SIMULATING FUEL REDUCTION SCENARIOS ON A WILDLAND-URBAN INTERFACE IN NORTHEASTERN OREGON

Alan A. Ager[1], R. James Barbour[2], and Jane L. Hayes[3]

ABSTRACT

We analyzed the long-term effects of fuels reduction treatments around a wildland-urban interface located in the Blue Mountains near La Grande, Oregon. The study area is targeted for fuels reduction treatments on both private and federal lands to reduce the risk of severe wildfire and associated damage to property and homes. We modeled a number of hypothetical fuel treatment scenarios and examined the resulting changes in fuel characteristics, fire potential, and stand structure over time. Aggressive thinning alternatives showed significant reductions in stand characteristics that contribute to severe crown fires, such as height to live crown and crown bulk density for the landscape as a whole. However, simulations with extensive thinning showed larger overall flame lengths and torching compared to a no management scenario. Significant changes in stand structure and other characteristics were noted for the thinning versus no management scenarios. Work is ongoing to refine the simulation methods and test a wider range of treatment alternatives. The study motivated a discussion of the long-term problem of managing forest fuels in areas like the Blue Mountains.

INTRODUCTION

Fuels reduction programs have been initiated on many areas throughout the western US, even though the long-term effects of these treatments for reducing severe wildfires on large landscape has not received much attention. While case studies show that stand-level treatments can reduce fire severity (Fule and others 2001; Kalabodkidis and Omi 1998; Pollet and Omi 2002; Stephens 1998), the effect of treatments on large forested landscapes over time and the consideration of other resource constraints remains an experimental topic (Finney 2001; Johnson and others 1998; Barbour and others 2004). Also problematic are the mechanics of using existing stand-based fire and vegetation simulation models (Wykoff and others 1982; Reinhardt and Crookston 2003) on large landscapes and extracting landscape-scale measures of fire behavior that are meaningful to the general public. Methods for the latter are in wide demand for use in project-level planning for fuels reduction treatments on Federal and other lands.

As part of a larger project to examine landscape management issues in the Blue Mountains of Eastern Oregon (Hayes and others 2004) we simulated a number of fuel management scenarios on a key wildland-urban interface near La Grande, Oregon. The Mt. Emily area and surrounding community was identified in the National Fire Plan as "high risk" due to the intermingling of homes and vegetation, potential fire behavior, and existing fire protection capabilities (Wallace 2003). The forests have accumulated high loadings of live and dead fuels after decades of fire exclusion and a large spruce budworm epidemic in the 1980s that resulted in extensive mortality (Quigley and others 2001). A number of state, federal, and local agencies and organizations are coordinating efforts to reduce stand density and ladder and surface fuels with the goal of reducing flame heights, spotting, and crown fire potential, as well as provide defensible space for fire-fighting crews to safely approach future wildfires (Wallace 2003).

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[1] Alan A. Ager is an Operations Research Analyst, Umatilla National Forest, Pendleton, OR. [2] James Barbour is Program Manager, Focused Science Delivery Program, Pacific Northwest Station. [3] Jane L. Hayes is a Research Biological Scientist, Managing Disturbance Regimes Program, Pacific Northwest Research Station, LaGrande, OR.

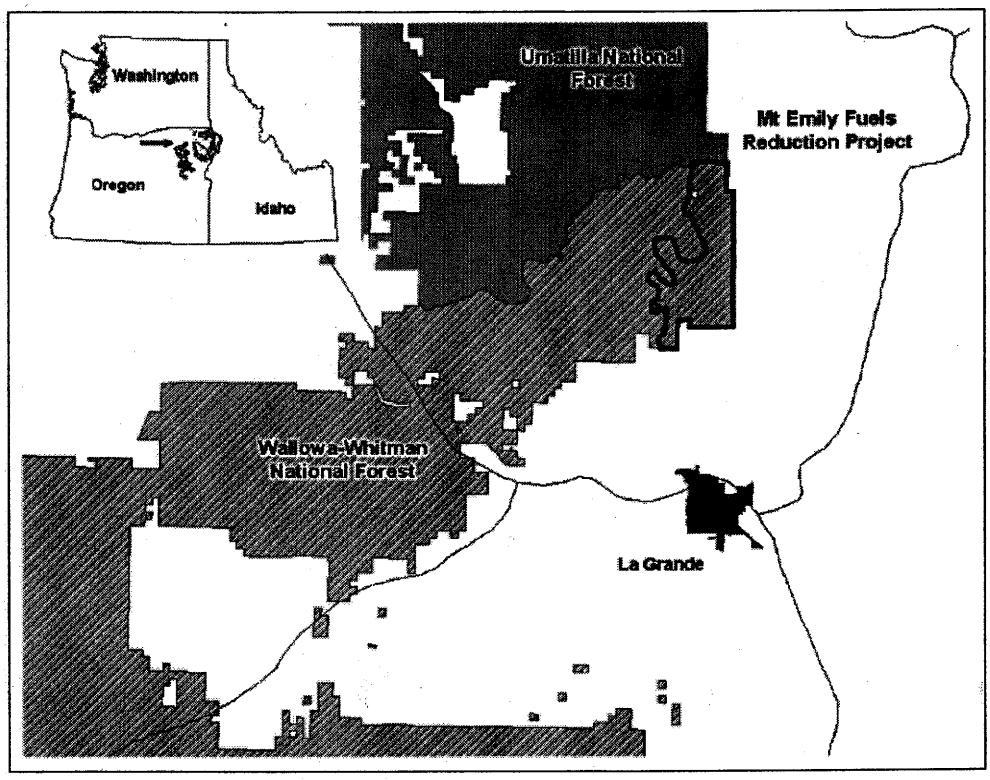

Figure 1—Vicinity map of the Mt Emily Study area.

The Mt. Emily project provided an opportunity to explore a number of questions related to landscape analysis of fuel treatment initiatives. We analyzed a broad set of hypothetical management alternatives that are beyond those being proposed for the Mt. Emily area in terms of treatment extent and intensity, with the goal of examining a number of strategic issues including: 1) How often are treatments needed to maintain desired vegetation conditions; 2) How effective are different types of treatments; and 3) What is the long-term effect of fuels treatments on fire behavior, fuels, and other resources. We report preliminary results
of our work to address these and related questions.

