Small Diameter Timber Alchemy: Can Utilization Pay The Way Towards Fire Resistant Forests?[1]

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Abstract

There is growing interest in using biomass removed from hazardous fuels reduction treatments in wood-fired electrical generation facilities. An application of FIA BioSum to southwest Oregon's Klamath ecoregion assessed the financial feasibility of fuel treatment and biomass generation under a range of product prices and fire hazard-motivated silvicultural prescriptions. This simulation framework consisted of linked models developed on a foundation of Forest Inventory and Analysis data. Small-diameter woody biomass and merchantable volume, and pre and post-treatment fire hazard were characterized from a systematic sample and combined with transportation infrastructure information to estimate potential biomass delivered under different objectives, constraints, and assumptions about costs and benefits. The FIA BioSum model allowed users to evaluate the financial feasibility of locating biomass plants in specific places or, alternatively, to identify the lowest cost processing plant locations within a landscape. Only a small fraction of the total forested landscape in the southwest Oregon study area could be treated via operations that generate positive net revenue, though there was potential to expand treated area via substantial subsidy of logging and/or hauling costs.

Introduction

Using the woody biomass derived from hazardous fuel reduction treatments for financially viable products is not easy, yet there is increasing pressure on managers to find ways to do this. As a result, various interests in almost every part of the country continually come forward with proposals to study or implement all manner of processing facilities to handle small diameter timber or other woody biomass. Managers need reliable ways to sort through these proposals to determine which ones make sense.

Several researchers have reported efforts to assess the impact of silvicultural prescriptions designed to reduce the risk of catastrophic fires or the impacts on forests when fires occur. A few of them have addressed the impacts of treatments on the ground, in terms of post-treatment fire effects attributes like tree mortality, char depth, fuel consumption and fire intensity (Omi and Martinson, 2002; Oucalt and Wade 1999; Pollet and Omi, 2002). A few have compared fire effects across treatment areas affected by a single wildfire, such as seedling establishment (Chappell and Agee, 1996) and runoff and sediment production (DeBano et al.,

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1996). Others have relied on simulation to assess the impacts and efficacy of alternative prescriptions. Through simulations in Sierra and Rocky Mountain coniferous forests with the Forest Vegetation Simulator (Forest Management Service Center 2001), Hollenstein et al. (2001) found that removal of some fraction of the large (>30” dbh) tree population was critical to the maintenance of a sustainable stand structure and to the efficacy of fuel treatments. These stand level analyses provide the foundation for integrated landscape scale analyses that have not been attempted before now.

There is also a small body of literature on landscape-scale biomass availability (Noon and Daly, 1996; Downing and Graham, 1996; Graham et al., 1997; Graham et al., 1996) that involves assessing potential biomass supplies in a location-specific fashion, and draws on FIA plot data as part of the biomass supply picture. However, in these studies, which were conducted primarily for Tennessee and included non-forest biomass sources such as mill-wastes and agricultural byproducts, forest-produced biomass was handled as an undifferentiated commodity (e.g., short rotation woody conifers grown for sale as biomass, not timber), and there was no specification of silvicultural prescriptions, evaluation of removal costs, or intent to modify or evaluate fuel or fire attributes.

With support from the National Fire Plan, and the Western Forest Leadership Coalition, and building on results from a previous Joint Fire Sciences project (Barbour et al., 1999), we developed the Forest Inventory and Analysis biomass summarization modeling framework (FIA BioSum) to estimate biomass availability, financial returns, and fuel treatment efficacy associated with silvicultural prescriptions devised to reduce fire hazard to forest stands (i.e., reduce the likelihood of stand replacement fire). FIA BioSum uses Forest Inventory and Analysis (FIA) plot data to:

1. Identify and evaluate the economic feasibility of potential sites for woody biomass processing facilities,
2. Provide economic analysis of alternative treatments, and
3. Predict the likely effectiveness of alternative treatments in improving fire hazard-related indices and attaining specified post-treatment stand conditions.

