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Market impacts of hypothetical fuel treatment thinning programs on federal lands in the western United States

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Abstract

This paper addresses the economics of forest fuel thinning programs on federal lands in the U.S. West, and presents a model of regional timber and product market impacts. The issue of economics is vital to the debate about fire management, and this paper presents market implications of two alternative silvicultural strategies, even-aged and uneven-aged thinning. Projections are based on a regional market model called FTM—West (*F*uel *T*reatment *M*arket model—West), which uses the method of price-endogenous linear programming to project annual market equilibria for softwood timber and wood products in the western United States from 1997 to 2020. The model takes into account variability in tree and log size, as well as economic effects of variable size class on harvest costs, log value, product recovery and mill capacity. Results show large potential market impacts from expanded thinning on federal lands, but impacts vary by silvicultural regime due to differences in size–class distributions of trees available under different thinning regimes. A hypothetical even-aged thinning program ("thin-from-below" strategy) results in net negative market welfare over the projection period (2005–2020), while a hypothetical uneven-aged thinning program (thinning based on stand density index) results in positive net market welfare. Net welfare results are the same over a range of different subsidy and administrative fee assumptions. An implication is that even-aged thinning regimes on federal lands in the U.S. West are less economical and therefore will be less effective.
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Keywords: Fuel treatment; Economics; Forest thinning; Market welfare

1. Introduction

In the United States, forest fuel treatments such as thinning to reduce fire hazard on public forest lands has become an important policy topic in recent years, particularly in the U.S. West where public (federal and state) forest lands are abundant and forest fires are more common. In 2002, there were 303 million hectares of forest land area in the United States, and fully one-third (33%) was owned and managed by the federal government. In the relatively arid western regions of the United States (apart from Alaska), where wildland fires are more common than in other regions, nearly two thirds of all forest land (65%) is owned and managed by the federal government. As reported recently by the United States Congressional Government Accountability Office (GAO), "In an effort to reduce the risk of wildland fires, many federal land managers—including the Forest Service and the Bureau of Land Management—are placing greater emphasis on thinning forests and rangelands to help reduce the buildup of potentially hazardous fuels. These thinning efforts generate considerable quantities of woody material, including many smaller trees, limbs, and brush—referred to as woody biomass—that currently have little or no commercial value" (U.S. GAO, 2005).

Utilization of woody material from thinning presents challenges, as noted by GAO, and estimates reported here confirm that hazardous fuel treatments involving thinning on federal lands in the U.S. West could generate substantial volumes of wood that could provide economic support for thinning operations. The size of trees removed in thinning operations is an economic issue because small trees have less commercial value. In this study we estimated carefully the likely size–class distributions of trees that could be removed from federal lands in hypothetical future thinning programs, and thus we evaluated economic impacts of different size–class distributions. We found that the size–class distributions of trees

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Table 1
Regional and commodity structure of FTM—West model

Supply and production regions
Coast PNW (OR, WA)
Eastern Washington
Eastern Oregon
California
Idaho
Montana
Wyoming–South Dakota
Four-Corners (UT, CO, AZ, NM)
Supply commodities
"Pines"
"Non-pines (trees, logs, chips)
Demand regions
U.S. West
U.S. East
Export market
Products in demand
Softwood lumber and boards
Softwood plywood
Poles and posts
Paper (five grades)
Paperboard (three grades)
Market pulp
Hardboard
Fuelwood

thinned made the uneven-aged thinning approach much more economical in terms of market welfare than even-aged thinning.

2. Study description, methods, and techniques

The study involved three stages: (1) development of the FTM—West model to project market impacts of thinning programs to the year 2020; (2) screening forest inventory data using the Fuel Treatment Evaluator (FTE 3.0) to provide data inputs for FTM—West on volumes and size classes of wood available for removal in hypothetical fuel treatment programs on federal lands, with corresponding estimates of forest area that could be treated and average costs of wood removal; (3) application of the FTM—West model to project regional market impacts of the hypothetical fuel treatment programs in the western United States from 2005 to 2020, including projection of the cumulative net market welfare impacts. The first two stages are discussed in this section, and the third stage is discussed in the subsequent section on results.

2.1. Development of FTM—West market model

In developing the fuel treatment market model for the U.S. West (FTM—West) we used the Price Endogenous Linear Programming System (PELPS). PELPS is a general economic modeling system that was developed originally at University of Wisconsin (Gilless and Buongiorno, 1985; Calmels et al., 1990; Zhang et al., 1993). For FTM—West we used the FPL version of PELPS, called FPL-PELPS (Lebow et al., 2003). The PELPS publications provide further mathematical details about the modeling system. A partial market equilibrium model is created in PELPS by defining a set of supply and demand regions, production processes, and commodities, and entering relevant input data such as initial supply and demand quantities, elasticities of supply and demand, manufacturing costs, input requirements, transportation costs, and exogenous assumptions such as growth rates of demand. The system solves for annual market equilibria over a projection period (determining equilibrium levels of supply, demand and prices each year, with annual adjustments in supply, demand and production capacity).

We designed FTM—West with eight supply/production regions and three product demand regions. Table 1 summarizes the regional and commodity structure of FTM—West. Trees that need to be thinned on federal forest lands in the U.S. West are mainly softwoods (conifers). Thus, we designed FTM—West to model softwood timber supply, along with production and demands for all principal categories of forest products produced from softwood timber in the U.S. West. The supply commodities in the model included trees (timber stumpage supply), as well as logs and chips, which we modeled as outputs of timber harvest or thinning operations. Because of differences by species in value and use, softwood supply was subdivided into "pines" (mainly Ponderosa pine) and "non-pines".