MATERIALS AND METHODS

Study Area

The Mt Emily wildland-urban interface (WUI) is a 16-mile long area immediately north of La Grande, Oregon where the forested slopes of Mt. Emily and adjacent ridges descend to the agricultural lands in the Grande Ronde Valley (fig 1). For analysis purposes, a boundary around the area was established, containing 40,368 acres including federal, state, and privately owned lands. About 30,348 acres within the study area are classified as forested lands based on potential vegetation data. Approximately 25,139 acres within the larger analysis area are Forest Service lands, administered by the Wallowa-Whitman (9,346 acres) and Umatilla (14,230 acres) National Forests. Forest Service lands are managed for a number of objectives including big game winter and summer range, dedicated old growth and roadless. Surface fuel loading ranges from 15 to 80 tons per acre with excessive dead ladder fuels in a large number of the stands. Fuel accumulations accelerated after the 1980s spruce budworm epidemic that caused extensive mortality within the grand fir (*Abies grandis*) and Douglas-fir (*Pseudotsuga menziesii*) stands in the project area (Wallace 2003). The area has experienced 129 documented fire starts since 1970, including both lightning and human caused fires. Ninety-nine percent of the fires have been contained within the first twenty-four hours, and only one fire has grown to any significant size (Frizell fire, 250 acres) in recorded fire history.

Treatment Scenarios

Fuels specialists on the Wallowa - Whitman National Forest developed a range of different fuel treatments for about 3,000 acres that prescribe: 1) mechanical thinning

trees under 21 inches to reduce crown bulk density and ladder fuels; 2) Site removal of fuels when they exceed 25 tons per acre; 3) Underburning after treatment to reduce surface fuels (Wallace 2003); and 4) Piling and burning of surface fuels. The choice of treatment(s) for a given stand was dependent on a number of factors related to stand conditions, management goals, and management restrictions, and was the subject of considerable debate among specialists and managers. The treatments were strategically located to reduce fire spread, create defensible space for suppression activities, and protect utilities like the Mt. Emily electronic site.

For the purpose of examining long-term effects of fuel treatments, we used the general treatment methods described above and simulated a broader, simplified set of seven hypothetical scenarios as follows:

1. No Management or Natural Disturbance [NOMAN].
2. Long Term Aggressive Thinning [LTAT]. Thin from below all stands that exceed 55 percent of the maximum stand density index (SDI) to 35 percent of the maximum SDI; site removal of fuels followed by underburning. Management is applied to all ownerships over time as needed.
3. Long Term Moderate Thinning [LTMT]. Same as LTAT except that thinning is triggered at 65 percent of maximum SDI and trees are removed until 45 percent of SDI is reached.
4. Thinning with Maintenance Burns [LTATMBURN]. Same as LTAT with the addition of decadal underburning of stands that are thinned for the entire period of the simulation.
5. Long Term Aggressive Thinning with Maintenance Burns on Forest Service lands only [LTATMBURNFS]. Same as LTATMBURN except that treatments are only applied on Forest Service lands administered by the Wallowa - Whitman National Forest. The remaining Forest Service lands in the project area are in a roadless area administered by the Umatilla National Forest and were not considered for treatment in any of the scenarios.
6. Long Term Aggressive Thinning with Maintenance Burns on Forest Service lands only, 21-inch diameter limit [LTATMBURNFS21]. Same as LTATMBURNFS21 except that the Region 6 old growth screens that prevent harvesting of trees greater than 21 inches is implemented.
7. Short Term Aggressive Thinning [STAT]. Same as LTAT except that stands are treated in the first decade only of the simulation. Management is applied to all ownerships.

We emphasize that these scenarios are hypothetical, and were formulated to better understand how existing models and typical Blue Mountain landscapes respond to long term management scenarios.

Vegetation and Fuels Data

We developed an initial vegetation database consisting of data on trees per acre by species and 1-inch diameter class for each stand using data from stand exams, photo-interpretation, and field reconnaissance. The resolution of the data was coarse in some areas, but adequately represented the project area for purposes of the present study. Where stand exam data did not exist we generated approximate tree lists from photo-interpretation of 1:12000 color resource photos from 1998. Photo-interpreted data consisted of canopy closure estimates by size class and species. These data were converted to trees per acre by diameter class using relationships between crown diameter and tree diameter developed from stand exam data at the La Grande Ranger District. Extensive field checks of the data were completed over the course of the study.

Detailed fuels data were obtained from stand exams and supplemented with a sub-sample of stands that were chosen to represent average fuel conditions for different fire regimes and commonly observed fuel models (Wallace 2003, Anderson 1982). Fuels were sampled with line transects according to Hilbruner and Wordell (1992) on a sample of 6 stands chosen to represent dominant fuel conditions. These data were used to adjust the initial fuels and default fuel loadings for the dense conifer stands (fuel models 8 and 10, Anderson 1982). Default values (Reinhardt and Crookston 2003; Anderson 1982) were used for the remaining fuel models found in the project area.

Models

For each of the 1060 stands in the project area we projected vegetation with the Blue Mountains Variant of the Forest Vegetation Simulator (FVS) (Wyckoff and others 1982), a distance-independent individual tree growth model. We simulated decadal time steps and report simulations for 60 years. We used a forest regeneration model (Wilson and Maguire in prep.) that was developed from extensive seedling survey data obtained from the La Grande Ranger District. Mechanical thinning was simulated within FVS using prescriptions developed for thinning studies in the Blue Mountains (Rainville 2002). Specifically, stands were thinned once they exceeded 55 percent of maximum SDI, thinning from below until the stand SDI was 35 percent of maximum. Maximum SDI values were specific to each plant

association and target species (Cochran and others 1994). The thinning prescriptions targeted removal of late-seral species like grand fir in mixed-species stands, favoring early seral species like western larch (*Larix occidentalis*) and ponderosa pine (*Pinus ponderosa*). Although the prescriptions used were relatively generic for the diversity of ecological settings and management goals in the project area, they were adequate for the present study.

Potential fire effects, dead and down fuel dynamics, and underburns were simulated with the Fire and Fuels extension (FFE) to FVS (Reinhardt and Crookston 2003) and FlamMap (Finney in prep). Due to space limitations the FlamMap results are not presented here. The FFE FUELMOVE keyword was used to simulate removal of the larger surface fuels, under the assumption that 90 percent of the 3 to 6 inch and 40 percent of the 1 to 3 inch materials would be removed from the site. Underburning followed thinning and fuel removal treatments, and was simulated with the FFE SIMFIRE keyword using typical weather for burning treatments on the La Grande Ranger District (table 1). Potential wildfire effects on each stand were simulated using the FFE POTFIRE keyword. 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. The Black Mountain Stations are located 10 miles east, and the J-Ridge stations are located 25 miles south of the project area on national forest land. Weather data for June to September from the years 1986 to 2002 were analyzed in Fire - Family Plus (Bradshaw and McCormick 2000) to generate 90th and 97th percentile temperature, wind speed, and fuel moisture values (table 1). Outputs were analyzed for crown fire activity, flame length, crowning and torching index, and changes in fuel models over time. The 10-minute average wind speeds generated in Fire- Family Plus were converted to maximum velocity gusts using the tables developed by NOAA (http://www.seawfo.noaa.gov/fire/olm/fire/10togust.htm).

