Financial Analysis of Fuel Treatments

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Abstract

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The purpose of this paper is to provide information and discussion that will be helpful in promoting thoughtful design of fire hazard reduction treatments to meet the full range of management objectives. Thoughtful design requires an understanding of the costs and potential revenues of applying variations of fire hazard reduction treatments in a wide range of stand conditions. This paper draws extensively on the My Fuel Treatment Planner (MyFTP) software to highlight and illustrate the effect of treatment variables on the cost and net revenue from fire hazard reduction treatments in dry forest types of the Western United States. Treatments covered are thinning with or without utilization, prescribed fire, and mastication. For thinning with removal to a landing, costs can be estimated for four ground-based systems, four cable systems, and two helicopter systems.

Keywords: Financial analysis, silviculture, fire, prescriptions, economics, fuel treatments

Preface

This document is part of the Fuels Planning: Science Synthesis and Integration Project, a pilot project initiated by the U.S. Forest Service to respond to the need for tools and information useful for planning site-specific fuel (vegetation) treatment projects. The information primarily addresses fuel and forest conditions of the dry inland forests of the Western United States: those dominated by ponderosa pine, Douglas-fir, dry grand fir/white fir, and dry lodgepole pine potential vegetation types. Information, other than social science research, was developed for application at the stand level and is intended to be useful within this forest type regardless of ownership. Portions of the information also will be directly applicable to the pinyon pine/juniper potential vegetation types. Many of the concepts and tools developed by the project may be useful for planning fuel projects in other forest types. In particular, many of the social science findings would have direct applicability to fuel planning activities for forests throughout the United States. As is the case in the use of all models and information developed for specific purposes, our tools should be used with a full understanding of their limitations and applicability.

The science team, although organized functionally, worked hard at integrating the approaches, analyses, and tools. It is the collective effort of the team members that provides the depth and understanding of the work. The science team leadership included Deputy Science Team Leader Sarah McCaffrey (USDA FS, North Central Research Station); forest structure and fire behavior—Dave Peterson and Morris Johnson (USDA FS, Pacific Northwest Research Station); environmental consequences—Elaine Kennedy-Sutherland and Anne Black (USDA FS, Rocky Mountain Research Station); economic uses of materials—Jamie Barbour and Roger Fight (USDA FS, Pacific Northwest Research Station); public attitudes and beliefs—Pam Jakes and Sue Barro (USDA FS, North Central Research Station); and technology transfer—John Szymoniak, (USDA FS, Pacific Southwest Research Station).

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Introduction

The strategies used for managing wildfire by the USDA Forest Service, USDI Bureau of Land Management (BLM) and other federal and state land management agencies are changing. Our current fire organizations were built almost solely around preventing unwanted ignitions and preparing for and fighting those wildfires that do occur. Emerging strategies call for altering the vegetative conditions (structure, composition, and density) that promote unwanted ignitions, allow fires that do start to grow larger or more severe than desired, or let wildfires damage housing or other infrastructure that people value (Western Governors' Association 2001). Ideally this means that one day we will manage vegetative conditions and design human infrastructure in ways that make it safe for many, perhaps even most, fires to burn without triggering massive fire suppression efforts because those fires will be smaller and more predictable. Meeting this objective calls for altering vegetative conditions on a grand scale throughout the Western United States (Vissage and Miles 2003). The National Fire Plan[1] and related congressional direction, for example, the Healthy Forest Restoration Act of 2003, draw attention to this need for vegetation manipulation and focus federal and state forestry resources on addressing the problem.

The three basic categories of tools available to forest managers for altering vegetative conditions are prescribed fire, mastication or mowing,[2] and thinning. The effectiveness of each of these methods in altering the structure of or reducing the amount of ground and ladder fuels, and reducing crown bulk density is different. Consequently, each of these leaves residual stands with different vegetative characteristics and environmental effects. Each type of treatment also has a different set of financial costs, and in times of tight budgets the choice of which method to use is important in achieving the best combination of risk reduction and environmental effects within the available budget.

Prescribed fire is generally used to remove ground fuels, understory vegetation, and small trees, and sometimes to kill larger trees. It is not a precise way of reducing stand density, and several prescribed fires spread over many years are often necessary to accomplish management objectives. Prescribed fire is, however, often seen as more environmentally benign than other methods for modifying vegetation. Mastication modifies the form of ground fuels, understory plants of various sizes, and sometimes fairly large trees (15 to 20 inches in diameter). Mastication is more precise than prescribed fire because human judgment is used to target particular trees and shrubs. Accordingly, managers can use mastication to achieve specific stand density and vegetative composition goals in a single entry. Mastication changes fuel structure by grinding or chopping it into smaller pieces that lay close to or on the ground, but it does not reduce fuel loads. Thinning is also quite precise and, like prescribed fire, can include removal of biomass from the site, some of which may be in the form of merchantable trees. Thinning is not particularly useful at reducing understory

[1] Managing the impacts of wildfires on communities and the environment: a report to the President of the United States in response to the wildfires of 2000. Signed by the Secretaries of Agriculture and the Interior September 8, 2000.

[2] Mastication is a special case of thinning without removal of the thinned materials. In the case of mastication, the thinned materials are ground and left on the site. This is different from precommercial thinning where the trees are simply cut down and left on site. The fuel characteristics after mastication and precommercial thinning are much different.

plants or ground fuels, and it typically adds to the surface fuel load in the form of tops and limbs, and even bolewood in the case of precommercial thinning. Like mastication, the precision of thinning makes it useful for accomplishing large changes in vegetative structure and composition in one entry.

The outcomes from prescribed fire, mastication, and thinning are so different they are frequently used in combination to capture the advantages of each. Combining treatment methods allows managers to tightly specify final conditions, and it can either add to or reduce the costs of treatments depending on how well planners understand the strengths and weaknesses of the methods they choose.

These types of management activities are different than those that were employed when timber production was the primary motivation for vegetative manipulation in federally administered forests. Planning teams are challenged to design treatments that meet fire hazard reduction goals while paying for their implementation. This is often not possible and made more challenging by the difficulty in estimating how much treatments will cost, especially when trying new things. Without a good understanding of costs, it is difficult to design a management program that efficiently uses the available budget to accomplish the goals of the National Fire Plan. Financial analysis can be used together with analytical tools that help planning teams understand how fires will behave before and after treatments (Finney 2001, Peterson and others 2005), the effects of treatments on other resources (Ritter and others, in press; Sutherland and Black, in press), and how to engage people in issues related to fire hazard reduction treatments (Sturtevant and others 2005) to improve the selection of stands for treatment and the design of fire hazard reduction treatment projects. In this paper we examine how financial analysis fits into broader economic analysis, the reasons for doing financial analysis, and the relative importance of numerous factors that affect the financial outcome of a treatment applied to a forest stand.

Economic Analysis Versus Financial Analysis

Many people are confused about the difference between economic analysis and financial analysis. The scope and complexity of a financial analysis resembles balancing your checkbook, whereas the scope and complexity of an economic analysis resembles planning for retirement. Understanding this distinction is important because the scope and complexity of an economic analysis make it difficult to perform even with formal training in economics; however, given the proper tools, even people with a limited background in economics and forestry operations can perform a financial analysis.