Methods

The FIA BioSum modeling framework (*fig. 1*) consisted of a linked series of generally available, documented models, including the Forest Vegetation Simulator, FVS, and its fire and fuels extension, FFE (Beukema et al. 2000), and STHARVEST (Fight and others, in press), a spreadsheet model composed of regressions and look-up tables for logging cost components derived from empirical data on timber sales. It also included a series of GIS data inputs (i.e., FIA plot locations and comprehensive road networks), GIS processing steps, databases, and linear programming optimization protocols.

This framework was tested in the Oregon portion of the Klamath ecoregion, 4.6 million acres of mostly forested land that contains diverse coniferous and evergreen hardwood forest types and a heterogeneous distribution of landownership, including National Forest, BLM, industrial and non-industrial private lands classes. Most of this study area has been characterized as fire regime condition class 2 or 3, indicating that fire regimes have been moderately or significantly altered from those of pre-settlement forests, and that risk of stand replacement fire is substantial (Schmidt and others 2002). Since this analysis was completed, the Biscuit Fire of 2002 burned a significant portion of the study area—the official fire perimeter contains over 500,000 acres.

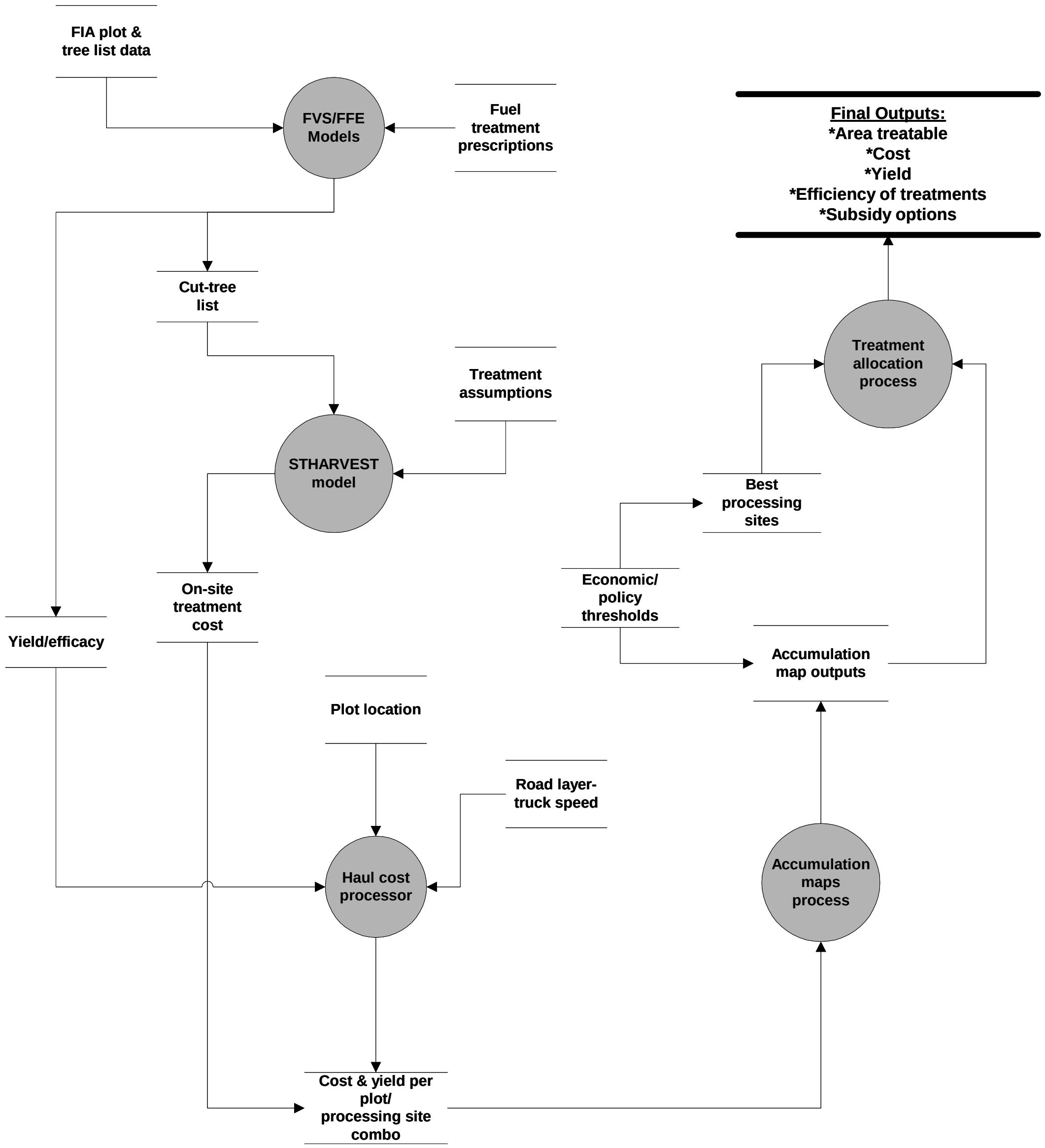

Figure 1—Flow diagram of the FIA BioSum modeling framework.

We characterized pre- and post-treatment fire hazard, biomass removed (by size class), and residual stand conditions for over 800 FIA and CVS (Continuous vegetation survey plots installed on National Forest and Bureau of Land Management lands) forest inventory plots located outside of designated wilderness and roadless areas. Two fuel-treatment motivated silvicultural prescriptions were simulated in FVS using tree lists from these plots: Prescription A, a stocking reduction in which stands were thinned proportionately across diameter classes to a residual basal area of

