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FOREST VEGETATION MANAGEMENT

Without Herbicides

Proceedings of a Workshop
February 18-19, 1992

Supported by

Forest Research Laboratory, Oregon State University
University of Georgia, Daniel B. Warnell School of Forest Resources
Oregon Department of Forestry
British Columbia Ministry of Forests
USDI Bureau of Land Management, Oregon State Office
USDA Forest Service, Region 6



College of Forestry
Oregon State University

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FOREST VEGETATION MANAGEMENT WITHOUT HERBICIDES

edited by

**Timothy B. Harrington
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at Oregon State University, Corvallis.*

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Forest Vegetation Management
without Herbicides

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ACKNOWLEDGMENTS

We would like to express our gratitude to the following agencies who generously provided the funding for editing, graphics preparation, and publication of these proceedings: Oregon Department of Forestry, British Columbia Ministry of Forests, USDI Bureau of Land Management (BLM) (Oregon State Office), and USDA Forest Service (Region 6). In addition, CRAFTS (Coordinated Research on Alternative Forestry Treatments and Systems), formerly a research cooperative on forest vegetation management at Oregon State University (OSU), provided much of the knowledge base and supporting personnel that enabled state-of-the-art workshops on forest vegetation management.

We appreciate the support and commitment of the following individuals who provided logistical as well as philosophical support during the workshop and subsequent compilation and publication of these proceedings: Dave Morman (Oregon Department of Forestry), Phil Comeau (British Columbia Ministry of Forests), Larry Larsen (BLM), Don Connett (USDA Forest Service), Toni Gwin and Continuing Education Staff (OSU College of Forestry), Ralph McNeese and Publications Staff (OSU Forest Research Laboratory), and Bart Thielges (OSU College of Forestry). Special thanks are due to Izella Stuiivenga, Deborah Safley, and Phyllis Casner for the many hours of word processing that were spent on this lengthy document, and to Gretchen Bracher for preparing the graphics that accompany many of the papers.

We thank the speakers for taking the time from their busy schedules in order to compile and present current information relevant to the workshop. Steve Knowe, Will Schneider, and Bob Shula, staff members associated with CRAFTS, were particularly helpful in moderating the sessions and the discussions that followed. Finally, we wish to extend our personal thanks to foresters throughout the Pacific Northwest who faithfully participate in Forestry Continuing Education as evidence of their continuing commitment to sound forest management.

The Editors

INTRODUCTORY COMMENTS¹

Timothy B. Harrington

The 1992 workshop on Forest Vegetation Management was held in Corvallis on the Oregon State University (OSU) campus. It was the tenth such workshop sponsored by OSU; the theme this year was forest vegetation management without herbicides. Previous workshops provided broad coverage of both herbicide and nonherbicide techniques of forest vegetation management. Because many of the public agencies in the Pacific Northwest have adopted policies that severely limit their use of herbicides, a forum was needed for discussing state-of-the-art information on nonherbicide techniques of forest vegetation management, especially as they pertain to the specifications and efficacies of common treatments.

The workshop was conducted over a 2-day period, and it was designed to meet the information needs of forest land managers from throughout the Pacific Northwest. To limit the scope of this broad topic, we focused our discussions on even-aged silvicultural systems that are dominated by conifers, particularly Douglas-fir (*Pseudotsuga menziesii*). Most presentations dealt specifically with artificially regenerated (i.e., planted) Douglas-fir. Three broad topics were covered in the sessions: (1) fundamentals of forest vegetation management (processes involved when we change the microenvironment of a plant community and vegetation responds to the changes); (2) site preparation techniques (fire and mechanical techniques); and (3) competition release treatments (animal grazing, grass and forb seeding, mulching and grubbing, and manual cutting).

The workshop was organized into a series of sessions, each of which focused on a common technique in forest vegetation management without herbicides. Each session for a given technique began with a research synthesis or a description of current research presented by an authority on the subject. This was followed by two presentations on current applications of the technique in either moist (coastal) or relatively dry (montane or continental) forest ecosystems of the Pacific Northwest.

It was encouraging to see the commitment of workshop participants to forest vegetation management and their interest in alternatives to herbicides. About 180 people attended, representing a variety of organizations: USDA Forest Service (46% of attendees), Bureau of Land Management (16%), Bureau of Indian Affairs (11%), state governments including Oregon and Washington (7%), forest industry (7%), and miscellaneous groups from around the region (13%). Most attendees were from the Pacific Northwest; over 90% were from Oregon and Washington.

What is forest vegetation management? Walstad and Gjerstad (1984) define it as the practice of efficiently channelling limited site resources into useable forest products rather than into noncommercial plant species. This view suggests that some type of disturbance by humans is required to shift resource availability to desired plant species. As papers in these proceedings indicate, not all forest vegetation management re-

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

quires a disturbance; sometimes succession is shifted by favoring one plant species over another. But, in general, a disturbance is applied.

As forest succession proceeds following a disturbance, silvicultural treatments typically are linked to specific stages of stand development (Figure 1). For example, stand regeneration treatments are applied during early succession when conifers and hardwoods are small seedlings or sprouts. Later, when conifers are large enough that precommercial or commercial thinning would be applied, hardwoods have become large saplings or trees. A cycle is an appropriate symbol to illustrate this silviculture-stand development link

because we inherit, to a certain extent, the problems in forest vegetation management from previous stages of stand development. Examining this relationship gives us an opportunity to look at strategies.

A typical strategy in forest vegetation management has been to control competing vegetation after it has become a severe problem, thus requiring an intensive and often costly treatment. For example, aggressive competitors, such as salmonberry (*Rubus spectabilis*) and bigleaf maple (*Acer macrophyllum*), often are allowed to fully overtop and shade conifer crop trees before the need for a competition release treatment is identified. This strategy can be expensive because it attempts to control undesirable vegetation after it has become quite vigorous. An alternative strategy is to apply preharvest treatments when the competing species are subordinate to the conifers and are in a suppressed stage. Various alternative strategies were considered during this workshop.

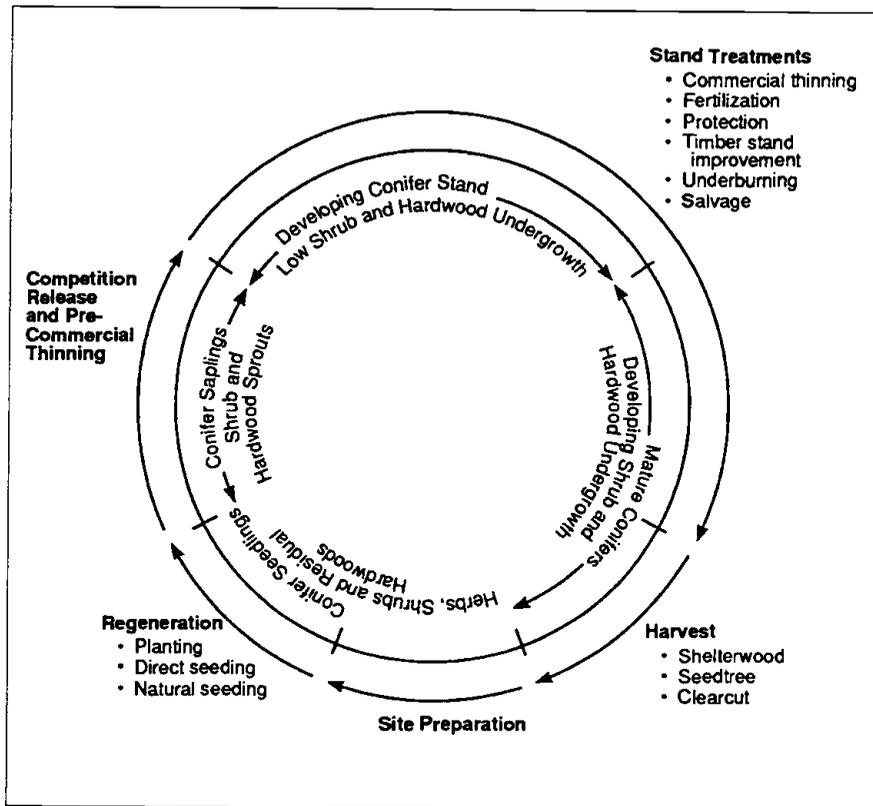


Figure 1. Conceptual diagram of even-aged stand management in forestry. Vegetation management considerations and opportunities exist throughout the cycle (modified from: Tappeiner and Wagner 1987; reprinted by permission of John Wiley & Sons, Inc., copyright© 1987).

Forest vegetation management is a broad topic. Over the years it has grown from its original focus on merely controlling vegetation that competes with crop trees to now encompass the introduction (i.e., seeding) and subsequent management of vegetation to favor species that are most compatible with conifer regeneration, as well as those that provide forage and habitat for wildlife. Now, with the availability of both herbicide and nonherbicide techniques in forest vegetation management, foresters can combine approaches in order to manage the plant community as a whole and create a desired composition and structure.

Recently, the management philosophies of public agencies have shifted such that silvicultural activities once focused on commodity-producing species are now being applied to sustain and, in some cases, to restore

the integrity and function of entire forest ecosystems. As a result, techniques in forest vegetation management have become even more relevant as attempts are made to enact changes in forest structure and species composition.

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FUNDAMENTALS OF FOREST VEGETATION MANAGEMENT

Microenvironmental Changes Following Forest Vegetation Management¹

PHILIP G. COMEAU
DAVID L. SPITTLEHOUSE

Introduction

Forest vegetation management involves manipulating vegetation and microenvironment to favor the survival and growth of crop trees or other desirable vegetation. To effectively achieve these objectives it is useful to know: (1) the environmental requirements for survival and growth of the crop species; (2) the effects of noncrop vegetation on the seedling microenvironment; and (3) the effects of treatments on the microenvironment of the crop.

Seedling microclimate is determined by the interaction of atmospheric conditions, site edaphic factors, and forest management activities. Atmospheric conditions (e.g., solar radiation, precipitation) strongly control microclimate. However, site edaphic factors (e.g., topography, soil type) and vegetation cover can significantly modify the effect of the atmospheric factors (macroclimate).

Microclimate influences physical and physiological processes of seedlings, which in turn affect their survival and growth. Microclimatic extremes can cause visible damage and may kill conifer seedlings. Sublethal effects can change growth rates and phenology, and may increase vulnerability of seedlings to other stresses, such as disease and pest damage.

The microenvironment after vegetation management treatment depends on a range of factors; some can be controlled and some cannot. Macroclimatic factors such as incoming solar radiation and precipitation, or site factors such as soil texture, cannot be readily modified. Vegetation cover and soil surface organic materials can be modified, and can significantly influence seedling microenvironment. However, we want to avoid creating new problems (e.g., frost damage, soil compaction) in our attempts to reduce the impact of competition on crop seedlings. This paper will discuss the effects of vegetation management treatments on the following microenvironmental factors: light, air temperature, soil temperature, soil water, and nutrients.

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

Light

Under laboratory conditions, needles from conifer trees reach maximum rates of photosynthesis at about 40% of the intensity of full summer sunlight. However, because mutual shading occurs within shoots and within tree crowns, trees or seedlings usually achieve maximum growth at full sunlight.

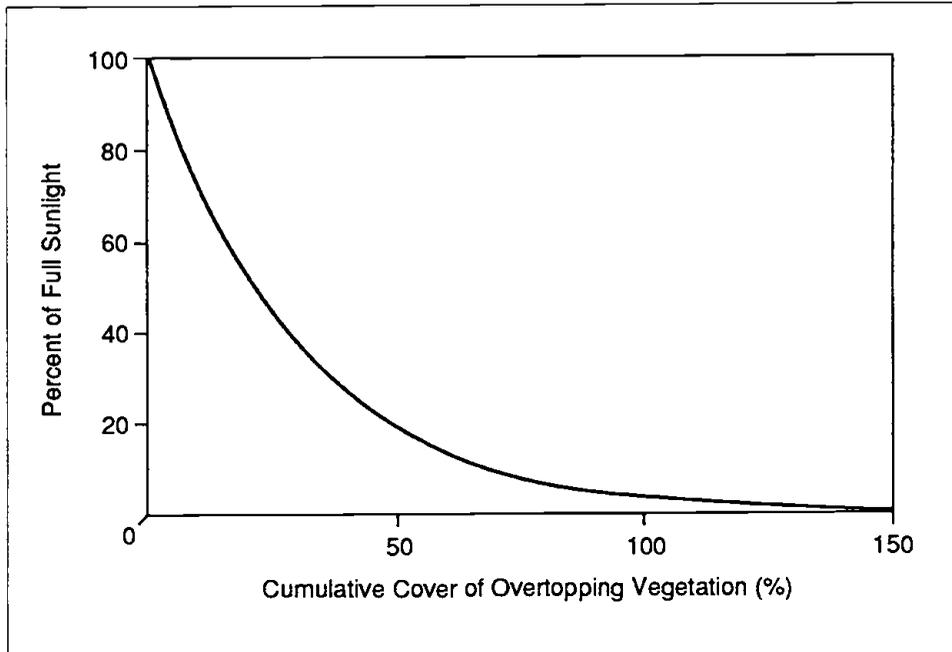


Figure 1. The relationship between available light and vegetation cover. Seedling growth will decline as available light decreases (source: Comeau and Braumandl 1991).

The amount of light that reaches tree seedlings decreases as the cover or leaf area of overtopping vegetation increases (Figure 1). Treatments that reduce the amount of overtopping vegetation will increase the availability of light to seedlings and reduce the risk of vegetation press (i.e., smothering by overtopping vegetation under conditions of heavy snowfall).

Air Temperature

The rates of many plant processes (photosynthesis, respiration, water uptake, and transpiration) are affected by temperature. Optimum air temperatures for photosynthesis and growth of conifers are between 10°C and 25°C. Most conifers that are exposed to temperatures over 50°C for a prolonged period will suffer tissue damage and reduced survival.

photosynthesis and growth of conifers are between 10°C and 25°C. Most conifers that are exposed to temperatures over 50°C for a prolonged period will suffer tissue damage and reduced survival.

Air temperatures are influenced by macroclimate, soil organic layers, and vegetation cover. Overtopping vegetation provides shade, which reduces daytime air temperatures on the ground surface. On warm, south-facing slopes, vegetation cover can reduce the incidence of lethal temperatures near the ground.

Exposure of conifers to nighttime air temperatures lower than -3°C to -5°C during the growing season can cause tissue damage. Risk of frost is greater in dry climates where clear night skies are common, at high elevations, and in areas where cold air accumulates (Steen et al. 1990).

Seedlings growing under vegetation canopies are generally more protected from radiative frost (i.e., rapid cooling that occurs under clear night skies) because most of the cooling occurs at the top of the canopy (Stathers 1989). Removal of overtopping vegetation may increase frost damage in frost-prone environments, particularly if soil organic layers are undisturbed. Exposing mineral soil by mechanical treatments, such as scalping or ripping, may reduce the incidence of frost damage by improving heat exchange between the soil and air (Figure 2).

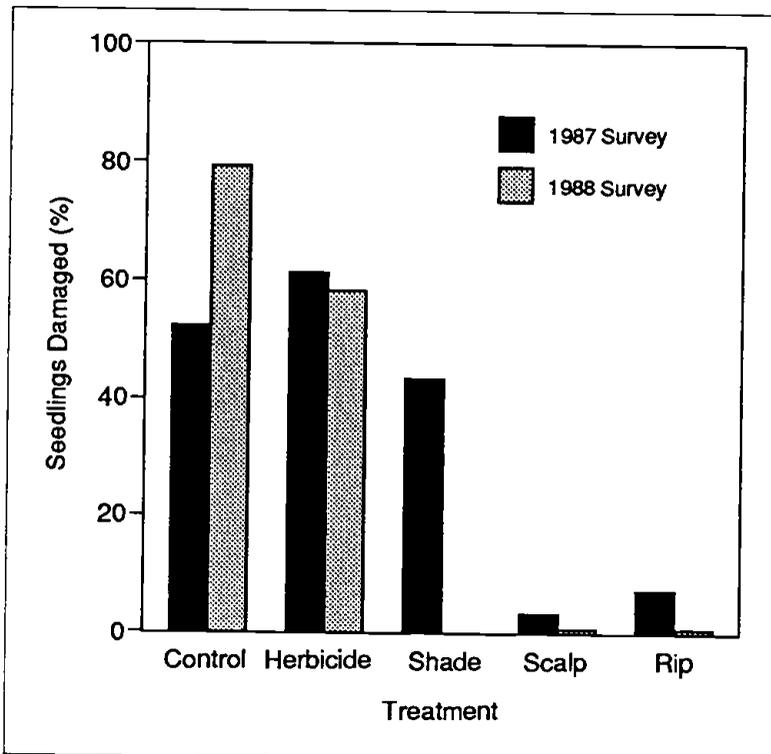


Figure 2. Effects of site preparation treatment on frost damage to Engelmann spruce (*Picea engelmannii*) seedlings at a site near Kamloops, B.C. Vegetation was dominated by pinegrass (*Calamagrostis rubescens*) and bluejoint reedgrass (*Calamagrostis canadensis*). Seedlings were planted in the spring of 1987. Mechanical site preparation treatments that remove the grass canopy and soil organic layer reduced frost intensity and frost injury (source: Black et al. 1991).

A short, dense grass canopy can increase the incidence of frost damage to seedlings. Dense grass cover can create a stagnant air layer with low temperatures near the level of maximum canopy density. Removing the grass canopy can reduce frost damage by increasing air movement and soil heat storage.

Soil Temperature

Soil temperatures are influenced by soil physical characteristics (e.g., surface organic layers, texture, and moisture content), macroclimatic conditions, and vegetation cover.

Low soil temperatures reduce the metabolic activity, water absorption ability, and growth rate of roots. In cool or cold environments, vegetation cover and surface organic matter can delay soil warming and, thus, limit soil temperatures (Figure 3). Removing vegetation cover and soil organic layers and improving drainage of wet soils can increase soil warming and improve growth where low soil temperature is a limiting factor.

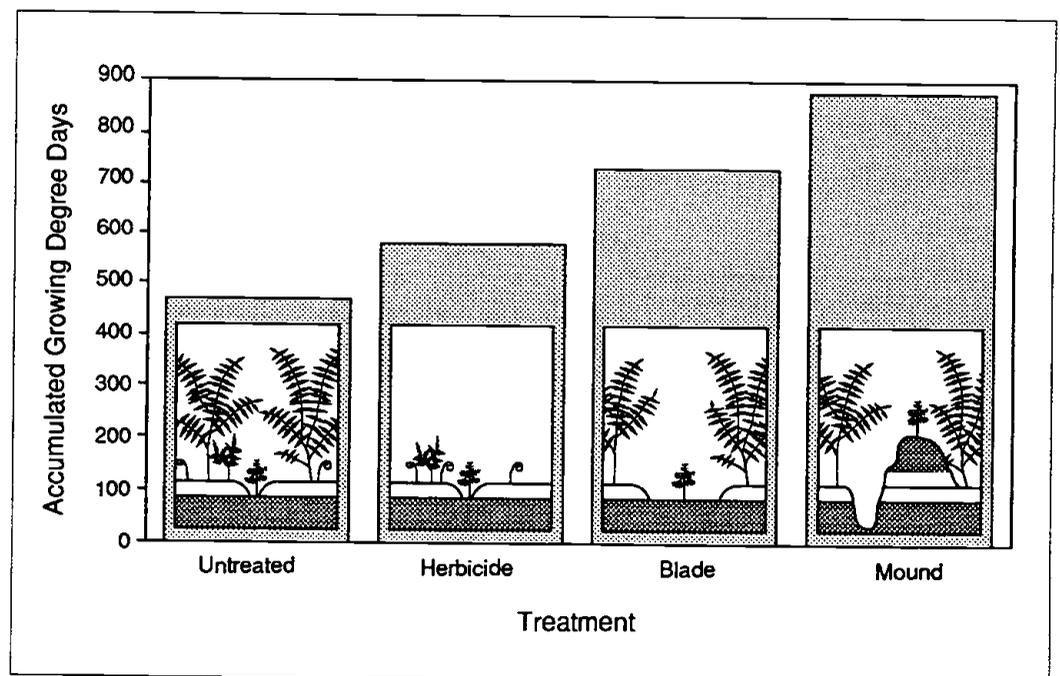


Figure 3. The effect of site preparation treatments on accumulated growing-degree days (5°C base temperature) at a soil depth of 10 cm for a site in the Sub-Boreal Spruce Zone (elevation 1100 m) near Prince George, B.C. Ladyfern (*Athyrium filix-femina*) is the dominant competitor, and the soil is a wet silty loam (source: Stathers and Spittlehouse 1990).

