Chapter 4: Overview of the Vegetation Management Treatment Economic Analysis Module in the Integrated Landscape Assessment Project

Xiaoping Zhou and Miles A. Hemstrom[1]

Chapter Summary

Forest land provides various ecosystem services, including timber, biomass, and carbon sequestration. Estimating trends in these ecosystem services is essential for assessing potential outcomes of landscape management scenarios. However, the state-and-transition models used in the Integrated Landscape Assessment Project for simulating landscape changes over time do not directly compute the variables necessary for volume and biomass estimation. This study illustrates a methodology for modeling timber production and biomass supply potential over time in central Washington, and gives an example on cost-benefit analysis of fuel treatment under different management scenarios to provide information on economic viability of potential vegetation management activities.

Introduction

The Integrated Landscape Assessment Project (ILAP) explores the dynamics of broad-scale, multiownership landscapes and develops information that can be used to prioritize management activities over time by evaluating and integrating information on fuel conditions, wildlife and aquatic habitats, economic values, and projected climate change in Arizona, New Mexico, Oregon, and Washington. Products from ILAP will help land managers, planners, and policymakers evaluate management strategies that reduce fire risk, improve habitat, and benefit rural communities.

This chapter documents the fuel treatment economic analysis completed as part of ILAP. This work involved analyzing economic feasibilities of proposed fuel treatments and addressed the following questions under alternative management scenarios: (1) Where might fuel treatments create biomass and timber products, and how much are they likely to create? (2) How much might it cost to harvest the

[1] **Xiaoping Zhou** is a research economist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 620 SW Main St., Suite 400, Portland, OR 97205; and **Miles A. Hemstrom** is a senior scientist, Institute for Natural Resources, Oregon State University, PO Box 751, Portland, OR 97207-0751 (formerly a research ecologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Forestry Sciences Laboratory, 620 SW Main St., Suite 400, Portland, OR 97205).

timber and transport biomass from specific areas? How does transportation distance affect the financial outcome of fuel treatments? and (3) How might government subsidies and other related policies affect the financial viability of fuel treatments?

The major objectives of this chapter are to (1) document methodology that can be used to estimate the potential timber volume and biomass for alternative landscape management scenarios, (2) describe procedures for economic assessment of vegetation management treatments related to alternative land management scenarios, and (3) present some preliminary results of the fuel treatment economic analysis in a central Washington study area (tools developed and results from this work can be found at www.westernlandscapesexplorer.info).

Study Area

The study area is approximately 1 million ha of mostly forested lands in central Washington (fig. 4.1). It includes 25 hydrologic unit code (HUC) 5 watersheds (USGS and USDA NRCS 2011) and 16 combinations of ownership and land management allocations (see chapter 2). Forested vegetation ranges from very dry environments that support ponderosa pine stands to upper elevation forests of subalpine fir and mountain hemlock. Much of the forest consists of mixed-conifer stands dominated by Douglas-fir, grand fir, and ponderosa pine.

Methods

State-and-Transition Models

We used state-and-transition models (STMs) developed by ILAP (chapter 2) to simulate the effects of natural disturbances and management treatments on forested vegetation. The STM approach treats vegetation as combinations of cover type and structural stages (boxes) within different biophysical environments. Boxes are linked by arrows (transitions) that represent natural disturbances, management actions, or vegetation growth and development. For example, grass/forb herblands might become dominated by small trees and shrubs after a period of time or might remain as grass/forb communities following wildfire. This approach builds on transition matrix methods that represent vegetation development as a set of transition probabilities among various vegetative state classes (e.g., Hann et al.1997, Hemstrom et al. 2007, Keane et al.1996, Laycock 1991, Westoby et al.1989). The STMs were developed in the Vegetation Development Dynamics Tool framework, version 6.0.25, (VDDT; ESSA Technologies Ltd. 2007) and run using the Path modeling platform, version 3.0.4 (Apex Resource Management Solutions 2012, Daniel and Frid 2012).