We measured forest structure (O'Hara and others 1996) for the scenarios using the cover extension to FVS (Crookston and Stage 1999).

RESULTS

Stand Development

The scenario that simulated long-term thinning of all lands in the study area (LTAT) resulted in the treatment of about 23 percent (7,032 acres) of the forested area per decade, averaged over the 60 year simulation (table 2). The same prescription with decadal maintenance burns thinned stands in about 15 percent of the study area (4,568 acres) per decade (LTATMBURN). Thus the addition of the maintenance burns reduced the area thinned by 8 percent per the decade. The LTAT scenario removed an average 6,394 MCF of merchantable material per decade (table 2), with the other scenarios resulting in lesser values commensurate with the acres treated. Thinning only Forest Service lands within the study area (LTATMBURNFS scenario) called for thinning only about 1,212 acres, and removed 1,154 MCF per decade (table 2). Thinning to the upper SDI management zone (LTMT) called for thinning about 6,291 acres per decade, or 21 percent of the forested area (table 2). For the landscape as a whole, the overall SDI was maintained at 135 for the LTAT scenario, while SDI for the no management scenario rapidly increased and eventually tapered off at 215 over the 60-year simulation period (table 2). The thinning schedule over time was most irregular for the LTAT scenario, and it was apparent that heavy thinning in the beginning of the simulation produced pulses of regeneration that required thinning in the future. The pulse of regeneration in the first decade is consistent with field observations. A large number of stands in the cool moist ecological settings have experienced severe mortality from spruce budworm, which has opened up the stands and set the stage for regeneration.

The LTAT and LTATMBURN thinning management scenarios resulted in large changes in crown bulk density and crown base height (fig. 2). By 2020 the average crown bulk density under both scenarios was reduced to 0.04 kg/m^3 compared to almost 0.1 kg/m^3 for the no management scenario. Crown base height was higher for the thinning scenarios, the difference being almost 15 feet by the year 2020. Trends in both crown bulk density and live crown height were strongly affected by regeneration in the early decades.

Stand structural characteristics showed a number of changes over time and differences among the scenarios were apparent (fig. 3). In the no management scenario, simulations indicated large increases in the stem exclusion (SE) structural stage, and by 2030, over half of the forested lands were in this structural stage. The effect of thinning within the LTAT or LTATMBURN scenarios was to convert the stem exclusion stage to single-stratum old forest. Thinning also increased the proportion of stands in the understory re-initiation stage as well (UR, fig 3).

The STAT scenarios that called for only a single thinning at the beginning of the simulation had little effect on the landscape through time (table 2). Likewise, recurrent

Table 1—Weather and fuel moisture parameters used in potential fire simulations and prescribed fires. The 90th and 97th percentile conditions were determined from analysis of local weather stations. See methods for additional details on weather station data and calculation of percentile values and velocity of wind gusts.

Variable	90th Percentile Values	97th Percentile Values	Maintenance Burns
Temperature (degrees F)	85°	90°	70°
1 hour fuel moisture (percent)	4	3	6
10 hour fuel moisture (percent)	6	4	12
100 hour fuel moisture (percent)	7	6	16
1,000 hour fuel moisture (percent)	9	7	26
Live fuel moisture (percent)	74	64	100
Duff moisture (percent)	42	20	—
10-minute average wind speed (mph) at 20 feet above ground	8	9	—
Maximum gusts	23	24	—

thinning and underburning of only Forest Service lands (LTATMBURNFS) showed relatively minor changes compared to the no action alternative (table 2) which could be expected given that only about 25% of the area is available for treatment in this scenario.

Fuels

Changes in fuel models among the scenarios generally followed expected trends (fig. 4). For the no management scenario, there was a rapid decrease in fuel model 5 acres (brush type), an increase in model 8 acres (closed canopy conifer), and, after 50 years, a dramatic increase in fuel model 10 acres (closed canopy with high surface fuels) (fig. 4). The change in fuel models reflected a landscape with active regeneration in the early part of the simulation, with stands building up down fuels and increasing mortality through time. In contrast, the LTAT alternative showed a large reduction in fuel model 8 as stands were thinned and converted to fuel models 2 and 5 (fig. 4). There was also an increase in fuel model 11 (closed canopy with high activity fuels) in the first 20 years, from thinning residue. The thinning treatments did not result in an overall decrease in surface fuels (table 2) even though we assumed that a large portion of the residual fuels (90 percent of the 3 to 6 inch and 40 percent of the 1 to 3 inch materials would be removed from the site as part of the treatments. Scenarios that called for lighter thinning (LTMT) and 10-year maintenance burns did not significantly reduce downed fuels either when measured as an average for the landscape.

Potential fire analysis

Acres of potential active crown fire increased in the first 30 years for all scenarios, with the no management scenario exceeding all other scenarios (fig. 5). For the LTAT scenario, acres increased from about 500 to 3000 acres between years 2000 to 2020, declining thereafter, and at 2030, acres of potential active crown fires were reduced to nearly 0. Acres of potential active crown fire also showed a decreasing trend for the no management scenario after about 30 years, although the acres with a crowning index less than 24 (meaning that they will carry a crown fire in 24 mph wind) remained high throughout the simulation while rapidly decreasing for the thinning scenarios (table 2). Although the LTAT and LTATMBURN simulations showed reduced acres of potential active crown fire, they resulted in a significant increase in passive crown fires (torching) throughout the simulation (fig. 5). The increase in torching was not simply the net result of decreased active crown fire (fig 5.) since the increases were much larger than the decrease in active crown fires. Also, the future trend in passive crown fire acres continued to increase in the LTAT scenario after the acreages of active crown were negligible. Passive crown fire for the no management scenario initially decreased until 2030 and stayed relatively constant thereafter. Increased torching in the aggressive thinning alternatives was caused by the increased fuel loadings and acreages of the grass and brush fuel models, which have a higher inherent flame length (Anderson 1982).