125 ft^2 ac^{-1}, and Prescription B, a thin-from-below which left a residual basal area of 80 ft^2 ac^{-1}. No trees larger than 21 inches dbh were removed in either treatment to be consistent with current policies on National Forests in portions of the study area. Biomass-sized trees (dbh < 7 in.) and most hardwoods were valued at 26 dollars per green ton ($ gr. ton^{-1}) and merchantable-sized trees (7 in. < dbh < 21 in.) were valued at 62 $ gr. ton^{-1}, a rate roughly equivalent to 300 $ MBF^{-1}. Biomass and merchantable removals from each plot were summarized in a database along with residual stocking, and pre- and post-treatment fire hazard, which was represented in the estimates of torching and crowning indices generated by FFE. Torching index is the wind speed in miles hr^{-1} at which a surface fire would climb into the crowns of individual trees, and crowning index is the wind speed at which a crown fire would spread from crown to crown. *Larger* values for both indices are indications of *lower* fire hazard. Plot expansion factors were used to extend plot outcomes to acres in the landscape.

Fuel treatment costs for each plot were estimated using a combination of the harvest cost simulator STHARVEST (Hartsough and others, 2001), other published information, and judgments of local experts. Cost components included felling, yarding, preliminary processing (e.g., limbing, bucking, chipping), brush-cutting, and rehabilitation/remediation (water-barring of roads). Whole tree harvesting, cut-to-length harvesting and combinations of these were assigned to each plot based on the diameter distribution of the removals and plot slope. Cable yarding was assumed on plots with slope > 40 percent. Trees < 3 in. dbh were always cut and left on the ground; trees 3-5 in. dbh were cut and removed as biomass on tractor yarded plots and left on cable yarded plots; trees 5-7 in. were always removed as biomass; trees 7-21 in. were removed as merchantable volume if selected by the prescription, and their tops and limbs utilized as biomass only if whole-tree harvested (which did not occur on steep slopes); trees > 21 in. were never removed.