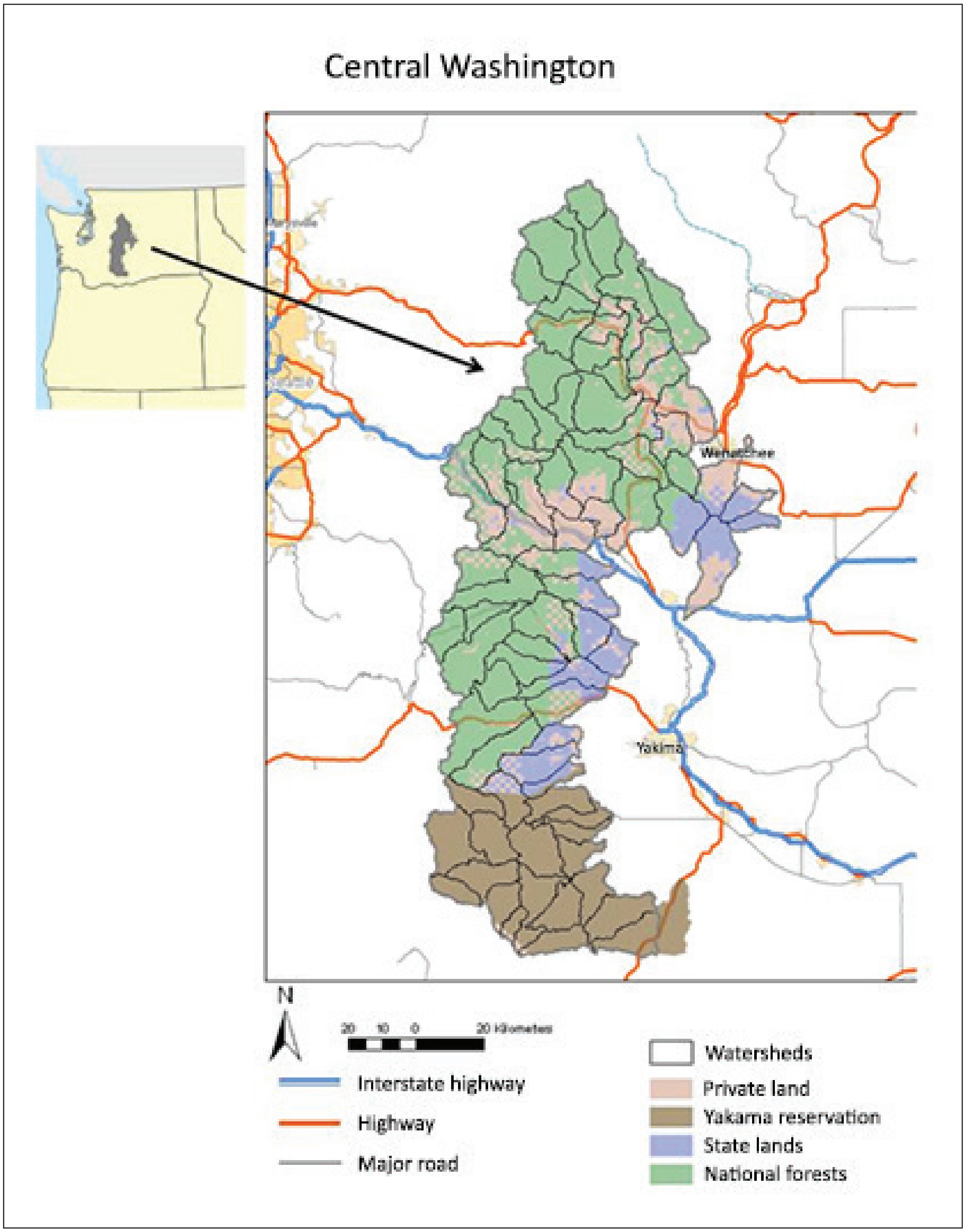

Figure 4.1—Central Washington study area.

Forest structural stages in the STMs were based on tree diameter, overstory canopy cover, and canopy layering (chapter 2). Forest diameter classes were based on the quadratic mean diameter of the dominant and codominant trees: (1) seedling/sapling (>0 to 13 cm diameter at breast height [DBH]), (2) young (>13 to 25 cm DBH), (3) small (>25 to 38 cm DBH), (4) medium (>38 to 51 cm DBH), (5) large (>51 to 75 cmDBH, and (6) very large (>75 cm DBH). Canopy cover classes were open (0 to 40 percent), medium (41 to 60 percent), and closed (>60 percent). Canopy layering was either single or multiple. A grass-forb condition represented early-seral state classes before establishment of a significant tree canopy. Postdisturbance state classes were also included, representing conditions resulting from a stand-replacing disturbance (insect outbreak or wildfire) prior to any salvage logging and consequently containing abundant large dead wood.

A current vegetation map was developed for the study area (chapter 2). The vegetation was mapped using nearest neighbor imputation techniques based on random forest nearest neighbor (Crookston and Finley 2008) and gradient nearest neighbor (Ohmann and Gregory 2002) methods. A rule set was developed for classifying the current vegetation to STM state classes within each vegetation type. These data became the initial conditions for STM simulations. Burcsu et al. (chapter 2) used these initial conditions to project future vegetation conditions, management activities, and natural disturbances for alternative management scenarios. The resulting vegetation, disturbance, and management activity projections were summarized by time step, potential vegetation, and state class.

Two forest management scenarios were applied in this study. The fire-suppression-only (FSO) scenario assumed that no management treatments were practiced except continued current levels of wildfire suppression. The current management (CM) scenario was based on estimated forest management treatment rates currently in place by land ownership and land management allocation (ownership-management; see chapter 2). Management differed widely among ownerships and management allocations from no treatments (except wildfire suppression) in wilderness and similar reserved areas, to commercial timber harvest on private timberlands. The treatment rates by ownership-management were gathered as part of an ongoing local collaboration. Treatments in the CM scenario included regeneration harvests, commercial thinnings, precommercial thinning, planting, prescribed fire, and mechanical fuel treatments. Importantly, timber harvests from federal lands did not include trees over 53 cm in diameter. Wildfire probabilities were computed by potential vegetation groups (dry, moist, and cold forest) using data from the Monitoring Trends in Burn Severity project (Eidenshink et al. 2007; www.mtbs.gov), and reflect wildfire occurrence in the Washington East Cascades ecological region for the 1984–2008 time period (chapter 2).

Volume and Biomass Look-Up Tables

The STM simulation output does not carry detailed vegetation attributes over time such as tree species, diameter, and height, which are key variables for estimating timber volume and tree biomass. The challenge for users interested in information about timber products and biomass is how to quantify timber production and biomass supply from vegetation management treatments and other disturbances with STM simulation output. The U.S. Department of Agriculture Forest Service (USDA FS) Forest Inventory and Analysis (FIA; USDA FS 2012) plot and tree information were used to build look-up tables with volume and biomass attributes linked to each state class for each ILAP modeling zone (see chapter 2; fig. 2.4). The process involved the following major steps:

1. Gather detailed tree information from the FIA periodic and annual plots that occurred in the study area and in the same potential vegetation in adjacent ILAP modeling zones.
2. Assign each plot to a state class within the study area (chapter 2).
3. Calculate volume and biomass for each plot (Zhou and Hemstrom 2010).
4. Summarize volume and biomass attributes, as well as other desired variables, for each plot by product group or by total.
5. Compute attribute averages for each STM state class and build a look-up table with the computed attributes associated with each state class.
6. Fill in holes for those state classes with no plot samples by using a rule set that substituted the most similar state class with plot samples.