DISCUSSION

Our simulations oversimplified the design of fuel treatment scenarios on the Mt. Emily landscape by not considering the spatial arrangement of treatments over time (Finney 2001, Finney and Cohen 2002). We also relied primarily on landscape averages to present the results, which can mask important trends at the stand level. In addition, there are many aspects of the FVS Fire and Fuels Extension

Table 2—Results of simulations for selected management scenarios examined in the study. See text for definition of scenario labels. Variable CI24 is the acres that had a crowning index below 24, meaning that the stand can carry a crown fire in the presence of 24 miles per hour wind (97th percentile gust wind speed, Table 1).

	NOMAN				LTAT				LTATMBURN				LTATMBURNFS			
	Year				Year				Year				Year			
	2000	2020	2040	2060	2000	2020	2040	2060	2000	2020	2040	2060	2000	2020	2040	2060
Acres thinned per decade	0	0	0	0	3699	6566	4825	6773	3699	5614	3356	4461	1442	1377	403	775
Stand density index	95	199	256	281	95	136	149	123	95	131	123	134	95	183	217	222
Decadal thinning volume (merch. MCF)	0	0	0	0	3973	3389	3234	8475	3973	2759	1904	5077	1630	923	277	736
Flame length moderate fire (ft)	3.2	1.8	1.9	2.3	3.4	3.1	3.1	3.5	3.4	3.1	3.3	3.5	3.2	2.2	2.3	2.6
Flame length severe fire (ft)	11.7	11.4	10.2	9.8	12.1	11.7	11.8	12.0	12.1	11.6	11.4	11.8	11.8	11.4	10.8	9.9
CI24 (acres)	10663	20148	14958	14566	9761	12615	3652	833	9761	12600	2905	588	10355	18760	12330	11632

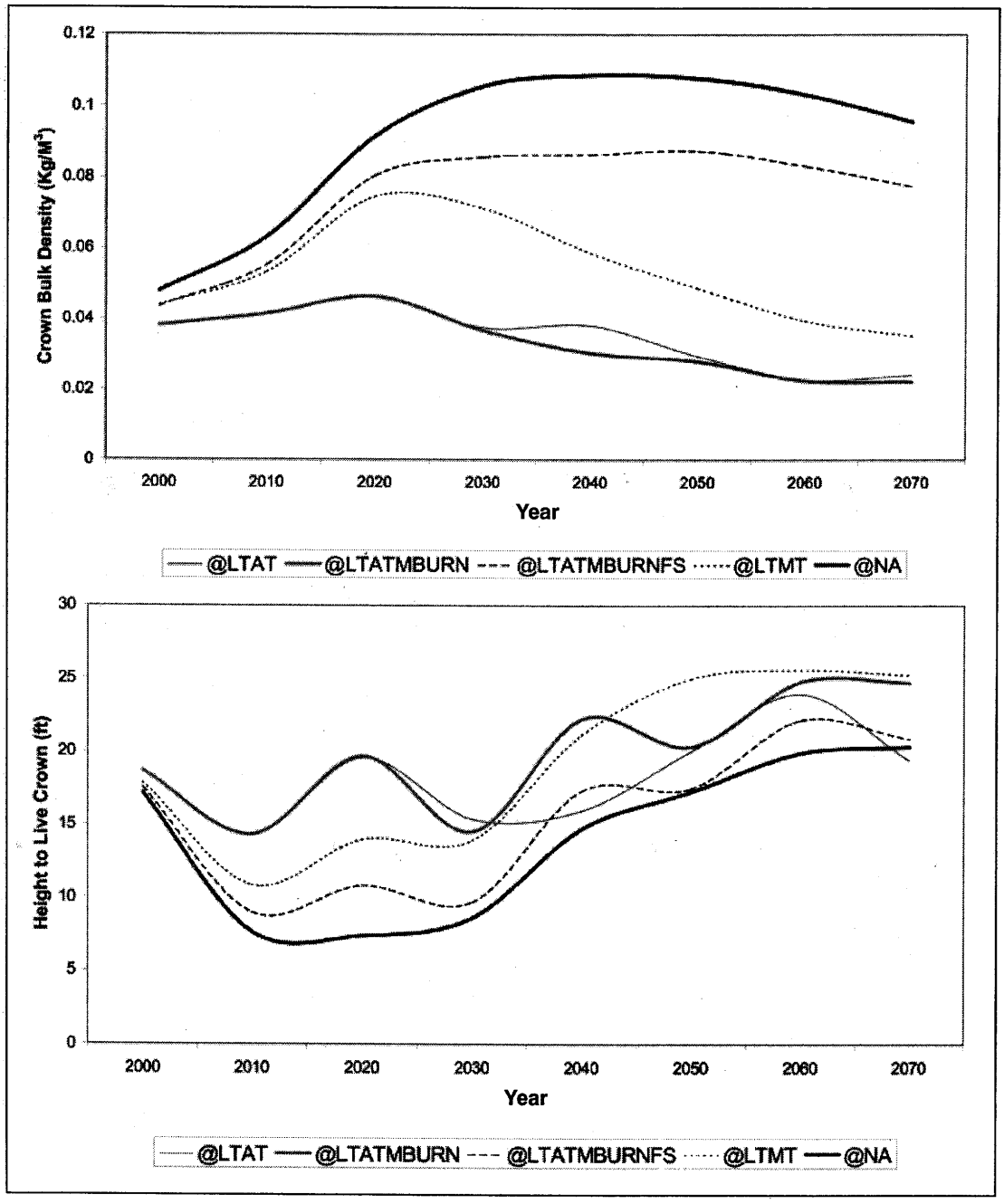

Figure 2—Results of simulations showing changes over time in crown bulk density (top) and live crown height (bottom) for selected scenarios examined in the study.

that have not undergone rigorous examination, and thus results we present pertaining to fuels and potential fire need to be viewed with some caution. One area in particular that needs attention is the assignment of fuel model 5 to stands that are dominated by conifer regeneration. These stands may or may not behave like the fuel model 5 in a wildfire depending on species composition and other factors not considered in the model. Nevertheless, the effect of thinning treatments had marked landscape-level effects on parameters like crown bulk density and live crown height,