To evaluate delivered raw material costs and identify promising locations for siting a biomass-to-energy generating plant (e.g., where biomass accumulation potential for a given delivered unit cost is greatest), a systematic 10 km grid of potential processing sites was established. Potential processing sites within designated wilderness and roadless areas were omitted from consideration. Unit round-trip haul costs for merchantable and biomass-sized material were estimated for each potential processing site by 1) tessellating (converting to raster) comprehensive, vector GIS road layers to produce a transportation cost surface of 500-meter grid cells and assigning to each grid cell the haul cost per ton associated with the traversing that cell on the highest-standard road contained therein, 2) processing this haul cost surface with a cost-distance GIS function to produce an accumulated-to-the-potential-processing-site haul cost map for each potential processing site, and 3) spatially joining the accumulated haul cost map to the inventory plots to obtain the haul cost from each plot to that processing site. The end result was a table of haul costs from each plot to each processing site. This haul cost table was ultimately combined with the plot-specific results to create a complete cost table inclusive of harvesting, skidding, loading, and hauling costs for delivering a ton of biomass from every plot location to every potential processing site.

When the removals, costs and fire hazard tables were combined, it was possible to evaluate the desirability of every potential processing site from multiple perspectives (e.g., biomass accumulation, net revenue, area of forest treated) and to develop maps depicting how the levels of these attributes varied over the landscape. Tradeoffs among costs, merchantable- and biomass-sized yield, area treated, and treatment effectiveness were evaluated for the most promising potential processing sites via linear optimization in which the model is allowed to choose among prescriptions (including the no treatment option) for each forested acre.

In this pilot study, we used the FIA BioSum modeling framework to address five questions: 1) Can we reduce fire risk? 2) How much of the landscape could be feasibly treated? 3) Will there be enough biomass to fuel a power plant? 4) Where are the best places to site a power plant? and 5) Would a subsidy help?

Results

Can we reduce fire risk?

Both prescriptions improved torching index and crowning index on most acres, but prescription B (thin from below to 80 ft^2 ac^{-1}), shown in *figure 2*, was more effective on nearly every plot.

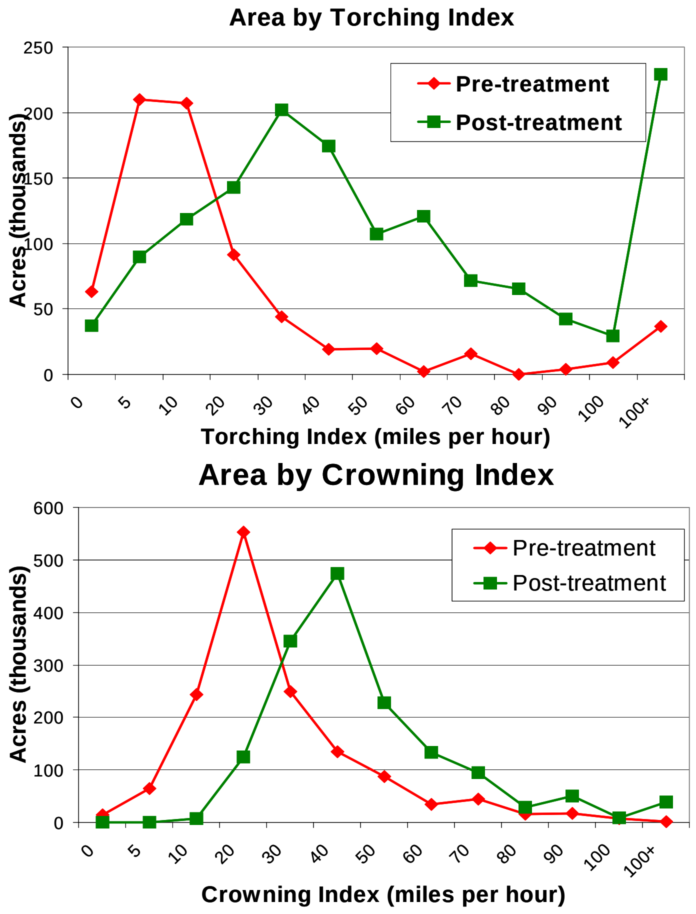

Figure 2 – Distribution of acres by torching and crowning index for prescription B for all treatable acres in the southwest Oregon study area.