2.1.1. Model inputs

FTM—West incorporated detailed input data on demand quantities, production capacities, manufacturing costs, prices, and elasticities of demand in the base year (1997) for all forest products produced from softwood timber in the U.S. West. Product demands were generally inelastic (price elasticity of demand ranged from −0.3 to −0.8 among the various products). Aggregate demand quantities for each product were equated to product output data for the U.S. West in the base year (1997) and proportioned to each of the three demand regions (Table 1) using estimates of regional shipments from the West. Product output was based on data published by industry associations, such as WWPA for lumber, AF&PA for pulp and paper, and APA-The Engineered Wood Association for plywood. Data on conventional timber supply and product output by supply region were gleaned from state level industry reports such as those by the Bureau of Business and Economic Research at the University of Montana and Forest Service (Keegan et al., 2001; Gebert et al., 2002). The model was programmed with a set of assumed future growth rates in demand (2005 to 2020) for each forest product commodity. Demand growth rate assumptions matched recent Forest Service RPA Assessment projections (2005 RPA timber assessment update).

The model included also base-year data on conventional timber supply and prices, elasticities of supply, and transportation costs among region. The model included detailed estimates of the supply of wood from conventional timber supply sources and also from future thinning programs, including the size–class distribution of trees, and the costs and volumes of wood available from thinning programs. Supply curves were used to model conventional softwood timber supply in each of the eight supply regions, while exogenous estimates of wood supply from treatment programs (upper bounds on harvest quantity and average harvest costs) were introduced as policy or program variables. Most conventional timber supply in the U.S.. West is currently obtained from timber harvest on state owned and private forestlands (non-federal lands), which are subjected mainly to even-aged timber management. Thus, inelastic supply curves were used for conventional timber supply (with an assumed price elasticity of 0.7). Conventional timber supply curves were programmed to shift over time in direct proportion (1:1 ratio) to net growth in softwood timber inventory volumes on state and private timberland within each supply region. Annual net growth in state and private timber inventories are computed in the model by deducting from standing timber inventories the harvest volumes from the preceding year and adding timber volume growth based on recent growth rates in each region (Smith et al., 2004).

In addition to supply and demand curves, FTM—West incorporated estimates of base-year manufacturing capacities for the various products in each of the eight production regions, along with manufacturing cost data and transportation cost data (for wood raw material and product shipments). A feature of PELPS is that production capacities shift over time in response to projected market conditions, and in FTM—West we used a representation of Tobin's q model to project regional capacity change as a function of the ratio of shadow price (or value) of production capacity to cost of new capacity (Lebow et al., 2003).

2.1.2. Special considerations in designing FTM—West

Beyond general elements of model structure, FTM—West incorporated unique features to account for economic complexities known to be associated with utilization of wood from fuel treatments. Specifically, we know that the size–class distributions of wood (distribution of wood volumes harvested by tree diameter class) may be significantly different for wood removed in fuel treatments than for conventional timber supply. Also, we know that timber market value and harvest costs per unit volume are dependent on tree size class or diameter (Keegan et al., 2002), while mill production capacity, processing costs, and product yields also vary with log diameter, particularly at lumber mills (Williston, 1976) and plywood mills.

In recognition of divergent size classes of trees harvested, both the conventional timber supply and the exogenously specified wood harvest from fuel treatments were modeled in FTM—West by 5-cm diameter classes, ranging from trees <12.5 cm d.b.h (diameter at breast height) to trees >37.5 cm d.b.h. Thus all wood supply quantities and values were disaggregated into seven different tree size classes, each of which assumes a unique market value in the FTM—West model. Furthermore, each different tree size class yields different proportions of logs (by 5-cm log size class) along with variable quantities of wood chip raw materials. Estimates of actual log and chip volume yields were derived for each tree size class and for each of the eight supply regions based on recovery data from regional utilization studies conducted at the Forest Service Pacific Northwest Research Station (compiled from mill studies by Dennis Dykstra, PNW Research Station).

Estimates of base-year (1997) timber stumpage values by tree size class for conventional timber supply were derived by subtracting harvest costs from reported log values, taking into account estimated log and chip recovery volumes by tree size class. Market values of logs were obtained from Log Lines (Log Lines, 2006), a timber price reporting service that publishes log prices for the Western United States by log grade. The log grades are partially size dependent, so we assigned values to different log sizes based on the progression in value from lower grade logs such as "pulpwood" and "chip and saw" logs to higher value logs such as "#3 sawlogs" and "#2 sawlogs". From this progression of log values we derived stumpage values of trees by 5-cm. size increments for FTM—West by taking into account log and chip recovery volumes and harvest costs. In the base year and subsequent years of the projection (to 2020) the model derives prices for timber by size class as part of the equilibrium solution. We observed that solution values for timber prices were consistent with actual historical log prices in the overlapping historical period (1997–2004).

Harvesting costs per unit of wood volume vary with tree size class due to the efficiencies gained in harvesting larger trees with more wood volume per tree or per log harvested. Thus, in addition to modeling wood supply by size class of trees and logs, we used harvest cost models to obtain estimates for FTM—West of harvesting costs unique to each tree size class. Harvesting costs for wood removed in fuel treatments were estimated by the FTE 3.0 program (Skog et al., 2006), using the calculation routine from "My Fuel Treatment Planner" (Biesecker and Fight, 2006). Timber harvesting costs for conventional timber supply were estimated by tree diameter class using a conventional timber harvest cost model by Keegan et al. (2002).

