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Simulations of Alternative Mechanical Thinning Treatment Programs on Western Timberland

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Abstract

We used the Economics of Biomass Removals model to evaluate the required treatment acreages, volumes removed, treatment costs and product revenues from national forest and other ownerships. We used three distinct treatment prescriptions to achieve two hazard reduction goals for treatable timberlands in the Western United States. The two hazard reduction goals were to maintain current hazard levels over 10 years, and to reduce hazard levels by 20 percent over 10 years. We also simulated one treatment prescription on national forest timberland only in order to evaluate the effect of requiring a minimum level of treatment in each State. These simulations show that costs and revenues differ by intensity of the hazard reduction goal and by treatment prescription. They show that uneven-aged treatment prescriptions tend to be more expensive than thin-from-below prescriptions for accomplishing hazard reduction goals. Uneven-aged prescriptions, however, yield greater timber product volumes and values for landowners, offsetting the higher costs. On the other hand, in situations without wood product markets, thin-from-below prescriptions could be a better option because of the lower net costs.

Keywords: Economics of Biomass Removals, fire hazard, mechanical thinning, treatable timberland, treatment costs.

Introduction

Increasing fire, increasing fire suppression expenditures, and deteriorating forest health have contributed to interest in using mechanical thinning treatments as a forest management option. In addition, timber and biomass removals from treatments could be used to produce bioenergy or biofuels. The Economics of Biomass Removals (EBR) model was developed to address the market impacts of large-scale mechanical thinning treatment programs (Abt and Prestemon 2006, Huggett and others 2008, Prestemon and others 2008). In this report, we extend past analyses with an updated EBR model that assesses the costs and economic effects of three treatment prescriptions. This version of the model simulates the rate at which stand growth will cause transitions from one hazard class to another for all forest types. Inclusion of these forest-type specific growth transitions allows assessment of long-term impacts and provides new descriptions of a prescription's effects on important policy outcomes, including estimates of jobs created and volumes of logging residuals. The objectives for this study were to simulate three mechanical thinning prescriptions on national forests and other timberlands in Western States (for the objective of maintaining or reducing fire hazard), and to summarize timber products and revenues, area treated, and jobs, as well as acres treated and acres remaining in high fire hazard status.

Research is needed to improve understanding of policy options available to land managers in fire prone regions of the United States. Assessments of mechanical thinning treatment programs currently implemented by the Forest Service, U.S. Department of Agriculture and other land management agencies have highlighted the need for agencies to come up with objective means of prioritizing these activities. Wildfire management is a complex task involving decisions on how to allocate scarce resources toward competing methods of improving forest health and reducing negative impacts. The EBR model provides a means of identifying priorities for mechanical thinning treatments. The model helps researchers sort through many of the complexities of mechanical thinning treatments because it provides objective information about the following: wildfire hazard recognizes the heterogeneity of fuels and forests across the landscape, the potential markets for timber products removed from forests upon treatment, priorities for treating wildland-urban interface and intermix areas, the costs of applying different treatment prescriptions, and the natural return to hazardous conditions that occurs following treatment. The remainder of this report outlines the essential elements of the EBR model and the simulations conducted to address current policy and land management concerns.

Methods

We used the EBR model to evaluate the effects of policy alternatives for reducing fire hazard with mechanical thinning treatments (Abt and Prestemon 2006, Prestemon and others 2008). With the model, we simulated markets, fire hazard, and growth transitions over time. Outputs from the model included jobs, as well as costs and revenues deriving from each of three treatment prescriptions.

[1] Research work accomplished through Research Joint Venture Agreement Number SRS-08-JV-11330143-088, "Modeling Dynamics in Support of National Resource Assessments," September 2008.

The EBR model is a two-stage mathematical program. The first stage uses a goal program to find the least expensive acres to treat, given a set of overriding priorities about the kinds of places needing treatment. The second stage uses a quadratic program to determine the market outcomes (prices, timber production, timber consumption, and wood transport) resulting from the removal of any timber products upon treatment. More details on the model are available in Prestemon and others (2008).

For these simulations, the EBR model used a starting budget and a treatment prescription, and simulated the treatment and market outcomes that resulted from that treatment program. The budget was then adjusted until the objective was met (within ± 0.3 percent). For each of the Western States, the simulations provide hazard reduction, costs, timber products and revenues generated, and jobs created[2]. We ran separate simulations for the two ownership categories in order to evaluate the outcomes from the different policies that would be necessary for the national forests as compared to other ownerships. A shortcoming of the current model is that the separate modeling of different ownership groups prevents the mathematical program from trading off treatment on national forests with treatments on other ownerships.

