Hastening the Return of Complex Forests Following Fire

The Consequences of Delay

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ABSTRACT

Over 54 days in 2002, the Biscuit Fire, the largest fire in recorded Oregon history, burned more than 400,000 acres. Much of the burned land was being managed under the federal Northwest Forest Plan to provide habitat for species that live in complex, older conifer-dominated forests as well as for recreation purposes. Only a narrow window of opportunity exists to hasten conifer restoration to complex forest conditions in a cost-effective manner, to reduce risks of insect epidemics and future fires, and to capture some economic value that could offset restoration costs. Delays in decisionmaking and implementation will likely destine much of the most intensely burned area to cycles of shrubs, hardwoods, and recurring fires for many decades. This is the opposite of what current management plans call for—maintenance of mature forests.

Keywords: biodiversity; forest health; Northwest Forest Plan; old-growth; policy; restoration

The Biscuit Fire began July 13, 2002. During the next 54 days, it burned approximately 400,000 acres on the Siskiyou National Forest *(fig. 1)*. The Biscuit Fire was the nation's most expensive fire suppression effort of 2002, reportedly costing $154 million in federal and state funds. Burned were congressionally reserved lands (152,900 acres mostly within the Kalmiopsis Wilderness Area), administratively withdrawn lands (64,100 acres), and under the Northwest Forest Plan, late-successional reserves (133,700 acres) and matrix lands (33,000 acres).

The Biscuit Fire poses a policy question regarding areas designated to function as mature and old-growth forests. After intense fires, are managers to let vegetation develop naturally, or are they to invest in regeneration of forests to achieve the intended late successional status quickly? The Northwest Forest Plan and the spotted owl final draft recovery plan indicate that management interventions are encouraged if natural vegetative recovery will not produce desired habitat conditions (USDI 1992; USDA/USDI 1994; Thomas 2003).

To understand the opportunities to

Above: **In July 2002, the Biscuit Fire burned through the 1987 Silver Burn. Note the snags igniting ahead of the fire front.**

Photo by Tom Link, Siskiyou National Forest hasten regrowth of structurally complex conifer-dominated forests, we examine prefire forest conditions, what exists now in the aftermath of the fire, and the likely consequences and tradeoffs of natural ecosystem recovery versus management interventions. This examination of forest policy was prompted by Douglas County commissioners who asked Oregon State University to examine costs of management delay following the large fires in southwest Oregon during 2002.

Landscape Condition

The area of the Biscuit Fire is a geologic patchwork, characterized by rough terrain, deeply incised valleys, and geologic strata that vary in resistance to erosion. Soils in the burned area can be loosely grouped into two categories, those derived from serpentine base rock and those that are not. The serpentine-derived soils are the most erosion prone. They are high in magnesium and low in calcium, and their water-holding capacity is low. Vegetation on these soils is sparse, and they are low productivity for conifer forests. About 25 percent of the soils in the Biscuit Fire perimeter are serpentine-derived. The remainder are derived primarily from sandstones and schists; their productivity for conifer forests is low to medium.

Within the Biscuit Fire, mature forests (>100 years) comprised Douglas-fir *(Pseudotsuga menziesii),* white fir *(Abies concolor),* tanoak *(Lithocarpus densiflorus),* Jeffrey pine *(Pinus jeffreyi),* and Port-Orford-cedar *(Chamaecyparis lawsoniana),* with scattered western white pine *(Pinus monticola),* sugar pine *(Pinus lambertiana),* ponderosa pine *(Pinus ponderosa),* madrone *(Arbutus menziesii),* and other species. Few stands reached great ages (>300 years) because of frequent fires, and most of the older stands were on north slopes, which do not burn readily. The prefire timber volume within the fire perimeter was estimated to have been about 10 billion board feet, Scribner scale.

One-third of the burned area may return to the desired forest conditions with minimal human intervention because it retains seed sources and elements of structural complexity. But on about 345,000 acres, according to the USDA Forest Service (2003), there now are more dead than live conifer trees *(fig. 2, p. 40).* At least 25 percent of the canopy was killed on more than two-thirds of the fire area.