How much of the landscape could be feasibly treated?

After subtracting out the roadless areas, non-forest (e.g., agriculture and urban) and forests with insufficient basal area to implement either treatment only 1/3 of the

Klamath ecoregion (i.e., 1.6 million acres) were potentially eligible (*fig. 3*). These were acres on which the distributions of torching and crowning indices in *figure 2* were based. But the reality was that even after accounting for revenue from sales of merchantable- and biomass-sized material, costs exceeded revenue most of the time, and there were only 270,000 acres of federal and non-federal land where estimated net revenue was positive.

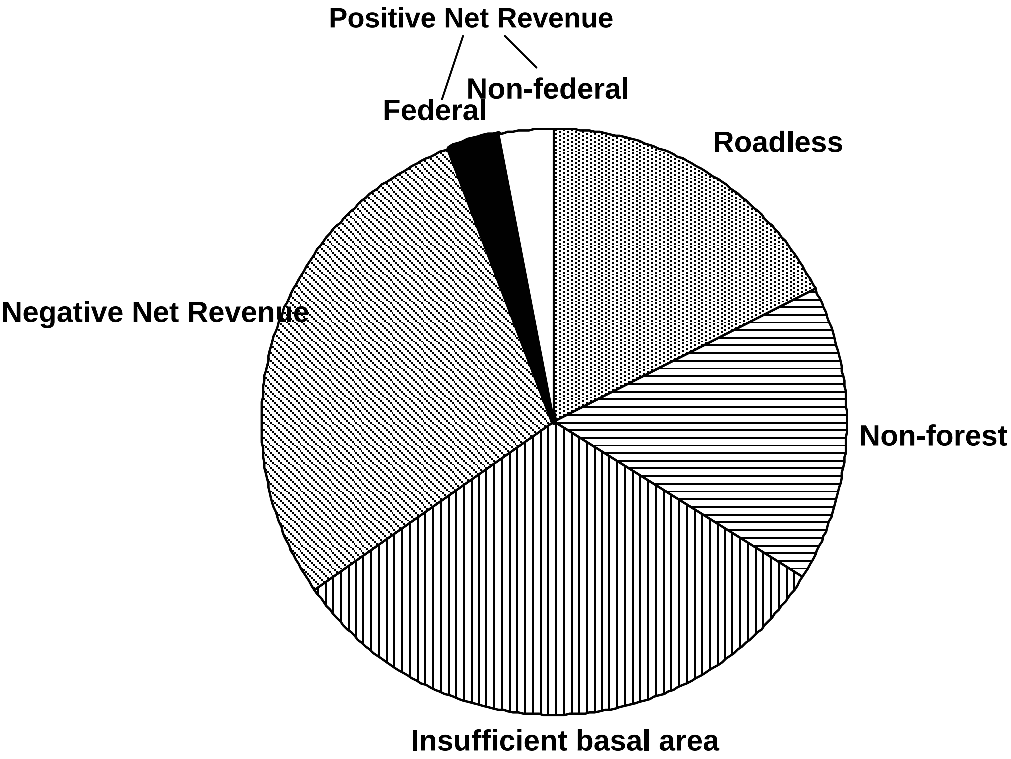

Figure 3—Fuel treatment opportunities that generate positive net revenue occur in only a small fraction of the 4.6 million acres of the Klamath ecoregion in southwest Oregon (the solid black and white slices)

Will there be enough biomass to fuel a power plant?

Under both prescriptions, nearly all of the removed material is in merchantable trees (*fig. 4*). Removals are nearly always greater for prescription B, most likely due to its specification of a lower residual basal area. Even under the most optimistic assumption that every landowner would treat every acre that could yield positive net revenue with prescription B, there would be sufficient biomass generated to fuel a 20 Megawatt biomass-based electrical generating plant for only 5 years.