Before we could run the simulations, we completed the following steps: (1) defined treatable land base by owner, (2) defined level of aggregation over space, ownership and/or management, (3) defined hazard level on the treatable land base, (4) developed and applied mechanical thinning treatment prescriptions, (5) estimated treatment costs, (6) estimated products from the treatment, (7) predicted hazard transition of all acres (treated and not treated), (8) defined modeling priorities, (9) defined mill capacities, (10) estimated transportation costs, (11) set replacement outcome for national forest harvest, (12) estimated jobs coefficients, and (13) calculated logging for biomass. These steps are discussed as follows:

1. Defined treatable land base by owner: For the 12 Western States, we used data from U.S. Department of Agriculture Forest Service Forest Inventory and Analysis (FIA) 2002 Resources Planning Act (U.S. Forest Service 2002). We selected only plots classified as timberland (land capable of producing 20 cubic feet per acre per year). From that group of plots, we then excluded reserved areas (wilderness) and inventoried roadless areas.

   In addition to these administrative exclusions, we made two ecological exclusions. First, we removed the plots on the west side of the Cascade Mountains in Oregon and Washington from the treatable timberland base because these wet forest types are at lower risk of crown fire and catastrophic damage. We also excluded forest types which require intense stand replacement fires for regeneration, such as interior spruce-fir (*Picea* spp.-*Abies* spp.) and lodgepole pine (*Pinus contorta* Dougl.) stands across the rest of the West. However, we retained these stand replacement forest types in the wildland urban interface to ensure treatments would occur next to high-valued resources.

   For this analysis, we addressed two ownership groups—national forests and other owners, which includes private and all non-national forest lands. Figure 1 shows the breakdown of forest land into timberland and nontimberland for these owner groups, and figures 2 (national forest) and 3 (other ownerships) show the treatable timberland base by State.

2. Defined level of aggregation: The simulation can be run for different aggregations over space, ownership, and management—e.g., by State, forest type, or wildland urban interface designation. These aggregations are necessary when using expanded FIA plot data to ensure a low approximation error on both acres and volumes of timberland. For these simulations, we aggregated to the State and LANDFIRE map zone (2010) by owner (as previously described) and by wildland urban interface designation. LANDFIRE is a national program to develop fire and fuels data, and map zones are sub-State areas of similar fire and ecology that allow us to simplify our treatment prescriptions and regrowth parameters. The wildland urban interface (WUI) is the area where forests and human development meet, as defined in Radeloff and others (2005). The definition of WUI by Radeloff and others (2005) differs from the community specific definitions mandated under the Healthy Forest Restoration Act of 2003. WUI areas established under this act are not currently mapped for the entire Western United States, nor are they developed in a systematic manner as are the WUI areas provided by Radeloff and others (2005). As a result, WUI maps by Radeloff and others (2005) are the best available source for estimating the WUI area with high fire hazard over large areas such as those analyzed in this study. We multiplied the expanded plot results for each plot times the percent of forest area in the WUI in each Western county to develop estimates of timberland characteristics in the WUI. A final aggregation was done after we determined the following hazard levels.

3. Defined hazard level on the treatable land base: Hazard was measured by a combination of stand-level torching index and crowning index, as shown in table 1. The use of torching and crowning index was based on Scott (1999) and Scott and Reinhardt (2001). The cutoff points for the hazard levels were consistent with levels used in Skog and others (2006), which were developed in conjunction with fire scientists and fuels experts. These levels put more weight on crowning index, as individual tree torching

[2] Residue volumes can also be converted to potential electricity or biofuels.

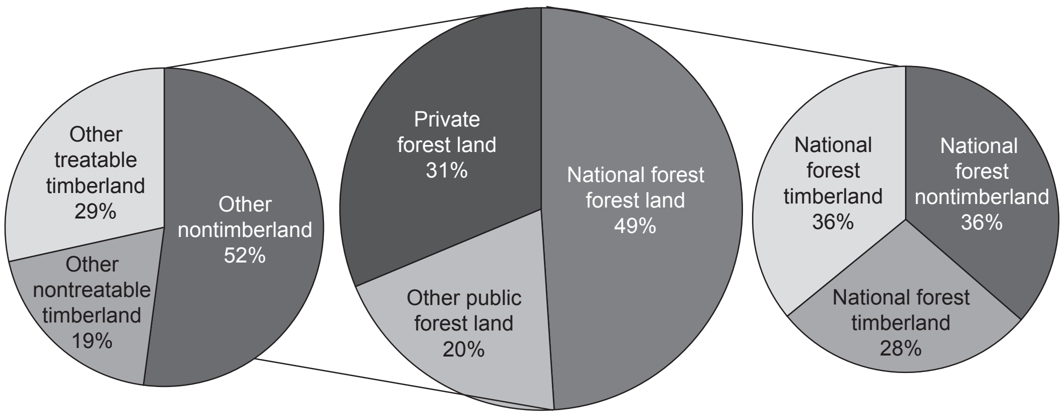

Figure 1—All forest land in Western States by ownership and subset of national forest (right) and other owners (left) into nontimberland, nontreatable timberland, and treatable timberland.