Furthermore, we adopted a policy assumption that treatment programs will require complete removal of all trees marked for thinning, on the theory that fuel treatment policies will not allow "high-grading" or just the removal of bigger or more valuable trees. Under that policy assumption, the harvest and transportation costs applied to wood from fuel treatments are the volume-weighted average costs across all tree size classes. These average costs for wood from fuel treatments were estimated to be higher than conventional timber harvesting and transport costs in the West (across all size classes of trees). The higher harvest and transportation costs were compensated however by an assumption that fees for wood removal in thinning programs would be set at a low level just sufficient to cover administrative costs (at $1250 per hectare), resulting in lower stumpage costs than prevailing stumpage prices for timber on state and private lands.

In addition we recognized that sawmill and plywood mill efficiencies vary with log size, in terms of product recovery per unit volume of wood input. Therefore, we estimated lumber recovery efficiencies and plywood recovery efficiencies per volume of log input by log diameter based on Williston (1981) and Spelter and Alderman (2005), and applied those efficiency parameters to FTM—West. Thus, the model accurately takes into account the economic effects of variable log size on lumber and plywood product yield.

Sawmill capacity also generally varies with the size of log inputs. This is because sawmill capacities are constrained by primary saw rigs that break down logs at the front end of sawmills. Primary breakdown saws (or "head rigs") are typically designed to process logs within certain size ranges, some designed to process small logs and some designed to process large logs. Small log mills run logs end-to-end at fairly constant speeds, but within a feasible range of equipment design larger logs yield more product output because each cut generates more volume (Fight, 2002). In contrast, large log mills may not process logs in one pass, but mostly require multiple passes before logs are sufficiently broken down to permit further processing, which results in unproductive dead time between passes. Furthermore, the larger cross sectional areas of cuts usually require a slower feed rate with large logs. Thus, the feed rate of logs or lineal throughput capacity tends to be higher with smaller logs, but the greater volume of wood and higher lumber yield from larger logs more than compensates for slower feed rate.

In order to model variability of sawmill production capacity in relation to log size we modeled sawmill capacity by log throughput capacity in lineal dimension (e.g. meters of log length processed per year). We assumed that regional sawmill capacity was constrained primarily by the lineal log throughput capacity of mill head rigs, and that variation in log size would result in shifts in lumber output capacity. For each region we estimated the lineal log throughput at sawmills in the base year and divided that estimate by the regional lumber capacity utilization ratio, using lumber production data reported by WWPA and capacity data estimated by Spelter and Alderman (2005). Thus, we derived lineal log throughput capacities at sawmills for FTM—West regions that were equivalent to actual lumber output capacity in those regions. Lumber output in the model is constrained by the estimated regional log throughput capacities, and since the model takes into account lumber recovery volume for each log size class, the effective lumber output capacity varies along with any variation in the distribution of log size classes.

As logs get bigger, at some point the log breakdown requires multiple passes through the head saw and/or feed speeds must be decreased (Williston, 1976). Since we didn't have actual data on mill capacities by feed speed limits, we approximated this aspect of sawmilling by introducing an arbitrary log speed adjustment factor, effectively speeding processing up for smaller logs and slowing it down for larger logs. This adjustment resulted in a realistic representation of how sawmill production capacity would respond to marginal change in log diameters, and produced sawmill capacities for FTM—West that varied realistically by size class of log inputs.

In addition, non-wood manufacturing costs at sawmills are also affected by log diameter and throughput. A mill's labor costs and capital costs for example are invariant with respect to the size of a log that is momentarily being processed, and thus they are marginally fixed costs relative to log throughput but variable with respect to product output. Thus, we also programmed manufacturing costs per unit of lumber output to vary in FTM—West by log diameter class. Plywood manufacturing capacity, manufacturing costs, and product recovery rates were modeled in a similar manner, as parameters that varied depending on the size of log inputs.

2.1.3. Model outputs

FTM—West solves sequentially the annual equilibria in Western U.S. softwood timber and wood product markets over a historical period from 1997 to 2004, and projects annual equilibria from 2005 to 2020. The solution is based on maximization of producer and consumer surplus as determined by PELPS (Lebow et al., 2003). Thus, the model produces outputs that include annual prices and quantities of production and consumption for all the softwood timber and forest product commodities in the model (Table 1). The model was calibrated to accurately track actual historical market data from 1997 to 2004. In scenarios where increased supply of wood is introduced by hypothetical fuel treatment programs, the model projects the equilibrium quantities of wood derived from fuel treatments versus conventional sources, and projects overall shifts in the market equilibrium (product volumes and prices) resulting from fuel treatment programs.

In scenarios that introduced increased supply of wood from fuel treatment programs, we found that FTM—West responded with capacity expansion (due to Tobin's q model), with increased regional wood harvest and displacement of conventional timber harvest by wood from fuel treatments. However, treatment regimes that introduced marginally higher proportions of small-diameter wood than conventional timber harvest also offset regional production capacities, reduced average product recovery, and increased manufacturing costs for lumber and plywood. Those impacts affected the producer surplus and consumer surplus consequences of fuel treatment programs.