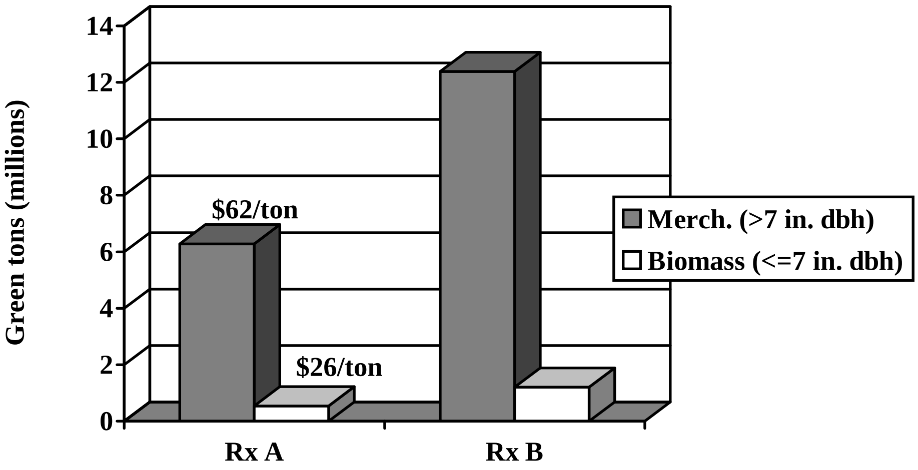

Figure 4—Amounts of merchantable- and biomass-sized material, by prescription (Rx), accumulated from acres that generated positive net revenue.

Where are the best places to site a power plant?

The best location depended on assumed product prices, prescription and one's objective (*fig. 5*). Maximizing biomass-sized accumulation gave one location, maximizing merchantable-sized accumulation another, and maximizing area treated or net revenue yet another. We evaluated every potential processing site on the 10 km grid, and found that the best locations were on the east side of the study area. In part, this reflected the locations of the forests needing treatment, but it also accounted for transportation infrastructure and lack thereof (i.e., the large designated wilderness and roadless areas in the southwest quadrant of the study area).

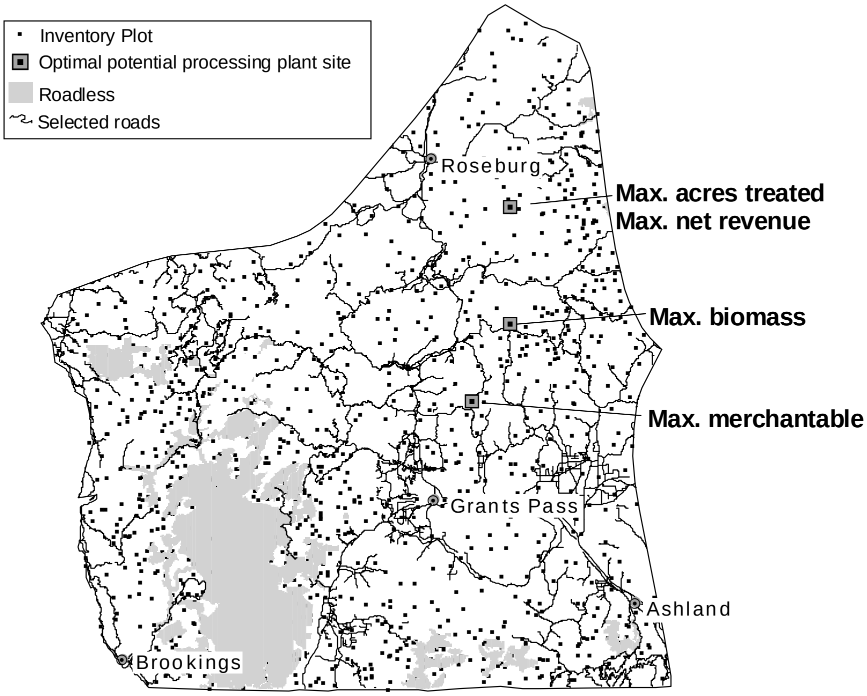

Figure 5—Map of the study area showing approximate locations of inventory plots and the locations of potential processing sites that maximize net revenue, biomass or merchantable material accumulation, or area treated.