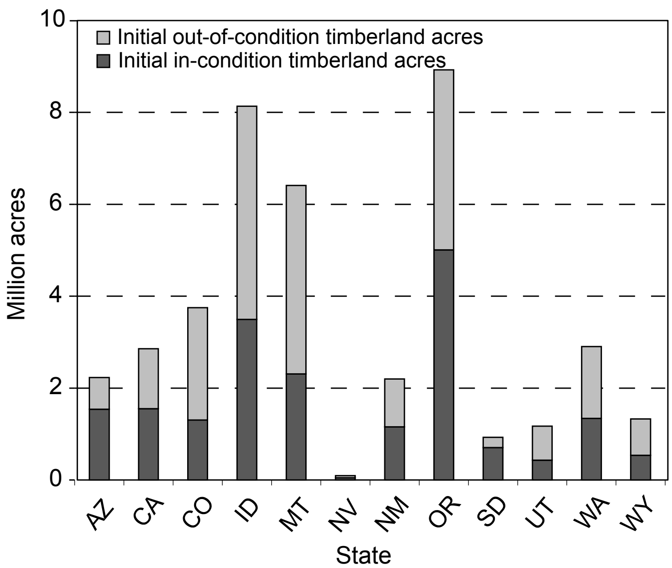

Figure 2—Initial treatable timberland acres in- and out-of-condition on national forests for 12 Western States.

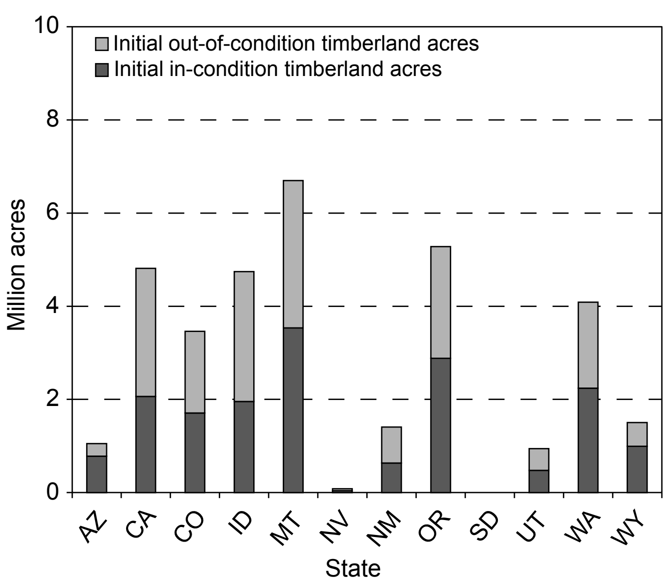

Figure 3—Initial treatable timberland acres in- and out-of-condition on other ownerships (non-national forest) for 12 Western States.

was deemed less significant than the spreading potential measured by the crowning index. Initial in- and out-of-condition acres are shown by State in figures 2 (national forest) and 3 (other ownerships).

4. Developed and applied mechanical thinning treatment prescriptions: The cut list and resulting hazard level for three types of mechanical thinning treatment prescriptions were developed from the plot characteristics. The three prescriptions were modeled separately, and included two uneven-age prescriptions based on regulation of stand density index to maintain an uneven-aged forest structure, and one even-aged prescription, based on regulation of basal area by thinning-from-below (TFB) (table 2). The two flexible stand density index (uneven-aged) prescriptions removed either more large trees (SDI-Large) or more small trees (SDI-Small) using techniques developed in Shepperd (2007). These prescriptions were not allowed to remove more than 50 percent of initial basal area. This prevented some treated stands from reaching in-condition status, in spite of the thinning, and thus hazard was not eliminated even if the treatment was conducted. Lodgepole pine and spruce-fir stands in the WUI were thinned only with the TFB prescription, while the other forest types were evaluated for all three prescriptions. Similar prescriptions were evaluated in Skog and others (2006).

5. Estimated treatment costs: Gross treatment costs were estimated by adding a fixed cost ($200 per acre for all government and $100 per acre for all other owners) and a variable on-the-ground treatment cost. Variable treatment costs were derived from Arriagada and others (2008). The $200 per acre fixed cost was assumed to account for preparation, environmental analysis, and monitoring costs on government lands. We assumed the fixed costs for nongovernment timberlands were less, only $100 per acre because of the more extensive environmental requirements for government projects.

Table 1—Hazard definitions based on index thresholds

Plots are classified as	Torching index threshold	Crowning index threshold
	mph	
Out-of-condition (hazard exists) if	TI < 25, and	CI < 25
or if	TI ≥ 25, and	CI < 40
In-condition (hazard does not exist) if	TI ≥ 25, and	CI ≥ 25
or if	TI < 25, and	CI ≥ 40

TI = Torching index; CI = Crowning index.