Economic analyses can help planners make strategic decisions about what to do and where to do it. These decisions often involve evaluating important tradeoffs among the effects on stand structure, fire behavior, and the cost of fire suppression (Kline 2004). For example, the size, nature, and placement of treatments may affect patterns of habitat for wildlife or rare plants and how new habitat develops over time. They could also alter opportunities for recreation, the associated economic impacts, and property values, or the treatments themselves could result in undesirable outcomes such as smoke production from prescribed fire. Our ability to understand and quantify these types of effects is limited by the availability of skilled analysts, a lack of economic models that relate ecological and social benefits to manipulations of vegetation at the stand or landscape scale, and the availability of sufficient budgets to even conduct such analyses.

A financial analysis is limited to addressing costs and benefits that are readily measured in dollar terms. The results of a financial analysis can be used with subjective judgments about the importance of benefits that cannot be reduced to dollar estimates to reach decisions about such tradeoffs. There are several reasons for doing financial analysis of fuel treatments. Most of the fire hazard reduction treatments in the Western United States are implemented on public land, and planners want to use tax dollars wisely to pay for these treatments. Financial analysis is well suited to determine the least-cost way to accomplish objectives where the costs and benefits that cannot be reduced to dollar terms are comparable or unimportant. Another reason for doing financial analysis is to determine whether the most appropriate arrangement to accomplish a project is a standard contract (all cost and no revenue), a timber sale (substantial net revenue), or a stewardship contract (a mechanism that allows net revenue from selected units to be used to cover part or all of the negative net revenue from other units so that the amount of appropriated funds needed to treat the units with negative net revenue will be reduced). Because financial analysis focuses on costs and revenues, it is an appropriate tool for making this type of determination. A third reason for doing a financial analysis is to assist in budget development and allocation. It might be useful to think of budgeting as determining how to combine different types of treatments and treatment locations to most effectively use the available budget. Because the selection of treatment locations and the costs of different types of treatments can differ widely, attention may be required in scheduling to match the acres treated with the anticipated budget over time. Alternatively, once a budget has been determined, the acres that can be treated will be affected by the selection of the places to treat and the way to treat them.

Once a strategic decision has been made to conduct fire hazard reduction treatments across broad areas, a financial analysis can be used to help decide what treatments to apply to what stands. This involves evaluation of tradeoffs in the selection of the intensity of treatment, the size and species of trees selected for removal, and the types of stands targeted for treatment. The My Fuel Treatment Planner (MyFTP) software was developed to provide a structured process for conducting financial analyses of fuel treatments.[3]

We used MyFTP to conduct several analyses for this paper that illustrate some ways financial analyses support both strategic decisions about what types of stands to treat across broad landscapes and tactical decisions about which treatment to select for a specific stand. In both cases, stand-level information is fed into the model and results compared on a stand-by-stand basis. The big difference is that in a strategic analysis, the “stands” actually represent classes of stands with similar characteristics, and in tactical analyses the stands represent actual treatment units. For example, a strategic analysis might involve looking at 15 or 20 stands that are representative of the stand types

[3] The My Fuel Treatment Planner software and documentation is available from http://www.fs.fed.us/pnw/data/soft.htm.

found on a national forest where thinning with removal of wood for sale, prescribed fire, or mastication might be options. MyFTP could be used to compare the relative cost of treating each stand type with variations of each treatment. A planning team could use the results in a discussion about the least expensive way to treat each stand type. In a tactical analysis, MyFTP could be used in planning a specific project to help the planning team discuss how to accomplish the most work with the available funds.

The examples we selected are intended to both demonstrate the capabilities of MyFTP and illustrate the relative importance of factors that should be considered in financial analyses of fire hazard reduction treatments. We simulated scenarios that demonstrated use of each of the modules in MyFTP. These allow estimation of the following costs: mechanical fuel treatments including mastication, prescribed fire treatments, harvesting, and hauling. MyFTP also includes modules to estimate potential revenue from wood products and to estimate the economic impact of fire hazard reduction treatments.

Things That Affect the Cost of Thinning

Tree Size

The volume per acre of trees being cut, processed, and moved to a landing[4] and the average size of the trees are the two most important variables in determining the cost of removing trees for a given harvesting system, slope, and size and shape of harvest unit. These two variables are determined by the starting conditions in the stand that is being treated and the choice of how many and which trees to remove. Fuel planners often have a lot of say in which trees to remove depending on the latitude given by policy on what silvicultural prescriptions are acceptable in fire hazard reduction treatments. This is a place where a good understanding of stand-level fire behavior can really help in deciding if an expensive or inexpensive treatment is needed to alter fire behavior in the desired way. Peterson and Johnson (2005) provided a detailed discussion of different categories of treatments and how they influence fire behavior. Their examples can help a planning team in making decisions about what treatments to use. The environmental effects of treatments will also be a point of discussion, and examples and tools can also help a planning team discuss the pros and cons of various treatment options.[5]

Other things being equal, thinning strictly from below will result in the smallest average size of material removed and ordinarily the highest thinning cost. For a given reduction in basal area, thinning from below will also provide the lowest total volume removed per acre and ordinarily the highest cost. Examining alternatives for the removal of small trees provides a good example of how seemingly small changes in treatment design can have big effects on costs. Options for treatment of small trees (<8 inches at breast height) might include among other things:

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[4]The terminology for moving logs to a landing is skidding for a ground-based skidder system, forwarding for a ground-based cut-to-length or harvester-forwarder system, and yarding for a cable or helicopter system. When referring to multiple systems or to no particular system we will use the generic term "moved" to the landing.

[5]A set of tools to evaluate the environmental effects of fire hazard reduction treatments can be found at http://www.fs.fed.us/fire/tech_transfer/synthesis/synthesis_index.

- Not cutting trees below a certain size and using prescribed burning after larger trees and ladder fuels are removed.
- Leaving cut trees at the stump without further treatment.
- Masticating or burning cut trees in the unit.
- Chipping or burning cut trees at a landing.
- Removing all or parts of the cut trees for wood products and then chipping, burning, or leaving the unused parts on the site or at a landing.

It is important to recognize that each step in the process has a cost associated with it and that each decision affects the ecological and aesthetic outcomes of treatments. Breaking the treatment into incremental steps and analyzing their cost with MyFTP can help in identifying the high- and low-cost parts of the various options. Understanding costs is an important part of discussions about the environmental and aesthetic affects of treatments because as more is spent on each treated acre, fewer acres can be treated.

One way to start thinking about this is to look at the cost of thinning and removing all of the cut trees from the stand. The example in figure 1 compares the stump-to-truck cost for removing equal volumes (600 cubic feet) of 6-inch diameter at breast height (d.b.h.) trees and 16-inch d.b.h. trees with whole-tree removal and hand felling. It illustrates the general conclusion that smaller trees are more costly to handle at every step of the thinning operation. The example in figure 2 illustrates that the same general conclusion also holds for whole-tree removal by mechanical felling. Although the total cost is less with mechanical equipment that is designed for handling small trees, smaller trees are still more costly to handle at every step of the operation.

