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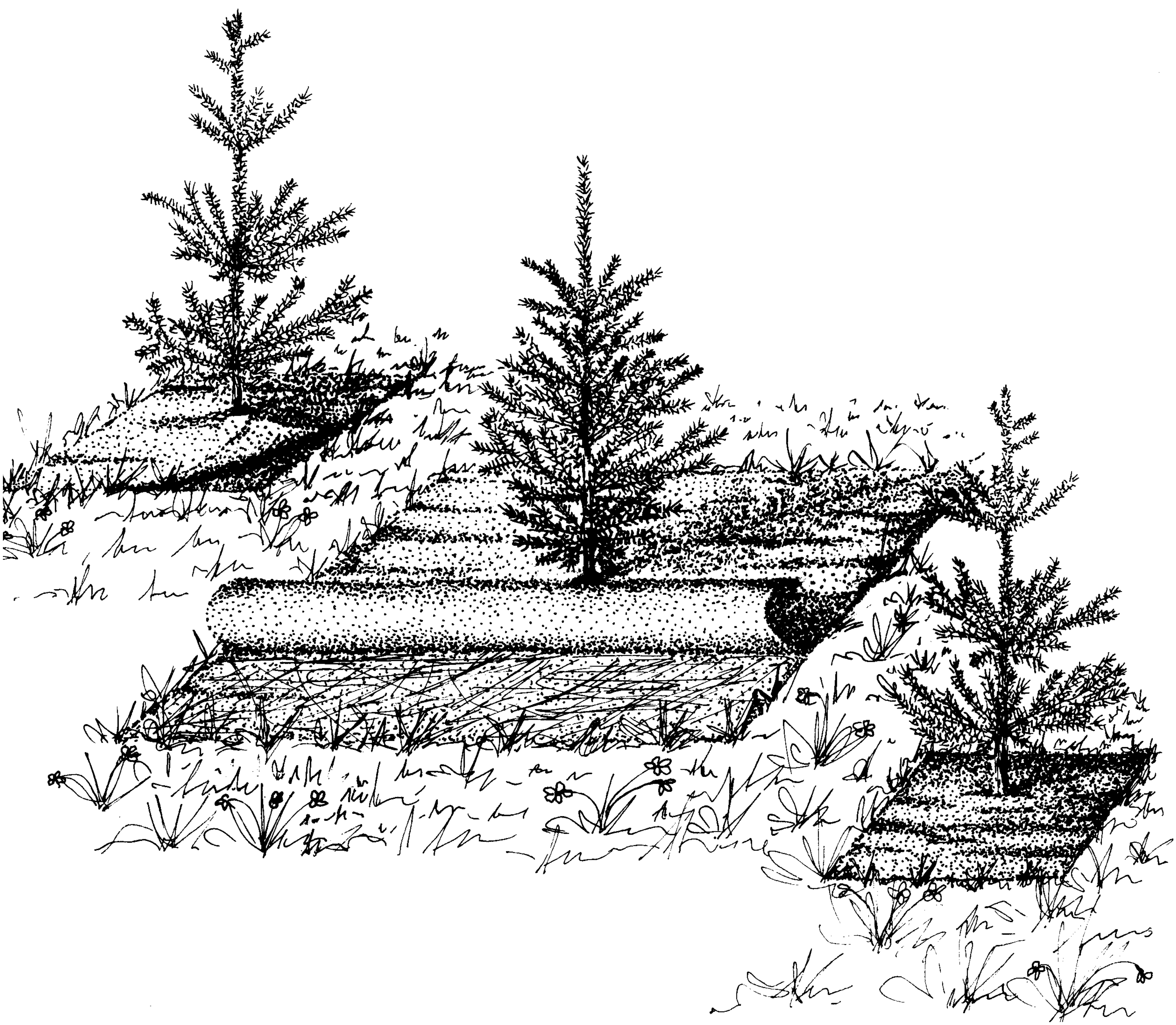
Mulching to Regenerate a Harsh Site: Effect on Douglas-fir Seedlings, Forbs, Grasses, and Ferns

Philip M. McDonald Gary O. Fiddler Henry R. Harrison



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Douglas-fir seedlings on the Arcata District, Bureau of Land Management, U.S. Department of the Interior, in central coastal California, were planted in an effort to restore the natural forest to what was then pastureland. Douglas-fir seedlings were released from a complex forb-grass-fern plant community by applying very large (10-ft square) and very small (2-foot square) durable mulches one month after planting. The large mulches were installed directly over the existing plant community, and the small mulches were applied over a similar-sized scalp. Two-foot-square scalps and an untreated control provided additional comparisons. After five growing seasons, stem diameter (measured at 12 inches above mean groundline) of Douglas-fir seedlings with large mulches was 1.61 inches, and of seedlings with small mulches was 1.36 inches. Only seedlings with large mulches were significantly larger than counterparts with small scalps (1.22 inches) or in the control (1.26 inches) after 5 years. In spite of high cost, the promising role of large mulches for establishing fast-growing Douglas-fir seedlings on a harsh site and the increased stability and sustainability that the future trees will bring to the more natural plant community give large mulches a place in the toolkit of ecosystem managers.

Retrieval Terms: central California, Douglas-fir seedlings, herbaceous species, mulches, plant community dynamics

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In Brief...

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As the 21st century approaches, sustainable ecosystems are receiving increasing attention. Such ecosystems in general are those that contain the species composition, structure, and functions that were present before severe perturbation by humans. Past logging, deliberate burning to promote pasture, and many years of grazing, first by sheep and then by cattle, certainly count as a severe disturbance. Chronic disturbance also leads to an unnatural and unstable ecosystem, and one that cannot provide the full range of commodities and amenities of which it is capable. Foresters in the Arcata District, Bureau of Land Management, U.S. Department of the Interior, recognized this and wished to begin restoring the land and its plant and animal components to a more desirable and sustainable future condition.