2.2. Estimation of wood supply from thinning programs and associated harvest costs

Estimates of potential wood supply from hypothetical fuel treatment programs and corresponding harvest costs for FTM—West were developed using the Fuel Treatment Evaluator 3.0 (Skog et al., 2006). FTE 3.0 is a web-based tool that selects forest areas for treatment and applies simulated treatments based on extensive forest inventory sample plot data on timberland in twelve western U.S. states. The data are from the Forest Inventory and Analysis Program (FIA) of the USDA Forest Service (Smith et al., 2004), along with additional plot information from the National Forest System. Altogether there were about 37,000 continuous forest inventory sample plots on all forestland in the twelve states. The twelve states included Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, South Dakota, Utah, Washington, and Wyoming. These states encompass the same geographic area as the FTM—West market model. We used FTE 3.0 and techniques developed by Skog et al. (2006), to select FIA plots eligible for treatment (e.g. plots with high levels of fire hazard), to derive estimates of wood biomass quantities that would be removed to achieve targeted reductions in fire hazard under different thinning regimes, and to estimate corresponding harvest costs.

We started with sample plot data for all federal timberland in the twelve western states. Timberland is defined as forest land capable of producing 1.4 m^3 of net wood volume growth per hectare per year and not withdrawn from timber utilization.

There are 31.5 million hectares of such federal timberland in the twelve western states.

We then applied a data screening process to exclude areas unsuitable or unlikely to be treated by commercial thinning. The screening was applied differently to two forest type groups on federal timberland. The two forest type groups were: (1) forest types with surface or mixed severity fire regimes and (2) forest types with high severity fire regimes. Group 2 included fire-prone lodgepole pine and spruce-fir forest types, and Group 1 included all other forest types. Plots screened out from Group 1 included: inventoried roadless areas that are not accessible to vehicles, certain counties west of the Cascade Mountains in coastal Oregon and Washington where forests have a long fire return interval, and plots with lower fire hazard — specifically plots having both crowning index (CI) and torching index (TI) values over 40 km per hour or CI alone over 64 km per hour. CI and TI are standard measures of forest fire hazard in the United States, relating the likelihood of fire spread to wind speed (Scott and Reinhardt, 2001; Rothermel, 1991; Skog et al., 2006). Plots screened out from Group 2 included: all plots outside wildland–urban interface (WUI) areas, inventoried roadless areas, those coastal counties west of the Cascade Mountains in Oregon and Washington where forests have a long fire return interval, and plots with low fire hazard (both CI and TI over 40 km/h, or CI alone over 64 km/h). Plots outside the WUI in Group 2 were excluded because severe fires are natural elements of lodgepole pine and spruce-fir forest types, and also residual trees would have high risk of wind throw if such stands were heavily thinned.

We then applied a second data screen to further exclude all plots with less than 21 m^3 per hectare of merchantable wood available for removal. Previous studies showed that mechanical treatments producing less than 21 m^3 of merchantable wood per hectare are unlikely to cover costs of treatment (Barbour et al., 2004; Fight et al., 2004). Other means of treatment such as prescribed fire or mechanical thinning without wood removal might be applied to low-volume stands. We excluded these low-volume plots from our analysis because we focused on future thinning programs involving wood removal, and we assumed that such programs will select stands for thinning only where revenues from tree removals could possibly cover the costs of treatment.

After exclusion of plots by data screening, we found 5.7 million hectares of federal timberland remaining, which we estimated to be eligible for fuel treatment by thinning. Using the sample plots in the area eligible for treatment (5.7 million hectares of federal timberland), we then estimated the regional volumes of wood that could be removed by diameter class, areas of federal timberland that could be treated, and average costs of wood removal under two alternative silvicultural thinning regimes.

The two alternative fuel treatment regimes were developed by a team that included silviculture experts and fire specialists (Skog et al., 2006). The treatments were designed to produce either uneven-aged or even-aged residual stands, while achieving the same fire hazard reduction goals as measured by crowning index (CI) and torching index (TI). These two approaches served as prototypes for the hypothetical fuel treatment programs that we projected in this study. In both treatment regimes, the goals were to raise both CI and TI to >40 km/h, or CI alone to >64 km/h. Higher TI and CI index values mean less hazardous fuel conditions, so the treatment rationale was to reduce fire risks by raising the index values above specified thresholds (Skog et al., 2006).

The uneven-aged thinning regime (also called "stand–density–index" or SDI treatment) achieves the fire hazard reduction goals by removing many small trees but still retaining an uneven-aged stand structure. Tree removal under the uneven-aged thinning regime is disproportional across tree diameter classes, with higher rates of removal for smaller trees, but trees are removed across all diameter classes. The stand density index (SDI) is reduced to simulate thinning of trees until TI and CI goals are reached or until 50% of the original stand basal area is removed. This type of thinning removes both smaller and larger trees, and leaves a diverse uneven-aged residual stand structure (Skog et al., 2006).

The even-aged treatment (also called "thin-from-below" or TFB) simulates an intermediate stand thinning regime under even-aged silviculture, where the result is a largely even-aged residual stand. Small trees are completely removed in successively larger diameter classes until the CI and TI goals are met, or until 50% of the original basal area has been removed. This type of thinning regime removes primarily smaller trees and leaves generally only larger upper story trees in the residual stand. It is also similar to intermediate thinning in even-aged commercial silviculture where the intent is to ultimately harvest and replace the existing forest (although that may not be the intent of thinning for fuel hazard reduction on federal forest lands).