Soil Water

Soil water provides a medium for many biochemical reactions in plant cells and for the transport of organic molecules, inorganic ions, and gases. An adequate water supply is required to keep stomata open for transpiration and photosynthesis.

Plants have evolved a variety of water-use patterns. Conifers have a conservative pattern whereby stomates close and transpiration and photosynthesis are reduced when plant water potential reaches specific threshold values. In contrast, salal (*Gaultheria shallon*), pinegrass (*Calamagrostis rubescens*), and ceanothus (*Ceanothus* spp.) do not rapidly close their stomates at the onset of moisture stress; with their extensive root systems, they are able to continue transpiring water under conditions that would cause conifer seedlings to close their stomates.

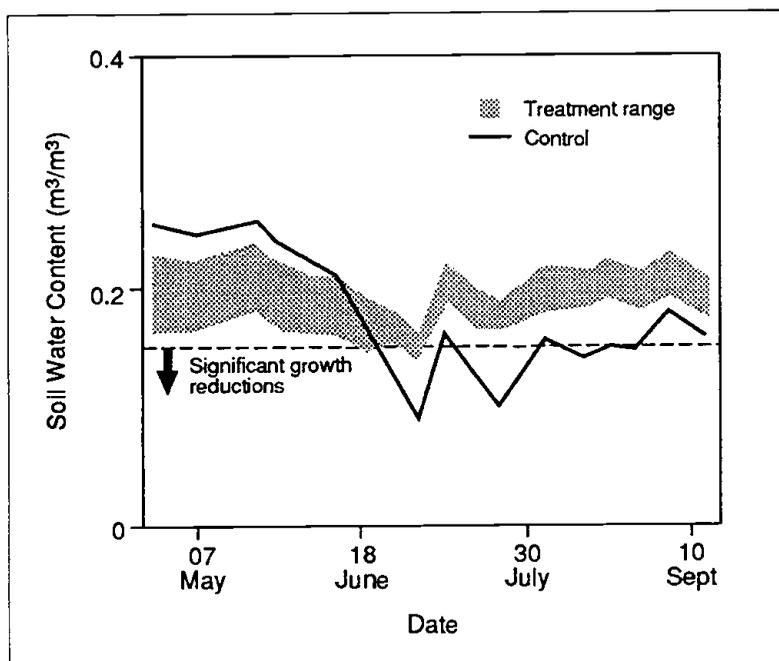


Figure 4. Soil water content over the growing season for Douglas-fir (*Pseudotsuga menziesii*) at a site near Fehr Mountain (elevation 1220 m) near Kamloops, B.C. The treatments were scalping, ripping, and herbicide application. The dashed line indicates water content (15%) corresponding to a soil water potential of -0.2 MPa (field capacity). Seedling water stress and reduced growth are expected to occur at soil water levels below this value (source: Black and Mitchell 1990).

The use of soil water by noncrop vegetation often results in soil moisture deficits (Figure 4) and reduced crop tree growth. Both understory and overstory vegetation can compete with conifers for water. Treatments that reduce vegetation cover will improve soil moisture availability by reducing water loss via transpiration.

Nutrients

Several mineral nutrients are essential for tree growth. Soil nutrient availability depends on the total amount present, the amount available for uptake, the rate of uptake by trees and noncrop vegetation, and the rate of replenishment to the soil.

Competing noncrop vegetation may reduce soil nutrient supplies. Also, some plants [e.g., salal and other species in the heath family (*Ericaceae*)] may effectively slow the rates of organic matter decomposition and nutrient cycling such that nutrients are tied up in live or dead plant material and are not available to crop seedlings. Vegetation control may improve nutrient availability and crop tree performance in situations where competing vegetation has captured a significant portion of total supplies or inhibited nutrient cycling. In addition, increased soil temperatures or soil moisture under reduced vegetation cover may improve nutrient availability by increasing rates of nitrogen mineralization.

Noncrop vegetation may also contribute to nutrient supplies by symbiotic nitrogen fixation [e.g., red alder (*Alnus rubra*), ceanothus, Scot's broom (*Cytisus scoparius*)], by accelerating nutrient cycling with improved litter quality, and by retaining nutrient supplies after disturbance. How-

ever, these long-term benefits to site quality must be balanced against the detrimental effects of competition for other resources such as light.

Treatments that remove only vegetation have little effect on total amounts of soil nutrients. Displacement or removal of soil organic layers and surface mineral horizons during mechanical site preparation or prescribed burning can reduce site nutrient supply. Treatments that mix or mound soils can help warm the soils and accelerate mineralization rates.

Vegetation management treatments rarely modify only one aspect of a seedling's microenvironment. Removal of surface organic matter can improve the soil thermal regime, but the accompanying loss of nutrients may reduce long-term site productivity. On cold, wet sites, mounding treatments may improve soil warming without losing soil nutrients and can elevate seedlings above wet soils.

Summary

Reducing vegetation cover by use of herbicides, manual or mechanical techniques, livestock grazing, or other methods increases light, soil water, and nutrient availability to crop seedlings and can result in soil warming. The net benefit to crop seedlings depends upon the duration of treatment effects. Manual cutting or browsing of competing vegetation may only improve conditions during the growing season in which they are applied, while herbicide or mechanical site preparation treatments may improve growing conditions for 2 or more years.

Treatment effects depend on climate, topography, soil characteristics, and vegetation cover. Identifying the microenvironmental factors that are limiting or are likely to limit crop performance is essential to the selection of appropriate treatments. For example, removal of overtopping vegetation in frost-prone areas may increase frost damage if treatments do not include mechanical disturbance of soil organic layers.

The individual effects of a specific vegetation management treatment on seedling microclimate vary (Table 1). Such information should be

Table 1. Effects of selected vegetation management treatments on seedling microenvironment. Increase or decrease refers to a change relative to no treatment of dense competing vegetation (modified from Spittlehouse and Stathers 1990).

Site treatment	Light	Frost hazard	Soil temperature	Soil moisture	Soil nitrogen availability	Area of impact	Duration (yrs)
Herbicide	Increase	Increase	Increase	Increase	Increase	Either whole site or around seedlings	2-5
Mulch	Increase	Increase	Decrease	Increase	No effect	Around seedlings	2-5
Scalp	Increase	Decrease	Increase	Increase or Decrease	Decrease	Around seedlings	>5
Burn	Increase	Decrease	Increase	Increase	Decrease or Increase	Whole site	>2
Rip	Increase	Decrease	Increase	Increase	Increase	Whole site	>3
Rototill	Increase	Decrease	Increase	Increase	Increase	Around seedlings	>3
Mound	Increase	Decrease	Increase	Decrease	Decrease	Around seedlings	>3

considered along with site conditions, treatment feasibility, equipment availability, cost, and impacts when choosing an appropriate treatment.

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Changes in Physiology and Morphology of Conifer Seedlings Following Forest Vegetation Management¹

TIMOTHY B. HARRINGTON
SAMUEL S. CHAN

Introduction

Understanding physiological and morphological responses of conifers to their environment is vital for the cost-effective practice of forest vegetation management. However, the answers to the following questions are often not intuitively obvious:

- What factors in a given environment most limit conifer response?
- What intensity of vegetation management is required to create a desired conifer response?
- At what levels of competitive stress will conifers respond to vegetation management?

Given the complexity of linkages between environmental factors and conifer growth responses, it is important to realize the limitations of treatments in forest vegetation management. In general, silvicultural inputs can only be directed toward the genetics of the tree and the environment in which it is growing (Figure 1). Conifer growth is driven by the physiological and morphological responses to environmental conditions and genetic potential.

This paper will discuss the following topics:

- Conifer responses to changes in microenvironment following vegetation management.
- Indicators of competitive stress in conifers.

Conifer Responses to Changes in Microenvironment

Individual plants respond to their environment primarily at the microsite level. High levels of competition can mask the responses of individual plants to microsite variability such that all plants perform similarly (Figure 2). When competition is reduced, other components of microsite variability are ex-

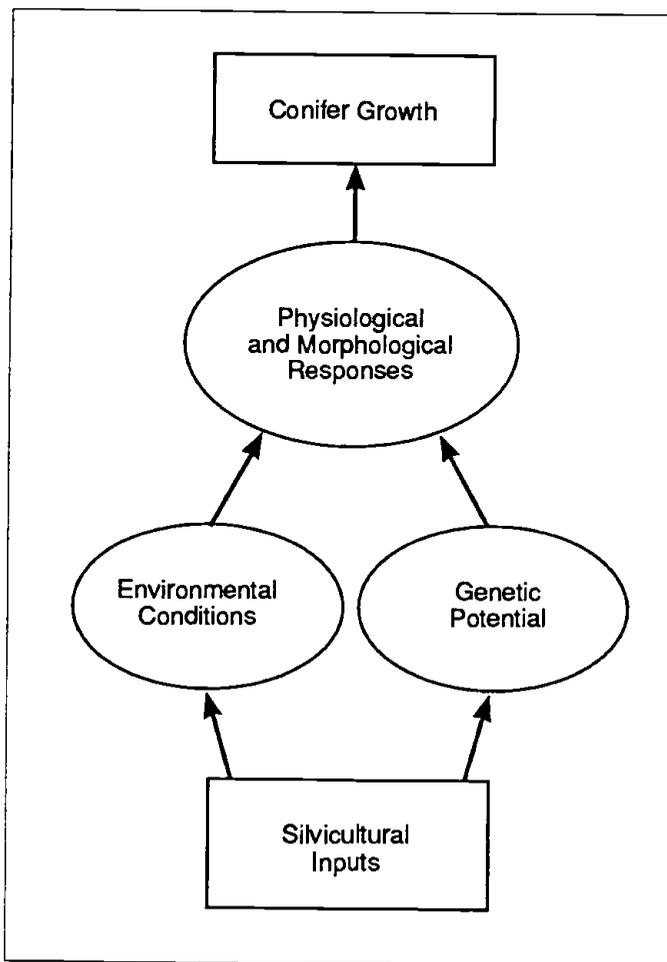


Figure 1. Silvicultural inputs indirectly influence growth. Achieving forest regeneration goals requires an understanding of the factors that drive growth.

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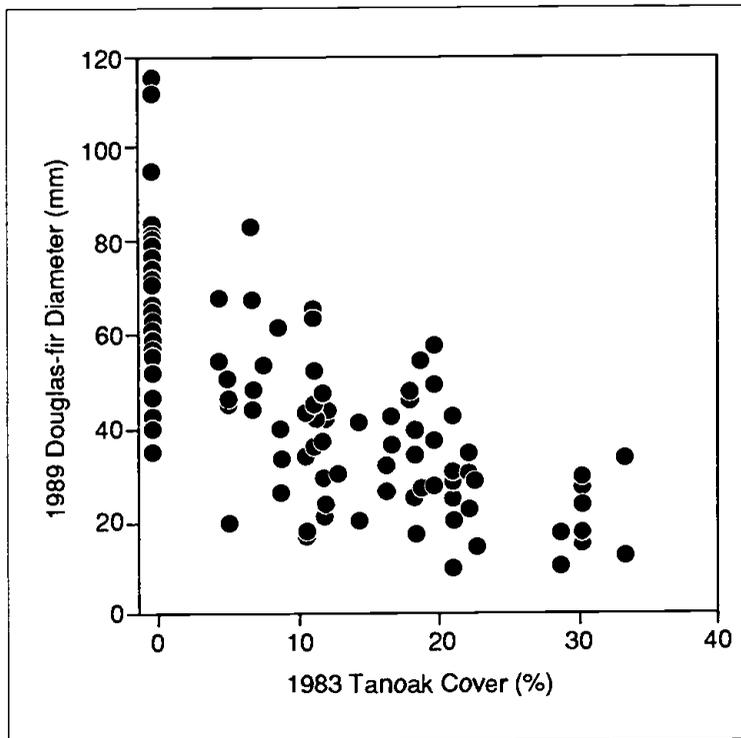


Figure 2. Variation in stem diameter of individual Douglas-fir 6 years after reducing cover in tanoak sprout clumps to various levels. Increasing variation in conifer response with decreasing competition can be attributed to microsite characteristics (source: T.B. Harrington, University of Georgia, Athens, unpublished data).

posed, and a wider range of plant responses are typically observed. When conifer seedlings are planted in "good" microsites (e.g., microsites near stumps from a healthy previous stand; locations where a tree was able to grow well), it is more likely that optimal conifer performance will result from vegetation management.

Environmental stress from competition can be expressed by plants in the form of slowed growth, restricted morphological development, and at the extreme, mortality. Suboptimal environmental conditions are usually the rule rather than the exception in forest ecosystems. It is difficult to diagnose the level of competitive stress in conifer seedlings without knowing their potential response when competing vegetation is absent. With time, a conifer will integrate the characteristics of its microsite (i.e., presence or absence of stresses) into the morphological features it displays. In a highly stressful environment (e.g., one with prolonged shade from overtopping vegetation), irreversible morphological changes can occur, resulting in reduced growth and an increased likelihood of mortality.

Vegetation management treatments are applied to reduce the stress that most limits conifer performance. However, in general, forest communities recover rapidly after a vegetation management "disturbance;" therefore, there is only a relatively brief window of opportunity in which a conifer can respond to increased resource availability. Growth and survival thresholds define the vegetation management intensity needed to produce a significant conifer response (Wagner et al. 1989). A threshold is reached when a given treatment intensity causes an abrupt positive change in conifer response. It is the forester's job to determine if the magnitude of the conifer response is sufficient to justify a given intensity of vegetation management.

Physiological Responses

The specific resource and the degree to which its availability is increased depend on whether a vegetation management treatment reduces plant cover that overtops or that is subordinate to a conifer. Reducing overtopping cover via nonherbicide techniques, for example, immediately increases light availability to the conifer. Any realized responses will be governed by the tree's current physiological and morphological status, which is a manifestation of the intensity and duration of shade to which it has been exposed.

Conifer responses also depend on the timing of the treatment. Shade-adapted conifers that are suddenly exposed to high levels of light energy

may experience chlorosis and loss of foliage, symptoms commonly referred to as "thinning shock." Such symptoms do not persist if conifers have sufficient leaf area for "maintenance" growth (i.e., viable buds on the main stem and branches). Shock symptoms can be minimized if the overtopping cover is reduced during the winter when sunlight intensity is at a minimum. Tree growth usually accelerates after the needles have acclimated to the higher light conditions and the foliage from the newly expanded buds has begun to photosynthesize. Also, root growth eventually increases, resulting in a lower, more balanced ratio of root biomass to shoot biomass.

Removal of overtopping cover with manual cutting treatments will increase soil water availability, but only until the recovering vegetation develops enough leaf area to completely consume available soil water (usually less than one or two growing seasons). Conifers respond to the increased water availability by decreasing the tension with which water is held in their vascular tissue (i.e., plant moisture stress). Freer movement of water through the plant results in increased efficiency of vital cell functions, such as metabolism and nutrient transport.

At higher elevations or frost-prone areas, removal of overtopping cover may increase the likelihood of frost damage to a conifer seedling, but it may also initiate earlier conifer growth (bud break and root growth) because warming of the soil will occur earlier in the spring.

Reduction of subordinate vegetation cover is most beneficial when soil moisture is at or near field capacity so that soil water availability will be prolonged during the growing season. The onset of soil moisture stress levels that greatly reduce conifer photosynthesis (-2.0 MPa or -20 bars) will thus be delayed until late August. Generally as summer progresses, the threshold of water stress that causes a substantial reduction in photosynthesis occurs progressively earlier in the day such that at the peak of the drought, conifers assimilate little or no net carbon.

Morphological Responses

A conifer's morphology can be viewed as an integration of its physiological history. An effective competition release treatment initiates a recovery process during which a conifer produces more crown and root growing points (Table 1), and eventually has an absorptive architecture that assimilates light energy, water, and nutrients more efficiently. Because conifer morphology integrates a series of physiological events that were driven by changes in environmental conditions, it is difficult to distinguish morphological changes which result from a reduction in overtopping cover versus those from a reduction in subordinate cover.

However, several distinct morphological changes are associated with increased light availability to conifers. For example, when overtopping cover is reduced, thin, shade-adapted needles become thicker and have a higher internal surface area of CO₂-absorbing mesophyll tissue. Release from overtopping cover generally accelerates conifer height growth. Height:diameter ratios, which indicate degree of light deprivation, tend to decrease from values over 100 for shaded conifers to more optimal values near 50.

Table 1. Changes in conifer morphology following vegetation management treatments that reduce vegetation cover.

Cover type	Morphological variable	Units	Change
Overtopping	Height growth rate (daily or yearly)	cm	Increase
	Height:diameter ratio	cm/cm	Decrease
	Specific leaf area	cm ² /g	Decrease
Overtopping or subordinate	Diameter growth rate (daily or yearly)	mm	Increase
	Diameter growth duration	days	Increase
	Lammas growth frequency	% of conifers	Increase
	Lammas growth	cm	Increase
	Bud number per shoot	no.	Increase
	Bud size (length x width)	mm ²	Increase
	Needle number per shoot	no.	Increase
	Interneedle spacing	mm	Increase
	Leaf area ratio (leaf area/biomass)	cm ² /g	Decrease

When vegetation management increases both light and water, the growing season becomes longer for cambial growth but not for height growth of conifers. Daily growth rates also increase; however, the increased rates of height growth are related more to the number of primordia (undeveloped stem internodes and leaves) stored within the bud from the previous growing season than to current physiological activity. The extent of shoot elongation between adjacent needle primordia is regulated by physiological processes that are dependent on current environmental conditions.

Shoot growth in conifer trees that set a winter bud (determinate growth) is largely a function of the number of primordia that developed in the previous year. Since bud size directly indicates the number of stored primordia, it can be used to predict the next year's height growth. Some of the variation in conifer height growth can be attributed to current-year growing conditions. This variation can be manifested as changes in interneedle spacing. A symptom of thinning shock that commonly follows manual cutting is a temporary loss of needles and a decrease in interneedle spacing.

Carbohydrates from enhanced photosynthetic activity help develop new growing points, which lead to increases in bud number and size. When the buds on a conifer are viewed as a population (each bud produces 1 to 15 new buds), an additive increase in current-year bud number leads to an exponential increase in bud number during subsequent

years. Such increases accelerate the development of conifer leaf area (Harrington and Tappeiner 1991), which is the primary determinant of whole-plant photosynthesis (Harrington 1989).

Indicators of Competitive Stress for Conifers

Because physiology and morphology are closely linked, visual examination of a conifer clearly indicates its competitive status (Figure 3). Conifers with the following characteristics on their terminal or prominent lateral shoots are probably under severe competitive stress: a few, small buds (1-4); compressed interneedle spacing (i.e., "bottle-brushing"); a few, short needles. These morphological characteristics indicate that minimal net carbon is assimilated each year and, therefore, marginal annual increases in crown development can be expected. In southwestern Oregon, Douglas-fir saplings that are free from competition have average annual rates of

photosynthesis that are almost 200 times higher than rates for saplings overtopped by evergreen hardwoods (Harrington 1989). Thus, when conifers with low vigor become completely overtopped by vegetation, mortality is likely—although it may not occur for 5 or more years.

Several good indicators exist for assessing availability of light and soil water. Howard and Newton (1984) and Chan and Walstad (1987) describe methods by which light availability can be estimated from the amount of shade cast by overtopping vegetation on an individual conifer (i.e., percent overtopping). Their research has shown that the percent overtopping cover is a good index of a conifer's ability to thrive at a site. High values of percent overtopping (>60%) usually indicate that conifers will have reduced height growth.