Table 2—Mechanical thinning treatment prescriptions used in the simulations

Prescription acronym	Description	Maximum percent of basal area removed
SDI-Large	Uneven aged based on stand density index, flexibly adjusted to remove more large trees	50
SDI-Small	Uneven aged based on stand density index, flexibly adjusted to remove more large trees	50
TFB	Thin-from-below removing small trees until hazard goal is reached or BA limit is reached	25

SDI = Stand density index; TFB = Thinning from below.

6. Estimated products from thinnings: Products from thinned stands included sawlogs from ponderosa pine (*Pinus ponderosa* Laws.), lodgepole pine, and other softwoods, and pulpwood (including all hardwoods), converted to chips. Chips were hauled to a mill if their value exceeded the cost of production and transportation.

7. Predicted transitions of all treated and not treated stands: An important element of the simulation model is the transition of stands (acres) from one hazard level to another as they grow. The transition matrix indicates how quickly stands change their in- or out-of-condition status. Three kinds of transitions are recognized: (1) transitions occurring through natural stand development without any treatment (pre-treatment transitions), (2) transitions that occur when a stand is treated (treatment transitions), and (3) transitions that happen in the years subsequent to treatment (post-treatment transitions). Pre-treatment transitions generally occur more slowly than post-treatment transitions. The current model does not account for transitions that occur due to natural disturbances like fire or insect outbreaks.

   Base rate pre-treatment and post-treatment transition matrices for each of our three prescriptions (SDI-Large, SDI-Small, and TFB) were derived from a sample of ponderosa pine-lodgepole pine stands in Colorado (Huggett and others 2008). To apply these transitions to other stands in other places in the West, we adjusted the pre- and post-hazard transition rates based on stand growth rates. These stand growth rates were obtained from LANDFIRE (2010) simulations and FIA volume growth rates (Smith and others 2004). Note that not all treated stands will move to in-condition status when treated because the treatment prescriptions will not remove more than 50 percent of basal area. The 50 percent limitation is based on consultation with Federal silviculturists, fuels specialists, and other technical specialists who have practical experience with the sorts of treatments that are typically implemented on Federal land given other ecological considerations and social constraints to Federal land management activities. These prescriptions are consistent with limits used in Skog and others (2006).

8. Determined modeling priorities for treatment: The EBR model allows different treatment priorities to be used, including WUI status, treatment cost, forest type, and out-of-condition (hazard) level. In these simulations, WUI acres were treated first in order of their treatment cost. Non-WUI acres were treated next, and again, the least cost were treated first.

9. Defined mill capacity by State: Mill capacity for sawtimber volumes was fixed throughout the simulations at current levels (Spelter and Alderman 2003, 2005), while mill capacities for merchantable materials other than sawtimber were based on average removal levels of these materials are reported by Smith and others (2004). In the modeling, stated capacities could not be exceeded by more than 40 percent because this is the limit that could be accommodated by adding additional shifts to existing mills. Instead when volumes removed in a State exceeded shift-adjusted local mill capacity products were shipped to other mills in the West, the rest of the United States, or the rest of the world, consistent with current prohibitions on the export of softwood logs removed from Federal lands in the Western United States.

10. Estimated transportation costs: For these simulations, transportation costs were $1 per thousand board feet per mile for sawlogs and $0.005 per cubic foot per mile for pulpwood. Distances to sawmills and pulp mills were estimated as the county-level weighted average distance from the county's FIA plots to the nearest five sawmills and pulp mill, respectively. Countywide average distances were used because we are not simulating individual plot treatments, but expanded plots, which represent many different stands within the county, each of which would have a different distance to each mill type (Prestemon and others 2008).

11. Set replacement outcome for national forest harvests: For this simulation, products from treatments were assumed to replace regular (nontreatment related) harvests on national forests if product quantities are less than base-level national forest harvests; otherwise, they add to regular harvests. Market forces were allowed to act so that treatment harvests will partially replace regular timber harvests occurring outside of national forests on the rest of the timberlands in a State.

12. Estimate job coefficients: Jobs were calculated using averages from Hjerpe and Kim (2008), where direct jobs derive from the actual expenditure of treatment money, and total jobs derive from actual expenditures plus the indirect effects of those businesses spending money and the induced effects of the employees of those businesses spending money. We assumed that the $200 per acre administrative cost to the government-owned treatments resulted in six direct jobs, and an additional five indirect and induced jobs, for a total of 11 jobs per million dollars of expenditure (e.g., for every 5,000 acres treated on government administered lands, a total of 11 jobs were produced). The treatment prescriptions were assumed to be accomplished by logging contractors, and the private administrative cost of $100 per acre as well as the on-the-ground treatment costs for all owners, were assumed to result in four direct jobs, and an additional 13.2 indirect and induced jobs, for a total of 17.2 jobs per million dollars of expenditure. These jobs estimates exclude the effects of treatments from regular harvests on national forests or the effects of treatments outside of national forests, thus we would expect that some timber harvesting jobs would be displaced by the thinning treatment jobs.