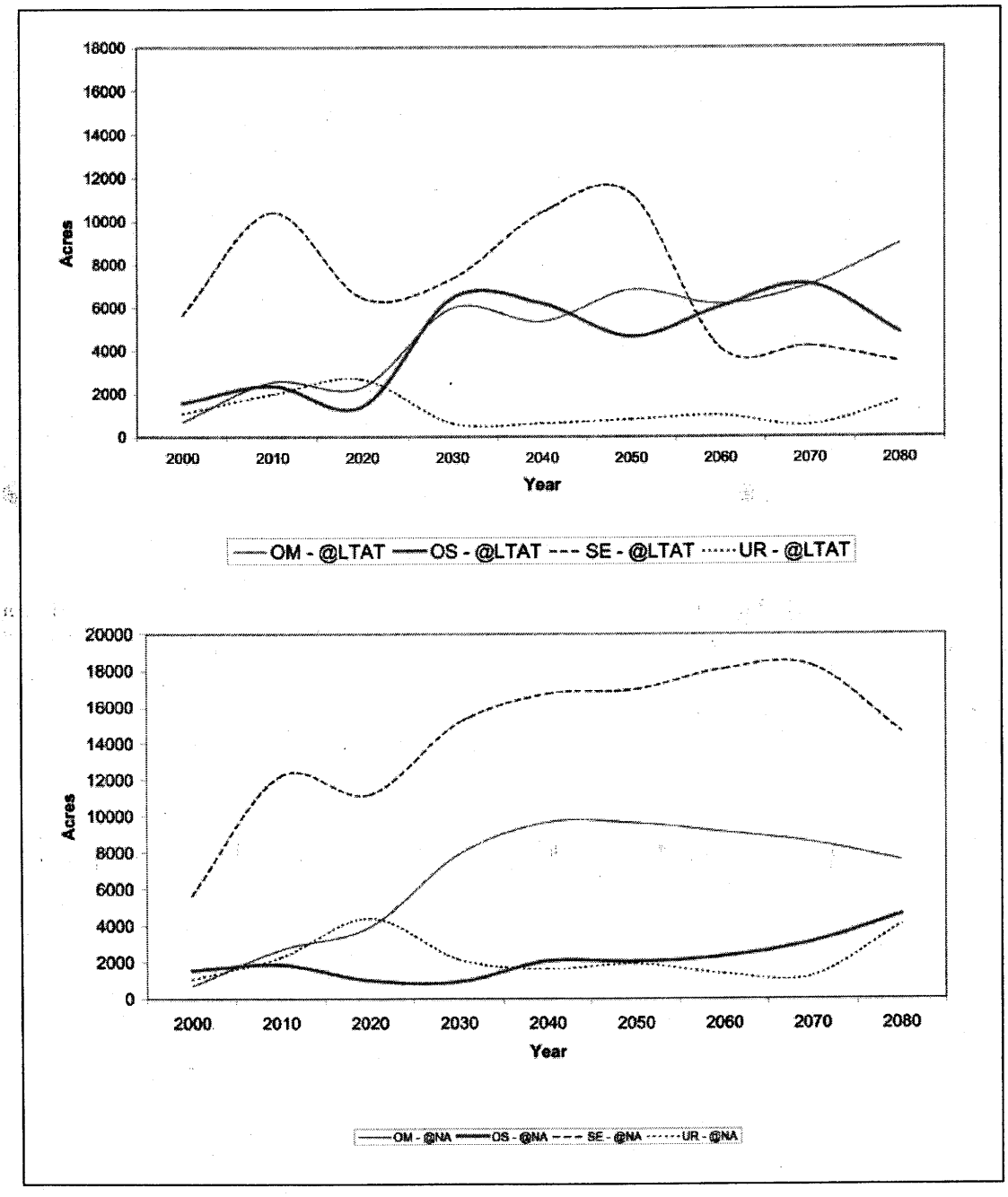

Figure 3—Results of simulations showing changes over time in forest structure for the no management (NOMAN, top) and long-term aggressive thinning (LTAT, bottom) scenarios. Structure classifications follow O'Hara et al. (1996) and were determined with the FVS cover extension (Crookston and Stage 1999).

both of which are strong determinants of crown fire activity. For instance, the average crown bulk density after 30 years of treatment was 0.01 kg/m^3, which is below the 0.050 kg/m^3 level required to sustain active crown fires (Keyes and O'Hara 2002). These changes were reflected in the lower proportion of the stands that exhibited active crown fire behavior in the potential fire simulations, and later on, a decrease in the crowning index. It was interesting to find