The estimated diameter class distributions of wood from the two hypothetical fuel treatment programs differ from one another, and differ from the estimated diameter distribution of wood harvested conventionally in the U.S. West (from conventional supply sources). These differences are illustrated in Fig. 1, which shows estimated volume distributions by tree size class (diameter at breast height) for conventional timber harvest (in 1996) and for wood from the two hypothetical fuel treatment programs on federal lands in the U.S. West. The even-aged thin-from-below fuel treatment was estimated to provide higher proportions of wood volume from smaller size classes of trees and smaller proportions of volume from larger trees as compared to conventional timber supply. The uneven-aged SDI treatment

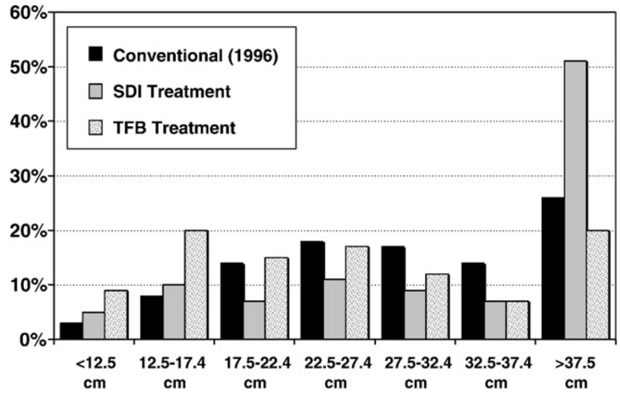

Fig. 1. Estimated volume distributions by tree size class for conventional timber harvest and for wood from fuel treatment regimes on federal lands in U.S. West.

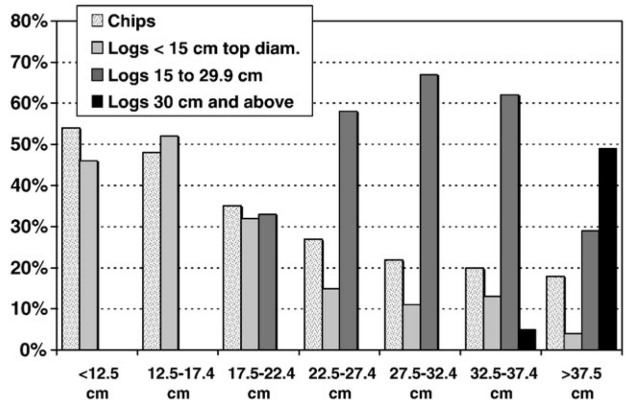

Fig. 2. West-wide average log and chip recovery estimates (percentages of cubic wood volume recoverable as chips and as logs of varying sizes) for different tree diameter classes.

regime was also estimated to provide higher proportions of wood volume from smaller trees than conventional timber supply, but it was estimated to provide higher proportions of wood volume from larger trees.

3. Results

When we applied the FTM—West model to project regional market impacts of the hypothetical fuel treatment programs, we observed significant differences in projected net market welfare impacts between the two hypothetical treatment program alternatives. We attribute the differences in welfare impacts to the effects of differences in size–class distributions of trees that are produced by the hypothetical treatment programs (Fig. 1).

Important determinants of these results were the estimated product volume recovery potential from trees and logs of different size classes as programmed into the FTM—West model. Fig. 2 shows our regional average volume recovery estimates for logs and chips from trees of different diameter classes. As shown in Fig. 2, smaller trees yield lower value chips and lower value small logs, while larger trees yield more volume in higher value larger logs. Furthermore, as shown in Fig. 3, the estimated recovery of lumber and plywood (as programmed into the FTM—West model) also increases with log size.

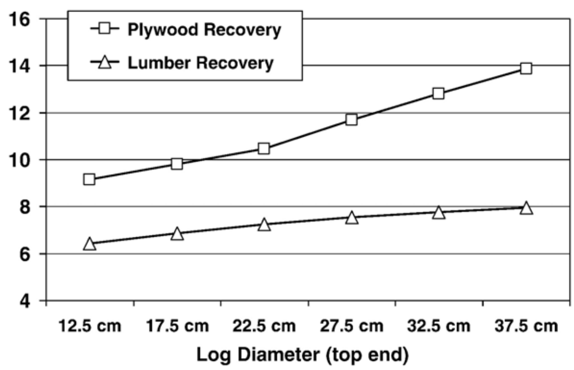

Fig. 3. Indexes of lumber volume recovery and plywood volume recovery per cubic volume of log input, estimated by log diameter.

Another important factor influencing results was the cost of wood delivered to mill locations in the U.S. West. The cost varied by tree diameter for conventional timber supply mainly because of varying harvest costs and stumpage prices. It also varied between the two hypothetical treatment programs because of differences in harvest costs and the distributions of volume by tree diameter class (Fig. 1). Fig. 4 shows the FTM—West equilibrium solution values for wood delivered to mills from conventional timber supply sources in 2005 (logs and chips averaged) in dollars per cubic meter for wood by tree diameter class, and also average delivered costs for wood from the hypothetical fuel treatment programs. As shown in Fig. 4, delivered costs per cubic meter of wood from the hypothetical fuel treatment programs are lower than the market equilibrium cost of wood from conventional supply sources. This result is mainly because of higher equilibrium stumpage prices for trees from conventional supply sources as compared to the modest administrative stumpage fee ($1,250 per hectare) that we assumed for wood from the hypothetical thinning programs.

It can be noted also that the market value of wood available from the SDI treatment program is higher than wood from the TFB program because of a higher proportion of volume from larger trees. Also, the average harvest cost was a bit lower for SDI because of the larger trees and more volume recoverable per hectare than for TFB.