13. Estimated logging residues: A West-wide average of 0.30 units of logging residues were assumed to be produced from each plot, half of which was assumed recovered and removed from the site. The recovered volumes are reported.

Once all of the above decisions and data manipulation were completed, we simulated the policy alternatives by solving the EBR mathematical programming model. We used an iterative approach which started with an initial budget for treatments, and then applied that budget to the model as a constraint. After a simulated 10 years of treatments given the budget, acres out-of-condition were compared to initial conditions to determine whether the budget was sufficient to achieve either a 0 percent or 20 percent reduction in hazardous acres, within our ± 0.3 percent tolerance range. If it was insufficient, the budget was adjusted upward and the simulation re-run. Likewise, if hazard levels were below the target reduction amounts, then the budget was adjusted downward and re-run. This process was repeated until convergence at either 0 percent or 20 percent reduction in hazardous acres.

Results and Discussion

We simulated a total of 13 different hazardous mechanical thinning treatment policies. Separate simulations were run for two ownerships (national forest and other), three treatment prescriptions (SDI-Large, SDI-Small and TFB), and two hazard reduction goals (keep hazardous acres constant, and reduce hazardous acres by 20 percent). This resulted in 12 separate simulations. In addition, we conducted one simulation for national forest treatable timberland using the SDI-Large prescription which required a minimum level of treatment in each State.

The two hazard reduction goals evaluated were:
(1) Maintain current conditions: treat enough timberland over the 12 States, within a ± 0.3 percent tolerance range, such that the area of treatable timberland out-of-condition did not change (i.e., remained approximately constant) by the end of a 10-year program of treatments; or, (2) Improve conditions by 20 percent: treat enough timberland over the 12 States, within a ± 0.3 percent tolerance range, to reduce the area of treatable timberland out-of-condition by 20 percent by the end of a 10-year program of treatments.

Next, we discuss the results of the simulations without minimum State treatment constraints for each of the owner groups, followed by a short discussion of the constrained simulation.

National Forest Treatable Timberland Simulations (Without Minimum Treatment Constraints)

Just over half of the treatable timberland in the 12 Western States is managed as national forest land. As well, 56 percent of the out-of-condition treatable timberland falls under national forest management. From the three prescriptions and two hazard reduction goals simulations, the average annual area treated ranges from 620,000 acres (0 percent reduction using TFB) to 2,250,000 acres (20 percent reduction using SDI-Large) (table 3). The difference in area treated derives from both the hazard reduction goal and from differences in growth rates on treated stands.

The average annual treated area by State is shown in figure 4. Note that initial in- and out-of-condition acres are identical for all national forest simulations and that final acres for each hazard reduction goal are within tolerances noted above for the hazard reduction goal. Over the 10 years of the simulations, the total acres treated comprises from 18 to 66 percent of all treatable timberland, with the higher acreages treated under the 20 percent hazard reduction goal.

Table 4 provides the average annual volumes removed for sawlogs and chips, as well as estimates of gross biomass and jobs resulting from the treatments. The 20 percent reduction simulations removed more than three times the volume of sawlogs and chips than did the 0 percent reduction simulations. In addition, the SDI-Large prescription removed much more volume than the TFB prescription for both hazard reduction goals.

The number of jobs produced was highest with the SDI-Large and lowest with TFB. More jobs are created in the SDI-Large treatment because more acres needed to be treated, and more acres needed to be treated because regrowth on treated stands was higher on the plots selected as least-cost under the SDI-Large treatments. Applying the SDI-Large prescription to reduce hazard by 20 percent on national forest treatable timberland contributed nearly 9,000 direct and more than 15,000 indirect and induced jobs per year, while TFB contributed 5,800 direct and 10,000 indirect jobs. To only keep hazard constant on treatable timberland, 60 to 65 percent fewer jobs per year were produced (table 4). Again, because some of these harvests would have occurred anyway, not all of these jobs are new jobs. Jobs are estimated from the expenditures made to accomplish the treatments.