Availability of soil water to individual conifers can be assessed with a pressure chamber. Given that significant precipitation has not just occurred, predawn measurements of plant water stress taken in late summer can be compared

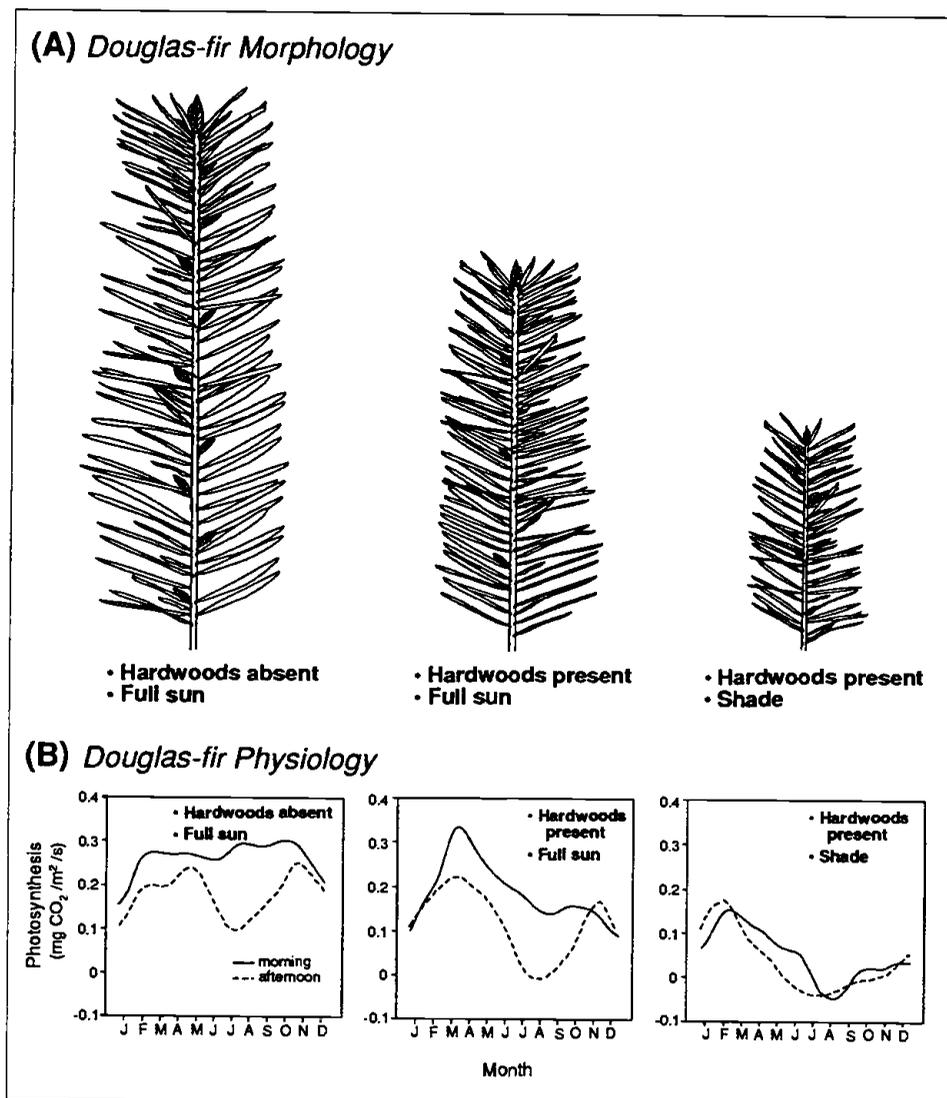


Figure 3. Generalized responses of Douglas-fir (A) morphology and (B) physiology to three regimes of hardwood competition in southwestern Oregon (source: Tappeiner et al. 1992).

among treatments to determine if soil water availability has been increased by vegetation management. Values less than -1 MPa (-10 bars) indicate that soil water availability is limiting conifer growth and photosynthesis.

Morphological assessments provide an integrative index of the competitive stress being endured by a given conifer. The number and size of buds on the terminal shoot indicate the potential for future crown development. Well-developed crowns (many buds; well-distributed foliage biomass) indicate a high probability for a conifer's long-term dominance at a site.

The best strategy for managing overtopping cover is to apply treatments before conifers become adapted to shade conditions. This minimizes delays in growth responses that result when a conifer must undergo rapid and dramatic morphological changes in order to adapt to its new environment. Treatments to reduce subordinate cover should be implemented when soil water is at or near field capacity.

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WHAT'S NEW IN FOREST VEGETATION MANAGEMENT WITHOUT HERBICIDES

L'il Beaver Stem Girdling System¹

GRAHAM B. ALBERTSON

When we cut our forested land, we assume responsibility for the management of that land. The objectives of this management can be diverse, but the techniques employed are relatively few. We can either add or enhance species, or take away or suppress species; the latter has often been done with chemicals. This paper will discuss an economical, efficient, viable alternative, the *L'il Beaver Power Girdler*.

Girdling is a very old technique that removes a band of outer bark as well as the phloem and the cambium from all the way around a tree. This process blocks the flow of photosynthates and the hormone auxin from the leaves to the roots. The sapwood, or xylem, is not cut in a properly girdled tree, thus retaining structural support and the flow of the hormone cytokinin from the roots to the leaves. When properly girdled, trees of many species will die slowly (it can take 1 1/2 to 4 seasons) and they will not coppice. The girdle must be below all live lower limbs.

A girdled tree retains at least some of its leaves until it dies, which inhibit light to new coppices. This also inhibits an increase in the soil temperature at the roots. These factors plus the high cytokinin-auxin ratio in the roots suppress coppicing (Bancroft 1987, 1989).

The *L'il Beaver Power Girdler* (Figure 1) is a simple, mechanically-driven cutting device built for difficult industrial use. It is comprised of a 35-cc chainsaw-type motor, mounted on a backpack frame, attached to a cutting head via a flexible drive shaft. The cutting head contains one long length of chainsaw chain. The operator is connected to the tool by a forearm grip, which allows safe one-handed operation. Because the operator can reach the tool around a tree or within a clump of trees with one hand, he or she can completely girdle a tree without having to move all the way around it. The operator's free hand can be used for support when cutting behind the tree or in other difficult positions.

The *L'il Beaver Power Girdler* produces a girdle that is 1 1/4 in. or larger in width. This large size allows the operator and the forester to check the quality of the girdle. Depth of the girdle is critical. Chainsaw girdling often cuts too deep into the sapwood, and this can cause treatment failure due to early blowdown, followed by coppicing. Girdling is not the only job required of this tool. It must, and does, have the ability to cut a stem or branch all the way through.

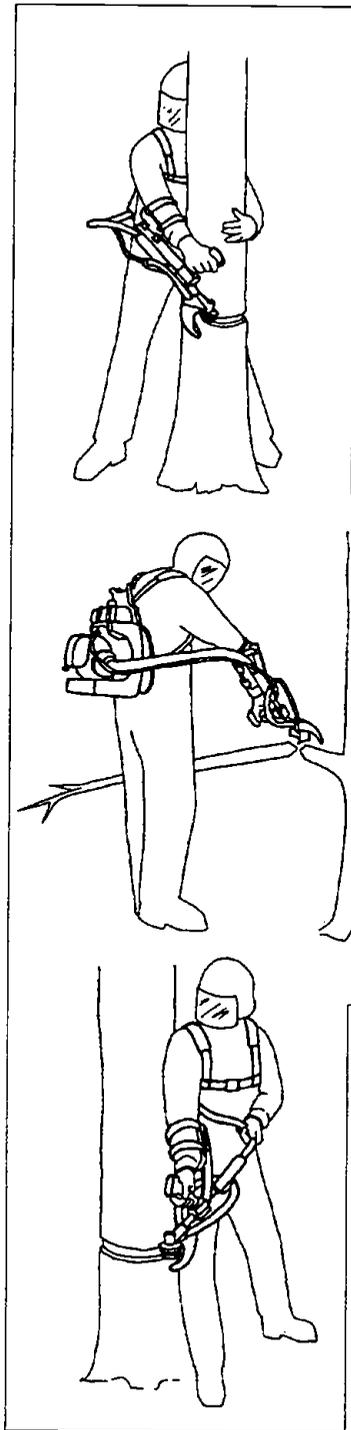


Figure 1. *L'il Beaver Power Girdler* for girdling large trees as well as cutting branches—safe, one-handed operation!

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

This equipment has been used to treat both red and Sitka alder (*Alnus rubra* and *A. sinuata*), aspen (*Populus tremuloides*), black cottonwood (*P. trichocarpa*), balsam poplar (*P. balsamifera*), black and paper birch (*Betula occidentalis* and *B. papyrifera*), both vine and bigleaf maple (*Acer circinatum* and *A. macrophyllum*), willow (*Salix* spp.), and all types of conifers. The results of this treatment have been excellent with the exception of willow and bigleaf maple.

Seven-year-old red alder girdled to a dbh of 1 in. was standing dead within 18 months (K. McGourlick, Western Forest Products, Port McNeil, B.C., unpublished data). Twelve- to fifteen-year-old alder was dead and lying flat, hinged at the root collar, at 3 years (S. Chambers, MacMillan Bloedel, Port McNeil, B.C., unpublished data). The size of the leaves of large older trees is reduced vastly after 1 year of treatment (L. Entzminger, Ministry of Forests, Bella Coola, B.C., unpublished data). Willow coppices from below the girdle, especially on an isolated tree. Efficacy studies are ongoing, and a list of foresters who have used this equipment is available.

The range of treatments for which this tool can be used includes thinning of both hardwoods and conifers, releasing conifers from hardwood competition, controlling trees on electrical transmission rights-of-way, creating wildlife and raptor trees, and excising cankers of white pine blister rust. The girdling of conifers can greatly reduce the fuel load inherent in current thinning techniques. Preharvest girdling offers substantial savings in postharvest brush control. On a site on the Peace River in northern British Columbia, preharvest girdling reduced the brush component of postharvest material by about 85%. Substantial savings could be realized with long-term planning and careful, practical forestry.

To offer a viable alternative to the use of herbicides, a tool has to be at least as effective and productive as individual stem injection. Since 1988, the *L'il Beaver Power Girdler* has been used on over 6,776 ha (16,737 acres) and a wide variety of sites; the average productivity of this tool has been over 1.1 ha (2.72 acres) per operator-day (D. Brinkman, Brinkman & Associates Reforestation Ltd., New Westminster, B.C., unpublished data). Productivity varied from 0.2 to 5 ha (0.5 to 12 acres) per operator-day, depending upon stand density and operator skill. It usually takes a new operator about 4 days to become proficient with this tool.

The *L'il Beaver Power Girdler* provides another potentially useful tool for forest vegetation management.

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A Regional Model for Predicting Stand Development Following Forest Vegetation Management¹

STEVEN A. KNOWE
ROBERT G. SHULA

CRAFTS (Coordinated Research on Alternative Forestry Treatments and Systems) and the USDA Forest Service (Region 6) are jointly developing what is currently called the Regional Vegetation Management Model. The objectives are to (1) develop a growth and yield model for young Douglas-fir (*Pseudotsuga menziesii*) stands in the Coast and Cascade Ranges, and Siskiyou Mountains; (2) provide a link to growth models for older Douglas-fir plantation or stand growth simulators like DFSIM, ORGANON, and PROGNOSIS; (3) develop growth and yield models for some of the major associated hardwoods like bigleaf maple (*Acer macrophyllum*), red alder (*Alnus rubra*), and tanoak (*Lithocarpus densiflorus*) that are common in this region; and (4) interface with vegetation treatment effects models like VEGPRO.

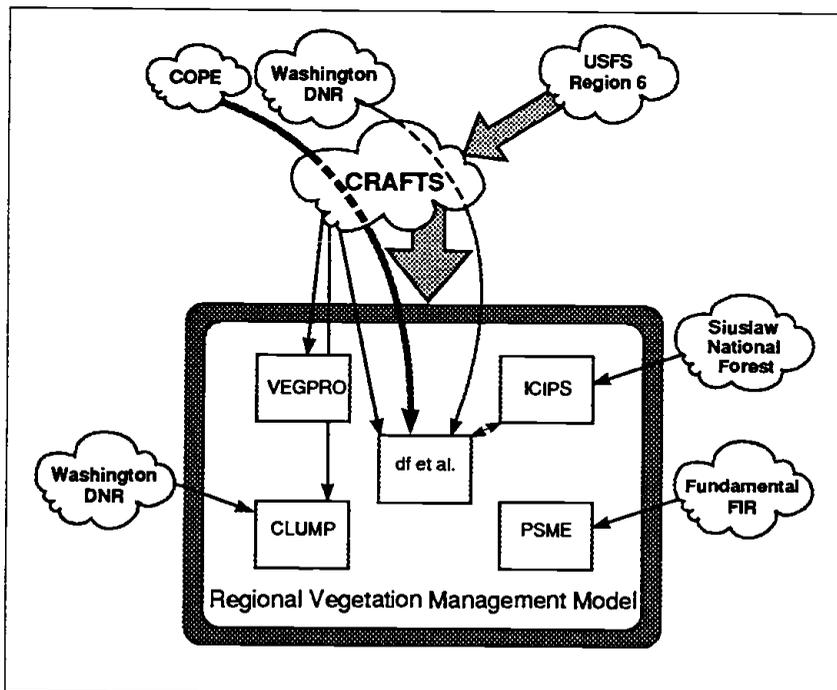


Figure 1. Component prototype models and associated funding sources (indicated by arrows) that have accelerated the evolution of the Regional Vegetation Management Model.

Figure 1 shows some of the funding sources that have been used to develop this model. The project started in 1986 with the development of ICIPS (Interspecific Competition Index Projection System), which was funded by the Siuslaw National Forest. Various other organizations have also been significant contributors, including FIR (Southwest Oregon Forestry Intensified Research) program, COPE (Coastal Oregon Productivity Enhancement) program, Washington Department of Natural Resources, and CRAFTS. Their contributions enabled the development of the precursor models *df et al.*, PSME, and CLUMP—components of which will be included in the Regional Vegetation Management Model. In 1990, Region 6 of the USDA Forest Service provided a very large grant to help finalize the project.

Figure 2 shows conceptually how the model will operate. The user will start with an existing stand, or a hypothetical stand will be created based on preharvest conditions, site productivity, and site preparation. Characteristics of the stand will be input to the growth models for conifer, hardwood, shrub, and herbaceous vegetation. The output from these models will provide inputs for

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

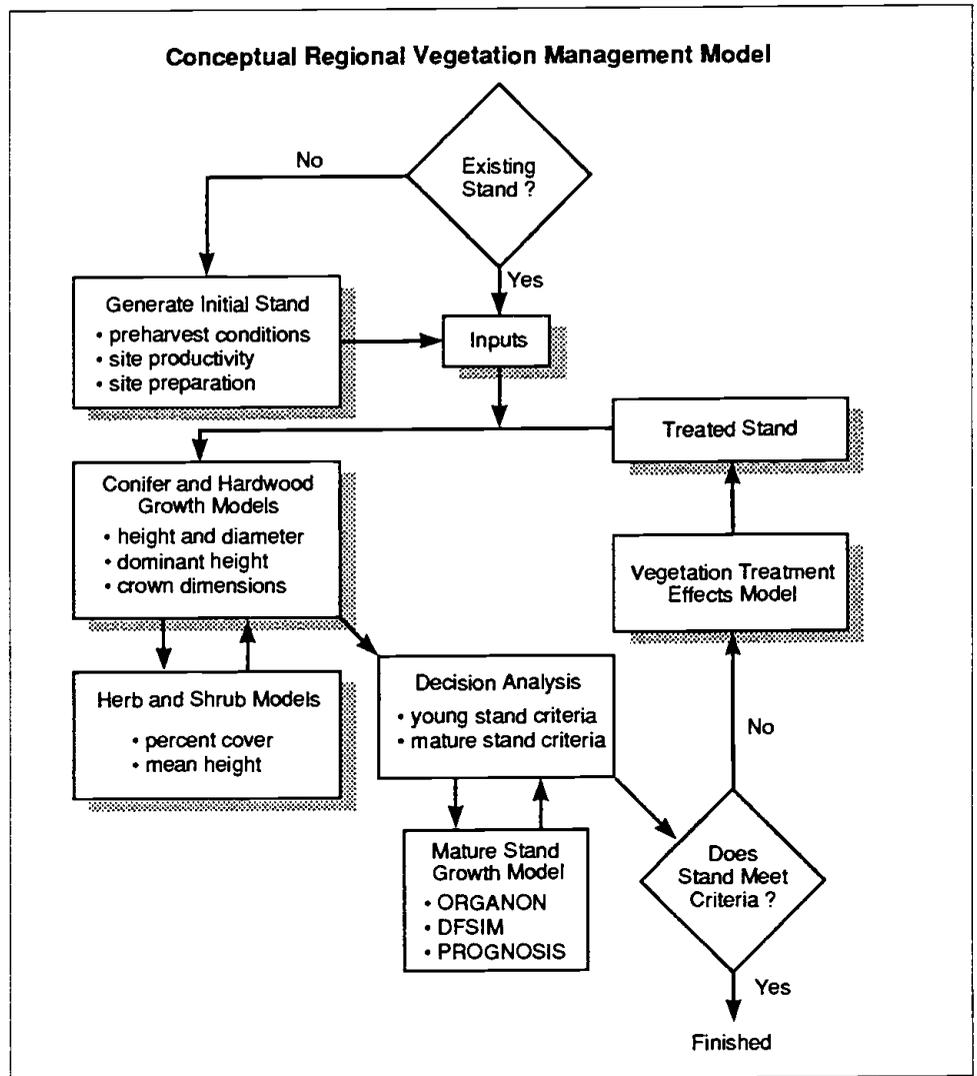


Figure 2. Conceptual flow chart of modules (boxes with shadows) and user interfaces (boxes without shadows) for the Regional Vegetation Management Model.

the older stand models like ORGANON, DFSIM, and PROGNOSIS. A decision analysis will not be incorporated directly into the model because different management objectives have different economic, biological, and social bases. The final step is to decide whether the stand meets the criteria that were initially defined. If not, the user can access a database in the treatment effects model to reassess treatment efficacy and vegetation recovery times, and then return to the growth models. Different treatments can be tested until management objectives are met.

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New Research on Herbaceous Vegetation Management in Conifer Plantations¹

D. ERIC HANSON
TIMOTHY B. HARRINGTON

Plant communities can undergo fairly rapid changes after a disturbance. For example, in the first 2 years after clearcutting and slashburning in the Oregon Coast Range, groundsel (*Senecio sylvaticus*) is often the dominant species of herbaceous vegetation. However, by the fourth year, foxglove (*Digitalis purpurea*) has replaced groundsel as the dominant species. CRAFTS (Coordinated Research on Alternative Forestry Treatments and Systems), Oregon State University's research cooperative on forest vegetation management, is currently researching the interactions between herbaceous vegetation and young conifers (Figure 1). The overall objective of this program of research is to improve our understanding of plant interactions during early succession to enable silviculturists to more effectively prevent or control competing vegetation and meet their management objectives.

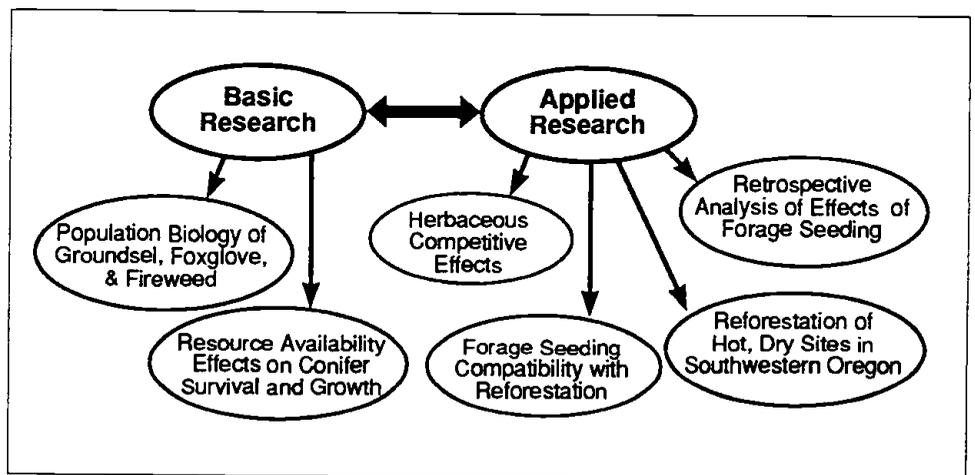


Figure 1. CRAFTS' basic and applied research on herbaceous vegetation management. Text within each oval summarizes the topic of an individual study on management and biology of herbaceous vegetation in plantations of Douglas-fir.