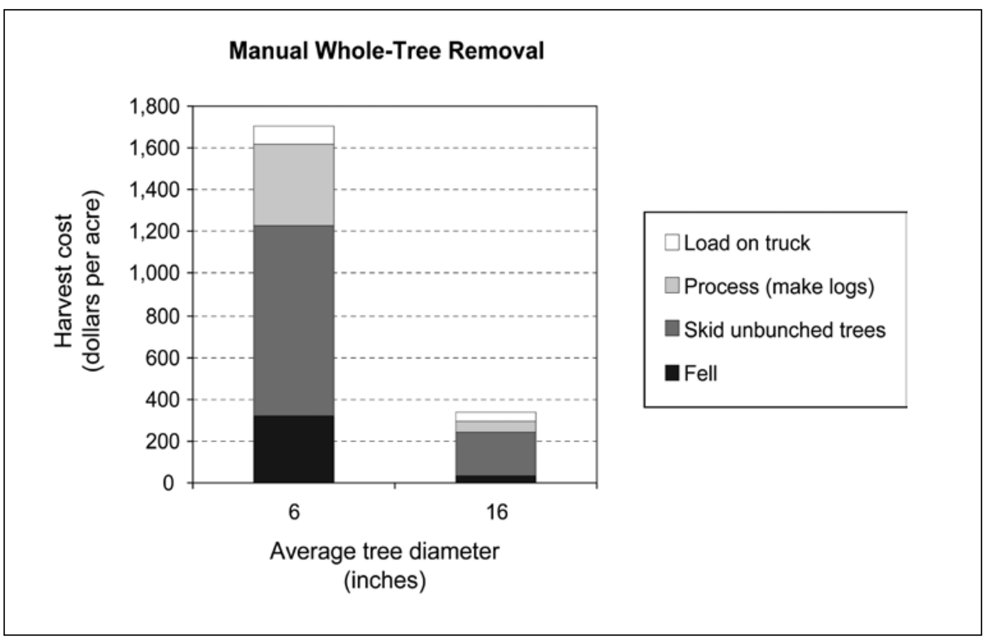

Figure 1—Cost of thinning 600 cubic feet per acre with manual felling and whole-tree skidding. When manual felling is used, the cost of removing smaller trees is higher in every step from the stump to the truck.

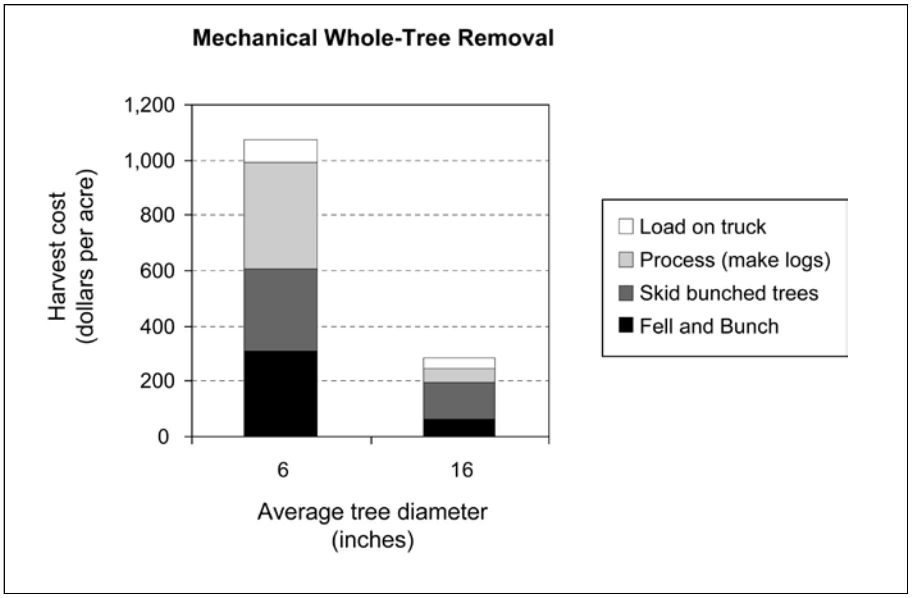

Figure 2—Cost of thinning 600 cubic feet per acre with mechanical felling and whole-tree skidding. Mechanical harvesting of trees reduces total cost, but the cost for smaller trees is still higher at every step from the stump to the truck.

Volume Harvested and Unit Size

The volume of merchantable wood removed and the amount of unmerchantable material that must be treated or removed are important in determining the cost of the treatment. Equipment move-in costs can also be important. Both the choice of stands to treat and the prescription selected to treat them affect the volume of merchantable and unmerchantable material that is removed per acre. When move-in costs are not considered, the effect of volume removed per acre is much less important than tree size (fig. 3). Figure 4 shows the obvious: total volume removed is related to the total area treated and the volume per acre. Move-in costs are spread over the volume that is harvested, so it is obvious that treating larger areas or clusters of areas reduces the cost of moving equipment from one place to another. When both the volume per acre and unit size are small, the move-in cost can be a substantial addition to total harvest cost per hundred cubic feet (fig. 5).

Where move-in costs are nominal, average tree size is much more important than volume harvested per acre. Adding move-in costs in most cases will shift costs up a few dollars per hundred cubic feet and will be visually indistinguishable from figure 3. This conclusion holds for other systems as well.

Terrain

Terrain is a major factor in determining the cost of thinning (Mellgren 1990). In general, stands on steep ground will be more expensive to mechanically thin because more expensive systems are required to operate on steep ground. Unfortunately it is also more difficult to control prescribed fires on steep ground because fuel ahead of the flame is heated more efficiently by radiant energy from the fire Rothermel (1983). In this situation mechanical thinning might be more desirable as an initial step in getting vegetation back under control as long as the treatment results in a higher canopy

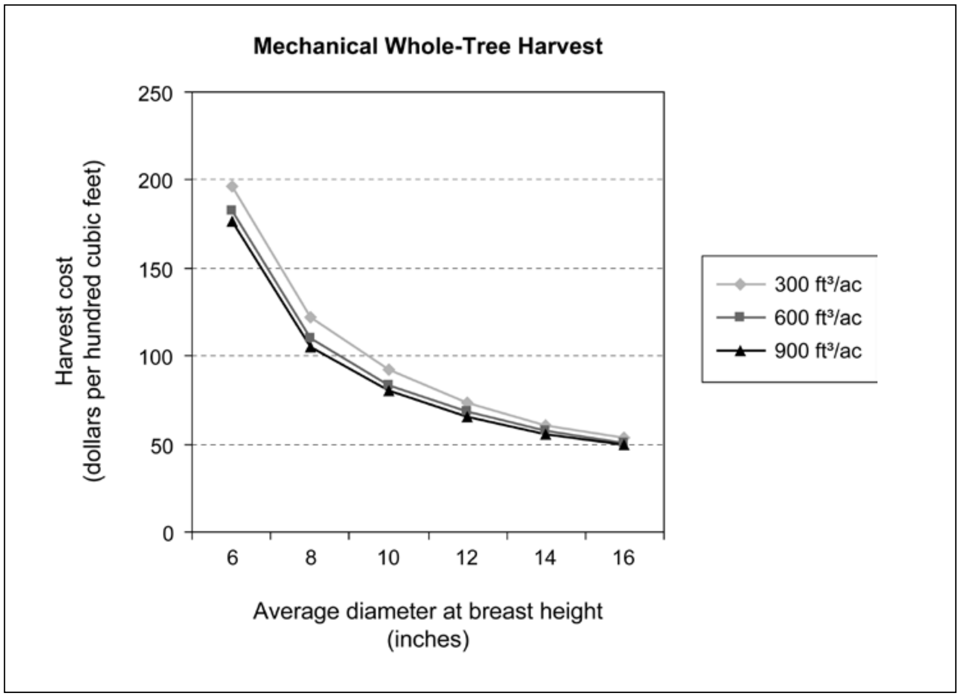

Figure 3—Cost of thinning with mechanical felling and whole-tree skidding with equipment move-in costs excluded. Volume per acre has little effect on harvesting cost when move-in costs are excluded.