This was a formidable job. The plant community consisted of a complex arrangement of forbs, grasses, and bracken fern. Rabbits and deer were animal components of this community as well. These plants and animals, plus steep slopes, summer drought, and incessant wind, caused this to be a harsh site for conifer regeneration. Planting Douglas-fir seedlings was the first of four steps in the restoration process, getting the seedlings to survive and grow well the second, treating the existing plant community to be less competitive the third, and mitigating animal damage was the fourth.

Five years after treatment, Douglas-fir seedling survival ranged from 70 to 98 percent and did not differ significantly among treatments. Also after 5 years, mean stem diameter, measured at 12 inches above groundline, of Douglas-fir seedlings with large (10- by 10-foot) mulches was significantly larger than counterparts in 2- by 2-foot scalps and the control. No significant differences in stem height were recorded anytime during the study period. Small 2- by 2-foot mulches over scalps and scalps alone did not ever differ from the control.

Looking under the mulches and digging beneath them showed many roots of nearby plants beneath the mulched scalps and the small scalps. Encroachment data of bordering vegetation indicated that the treated space of small mulches and scalps did not give Douglas-fir seedlings enough competition-free space for enough time to stop the drain on site resources that limited diameter growth. Dead and live fiddlenecks of bracken fern also were observed pushing against the large mulches throughout the study period, indicating the constant pressure exerted by this species on both the mulch and other plant species. Another significant finding was that the dead vegetation under the large mulches and the organic matter from it formed a highly effective second mulch. This second mulch absorbed many times its weight in moisture and temporarily blocked at least some upward-moving moisture from passing through the pores of the polypropylene mulch.

That large mulches lasted for at least 5 years and that they significantly improved conifer seedling growth earns them a place in the foresters' cornucopia of effective vegetation management treatments. Although costs were high, operational mulching should be more cost-effective. Another effective treatment was the vexar leader protectors. Although deer and rabbits heavily browsed lateral branches, few terminal buds were damaged.

The existing plant community in the study area in 1989 consisted of 1 hardwood tree species, 2 species of shrubs, 14 forbs, 8 grasses, and bracken fern. Five years later, community makeup was still 26 species with the same number of species in each vegetation class. However, 6 species of forbs were now present that had not been noted earlier. The cumulative effect of 6 consecutive drought years is suspected of causing the change. Changing density and growth patterns of the forbs, grasses, and ferns also were noticed. The ever-taller Douglas-fir seedlings and the increasing shade that they produce are influencing the plant community. Not only were noticeably shorter forbs and grasses growing under the seedlings, but tall, thin plants were also noticed growing within the seedling crown, or into and out of it. Large reductions in forb density and foliar cover and in fern density also were noted. The grass component of the community, however, increased in density and height during the 5-year study period.

Introduction

A fundamental concept in ecology and vegetation management is that desired plants of a given species will develop best when they become established before the competitors, are well separated from the competitors, and the competitors are weak or have been weakened (McDonald and Fiddler 1989, Radosevich and Conard 1982). Our study was located in part of a large area that had once supported an open Douglas-fir forest with trees above and herbaceous vegetation below. A century or more of logging and fire, plus grazing first by sheep and then by cattle, created a plant community of forbs, grasses, and ferns typical of an unimproved pasture. No trees remained to shelter the land from high amounts of rainfall, constant wind, and high insolation. And no snags or logs were present to provide habitat for diverse microbial, insect, and animal populations. Reestablishing a conifer forest in this environment meant planting Douglas-fir seedlings on a degraded site where plant competitors were both numerous and well established.

The competitive capability of the short and often inconspicuous forbs and grasses tends to be underestimated, and many a vegetation management specialist visiting a new plantation in the fall has been shocked at the poor survival and growth of the conifer seedlings. "What killed all the seedlings?" is often heard. Had the plantation been visited in late spring, the cause would have been more discernible.

The reason for the poor seedling response is that, on most sites, the forb-grass-fern community that forms during and after disturbance often is extensive and complex. Many species are present, each has a particular niche above and below ground, and each develops best at a specific time. Because plants rarely, if ever, occupy the same space at the same time (Daubenmire 1968) and seldom maximize growth simultaneously, site resources are utilized continually from very early in the growing season to very late. Growing space both above and below ground often is fully occupied. The result is a strong and consistent drain on site resources, often before roots of conifer seedlings become active in the spring, or after they become inactive in the fall. In some instances, the forbs have completed their life cycles, dried up, and blown away by midsummer. No wonder the confusion associated with fall observations.

In a southwest Oregon plant community of shrubs and herbs, White and Newton (1989) noted that herbs extracted soil moisture from depths of up to 30 inches and that they significantly reduced the biomass of both planted Douglas-fir seedlings and shrubs. In the Oregon Cascades, Petersen and Newton (1982) found that removal of forbs, shrubs, and ferns resulted in considerably greater stem diameter and volume of 5- and 10-year-old Douglas-fir seedlings than removal of shrubs alone. In a more moist community of the Oregon Coast Range, Newton and Preest (1988) reported that Douglas-fir seedlings experienced a 217 percent gain in volume when herbs were removed during the first 3 years after planting. Furthermore, the herbs reduced seedling growth even after the conifer seedlings were dominant over them. After a forest fire in the Klamath Mountains of northern California, McDonald and Fiddler[1] found competition from a mostly forb community (20 species) with some grasses (four species) and bracken fern to be so severe that heavy mortality of planted Douglas-fir seedlings in the control caused the study to be abandoned.

Planted conifer seedlings face a double-barreled threat from bracken fern. Minore (1966) noted that bracken fern is found from the Arctic Circle to the Equator and on every continent. It has no serious natural enemies and is well protected from fire. Its rhizomatous root system, with new plants arising from nodes, enables it to rapidly occupy disturbed areas; its emission of toxic metabolites that negatively affect the life cycle of other plant species, a process called allelopathy, enables it to interfere chemically (Ferguson and Boyd 1988). Walstad and Kuch (1987) recognized the importance of both ferns and the "little plants" and recommended that competitive herbaceous vegetation be controlled before planting conifer seedlings or within the first growing season.