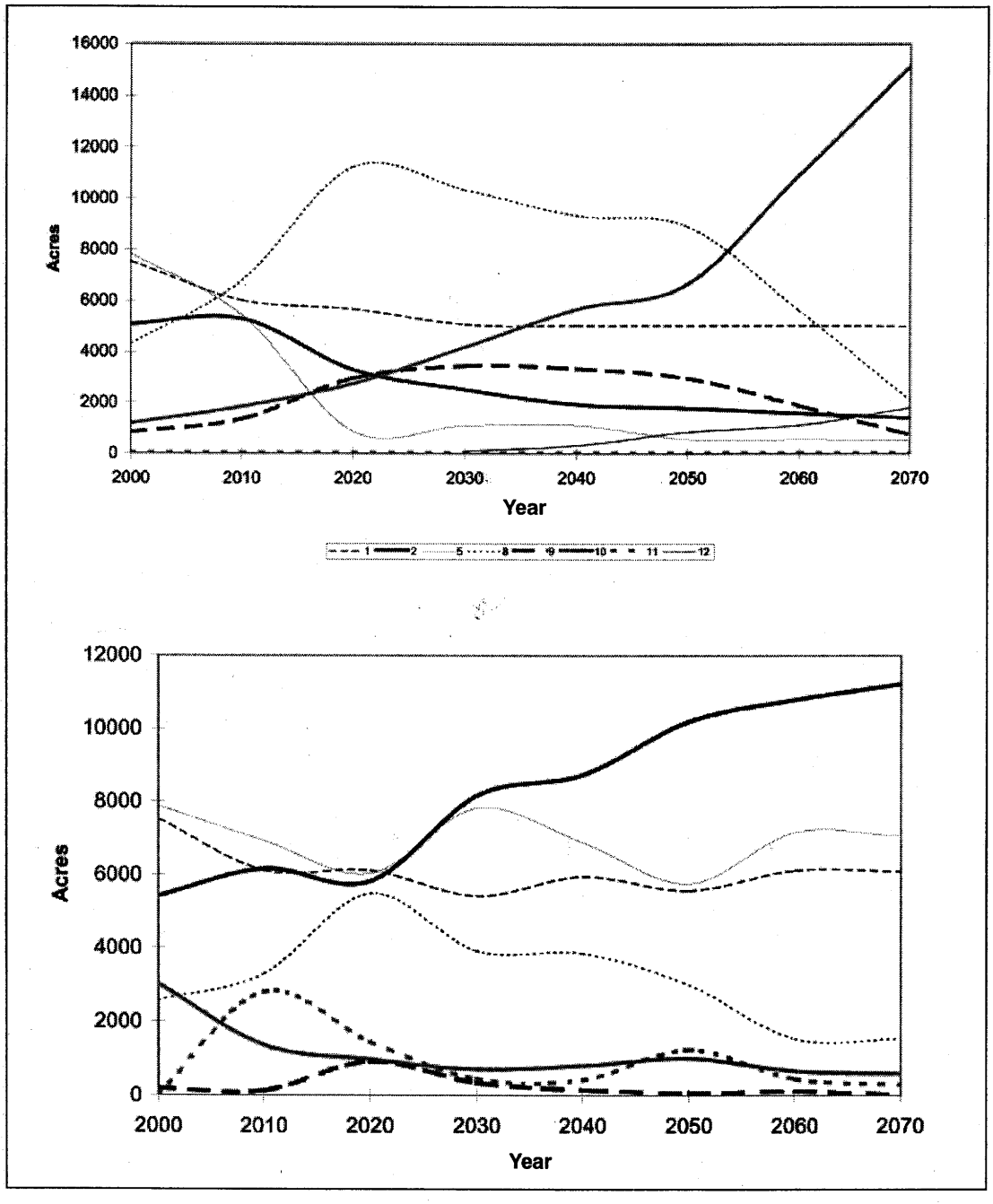

Figure 4—Results of simulations showing changes over time in fuel models for the no management (NOMAN, top) and long-term aggressive thinning (LTAT, bottom) scenarios.

that acreage of active crown fire sharply decreased after 40 years for the no management scenario. Examination of the acreages that could sustain a crown fire under 97th percentile weather conditions for the no management scenario (table 2) showed that while crown fire could not be initiated, a large portion of the project area could sustain a crown fire spreading from an adjacent stand. If we had simulated small disturbances like windthrow and root disease pockets, regeneration would probably provide the ladder fuels needed to initiate a crown fire and alter the results.

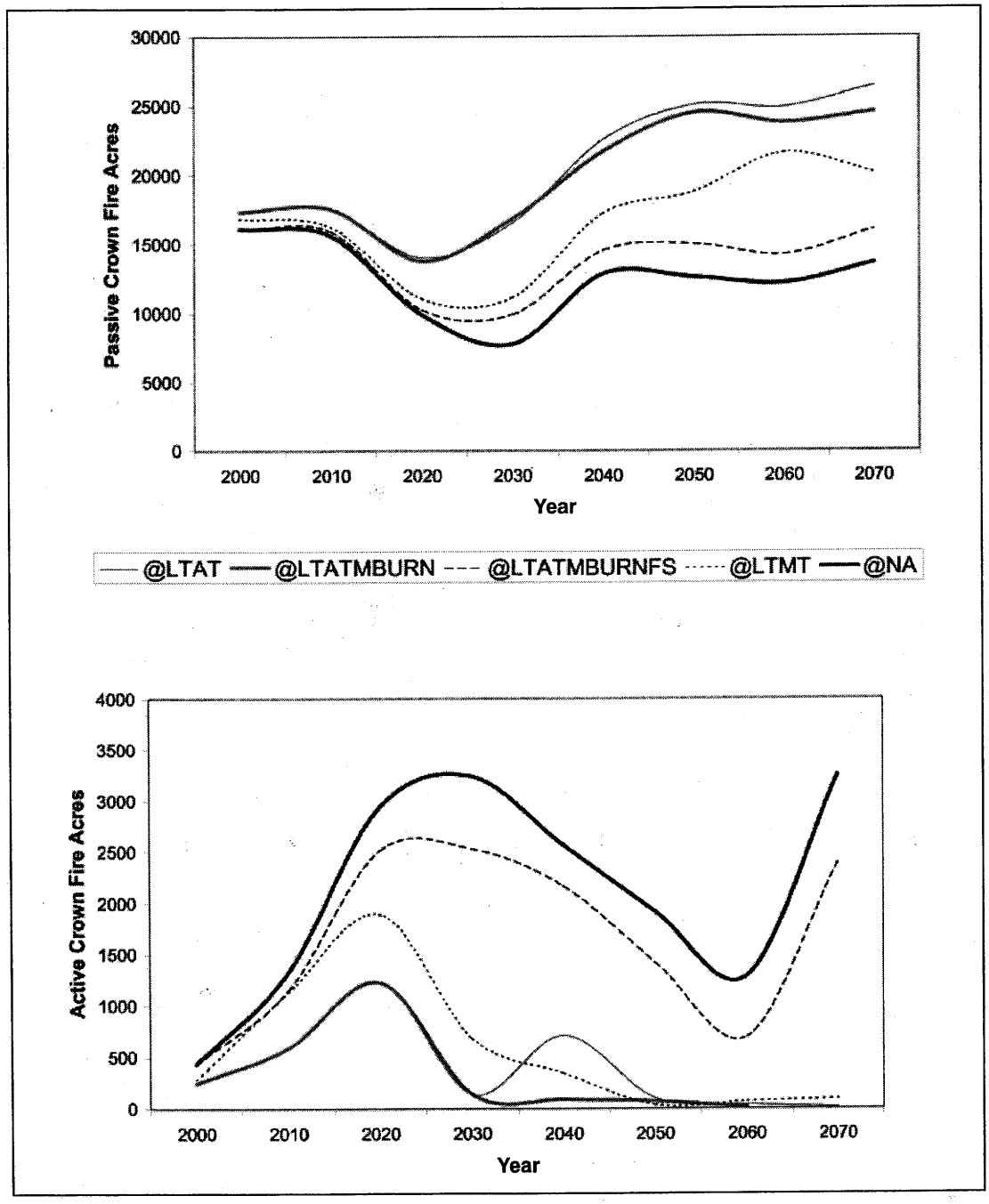

Figure 5—Results of simulations showing changes over time in acres of potential passive (top) and active (bottom) crown fire for the no management (NOMAN) and long-term aggressive thinning (LTAT) scenarios.