Look-up tables were built in step five for each modeling zone. Volume attributes included in look-up tables were total volume (DBH ≥2.5 cm), merchantable tree volume (DBH ≥12.7 cm), and sawtimber volume (DBH ≥22.9 cm for softwood and DBH ≥27.9 cm for hardwood); biomass attributes include biomass of stem, branch, bark, and leaf. The total biomass is the sum of all these parts. Merchantable biomass is computed separately. Five products were defined in this study based on tree diameters: (1) small tree with DBH <12.7 cm; (2) chip tree with DBH ≥12.7 cm, and <17.8 cm; (3) pole tree with DBH ≥17.8 cm and <22.9 cm for softwood and 27.9 cm for hardwood; (4) small sawtimber, a sawtimber tree with DBH ≥22.9 cm for softwood and 27.9 cm for hardwood and <50.8 cm; and (5) large sawtimber, a sawtimber tree with DBH ≥50.8 cm.

The attributes included in the look-up table were then linked to STM output, and the desired attributes were summarized for each modeling stratum by year.

Vegetation Management Treatment Economic Analysis

Timber products and biomass were estimated annually to examine potential economic outcomes from the two alternative land management scenarios. The process included the estimation of removed materials, harvesting costs, the transportation costs, and the market values of the removed timber, as well as the values of the woody biomass delivered to known mill locations.

Estimation of removals—

Various management activities, such as harvesting and prescribed fires, were applied to achieve ecological objectives and reduce fuel accumulations. The STM simulations forecasted annual area treated with different management activities for each year by modeling stratum and state class. In addition, model output included the transition pathway ("from" state class, and "to" state class) for every management transition that occurred in the simulations. Using this information, removed volume and biomass were calculated based on the difference of volume and biomass in the "from" state class and the "to" state class. Treatment was assumed to have occurred in the middle of the year, and growth was not considered during the treatment year. Merchantable timber volume was calculated for trees with DBH ≥12.7 cm, including pulpwood size trees (chip or pole trees) and sawtimber size trees. The sawtimber volume is the tree volume with DBH greater than sawtimber size (22.9 cm and above for softwood and 27.9 cm and above for hardwood). Aboveground biomass was calculated including stem, bark, branch, top, and leaves of all trees.

Harvesting cost—

The Fuel Reduction Cost Simulator (FRCS; Fight et al. 2006) software was modified and used to estimate harvesting costs, including removal of trees of mixed sizes in the form of whole trees, logs, or chips. In FRCS, equipment production rates were developed from existing studies, and cost assumptions for labor and equipment were modified with the most current available information. The FRCS includes four ground-based systems, four cable systems, and two helicopter systems. The helicopter systems were not included owing to high costs. Harvesting estimates generated by FRCS were in U.S. dollars per 100 ft^3, or per 2.83 m^3. The harvesting costs included five major components: felling (and bunching), skidding, processing, loading, chipping (if applicable), and machine move-in cost.

Stumpage and product prices—

Stumpage price differs among regions and ownership. The average stumpage price for eastern Washington on public timberland was about $147 per thousand board feet (MBF) from 2003 to 2010, with an average of $218/MBF for the Washington state-owned timberland and $76/MBF for the Forest Service-owned timberland

(Warren 2011). The average log export price from port districts in Washington and Oregon to major Asian countries (China and South Korea) was used as a ceiling log price. The averaged saw-log price to these two Asian countries from 2006 to 2010 was about $560/MBF from Seattle and Columbia-Snake districts, $619/MBF to China, and $500/MBF to South Korea (Warren 2011). The pulpwood size timber was valued as average chip export prices from Seattle and Columbia-Snake districts, with an average of $75/tonne (t) from 2006 to 2010, $56/t from Seattle and $93/t from the ports of Columbia-Snake districts. The potential woody biomass supply included the removed trees with diameter at breast height <12.7 cm, plus the tops and branches from the larger removed trees. We assumed $33 per bone dry tonne of delivered biomass.

Transportation cost—
The transportation cost of biomass substantially affected the economic feasibility of the biomass supply. The distance from each watershed to all the biomass facilities was estimated, and only the facilities with transportation distance <402 km were considered for biomass supply. The total transportation cost depended on hauling distance, the truck load, labor, and fuel costs. Travel time for transporting biomass from watershed source areas to various mills was calculated based on posted road speed limit. Railroad transportation was not considered for this study. We assumed 22.7 t per truck load and $4.40 per hour and per tonne truck for transportation costs.

Results

Standing Biomass and Timber Volume

Total aboveground live tree biomass peaked at year 44 for both scenarios, at 214 billion dry tonnes for the FSO scenario and at 204 billion dry tonnes under the CM scenario; it declined after that time and then stabilized or slightly increased near the end of the simulation period (fig. 4.2a). Total standing merchantable tree inventory followed the same trajectory as biomass; it increased rapidly for both the CM and FSO scenarios during the first three decades, stabilized for 10 to 20 years, and then decreased. The timber inventory under the CM scenario peaked at 0.31 billion m^3 around year 33, about 13.5 percent higher than the initial inventory, and then declined. The inventory under the FSO scenario reached its maximum of 0.33 billion m^3 at year 40 and remained steady for about a decade, then declined (fig. 4.2b). In both scenarios, timber inventories at the end of simulation period were above their initial level. The merchantable tree inventory under the FSO scenario ended about 10 percent higher than under the CM scenario.