In complex herbaceous plant communities with high plant density, the key to successful conifer seedling establishment is to keep competing plants, and specifically competing plant roots, from impinging on the conifer seedlings. Unimpeded root growth by conifer seedlings for the first 3 years after planting is critical for attaining growth at the potential of the site (McDonald and Fiddler 1986). The minimum vegetation-free area necessary to give a conifer seedling unimpeded growth for 3 years is a circle with a 5-foot radius (Fiddler and McDonald 1987).

Although selected herbicides as a site preparation tool would have been effective, they were not available. Manual release was not feasible. Mulching- "the application or creation of any soil cover that constitutes a barrier to the transfer of heat or vapor" (Rosenberg 1974)-was the only available alternative.

To find a material that would effectively exclude competing plant species, favorably alter the micro-environment, and be of reasonable cost, foresters have tried many mulch materials to enhance conifer seedling survival in the past 30 years. Sheets of plastic, newspaper, and plywood; layers of bark, sawdust, sand, and straw in various thicknesses; sprayed petroleum emulsions; and even large plastic buckets have been tested (McDonald and Helgerson 1990). Most were found to be ineffective or too costly or both. Almost all were intended to enhance only seedling survival, not seedling growth. Most affected only a small area (3 ft^2 or less) and lasted only for 1 or 2

[1]Unpublished data on file, Pacific Southwest Research Station, Redding, CA

years. Needed was an area that was large enough and free of undesirable vegetation long enough to give the conifer seedling a chance to develop unimpeded. Large durable mulches seemed promising.

This paper reports a study that broadens the applicability of mulching in several ways: (1) by using mulches to restore a key tree species that was displaced many years ago by conversion to pasture, (2) by installing mulches directly over the existing plant community, (3) by using mulches to try to enhance conifer seedling survival on a harsh site, and (4) by applying large mulches to promote seedling growth. The paper also denotes the complex grass-forb-fern community and shows changes in it for 5 years after planting. Related cost information for the various treatments also is presented.

Methods

Location and Site Characteristics

This study is located on the Arcata Resource Area of the Bureau of Land Management, about 30 airline miles south of the town of Eureka in a part of California known as the Lost Coast and more specifically in the King Range Conservation Area. This coast extends along the shores of the Pacific Ocean from just north of Shelter Cove to Petrolia, California and inland for 8 to 10 miles. It occupies about 60,000 acres. Its environment is described as "unique" not only because of very high rainfall, but also for the long summer drought (Bain and Matis 1989).

The study area is located in the headwaters of the Mattole River. The lush valley and the forested hillsides attracted settlers in the 1850s and led to early use of the forest. Providing lumber for buildings, bark of tanoak for softening leather, and grazing were early industries. The steep hillsides, often with open "prairies," were a natural for pasturing sheep, and huge numbers were present for scores of years. Wildfire associated with logging, lumbering, and homesteading burned much land, and deliberate burning by the stockmen to enhance pasturage destroyed countless acres of forest. In the 1930s, a shift in grazing animals occurred, and cattle became preferred over sheep. Burning to enhance pasturage continued, however, until the 1960s, when it virtually stopped. Logging and lumbering operations peaked in the 1950s when four sawmills were operating in the area.

Occasional burned stumps and logs, as well as living clumps of hardwoods, indicate that past vegetation in the study area included at least a few large Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco), canyon live oak (*Quercus chrysolepis* Liebm.), and tanoak (*Lithocarpus densiflorus* [Hook. & Arn.] Rehd.) trees as well as the herbaceous plants and ferns present today. This vegetation corresponds to the Douglas-fir-tanoak-Pacific madrone forest cover type (SAF 234) (Sawyer 1980).

When the study began, the plant community consisted of no Douglas-fir (no seed source remained), the hardwood species above, 2 species of shrubs (*Ribes* spp., *Rubus* spp.), 10 forbs, 8 grasses (7 introduced), and bracken fern (*Pteridium aquilinum* (L.) Kuhn var. *pubescens* L. Underw.) (*fig. 1*). The principal grasses were of the genera *Aira, Avena, Bromus,* and *Holcus.* The most abundant forbs represented the genera *Geranium, Hypochoeris, Rumex,* and *Stachys).*

Site quality of the study area is medium (III) with height of dominant Douglas-firs averaging 90 to 110 feet at a breast-height age of 50 years (King 1966). Slopes range from 35 to 65 percent and average about 50 percent. The elevation is 1400 feet. The aspect is north. The predominant soil is of the Honeydew series (Typic Haploxerult). Such soil is formed in material that has been weathered from sedimentary rock (sandstone). The soil is moderately deep (36 inches) and well drained, with a texture of dark brown very gravelly loam grading to very gravelly clay loam below 12 inches. Average annual precipitation, all falling as rain, is 125 inches. Fog is rare in the summer. In spite of the high amount of precipitation, summer drought is common and often lasts at least 100 days. Wind is common and at times is of gale force. Annual temperatures range from a high of 100 °F to a low of 25 °F.

Study and Design

The study includes developmental data on Douglas-fir seedlings, forbs, grasses, and ferns collected from 1989 through 1993. It includes information gathered on plant species developing naturally (untreated control) and after receiving a variety of treatments.

The experimental design was completely randomized with one-way treatment structure. There were four treatment levels, all installed in March 1989. Each treatment was replicated three times. The treatments were:

Large Mulches 10- by 10-feet square made of light-weight polypropylene with a "fuzz" of polyester on the underside, installed over existing plant community, held down by thirteen 9-inch metal pins;

Small Mulches 2- by 2-feet square of the above mulch material applied over a scalp of similar size, held down by four pins;

Small Scalps 2- by 2-feet square with all surface vegetation removed;

Control No mulching or scalping.

The area was planted (hoedads) to 2-0 bareroot Douglas-fir seedlings in February 1989 on a 10- by 10-foot spacing. Because damage from deer (*Odocoileus* spp.) and rabbits (*Sylvilagus* spp.) *is* common in the area, each seedling was fitted with a 24-inch vexar leader protector. Each replicate (plot) was roughly rectangular and consisted of about 0.25 acre with 40 to 50 conifer seedlings surrounded by two to three rows of buffer (seedlings

Figure 1-An early spring overview of the most gentle slope in the study area showing the large mulches and the plant community.

receiving similar treatment). In each plot, about 25 of the best seedlings, identified as potential crop trees, were flagged. As their name implies, these were well developed seedlings that had good potential of becoming harvestable trees. On each of the sample seedlings, stem diameter and height were measured. Diameter was recorded at 12 inches above mean groundline. The seedlings also were checked for injury by animals and insects.

