Broad-Scale Assessment of Fuel Treatment Opportunities

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Abstract.—The Forest Inventory and Analysis (FIA) program has produced estimates of the extent and composition of the Nation's forests for several decades. FIA data have been used with a flexible silvicultural thinning option, a fire hazard model for preharvest and postharvest fire hazard assessment, a harvest economics model, and geospatial data to produce a Web-based tool to assess fuel treatment opportunities at a strategic level. This tool, the Fuel Treatment Evaluator, was used in this study to show how to identify potential fuel treatment hotspots in the Western United States.

Introduction

Decades of fire prevention and suppression efforts in the Western United States have led to an accumulation of fuels that are increasing the risk of catastrophic fire. In the past, fire-adapted forests had relatively open canopies and small amounts of ladder fuels due to frequent low-intensity fires. Today, due to fire prevention and suppression efforts, canopies and vertical structure are more closed. Although most fires continue to be low-intensity ground fires, an increase in the incidence of high-intensity crown fires has occurred. Crown fires are much more difficult and expensive to control, cause greater ecological disturbance, and impose a higher risk to life and property than ground fires.

Concern over increased fire hazard has led to research at local and regional levels. The Pacific Northwest Research Station developed an analytical tool called BioSum that uses forest inventory data to determine areas at risk and subsequent fuel treatment opportunities (Fried *et al.* 2003). BioSum intensively examines a multicounty project area. With the development of a nationwide forest inventory database in 2002 (Miles *et al.* 2004), it became possible to take a more strategic, albeit less intensive, multiState approach to fire hazard assessment.

In April 2003, a white paper entitled "A Strategic Assessment of Forest Biomass and Fuel Reduction Treatments in Western States" (USDA Forest Service 2005) was released. This "westwide biomass assessment" combined forest inventory data with a coarse-scale current fire condition class map (Schmidt *et al.* 2002) to identify areas at risk and the amount of biomass on those areas. Potential removal volumes were identified based on selective removal prescriptions using the stand density index (SDI) criterion (Reineke 1933).

As a result of the westwide biomass assessment, it was estimated that in the 15 western States at least 28 million acres of forest could benefit from some type of mechanical treatment to reduce hazardous fuel loading.

This article describes enhancements to the methods used in the westwide biomass assessment. Both the silvicultural thinning prescriptions and the fire hazard assessment were enhanced. Additional information is developed on harvest costs and the area and amount of thinning that occurs in the wildland-urban interface (WUI) (Radeloff *et al.* 2005).

Methodology

This analysis used a Web-based tool called the Fuel Treatment Evaluator (FTE), available at www.ncrs2.fs.fed.us/4801/fiadb/fueltreatment/fueltreatmentwc.asp. The FTE combines forest inventory data with other information to aid in the development

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of fuel reduction alternatives to reduce fire hazard. Other sources of information include a silvicultural prescription for thinning based on SDI, a method for estimating fire hazard (before and after treatment) based on stand and tree characteristics, a method for calculating harvest costs/benefits based on stand and tree characteristics, and geospatial information such as current fire condition class and WUI.

Forest Inventory Data

The FTE program currently uses data from the 2002 Resources Planning Act (RPA) database. (For a complete listing of data sources for the 2002 RPA database, see Smith *et al*. 2004).

The FTE can be used to generate files in Forest Vegetation Simulator (FVS) format for preharvest and postharvest conditions (Dixon 2004). These data could then be run through the Fuels and Fire Extension component of FVS to project future fire hazard (Reinhardt and Crookston 2003). Projecting future fire hazard is beyond the scope of this analysis.

Flexible SDI Thinning Prescription

SDI is a long-established, science-based, forest stocking guide that can be adapted to uneven-aged forests (Long and Daniel 1990) using data from broad-scale inventories. SDI measures can be used to identify areas or stands that would benefit from biomass reduction.