Would a subsidy help?

A histogram of acres by net revenue class confirms that the vast majority of treatable acres would generate negative net revenue (*fig. 6*). Subsidies of up to $100 per acre would result in almost no increase in treated area, and even subsidies of $1000 per acre would leave 2/3 of the treatable landscape untreated. The highly negative net revenues were partly the result of the high costs of operating on steep ground; about half of the inventory plots had slopes over 40 percent. Every ton of biomass-sized trees on every acre had negative net revenue, so in a sense, the harvest of merchantable-sized trees represented a subsidy already, although in most cases, these removals also contribute to reducing fire hazard.

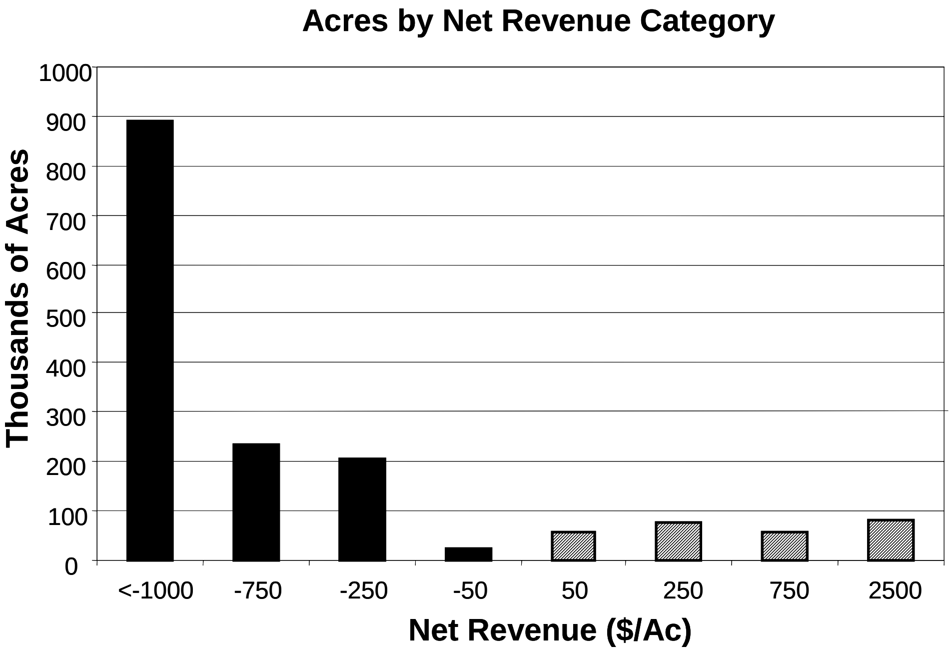

Figure 6—Frequency distribution of acres by net revenue class under prescription B for all treatable acres; solid bars represent acres with negative net revenue under the assumptions embedded in this analysis.