Only in the control was all vegetation sampled. The assumption for the other treatments was that the mulch would preclude new vegetation and that competition for site resources would be from plants on the edge of the mulches or scalps. Because this vegetation already was established, it would be similar to that in the control. This was confirmed by visual observation throughout the study period.

Hardwoods and shrubs were too few to comprise an adequate sample. But forbs, grasses, and ferns were abundant and measured as classes, rather than as individual species. Sampling intensity for them was seven randomly selected subplots in each plot. Subplots were centered around Douglas-fir seedlings. They were square and contained 1 milacre (0.001 acre) of area. Measured variables were density, foliar cover (the sum of shadows that would be cast by leaves and stems of individual species expressed as a percentage of the land surface) (Daubenmire 1968), and average dominant height (average of the three tallest stems measured from mean groundline to bud). All plant species were noted on a species list at the beginning of the study and after 5 years.

Vegetation was measured in 1989, 1990, 1991, and 1993. Statistical analysis was performed each year. To test for treatment effects and significant differences among treatments, one-way analysis of variance of treatment means (fixed model, Steel and Torrie 1980) and Tukey tests were the analytical tools (SAS Institute Inc. 1988). Significance in all tests was at $\alpha = 0.05$. Data were gathered from permanent plots measured each year, and where analyses of means from repeated measurements are concerned, the data are not truly independent. The α levels or type I errors given for various tests apply to each measurement and year separately.

The scalping and mulching treatments were installed by six high school students and their teacher with close supervision by a forester. The students adopted this work as a "hands-on" project that would give them insight into natural resource management. Time to install the various treatments was recorded. No overhead, transportation, or other costs were included. The basis for cost was $8.74 per hour-the rate for a WG-1 laborer, U.S. Department of Labor, as of June 1993. Consequently, the treatment installation data presented in this paper are unique to motivated but untrained "partners." The quality of the work was high, and described as "better than operational" by the forester.

Results

We present observations on the efficacy of the treatments and the vegetative response to the treatments. More specifically, we denote survival, stem diameter, and height data for planted Douglas-fir seedlings in the four treatments; and density, foliar cover, and height for forbs, grasses, and bracken fern in the control.

The Treatments

After 5 years, the polypropylene mulches are holding up well. Although the upper side is no longer shiny, the mulches have not deteriorated to the extent that vegetation is poking through. Indeed, examination under the large mulches has shown both living and dead fiddlenecks of bracken fern pushing against the mulches. That they have not broken through attests to the integrity of the mulch material. The dark color of the mulches also is a factor. It allows them to absorb heat, and the hot mulches probably kill the fiddlenecks upon contact. In a few instances, vegetation, especially bull thistles (*Cirsium vulgare* [Savi] Ten.), is growing from the slit in the center of the mulches along with the Douglas-fir seedlings. A few plants also have become established where the hold-down pins were installed. However, given the large treated area under the large mulches, these plants are thought not to be a major drain on site resources.

Several examinations under the large mulches showed their moisture-conserving tendency. On March 26, 1990, for example, the soil was described as hard and dry throughout the study area but loose and moist beneath the large mulches. On April 2, 1991, the soil beneath the large mulches was described as being warm on top with high moisture content beneath the top one-quarter inch. On August 19, 1993, however, the surface soil was described as hard and dry everywhere, including under the large mulches.

To better evaluate the small scalps and mulches, we recorded "encroachment" of vegetation into the 2- by 2-foot area of the treatments in 1989 and 1990 or for the first and second full growing seasons after treatment. Encroachment was denoted in percent. Encroachment for scalping alone was by plants growing into the treated area and leaning into it. For scalping and mulching, encroachment was determined by plants leaning over the mulches and recorded as solid shadow, much like foliar cover was defined earlier. Although new plants from seed originated in the bare soil of the freshly prepared scalps, few if any lived beyond the first growing season. Encroachment was almost entirely by plants just outside the treatment borders *(fig. 2)*, and was both above and below ground. Digging with a shovel showed many roots of border plants in the treated space after one growing season.

For scalping alone, encroachment over the three plots averaged 58 percent after one growing season and 92 percent after two seasons; for scalping and mulching, encroachment the first year was 15 percent and 34 percent the second *(table 1)*. By the third year, scalped areas were almost 100 percent encroached upon and the mulched and scalped areas were over 50 percent.

Table 1 - ***Encroachment of small scalps and mulches, Beartrap study area, 1989 and 1990.***

Year	2 x 2 Foot Scalps		2 x 2 Foot Scalps and Mulches	
	Mean	Range	Mean	Range
	Percent			
1989	58	25-98	15	0-70
1990	92	70-100	34	2-90

Douglas-fir

The need for ecological knowledge, and specifically for information on the composition and structure of plant communities, suggested that results be presented both for individual species and species aggregations. But because the presence of individual forb species is both tenuous and fleeting, and because finances dictated that we could sample the area only once per season, it seemed prudent to denote the plant community by its component classes.

"Precarious" best describes the status of the newly planted Douglas-fir seedlings. One month after planting, browsing was noticed. Three months after planting, an examiner noted, "most needles brown and falling off from cold temperatures and high winds." The buds, however, proved to be healthy and new needles formed. Two months later, which was mid-August, they again were described as brown with incessant wind the likely culprit. It was also on this date that wind "cups" were first noted around many seedlings. Wind cups are voids just below groundline between the seedling stem and the soil. They are caused by the wind-whipped stems constantly pushing against the soil. Leaning seedlings and loss of soil moisture often result. In spite of all this, most seedlings survived. For the next few years, browsing of unprotected buds and needles by deer and rabbits was a constant drain on seedling vigor. A recurring, but unsubstantiated, theme among foresters is that animals will not step on large mulches. As noted in *figure 3,* this is not true, at least for rabbits. Wind cupping was again noted in spring 1991, but not for seedlings with mulches.