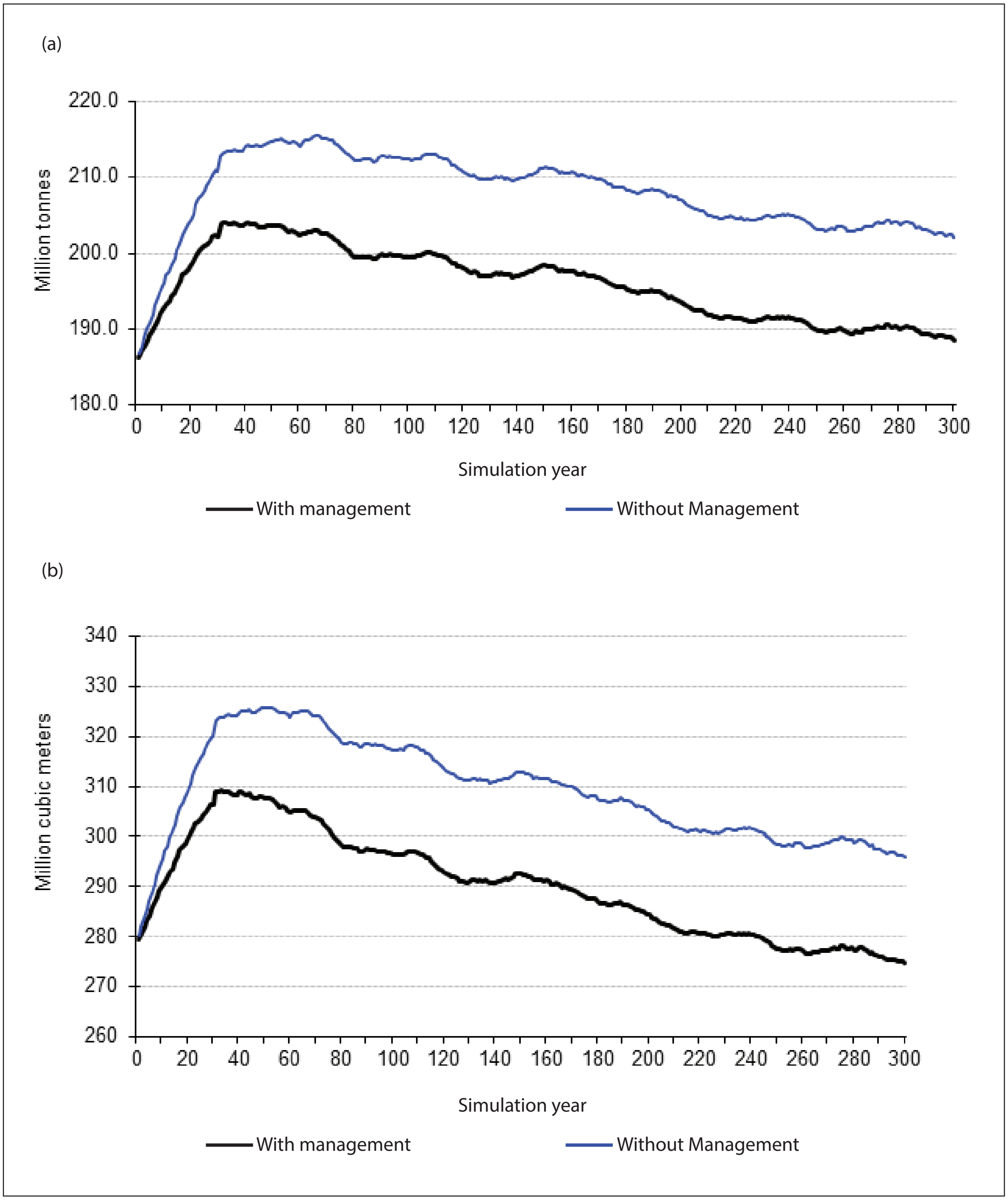

Figure 4.2—(a) Total aboveground live tree biomass in the central Washington landscape, and (b) total merchantable volume in the central Washington landscape.

Removals From Vegetation Management Treatments

We examined the first 50 years of simulation results for the economic analysis. The removals of merchantable tree volume from USDA FS and Yakama Nation tribal lands increased gradually for the first two to three decades and then stabilized, while the removals from private lands were relatively low during the entire simulation period owing to the small area of privately owned forest land in the study area (fig. 4.3a). Removals of merchantable tree volume from the Washington state-owned forest lands were about 68 percent of the total removals at the beginning of the simulation period, decreased dramatically to less than 40 percent of the total after three decades, then stabilized at 20 to 25 percent of the total at the end of the simulation (fig. 4.3a). These patterns reflect differences in management treatments and initial forest conditions on different ownership-management strata. Management treatments were more likely, given appropriate stand conditions, on Washington state and tribal lands compared to those on lands managed by the USDA FS. Conversely, much of the forested land in the Yakama reservation had been treated following extensive, recent insect damage, while state lands had a mixed history and many had not been recently managed. Lands managed by the USDA FS were generally not recently managed, and there was considerable area in reserves that are not subject to much active management. As a result, removals rates reflected (1) relatively stable levels on tribal lands, (2) initially high then declining levels on state lands, as most of the available area became managed, and (3) stable and relatively low levels on USDA FS lands constrained by lower management probabilities and relatively extensive reserves. The same general patterns emerged for biomass removals.

The woody biomass supply from USDA FS and Yakama tribal lands increased gradually over the first two to three decades and then stabilized, while the removals from private land remained at relatively low levels during the simulation period (fig. 4.3b). Total biomass removals from USDA FS lands averaged 12 percent of the total biomass removals initially, and reached 25 percent of the total at the end of 50 years. Biomass removals from tribal lands during the same period increased from 19 to 35 percent. The biomass supply potentials from Washington state-owned forest were about 65 percent of the total initially, and decreased dramatically for the first half of the century to 35 percent of the total potential biomass supply. The contribution of woody biomass from private forest land in the study area was relatively small, but increased from 3.8 to 5.4 percent of the total over 50 simulation years.