In the westwide biomass assessment, a stand was thinned until it was minimally fully stocked (30 percent of the maximum SDI for that forest type and ecoregion). To accomplish this, the target SDI was evenly divided among diameter classes in an inventory plot. The excess number of trees in each diameter class is the harvest yield for the treatment. This method identifies trees in each diameter class that may be available for fuel-reduction removals while ensuring sufficient "leave" trees to maintain site occupancy (Vissage and Miles 2003).

One problem associated with the apportionment of desired SDI values across diameter classes in multi- or uneven-aged forests was the inability to systematically adjust the slope of the desired stocking curve. Basically, adjusting the desired percentage of maximum SDI desired after thinning raised or lowered the stocking curve but did not change its shape. This adjustment resulted in large numbers of small trees being retained regardless of the percent of maximum SDI prescribed, which has been a major criticism of using SDI-based stocking control for fuels treatment biomass estimates.

As a result of this criticism, a flex factor option was added to the FTE to proportionally reduce the amount of SDI assigned to successively smaller diameter at breast height (d.b.h.) classes. Changing the flex factor changes the shape of the desired stocking curve. For this study, however, the default values used in the westwide biomass assessment were used.

Crowning and Torching Indexes

Torching index is the wind speed, in miles per hour (mph), 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 indexes indicate lower fire hazard. In this study, plots with crowning or torching index values below 20 mph were considered suitable candidates for thinning to reduce fire hazard.

The NEXUS 2.0 (Scott and Reinhardt 2001) crown fire hazard analysis software was incorporated into the FTE and used to estimate crowning and torching indexes for all Forest Inventory and Analysis (FIA) plots before and after simulated thinning. The NEXUS program links separate models of surface and crown fire behavior to compute indexes of relative crown fire potential.

Unfortunately, the 2002 RPA data set does not contain information on standing dead and down woody material. This information is necessary to more accurately assess fire hazard. Not having this information results in the underestimation of fire hazard. Standing dead and down woody material data are currently being collected and will be available in future versions of the FIA database.

Harvest Economics

The harvest economics module was based on the STHARVEST program (Fight *et al*. 2003). The STHARVEST model and software program is a general model that is intended to be used for broad planning applications. It develops estimates of harvesting cost for six harvesting systems for an average tree size ranging from 1 to 80 or 150 cubic feet, depending on the system selected. Cost estimates are in U.S. dollars per 100 cubic feet or per green ton.

Geospatial Layers

Attributes from two geospatial layers were added to each 2002 RPA plot record: (1) current fire condition classes and (2) WUI class.

"Condition classes are a function of the degree of departure from historical fire regimes resulting in alterations of key ecosystem components such as species composition, structural stage, stand age, and canopy closure" (Schmidt *et al*. 2002). In the westwide biomass assessment, fire condition class was used exclusively as a measure of fire hazard. In the FTE, torching and crowning indexes derived from FIA data fulfill this role. The ability to report by fire condition class has been retained for comparison purposes.

> The wildland-urban interface (WUI) is defined as the area where structures and other human development meet or intermingle with undeveloped wildland. The expansion of the WUI in recent decades has significant implications for wildfire management and impact. The WUI creates an environment in which fire can move readily between structural and vegetation fuels. Its expansion has increased the likelihood that wildfires will threaten structures and people (Radeloff *et al.* 2005).

The FTE gives the analyst the ability to restrict the analysis area to certain WUI classes. The FTE also enables the analyst to view treatment results by WUI class.

Results

The results come from a single run of the FTE that illustrates a potential thinning alternative for 15 Western States. Only stands with both crowning and torching indexes of less than 20 mph were included (high fire hazard). A silvicultural prescription of thinning until the SDI was reduced to 30 percent of the maximum was selected, and no flex factor was applied. An additional requirement that the thinning prescription result in a minimum harvest of 300 cubic feet per acre was imposed.