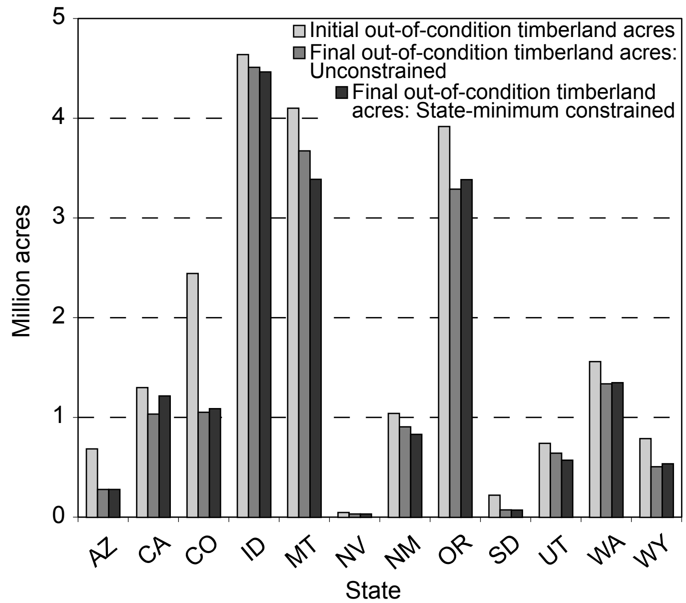

Figure 4—Initial and final treatable timberland acres out-of-condition on national forests in 12 Western States, under unconstrained and State-minimum-constrained simulations, for the stand density index-large prescription with an objective to reduce the West-wide area out-of-condition by 20 percent in 10 years.

The SDI-Large treatment cost more to implement than the SDI-Small and the TFB for both hazard reduction goals (table 5). The SDI-Small prescription had the smallest net

Table 3—Acreage simulation results for national forest treatable timberlands by hazard reduction goal and treatment prescription

Hazard reduction goal	Treatment prescription	Treated area (annual average)	Initial out-of-condition	Final out-of-condition	Initial in-condition	Final in-condition
		Million acres				
Keep hazardous acres at current level	SDI-Large	0.83	21.51	21.63	19.43	19.31
	SDI-Small	0.68	21.51	21.69	19.43	19.25
	TFB	0.62	21.51	21.68	19.43	19.26
Reduce hazardous acres by 20 percent	SDI-Large	2.25	21.51	17.36	19.43	23.58
	SDI-Small	1.89	21.51	17.21	19.43	23.73
	TFB	1.63	21.51	17.20	19.43	23.74

SDI = Stand density index; TFB = Thinning from below.

Table 4—Volume and job simulation results for national forest treatable timberlands by hazard reduction goal and treatment prescription

Hazard reduction goal	Treatment prescription	Sawlog volumes removed	Merchantable chip volumes removed	Gross biomass available	Direct jobs	Indirect and induced jobs
		- - - - - Million cubic feet	*- - - - -*	*Million oven-dry tons*		
Keep hazardous acres at current level	SDI-Large	211	91	183	3,064	5,340
	SDI-Small	110	72	162	2,468	4,303
	TFB	16	23	142	2,033	3,559
Reduce hazardous acres by 20 percent	SDI-Large	697	289	212	8,756	15,232
	SDI-Small	378	245	187	7,318	12,732
	TFB	68	127	162	5,755	10,044

SDI = Stand density index; TFB = Thinning from below.

Table 5—Cost and revenue simulation results for national forest treatable timberlands by hazard reduction goal and treatment prescription

Hazard reduction goal	Treatment prescription	Gross revenues	Gross treatment costs	Net treatment costs	Average gross treatment cost	Average net treatment cost
		- - Annual average	*in million dollars*	*- -*	*- - - - Dollars per acre*	*- - - -*
Keep hazardous acres at current level	SDI-Large	390	670	280	805	337
	SDI-Small	239	539	300	798	441
	TFB	45	438	393	706	634
Reduce hazardous acres by 20 percent	SDI-Large	890	1,927	1,037	857	461
	SDI-Small	808	1,610	802	853	424
	TFB	139	1,253	1,114	771	683

SDI = Stand density index; TFB = Thinning from below.

cost (gross treatment revenues less gross treatment costs), while TFB had the lowest total revenue, gross cost and cost per acre. To reduce the area of timberland out-of-condition by 20 percent in 10 years would cost $1.25 to $1.93 billion per year for national forest treatments. In simulations where hazard level was kept constant, total treatment costs were 40 to 70 percent lower than the cost of achieving a 20 percent reduction in hazardous acres.

The value of timber products removed was highest with the SDI-Large and lowest with TFB. Note that for Federal lands the revenues were not returned to the agency, but would accrue to the U.S. Treasury directly unless stewardship contracting authorities were used to implement treatments. Our simulations were based on timber sale authorities, so reducing hazard by 20 percent, generated products from national forest timberland treatments that could be sold and would potentially have an annual stumpage value ranging from $0.14 to 0.89 billion. In simulations where hazard was kept constant, values of timber products were about 40 to 75 percent lower (table 5).

Under stewardship contracting authorities there would be a potential to use some or all of these revenues to offset treatment costs. Even if revenues were returned to the U.S. Treasury, policymakers may be interested in understanding the total net cost of treatment alternatives. For the 20 percent hazard reduction goal, the net cost of treatments—treatment costs minus revenue from harvest—was highest for the TFB prescription, followed closely by the SDI-Large prescription, and, notably, lowest for the SDI-Small prescription (table 5). Because the revenues obtained from treatments were assumed to be replacing harvest that already would have occurred on national forests, only a part of the revenue will be additional to what would have been received without the fire hazard treatments. The average gross treatment cost per acre was slightly higher for the SDI-Large prescription and lowest for TFB, ranging from about $706 per acre to $857 per acre, depending on the prescription and hazard reduction goal (table 5). These costs excluded the potential revenues obtainable by selling timber products from treatments. Net costs of treatment per acre, which include these revenues, were also lowest for the SDI-Large prescriptions, resulting in part from the smaller acreages treated to meet the goals, as well as moderate treatment costs and revenues (table 5).