A study to quantify the competitive effects of herbaceous vegetation on Douglas-fir (*Pseudotsuga menziesii*) seedlings in the Coast and Cascade Ranges is currently under way. The objective of this study is to quantify the thresholds of competition beyond which herbaceous vegetation management becomes cost-effective. Herbicides are being used to create various levels of herbaceous competition with and without removal of associated woody vegetation. These treatments are being com-

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

pared to seeding with a native grass, blue wild rye (*Elymus glauca*); the hypothesis is that grass seeding may inhibit germination and survival of the more competitive shrub and hardwood species.

Because herbicide use is restricted on public lands in southwestern Oregon, reforestation techniques have often included competition-release treatments such as paper mulching, scalping, and manual cutting. The efficacy of these treatments is poorly understood and has not been properly quantified. CRAFTS is studying the morphological and growth responses of Douglas-fir and ponderosa pine (*Pinus ponderosa*) seedlings on difficult-to-regenerate sites in order to develop a system for monitoring plantation establishment and for predicting the need for a release treatment. The rationale for this research is that conifer responses can be used as indicators of competitive stress and, thus, the need for vegetation management.

Grass and legume species are currently being seeded on public lands to enrich forage for Roosevelt elk (*Cervus elaphus roosevelti*), yet such herbaceous vegetation can be highly competitive with conifer seedlings. In a study that is co-sponsored by the Willamette National Forest and the Oregon Department of Fish and Wildlife, CRAFTS will determine the compatibility of various species mixtures and timing of seedings of grasses and legumes with the survival and growth of conifer seedlings in the western Cascade Range. In a related study, the Siuslaw National Forest recently provided reforestation records to CRAFTS to enable a retrospective study on the effects of forage seedings on characteristics of Douglas-fir plantations. Seeded and unseeded plantations up to 10 years old are being compared to determine if differences exist in their conformity to the reforestation standards of the USDA Forest Service.

Finally, CRAFTS conducts basic research to answer the more fundamental questions regarding the underlying mechanisms that drive biological systems. As part of his dissertation research, Eric Hanson is studying the population biology of three common herbaceous species in the Pacific Northwest: groundsel, foxglove, and fireweed (*Epilobium angustifolium*). He will determine how population dynamics of these species are affected by their interactions in pure and mixed stands, as well as their effects on resource levels. These species probably play an important role in the sequestering and cycling of soil nitrogen, and Mr. Hanson hopes to determine how these mechanisms affect survival and growth of associated Douglas-fir seedlings.

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Site Preparation for Forest Vegetation Management in the Southeastern United States: An Overview¹

WILLIAM G. SCHNEIDER

As an introduction to mechanical site preparation and burning, I will outline some of the practices used in the Southeast by way of comparison with those in the Northwest. The basic reasons for site preparation in the Southeast are the same as in the Northwest: reducing the amount of debris or slash after harvest to facilitate planting, controlling competition, and preparing a good seedbed for regeneration. But, for a variety of reasons, including the fairly level terrain in the Southeast, site preparation has been more intensively practiced there than it has been in the Northwest. Even so, the trend in the Southeast appears to be less reliance on some of the more intensive mechanical methods of site preparation and greater use of herbicides.

Intensive forestry in the Southeast is largely centered in the Coastal Plain, which extends roughly from Virginia around to Texas and is relatively flat. As one moves away from the coast toward the Piedmont, the land becomes more rolling. The Piedmont is also an area of intensive forestry; however, even though it is relatively flat in comparison with the Northwest, it has a high risk of erosion because of fine-textured soils and rains that fall as thunderstorms and downpours rather than as the low intensity but frequent rain common in the Northwest. Thus, erosion is a concern in the Southeast, especially when methods of site preparation result in substantial mineral soil exposure.

Several characteristics of this region have led to the evolution of the methods used there. First, because the Coastal Plain is fairly flat, many sites have very high water tables. Some of these sites can be the most productive in the South if either the water tables are lowered or the land is raised in some manner. Thus, one of the common treatments there is bedding—mounding the soil into ridges and planting the seedling there so that drainage and aeration of the microsite are improved. Bedding requires a site which is relatively free of logging debris. In the past, many of these areas have also been ditched and drained, lowering the water table. But that practice has been discontinued because of concerns over loss of wetlands.

Another characteristic which has likely contributed to present practice is that much of the land in the Southeast has been cleared at one time, often many times, for agricultural use and then abandoned when yields became poor. When many of these abandoned fields were subsequently planted with trees, it was apparently noticed that plantation

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

growth in these areas was better than in forested areas that were clearcut-harvested, and then subsequently planted with trees. Better growth on old fields has usually been attributed to less hardwood competition and repeated soil tillage (Haines et al. 1975). Thus, foresters have adopted methods which create conditions similar to those practiced on agricultural lands. For example, raking and piling debris into windrows for burning and then disking has been an accepted set of practices.

Many years of using these practices in tandem with prescribed burning have shown that, although growth increases during the first few years, yields over the long term can be lowered presumably because of nutrient loss through erosion or redistribution. In addition, since cable logging is not common, compaction of inherently dense Piedmont soils by skidders or site preparation equipment can lead to restricted root growth. Consequently, managers are scrutinizing mechanical site preparation practices.

Table 1. Percentage of forest land in the Southeast receiving various site preparation treatments; based on responses to a 1982 survey (modified from Kluender et al. 1985, Straka and Watson 1985).

Treatment	% of forest land	Cost (\$/acre)
Burn	92	17
Chop	55	55
Shear	43	62
Bed	36	29
Rake-pile	34	65
Disk	11	46
Herbicide	<5	75

Table 2. Acres of forest land in the Southeast burned for site preparation; based on responses to a 1990 survey¹ (modified from Dubois et al. 1991).

Treatment	Thousand acres	Cost ² (\$/acre)
Burn	532	7
Spray-burn	139	11
Chop-burn	116	8
Burn windrows	8	6

¹Note: 47% of the survey respondents were from forest industry, 29% were consultants, and 24% were from public agencies.

²Cost of burning only.

Another factor that has led to current practice in the Southeast is that many abandoned farmlands have reverted to hardwood or mixed hardwood-pine stands and are subsequently being harvested and converted to pine plantations. When these hardwood stands are harvested, much unmerchantable residue is left—either as standing trees or as logging slash. The widespread use of planting machines in the Southeast, especially in the Coastal Plain, requires cleaner sites than necessary when hand planting. Furthermore, most of the hardwoods, such as oaks (*Quercus* spp.) and red maple (*Acer rubrum*), are species that sprout vigorously from rootstocks, adding to the competition for growing space. Hardwood competition and machine planting have resulted in the need for fairly intensive site preparation.

Among the machinery used for site preparation is the roller drum chopper, which is a blade-studded cylindrical drum filled with water; it is rolled over the surface of slash and sprouting hardwoods, breaking them up and pressing them down. A machine used in more intensive preparation is the root rake, which is usually applied after all standing residues have been sheared with a bulldozer-mounted blade. The debris is raked into piles or windrowed, after which the site might be disked.

According to a survey done in 1982 by the American Pulpwood Association, fire was prescribed on almost all land that was regenerated in the Southeast and drum chopping occurred over 50% of the time (Table 1). In fact, chopping and burning is one of the most common combinations used because, relatively speaking, it is not intensive and it is cheap. More intensive practices include (1) shearing, raking, and piling, and (2) bedding. Herbicide usage 10 years ago was relatively slight, occurring on less than 5% of the land being regenerated. A more recent survey by the Forest Farmers Association shows that burning is still one of the major tools, often preceded by the spraying of herbicides or drum chopping (Tables 2 and 3).

Table 3. Acres of forest land in the Southeast receiving various site preparation treatments; based on responses to a 1990 survey¹ (modified from Dubois et al. 1991).

Treatment	Thousand acres	Cost (\$/acre)
Chop	76	66
Chop-bed	35	90
Shear	23	65
Shear-rake-pile	32	119
Shear-rake-pile-bed	21	167
Shear-rake-pile-disk	8	175
Disk only	11	48
Chemical	239	83

¹Note: 47% of the survey respondents were from forest industry, 29% were consultants, and 24% were from public agencies.

As fewer site conversions from hardwood to pine are undertaken in the Southeast and more young pine stands are cultivated and then harvested, there may be less debris and hardwood competition and less need for heavy machinery to prepare sites for pine regeneration.

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Prescribed Fire in Forest Vegetation Management: A Research Synthesis¹

J. BOONE KAUFFMAN

In many North American forest ecosystems, the use of prescribed burning is an indispensable component of natural resource management. In many forests of the Pacific Northwest, this practice is necessary in silviculture, the conservation of biological diversity, fuel hazard reduction, and the maintenance of site productivity. Prescribed burning can be an effective means of controlling vegetation to decrease competition with conifers as well as to manipulate vegetation for wildlife habitat or livestock grazing. Types of prescribed fire that are used for vegetation control include natural fires, slash fires following clearcut logging, underburns in seed-tree or shelterwood cuts, and preharvest burns.

Environmental tradeoffs associated with the use of prescribed fire in vegetation management must, however, also be considered. These include reductions in coarse woody debris, influences on long-term site productivity, constraints associated with air quality/smoke management, and costs and hazards if controlled fires escape to become wildfires. Prescribed burning for vegetation management is most justifiable when used to accomplish a variety of land-use goals (i.e., creation of planting sites, fuel hazard reduction, wildlife habitat enhancement, and as an alternative to the use of herbicides).

Successful prescribed burning requires an understanding of forest ecosystem dynamics. Plants in Pacific Northwest forests have evolved to survive the natural fires that occurred in their habitats. Plant adaptations to fire are defined as those morphological, physiological, or reproductive adaptations that facilitate survival of a plant species in the regime in which it evolved (Kauffman 1990). Plant adaptations can be classified as those that facilitate the survival of individuals (i.e., K-selected traits such as thick bark and sprouting from belowground burls, roots, or rhizomes) and those that facilitate survival or perpetuation of plant populations (i.e., r-selected traits such as hard seeds, fire-enhanced flowering, and cone serotiny). Ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), and western larch (*Larix occidentalis*) all have the K-selected trait of thick bark to survive surface fires. Tanoak (*Lithocarpus densiflorus*), chinkapin (*Castanopsis chrysophylla*), snowbrush (*Ceanothus velutinus*), and many other woody species will survive by sprouting. Conversely, many ceanothus (*Ceanothus* spp.), manzanita (*Arctostaphylos* spp.), and legume species have the r-selected trait of refractory seeds (i.e., seeds that will remain dormant yet viable until stimulated to germinate by fire or some other disturbance). Through a knowledge of these traits, we can utilize prescribed burning to decrease sprouting and deplete soil seed populations of the competing shrub species. Prescribed preharvest underburning

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

has been especially effective in decreasing both sprout-origin and seed-origin competitors (Martin 1982, Kauffman and Martin 1985, 1990).

The level of sprouting mortality will vary by level of biomass consumed by the fire, season of burn, and plant characteristics. Typically, as levels of biomass consumption increase, mortality increases. In a recent study in slashed tropical dry forest of Brazil, density of sprouts was 5,815 per ha in unburned controls and 2,495, 1,198, and 564 per ha in three burn treatments of low, moderate, and high biomass consumption, respectively (Sampaio et al., in press). In underburns in California, mortality of sprouting vegetation [i.e., principally tanoak, black oak (*Quercus kelloggii*), and whitethorn ceanothus (*Ceanothus cordulatus*)] ranged from 27%-88% (Kauffman and Martin 1990). High-consumption burns in early fall resulted in the highest mortality. Season of burn also influenced mortality. Black oak mortality was 24% higher (31% vs. 55%) when burns were conducted during active aboveground growth in the spring than when burns were conducted during dormancy. Finally, small or young sprouts can be more easily controlled than can subarborescent individuals. In high-consumption understory burns, tanoak mortality was 97% for small shrubs (<30 cm in height) and declined to 55% for those greater than 1.5 m in height.

The quantity of seed stored in the soil by ceanothus and manzanita species can be remarkable. Anderson (1985) measured 2,940,000 viable seeds per hectare of these species in a mature mixed-conifer stand in the northern Sierra Nevada, California. High-consumption underburns have been reported to kill or to stimulate germination of the majority of seeds in the seedbank (Anderson 1985, Weatherspoon 1988). When understory fires are used to decrease seedbanks, the majority that are stimulated to germinate will soon die because of competition with the overstory conifers. Historically, fire-return intervals were 8-10 years in many forests dominated by ponderosa pine (or mixed conifers). These frequent fires limited soil seed populations to the point where competition with pine regeneration was minimal. One of the many negative tradeoffs associated with fire suppression has been the buildup of seed populations. This buildup is hypothesized to be a causal factor contributing to the difficulties in stand regeneration (Kauffman 1990).

Prescribed preharvest burning can be an effective tool in decreasing woody competition. It is a very effective and appropriate tool in ecosystem management in that it mimics natural ecological processes to achieve management goals. The combination of fire-induced mortality and overstory competition will reduce postharvest competition. Prescribed burning can also be utilized as an effective component of alternative timber management practices, such as "green-tree retention." Prescribed fires and overstory competition in this scenario may be as effective as underburning natural fuels. In green tree retention, prescribed fire could also be utilized to reduce fuel hazards, create planting sites, create snags, enhance diversity, and stimulate natural establishment of conifers.

Numerous factors are limiting the use of fire in forests. These factors are related to social constraints, negative impacts on site quality, misunderstandings of how forest ecosystems function, and tradeoffs associated with air quality and other valid forest uses. However, a failure to recognize and manage for natural ecological processes such as forest distur-

bances (e.g., the natural role of fire) is likely to result in catastrophic consequences. The massive forest die-offs in eastern Oregon, the preponderance of devastating wildfires resulting from unnatural fuel accumulations, and the numerous unproductive brushfields that are difficult (if not impossible) to regenerate are primary examples. Given the negative consequences of fire suppression, properly conducted prescribed burning is among the most important activities that resource managers can use to maintain forest health, productivity, and biological diversity, as well as to manage competing vegetation.

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Prescribed Fire for Vegetation Management on the Bear Springs Ranger District, Mount Hood National Forest¹

GARY STARKOVICH
TIMOTHY B. HARRINGTON

Introduction

On the Bear Springs Ranger District, Mount Hood National Forest, we use prescribed fire as a multipurpose tool to fulfill a variety of management objectives. These include the reduction of wildfire fuels (living and dead), the improvement of wildlife habitat, and the encouragement of desired vegetation, especially conifer regeneration and big-game browse. In addition, we use prescribed fire to thin dense conifer stands and to prune lower limbs from crop trees. Factors that influence our decision to burn include availability of funds, a given stand's priority for receiving a burn, and the current USDA Forest Service policies and guidelines for use of prescribed fire on national forests.

The district is located east of the crest of the Cascade Range in Oregon, on the northern boundary of the Warm Springs Indian Reservation. Average annual precipitation varies from 80 in. at high elevations in the west to 12 in. at relatively low elevations in the east. Our conifer stands are dominated by true firs (*Abies* spp.) at the higher elevations (>4,000 ft), mixed conifer at mid elevations (2,000-4,000 ft), and ponderosa pine (*Pinus ponderosa*) at lower elevations (<2,000 ft).

This paper presents examples of how prescribed fire has been used to meet management objectives on the Bear Springs Ranger District in three settings: natural riparian meadows, ponderosa pine plantations, and natural second-growth stands of mixed conifers.

Rehabilitation and Maintenance of Natural Riparian Meadows

Natural riparian meadows, which occur throughout the Bear Springs Ranger District, often are associated with springs or small lakes. For much of the year, these meadows contain standing water with depths of 3-10 in. Meadow topography varies from level grass-dominated areas to scattered elevated islands dominated by willow (*Salix* spp.). Natural fire regimes have been suppressed in these meadows for many years and, as a result, previously grass-dominated areas are being replaced by woody vegetation. Willows have become more abundant in the meadow interior while conifers have begun to encroach upon the meadow edges. In many

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992. This paper was written by Timothy B. Harrington from transcripts of the oral presentation by Gary Starkovich.

cases, wildlife forage (grass) and browse (willow and other woody vegetation) are of poor quality because of the advanced size and age of the vegetation.

In 1978, we received funds from the Rocky Mountain Elk Foundation and the USDA Forest Service to apply prescribed fire to rehabilitate several meadows. Our objectives were to improve big-game habitat, to reduce conifer encroachment along the meadow edges, to improve the availability and quality of forage and browse, and to initiate a regular burning schedule.

The optimum conditions for meadow burning occur soon after the first fall rains when daytime conditions are relatively warm and dry. Such conditions are most common immediately following a moderate cold front, which generates a continuous westerly breeze. Burning in the spring is less desirable because late snows can delay the burn until after the vegetation has begun to grow. Flames that reach the new shoot tips can cause brown streaks in the emerging leaves, resulting in less palatable vegetation for big game. Fall burns provide moderate to high consumption of dormant vegetation and promote abundant growth of new sprouts and shoots in the spring.

In general, meadow burning was most successful when it was conducted during the day. The humidity climbs rapidly at sunset in the fall, and fine fuels, especially grasses, are able to capture that moisture, making them almost incombustible. Night-burning of meadows is possible under certain conditions of low humidity and light winds. The timber surrounding the meadow must have a sufficient moisture content to reduce its flammability so that it can stop the fire. Tall, dry grass will easily carry a fire, but it is critical for the safe coordination of fire crews to know the direction in which the fire will spread. The presence of light winds provides more certainty regarding a fire's direction and rate of spread.

We found that hand-lighting 400 acres of meadow required six or more crew members. Many of our crew lacked experience in setting prescribed fires. As a safety precaution, we had preburn coordination meetings to explain the objectives of the fire and describe the scenarios that each crew member should expect during the operation. Initially we used standard drip torches, fueled by a mixture of diesel and gasoline, to ignite the meadow fire. Later we changed to propane torches in an effort to avoid contamination of the standing water in the meadow.

Snowmobiles with attached transport sleds were the best vehicles for transporting personnel and materials during meadow ignition because they caused little or no disturbance to the meadow vegetation. We found that the three- and four-wheel all-terrain vehicles always left a track that was evident for several years after burning. Because some meadows are too wet or do not contain enough fuel to sustain a fire, it is necessary to check the fuel abundance and moisture content prior to scheduling a burn. Simply getting a meadow to ignite does not ensure that an adequate amount of vegetation will be consumed to successfully stimulate browse production and reduce forest encroachment.

Some of our management objectives required specific burning methods. In order to kill conifer saplings that were encroaching on the meadow edge, we needed to allow the fire to gain enough velocity to carry it a

short distance into the stand with sufficient heat to scorch saplings. We accomplished this by lighting the fire near and upwind from the stand edge. For burning large willow, it was necessary to light a strip all the way around the sprout clump; a convection column would then build and consume much of the vegetation.

The willows and other woody vegetation later sprouted and provided high-quality browse for Roosevelt elk (*Cervus elaphus roosevelti*), mule deer (*Odocoileus hemionus columbianus*), and black-tailed deer (*Odocoileus hemionus*). Complete consumption of the vegetation by the fire was not necessary in order to fulfill our objectives. If possible, we avoided burning cattail (*Typha* spp.) patches because they provide habitat for birds and mice. Those cattail patches that we burned were mostly recovered the year after burning.

With these methods, we rehabilitated a 400-acre meadow for about \$4,000. By late spring to early summer of the next year, the vegetation had recovered sufficiently such that visual signs of the burn were almost undetectable to the general public. Both browse and forage were improved considerably.

Fuel Reduction and Thinning in Ponderosa Pine Plantations

We have conducted underburns in plantations of ponderosa pine to improve browse production of snowbrush (*Ceanothus velutinus*), to thin the stand, and to prune lower limbs of the pine. Accomplishing these objectives reduces the likelihood that future wildfire will climb into the upper canopy and destroy the stand. These pine plantations vary from 20-30 years old (8 in. dbh with 0.5 in. bark thickness) and typically have dense understories dominated by snowbrush that are 4-8 ft tall. There is considerable risk in using prescribed fire in these plantations: the dense understory is highly flammable and the high concentrations of pine needle litter suspended in the vegetation provide additional fuel.