The FTE program generates 7 bar charts and 31 tables of output for each run. A subset of this output is presented for this alternative. In addition to these charts and tables, dynamic maps can be generated depicting biomass, numbers of trees, or growing-stock volume. The mapping units can be set to either counties or Ecological Mapping and Assessment Program hexagons (hexagons approximately 160,000 acres in size). The maps can depict pretreatment condition, post-treatment condition, or the amount of material to be removed by the treatment. Figure 1 is a map of pretreatment growing-stock volume, in cubic feet, per acre of all land.

The thinning prescription would remove a large number of trees. Most trees would come from the smaller diameter classes (fig. 2). Most of the biomass, however, would come from the larger diameter classes (fig. 3).

This silvicultural prescription was not completely effective in increasing the crowning and torching indexes above 20 mph. Only plots that had a crowning and/or torching index of less than 20 mph were considered for treatment in this study. After

Figure 1.—*Pretreatment growing-stock volume, in ft^3, per acre of all land, 2002.*

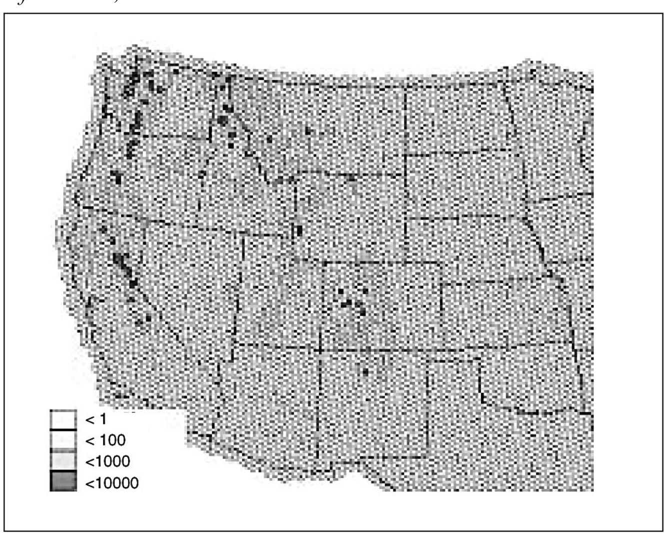


Figure 2.—*Live trees per acre by diameter class.*

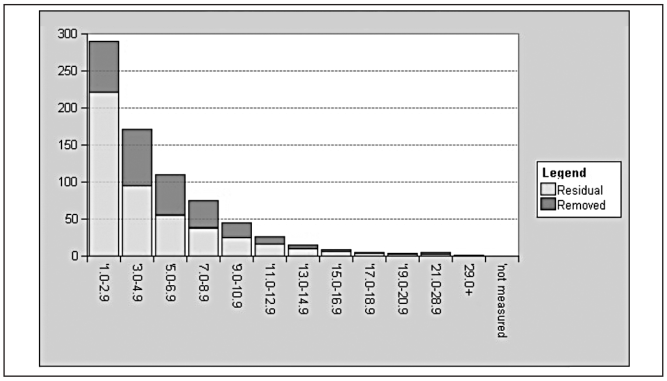


Figure 3.—*Live tree dry biomass tons per acre.*

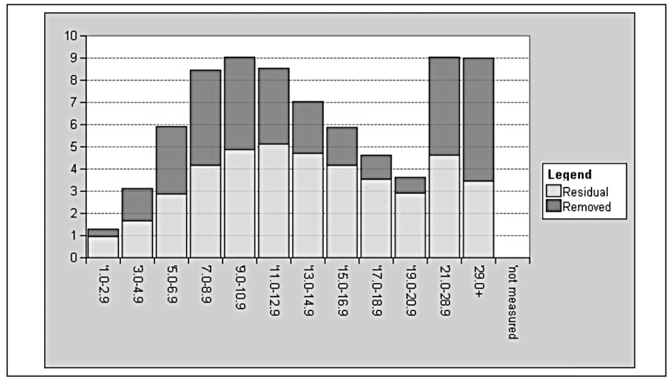
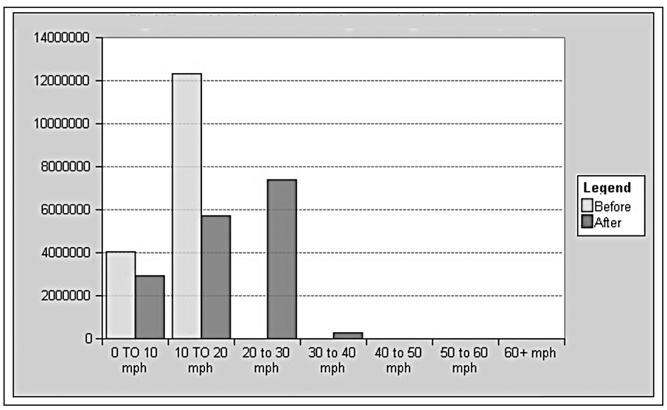