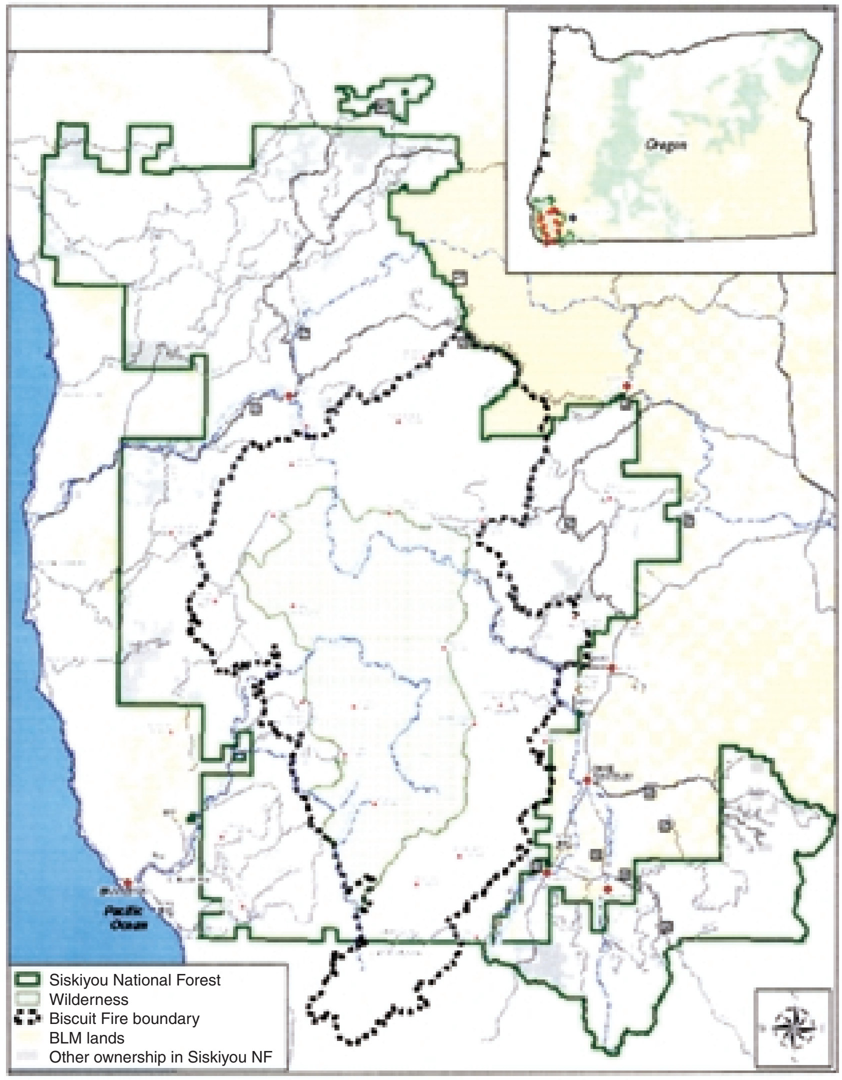

Figure 1. **The 2002 Biscuit Fire, encompassing 500,000 acres, affected critical habitat for the northern spotted owl, as well as other species . *Source:* USDA Forest Service (2003).**

The affected area includes about 20 percent of the entire natural range of Port-Orford-cedar and is also an important area for sugar pine and western white pine (Don Goheen, pers. commun., July 2, 2003). If naturally seeded, these five-needle pines have little resistance to an exotic blister rust, and naturally seeded Port-Orford-cedars have almost no resistance to Port-Orford-cedar root disease, another exotic. These species can be successfully established on sites within the Biscuit Fire area only if disease-resistant seedlings from improved stock are planted.