In 1980, we conducted our first burn in a stand that had been thinned with chainsaws 5 years earlier. Given the potentially explosive understory fuels, we wanted to maintain control of the fire and prevent it from igniting the crowns of the pine. We waited for a day when the wind speed was high (30 mph) and the humidity was sufficiently low (<60%) to ignite the suspended pine needles and carry a fast-moving fire that we could control. Such conditions can occur in early June between 11 a.m. and 7 p.m. During other times of the day the humidity often exceeds 65%, making ignition difficult and impractical.

Because our soils tend to be relatively free of rocks, we were able to use heavy-duty rototillers to build a fire line around the area that was scheduled to be burned. We found that a rototiller was as productive in building a fire line as six people working with hand tools. The rototiller mixes small limbs and needles with mineral soil to produce a barrier of wet fuels that the fire cannot penetrate.

After the perimeter fire line was complete, we typically began a back-fire on the downwind side of the site to burn a large buffer area. Meanwhile, another fire line was built upwind about a quarter of the way into

the site. Another backfire could then be started as this line neared completion. This routine was quite productive because we were able to build a line and burn at the same time. In addition, if the wind direction changed we could isolate each individual area that was burning, maintain control of the fire, and, if necessary, shut down burning operations.

Prescribed fire thins a stand of trees in a nonselective way. Some of the better crop trees may be killed while less desirable trees are saved. Lower limbs can be successfully pruned if a fire scorches them, because they will die and eventually fall off. We found that trees that were scorched prior to budbreak tended to survive because their buds were not killed. In contrast, trees were severely injured or killed if prescribed burning was conducted following budbreak and their new shoots had been scorched.

Our District Silviculturist had expected to see some decline in growth rate from the tree injuries associated with the fire. However, measurements of diameter growth rates in our plantations revealed that the annual ring increments were relatively constant after the prescribed burn. Such growth rates indicate that the stand basal area was actually accelerating.

Porcupines (*Erethizon dorsatum*), which can girdle and kill small pine trees, were less abundant following the prescribed burn. The fire restricted the animals' access to their food source, the succulent cambial tissue of the upper crown. Also, porcupine habitat was less abundant because the fire reduced the density of understory vegetation.

Soon after the fire we found a temporary increase in pine bark beetle (*Dendroctonus* spp.) populations. The insects attacked and killed most of the trees that were severely stressed by the burn. Healthy trees were not attacked by the beetles, presumably because they were able to "pitch" them out with their protective chemicals.

The fire opened up the stand, pruned the lower limbs, and reduced the height of understory vegetation. These characteristics are similar to those in stands that developed under natural fire regimes, and they decrease the likelihood of a crown fire. For several years following the fire, browse from sprouting snowbrush was extremely abundant, which encouraged a high level of deer and elk use.

Fuel Reduction and Thinning in Second-Growth Stands of Mixed Conifers

Over the years "high-grading" (i.e., selective harvesting of the best trees) of virgin ponderosa pine stands has encouraged the development of mixed-conifer forest. Dominant tree species that have been favored include Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), and incense cedar (*Calocedrus decurrens*). In their current state of overstocking, these stands provide little forage or browse for deer and elk. Prescribed fire is difficult to apply in these stands because typically they have dense fuel concentrations and are composed of species with relatively thin bark. As a consequence, both crop trees and regeneration are easily damaged or killed by fire.

Prescribed fire can be used successfully in mixed-conifer stands when applied judiciously. Fuel breaks need to be larger than in ponderosa pine

plantations to accommodate the hazard associated with the denser fuel accumulations. The intensity and size of the fire should be restricted to maintain its control and to prevent the development of a convection column which can move the flames into the crowns of trees and promote severe crown scorch or crown fire.

The timing for underburning mixed-conifer stands (June and July) and the dense concentrations of fuels typical in this forest type allow us to sustain the burns well into the night and sometimes up to a full 24-hour period. Because of the extensive acreage we have in mixed-conifer forest, it was most cost effective to burn sites that are at least 50-100 acres in size.

We avoid hot fires that could consume the entire duff layer, because much of the forest nutrients are stored there. In areas that were burned with an excessively hot fire, we found little vegetation recovery up to 10 years later. Moderately hot burns are necessary if the objectives are to stimulate the reintroduction of snowbrush. Very cool burns do little more than reduce the fuel loading. Moderate burns tend to mimic the natural role fire played in these areas. By limiting the duration that a fire burns in any one spot, we are able to restrict the intensity of the burn. In order to prevent tree injury, we avoid underburning in stands of Douglas-fir if their diameter at stump height is less than 12 in.

One should not expect instant visual improvement of a stand following an underburn. It takes about 5 years for damaged trees to fully recover and for the understory to green up. After that time, a successful burn can open up the stand and encourage natural regeneration of desirable conifer species such as western larch (*Larix occidentalis*). Browse is generally improved because the fire stimulates germination of snowbrush and other shrubs; increased utilization of the stand by deer, elk, and wild turkey (*Meleagris gallopavo*) generally follows.

Summary

We use prescribed fire as a multipurpose tool for vegetation management on the Bear Springs Ranger District. Fire improves the structure and species composition of our forests in several ways. It thins out trees that are subordinate and susceptible to fire (e.g., thin-barked understory conifers), it prunes the lower branches of crop trees and thus reduces the likelihood of crown fires, and it stimulates the production of high-quality browse in the form of succulent sprouts and new seedlings of desirable shrub species. In addition, fire opens up the stand to increase big-game access and to stimulate regeneration of conifers. Most importantly, judicious use of prescribed fire in overstocked and fuel-laden forests mimics their natural disturbance regime, thus avoiding potentially devastating holocausts in the future.

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Prescribed Fire for Conifer Regeneration in the Oregon Coast Range¹

RICHARD L. POWELL

Introduction

Starker Forests, Inc., (SFI) is a family-owned business that owns and manages 60,000 acres of forest land in Oregon's central Coast Range. Most of the land is within an hour's drive of our office near Corvallis. We are a tree-farming business; we own no processing facilities. All harvesting and most labor (e.g., tree planting, slash burning, road building) is contracted. The business is currently owned by the second and third generations of the family; the fourth generation is presently in middle school and elementary school.

The company grows trees for the long term and, consequently, places the highest priority on attaining the best reforestation possible. Towards that end, we have a number of tools available to us. Prescribed burning is one of those tools.

Although this paper deals specifically with prescribed burning as a reforestation tool, in most cases a reforestation prescription will use a combination of tools. Properly done, a prescribed burn may use herbicides, manual methods, mechanical methods, or a combination of these.

Benefits of Burning

There are a number of reasons that prescribed burning may benefit a site. This paper will discuss hazard reduction, animal habitat modification, vegetation control, planting site improvement, and worker safety.

Hazard Reduction

In Oregon, the State Forester can declare that heavy slash on a logged site is an "additional hazard" and can require that the hazard be reduced. Prescribed burning is one of the options by which this reduction can be accomplished.

Deeming (1990) cited several studies of wildfires. A study of nearly 10,000 fires in the 1930s in western Montana and northern Idaho found that the per-million acre rate of area burned by wildfires was 10 times greater in untreated logged areas than in green forests (Barrows 1951). Also, 21% of the fires that started in untreated slash of western white pine (*Pinus monticola*) burned more than 300 acres, whereas only 1.7% of the fires that started in treated slash burned more than 300 acres (Lyman

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

1947). Another study of several different forest types showed that, overall, the per-million acre rate of acres burned by wildfire on treated areas was only one-seventh the rate on untreated areas (Lyman 1947). All 14 of the major fires on the Mt. Hood National Forest between 1960 and 1975 either started or gained momentum in untreated slash (Dell 1977). However, the cost effectiveness of prescribed burning to reduce hazards was not clear in the studies Deeming (1990) cited. He concluded that, "for reducing losses to wildfires, there is certainly a role for selective application of fuel reduction, fuel breaks, and other fuel hazard management strategies utilizing prescribed fire" (p. 101). He further stated that "seed orchards, plantations, and intensively managed timber stands are examples of high-value resources where considerable expenditures for fuel hazard reduction in adjacent areas may be warranted" (p. 101-102).

Animal Habitat Modification

Habitat modification by means of prescribed burning has proven effective for controlling animals, such as rodents, that can cause extensive damage to new plantations.

Mountain beavers (boomers) (*Aplodontia rufa*), for example, are a serious problem on forest land managed by SFI, and it is necessary to trap them prior to planting. However, good boomer habitat (heavy brush) makes trapping difficult and ineffective. A prescribed burn can reduce the boomer population by 50% (Hooven and Black 1978). The remaining 50% of the population can still cause unacceptably high levels of damage to conifer seedlings and, therefore, must be trapped. A burn that clears heavy brush will make trapping boomers easier and more effective.

The cost of trapping boomers on an unburned site is \$10-\$15 per acre higher than on burned sites. Because trapping in an unburned site is not as effective, the newly planted seedlings will have to be protected with plastic mesh tubes at an additional cost of \$91 per acre.

Vegetation Control

Even if a site can be planted without burning, vegetation competition can cause a plantation to fail. The presence of competing vegetation makes it difficult to plant the site with the desired planting quality and density. Vegetation can be controlled with herbicides or by piling, cutting, or burning.

Methods that leave dead brush on the site create a "dead shade" canopy that may inhibit seedling growth. Newton (1990) suggested that the more open the canopy, the better; all species, tolerant and intolerant, like freedom from competition, but Douglas-fir does not even like dead shade.

Walstad and Seidel (1990) cited a study by Stein (1986, 1989) that compared six site preparation methods; of these, broadcast burning substantially improved growth and survival of Douglas-fir (*Pseudotsuga menziesii*)

during the first 7 years after planting. In burned plots, seedling survival, height, and diameter growth were 28%, 36%, and 68% greater, respectively, than in unburned plots. After 7 years, the cover of competing vegetation in the burned plots approached that of the unburned plots. However, the initial suppression of competing vegetation allowed the tree seedlings in burned plots to get a head start.

Planting Site Improvement

Logging debris and brush, either dead or alive, will impede the planting process. Portions of a site may be rendered unplantable by the presence of debris. If not removed, the planting quality, density, and distribution will be poorer, and the resulting survival rates and plantation vigor will be less than expected.

Zasada and Tappeiner (1988) reported on the effects of slash burning on planting time and planting spot availability. Test sites in the Oregon Coast Range were burned in the spring; conditions were such that few of the large diameter fuels were consumed. After burning, planting time was reduced about 50%, planting spot availability was increased by about 15%, and over 90% of every clearcut was ready for planting.

SFI expects that a prescribed burn will increase stocking rates by at least 15% to 350 trees per acre and will reduce planting costs by \$25-\$45 per acre. These estimates are similar to those reported by Zasada and Tappeiner (1988).

Worker Safety

The contractor who provides most of the labor for SFI estimates that 60% of crew injuries resulting from plantation work (planting, backpack spraying, precommercial thinning, and so forth) are on unburned plantations (L. Miller, Miller Timber Services, personal communication). Worker's compensation insurance rates are \$5,000-\$10,000 per year higher on unburned plantations; these additional costs are passed on to clients.

Limiting Factors

While prescribed burning has many potential benefits, there are some limiting factors that must be considered. Among these are site characteristics, weather, and labor availability.

Because the fuels on north-facing slopes dry slower than those on south-facing slopes, north slopes may have to be burned under riskier fire conditions in the summer or early fall for good fuel consumption. The land manager must choose between higher fuel consumption and higher risk (summer or early fall), lower fuel consumption and lower risk (spring or after rain), or not burning at all. Slope steepness may also be limiting. Fire lines on steep mid-slopes can be particularly difficult, especially if the adjacent fuels are hazardous. The fire can be difficult to keep within the

fire lines and any escaped fire can be difficult to contain and put out. There is always a risk of a fire escaping from the site. If landowner-neighbor relations are poor, any risk of a fire crossing a property line may be unacceptably high.

Weather strongly dictates when (or if) a burn can take place as well as the quality and cost of the burn. While winter is usually the safest time of the year to burn, fuel ignition is nearly impossible under wet conditions. Late summer and early fall generally give the most complete burn, but the typically hot, dry conditions can be extremely dangerous. Spring is becoming a preferred time to burn for safety and smoke management considerations. However, spring burns generally do not give as complete fuel consumption as summer or fall burns.

Closely related to weather is the Oregon Smoke Management System, which regulates the amount of smoke that is allowed into the air. A prescribed burn may not be conducted until the weather conditions are "right" on a given day. Consequently, a forester may have to wait from several days to several months to burn a site; sometimes the "right" weather conditions are a safety risk. On SFI lands, the best smoke management days are in early fall with the typically warm, dry, east winds. Fire risk is at a peak then and we must decide whether to accept that risk.

Availability of labor may be limited during prime burning conditions when there is a high demand for hired crews and other contractors. A good crew and a helicopter can be very hard to find on short notice.

Table 1. Average costs for prescribed burn treatments on lands managed by Starker Forests, Inc.

Treatment	Cost (\$/acre)
Preburn Treatments¹	
Herbicide	65
Scarification	142
Slashing	52
Fire-trailing	8
Broadcast-burned Sites	
Ignition	56
Mop-up	48
Preburn costs	45
Total	149
Scarified Sites (debris piled)	
Ignition	13
Mop-up	5
Preburn costs	143
Total	161

¹Varying combinations of these treatments may or may not be needed.

Costs and Benefits to Starker Forests, Inc.

SFI has never attempted to estimate either the costs or benefits of prescribed burning for hazard reduction. We do know from limited experience that any fire that gets into an unburned plantation is extremely difficult to contain and extinguish.

Certain treatments may be necessary in order to burn a logged site. Table 1 summarizes SFI's average costs for these treatments. Table 2 compares the cost on two typical adjacent sites. One was burned and the other was not burned due to a long, warm, dry fall.

Expected Gains to Starker Forests, Inc., from Burning

SFI expects that benefits from prescribed burning will include 50-75 more trees per acre, 15% more ground planted, 2-4 year reduction in rotation length, and additional wood volume of 4-5 thousand board feet per acre. Burning will reduce the risk of planting failure or the need to replant or interplant, and will reduce the hazards on the site. A prescribed burn is expected to increase present net worth by \$200-\$240 per acre.

Table 2. Forest regeneration costs on adjacent unburned and burned sites managed by Starker Forests, Inc.

Treatment	Cost (\$/acre)	
	Unburned site	Burned site
Site preparation spraying	65	—
Slashing	60	60
Trailing	—	15
Burning	—	149
Boomer Trapping	45	32
Tubing (for boomers)	91	—
Planting	168	133
Grass spraying	25	25
Total	454	414

Conclusions

Although this workshop focused on forest vegetation management without herbicides, the forest land manager must consider using combinations of vegetation management tools, including herbicides, to be effective. For example, brush or weed tree species may need to be manually cut before a prescribed burn.

If the ground is flat enough, the slash and brush can be machine-piled and then burned after the fall rains start. If the brush species are vigorous sprouters, it may be helpful to spray the vegetation before burning; dead brush burns hotter, and a more complete consumption of fuels will lessen the need for retreatment.

SFI reforestation foresters, who have considerable experience planting and conducting stocking surveys, are convinced that prescribed burning is an essential tool. While this tool is not appropriate for every site, it is one that should be considered.

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Mechanical Site Preparation in Forest Vegetation Management: A Research Synthesis¹

ROBERT G. McMINN

Introduction

The objective of site preparation is to modify the uppermost soil horizons in order to provide conditions favorable for survival and growth of crop tree seedlings. Research and operational experience have shown that mechanical site preparation, appropriately applied, can ameliorate many of the adverse conditions which may be present after a stand is harvested (McMinn 1985, Bedford and McMinn 1990).

Mechanical site preparation can modify many factors, including vegetation, air and soil temperature, light, soil water, soil structure, and susceptibility to insect and small mammal damage. Since many of these factors interact, land managers must avoid adversely affecting one factor while trying to improve another. Site preparation must be site-specific because what works in one ecosystem may be ineffective or deleterious in others. Differences in climate, vegetation, or soils must be taken into account when making site preparation prescriptions.

Methods of Mechanical Site Preparation

There are three basic, biologically different methods of mechanically modifying the soil surface: scalping, inverting, and mixing. Each can have different effects on the microenvironment of planted or naturally regenerated seedlings.

Scalping (also known as scarifying), removes surface layers to expose mineral soil. Where competing vegetation is a severe problem, removal of surface layers must be deep enough to dig out and control the roots of competing plants. On many sites such deep scalping reduces site fertility in the immediate vicinity of the planted seedling because much of the fertility of forest soils is in the uppermost soil horizons removed by scalping.

Inverting places a mineral soil cap over an inverted (upside down) patch or strip of vegetation and surface organic matter (duff, humus). When the mineral soil cap is deep enough, competing vegetation is controlled and the planting spot benefits from the enhanced soil temperature characteristic of bare mineral soil. Seedling roots are in immediate contact with the fertility inherent in the upturned surface organic matter.

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

Mixing chops up surface organic matter and incorporates it with the underlying mineral soil, enhancing its fertility. If roots are chopped finely enough, the resprouting potential of competing vegetation is reduced.

Mechanical site preparation can provide raised planting spots which increase aeration on wet sites. Sunken planting spots can accumulate and conserve moisture on dry sites. Treatment can cover the whole site or it can be applied as strips or patches. Each type of application can be appropriate for different circumstances.

Scalping

The enhanced temperature of bare mineral soil exposed by removing surface soil horizons can improve seedling root growth compared to that in cooler soil insulated from the sun's warmth by surface organic matter. However, this advantage can be negated when the exposed soil is fine

Table 1. Performance of lodgepole pine (*Pinus contorta*) seedlings 5 and 10 years after planting in a trial comparing scalping and no treatment of a sandy soil in the Subboreal Spruce Zone east of Prince George, B.C.

Treatment	Survival (%)	5th year		10th year	
		Height (cm)	Volume (ml)	Height (cm)	Volume (ml)
Scalped	90 ¹	126	250	410	1,050
Untreated	42	77	64	330	590

¹All values are significantly different ($p = 0.05$).

low significant "re-radiation" of the heat absorbed by exposed soil during the day. Frost heaving is a potential problem for seedlings planted in bare, fine-textured soil. When a calcareous layer is close to the surface, scraping off too much surface soil can impair seedling growth.

Inverting

Vegetation and surface organic matter can be inverted and placed upside down under a mineral soil cap by plowing or by implements that form mounds. Mounds are advantageous in wet soils because the raised position of seedlings improves aeration around their roots. Plowing produces inverted planting spots which conserve soil water in dry climates because seedling root systems are not elevated above the average ground level.

When the overlying mineral soil cap is deep enough, even aggressive competing vegetation is controlled by inverting surface layers. However, mineral soil caps tend to dry out. Care, therefore, should be taken to

ensure that seedling roots are planted deeply enough to reach a stable water supply below the cap. Desiccation of the mineral soil cap helps control weedy plants but can be deleterious to the survival of crop tree seedlings. Research results have shown that 14 cm of mineral soil cap (after settling over winter) can be optimum (Table 2). A deeper cap may be difficult to plant through. A shallow cap may not provide adequate control of competing plants. Inverting can result in more favorable seedling responses than scalping when soil textures are fine.

Table 2. Performance of white spruce (*Picea glauca*) seedlings 5 years after planting in fine-textured soils prepared by different treatments in the Subboreal Spruce Zone east of Prince George, B.C.¹

Treatment	Survival (%)	Height (cm)	Internode (cm)	Diameter (cm)	Volume (ml)
Mound 1 cm cap/PSB 211 ²	60	24c ⁴	6c	0.5c	6cd
Mound 6 cm cap/PSB 211	63	36b	10b	0.8b	11b
Mound 14 cm cap/PSB 211	96	55a	17a	1.3a	27a
Mound 20 cm cap/PSB 211	96	55a	16a	1.2a	25a
Blade scarified/PSB 211	66	20cd	5cd	0.4cd	4cd
Patch scarified/PSB 211	44	15d	3d	0.3d	3cd
Untreated/PSB 211	52	15d	3d	0.3d	2d
Untreated/PSB 313 ³	80	33b	6c	0.6c	7c

¹Data from Field Tour Guide of the Upper Coalmine Plot (FRDA 1.10).

²Planted with standard sized container stock [PSB 211 (2 in.³ container volume)].

³Planted with larger container stock [PSB 313 (4 in.³ container volume)].