In fall 1993, or after five growing seasons, Douglas-fir seedling survival was 93 percent with large mulches, 98 percent with small mulches over scalps, 70 percent with scalping alone, and 96 percent in the control. Drought was the chief cause of mortality. Browsing contributed to seedling damage, but not to mortality. Seedlings with large mulches were browsed more than seedlings in other treatments, and in many instances now resemble sheared Christmas trees with long leaders. A likely explanation, based on observations of deer activity, is that added moisture beneath the large mulches kept seedling foliage succulent longer in the spring and early summer, and the deer fed on them when other food was scarce.

The high worth of the vexar leader protectors is undeniable. In almost all instances, protected seedlings now are straight and tall with one or two leaders. Al-

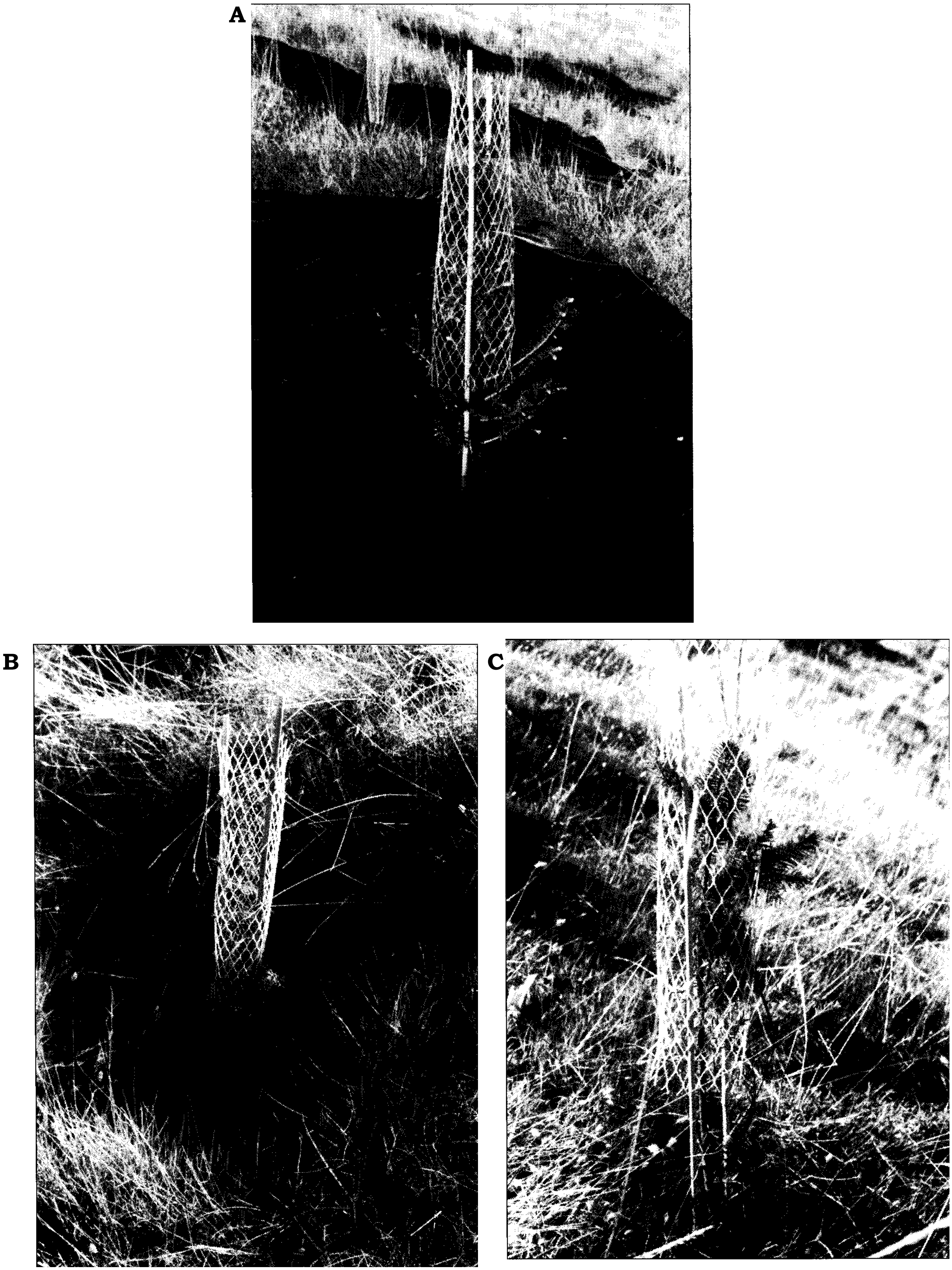

Figure 2- Encroachment of vegetation into treated plots in March 1990, or just before the second growing season: (A) large mulches, (B) small mulches, and (C) scalps.

Figure 3-Rabbit pellets on a large mulch in spring 1990 indicate that this animal has no fear of stepping on the mulch.

though some twisting of lateral branches from the vexars has occurred, leader growth has not been impaired. Unprotected seedlings outside the study area have been repeatedly stripped of buds and needles to the point that they have either died or become short "sticks" with a few tufts of needles.

Transformed (arc-sine, Snedecor 1956) mean survival values after the fifth growing season were examined by ANOVA. Survival did not differ significantly among treatments.