Fig. 5 shows our estimates of maximum potential area of federal timberland that could be treated annually in the U.S. West (all twelve states) from 2005 to 2020 under the two hypothetical fuel treatment programs. The data screening process (described previously) gave us gross estimates of maximum areas that could be treated by thinning on federal timberland, amounting to 4.4 million hectares under the SDI regime and 2.3 million hectares under the TFB regime. We distributed those maximum potential treatment areas over time (from 2005 to 2020) using a log growth curve as shown in Fig. 5. The reason why more federal land area is eligible for treatment under our SDI regime is because more of the forest sample plots could yield the minimum 21 cubic meters per hectare output of merchantable wood under the SDI regime than under the TFB regime.

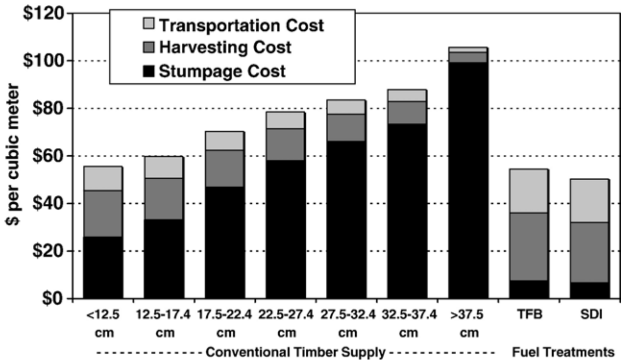

Fig. 4. Estimated average delivered cost of wood in dollars per cubic meter from conventional supply sources (averaged by volume for tree diameter classes across the West), and estimated average delivered cost of wood from the hypothetical fuel treatment programs, including log and chip volume.

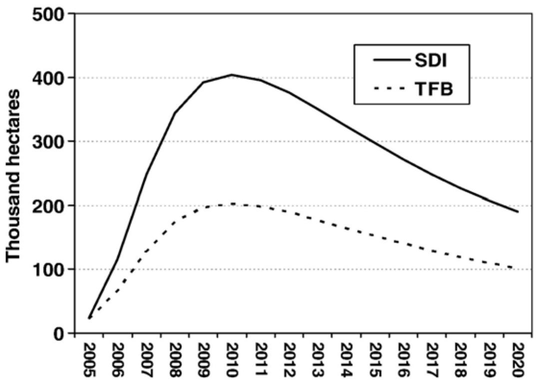

Fig. 5. Estimated maximum areas (thousands of hectares) annually treatable on federal timberland in the U.S. West under two hypothetical thinning programs (SDI and TFB).

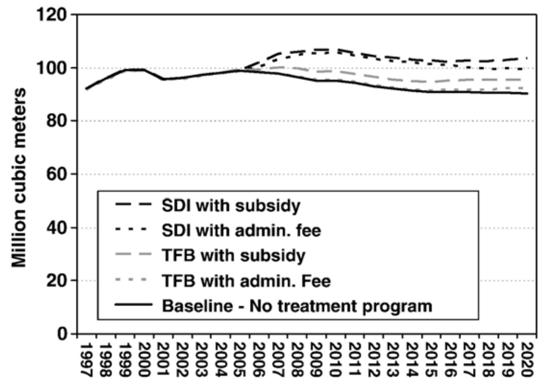

Fig. 7. Total volumes of softwood harvested annually in the U.S. West, 1997 to 2020, showing FTM—West projections both with and without hypothetical treatment programs, and with and without hypothetical subsidy.

Fig. 6 illustrates our corresponding estimates of maximum volumes of wood that could be removed annually via fuel treatments on federal timberland in the U.S. West under the two hypothetical thinning programs (SDI and TFB). The projected areas actually treated and projected volumes of wood removed according to the FTM—West analysis were less than the maximum areas treatable and maximum volumes removable, because the market equilibrium solution resulted in only 54% to 84% of wood available for thinning being harvested economically in the period from 2005 to 2020, varying by treatment regime and subsidy levels or fees.

Fig. 7 shows the projected total volume of softwood timber harvested annually in the U.S. West from 1997 to 2020, including FTM—West projections of equilibrium harvest with and without hypothetical treatment programs, and with and without hypothetical subsidy. In treatment scenarios with no subsidy we assumed that a $1,250 per hectare administrative fee would be assessed for fuel treatments. In the treatment scenarios with subsidy we assumed that the administrative fee would be waived and additional subsidy of $5.66 per cubic meter would be provided for wood removed via thinning. The total harvest (Fig. 7) includes harvest of timber from conventional supply sources and wood from the hypothetical treatment programs on federal timberlands. As shown in Fig. 7, the fuel treatment programs were projected to result in marginally higher total softwood harvests in the US West, relative to projections without the treatment programs. In contrast to the marginal impacts on total wood harvest, the treatment programs resulted in a more significant displacement of timber harvest from conventional supply sources.

Fig. 8 shows the volumes of wood harvested annually from conventional timber supply sources only (excluding harvest from fuel treatment programs) in the U.S. West, from 1997 to 2020, showing projected treatment program impacts on timber harvest from conventional supply sources (mostly state owned lands and private timberlands). The projections indicate that expanded supply of wood from fuel treatment programs could displace large volumes of conventional timber supply from conventional sources. The expanded supply of wood from fuel treatments and displacement of demand for wood from conventional supply sources was projected by FTM—West to result in significant reductions in softwood timber prices in the U.S. West.