The quantity of potential biomass supply varied substantially by watershed and ownership-management (fig. 4.3c). Four major watersheds produced woody biomass over 181,000 dry tonnes each over the 50-year simulation period, while other watersheds produced much less. Most of the Yakama Tribe contributions were from two watersheds. The biomass removals in four watersheds were all from Yakama Tribal lands. Washington state lands produced most of the biomass from three watersheds.

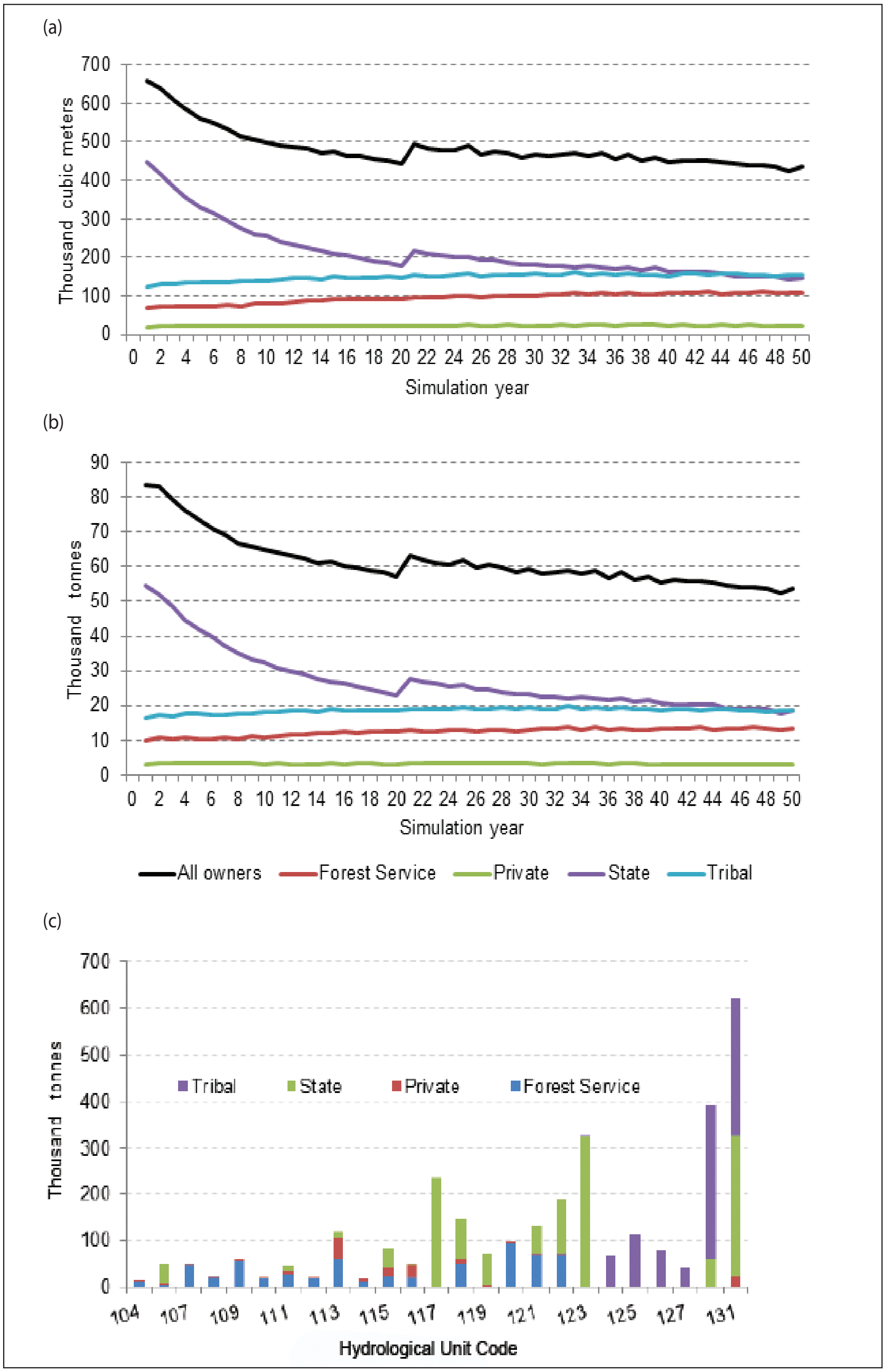

Figure 4.3—(a) Merchantable volume removals (trees with diameter at breast height [DBH] >12.7 cm) from fuel treatments by ownership under the current management scenario, (b) potential biomass (trees with DBH <12.7 cm and residues) supply from fuel treatments by ownership under the current management scenario, and (c) total biomass (DBH <12.7 cm plus branch and top) of removals over 50 years by watershed and ownership.

Economic Analysis

The economic outcome of vegetation management treatments was determined by the total cost of the treatment and the possible revenues generated from the removed products, including commercial timber and woody biomass. For this study, woody biomass supply included all removed trees <12.7 cm DBH, plus the branches and tops from the larger removed trees, estimated in bone-dry tonnes. Trees above 12.7 cm in diameter were considered as timber products. The biomass value was also affected by the distance from the supply point to the processing facility.

The analyses in this section addressed two major questions under the CM scenario: (1) For given timber prices, would selling only commercial timber products be profitable? (2) Would adding woody biomass as a commercial product for fuel energy improve the economic outcome?

We estimated the total stumpage value from potential treatments under the CM scenario to be over $15 million annually. To simplify the calculation process, and for the purposes of this paper, we assumed an average stumpage price of $218/MBF for all ownerships (fig. 4.4a), likely an overestimate for stumpage on USDA FS land. The average harvesting cost for all ownership-management ranges from $159/MBF to $170/MBF, with USDA FS averaging from $169 to $191/MBF (fig. 4.4b).

Potential profit varied considerably among owners including woody biomass as biofuel made a considerable difference to profits.