Other Ownerships (Non-National Forest) Treatable Timberland Simulations (Without Minimum Treatment Constraints)

Other ownerships include Federal lands managed by the U.S. Department of the Interior, State and county managed forest lands, and all privately owned forest land. With 48 percent of treatable timberland and 44 percent of out-of-condition acres, the actions of these owners have considerable influence on overall fire hazard throughout the West. For the private and non-Federal government (i.e., State, county, and local government) landowners, much of the required treatment will be accomplished only if the treatments pay for themselves through thinning revenues, or if some type of subsidy program is utilized. The analysis of a subsidy program is beyond the scope of this study, thus the simulations run for non-national forests provide total costs and revenues for treatment programs but do not specify how the programs would be administered or funded.

Average annual acres treated in the six simulations ranged from 0.64 million (0 percent reduction using TFB) to 1.99 million acres (20 percent reduction using SDI-Large) (table 6). Using the SDI-Small prescription required that only 14 percent more acres were treated than under TFB under both hazard reduction goals, while SDI-Large required an additional 17 to 22 percent increase in treated acres. The increase in acres treated in the SDI treatments is needed to account for increased growth on the treatments, which results in treated stands transitioning to out-of-condition faster on the SDI-Small and faster still on the SDI-Large treatments.

As with national forests, initial in- and out-of-condition acres were identical for these simulations, and final acres for each hazard reduction goal were within tolerances noted above for the hazard reduction goal. Over the 10 years of the simulations, the total area of non-national forest treated area comprised from 19 to 58 percent of all treatable timberland, with the higher acreages treated under the 20 percent hazard reduction goal.

These ownerships had treatment responses similar to the national forests, with the 20 percent goal treatments removing substantially more volume, and the SDI-Large removing more sawlog and chip volumes than the other two prescriptions (table 7). And as in the national forest simulations, higher logging residues were obtained from the TFB prescription. Jobs produced also follow trends similar to the national forests for both the treatments and hazard reduction goals.

The trends of the treatment costs and revenues were similar for both ownership groups, with, generally, the more intense and extensive treatments showed higher gross revenues and higher gross costs (table 8). Net treatment cost per acre also differed slightly for the other owners, though these differences were small.

National Forest Treatable Timberland Simulation (SDI-Large Only; With Minimum Treatment Constraints)

We conducted an additional simulation where we set a minimum treatment level for national forest treatable timberland in each State using the SDI-Large treatment prescription. In this simulation, we required that the total spending on treatment each year on national forests in each Western State be at least half of that State's remaining treatment costs relative to West-wide remaining treatment costs on the national forests. For example, if California had 20 percent of the treatable hazardous timberland on national forests in the Western United States in year *t*, then the model required that at least half of the 20 percent (or 10 percent) of hazardous national forest timberland treated in year *t* West-wide had to be in California. This simulation treated only national forest land, and used only the SDI-Large prescription. Beginning and ending values of timberland area out-of-condition are shown in figure 3.

We compared this simulation to the unconstrained simulation for the same prescription (SDI-Large), also reducing national forest hazardous acres West-wide by 20 percent. We found the following:

1. Treated area by State is less variable over time when the constraint is imposed. When the constraint is included, the variance in treated acres from year to year drops by 43 percent.

2. Treatment acreages are lower in California, Colorado, Oregon, and Wyoming, and increased in Idaho, Montana, New Mexico, and Utah when the constraint is imposed.

3. The total cost of the constrained treatment program is slighty lower when the constraint is imposed; this occurs because the requirement to treat a minimum acreage in each State overrode the requirement to treat WUI first. This trade-off resulted in cheaper, non-WUI timberland in some States getting substituted for WUI timberland in other States.

Table 6—Acreage simulation results for other ownerships (non-national forest) treatable timberlands by hazard reduction goal and treatment prescription

Hazard reduction goal	Treatment prescription	Treated area (annual average)	Initial out-of-condition	Final out-of-condition	Initial in-condition	Final in-condition
		Million acres				
Keep hazardous acres at current level	SDI-Large	0.86	16.75	16.86	17.31	17.20
	SDI-Small	0.73	16.75	16.86	17.31	17.21
	TFB	0.64	16.75	16.86	17.31	17.21
Reduce hazardous acres by 20 percent	SDI-Large	1.99	16.75	13.45	17.31	20.61
	SDI-Small	1.63	16.75	13.50	17.31	20.57
	TFB	1.44	16.75	13.41	17.31	20.66

SDI = Stand density index; TFB = Thinning from below.