It was also interesting to find that thinning resulted in a large increase in passive crown fires (torching) and a small increase in average flame length for the landscape as a whole. Thinning treatments resulted in a larger proportion of the area assigned to fuel models 2 and 5 (grass, brush), which by default, have higher flame lengths and spread rates, contributing to a higher potential for torching (Anderson 1982). In addition, activity fuels most likely contributed

to the torching potential. Although the fuel models 2 and 5 have relatively high flame lengths and spread rates, they burn at low intensities relative to crown fires, and fire suppression in these fuel types is more effective (Finney 2001). A number of empirical observations have shown that treatments like those simulated here lower the intensity, spread rates, and tree mortality from wildfires.

The scenarios that simulated treatment of the Forest Service lands only showed a relatively minor response for the study area as a whole (table 2), although in part this result is strongly influenced by the size of the study area relative to the Forest Service land base. In any case, the LTATMBURNFS scenario reinforces the importance of cooperation among landowners to bring about fuels treatments on all areas. It is important to recognize that we did not attempt to model an array of resource constraints on Forest Service lands that would further limit treatments.

The mechanical thinning scenarios provide some indication of future treatment schedules for landscapes like the Mt. Emily WUI, which is useful information for strategic planning efforts that are underway on the National Forests in the Blue Mountains province. Treatment schedules for different scenarios can be used to forecast fiber supply and net revenues of thinning treatments over the long run. Under a scenario that calls for thinning based on a relative density measure like SDI, a shorthand method to calculate treatment rates can be approximated as

Treated acres/year = (Watershed Acres)/ (F'[SDImax] - F'[SDImin])

Where SDImax and SDImin are the values of SDI at the upper and lower management threshold and F'(t) is the inverse of the function that predicts SDI change over time. The latter can be derived from stand growth simulations and averaged for all stands in a landscape.

The current and future density problems in areas like Mt. Emily demand additional ecological discussions (Tiedeman and others 2000) and perhaps new and innovative solutions. Thinning, fuels treatments, and underburning have well-documented beneficial effects on overstocked stands in terms of general forest health and wildfire risk. However, thinning overstocked stands induces waves of regeneration and sets the stage for future development of ladder fuels and high crown bulk density. If recurring treatments are not applied, the initial thinning 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 2000) and a variety of resource values must be considered on the Federal land base.

While fire suppression and removal of fire tolerant species has been a major factor in the development of fire-prone conditions, there are many processes besides wildfire that regulate stand density through time in coniferous forests. For instance, thinning treatments can enhance seed production in residual trees (Reukema 1961), leave a favorable substrate for seed germination (Schopmeyer 1974), and degrade habitat for small mammals (Tiedemann and others 2000) that consume conifer seed (Sylvester and others 1994). Thus treatments may set the stage for prolific conifer regeneration and, eventually, dense stands with high crown fire potential. New research is needed to find ways to manage seed production, seed survival, germination and seedling establishment after underburning and mechanical treatments.

There are many issues that need to be explored with the simulation approach we have used here, such as the spatio-temporal patterns of treatments (Finney 2001), interactions between wildfire and other disturbances (Quigley and others 2001), and secondary effects of fuels treatments on other resources including wildlife and forest productivity (Tiedemann and others 2000; Johnson and Miyanishi 1995). For instance, optimal spatial patterns of shaded fuel breaks (Finney 2001) could fragment stands of late-old structure considered important to keystone wildlife species like American marten (*Martes americana*) (Hargis and others 1999). On the other hand, these treatment patterns might create desired foraging habitat for Canada lynx (*Lynx canadensis*) (Aubry and others 2000) and Rocky Mountain elk (*Cervus elaphus*). Frequent burning can reduce foraging substrate (down wood) for a number of important avian and mammal species that feed on ants and other insects (Torgersen and Bull 1995). Economic questions about the kinds of investments that will be needed in the long term to finance forest restoration treatments (Christiansen and others 2002) have not been addressed in a way that reflect spatially explicit harvesting and transportation costs. All of these issues contribute to a long-term landscape design questions of how to achieve restoration goals in the Blue Mountains (Quigley and others 2001) within a constraint matrix that includes riparian buffers, roadless area, visual objectives, and habitat for listed species.

Many improvements are needed to the simulations we presented here, and work is in progress towards that end. We are analyzing the different scenarios in terms of wood utilization, habitat for selected wildlife species, and insect

and disease risks for the Mt Emily WUI. We are also developing mortality models for insects and disease using a multi-agent approach (Roberts and Weatherby 1997). Mechanical thinning prescriptions are being refined for the different ecological settings and management goals within the project area. These refinements will be used for additional simulations on the Mt Emily area to gain further insights into the long-term problem of managing for multiple resource objectives in the Blue Mountains.

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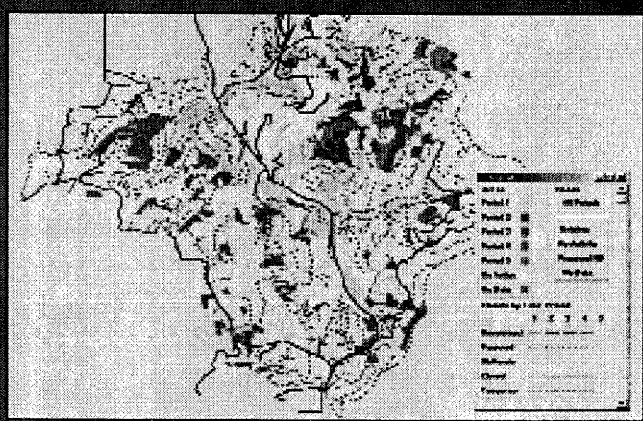