Potential profit varied considerably among owners. Assuming an average stumpage price of $218/MBF, figure 4.5a shows the potential treated hectares with positive profits at different log prices of $360, $380, $400, $420, and $450. When log prices averaged $360/MBF, about 10 percent of the area treated generated profits, mostly Yakama and private forest land. Almost all treated area on USDA FS land lost money at this log price. However, almost all treated hectares generated profit when log prices were above $450/MBF, regardless of ownership. Figure 4.5b maps the profitability for the first 30 years for each watershed at the saw-log price of $400/MBF and pulpwood log price of $75 per dry tonne, with timber as the only product for different ownerships. In this case, profits occurred for USDA FS managed lands in 4 out of 19 watersheds, Washington state owned lands in 2 of 13 watersheds, private lands in 8 of 21 watersheds, and Yakama tribal lands in five of seven watersheds.

Including woody biomass as biofuel made a considerable difference to profits (fig. 4.6a). For example, at a log price of $380/MBF, selling the woody biomass added 1 to 7 percent to the area that could be treated at a profit. However, the marginal benefit of selling woody biomass decreased as the log price increased. When log price was $420/MBF and more, the marginal benefit of selling the woody biomass was insignificant (fig. 4.6a).

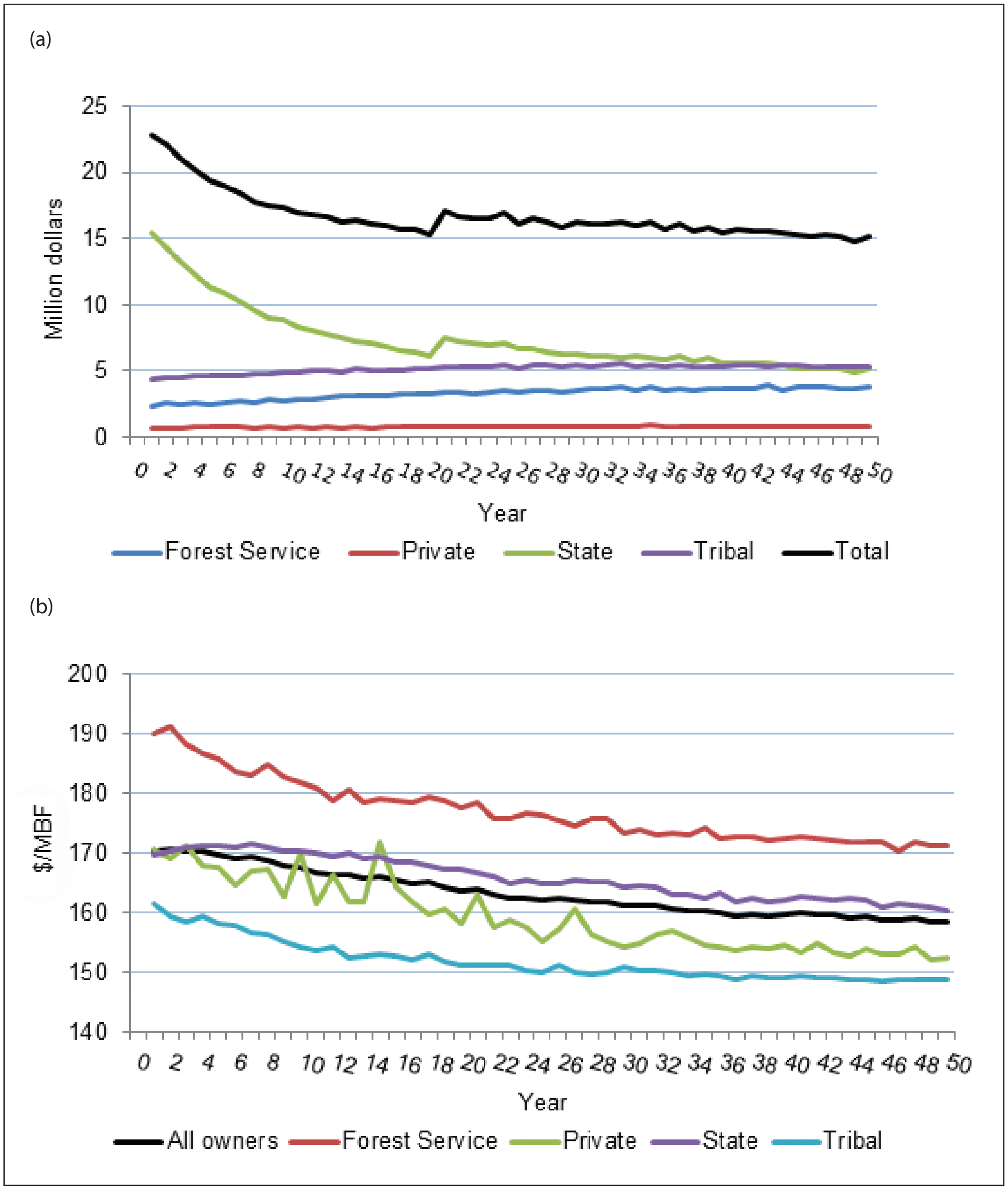

Figure 4.4—(a) Stumpage value by owner (at a price of $218 per thousand board feet [MBF]), and (b) average harvesting cost by owner.