Figure 4.—*Treatable timberland area by crowning index class (acres).*



treatment, 53 percent of the area represented by these plots still had a crowning index of less than 20 mph (fig. 4), and 51 percent had a torching index of less than 20 mph. Adjustment of the thinning prescription to remove additional biomass is needed, especially in the lower diameter classes.

The FTE generates 31 tables of output. This information can be grouped into two broad categories: information to help calibrate the alternatives and information that can be used in a broad assessment. Table 1 contains output from the FTE that could be used in an assessment. It provides information on the impacts of the alternative by State. Montana had the largest area of treatable timberland in this study with more than 2.6 million acres. California had the largest potential yield with almost 100 million dry tons.

Table 1.—*Treatable acres and potential yield by State for alternative thinning treatment.*

State	Total treatable acres	Potential yield (dry tons)
Montana	2,648,318	70,929,635
Colorado	2,549,387	65,551,237
California	2,132,695	97,676,889
Idaho	1,892,542	60,361,378
Washington	1,621,094	68,053,090
Oregon	1,371,935	63,667,586
Utah	870,716	23,073,807
Wyoming	847,337	23,797,380
Kansas	751,545	17,186,238
New Mexico	638,171	16,646,198
Nebraska	470,594	10,750,054
North Dakota	193,428	4,528,753
Arizona	181,743	6,922,558
South Dakota	145,438	2,698,311
Nevada	40,904	883,991
Total	16,355,846	532,727,105

Identifying forest areas that have high concentrations of people and property is essential for prioritizing areas to be treated for fuel reduction. Incorporation of the WUI layer into the FTE program enables planners, policymakers, and land managers to identify areas that have a high fire risk and pose a significant threat to life and property. Table 2 provides information on the impacts of alternatives by WUI class. Resources should be directed to those States with large areas of treatable acres in the interface and intermix WUI classes.

Table 2.—*Treatable acres and potential yield by WUI class for thinning treatment.*

WUI class	Acres	Potential yield (dry tons)
Interface	48,217	1,760,636
Intermix	8,448,689	255,609,982
Uninhabited	6,980,132	253,524,483
Wildland	685,536	16,317,959
NoVeg and others	878,808	21,832,003
Total	16,355,846	532,727,105

Conclusions

The inputs to the FTE in this study were similar to those used in the westwide biomass assessment. The two major differences were the substitution of plot crowning and torching indexes for current fire condition class and the constraint that at least 300 cubic feet of growing-stock volume should be removed under the prescription. These two changes resulted in the treatment area being reduced from 28 million acres to 16 million acres. Additional refinement of alternatives should focus on identifying areas in close proximity to populated places.

The 2002 RPA database did not have information on standing dead or down woody material. These inputs, which are important to the crowning and torching indexes, will be available in the future and need to be incorporated in the FTE.

The FTE is a relatively simple model that links FIA data with a silvicultural treatment model, a fire hazard model, a harvest cost model, and geosocial data to provide information for broad strategic assessments. More sophisticated models, such as BioSum or FVS, may be needed for regional or local planning.

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