Statistically significant differences among treatments for Douglas-fir stem diameter, measured at 12 inches above mean groundline, first showed up in fall 1989 or after the first full growing season. Mean diameter of Douglas-fir seedlings with large mulches was signify-cantly larger than counterparts in scalped plots (*fig. 4*). In fall 1990 and continuing through fall 1993, stem diameter of seedlings with large mulches was significantly larger than that of seedlings in both scalped plots and the control (*fig. 5*). Only in 1993 did diameter of Douglas-fir seedlings with large mulches not differ from counterparts that received both scalping and small mulches. Mean stem height (standard error in parentheses) did not differ significantly among treatments during the study period

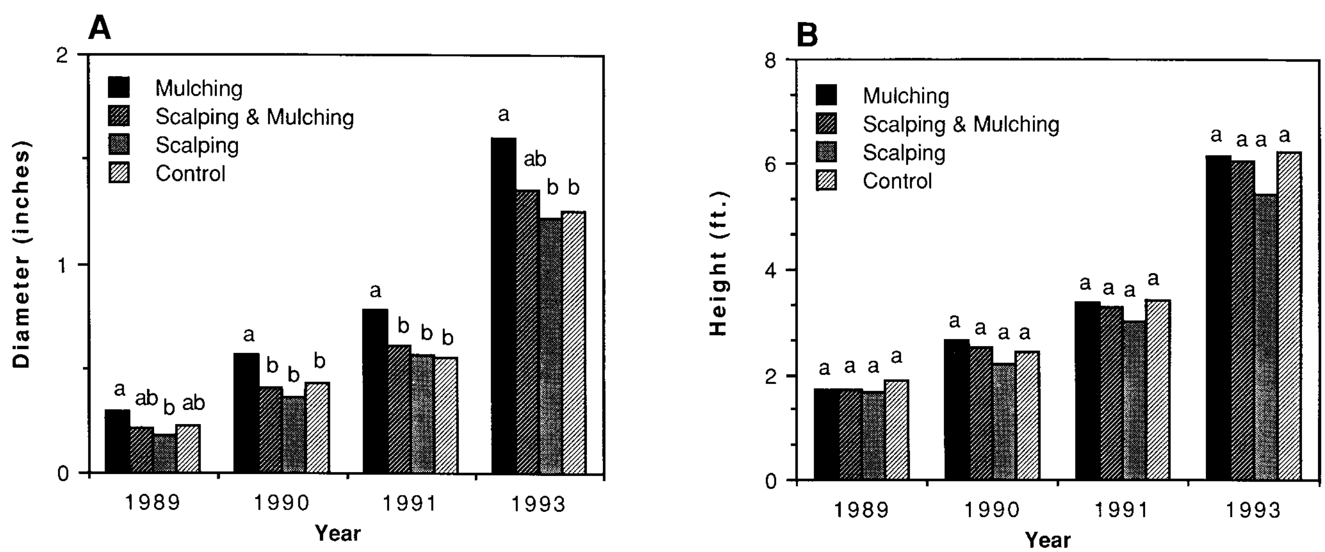

Figure 4-Average Douglas-fir stem diameter at 12 inches above mean groundline (A) and average stem height (B), 1989-1993. Standard errors each year for diameter ranged from 0.01 to 0.09 inch, and for height from 0.06 to 0.52 foot. For each year, treatment means followed by the same letter do not differ significantly at the 0.05 level.

(fig. 4). After five growing seasons stem height was 6.2 (0.3) feet with large mulches, 6.1 (0.5) feet with scalping and small mulches, 5.5 (0.4) feet with scalping alone, and 6.3 (0.2) feet in the control *(fig. 6)*.

On the basis of experience, BLM foresters estimated that the potential of the study site, as expressed in Douglas-fir seedling growth variables, was 1.5 inches for stem diameter and 6.0 feet for stem height of 5-year-old seedlings. Consequently, seedlings with large mulches were the only ones to exceed this value for diameter; seedlings in all treatments except scalping exceeded the above value for stem height.

Forbs

For the 1989-1993 period, the naturally developing forb component of this plant community was in a state of dynamic change. Mean plant density declined from over 84,345 to 14,120 plants per acre, and foliar cover from 22 to 11 percent *(fig. 7)*. Mean height, however, increased steadily from 0.2 feet to 1.5 feet after 5 years. The trend of fewer but taller plants could be a result of competition from the taller Douglas-fir, bracken fern, and grass populations.

Within this framework, however, changes occurred. The most notable was the development of patchy and very dense aggregations of *Galium, Hypocheris,* and *Rumex* plants. Sometimes they appeared as single species, sometimes in combination.

Grasses

Natural development of the grass community also changed over the 5-year study period. Average grass density increased from more than 107,000 plants per acre to more than 558,000 plants per acre, but foliar cover declined from 60 to 38 percent *(fig. 7)*. Mean height increased steadily from 2.0 to 3.6 feet. More but narrower-crowned plants characterized this component of the plant community. Changes within the grass community also occurred. The most noteworthy of these was the widespread increase in dogtail (*Cynosurus echinatus* L.) in the upper portion of the study area, and in wild oats (*Avena fatua* L.) in the lower portion. On a smaller scale the tendency of some annual grasses was to form dense patches of short plants beneath the Douglas-fir crowns and taller plants in the more open spaces.

Figure 5-Although hard to see, the average stem diameter of these 5-year-old Douglas-fir seedlings with 10- by 10-foot mulches is significantly larger than that of seedlings in other treatments.

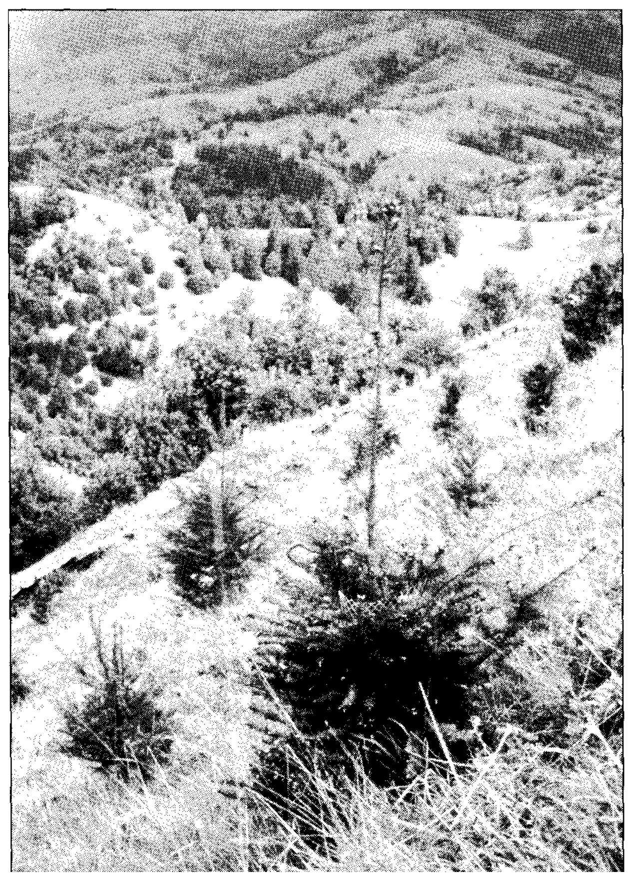

Figure 6-This Douglas-fir seedling in the control is the tallest tree in the study. Note, however, the shorter seedlings nearby.