Table 7—Volume and job simulation results for other ownerships (non-national forest) treatable timberlands by hazard reduction goal and treatment prescription

Hazard reduction goal	Treatment prescription	Sawlog volumes removed	Merchantable chip volumes removed	Gross biomass available	Direct jobs	Indirect and induced jobs
		Million cubic feet		*Million oven-dry tons*		
Keep hazardous acres at current level	SDI-Large	220	96	221	2,749	4,721
	SDI-Small	121	79	196	2,280	3,917
	TFB	12	25	321	1,811	3,119
Reduce hazardous acres by 20 percent	SDI-Large	521	280	247	6,789	11,645
	SDI-Small	282	222	221	5,524	9,477
	TFB	44	111	351	4,469	7,679

SDI = Stand density index; TFB = Thinning from below.

Table 8—Cost and revenue simulation results for other ownerships (non-national forest) treatable timberlands by hazard reduction goal and treatment prescription

Hazard reduction goal	Treatment prescription	Gross revenues	Gross treatment costs	Net treatment costs	Average gross treatment cost	Average net treatment cost
		Annual average in million dollars			*Dollars per acre*	
Keep hazardous acres at current level	SDI-Large	398	630	232	729	270
	SDI-Small	237	522	285	715	390
	TFB	33	412	379	640	592
Reduce hazardous acres by 20 percent	SDI-Large	714	1,564	850	786	427
	SDI-Small	543	1,272	729	778	447
	TFB	112	1,023	911	710	633

SDI = Stand density index; TFB = Thinning from below.

Conclusions

Federal land management agencies are interested in reducing overall wildfire hazard. Mechanical thinning treatments are one means to help achieve this goal. In this report, we used the EBR model to evaluate mechanical thinning treatments as a tool to accomplish this goal on national forest and other timberland. We also estimated economic benefits to the geographic areas where the work is done. The model considered the ability of wood product markets to absorb materials removed during fire hazard reduction treatments. It also considered stand growth, which allows tracking of how untreated stands grow out-of-condition and how long treated stands stay in-condition.

The EBR model simulates mechanical thinning treatments, resulting fire hazard levels, growth on treated and untreated stands, and market equilibrium solutions. We conducted 13 simulations for this analysis—six simulations (for three prescriptions and two owners) that maintain hazard at the current level; six simulations (for three prescriptions and two owners) that reduce hazard by 20 percent; and one simulation for one prescription on national forests that required reducing hazardous acres by 20 percent but also establishing a minimum treatment amount for each State.

Of the three prescriptions, the TFB had the lowest gross cost per acre, but this prescription also resulted in the lowest revenues from the lowest level of removals. The uneven-aged prescription that removes more large trees (SDI-Large) was the most expensive to implement, but it also brought in the highest revenues and provided more jobs.

Keeping hazard levels constant on treatable timberland in the Western United States will require large, costly programs. The costs and revenues will vary depending on where and how the treatments are implemented, with higher costs and revenues attributing to the more intense removals, which also require treating more acres to keep hazard levels constant because regrowth is higher on stands treated with more intense treatments. Reducing hazard on treatable timberland by 20 percent over 10 years would require even larger programs, would result in larger volumes of wood products, and would treat more acres.

To enhance accuracy and usefulness of this research, future modeling efforts should include developing new methods for measuring both hazard and values at risk; expanding the data and methods to include nontimberland (i.e., woodlands, grasslands and other forest land); developing new transition estimates to more accurately quantify how fire hazard changes over time for both untreated and treated stands; expanding the modeling to include prescribed fire treatments and wildfire as a fuel treatment; adjusting the uneven-aged treatment simulations to more closely match local management objectives or policy constraints; developing methods to account for transitions that occur due to other natural disturbances such as windthrow or insect and disease outbreaks; and incorporating expansion or contraction of traditional and/or bioenergy wood using capacity.

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We used the Economics of Biomass Removals model to evaluate the required treatment acreages, volumes removed, treatment costs and product revenues from national forest and other ownerships. We used three distinct treatment prescriptions to achieve two hazard reduction goals for treatable timberlands in the Western United States. The two hazard reduction goals were to maintain current hazard levels over 10 years, and to reduce hazard levels by 20 percent over 10 years. We also simulated one treatment prescription on national forest timberland only in order to evaluate the effect of requiring a minimum level of treatment in each State. These simulations show that costs and revenues differ by intensity of the hazard reduction goal and by treatment prescription. They show that uneven-aged treatment prescriptions tend to be more expensive than thin-from-below prescriptions for accomplishing hazard reduction goals. Uneven-aged prescriptions, however, yield greater timber product volumes and values for landowners, offsetting the higher costs. On the other hand, in situations without wood product markets, thin-from-below prescriptions could be a better option because of the lower net costs.

Keywords: Economics of Biomass Removals, fire hazard, mechanical thinning, treatable timberland, treatment costs.