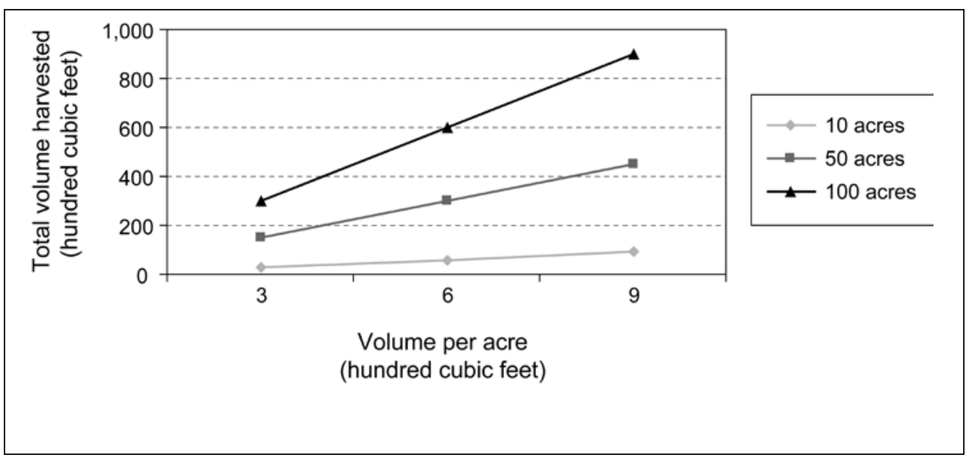

Figure 4—Total harvest volume for a range of volumes per acre and size of unit.

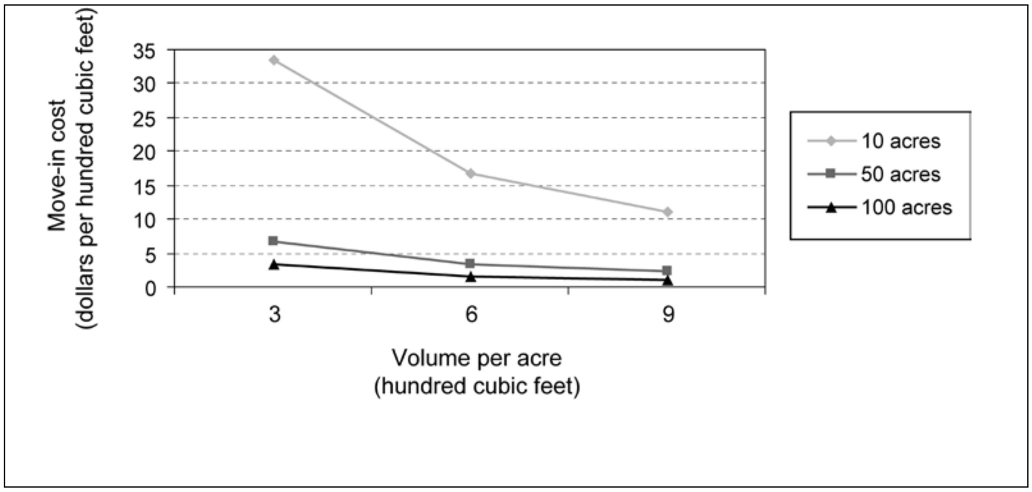

Figure 5—Contribution of move-in cost to total cost per hundred cubic feet for a range of volumes per acre and size of unit when move-in cost is $1,000. The cost of moving equipment to the site can be substantial for small isolated units.

base height and does not add too much surface fuel in the process (Agee 2005). The cost of thinning on steep ground with a cable system is higher than the cost of thinning on flatter ground with a ground-based system even when all of the steps in the process are the same, that is, manual felling, limbing, and bucking (fig. 6). The cost differential becomes even greater when it is possible to use mechanical felling and whole-tree skidding for the ground-based system (fig. 7).

To accomplish the goals of the National Fire Plan, it is important to understand the things that cause fires to become large and threatening. To do so, planners need to think beyond the cost of treating individual stands and think about the strategic placement of treatments on the landscape (Finney 2001). If cost is the only thing taken into account, planning teams will tend to select stands on flat ground and avoid stands on steeper sites, but these could be the least effective places to put treatment units (Finney 2001).

Another important factor related to terrain is the equipment that can be used to accomplish the treatment. In general, ground-based systems are least expensive, followed by cable systems and then helicopter systems. Within each of these three system types, there are equipment choices. Sometimes equipment choices are restricted because of concerns about soil compaction, soil disturbance, residual stand damage, or other resource issues, again, often related to terrain. These restrictions can have significant cost implications. Figure 8 shows costs for four ground-based systems over a range of tree sizes. Understanding how equipment choice is affected by resource conditions and objectives can help fuel planners explain high costs to other resource specialists. Armed with this information, it is easier to discuss the way decisions about how to accomplish a task may influence the overall effectiveness of a fire hazard reduction program. For example, it might be possible to discuss the relative importance of spending a lot of money on protecting some aspect of a particular area as opposed to treating many acres.

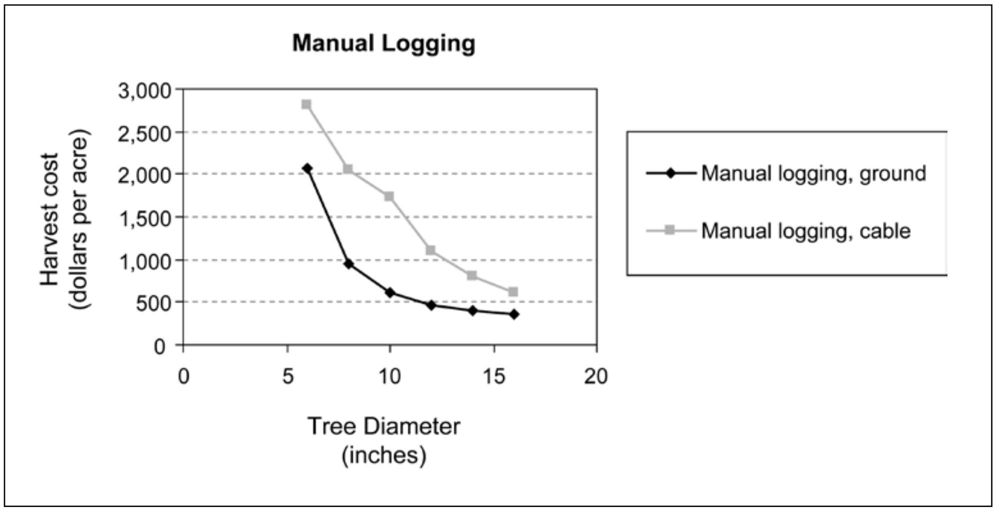

Figure 6—This comparison of the cost of a cable yarding system and a ground-based skidding system both with manual logging illustrates the cost disadvantage of harvesting where cable systems are required.