Of the 300 wildlife species that meet at least part of their yearly needs on the Rogue River–Siskiyou National Forests, three are listed as threatened or endangered: the bald eagle, the marbled murrelet, and the northern spotted owl. Habitat for the owl is the most significant consideration, as about 25 percent of the 202 known spotted owl activity centers on the Siskiyou are within the fire area. The fire transformed 23 of the 40 “functional home ranges” to “nonfunctional” habitat and made 75,000 to 80,000 acres of nesting habitat unsuitable (USDA Forest Service 2003). In addition, some 460 miles of streams

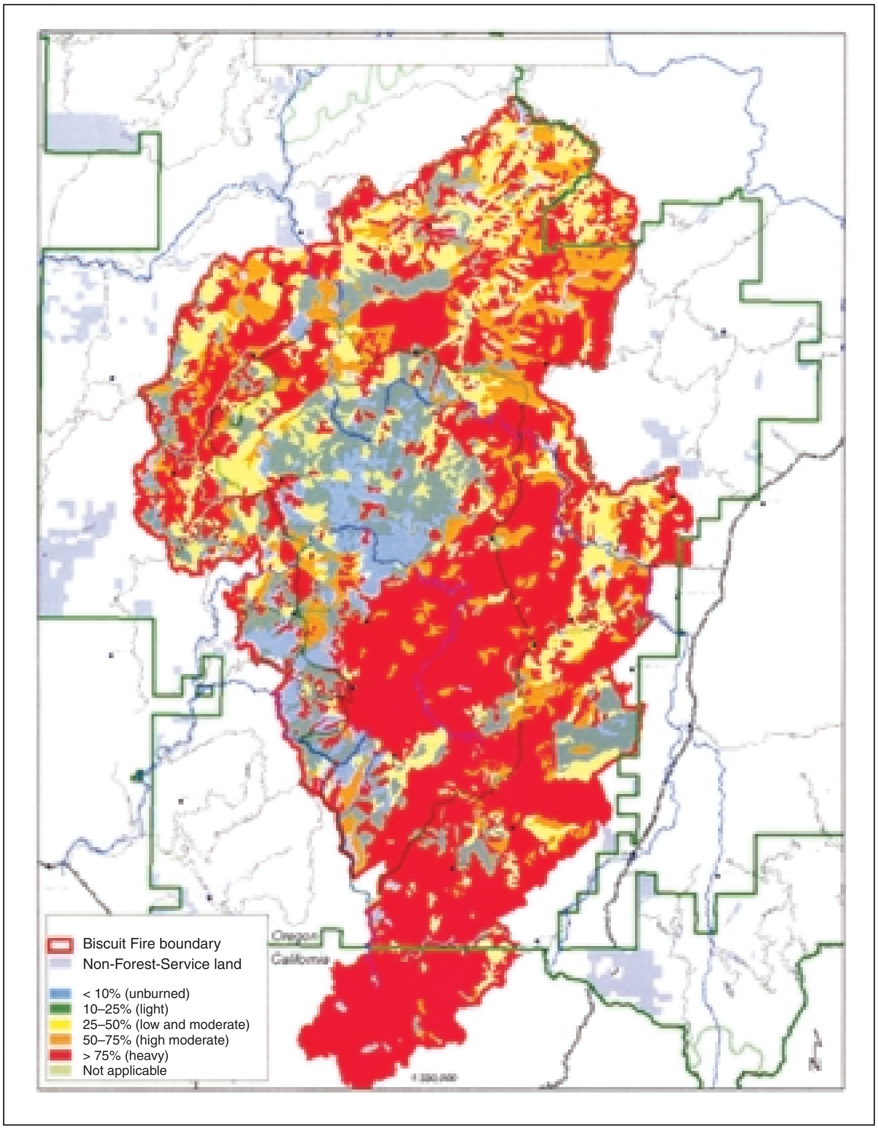

Figure 2. **Canopy mortality within the Biscuit Fire perimeter.** ***Source:*** **USDA Forest Service (2003).**

and rivers within the Biscuit Fire area contain both resident and anadromous salmonids, the most sensitive being the federally listed coho salmon.

The choices facing forest managers and society can be summarized:

• Supplement natural ecological processes with investments to regenerate conifer species, at stocking rates and with supplemental management actions that hasten return to complex forest structure, *or* let nature take its course.

• Salvage some fire-killed timber (outside the wilderness area) to help achieve desired future conditions in species composition, diversity, and resilience or resistance to fires, storms, insects, or weeds, *or* leave all dead and dying trees.

• Pay for necessary investments by salvaging some commercially valuable wood from the area, *and/or* seek appropriations from Congress.