Fig. 9 shows FTM—West projections of weighted average stumpage prices for softwood timber from conventional supply sources in the U.S. West, 1997 to 2020, both with and without hypothetical treatment programs, and with and without

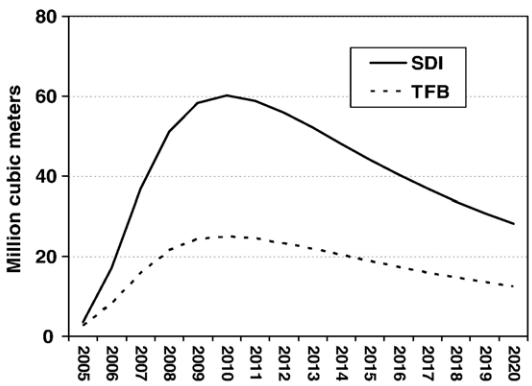

Fig. 6. Estimated maximum volumes of wood removable annually via fuel treatments on federal timberland in the U.S. West under two hypothetical thinning programs.

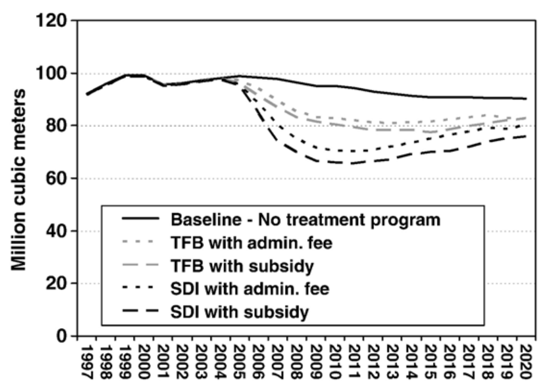

Fig. 8. Volumes of wood harvested annually from conventional timber supply sources only (excluding harvest from fuel treatment programs) in the U.S. West, 1997 to 2020, showing FTM—West projections both with and without hypothetical treatment programs, and with and without hypothetical subsidy.

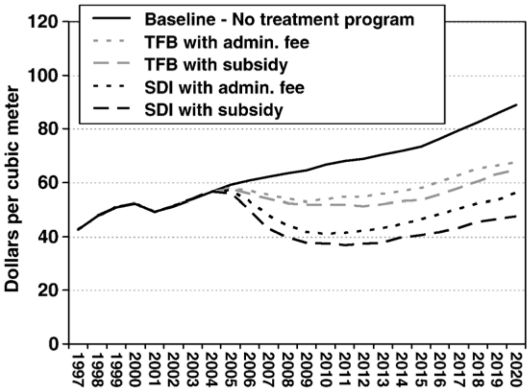

Fig. 9. Weighted average stumpage price of softwood timber from conventional supply sources in the U.S. West, 1997 to 2020, showing FTM—West projections both with and without hypothetical treatment programs, and with and without hypothetical subsidy.

hypothetical subsidy. The increases in supply of wood from thinning programs and lower demand for timber from conventional sources resulted in significant projected declines in timber prices. The TFB treatment program had less impact on prices than SDI, but still significantly reduced projected timber prices. Subsidies for fuel treatments were projected to increase the impacts on timber prices because of expanded utilization of wood from treatment programs with subsidies.

Fig. 10 shows cumulative impacts on producer surplus of the hypothetical treatment programs, in terms of losses in producer surplus relative to the market outlook with no fuel treatment programs, 2005–2020. The projected declines in softwood timber prices (Fig. 9) and projected displacement of timber harvest from conventional supply sources resulted in significant loss of producer surplus for timber producers in the U.S. West (primarily state and private timberland owners). The projected cumulative impacts on producer surplus for conventional timber suppliers ranged from −$34 to −$70 billion by 2020, depending on treatment scenario, with bigger impacts resulting from the SDI program versus TFB, and from subsidized programs versus unsubsidized programs.

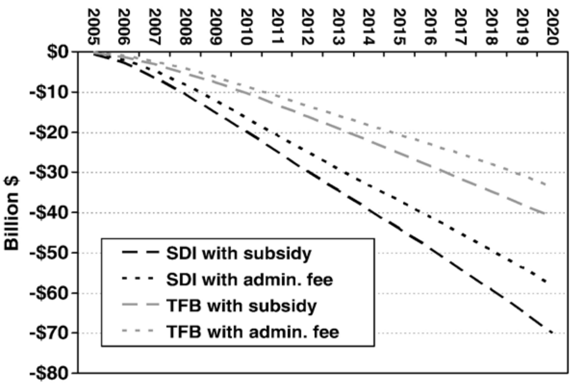

Fig. 10. Cumulative losses in producer surplus for timber markets of the U.S. West under hypothetical treatment programs as compared to a scenario with no fuel treatment programs, 2005–2020.

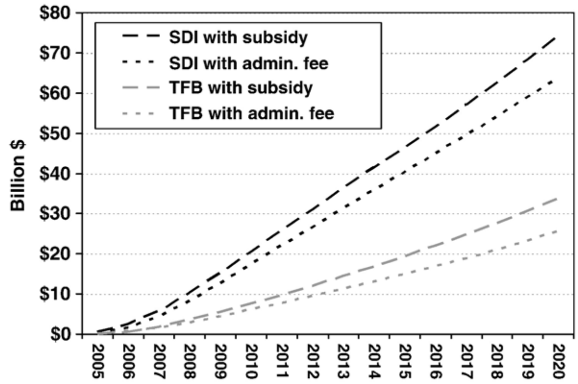

Fig. 11. Cumulative gains in consumer surplus for timber markets of the U.S. West under hypothetical treatment programs as compared to a scenario with no fuel treatment programs, 2005–2020.