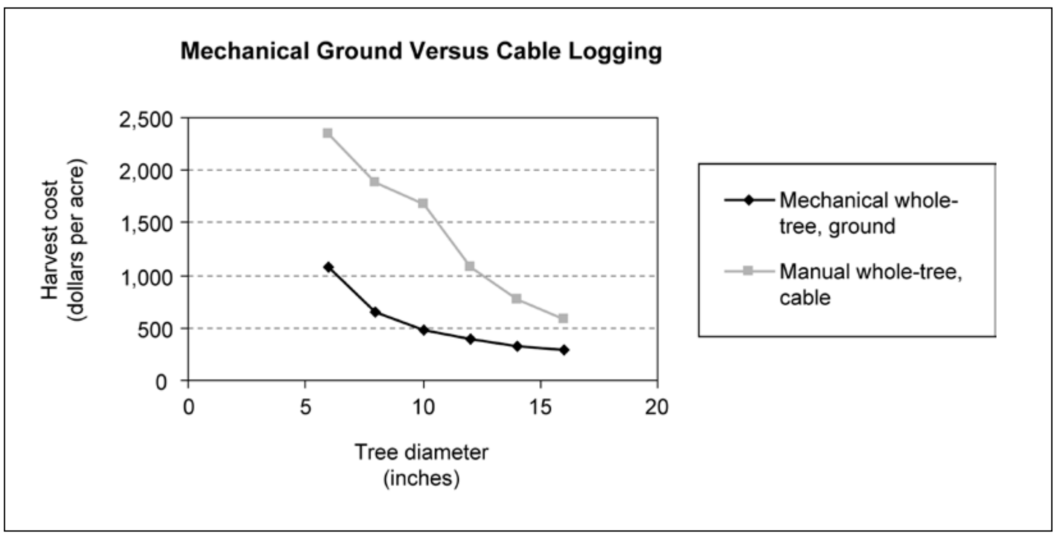

Figure 7—This comparison of harvesting cost for whole-tree logging with cable and ground-based systems illustrates the cost disadvantage of harvesting where cable systems are required. Cost differences are magnified, especially for small-diameter trees, when the ground-based system can use mechanical felling and whole-tree skidding.

Markets and Net Thinning Cost or Revenue

The net revenue from thinning is the revenue from the sale of logs and chips minus the cost of harvesting and hauling, so prices in product markets are important. Higher product prices mean more revenue to offset treatment costs. Three product markets are important for fire hazard reduction treatments: solid-wood products, paper and board products from wood chips (clean chips), and wood used for energy (dirty chips or hog fuel) (Barbour 2004, Barbour and others 2004). Trees less than

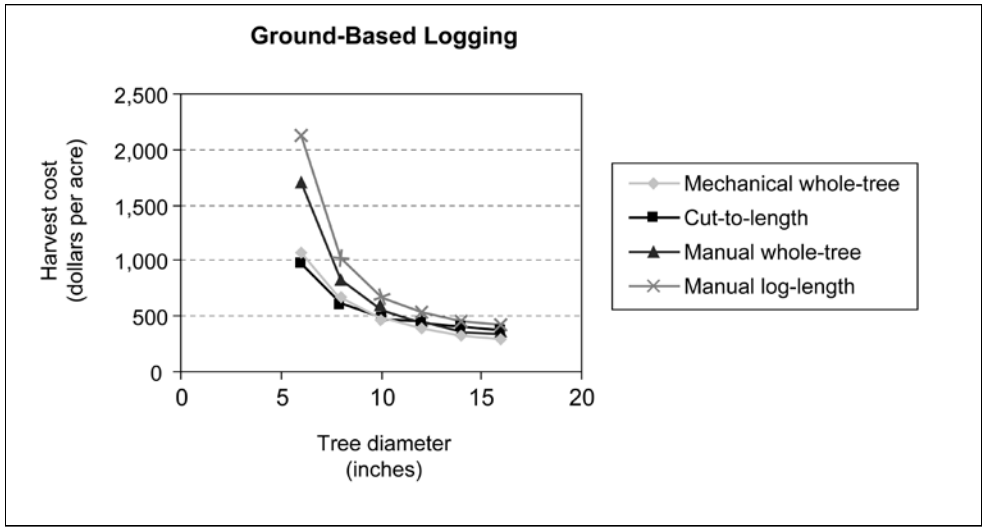

Figure 8—Harvesting costs for 600 cubic feet per acre for different types of ground-based harvesting systems. Notice that the differences are much greater for small-diameter trees than for larger trees.

about 7 inches at breast height are generally only used for pulp chips and hog fuel and by themselves rarely pay their own way out of the woods. Trees between about 7 and 9 inches d.b.h. can produce some solid wood products, but they are considered at or below the merchantable limit in most markets. Where saw-log markets are poorly established, as is the case over much of the interior West, these trees tend to be used for pulp chips or hog fuel. When saw-log markets are stronger, 7- to 9-inch d.b.h. trees tend to be sold for solid wood products. A point that is often confusing for fuel planners is that trees of this size are sometimes an important part of the solid products resource. For example, in places like the boreal forests in Canada where ground is flat and mechanized clearcutting is typically used over fairly large contiguous areas, trees of this size can be an important part of the resource used to manufacture solid wood products. But where partial cutting of small volumes per acre is the norm, as is usually the case with fuel treatments, things are quite different. Figure 9 illustrates the general conclusion that larger trees are worth more per unit volume because of efficiencies in manufacturing and increased product recovery per cubic foot of log. There is, however, a limit to this trend because as more and more wood comes from industrial plantations and less from natural stands, mills are adapting to a much more uniform-sized raw material (Barbour et al. 2002). In practice, this means that in many places logs larger than about 24 inches on the large end receive a lower selling price than smaller logs because there are so few mills that can physically accommodate them.

Many people hope for development of new products from small trees to provide the break that is needed to make them more valuable. We believe this hope is based on a misunderstanding of how markets work. The wood properties of the small trees coming from fire hazard reduction treatments are not very different from the properties of larger trees associated with traditional timber

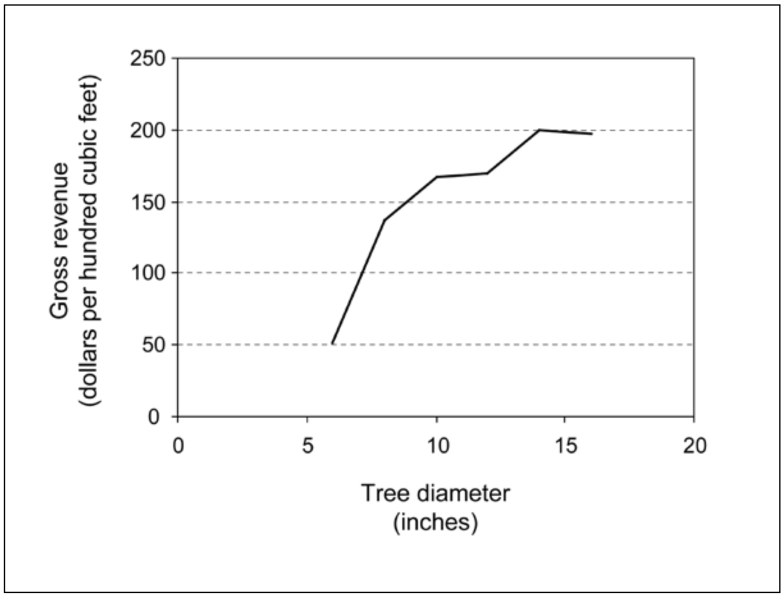

Figure 9—Example of gross revenue from logs calculated for 6- to 16-inch ponderosa pine trees. Pricing in Scribner scale is the primary reason that the curve is not smooth.

harvesting. This means that in most cases, new products from small trees tend to lift the overall demand for wood but not the demand for small trees in particular. Products would be needed where using small trees confers a cost advantage in processing or use, such as use of logs directly as round timber in structures (Wolfe and Murphy 2005) or products where the very fine grain of slow-grown understory trees is important (Green and others 2005). So far, nothing has been developed for which the market would be big enough to substantially change the market price of small trees. The most common reason that small trees are worth less than larger trees is that the cost is higher to handle and process enough small trees to get the same volume of products that you get from handling and processing larger trees.