• Use herbicides to regenerate the largest number of acres with the greatest probability of achieving complex forest structures, *or* attempt mechanical control of vegetation competing with conifers, *or* do not attempt to control competing vegetation.

Methods

We developed databases to help us evaluate the economic, ecological, and social effects of regeneration, stand maintenance, insect infestation risk, heavy fuels, and salvage operations related to potential management actions.

For prefire stand attributes, timber volumes, and accessibility, we obtained tree and plot data from the USDA Forest Service current vegetation survey. Within the study area, 210 randomly selected plots were used to describe vegetation types. A circular training area of 2 hectares was created around each plot location. Landsat 5 Thematic Mapper images from 1995 were classified by using the sequential maximum a posteriori estimation (Schowengerdt 1997) with the GRASS software package (US Army 1993). The classified image, showing areas of similar vegetation characteristics, was then imported into Arc/Info for further processing.

Polygons were created from the classified grid and intersected with other polygon databases for the Siskiyou National Forest, including land-use allocation and soils GIS layers. Areas within two miles of a road were delineated for potential timber salvage and regeneration cost analysis.

The postfire vegetation was derived by overlaying a GIS layer of canopy mortality developed by the Siskiyou forest using aerial photography interpretation (USDA Forest Service 2003).

Four site index values were assigned for nonserpentine-derived soils based on aspect. The wetter, west side was projected at higher site index values. High and low ranges were used to simulate competing shrub conditions based on height and diameter growth results from regeneration experiments (Newton and Cole 2004). King's site index values were used for projecting the basic 210 vegetation types.

We identified trees that were most likely killed by the fire and decayed them over time, using relationships from Lowell et al. (1992) to determine the amount of sound wood available for salvage within five years.

Additional mortality from stressed trees believed to have high insect infestation risk was also estimated using the results of a postfire survey (USDA Forest Service 2003). Risk to stressed trees was assumed to be concentrated in the low-moderate to high-moderate burned areas. These trees were not removed from the tree lists for growth projections.

The basic 210 vegetation types were then expanded to account for the five levels of canopy mortality that determined the amount of direct fire-induced mortality and expanded again by the four site index values, resulting in 4,200 stand types. The vegetation types were projected for 100 years with the ORGANON Dynamic Linked Library growth-and-yield model (Hann et al. 1997).

To estimate the decay of standing fire-killed trees and their contribution to down wood over time, we used a snag-and-down-wood decay model (Mellen and Ager 1998).

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Grasses sprouting from hay bales dropped by helicopter to prevent soil erosion will compete with regenerating conifers in the late-successional reserve outside Onion Camp.

Regeneration. Historically in southwestern Oregon, large burned areas regenerate naturally from seed. Where seed is readily available and site conditions are conducive, natural stands of Douglas-fir begin with more than 1,000 seedlings per acre (Hermann and Lavender 1990). However, Douglas-fir seed crops occur at irregular intervals. On drier sites, restocking can take decades, sometimes a century or more. Wetter areas can develop more rapidly, but shrub and hardwood competition can be severe.

To estimate regeneration costs, we assume that the goal is to establish 200 young conifer trees "free to grow" on each acre of future complex conifer forest. This is considerably below stocking levels on private industrial forests (300 to 400+ seedlings per acre). Species composition would reflect aspect and elevation. We assume natural seeding will occur on nonserpentine-derived soils that have not lost a large part of their canopy. We also assume natural seeding as the regeneration method on the very low productivity serpentine soils.

The biggest problem facing conifer regeneration in the region is competing vegetation. With limited soil moisture, competition from woody and herbaceous vegetation greatly reduces the survival and growth of conifers. Hughes et al. (1990), for example, indicate that shrub stands reach high competitive vigor earlier than conifer stands and that shrub species can rapidly occupy a site. Climate change may also be a factor (e.g., Cromack et al. 2000). Current and likely future climates may be more favorable to root-sprouting shrubs than when the burned conifer forests originated (Tom Atzet, pers. commun.).