The quantity of potential biomass supply from watersheds and the distance or transportation time considerably changed the economic outcome of using woody biomass as fuel. Depending on where the biomass facilities were located, the contribution of selling woody biomass as products increased or decreased the total revenue. At a saw-log price of $400/MBF, pulpwood log price of $75 per dry tonne, a biomass price of $33 per dry tonne, and delivery to the processing facility with cheapest transportation costs, all the ownerships in all watersheds benefitted

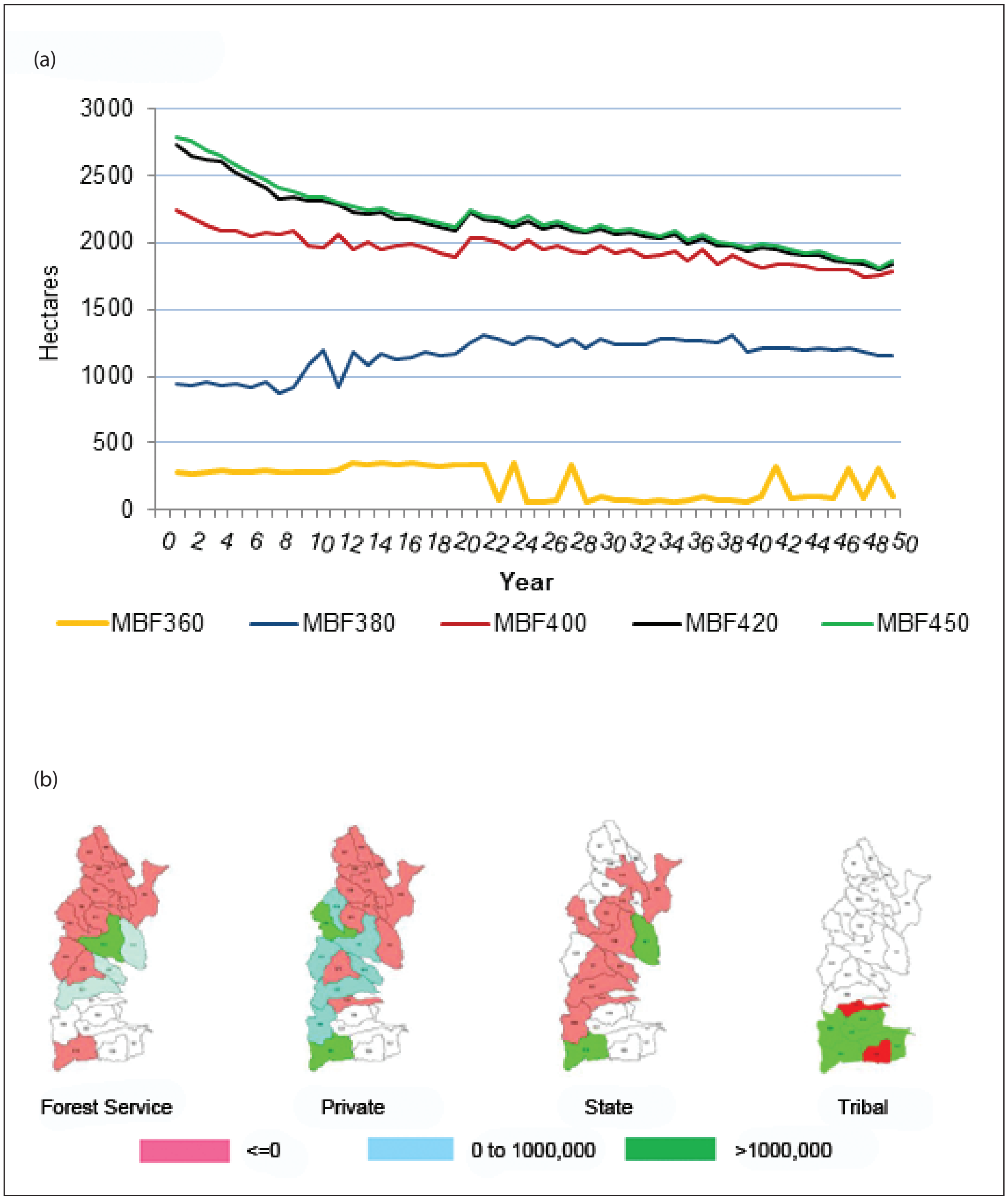

Figure 4.5—(a) The potential treated hectares with positive profits at different log prices of $360, $380, $400, $420, and $450 (including timber volume only), and (b) the profitability of timber only by owner and watershed. Profits are 30-year totals in dollars.

from selling the woody biomass. In addition, compared to selling timber only, all owner groups increased the number of watersheds with positive economic returns when biomass sales were included (fig. 4.6b). In this case, profits came from USDA FS lands in 5 of 19 watersheds, Washington state owned lands in 3 of 13 watersheds, private lands in 13 of 21 watersheds, and Yakama tribal lands in six of seven watersheds.