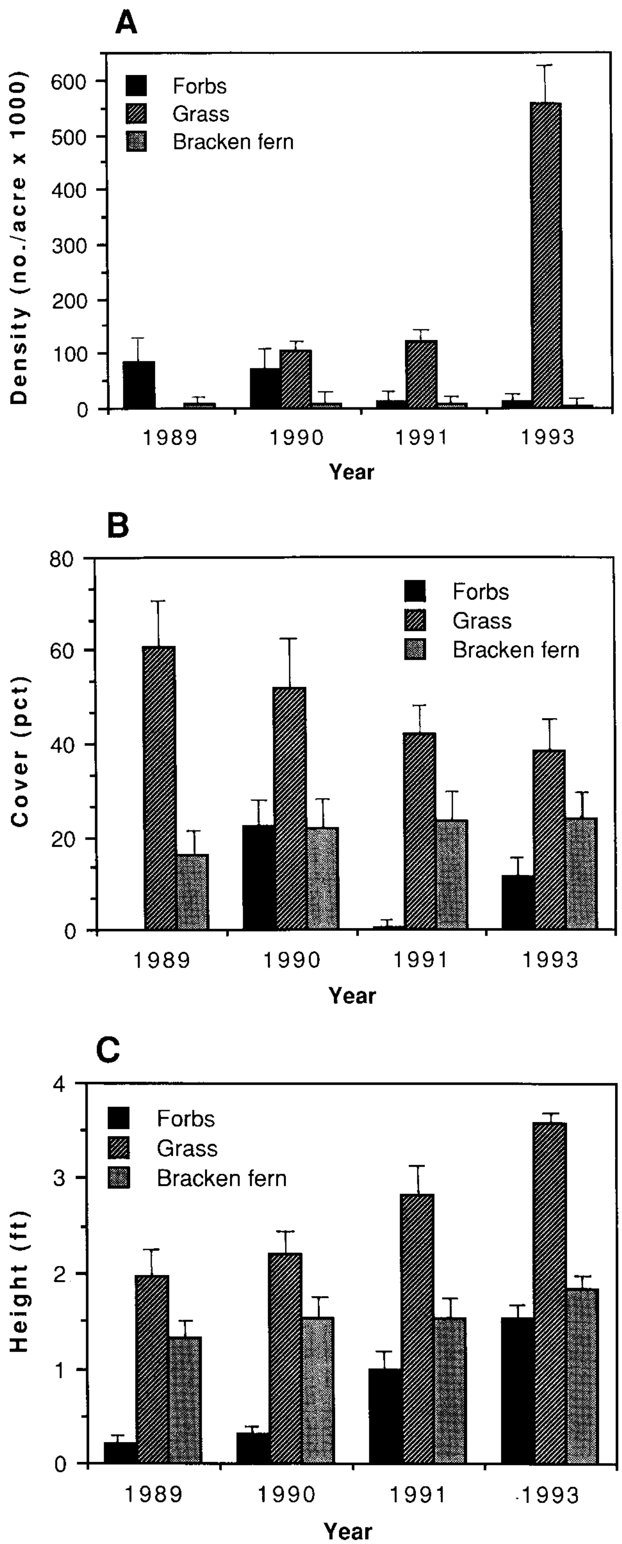

Figure 7-Average density (A), foliar cover (B), and height (C) with standard errors, of forbs, grasses, and bracken fern in the control, 1989-1993.

Bracken Fern

Naturally developing bracken fern in the control decreased irregularly from 8,765 plants per acre in 1989 to 4,841 per acre in 1993; foliar cover increased slightly from 16 to 24 percent, and mean height increased from 1.3 feet to 1.8 feet *(fig. 7)*. Fewer but wider and taller plants characterized bracken fern in this community.

Plant Species Dynamics

The forb-grass-fern components of this community are being ever more influenced by the planted Douglas-fir seedlings. Increasing foliar cover and height of the conifer seedlings are causing some plants to grow taller and others to endure more shade. The net result is a large decline in forb and fern density, and in forb cover. The grass component of the community appears to be holding steady or even increasing. Although foliar cover of the grasses has declined almost 37 percent, density has increased 421 percent, and height has increased more than 82 percent during the study period.

The structure of a forb-grass-fern plant community, although seldom recognized, is amazingly complex. This complexity takes place, at least in this study, on a vertical scale of less than 42 inches. At any given time in the growing season, the community is made up of species that are tall, short, and in-between; some species are represented by living plants; some by dying plants; some are flowering and some are not. And in many instances, the above are true for the plants within a species. The net effect of all the species and all the plants is that very little growing space remains within 2 to 3 feet of the soil surface, both above and below ground.

Plant Diversity

The plant community of the study area initially consisted of 26 species including I hardwood tree species, 2 species of shrubs, 14 forbs, 8 grasses, and bracken fern. After 5 years it was composed of 26 species with exactly the same makeup as above. The only difference was in the forbs. Six species of forbs were present in 1989 that were not present in 1993, and six species were present in 1993 that were not found in 1989.

Treatment Costs

To be realistic, the cost of a mulching treatment must include the cost of the material, installation of the mulches, and their maintenance. Maintenance or, more specifically, periodic inspection is needed to re-pin blown-out corners and to keep each mulch in place and at its full size. The cost of the material in this study was $900. When prorated by size of mulch and assessed on a per-acre basis, it amounted to $2059 per acre for large mulches and $86 per acre for small ones. Installation costs were $514 per acre for large mulches, $158 per acre for scalping and small mulches, and $119 per acre for scalping alone *(table 2)*.