Aerial seeding can quickly achieve reforestation of large roadless areas but is not currently an option for the Biscuit Fire area because of lack of approved bird and rodent repellents. Seeding and planting are most effective if done immediately (Zavitkovski et al. 1969, Tappeiner et al. 1992). Even the best nursery-grown stock is affected by competition during the first few years after planting; initially high levels of herbaceous and shrub cover can increase seedling mortality and reduce growth (e.g., Harrington and Tappeiner 1997).

Tools to reduce shrub competition on tens of thousands of acres are limited. Prescribed fire cannot be used when shrubs are too small to provide adequate fuel. Personnel and budgets are generally inadequate to provide effective manual or mechanical control, and success of these techniques is at best limited. For each 10,000 acres, manual treatment would require 300 to 500 person-years, is difficult work, and is hazardous (e.g., Stavins et al. 1981).

Using results from the Forestry Intensified Research (FIR) Program (a collaboration between Oregon State University and the Forest Service Pacific Northwest Research Station), Newton and Lavender (unpublished) have esti-

Table 1. Estimated regeneration cost (dollars per acre) to successfully establish 200 conifer trees per acre considering initial cost, probability of success, and cost of restocking failures.

	North slope				South slope			
Regeneration method	2004	2005	2006	2007	2004	2005	2006	2007
Plant plugs	**$ 250**	**$ 286**	$ 667	$ 1,000	$ 333	$ 400	$ 1,000	$ 2,000
Plant plugs + 1	259	293	**367**	733	**314**	**367**	550	2,200
Plant plugs + chemical prep	335	335	357	383	383	383	447	536
Plant plugs + 1 + chemical prep	320	339	360	**360**	360	384	**443**	**443**
Plant plugs + 1 + chemical prep + chemical release	372	394	394	394	419	479	479	479

NOTES: Values displayed in bold show the most cost-effective method for year of establishment. Cost-effectiveness considers only tree survival, not the costs of later controlling shrub competition.

mated the initial cost of regeneration options, the declining probability of success related to time, and the differences of success on north- versus south-facing slopes. Federal costs are likely to be higher than those on private forests, but the relationships between methods and delay of regeneration should remain valid. Rogue River–Siskiyou National Forest managers (USDA Forest Service 2003) estimate reforestation costs at $1,000 per acre, without use of herbicides. We estimate that aggressive use of the most promising techniques, including planting only 200 trees per acre, could reduce these costs by up to two-thirds. *Table 1* considers cost per acre to reestablish conifer forests by year of planting, including probability of failure and cost of restocking to achieve success by slope orientation. Cost-effectiveness depends on year of planting—that is, on delay in establishment.


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A young plantation on private land (background, left) received vegetation management using herbicides; the federal land near Gold Hill, Oregon, established following the 1994 Hull Mountain Fire has had mechanical release.

Three things stand out from an examination of regeneration costs: The most cost-efficient method of establishing conifers is immediate regeneration; planting delays beyond 2005 can substantially increase costs if weed control is not adequate; and when delays are unavoidable, herbicides for site preparation and release will dramatically reduce costs.

Stand maintenance. Once a site is reforested, seedlings benefit tremendously from several years of vegetation management, as illustrated by the reforestation experiments by Newton and Cole (2004). Even when planting was completed immediately after a fire, failure to control shrubs in the first two years afterward reduced tree growth by 75 percent, substantially delaying attainment of tree sizes desired for late-successional wildlife habitat. These differences increase even more if hardwoods have one or more years to develop before planting.

Atzet et al. (1992) describes a short-term growth reduction of up to 45 percent from failure to control competition. Longer-term experiments from the FIR program showed that when shrubs were completely removed, the growth rate of conifers saw a four-fold increase over 23 years. If wildlife associated with late-successional forests need big trees for habitat, such findings have important implications.

Insect infestation. Trees weakened by fire lose their ability to repel and survive insect attacks. Bark beetles often kill many trees that might otherwise survive, and the resulting snags and fine fuels create high rates of fire spread. Insect buildups can threaten live trees in adjacent unburned forests, leading to even higher fuel loadings. The largest numbers of fire-stressed trees are likely to be infested in the year after a fire.

To estimate the additional mortality from fire-stressed trees, we used the results of a postfire survey (USDA Forest Service 2003) that provided probability of infestation by species and tree diameter. Risk to stressed trees was assumed to be concentrated in the low-moderate to high-moderate burned areas. Trees in unburned and lightly burned areas were assumed not to be fire-stressed.