However, the loss of producer surplus is not the only likely or projected market welfare impact of fuel treatment programs, since treatment programs also result in expanded supply of wood and higher product output. The expanded supply of wood, lower wood prices, and higher product output result in welfare gains for consumers of softwood forest products from the U.S. West. Fig. 11 shows the FTM—West projections of cumulative gains in consumer surplus under the hypothetical treatment programs as compared to a scenario with no fuel treatment programs, 2005–2020. By boosting supply and reducing wood prices, the treatment programs were projected to reduce product prices and increase consumption, providing gains in consumer surplus that cumulatively ranged from $26 to $74 billion by 2020.

The sum of projected gains in consumer surplus and losses in producer surplus provided estimates of the net market welfare impacts resulting from the hypothetical fuel treatment programs. Fig. 12 shows FTM—West projections of the cumulative change in net market welfare (changes in the sum of producer surplus and consumer surplus) for timber markets of the U.S. West under hypothetical treatment programs as compared to a scenario with no fuel treatment programs, 2005–2020. The projected cumulative net market welfare impacts of treatment programs are positive and increasing for the SDI program, but negative and decreasing for the TFB program. The unsubsidized SDI program

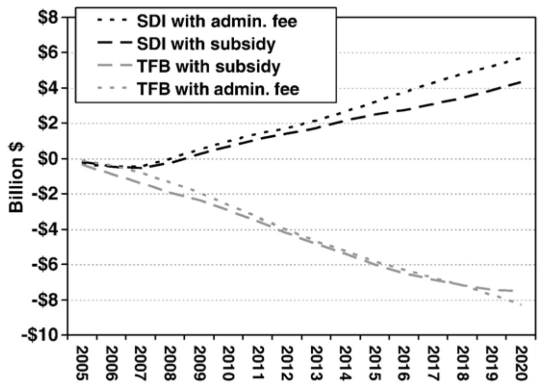

Fig. 12. Cumulative change in net market welfare (the sum of impacts on producer surplus and consumer surplus) for timber markets of the U.S. West under hypothetical treatment programs as compared to a scenario with no fuel treatment programs, 2005–2020.

was projected to achieve highest net welfare. Since the SDI program would treat more forest area (and therefore achieve more extensive fire hazard reduction) the SDI program appears to have unambiguously superior welfare impacts. The TFB program market welfare impacts are negative, regardless of subsidy. We did not estimate the non-market welfare impacts of either program, although both the SDI and TFB programs would provide fuel hazard reduction benefits on federal lands. Thus, this study has not determined whether overall economic benefits of the TFB program would be positive (taking into account the estimated negative market welfare impacts and unknown but likely positive fire hazard reduction benefits).

Our study was unique in comparing economic impacts of even-aged and uneven-aged treatment regimes, but in general our projected market and welfare implications were similar to results of other recent studies. For example, Keegan et al. (2004) evaluated impacts of a forest restoration and fuel hazard reduction program involving thinning of 1% per year of the forest areas with high and moderate fire hazard in Montana. The Montana program was projected to have significant welfare implications, yielding around 2 million cubic meters per year of sawlogs, generating employment for 3000 workers, boosting income by \$90 million, and shifting revenues to landowners by \$40 million annually. A recent study by Adams and Latta (2005) developed an intertemporal spatial equilibrium model of the eastern Oregon softwood log market, and projected the market and welfare impacts of hypothetical thinning programs on national forests in the region. The study examined a range of different program subsidy options. It found that in general thinning programs would increase consumer surplus and reduce producer surplus, with higher subsidy levels mostly increasing the impacts. Another recent study by Abt and Prestemon (2006) developed a model of interregional timber markets in the U.S. West to assess the market impacts of large-scale fuel reduction programs. Results showed similarly that the projected impacts of expanded thinning programs include losses to U.S. private timber producers, which are offset by the gains to U.S. timber consumers (mills). The type of thinning regime evaluated in that study was the uneven-aged (SDI) regime, for which we found generally similar results.

4. Summary and conclusions

Market welfare implications vary significantly between two hypothetical alternative thinning programs, even-aged and uneven-aged treatment regimes. The hypothetical even-aged treatment program (thin-from-below or TFB) was projected to generate negative market welfare impacts and a smaller land area treated, while the hypothetical uneven-aged thinning program (SDI thinning) was projected to generate positive market welfare impacts, with larger area treated and larger volumes of wood removed than TFB. The differences in market welfare impacts are attributable largely to differences in the size–class distributions and corresponding sale values and volumes of trees that could be removed in the two alternative thinning regimes, with generally smaller trees and lower market value available from even-aged thinning as compared to uneven-aged thinning.

FTM—West model projections indicated that over the next 15 years the wood product industries in the U.S. West could economically utilize much of the wood volumes likely to be made available from hypothetical fuel treatment thinning programs on federal lands across the range of size classes likely to be available. This result assumes that the thinning operations are charged only a modest administrative fee for wood removal (at \$1250 per hectare). Somewhat higher volumes will likely be removed if the thinning operations are subsidized (e.g. with a subsidy of \$5.66 per cubic meter and the administrative fee waived).

Taking into account many factors that influence the economic potential for fuel treatment programs, including size class distributions of trees and logs, economic relationships between size class and production efficiencies and mill capacities, and regional demand trends, we conclude that hypothetical fuel treatment programs on federal lands in the U.S. West could have significant market and welfare implications. Furthermore, the welfare impacts of an uneven-aged thinning regime appear unambiguously superior to the welfare impacts of an even-aged thinning regime according to our analysis.

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