Maintenance consisted of at least two visits per year by Bureau of Land Management employees, usually in conjunction with other duties nearby. Time spent on the study site amounted to 4 hours per inspection or 8 hours per year with at least 3 years necessary. On a per-acre basis this amounted to $400 per acre for large mulches and $171 per acre for small mulches over a 3-year period. Total cost for material, installation, and maintenance for 3 years for large mulches was $2900 per acre, and for small ones applied over a 4-foot-square scalped area was $393 per acre.

Discussion and Conclusions

In many instances, restoration of the native plant community and vegetation management to enhance survival and growth of the desired species are needed, but the kind of vegetative manipulation is limited by geographical and societal considerations. Where mechanical site preparation is not feasible, as on steep slopes; where social pressures or legal restrictions deny the use of herbicides; or where air quality standards prohibit broadcast burning, few manipulative alternatives remain. Of those that do, the vegetation management specialist is obligated to try the one that will be the most biologically effective. In general, if a technique is biologically feasible, the cost can be reduced. Mulching fits this scenario.

The large mulches, after 5 years of trial, have proven to be worthy of future consideration as a means for restoring a key tree species to a harsh site. This is because Douglas-fir seedling survival is high and stem growth is at the potential of the site. Furthermore, the large and dense seedling crowns, as noted in the photos, suggest rapid future growth. Applying the large mulches directly over the existing plant community in the spring showed an unforeseen benefit-the formation of what in essence became a mulch under a mulch. The organic matter from the dead vegetation under the polypropylene mulch absorbed much moisture and stayed moist well into the growing season. It also temporarily blocked at least some upward-moving soil moisture from escaping through the pores of the polypropylene mulch. Together, these mulches provided critical water that surely must have contributed to the significantly larger stem diameter of the Douglas-fir seedlings.

Applying mulches over existing vegetation is best if done in the spring. Doing so when the soil is at field capacity locks in high soil moisture. And spring application of the mulches is made easier because the vegetation is already well matted to the ground by wind and rain.

Scalping 2- by 2-foot squares with no further treatment and covering them with similar-sized mulches as a second treatment never provided a significant increase in Douglas-fir stem diameter and height relative to counterparts in the control. That these treatments did not provide competition-free space long enough to alleviate moisture stress for the conifer seedlings is likely.

Table 2- ***Cost and production rates for installing mulching and scalping treatments, Beartrap study area, 1989***

Treatment	Production rate	Cost
	Crew hours/acre	*Dollars/acre*
Large mulches	58.8	514
Scalp, small mulches	18.1	158
Scalp	13.6	119

After considering the harshness of the site for establishing conifer regeneration, fifth-year Douglas-fir seedling survival and stem height were satisfactory in both the scalped and mulched treatment and in the control. The low cost associated with these treatments provides alternatives to managers having low budgets and a less urgent timeframe to establish a mature forest environment.

The high cost of the large mulches in this study is daunting and, at first glance, weighs heavily against their usage in all but the most urgent situations. This cost, however, is unique in three ways: it was done for research purposes and thus was higher than operational, it pertained to a small quantity of material applied over a small area, and it was installed by untrained workers. Operational installation over larger acreages should have economies of scale that would reduce the per-acre cost. And, if the manager can be virtually guaranteed that Douglas-fir seedling growth will be at or better than the potential of the site for 5 or 10 years (the timespan that these mulches could last) with no further costs or disruptions of the ecosystem, large mulches might be attractive. Another reason for using large mulches concerns the growth/cost interaction. Results from our work with mulches elsewhere in California, and from that of other researchers worldwide, suggest that mulches significantly modify the environment for the better. There is some evidence, for example, that mulching causes water to remain in the ground longer. Surely this moisture must lengthen the growing season, and in turn, add to growth. When the increased growth is matched with cost, mulching should be more cost-effective.

The finding that Douglas-fir seedlings in the control and with small scalps and mulches continue to emphasize height growth when the competition is much shorter is of interest to ecologists. Previous work with Douglas-fir seedlings (McDonald and Fiddler 1986) and with ponderosa pine seedlings (McDonald and Fiddler 1989, 1990) in northern California, and indeed by many authors for many conifer species throughout the world (Gjerstad 1993), has indicated that stem diameter is a better predictor of competition than stem height. This, in general, is because overtopping means eventual death of the seedling. To avoid overtopping, amount and length of needles, crown development, and stem diameter develop less so that height can develop more. That tall, skinny Douglas-fir "whips," growing with intense competition, become so slender that they fall over if not supported by other vegetation support the contention of seedling height development at any cost.

But in this study, overtopping beyond the first year or two was not a problem. Competition for site resources obviously was not above ground, but below, and probably at the fine root level (Kozlowski 1985). Why did the Douglas-fir seedlings continue to emphasize height over diameter when the potential for overtopping was low? Perhaps when site resources are limiting, seedling developmental strategy is for height; if future resources continue to be limited, the additional height lessens the danger of overtopping by competing vegetation.

The finding that the diversity of the plant community remained constant over the study period was no surprise. No real disturbance had occurred to cause a change. A possible explanation for shifts in the forb population was the effect of the 1987-1992 drought. We noticed that new species in 1993 tended to be wind-blown invaders; those missing were minor members of the established plant community that could have needed more moisture.

That competing vegetation must be controlled to provide site resources, especially soil moisture, to conifer seedlings is almost universally agreed upon (Gjerstad 1993, Stewart and others 1984). Survival alone is not enough, the seedlings must grow well, preferably at the potential of the site. This is because the forested stand that they comprise may well be needed at this location in the landscape at a specific time in the future. A species of wildlife, for example, might be projected to need this forested environment 150 years from now. The large mulches used in this study got the forest community off to a good start. Moreover, this community, with its tallest species restored, has a good chance of becoming more stable, more sustainable, and more useful to future users because of added diversity and the additional commodities and amenities that it will provide.

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