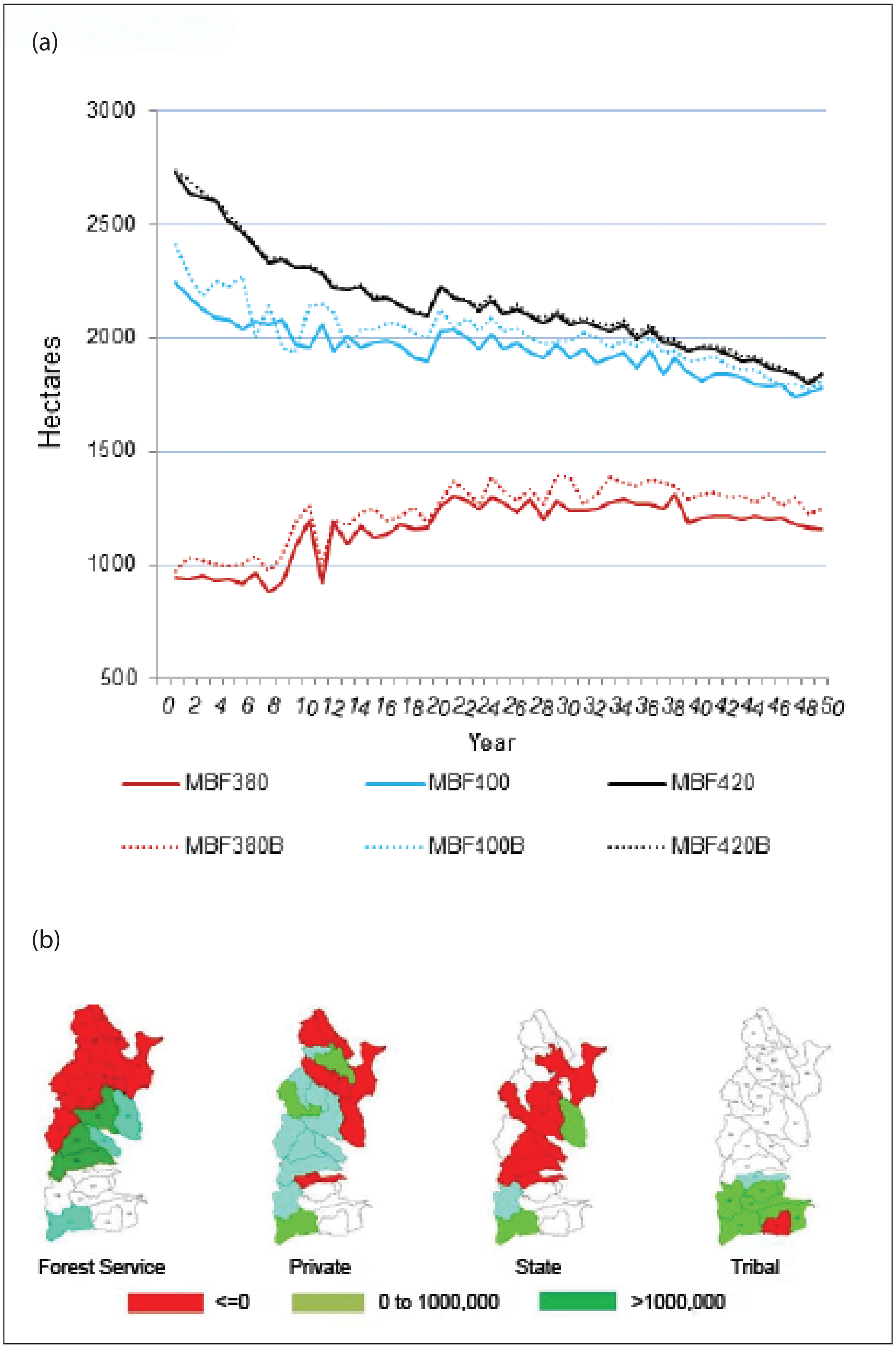

Figure 4.6—(a) The potential treated hectares with positive profits at different log prices of $360, $380, $400, $420, and $450 (timber and timber plus biomass (dotted lines), and (b) profitability of both timber and biomass by owner and watershed. Profits are 30-year totals in dollars.

Discussion

Management to achieve forest health and restoration objectives can be expensive. Many management treatments could produce a variety of potentially valuable forest products, but economic costs and benefits differ widely depending on the kind of product, transportation distances, product prices, and other factors. Although the ecological value of treatments is often debated, the fact is, treatments cost money. The realities of treatment economics play a critical role in the selection of a set of treatments to achieve objectives. In a setting where ecological restoration and forest health are primary considerations, the value of forest products generated by management treatments may be relatively low. This suggests that several land managers and organizations in a large landscape may need to coordinate treatments to generate enough product value to make overall forest objectives economically viable. In many cases in the Western United States, federal lands make up a large portion of the area that might generate forest products in the course of restoration, but declining budgets, transportation costs, product values, treatment costs, and available infrastructure can severely limit the ability of federal land managers to implement restoration treatments.

Our study illustrates procedures that can be used for economic analysis of STM simulations across large landscapes. Vegetation management treatment may effectively treat dense stands to create a desirable mix of future stand conditions to meet forest health and habitat objectives and to reduce fire hazard. However, the cost of harvesting and the limited use of small trees removed from treatment can directly affect the economics of management practices. The study presented in this paper for the central Washington landscape reveals that the economic outcome of fuel treatments differs significantly among owners and watersheds, depending on the quality of the timber and the market value of logs and woody biomass. Although we focused on vegetation management treatments, any combination of treatments to achieve a wide variety of forest conditions could be addressed with our methods.

We found that adding the woody biomass as biofuel could add value to the treatment if the cost of processing small trees and branches onsite is low and the facility is relatively nearby. In general, we found that when the log prices were low, the marginal benefit of adding biomass as a commercial product was higher, but that marginal benefit diminished as log price increased. In our CM scenario, the area that could be profitably treated annually increased by 5 to 10 percent when log prices were $400/MBF or less (fig. 4.6a). Economic values associated with biomass production were primarily limited by transportation costs. Even though this scenario did not harvest trees over 53 cm diameter on federal lands, the production of timber products drove most of the economic value derived from treatments.

This does not necessarily imply that biomass harvest could not provide benefits to local communities. It does imply that, in this area and under this scenario, biomass generated by the proposed treatments is of relatively small marginal value.

Conclusions

The estimation of the materials or products removed from treatments, product market projections, and bioenergy policies all affected the economic outcome of the CM scenario. When considered across all lands, the CM scenario generated net positive revenue if the price of log was above the sum of harvesting cost and stumpage value, and the cost of transporting woody biomass was lower than that value. But revenues differed widely by ownership, treatment type, and general landscape location. In general, Yakama tribal and privately owned lands with lower harvesting cost generated more net positive revenues, while public lands with higher harvesting costs generated net negative revenues. By working together in a collaborative fashion, the local land managers might generate additional positive benefits. Our process, as part of ILAP, allows land managers, policymakers, and others to evaluate potential economic benefits in conjunction with the effects that alternative scenarios might have on wildlife habitat conditions, wildfire and fuel hazards, and other important resource values.

Acknowledgments

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