Fuel loads. To estimate the number of snags per acre and down wood from dead trees, we combined the Forest Service photo-interpreted canopy mortality estimates with our vegetation overlay. The number of trees by diameter class and species that were killed by the Biscuit Fire was then entered into the Mellen and Ager (1998) snag decay model and their conditions projected over time. We added to the fire-killed trees those still-living trees that would be expected to die naturally over the next 100 years.

Salvage opportunities. Ground-based methods of tree harvest (rubber-tired and tracked skidders) are normally used where slopes are accessible and less than 30 percent, and cable systems (skylines) are used for steeper slopes. Ground-based systems are not limited in the distance they can operate from roads, but costs increase with distance. Cable systems are limited to about one-half mile or less. At longer distances on steep terrain, helicopters must be used or additional roads must be constructed. The economically feasible transport distance is limited by the value of the timber. If trees of mixed sizes and values are extracted, the maximum economic distance for helicopters is about two miles. If only the most valuable logs are removed, the maximum economic distance increases. Helicopter logging, although expensive, permits immediate salvage without additional roads and with little soil disturbance. Helicopter logging capacity in Oregon is sufficient to deliver more than 2 million board feet per day.

Improperly done, however, timber salvage can contribute to increased surface runoff and soil erosion (see McIver and Starr 2001). Poorly located and improperly constructed roads, improper choice of harvesting systems, and inadequate road maintenance can contribute to erosion. Yet mineral soil is the ideal seedbed for establishing most conifers. If adequately planned and controlled, logging disturbance can produce excellent results and may be the best method of site preparation in shelterwood, selection, and partial-cut silvicultural systems where use of fire or chemicals is limited (Cleary et al. 1978).

On slopes less than 30 percent, skid

trails could be limited to about 10 percent of the area and treated after use to control runoff and erosion. Preliminary results from an eastern Oregon study of carefully planned salvage-logging operations with ground-based machines are encouraging (USDA Forest Service 2002). Although some soil disturbance was observed after the operations, little or no sediment left the harvest units, and the reburn hazard was estimated to be either reduced or unchanged. Any increased sediment yield would be temporary and dwarfed by increases due to the recent fire and by natural geologic erosion in the Biscuit area.

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Much of the burned area looks as this did in April 2003.

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Road access exists in much of the matrix and some of the administratively withdrawn and late-successional reserves, making possible management action to regenerate the damaged areas.

Markets for salvaged timber depend on quality, quantity, and price. Processing capability in southern Oregon is approximately 2.75 billion board feet per year (Paul Ehinger, pers. commun., 2003). Additional processing centers exist in northern California. The actual effect of Biscuit salvage harvests on regional employment would depend on whether fire-killed timber is additive or substituted for green timber from other forestlands. In the current forest products market, substitution would probably be more likely.

Results

With human assistance, we estimate that large conifer trees (>18 inches diameter)—those that provide much of the character of a complex mature forest and most of the habitat for old-growth-dependent wildlife—will take 50 years or more to develop and supplement the surviving larger trees and up to 100 years to approach prefire conditions. Without planting and subsequent shrub control, however, it could take more than 100 years to even establish conifer forests. This is well beyond the guidelines in the draft recovery plan for the northern spotted owl (USDI 1992) to provide future large green conifers and future large snags.

Wilderness areas and areas with serpentine soils aside, if the remaining areas with 25 percent or more canopy mortality were considered for reforestation, more than 137,000 acres would be candidates for reforestation. Prompt and successful regeneration on these areas could produce nesting habitat for spotted owls within 80 years.

On average, the fire killed more than 160 trees per acre. These trees will fall over time, and while providing habitat for many species and slowly returning organic matter to soils, the debris could also fuel the intensity of future fires . Significant portions of dead and dying trees in a largely shrub and hardwood plant community will leave the landscape susceptible to large, intense wildfires for at least 60 years into the future, further jeopardizing the potential of remaining conifers and newly planted conifers to reach late-successional conditions.