⁴Values in a column followed by same letter are not significantly different ($p = 0.05$).

Table 3. Performance of white spruce (*Picea glauca*) seedlings following planting in plots prepared by scalping or mixing treatment of a fine-textured soil in the Subboreal Spruce Zone east of Prince George, B.C.

Treatment	Stem volume (ml)			
	3 yr	5 yr	7 yr	11 yr
Mixing	16 ¹	95	310	2,800
Scalping	9	55	160	1,060

¹All values are significantly different ($p = 0.05$).

Mixing

High-speed mixing, which chops the roots of competing vegetation small enough to control resprouting, is only suitable for soils that are relatively stone free. When vegetation is adequately controlled, fine mixing can result in more favorable seedling performance than scalping fine-textured soils (Table 3).

Coarse mixing, which may be done with a disc or bedding plow, mixes chunks of organic matter with the mineral soil. Generally coarse mixing is not suitable where competing vegetation is aggressive because coarse mixing stimulates vegetation regrowth to the detriment of seedling performance.

Vegetation Control

Vegetation control is important because shading by competing plants reduces the levels of light and temperature needed for optimum tree seedling growth. Where competing vegetation is dense, crop tree seedlings may be smothered when snow presses vegetation and seedlings to the ground. In dry climates, all available soil water may be used up by competing vegetation, leaving tree seedlings to desiccate. Although shading vegetation reduces high temperatures that can be detrimental for seedling growth, living vegetation transpires sufficient water for crop tree seedlings to die of drought. Advantage should be taken of inanimate objects such as stumps and cull logs to provide shade without using scarce soil water.

Site Preparation Implements

A wide variety of site preparation implements are currently being used in British Columbia. Bulldozers, equipped with either brush blades or V-blades, are still quite commonly used for scalping. Two implements, powered disc trenchers and excavators, have become common in recent years and now account for much of the mechanical site preparation done in British Columbia.

Powered Disc Trenchers

There are currently about 35 powered disc trenchers in use in British Columbia. All are Swedish- or Finnish-made. Powered trenchers can produce three planting microsites, a trench, a berm, or a hinge position (Figure 1). The trench is useful on dry sites because any rainfall tends to accumulate in the sunken trench position. Trenches are subject to the disadvantages of scalped microsites. The berm is a planting microsite with the characteristics of a continuous coarsely mixed mound. Soil fertility is enhanced but the degree of mixing is inadequate to control aggressive competing vegetation. The site must also be moderately moist, because the raised position of the berm tends to allow it to dry out. The hinge position is preferred when the site is neither dry nor excessively wet. Competing vegetation must be only moderately aggressive, however, because the hinge position provides only minimal control of competing vegetation.

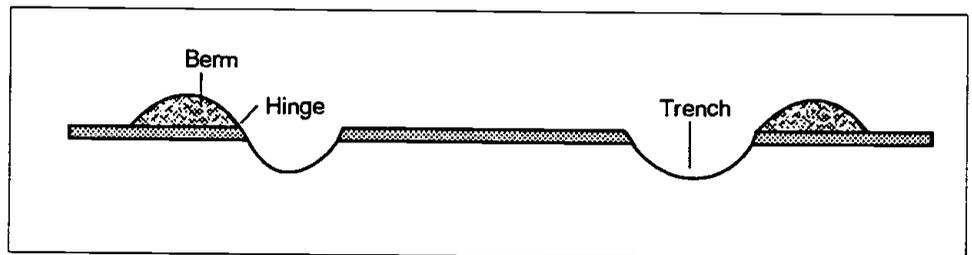


Figure 1. Cross-section of strip prepared by a disc trencher showing three planting spot alternatives.

Excavators

Excavators are currently the most versatile type of equipment used for site treatment in British Columbia. About 80 machines are in use. Excavators can be equipped with a variety of site preparation implements; rakes are currently the most common. Mixing devices mounted on the excavator's boom have been introduced recently. Excavators can produce large mounds on wet sites. On drier sites, the rake can be used for pushing slash aside preparatory to making a scalped patch. Excavators can be used on slopes up to 35% as well as on wet ground. Although the hourly rate on excavators is relatively high and productivity is only moderate, excavators can operate on steeper and wetter ground than most other machines. Using a relatively expensive machine should be more cost effective than leaving areas to become unproductive fields of woody vegetation.

Research Plots

Research during the past couple of decades has provided considerable information to improve the quality of site-specific prescriptions. The development and adaptation of equipment has enabled much of this information to be put into practice. There is still, however, insufficient information for the wide variety of ecosystems present on forest land and insufficient information on the long-term effects of treatments. More comparative trials using blocks of 80 or more seedlings which can be followed to stand closure and beyond are needed if prescriptions are to be adequately site-specific and accurate about long-term effects.

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Mechanical Site Preparation in Southwestern Oregon¹

BRUNO MEYER

Medite Corporation is a private company with a small forestry staff that manages 167,000 acres of forest land as well as three medium-density fiberboard plants, a stud mill, and a chip and veneer facility. We have done extensive site preparation work over the years in the southern Oregon Cascade Range northeast of Medford, where the largest block of our land lies. The area has relatively gentle slopes with some shallow "V" canyons. This topography gives us a lot of flexibility as far as management is concerned, both in logging prescriptions and in follow-up site preparation.

Much of the early logging in this area was done in conjunction with a railroad. The prescription was to cut the high-quality ponderosa pine (*Pinus ponderosa*), sugar pine (*Pinus lambertiana*), and the best Douglas-fir (*Pseudotsuga menziesii*). Second entries followed in the 1940s and later with fairly heavy cuts. Partial cuts in which individual trees were marked became the standard in the early 1960s. With the repeated entries, site preparation and planting became necessary. The predominant objectives were hazard reduction and natural regeneration. Concentrations of slash were piled by tractor and burned in the fall. The driving force was the forest practices rules at that time which emphasized the leaving of seed trees and a suitable seedbed. The result turned out to be a shelterwood cut with natural regeneration being established in the disturbed soil. The successes were certainly also a function of adequate seed crops.

Early piling was done with large tractors, such as the D-8. Since then we have been using different-sized tractors over the years. The lighter, straight-blade D-6 tractor with a swing rake maneuvers well within a partial cut or on steeper slopes. The larger D-7 has much more horsepower and can make much larger piles. The D-8 tractor is ideal on gentle slopes and in heavy slash sites, but its large weight makes it more likely to get stuck in soft areas.

The machines can either be equipped with swing rakes that can be quickly mounted on the front of the regular straight blades with two pins, or the blade can be removed and a brush rake installed. The swing rake option has the advantage of allowing the tractor to do water barring, road straightening, and ditching. Removing or attaching the rake takes less than 10 minutes, whereas the full blade change takes two people more than an hour. The fixed brush blade has the advantage of being much sturdier and allowing the tractor to grub stumps and brush with less downtime.

Slash piling is often combined with shrub and hardwood removal from low-stocked areas. Many of our hardwood species are hard to kill totally and then they are still a barrier to the tree planters. A good piling job improves overall planting quality and seedling survival.

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

Piles are our preferred practice because of the ease of burning. However windrows are slightly faster to build, particularly on steep slopes. Covering a portion of a pile will keep it dry and speed up the lighting time after over 4 in. of rainfall has occurred. We have successfully used 6-by 6-ft square fiberglass-reinforced paper and used sticks and chunks of wood to hold it in place. The cover has to be placed over some clean, fine fuels or lighting will still be slow. Polyethylene has not worked well because the water tends to pond up and then burst as heat from the fire melts the plastic; also the sticks from the slash puncture and tear the plastic as water collects in the low areas.

Slash piling accomplishes several objectives besides hazard reduction. Foremost is that we lengthen the period in which we can burn. Because we have Crater Lake National Park to the northeast, the city of Grants Pass to the west, and Medford to the southwest, we are restricted as to when we can burn without smoke intrusions into these Class I areas.² We simply cannot get many fall broadcast burns accomplished. But by machine piling we can extend that "window" and get much more burning done. Most of our burning takes place during the period when the fall storm fronts are moving through. As soon as the air mass stabilizes, burning is restricted. We also prefer to wait until 1-2 in. of rain have fallen before ignition. There needs to be enough moisture in the duff to stop fire from spreading around the unpiled areas that already have natural seedlings.

Our constant goal is to have soil-free piles in order to maintain the topsoil and get the piles to burn rapidly with less smoke and smoldering time. The amount of hardwood trees or brush clumps that needs to be grubbed out greatly increases the soil content of the piles.

We try to cut all our stumps to under 12 in. in height. The low stumps reduce the hang-ups of the tractors as they pile over the stumps.

After the piles are burned, the ashes need to be scalped away before planting. Usually our best looking seedlings grow around the outside edge of burn piles. They are able to take advantage of the released nutrients. We do not always burn all sites that we pile. Those that are left will be burned the following fall after planting. We will plant within 3 ft of the pile. Usually convection currents from the fire are such that seedlings planted nearby will survive. For added safety, burning in that situation is best done during a rainstorm.

Our best seedling survival is always in areas that have had some kind of ground disturbance. We tend to get considerable soil tillage from the brush rake. The duff is mixed into the soil, skid trails are broken up, and roots from brush and other herbaceous plants are torn up. Water penetration is generally improved.

An additional method for site preparation that we have used extensively employs winged rippers, which are plow-like shoes welded to the two shanks of a D-8 ripping tractor. They were built in-house. We used winged rippers successfully in understocked brushy or grassy sod plantations. The trees enjoyed a year with much less moisture competition. It

²The Oregon Department of Environmental Quality has designated certain population areas and national parks as Class I areas that are to remain smoke free. The burning permit system is keyed to this objective.

also improved planter access. We found that it is best to plant on the side of the furrow and not in the bottom. The ripped furrows are often used by elk and cattle as travel corridors, which can result in many trampled seedlings. By the second year, a lot of seed has fallen into the trench, and grasses and weeds reinvade the site.

Mechanical site preparation has several predictable results on the recolonization of the bare soil. We typically get an invasion of thistle (*Cirsium* spp.) along with the native herbs during the first year. The thistle will usually decline rapidly after the second year. Previously entered partial cuts already have a lot of weed seeds available and are much weedier after the final cut than are dense, first-entry stands. We often use the herbicide atrazine for grass control in first- or second-year Douglas-fir plantations. The timing of site preparation also affects the weed development. The sites that we piled after fall green-up will not have as much of a weed problem during the first year.

Mechanical site preparation has been an important tool in our reforestation efforts on our moderate slopes. It has given us good reforestation results at a predictable cost. The opportunity to maintain islands of cover for wildlife is much easier than with broadcast burning. We will continue to use various combinations of mechanical site preparation for reforestation.

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Mechanical Site Preparation in Western Washington, Oregon, and British Columbia¹

DOUGLAS BELZ

Introduction

Site preparation refers to a silvicultural treatment in which the ground is prepared for either natural or artificial regeneration of a forest stand. Diverse techniques may be used either alone or in combination. Treatment specifications depend on the crop tree selected, condition of any competing vegetation before and after harvest, and environmental conditions on the site. The primary objective of site preparation is to reduce interference to seedlings at the time of establishment. Secondary objectives are to improve access to the soil and passage of personnel and equipment across the ground.

Reasons for Site Preparation

Site preparation should be coordinated between timber harvest and regeneration functions. It can be done either during timber felling and yarding, after logs are removed, or shortly before planting. Primary reasons for site preparation are creation of plantable spots, improvement of stocking uniformity, and increased survival. Many times, harvesting alone prepares the ground adequately. At other times, additional treatment is needed. The following conditions may necessitate supplementary treatment:

- Depth of slash can limit worker access to planting spots during tree planting. Normal planting with a shovel or hoe can be accomplished in less than 2 ft of slash. Creation of a planting spot should be possible without using an extra tool such as a saw or axe or resorting to unusual specifications in the planting contract. Uncompacted slash may be more than 2 ft deep. Degree of planting difficulty can be determined by a survey that gauges vertical access to the soil. Such a survey involves one plot per 4 acres (a 1/250-acre evaluation spot, 7.5-ft radius) and placement of a single tree anywhere within the circle. If approximately 30% of the plots are difficult or impossible to plant, then additional site preparation may be considered. Definition of *difficult*: extra effort is necessary to create a plantable spot and to reach the soil. Definition of *impossible*: a planting spot cannot be created without using extra tools.
- Existing vegetation would hinder seedling survival. Examples of such plant communities are sod grasslands, homogeneous shrub complexes, or abundant and aggressive resprouting species.

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

Treatment Specifications

Mechanical site preparation involves the uprooting of green woody vegetation, moving of logging debris, or general loosening of the mineral soil. Contracts for site preparation on lands managed by the Washington State Department of Natural Resources and by other industrial forest owners commonly require that green woody vegetation and any logging slash be extracted from the soil and collected in reasonably dirt-free piles or windrows. Large, sound stumps are usually not required to be removed from the soil, nor are large-diameter logs required to be added to piles. No green vegetation or slash can be pushed up against or piled around snags or dead trees. All piles or windrows shall be not less than 10 nor more than 30 ft wide nor longer than 200 ft. Space between piles or windrows shall be 30 ft or greater.

Some site preparation contracts have particular specifications. For example, within an area to be shovel-logged (i.e., transport of logs accomplished with a tracked vehicle that is equipped with a shovel or clamshell bucket), all concentrations of logging debris larger than 10 by 10 ft shall be broken up by the shovel operator to allow exposure of natural forest soils. All nonmerchantable stems over 1 in. in diameter at 1 ft above the ground shall be felled. In order to minimize soil compaction, no more than one round trip per shovel road is authorized. Shovel roads will be preplanned and approved prior to yarding. These roads shall be at least 70 ft apart unless otherwise approved.

When mastication, shredding, or mulching of woody material is used to prepare the ground, a minimum number of well-distributed planting spots or strips shall be created. Preparation shall include the clearing or scalping to mineral soil of an area at least 3 ft wide. Distance between prepared spots shall not be less than 8 ft, depending on the specifications for subsequent tree planting. Strips should be evenly distributed. Size of strips should be approximately 3 by 24 ft to permit the planting of three to four evenly spaced seedlings.

Machinery, Productivity and Cost

The following are descriptions of various types of equipment and methods used to modify conditions or prepare the ground prior to planting. Included are potential production rates and estimated per-acre costs.

Rotating Head

This is a track-mounted or articulated machine with extendable arm. Some machines are not restricted by terrain. The head can grasp and move obstacles. The machine creates mulched spots or strips at spaced intervals. It also shatters debris to improve access. Operating cost is \$95-\$150 per hour. The machine can process 1/3 acre or more per hour depending on debris type and size. Approximate cost per acre ranges from \$215 for light debris to \$420 for dense debris and thickets.

Scratching Fingers and Thumb

This is a track-mounted excavator or Spyder platform that operates with the "scrape and scratch" technique. It produces plantable spots spaced in an arc or scattered intervals, either as individual spots for single seedlings or long strips for multiple (3 to 4) seedlings. Operating cost is \$95-\$200 per hour. This cost varies with machine size and terrain. Cost is about \$185 per acre. The machine processes one or more acres per hour.

Flail or Rotating Arm

This machine is suitable when there are no obstacles to interfere with passage across ground. The large, heavy cutting head shreds the vegetation. Operating cost is \$200 per hour. The machine processes 8+ acres per day. Cost is about \$160 per acre.

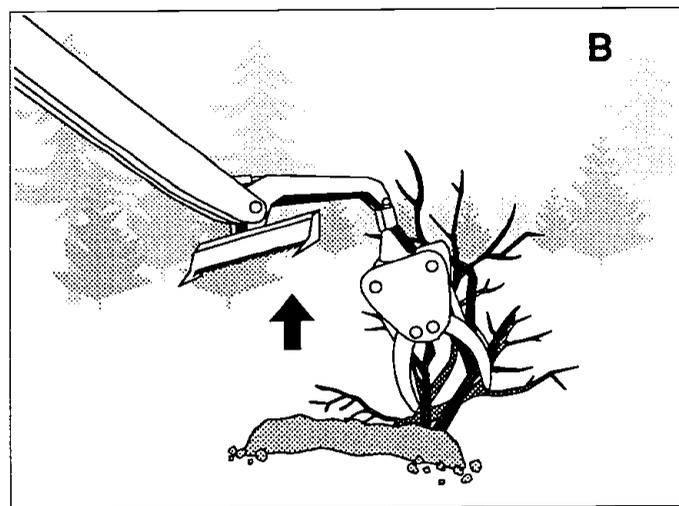
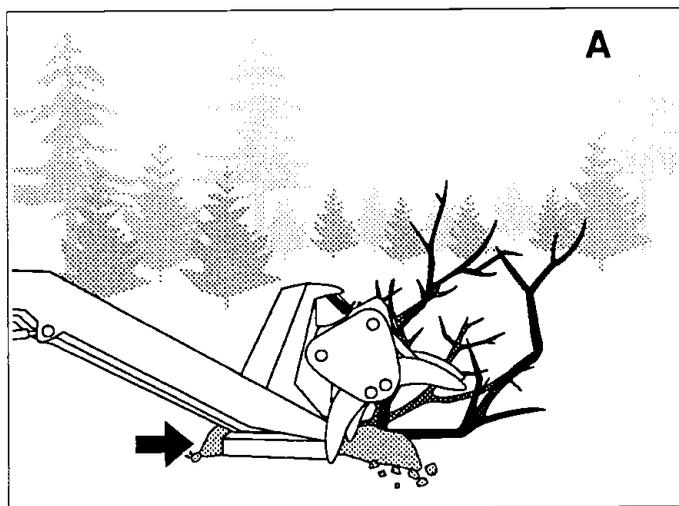


Figure 1. Diagram of a shovel extractor that can remove hardwood clumps in conjunction with the yarding of logs. A two-step procedure is used: first (A) the hardwood clump is pushed over (see arrow), and second (B) the extractor grabs the clump with its tongs and uproots it.

Modified Weighted Cylinder or Rake

This apparatus is moved by a suspended cable similar to a cable yarding machine. The cylinder drags or shoves material out of a track. Each track must be repositioned. It processes area in a uniform pattern as radiating arcs. Current cost is unknown, but cost in 1975 was \$210 per acre.

Extractor

This machine is a shovel used to move, lift, and load logs. The head of the boom mashes the hardwood clump; tongs grasp the base of the clump and pull it from the ground (Figure 1). The hardwood clump is thrown to the side as the shovel travels across the terrain. The machine can remove hardwood clumps in conjunction with the yarding of logs. The shovel can also be used to scatter concentrations of logging debris. No extra costs above those for timber harvest are associated with this treatment.

Ripper

This is a bulldozer with ripper teeth mounted behind tracks. A D-6 or larger machine is recommended. The objective is to break and spread obstructing layers of debris, surface vegetation, rock, and soil. Penetration depth of ripper teeth is about 18-24 in. Operating cost is \$125 per hour. The machine covers 10+ acres per day.

Timber Harvest Only

All plants are cut, crushed, or pulled during the felling and yarding process of timber harvest. Log removal causes the indirect displacement of vegetation. Timber sale contract and utilization clauses specify the minimum size of trees that shall be cut and removed. There usually is no adjustment in the price per thousand board-feet for the work performed. There is no extra cost associated with the treatment.

Conclusions

Most of these site preparation treatments can be done any time of the year. Because the site in question has already undergone the drastic disturbance of harvesting, minimal additional impact should occur. Rip-ping and extraction could cause the most surface disturbance. Some of these operations require creativity, prior assessment, and considerable planning. Nonconventional pieces of equipment may not be easily accessible and therefore may require time to locate or manufacture.

A difficulty observed with these techniques is in getting the machine operator to treat the vegetation and woody debris that actually need treating. The operator should treat an acre here and an acre there (the most difficult spots) and not the whole site. For the first few times a new technique is employed, the forester who is administering the contract must be at the site constantly to suggest places that actually need to be treated. Once the operator learns what is expected, then the machine and the treatment can be used effectively.

The use of mechanical site preparation to create favorable microsites for planted seedlings is becoming a more important technique as stronger restrictions are imposed to protect air and water quality or other resources. Sometimes it will be necessary to perform additional treatments to a site after harvest is finished in order to meet regeneration targets. Access across the ground, ease of planting, uniform stocking, expected survival, and cost of additional treatments beyond harvesting timber have to be balanced against the consequences of not achieving regeneration goals.