Unit Location

Location not only determines what set of market prices apply, it also determines the cost of reaching the market. The distance from a treatment unit to a location where wood products are manufactured will have an important effect on the cost of hauling logs to market. The hauling cost module in MyFTP uses a simple model to predict hauling cost. A truck has an assumed haul capacity and a total cost per day for the truck and driver including fuel and other expenses. The cost per unit of volume is then determined by how many round trips the truck can make in a day. Figure 10 shows estimated loads per day as a function of the one-way mileage to the mill. This is a rough approximation that will be affected by the miles that are driven on forest roads and their condition and the miles that are driven on higher speed highways, because the issue is travel time. Local traditions, work rules, and flexibility in the hours worked per day will also have an effect. As the distance increases, the loading and unloading time remains the same, but the travel time increases. The total time increases proportionately less than the increase in distance, so the cost goes up, but at a decreasing rate with distance. Figure 11 illustrates this relationship for a truck and driver cost of $580 per day and a truck capacity of 26 tons per load. The MyFTP software allows the user to change any of these assumptions as appropriate for their area.

Unit Design and Landing Location

The average distance that trees or logs have to be moved to a landing will have an effect on cost. This will be determined primarily by the proximity of a unit to a permanent or temporary road. The size, shape, and orientation of a unit relative to the road will also affect the average distance that logs or trees are moved from the stump to the landing. Figure 12 shows the cost for different average stump-to-landing move distance with all other variables held constant. Because the move component of the operation is a small part of the total cost, a doubling or tripling of the travel distance increases the total cost by only about 10 to 20 percent; the percentage increase for a cut-to-length (CTL) system is even less because most forwarding time (moving logs from the stump to landing with a piece of equipment called a forwarder) is spent accumulating the load rather than forwarding it to the landing. Although the placement and design of units can reduce the stump-to-truck distance and cost of harvesting, treating only along roads, for example, can make it difficult to go back to treat areas behind those units because there will be no low-cost parts to average in with the higher cost of the area that is farther from the road. Unless building roads is an option, there is not much flexibility to reduce the average distance to a landing.

Cost of Other Treatments

Prescribed Fire Treatments

Prescribed fire is often one of the least expensive ways to reduce fuel loads. Some of the cost-influencing variables include activity type, project objective, and site characteristics such as fuel type. This discussion illustrates a method for evaluating the costs of prescribed fire treatments by using

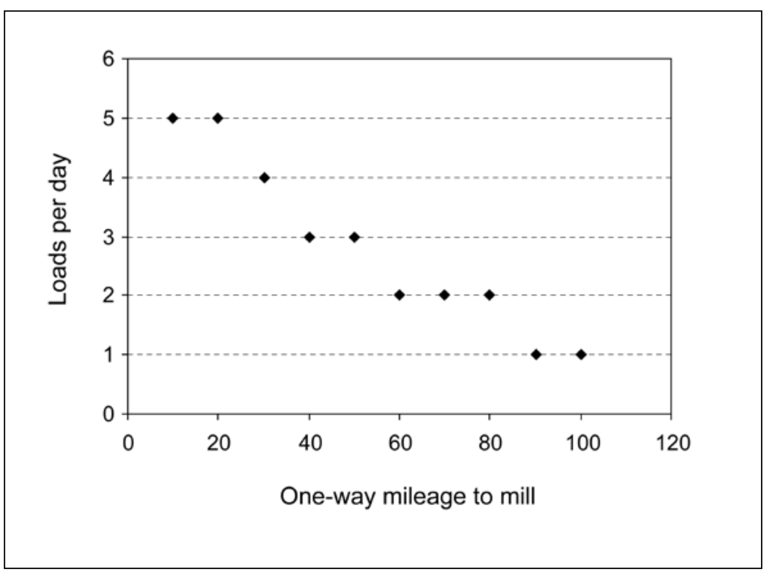

Figure 10—Loads per day for a range of one-way distances estimated by My Fuel Treatment Planner.

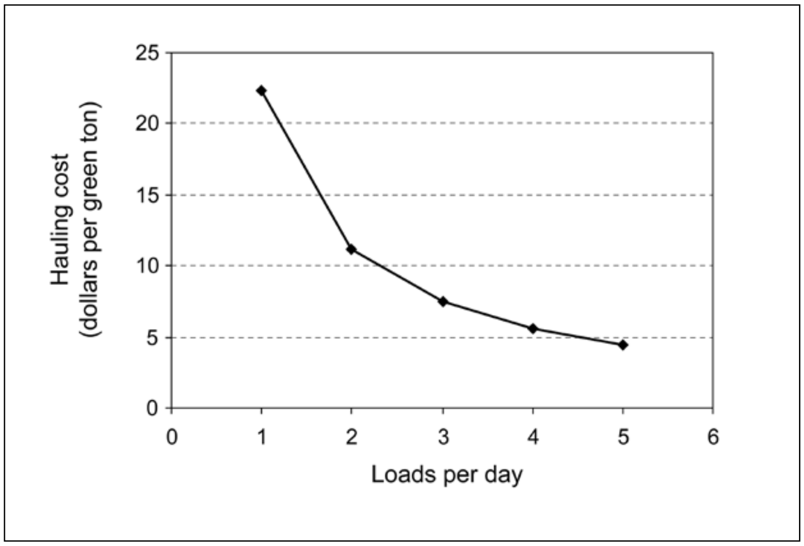

Figure 11—Hauling cost per green ton for a range of loads per day for a truck hauling 26 tons and costing $580 per day.