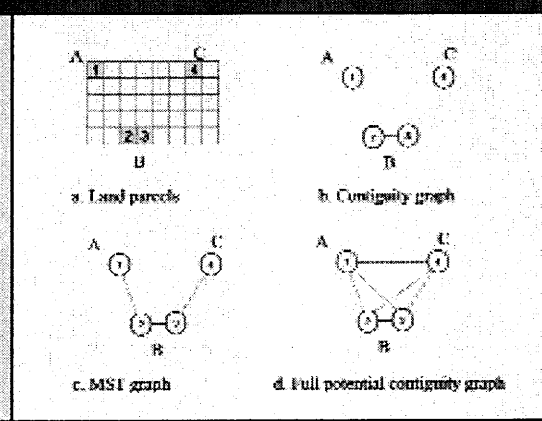

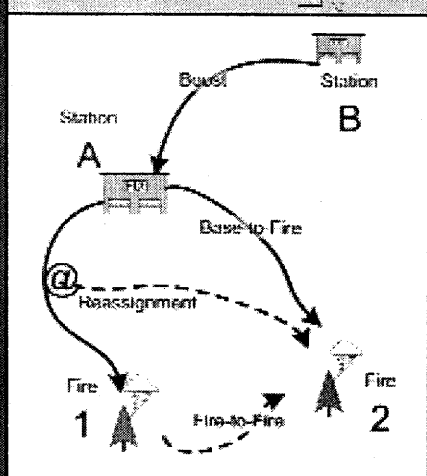

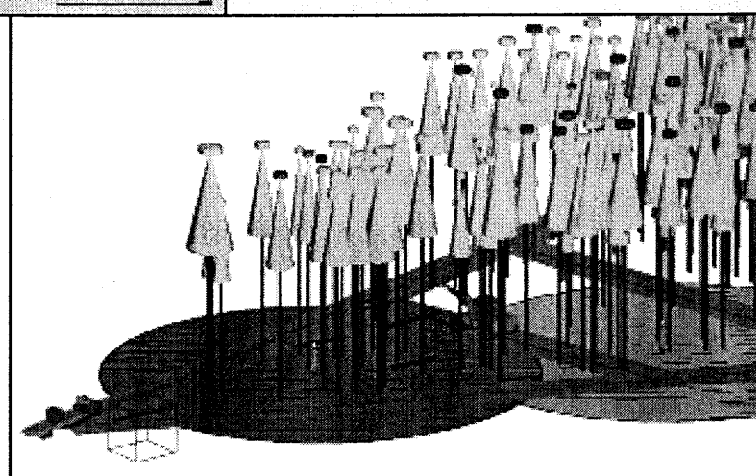

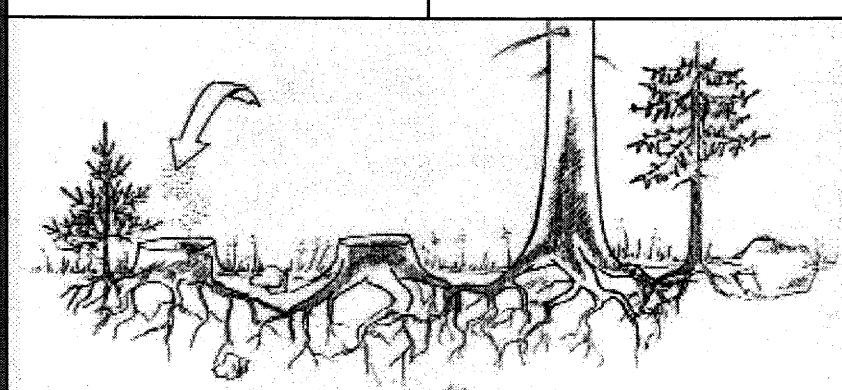

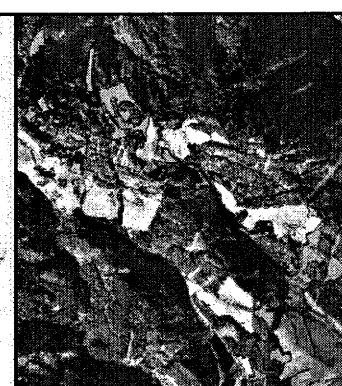

COMPILED BY

Michael Bevers, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado and **Tara M. Barrett**, U.S. Department of Agriculture, Pacific Northwest Research Station, Portland, Oregon.

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ABSTRACT

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The 2003 symposium of systems analysis in forest resources brought together researchers and practitioners who apply methods of optimization, simulation, management science, and systems analysis to forestry problems. This was the 10th symposium in the series, with previous conferences held in 1975, 1985, 1988, 1991, 1993, 1994, 1997, 2000, and 2002. The forty-two papers in these proceedings are organized into five application areas: (1) sustainability, criteria and indicators, and assessment; (2) techniques and decision support for forest planning; (3) forest assessment and planning case studies; (4) fire suppression, fire planning, and fuels management; (5) harvest scheduling; and (6) mill supply and forest product markets.

KEYWORDS: Forest planning, forest management, forest modeling, operations research.

PREFACE AND ACKNOWLEDGMENTS

The 2003 symposium on systems analysis in forest resources was the 10th symposium in this series. Originated as a conference of the Systems Analysis Working Group of the Society of American Foresters, the first meeting was held in Athens, Georgia, in 1975. The second symposium was held again in Athens in 1985. The international success of these conferences has motivated additional meetings every 2 to 3 years since 1985, including systems analysis symposia in Asilomar, California (1988 and 1994), Charleston, South Carolina (1991), Valdivia, Chile (1993), Traverse City, Michigan (1997), Snowmass Village, Colorado (2000); and Punta de Tralca, Chile (2002). Future meetings are being planned in Brazil in 2005 and in the United States in 2006.

The 2003 symposium was made possible through the contributions of many people and organizations. Participating organizations included three Society of American Foresters scientific groups (the management science and optimization (E-4) working group, the economics, policy, and law (E-1) working group, and the technology assessment and future analysis (E-5) working group), scientific divisions of the International Union of Forest Research Organizations, the College of Forestry and Department of Statistics at Oregon State University, the Western Forestry and Conservation Association, the Forest Inventory and Analysis program at the Pacific Northwest Research Station, and the Natural Resource Assessment, Ecology, and Management Science work unit at the Rocky Mountain Research Station, USDA Forest Service.

We thank our program committee: Doug Brodie, Peter Ince, Darek Nalle, Kevin Boston, Matt Turner, John Sessions, and Jeff Arthur. We were grateful for the assistance of Masha Konoshima, Jules Comeau, Rafael de la Torre, Paul Dunham, Hamish Marshall, Glenn Christensen, Phil Lacey, and Demetrios Gatziolis. We appreciate the efforts of Robert Haight and Mikael Rönnqvist, who provided the keynote address, Andy Gray, who led the field trip, and John Hof, Peter Ince, and Dave Martell, who gave the general session talks. We thank Doug Brodie for his closing remarks. We recognize the session moderators including Pete Bettinger, Joe Buongiorno, Larry Davis, Matt Pelkki, Alan Murray, Darius Adams, Jeremy Fried, Mikael Rönnqvist, Marc McDill, Stephanie Snyder, and Marc Wiitala. Richard Zabel, Aimee Sanders, and Virginia Hokkanen helped with logistics. The Skamania Lodge in Stevenson proved to be an excellent facility for this meeting. The continued support and enthusiasm of participants in this symposium series is very much appreciated.

Mike Bevers and Tara Barrett, Compilers

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