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COMPETITION RELEASE: ANIMAL GRAZING AND GRASS AND FORB SEEDING

Animal Grazing and Grass and Forb Seeding in Forest Vegetation Management: An Overview¹

ROBERT G. SHULA

Various treatments for releasing conifer seedlings from competing vegetation were discussed during the remainder of the workshop. Competition release can be achieved in three ways: by reducing current abundance of competing vegetation, by limiting its reproduction, or by establishing or encouraging vegetation that is less competitive. Animal grazing systems can achieve all three forms of competition release. The primary objectives of animal grazing systems in forestry are to reduce competition levels, to foster survival and growth of associated conifer seedlings, and to provide by-products such as meat, wool, and increased rates of nutrient cycling. From what I have read, reducing tree mortality is not as much of a concern. Increases in tree growth have been observed primarily in stem diameter, but height also increases somewhat. Grazing animals provide some organic fertilizer naturally. Grazing also provides an opportunity to obtain some products from the animals themselves. There are several other possible benefits from grazing: reducing cover for rodents, conditioning forage for wildlife in the area, reducing fire hazard, and producing some grazing fees.

Many considerations are involved with animal grazing. Management is paramount. Managers cannot just let the animals loose and hope to eventually track them down. They need to stay aware of the location of the animals and the type of forage on which they are grazing. The type and the class of livestock obviously are important. Distribution of livestock must also be considered with regard to the dynamics of regrazing and regrowth, where they move, how fast they consume the forage, and when they can come back through the same area. Distribution also ties in with the season of use and with the potential for shifting livestock to different elevations on the property. Some other things to be aware of are protection of critical habitat and wildlife in the area, control of predators on the livestock, water management, and provision of mineral blocks.

To be a successful competition release treatment, animal grazing requires staff time and attention. I suppose there is always potential for conifer damage or even mortality from animal grazing. In the future, or even right now, there may be more bureaucratic regulations requiring paperwork and management plans that may end up simply being busy work. A lot of this involves protection of wildlife populations and their habitat. I think everybody needs to make a conscientious effort to formu-

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

late and follow management plans. It makes good sense to do those things. But, if you have to go beyond that, it is going to be a drawback. Also, cattle and sheep in the trees may not be aesthetically pleasing to some people, so that has to be considered, too.

Grass and forb seeding, preferably with native species, has been used to manipulate noncommercial vegetation in order to provide forage for Roosevelt elk (*Cervus elaphus roosevelti*), as well as to modify the species composition and abundance of the plant community such that it is less competitive with conifer seedlings than with the native community. The timing of grass and forb seeding is usually at tree planting or within a year or so after. Some other possible objectives are soil stabilization, enhancement of the visual aspects of a site after harvest, and increasing survival and growth of conifer seedlings. Successful establishment of forage species requires a well-prepared site with exposed mineral soil. This site preparation has usually been accomplished with broadcast burning following clearcut harvesting, but mechanical techniques can also be used. Other considerations are the species of grasses, forbs, and legumes that are used, the proportions in which they are used, and the seeding rate. Sometimes, depending on the characteristics of the site, it may be desirable to fertilize at the time of seeding.

Finally, grass and forb seeding can present several drawbacks. If a nonnative species is seeded and it takes over the site, native species may be displaced. Another potential drawback is site-specific variability in effectiveness, which can be related to the microenvironment of the site or to tree damage caused by animals that are lured by the forage. Tree growth may not be enhanced if a site is seeded with a species that competes with the trees. Finally, additional reforestation costs may be incurred because of the cost of seed and sowing, in addition to those of preparing and planting the site.

Animal grazing systems have seen increased use in forest vegetation management during the past 10 years. In general, they require intensive management of the site and of the animal herd; thus, they tend to be expensive techniques for competition release of conifer seedlings. However, on public lands where multiple-use objectives are prominent, these systems have an important place by providing by-products from grazing animals and by enhancing forage for wildlife.

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Animal Grazing in Forest Vegetation Management: A Research Synthesis¹

STEVEN H. SHARROW

My plan is to present a little bit of the research that has been done at Oregon State University (OSU) that pertains to the subject of sheep and cattle grazing. My purpose is to try to persuade you that we do know what we are doing and that there is a scientific basis for what the next two authors present. The information comes predominantly from faculty in the Department of Rangeland Resources, but the work is done cooperatively with scientists in the Department of Forest Science at OSU and with staff in the USDI Bureau of Land Management and the USDA Forest Service. It is a group effort involving many people.

OSU has an agroforestry program which has two components: agrosilvipastoralism and silvipastoralism. In Oregon, agrosilvipastoralism is essentially growing high-producing pastures and trees on the same piece of land. The benefits of this are early income from livestock during the timber rotation and faster tree growth from enhanced growing conditions. My newest agrosilvipastoral plantations are growing 40% faster in height and 20% faster in diameter than conventional forestry plantations on the same site.

What I want to present in this paper is silvipastoralism—that is, grazing of native understories within an existing forest. I work predominantly with sheep, but I have colleagues who work with cattle. Typically we get better results with sheep than we do with cattle because the application is more intensively controlled. I think that if we used the same management intensity with cattle that we do with sheep, our results would be as good. Where we have used intensive cattle management, we have obtained very good results.

One thing that we are trying to do, of course, is to manipulate the successional process in the forest to allow co-occurrence of a very early seral state (i.e., a grass-forb community) with later seral states (i.e., conifer forest). Many of the sites that we deal with are highly productive. They produce a lot of vegetation. In the early seral stage, they are dominated by grass and forbs which succeeds very quickly to impenetrable woody vegetation on many sites.

We are concerned about a number of aspects of competing vegetation. We are concerned about providing habitat for animals that we do not want—rabbits (*Sylvilagus* spp.), pocket gophers (*Thomomys mazama*), other animals that will damage trees—and about competition for light, soil water, and nutrients. I think most of us agree that animals are good at manipulating vegetation. The trick is manipulating vegetation to get what you want.

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

Factors that we consider in this work are: (1) the type and the class of livestock, which to range managers are different things (*type* distinguishes between animal species—sheep or cattle; *class* refers to the reproductive status of the animal—a castrated versus an intact male, or a lactating female versus a nonlactating female); (2) season of grazing as it relates to nutrient needs and food preferences of animals; (3) degree of grazing, which is generally measured by the percent use of the vegetation; and (4) livestock distribution patterns. These are the things that can be manipulated to get livestock working for you to achieve vegetation control with minimal damage to conifers.

I would like to share several examples. The first is a mixed-conifer stand near La Grande in eastern Oregon that was planted in 1965 (Krueger and Vavra 1984). Normally we have an untreated control and a livestock grazing site in these types of studies. Control in this case means that deer and elk have access to the plots, but cattle do not. In the cattle-grazing site, deer, elk, and cattle have access. Introduction of cattle into this system increased the height growth of Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), western white pine (*Pinus monticola*), and western larch (*Larix occidentalis*) (Table 1). The response varies somewhat from species to species but is positive.

Table 1. Height and diameter (dbh) growth of planted conifers in 1983, 18 years after planting, and under different grazing regimes (source: Krueger and Vavra 1984).

Species	Cattle & game grazing		Cattle only		Game only	
	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)	Height (m)	Diameter (cm)
Ponderosa pine	6.1	12	5.7	12	5.4	11
Douglas-fir	7.8	11	6.6	9	6.6	9
Western white pine	7.3	10	6.8	10	5.1	6
Western larch	8.9	13	8.7	11	6.5	8

Another study was conducted at the Blodgett Experimental Forest, University of California, Berkeley (Allen and Bartolome 1989). It shows tree growth responses similar to those from the La Grande study. Woody vegetation encroaches very quickly when there is no grazing by wildlife or cattle (Figure 1). The untreated control in this study is wildlife grazing but no livestock. Wildlife provide a lot of control of woody vegetation and introduction of cattle increases the benefit. We think that livestock reduce competition from woody vegetation, and that is perhaps why we see increased tree growth. We can control grass as well as woody vegetation. Grass tends to regrow quickly once it is grazed, so controlling grass often requires more than one application of grazing each year.

The third study was conducted in the Willamette Valley, near Corvallis (Hall et al. 1959, Jaindl and Sharrow 1988). It is a very dry Oregon white oak (*Quercus garryana*) site that is marginal commercial forestland. It was planted with Douglas-fir in 1952-3, so we have 30 years of data from it

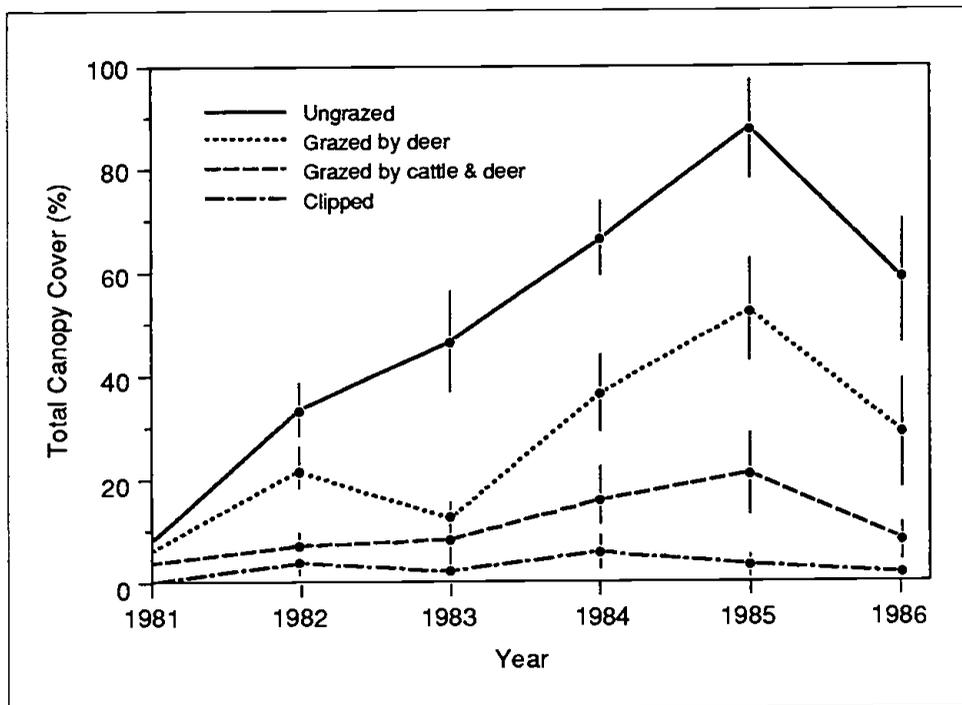


Figure 1. Changes in total shrub and herbaceous canopy cover on a clearcut following tree planting. Values are means from twenty 2.5- x 2.5-m quadrats with 95% confidence intervals. The site was harvested in June 1980, prepared for planting in August 1980, burned in the winter of 1981, and planted in spring 1981 (source: Allen and Bartolome 1989; reprinted by permission of Northwest Science, Northwest Scientific Association, copyright© 1989).

(Jaindl and Sharrow 1988). It was grazed by sheep from 1954 to 1960. As a result, by 1964 both height and stem diameter were greater in grazed plantations (Table 2). The differences measured in 1984 were not as great as they had been in 1964, but they were still there. I suspect that the size of those differences would have persisted longer if our level of forest management had been better. These effects, once obtained, are long-lasting. The authors (Hedrick and Keniston 1966) concluded that increased tree growth occurred because grazing reduced depletion of soil moisture. We believe this happens for two reasons: (1) when foliage is removed from a plant, it does not have as much leaf surface to use water; and (2) plants maintain a balance between root biomass and shoot biomass.

So, grazed grass and shrub plants have less root biomass to draw water than do ungrazed plants (Doescher et al. 1989).

In a study conducted near Medford, Oregon, on the west side of the Cascades (Doescher et al. 1989), grass was the dominant competition. Douglas-fir seedlings were planted in 1983, and by 1986, both their height and stem diameter were increased as a result of grazing. We believe this is a result of reduction in competition for soil moisture. In this particular study there are no-competition, untreated, and cattle-grazed plots. No competition means that a graduate student hoed out all competing vegetation to bare soil. Grazing reduced the moisture stress on trees about as well as removing all competition (Table 3). This is a comparison that we do not often have. There was a lot of mortality in this stand. It is very rare for tree mortality to result from browsing damage. On this particular site, most mortality was due to frost damage. If you did not know the difference, you would have assumed that competition was killing trees, unless you had gone out right after the frost and seen the damage.

Table 2. Mean height and diameter (dbh) of Douglas-fir trees on grazed and ungrazed treatments. Data for 1964 is from Hedrick and Keniston (unpublished) (source: Jaindl and Sharrow 1988).

Measurement	Year ¹	Treatment		Standard Error
		Grazed	Ungrazed	
Height (cm)	1960	157	124	13.0
	1964*	297	234	25.7
	1985	1,311	1,189	95.3
Diameter (cm)	1964**	2.5	1.8	0.4
	1985	14.2	13.2	1.1

¹Symbols indicate years in which treatment means differed significantly: * = $p < 0.10$ and ** = $p < 0.05$.

Table 3. Mean growth measurements of ponderosa pine and Douglas-fir in 1986 for the grazed and ungrazed competitive environments. Standard errors are in parentheses (source: Doescher et al. 1989).

Growth measurements	Ponderosa pine		Douglas-fir	
	Grazed	Ungrazed	Grazed	Ungrazed
Diameter (cm)	3.3 (0.1)a ¹	2.6 (0.1)b	2.1 (0.1)a	1.6 (0.1)b
Height (cm)	94.4 (3.3)a	82.1 (3.2)b	74.6 (3.5)a	69.5 (3.1)a
Volume (cm ³)	388.0 (36.0)a	213.5 (26.3)b	137.5 (16.0)a	71.0 (9.0)b
Non-nodal buds (no.)	—	—	6.1 (0.4)a	4.5 (0.5)b
Needle length (cm)	16.7 (0.3)a	14.5 (0.4)b	—	—

¹Similar letters denote nonsignificant differences ($p < 0.05$) between seedlings in the grazed and ungrazed competitive environments.

Among the work I have done with sheep is a study near Alsea, Oregon, that we conducted for several years in cooperation with the Siuslaw National Forest. The site was grazed by sheep for 2 years. When we started, the salmonberry (*Rubus spectabilis*) and Douglas-fir were about the same height. In the first year of the study, the salmonberry did not grow at all because it was grazed, whereas the Douglas-fir grew almost a meter in height. In the second year, the salmonberry again showed no net growth, and the Douglas-fir continued to increase in height. Essentially, after 2 years of treatment the trees were sufficiently taller than the woody vegetation that they could be considered released. That is what we are trying to do—alter the competition between the plants by giving trees the opportunity to just outgrow the understory.

We are concerned about how to get animals to eat the undesirable vegetation and leave the desirable plants ungrazed. Quite a bit is known about animal preferences, which vary seasonally. The animal has a priority list, much like going to the smorgasbord at the restaurant. The good things are going to go first, but if you are hungry enough you may eat lower priority items. We observe what animals eat and compare it to what is there. If they eat a given plant in greater proportion than it occurs in the plot, they are probably selecting for it; if they are eating it in a smaller proportion, they are probably selecting against it. We call this ratio the relative preference index.

In the Coast Range, graminoid plants are one of the food sources for sheep. They will feed on them at least in the same proportion that this vegetation is present (Table 4). However, forbs are preferred; the animals actually exert a little effort to walk around and find them. Browse (i.e., woody vegetation) is not preferred in the spring. In May, there are more desirable plants to eat than many of the shrub species that are present. In July and August, the animals start to actively select for shrubs because the quantity of the other good species is decreasing. Douglas-fir is never preferred. That does not mean the sheep will not eat it; it means they do not want to eat it. The relative preference index for Douglas-fir is higher in May during budburst and lower in July-August. For competition release, we are trying to control shrubs, and the best time for this is July and August, not May. In July and August, palatability of Douglas-fir is lowest and palatability of shrubs is highest, so that is when we want to

Table 4. Relative preference indices for different forage classes in five Douglas-fir plantations grazed by sheep in 1981 and 1982. Data are mean \pm standard error (source: Leininger and Sharrow 1987).

Year	Forage class	Plantation age—Month of grazing ¹					Y-My/Ag
		O-My	O-Jy	O-Ag	Y-My	Y-Jy	
1981	Graminoids	1.17 \pm 0.06 ⁿ²	1.34 \pm 0.08 ^P	0.98 \pm 0.06 ⁿ	1.04 \pm 0.03 ⁿ	0.88 \pm 0.11 ⁿ	
	Forbs	1.19 \pm 0.06 ^P	1.54 \pm 0.12 ^P	1.60 \pm 0.04 ^P	0.75 \pm 0.13 ⁿ	1.49 \pm 0.20 ⁿ	
	Ferns	0 ^a	0.36 \pm 0.36 ⁿ	0.79 \pm 0.48 ⁿ	0.84 \pm 0.43 ⁿ	0.51 \pm 0.37 ⁿ	
	Browse	0.85 \pm 0.22 ⁿ	1.54 \pm 0.08 ^P	1.47 \pm 0.25 ⁿ	1.28 \pm 0.08 ^P	1.34 \pm 0.29 ⁿ	
	Douglas-fir	0.17 \pm 0.08 ^a	0.04 \pm 0.03 ^a	0.02 \pm 0.01 ^a	0.60 \pm 0.10 ^a	0.03 \pm 0.01 ^a	
1982	Graminoids	1.41 \pm 0.07 ^P	1.76 \pm 0.10 ^P	1.41 \pm 0.28 ⁿ	1.09 \pm 0.02 ^P	1.21 \pm 0.01 ^P	1.01 \pm 0.12 ⁿ
	Forbs	1.35 \pm 0.05 ^P	1.47 \pm 0.42 ⁿ	2.38 \pm 0.26 ^P	0.63 \pm 0.12 ^a	1.07 \pm 0.08 ⁿ	0.72 \pm 0.31 ⁿ
	Ferns	1.23 \pm 0.15 ⁿ	1.60 \pm 0.68 ⁿ	2.04 \pm 1.49 ⁿ	0.88 \pm 0.88 ⁿ	0.43 \pm 0.32 ⁿ	0 ^a
	Browse	0.09 \pm 0.04 ^a	1.97 \pm 0.37 ⁿ	2.18 \pm 0.39 ^P	0.55 \pm 0.20 ⁿ	0.52 \pm 0.17 ⁿ	1.64 \pm 0.08 ^P
	Douglas-fir	0.27 \pm 0.06 ^a	0.02 \pm 0.01 ^a	0.08 \pm 0.03 ^a	1.08 \pm 0.04 ⁿ	0.04 \pm 0.01 ^a	0.57 \pm 0.26 ⁿ

¹Abbreviations are for plantation age class (O = older—4-6-year-old, and Y = younger—2-year-old) and month of grazing (My = May, Jy = July, and Ag = August).

²n, p, and a are neutral, preferred, and avoided, respectively ($p \leq 0.10$).

keep the animals on the site and increase the grazing pressure on shrubs (Sharrow et al. 1989).

Management decisions are critical because the grazing pressure can be quite high, especially with cutting patterns in forests where small acreages are cut. It does not make sense for someone to hire a sheepherder for 20 sheep; big bands of sheep are needed. The timing of movement is critical. On a 20-acre area with 1,000-1,500 sheep, 2 hours is a lot of time. The sheep tend to move so they will not overgraze. A manager should be most concerned about browsing damage to trees when there is new growth on the trees but few other things for sheep to eat. New foliage of conifers has a lower content of terpenes (aromatic chemical compounds), which makes it a little more palatable, although Douglas-fir probably do not taste good to sheep at any time. There is such a great concern about damage to trees that many recommendations suggest that a site not be grazed until the trees are above an animal's reach. However, if managers wait until the trees are 6 ft tall to allow a site to be grazed, it is too late for brush control; grazing needs to be started early when livestock can still reach the top of shrubs.

Dr. Khalid Osman and I have just completed a research project to simulate the effects of defoliation from grazing on growth of Douglas-fir. We know from previous work (Sharrow et al. 1992) that removal of terminal shoots results in a loss of the current-year growth in height as well as in stem diameter. But we were curious about whether removing the lateral branches and leaving the terminal shoot would have much impact on tree growth. We were looking for an economic threshold. To express this over time, we used relative rate of diameter growth, which is essentially similar to the compound interest rate on a loan. It takes into account that big trees grow faster. We found that up to 75% of the new lateral branches can be taken off of a young Douglas-fir without much effect on its growth.