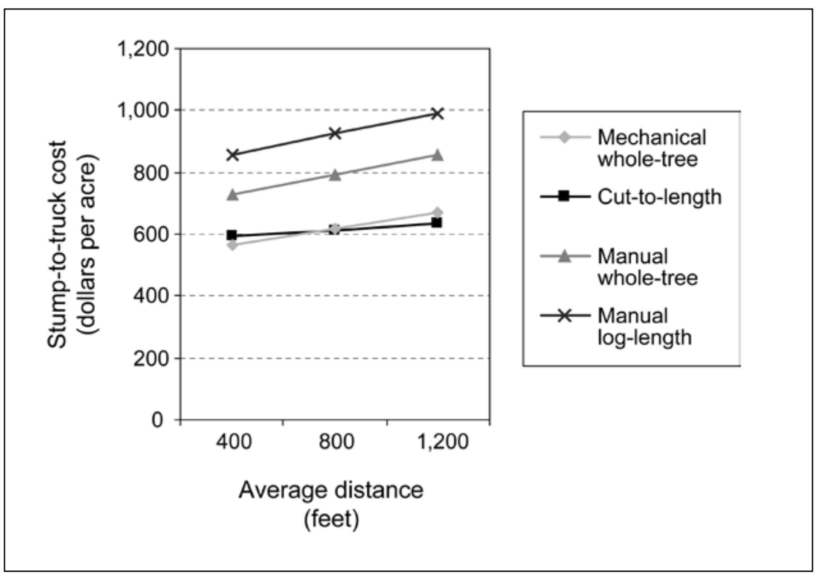

Figure 12—Stump-to-truck cost for ground-based systems harvesting 600 cubic feet per acre of 8-inch ponderosa pine on a 25-percent slope with skidding or forwarding distances of 400 to 1,200 ft.

a model developed by Calkin and Gebert[6] with data from national forests in the Western United States. They present a base case treatment scenario that represents conditions commonly found in the database. The base case is a broadcast burn or underburn of 100 acres in a fuel model 1, 4, 8, 9, or 13 (Anderson 1982) with mechanical or hand ignition, located in Forest Service Regions 1 (Northern), 3 (Southwestern), 4 (Intermountain), or 6 (Pacific Northwest) and with any of the following as the primary objective of the treatment (which affects how the treament is applied): fuel reduction, defensible space, protecting threatened and endangered species, or ecosystem restoration.

The estimated cost of this base case is $105 per acre. We can see the cost of some alternative scenarios by changing variables from the base case scenario one at a time. The effect of changing multiple variables is not additive, so the model must be run to see the effect on cost of changing two or more variables at one time.

One of the most important cost variables is the treatment acreage. The model calculates a 0.38-percent reduction in cost per acre for every 1-percent increase in the treatment acreage. The following tabulation lists variables that cause a treatment to cost more than the base case, and shows the resulting cost increase (provided each item is the only thing that differs from the base case):

Variable	Increase in cost per acre above base case cost of $105 per acre
Fuel model 5	108
Fuel model 10	45
Presence of threatened and endangered species	50
Located in wildland urban interface	37

The following tabulation lists those variables that cause a treatment to cost less than the base case and shows the resulting cost decreases (again, provided that each item is the only thing that differs from the base case):

Variable	Decrease in cost per acre below base case cost of $105 per acre
Fuel model 2	64
Fuel model 6	56
Fuel model 11	40
Fuel model 12	59
Burning hand piles	50
Burning machine piles	80
Using aerial ignition	45
Objective is forest health	28

There are no cost estimates available for fuel models 3 and 7 because no data were included in the sample for those fuel models.

These results come from data collected on a sample of projects on national forests that were reported in the National Fire Plan Operations and Reporting System (NFPORS) database. The data used went beyond what are found in the database and were provided by people with direct knowledge of the project. The cost estimates provided are the result of applying statistical models to the collected data. Substantial variation in cost was observed because of the large geographic scope of the study and the variability of conditions experienced in prescribed fires. The results are only valid for projects that are similar to the ones included in the database. Your good judgment is required in order to get reasonable cost estimates. If you know you are doing a novel treatment not represented in

[6] Calkin, D.; Gebert, K. Modeling fuel treatment costs on Forest Service lands in the Western US. Manuscript in preparation. On file with: dcalkin@fs.fed.us.

the database, do not expect the estimated cost to be reliable.

Mechanical Fuel Treatments

Mechanical treatments to reduce fuel loading are usually more expensive than prescribed fire treatments. This discussion shows how the costs of various mechanical fuel treatments can vary, by using a model developed by Calkin and Gebert (see footnote 6). As with prescribed fire, the effects of changing a treatment are compared to a base case that represents conditions commonly found in the database. Here, the base case consists of hand piling, machine piling, lopping and scattering, or thinning without utilization. It covers a treatment area of 100 acres with a fuel load of 20 tons per acre at an elevation of 4,000 feet, in a fire regime I, II, or V, (Hardy and Bunnell 2005) located in Forest Service Regions 1, 2, 5 (Pacific Southwest), or 6, and with any treatment objective except wildland urban interface protection. The estimated cost of the base case is $150 per acre.

We can see the cost of some alternative scenarios by changing variables from the base case scenario one at a time. The effect of changing multiple variables is not additive, so the model must be run to see the effect of changing two or more variables at one time. One of the most important cost variables is the treatment acreage. The model calculates a 0.33-percent reduction in cost per acre for a 1-percent increase in the treatment acreage. If all other things are equal, an additional ton of fuel increases the cost per acre by 1 percent and an increase in elevation of 1,000 feet reduces the cost per acre by 13 percent. Other variables affect costs differently. The following tabulation lists the variables that cause a treatment to cost more than the base case and shows the resulting cost increase (provided each item is the only thing that differs from the base case):

Variable	Increase in cost per acre above base case cost of $150 per acre
Project located in wildland urban interface (WUI)	112
Located in WUI with WUI protection objective	228

The following tabulation lists the variables that cause a treatment to cost less than the base case, and the resulting cost decrease (again provided that each item is the only thing that differs from the base case):

Variable	Decrease in cost per acre below base case cost of $150 per acre
Fire regime III	67
Fire regime IV	91

These results are from the NFPORS database, and the same caveats discussed about the prescribed fire model apply here. Note that in this analysis, the costs of the four mechanical treatment types (hand piling, machine piling, lopping and scattering, or thinning without utilization) were not statistically different. That does not mean that you might not experience large differences in cost between types of treatments for similar conditions on your area. Lack of statistical significance is a result of the combination of the sample size, the variability of the data owing to the large geographic scope of the project, and the variables that were available to relate to cost. It only means that with this data and model we are unable to predict with confidence what the difference in cost between types of treatments will be. Again, your professional judgment must be used to get reasonable cost estimates for conditions specific to your site and objectives.

Although mastication is a mechanical fuel treatment, data were not available to include it in the mechanical fuel treatment cost module described above. In the MyFTP software, mastication costs are simulated with an engineering cost model that is similar to the harvesting cost model. As with the other mechanical treatments, amount of fuel is an important variable affecting cost per acre. Another important cost variable with mastication is the type of mastication equipment required. Mastication in conditions that require an excavator-mounted masticator (larger material, steeper slopes, and broken terrain) will cost considerably more than mastication in conditions where a wheeled machine can be used.

Net Cost or Return and Treatment Outcome

Tradeoffs Between Treatment Method, Cost, and Outcomes

As fire hazard reduction projects are developed, it is necessary to keep in mind the multiple objectives of land management. The scenarios discussed here illustrate a process for gaining understanding of the relative costs involved in implementing scenarios designed to meet management objectives. In this section, we use MyFTP to look at several typical modifications to hazardous fuel treatments that are often proposed to reduce costs, increase revenues, or address resource concerns not directly associated with fire hazard reduction.