Comparing Policies

FIA BioSum presents policy makers with the opportunity to display various policy options and discuss them in terms of costs, volume produced, and effectiveness in fire hazard reduction. A partial set of possible policies for the pilot area is presented in *table 1*. Each row in the table represents an alternative and the columns describe the details used in the analysis. The first two rows represent policies that focus on production of raw material where there are no restrictions on the plots that are selected for treatment, but in one net revenue is maximized, while in the other total recoverable biomass is maximized. When net revenue is maximized there is a net return of $211 million and 290,000 acres are treated with significant fire hazard reduction on 162,000 of them. When biomass recovery is maximized there is a net loss of almost $1.7 billion and 1.5 million acres are treated with significant fire hazard reduction on nearly 1 million of them. The third policy shown in *table 1* includes creating a package of treatments where the net revenue is zero, there is no subsidy in total, treatment acres are maximized, and revenues from treatments with positive net revenue can be used to subsidize treatments with negative net revenue. This policy basically reflects the ability to trade goods for services. In the 4th row of *table 1*, only plots with positive net revenue are treated while maximizing biomass yield. The final three rows repeat policies depicted in rows 2 through 4 but maximize area treated instead, focusing on significant fire hazard reduction rather than biomass yield. Some of these policies require subsidies but treat more acres or produce more biomass, while others require no subsidy but are less effective. Depicting alternative policies in this way can help policy makers, landowners, managers, and the public discuss outcomes in an objective and consistent manner.

Table 1 – *Seven sets of alternative objective function/constraint combinations and model outputs for one potential biomass processing site.*

Maximize	Constraint	Biomass generated	Area treated	Effective area treated[1]	Net Revenue
		10^6 tons	10^3 acres	10^3 acres	10^6 dollars
Net Revenue	None	1.3	290	162	211
Biomass	None	9.7	1490	943	-1697
Biomass	In aggregate, Net Rev. ≥0	4.7	559	350	0
Biomass	Each acre has Net Rev. ≥0	1.3	217	134	116
Effective area treated	None	5.2	1035	1035	-1053
Effective area treated	Each acre has Net Rev. ≥0	0.7	178	178	67
Effective area treated	In aggregate, Net Rev. ≥0	2.7	636	519	0

[1] Includes only area represented by plots where torching index is improved by at least 20 mph.

Conclusions

In the Klamath ecoregion, utilization can pay the way towards fire resistant forests in some cases, but it is the utilization of the merchantable-sized material, not the biomass-sized material, that makes this possible, and only a small fraction of the landscape can be treated without infusions of considerable additional subsidy or incentives. Those wishing to conduct policy analysis concerning fuel management will likely want to consider that such subsidies may be justified by the benefits of fire hazard reduction in the form of reduced and avoided future costs and impacts (e.g., fire suppression, fire damages, post-fire rehabilitation, smoke effects). However, this question is beyond the scope of the current study and would require the estimation of such avoided costs and impacts—not a trivial undertaking. Biomass-to-Energy generation at least affords an opportunity to remove biomass-sized material from the woods, as leaving such material on the ground would not likely be acceptable to most fuel managers, and disposing of it by burning would add other costs and risks to the fuel treatment enterprise.

A few caveats are necessary. FIA BioSum is not a spatially explicit model in the sense that it does not track the location of every acre, evaluate hazard from the perspective of the off-site values at risk (e.g., nearby homes in a wildland urban interface setting, or an adjacent, irreplaceable habitat) associated with any plot or acre in the landscape, or generate spatially comprehensive predictions of changes in fire hazard or expected area burned. Nor is there any dynamic component in this strategic fuel treatment model—all treatments are assumed to happen at the outset. Furthermore, considerable planning costs would likely be incurred before any kind of treatments occurred on the ground, and these are omitted from this analysis, not because they are unimportant but because their magnitude is unknown. And finally, the example policy comparisons outlined above are simplistic—maximizing acres treated makes little sense unless, for example, priority acre groupings (e.g., high initial risk or characterized as wildland-urban interface) are incorporated into the optimization framework, certainly a feasible extension of the analysis presented here.

The FIA BioSum modeling framework was developed for a one time in-house analysis. However, the ability to quickly and efficiently assess the financial viability and effectiveness of landscape-scale treatments intended to reduce fire hazard and supply wood-processing plants is generating a lot of interest from managers and consultants. Because the current model formulation is not readily transferable to users external to the development group, we are seeking support to transform this analytic framework into a suite of semi-automated software tools and process descriptions that will facilitate the use of FIA BioSum by others.

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