We estimate that the Biscuit Fire destroyed approximately 4.2 billion board feet (conifer and hardwood), or 40 percent of the prefire tree volume within the fire perimeter, and that the average standing live tree volume in the area (excluding low-productivity serpentine soils) has declined from 26,000 to 14,000 board feet per acre. We believe that fire-stressed conifers containing an additional 0.8 billion board feet are at high risk of insect attack in the near future. Ongoing Forest Service studies will refine these estimates.

The recovery value of fire-killed timber will decrease as trees deteriorate from checking, fungal decay, and woodborer activity. Based on data in Lowell et al. (1992), we estimate that approximately 22 percent of the fire-killed volume that existed immediately after the fire was lost during the first year, and by the fifth year, only volume in the lower logs of the larger trees will have economic value. The economic loss due to timber deterioration is already in the tens of millions of dollars.

Access to fire-killed trees across the burn varies. In total, approximately 75 percent of the fire-killed timber in the nonwilderness fire area is within two miles of existing roads. Almost all the fire-killed timber volume within the matrix lands is accessible, as are about 60 percent of the volume in administratively withdrawn areas and 80 percent in the late-successional reserves.

Depending on the scope and timing of a salvage program, we estimate that, at a stumpage value (mill value minus logging costs) of $100 per thousand

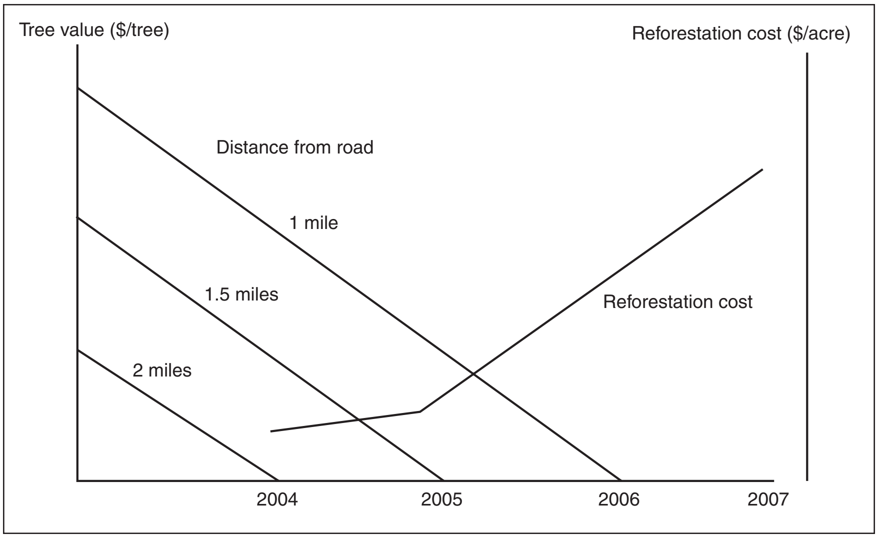

Figure 3. **Average salvage value of fire-killed trees as a function of distance from road and year, using helicopter logging, and cost of reforestation.**

board feet of salvage, 1 billion board feet of salvage by helicopter would recover $100 million of stumpage value. Salvage by ground-based and cable systems would return higher stumpage values, but helicopters would minimize disturbance to soils. One billion board feet of salvage would remove approximately 50 percent of the total volume of fire-killed trees from accessible areas, or about 40 percent of the combined volume of the fire-killed plus fire-stressed trees that are expected to die.

Discussion

Choices for management options following the Biscuit Fire revolve around societal goals for future forests and the relative risks, benefits, and costs of both action and inaction. Where society and managers choose to let nature deliver future landscapes and ecosystems, human-aided forest restoration and timber salvage are not only unnecessary but counterproductive. If the goal is to let natural processes dominate, there may be "no ecological need for immediate intervention on the postfire landscape" (Beschta et al. 1995). More recently, Everett (1995) and Ice and Beschta (1999) have provided differing perspectives. Our understanding of forest management, including the use of "light-on-the-land" harvesting methods on ecologically sensitive sites, has greatly improved. Researchers have found enormous variability in both the effects of natural processes and the consequences of human intervention on watersheds. For example, reviewing studies with unlogged controls, McIver and Starr (2001) find that human intervention can reduce adverse watershed impacts or be largely neutral as well as aggravate impacts. Following monitoring on the 1987 Silver Fire within the Biscuit Fire area, Kormeier and Park (1995) concluded that "the lack of adverse impacts from salvage logging is attributed to protection of riparian areas, improved road construction practices, and minimizing disturbance through the use of helicopter logging."