The three panels of figure 13 illustrate the use of MyFTP to compare different ways to remove small trees (3 to 5 inches d.b.h.) from a stand. Panel A shows the costs, revenues, and outcomes associated with chipping the 3- to 5-inch trees. Panel B shows the results for piling and burning these trees, and panel C shows the results for masticating them. In all cases, trees greater than 5 inches are made into logs.

In the first two cases (fig. 13a and b), the small trees are removed from the stand, and this is reflected in the lower amount of surface fuel remaining at the end of the treatment as compared to the third case (fig. 13c). In situations like this, planning teams must use judgment to decide whether it is better to select the cheapest treatment (pile and burn) or whether some potentially negative aspect of this treatment, such as smoke or the risk of escaped fire, would justify one of the higher cost options. For example, in much of the interior West, soils are relatively low in organic matter, and mastication could provide a viable alternative that improves soil by leaving more nutrients on the site (Ferguson 2005). If nutrients are not an issue but smoke or escaped fire risk are, or if there is potential for soil damage from soil heating if the masticated fuels are burned, then chipping and removing the small trees may provide the best alternative. In any event, this type of analysis provides a planning team with some objective measures to use when considering the outcomes of a treatment along with its cost.

When Other Things Are Not Equal

As we stated at the beginning of the paper, financial analysis is well suited to determine the least-cost way to accomplish objectives where the costs and benefits that cannot be reduced to dollar terms are comparable or unimportant. Unfortunately, the conditions resulting from different treatments are often not comparable. Financial analysis can be used along with subjective judgments about the importance of benefits that cannot be reduced to dollar estimates to reach

a

Chip 3 - 5 inch trees				
	$ / Acre			**Dry Tons / Acre**
Gross Revenue	$1,325		**Cut Trees (Biomass)**	**22.9**
Harvest Costs	$1,063		Logs Removed	11.5
Hauling Costs	$361		Chipped Trees	6.9
Mastication Costs	$0	☐ Check to include	Residue Collected	2.3
Mechanical Treatment Costs	$0	☐ Check to include	**Remaining Activity Fuels**	**2.1**
Prescribed Burn Costs	$0	☐ Check to include	**Pretreatment Surface Fuels**	**15.0**
Other Costs (user specified)	$0		Masticated Fuels	0.0
Net revenue per acre	**-$99**		Fuels Burned	0.0
	CCF / Acre			
Volume of Logs	8.4		**Remaining Surface Fuels**	**17.1**

b

Pile and burn 3 - 5 inch trees				
	$ / Acre			**Dry Tons / Acre**
Gross Revenue	$1,186		**Cut Trees (Biomass)**	**22.9**
Harvest Costs	$597		Logs Removed	11.5
Hauling Costs	$201		Chipped Trees	0.0
Mastication Costs	$0	☐ Check to include	Residue Collected	0.0
Mechanical Treatment Costs	$368	☑ Check to include	**Remaining Activity Fuels**	**11.4**
Prescribed Burn Costs	$21	☑ Check to include	**Pretreatment Surface Fuels**	**15.0**
Other Costs (user specified)	$0		Masticated Fuels	0.0
Net revenue per acre	**$0**		Fuels Burned	11.4
	CCF / Acre		**Surface Fuels Remaining**	
Volume of Logs	8.4		**After Prescribed Fire**	**15.0**

c

Masticate 3 - 5 inch trees				
	$ / Acre			**Dry Tons / Acre**
Gross Revenue	$1,186		**Cut Trees (Biomass)**	**22.9**
Harvest Costs	$597		Logs Removed	11.5
Hauling Costs	$201		Chipped Trees	0.0
Mastication Costs	$506	☑ Check to include	Residue Collected	0.0
Mechanical Treatment Costs	$0	☐ Check to include	**Remaining Activity Fuels**	**11.4**
Prescribed Burn Costs	$0	☐ Check to include	**Pretreatment Surface Fuels**	**15.0**
Other Costs (user specified)	$0		Masticated Fuels	11.4
Net revenue per acre	**-$118**		Fuels Burned	0.0
	CCF / Acre		**Surface Fuels Remaining**	
Volume of Logs	8.4		**Including Masticated Fuels**	**26.4**

Figure 13—Output from My Fuel Treatment Planner software illustrating the financial and fuel results for three treatment options: (a) chipping the small trees at the landing, (b) piling and burning the small trees, and (c) masticating the small trees.

decisions about such tradeoffs. Making those comparisons is not easy.

The choice of prescribed fire or mechanical treatment can have a large effect on at least the initial treatment cost. Prescribed fire generally costs less per acre, especially when large areas can be treated as a unit. Average costs may be deceiving, however, because the acres that have been burned and the acres that have been mechanically treated usually had very different vegetation. Furthermore, in most cases, both prescribed fire and mechanical treatment will require a series of followup treatments in the decades ahead.

Mechanical treatment is often used in places where the amount of fuel or other conditions make it risky to use prescribed fire. In those cases where either method might be safely employed, other resource management objectives will often dictate which treatment method is more appropriate. Choosing the more expensive option will have implications for meeting broader management objectives for fire hazard reduction programs. A logical next step in this analysis would be to look at the relative posttreatment fire hazard associated with each scenario. This analysis would make it possible to compare the ease of following the thinning with a prescribed fire to reduce the surface fuels generated by the thinning. Combining such an analysis with information on the treatment effects on other resources such as understory plants (Sutherland and Miller 2005), wildlife habitat (Pilliod 2005), effects of erosion (Elliot and Robichaud 2005), or spread of Armillaria root disease (McDonald and others 2005), would provide a fairly complete picture of what each scenario would cost and how it will influence many of the things people care about in forested landscapes.

Economic Impacts of Fire Hazard Reduction Treatments

Fire hazard reduction treatments and other activities carried out on national forests expand, at least temporarily, the economic activity in the area surrounding the treatment area as contractors buy supplies and equipment and pay wages for workers needed to conduct the activity. When estimates of these economic impacts are needed, the information developed in a financial analysis is the starting point. The most commonly used source of economic impact information for USDA Forest Service projects is the IMPLAN model (Alward and others 2003). A customized version of the IMPLAN model has been incorporated in MyFTP so that economic impacts are estimated for each scenario with very little additional work. Contract costs, agency costs, and forest products that are produced are used to estimate the employment and income that will be generated in the economic area in question.

Conclusion

Although financial analysis is limited in its ability to deal with tradeoffs between costs and benefits of large fuel treatment programs over the long term, it is the appropriate tool to address many issues once a decision to implement a program of fuel treatment has been made. Financial analysis can be used to explore the cost of doing treatments under different conditions and different treatment designs. This information is useful in budget development and in the allocation of funds once given a budget. Financial analysis can help determine whether the most appropriate arrangement to accomplish projects in different circumstances is a standard contract (all cost and no revenue), a timber sale (substantial net revenue), or a stewardship contract (a combination of units, some with positive and some with negative net revenue). Where environmental documents require an estimate of the economic impacts of a project, financial analysis provides the information needed to make that estimate. This paper uses the MyFTP software to illustrate the results of financial analysis of fuel treatments and to highlight the factors that have a big effect on fuel treatment costs.

Metric Equivalents

When you know:	Multiply by:	To find:
Inches (in)	2.54	Centimeters
Acres (ac)	.405	Hectares
Feet (ft)	.3048	Meters
Cubic feet (ft^3)	.0283	Cubic meters
Tons per acre	2.24	Tonnes per hectare

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