All of these issues contribute to fine-scale landscape design questions of how to best achieve restoration goals in the Blue Mountains (Quigley et al., 2001).

4. Conclusions

The broad-, mid-, and fine-scale analyses we present each provided a different but useful perspective on managing large landscapes for wildfire risk. Broad-scale analyses provide context for local decisions by helping managers and others prioritize treatments and focus scarce resources in the places where they will do the most good. Mid-scale analyses help managers and others evaluate tradeoffs among resource effects. Fine-scale analyses address the issue of whether or not proposed broad and mid-scale approaches will likely achieve objectives given local conditions.

Even though considering a range of scales and a variety of resources makes analyses more difficult, it helps us to think through tradeoffs. Simulations of changes through time can help managers, communities, and others understand how choosing various management approaches (including no action) might favor different resources at different times on the same landscape. Multiresource analyses are more straightforward to conduct at the mid scale because we are more certain about current conditions than at the broad scale, but they do not require high-resolution data needed for fine-scale analyses. Even so, people can understand outcomes in the context of places with which they are familiar. This can also make it difficult to gain agreement because when simulations include places that people know well, they tend to want the results to reflect reality better than results we can currently achieve and better than might be required to understand and evaluate potential outcomes. It is therefore sometimes necessary to use fine-scale analyses to allow people to discuss protecting specific resources. Tying such analyses to mid-scale and broad-scale analyses helps people to think about the relative importance of different resources through space and time in the context of the larger landscape.

Our broad-scale example revealed regional patterns in changed fire regimes and human habitations that provide information useful in setting regional policies and priorities. In general, forests have become more dense, and fire regimes have shifted from frequent and nonlethal to less frequent but more lethal in areas where humans have increasingly built homes. The broad-scale analysis indicated that the upper Grande Ronde subbasin has a combination of high fire risks and human habitations that might make it a high priority for fuel treatments.

Mid-scale analyses, in turn, show that this landscape has only a small area in old forests and large trees at present. Fuel treatments that thin-from-below are not likely to generate revenue in much of the landscape, but revenues generated in some areas might help pay for treatments in others, and a subsidy of US\$ 615–1230 ha^{-1} (US\$ 250–500 per acre) could make a substantial difference. On the other hand, harvesting large trees to subsidize fuel treatments would not be a particularly effective way to reduce fire hazard reduction costs on this landscape and might, in some situations, delay meeting nonfire policy goals such as habitat for wildlife species that depend on large trees. The mid-scale analyses suggest that limited resources would require carefully focusing treatments in the highest priority areas, implying the need for consensus on what defines high-priority area, not only at the fine scale but also at the mid and broad scales.

Fine-scale analyses help us understand how fire hazard reduction treatments might be most cost and goal effective within a highly settled wildland–urban fire interface area adjacent to the upper Grande Ronde subbasin. We found that thinning-from-below could reduce fire risks, but that an approach that spreads treatments across all ownerships might substantially increase effectiveness over a strategy that only treats federally administered land. In addition, our projections suggest that once a treatment program is initiated it will need to be continued, or the situation will get worse. Regular fuel treatment using prescribed fire or mechanical methods will be necessary to maintain the effectiveness of initial thin-from-below treatments.

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