If the goal is to hasten restoration of complex mature conifer-dominated forests on the Biscuit Fire landscape, careful timber salvage can be useful. Ecologically, it would allow full sunlight to reach young seedlings, reduce future fuel loads, and reduce potential additional tree death from insect attack, all of which will hasten the regrowth and recovery of a complex forest. Economically, it would generate source of funds for forest restoration, reduce the costs of future fire suppression, and make future helicopter stand-maintenance operations feasible. Timber salvage could also provide a temporary source of extra revenue for schools or other public services that have suffered under the current state budget crisis. Socially, timber salvage and subsequent forest regeneration would provide short-term local employment and enhance long-term recreational opportunities.

The fixed and variable costs of harvest are particularly important because of time constraints. As timber deteriorates, there is a smaller economic base over which to spread the fixed costs of harvest. For low-impact, high-cost systems such as helicopter logging, the window of opportunity for cost-effective salvage closes quickly.

A Science-Based Strategy

Given the immense number of fire-killed trees within the Biscuit Fire area, a location-specific strategy for timber salvage would necessitate consideration of erosion control, including contour felling; sensitive areas, including steep slopes and exposed soils; stream protection; protection and reforestation of critical wildlife sites, especially riparian areas; log value, yarding distance, and method; loss in salvage value over time; regeneration activities and future access; dead wood for wildlife and streams; probable fire-stressed tree death from insect attack; potential fire risk from dead trees and down wood; future stand maintenance activities; and public involvement.

Alternative timber sale preparation procedures could also be considered. Typical federal timber sale procedures now take up to two years. For live tree timber sales, this time investment reflects the costs and benefits of the proposed actions. In timber salvage, however, the costs of delay are extreme: Fire-killed trees will lose more than 40 percent of their value in two years, and delays in forest regeneration will increase costs *(fig. 3).* Alternatives such as "end-result contracting," tested by the Bureau of Land Management, offer significant time savings. Marginal cost timber pricing to encourage salvage at longer distances from roads could also be considered.

The Northwest Forest Plan attempts to protect and perpetuate mature forests and their associated biological and ecological diversity. The original intent of management on late-successional reserves was to reduce stand density and clean up accumulating fuels to decrease the risk of standreplacing fires. Fires that threatened these reserves were to be given the highest priority. Continued public resistance to planned management, however, has resulted in very little management, and the statutory and administrative guidelines are largely silent about regeneration after major disturbances. Although the potential benefits of timber salvage in critical owl habitat are identified and criteria for salvage established, less attention is directed toward criteria for hastening forest regrowth through regeneration and control of competing vegetation. The plan anticipated a dynamic—in contrast to a static (or no action)—strategy on severely damaged areas, such as those affected by the Biscuit Fire (Thomas 2003), but inaction has been the norm.

Conclusion

How can agencies speed up consideration of reforestation, salvage, and fire and insect hazard reduction within the Biscuit Fire area? Will the land—and the people affected by it—be better served by letting nature take its course or by making strategic investments to influence the course of future ecosystems? Will society or forest managers accept the consequences of inaction versus action for future forests?

Time is not neutral. If society or land managers choose not to expedite postfire decisionmaking for the roughly 200,000 acres outside the designated wilderness so that restoration action can begin in 2004 and end by 2006 or 2007, then nature alone will determine the future conditions in as much as 400,000 acres of the entire Biscuit area. Regardless of congressional or administrative intent, these forests will likely be dominated by cycles of shrubs, hardwoods, and fires for a long time.

The Biscuit Fire is not unique. Society faces similar choices after virtually every large burn in dry, fire-prone forests with high accumulations of fuels. The recent 91,000-acre Booth and Bear Fire on the Deschutes National Forest proves that point again in Oregon. The consequences of delay in hastening forest regrowth are large, important, and real.

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