Shoot removal during spring affects only current-year growth, whereas shoot removal during summer will affect growth in the next season. But the growth loss does not persist through time. Douglas-fir is tremendously tolerant of lateral branch browsing. A manager who is concerned about browsing damage to trees should not worry about the lateral branches, but should protect the terminal shoot.

There are two potential explanations for why trees are so sensitive to terminal shoot removal. One is that the terminal bud is an important source of hormones that regulate growth. Also, the loss of buds that would develop into the whorl of branches for the succeeding year is a loss of crown growth potential. Our mathematical models of Douglas-fir trees show that if 75% of a tree's foliage is taken off by grazing, in 2 years the tree is as tall and about as big in diameter as it would have been if not grazed. It has slightly fewer new branches and those branches are slightly smaller, so canopy area is lower but more diffuse. We think

that light penetrates that canopy better. Although there is less canopy, trees grow as fast because they make better use of available light.

Table 5. Biomass (kg/ha) present on grazed and ungrazed plantations in October 1981 and 1982 (source: Sharrow et al. 1989).

Biomass component	Year		Treatment	
	1981	1982	Grazed	Ungrazed
Total	1,418	1,600	1,096	+ ¹ 1,922
Graminoids	242	316	299	260
Forbs	566	510	374	+ 702
Woody vegetation	610	772	422	+ 960

¹Symbols indicate significant differences between years or grazing levels: + = $p < 0.10$ and * = $p < 0.05$.

Table 6. Height and diameter growth during 1981-82 and 1982-83 and total height and diameter (dbh) in 1985 of Douglas-fir trees from grazed and ungrazed plantations (source: Sharrow et al. 1989).

Measurement	Year			% Difference ¹
		Grazed	Ungrazed	
Height growth (cm)	1981-82	87.7	87.3	0.4
	1982-83	96.4	95.3	1.1
Height (cm)	1985	591	564	4.8*
Diameter growth (mm)	1981-82	15.7	14.2	10.6*
	1982-83	16.6	14.3	16.1**
Diameter (mm)	1985	81.2	76.2	6.6**

¹ Symbols indicate significant differences between grazed and ungrazed plantations: * = $p < 0.05$ and ** = $p < 0.01$.

At a site near Alsea, we have studied effects of grazing on control and subsequent recovery of vegetation. In October, at the end of the growing season, we measured how much biomass had accumulated in grazed and ungrazed areas. We found about 43% less biomass in grazed areas (Table 5). There is actually more grass because the grass regrows. There are fewer forbs because grazing removes their growing points; they have to make new ones, so regrowth is slow. Woody vegetation is slow to regrow for the same reason. Grazing yields very good control of forbs and woody vegetation. We would just as soon not control forbs because, in many cases, they are good wildlife feed. Woody vegetation certainly is what we were trying to control. Grazing increased stem diameter and height of Douglas-fir (Table 6).

Conifers may benefit from forage seeding even if forage plants compete with trees, provided that forage plants exclude an even more fierce competitor. In our case, grass may help exclude red alder (*Alnus rubra*). Some of the high-producing forage species self-shade, becoming so dense in a good stand that no light reaches the base of the plant. Without light

to activate new buds, the plant dies. In the case of orchard-grass (*Dactylis glomerata*), very heavily producing stands will usually die out in 1 or 2 years unless they are grazed. Grazing and forage seeding need to be combined to exclude red alder in many cases. In the Coast Range, red alder will begin to replace orchard-grass in the second year after forage seeding in the absence of grazing, because the declining grass cover creates safe sites for alder establishment. Another thing we observed was that if shrubs come into a site that is dominantly grass, animals will spend more time trying to find those shrub plants to browse on than if there is an extensive shrub patch. Animals like variety.

At one long-term research site in the Coast Range, it took 10 years for Douglas-fir in grazed areas to exceed the size of those in ungrazed areas (Table 7). There are two reasons for this protracted lag period of growth

responses. First, the grazed trees lost their terminal shoots, and tree growth responses become delayed by the period of crown recovery. Second, red alder usually invades ungrazed areas by the fifth year of a study, at which time it becomes considerably more competitive with Douglas-fir than the herbaceous and shrub vegetation that continue to dominate in grazed areas.

Grazing can give good results and a lot

of what happens is manipulation of succession to keep it in an early seral stage. This has wildlife benefits; many of the wildlife species like deer and elk are interested in the early seral plant species. The plants that regrow after grazing are higher in nutrition quality for wildlife (Rhodes and Sharrow 1990). Grazed areas green up earlier, partially because of the nitrogen in animal urine and feces, and partially because the sun strikes the soil surface (and warms it) instead of the top of dead or dying vegetation. That is good for wildlife during the critical feeding periods of late winter and early spring. Improved health in deer and elk herds in areas that have been grazed has been reported.

I want to make a comment about predation of grazing animals. We have not had much trouble with predation, even of small animals (Leininger and Sharrow 1989). We do use guard dogs, but have had good results even where we did not.

I think the available research shows that very good results can be obtained with controlled sheep grazing. Prescription grazing can both increase timber volume and improve wildlife habitat.

Table 7. Douglas-fir diameter and height for trees growing in ungrazed and grazed plots near Alsea, OR. Data are mean \pm standard error¹ (source: Sharrow et al. 1992).

Year	Diameter (cm)		Height (m)	
	Grazed	Ungrazed	Grazed	Ungrazed
1981 ²	1.2 \pm 0.03	1.1 \pm 0.04	0.79 \pm 0.02	0.80 \pm 0.02
1982 ²	1.6 \pm 0.05	1.6 \pm 0.11	0.98 \pm 0.03	1.02 \pm 0.04
1983 ²	2.4 \pm 0.07	2.4 \pm 0.06	1.47 \pm 0.07	1.44 \pm 0.06
1984 ²	4.5 \pm 0.12	4.6 \pm 0.13	2.57 \pm 0.09*	2.87 \pm 0.08
1985 ³	3.9 \pm 0.11	4.2 \pm 0.15	3.41 \pm 0.09*	3.76 \pm 0.10
1990 ³	10.0 \pm 0.34*	8.2 \pm 0.30	7.97 \pm 0.11*	7.54 \pm 0.04

¹An asterisk (*) indicates significant differences ($p < 0.05$) between grazed and ungrazed plots.

²Basal diameter.

³Diameter at breast height.

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Sheep Grazing in Conifer Plantations of British Columbia¹

GEOFF ELLEN

Introduction

In the Clearwater Forest District of the British Columbia Ministry of Forests, we have used many ideas from the cooperative work between the USDA Forest Service and Oregon State University (OSU) on sheep grazing at the Alsea Ranger District. Indeed, we can be said to have recycled the Oregon agroforestry experience in British Columbia with different competing vegetation and our own existing markets for lamb and wool, and to have come up with somewhat different cost-benefit models. I believe that in the Oregon model, broadcast burning, aerial grass-legume seeding, and sheep grazing (in that order) were used to control red alder (*Alnus rubra*). In British Columbia, sheep are used for controlling dense herbaceous vegetation in newly planted conifer plantations and, in our district, for brushing, weeding, and site preparation for planting. Actually, many practicing foresters in British Columbia use information from OSU in many different disciplines. Public interest in agroforestry is much greater than what is actually being practiced in British Columbia right now.

Our mission is to explore all perceived cost-effective methods for promoting the best plantation survival and growth rather than as a response to public apprehension of herbicides. The more tools and information available, the greater the possibility of dealing silviculturally with individual sites, of achieving integration with other resources, and of spending public funds wisely.

Our form of agroforestry deals mostly with younger plantations in which survival and long-term growth is directly compromised by initially dense herbaceous vegetation or hardwood competition. Discussion in this paper will center on the following topics: an overview of our district, our past experience in agroforestry, the current silvipastoral system, and our own thoughts on cost-benefit of silvipastoralism.

Overview of the Clearwater Forest District

Our forest district is about 2 million acres in size. We receive about 30 in. of rain per year in the southern portion of our district; the northern part receives about 55 in. Common species of hardwood, shrub, and herbaceous competing vegetation include: birch (*Betula* spp.), aspen (*Populus* spp.), thimbleberry (*Rubus parviflorus*), salmonberry (*R. spectabilis*), rasp-berry (*R. idaeus*), fireweed (*Epilobium angustifolium*), and, at the high elevations, Sitka valerian (*Valerian sitchensis*). We have found that vegetation is most competitive where it occurs on the moistest, most nutrient-rich sites and here it compromises survival of conifers by restricting light at all elevations and by keeping the soil cool at higher elevations.

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

We are currently involved in a Five-Year Plan for reforesting backlog sites, each of which has an individual prescription for mechanical, broadcast burn, and agroforestry methodologies. Steep slopes, understocked sites with a relatively high proportion of natural regeneration, and sites with good soil where herbaceous competition compromises survival are all candidates for sheep grazing.

Past Experience with Sheep Grazing

We became interested in agroforestry in 1985. Trees were encroaching in many grazing areas at that time. We are not sure whether such encroachment occurred because sheep were creating spots for natural seeding-in or whether they were getting rid of vegetation that would carry a fire through these areas. (In other words, it was abnormal to have conifers on these areas.) We moved sheep into the high-elevation clearcuts, ironically because initially we were only looking at the forage value of these sites. They contain some of the most nutritious feed in the world. Thus, one person's competing vegetation is another's forage.

The forest company who was managing these lands was a little apprehensive about 3,000 sheep moving onto these clearcuts, so we set up exclosures as controls. In 1985, we concluded that sheep and spruce are very compatible, perhaps complementary with good herd management. On the clearcuts outside of the exclosures, the sheep removed 80% of the biomass of competing vegetation, nipping 2% of the conifer terminals and basally scarring 1% of the conifer stems. Sheep can easily consume well over 90% of the high-elevation biomass and thereby gain weight (0.5 lb/day). In 4 days, 3,000 sheep can consume over 80% of the herbaceous and woody biomass from a 60-acre block.

Our next series of studies was conducted with small mobile enclosures in which we tried to duplicate the conditions of an actual grazing operation. We put about 30 sheep into half-acre areas in order to find out what they eat and the descending order of palatability of plant species within many different biogeoclimatic sites.

Current Silvipastoral System

Our operational trials led us to several conclusions, not all of which have been verified by statistically valid experiments in subsequent studies. We found that white spruce (*Picea glauca*) are tremendously resilient to grazing and generally sheep will not touch them unless that is the only forage available. In terms of susceptibility to terminal nipping, conifers ranked in descending order as follows: lodgepole pine (*Pinus contorta*), Douglas-fir (*Pseudotsuga menziesii*), and white spruce.

Conifer browsing by sheep is influenced by the palatability and the within- and among-season availability of individual forage species, as well as the overall abundance and species composition of the forage community. Forest managers considering the use of sheep in forest vegetation management should have an experienced agroforester look at their plantations before committing themselves.

The relationship of terminal nipping to percent biomass removal of competing vegetation is not linear but is influenced by the relative palat-

ability and availability of forage and conifer vegetation. For example, young flushing plantations of Douglas-fir should only be grazed when immediate survival is compromised by competing vegetation that is highly palatable to sheep. Older flushing plantations of Douglas-fir (3-5 years) can be grazed to approximately 70% biomass removal of the highly palatable vegetation types, but this treatment is probably not worth the cost unless long-term tree growth is perceived to be severely compromised by initial dense woody competition.

Repeated and thorough grazing of competing vegetation is required in order to get prolonged control. Thus, a large number of sheep in relation to clearcut size should be grazed in order to get good vegetation control and minimize the grazing time spent on a particular area. Grazing several times instead of once yearly is more damaging to competition, and it causes regrowth to be more palatable and nutritious. A 30- to 40-day turnaround between grazings would be ideal. Previous grazings in this manner have decreased the frequency and vigor of competing woody and herbaceous vegetation for as much as 2 years. Aspen can be controlled in 2-3 years with sufficient multiple grazing conducted yearly. Thus, multiple grazings each year are effective for maximizing weight gain by the grazers and control of competing vegetation. We have also worked with low-growing cultivated grasses and legumes that will supplant taller, less palatable native vegetation and ensure that more biomass can be removed by sheep before terminal nipping occurs on conifers such as Douglas-fir.

Cost-benefit of Silvipastoralism

Sheep grazing in British Columbia costs a little more than was experienced in Oregon during the early 1980s, mainly because there is a limited market for Canadian lamb. The more markets we can find for Canadian lamb, the lower the cost of silvipastoralism. In other words, New Zealand is dictating some of the prices of silviculture in British Columbia.

In terms of cost benefits, the use of sheep grazing (at current prices, with or without a grass-legume) should only be targeted for those plantations where immediate survival of conifers is directly compromised by the early-successional herbaceous and woody species or where long-term growth is severely compromised by invasion of woody vegetation. When a number of these problem clearcuts are within a sheep run, then we have an area in which sheep grazing becomes cost-effective for competition release. A *run* is a New Zealand term loosely meaning a collection of range areas designed to maximize weight gains in relation to availability of forage at various elevations, distance between areas and bedding grounds, and distance between the start and the finish of the run.

An agroforestry design would take many forms—from a grazing sequence at the same elevation throughout the season to regrazing a minimum of two clearcuts at a lower elevation, then grazing higher-elevation clearcuts, and then regrazing at the lower elevation after mid-summer (Figure 1). The ideal situation and highest cost benefit would involve highly qualified herders taking the largest manageable flocks. With a competent agroforestry design in a logistical cost-benefit area (i.e., areas linked by a trail and within easy walking distance of each other), a threatened plantation of young spruce can be released from competition effectively within a single season. Such a

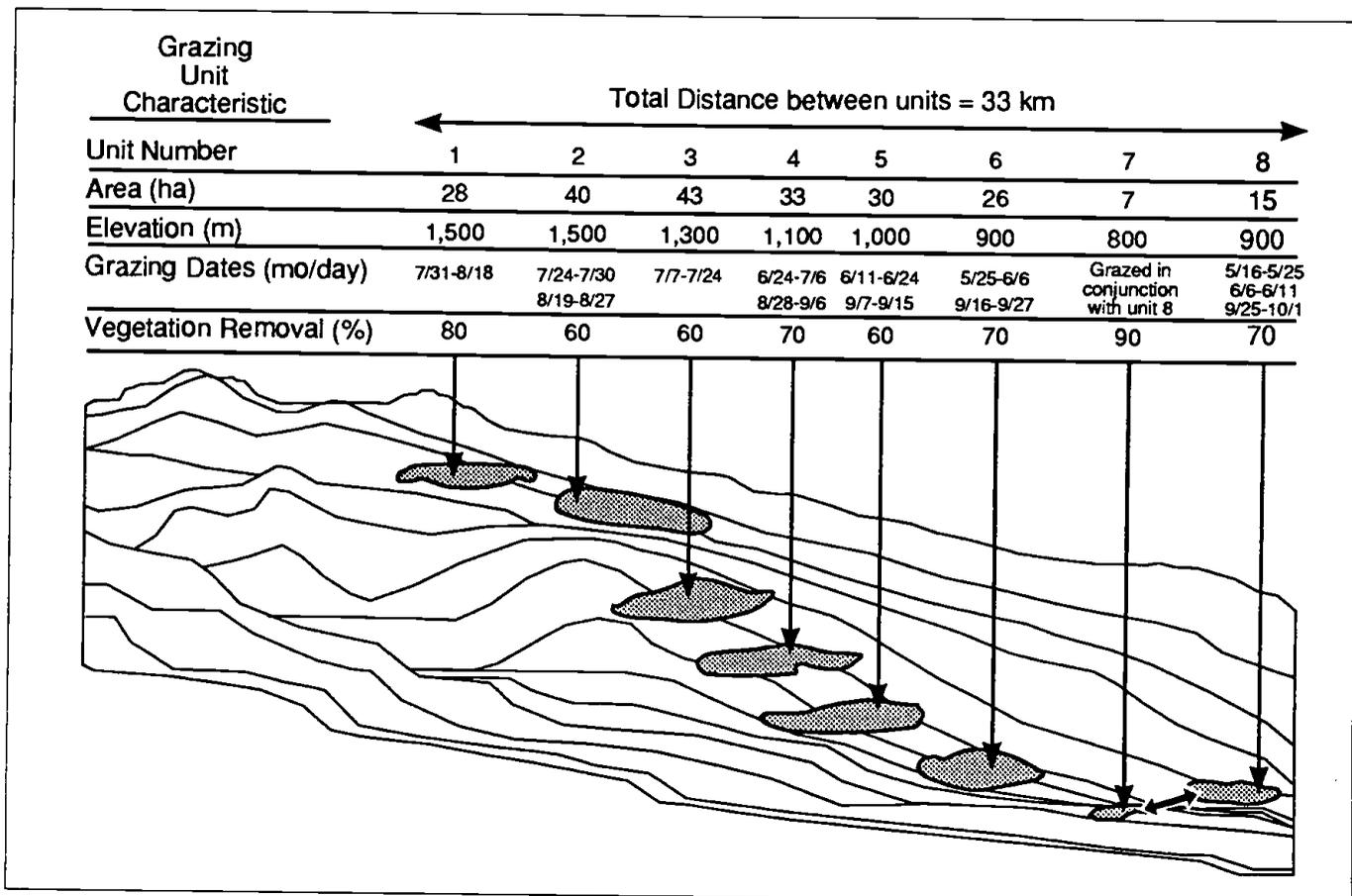


Figure 1. Example of a sheep run on the Clearwater Forest District of British Columbia. Grazing sites are arranged along an elevational gradient to permit early and repeat grazing at low to mid elevations, followed by late grazing at the higher elevations.

system can also be applied to site preparation, planting of large conifer stock, and seeding of grass-legume mixes.

It is important to emphasize that what I have presented is not just a plan for sheep grazing, but rather it is an overall plan for silviculture—site preparation and competition release. The plan requires ongoing monitoring of efficacy and feasibility. You do operational assessment as the work proceeds, and you always leave ungrazed areas on some sites that can be monitored over time. This allows you to look backwards to see if you are doing the right thing, not only for sheep grazing but for everything you do during forest regeneration.

1993 Addendum

Sheep grazing is a promising tool for site preparation and competition release. Experiments and operational assessments are taking place presently with 30 flocks spread across British Columbia in many different silvicultural situations. With data from 24 of the flocks grazed in 1992 and a few from previous years, there should be a significant amount of information and operational critique by the end of 1993. The resultant demand in

1994 will be a very good indication of the true worth of sheep grazing as a management tool.

Since our agroforestry site preparation work started in 1990, our surveys have indicated that survival of planted conifers averaged over 85%. Repetitive sheep grazings have resulted in improved conifer survival and the removal of undesirable aspen and birch. We consider the site preparation of steep, mid-elevation backlog sites with a significant portion of well-spaced naturally-regenerating conifers to have the highest cost-benefit ratio. The price increases of 1992 and 1993 are forcing us to look strongly at other options and hence force us to use them only in the highest cost-benefit situations, which might not be beneficial to the agricultural industry in the long run.

Clearcut characteristics can dictate the method of vegetation management. In steep terrain, high costs and limited feasibility can restrict the use of mechanical site preparation. Under these conditions, sheep grazing is the only option for site preparation and competition release. However, steep terrain, prolonged wet weather, and abundance of hardwood clumps can lead to the development of herd trails, which result in mechanical damage to newly planted conifers. Obstacle plantings, the use of large conifer stock, and special herding tactics are methods that can be used to restrict the damage from over 6,000 hooves of an average flock.

Cost beneficial agroforestry exists only when one industry can help another. It is no surprise that the western Canadian sheep producers are not operating on the same scale as the timber industry in this region and therefore the costs are higher. There is no local sheep industry to respond to local competing vegetation demand in most cases, and expensive trucking is involved if an area is to be grazed. Low market prices for lamb have also had a negative effect; the contractor actually rents the sheep and pays for the medical supplies and the numerous vet inspections involved with the disease protocol, which is certainly not what we had originally intended. Our objective was, and still is, to couple sheep producers looking for forage with silviculturists looking for removal of competing vegetation without a lot of money changing hands. It is not always clear who should be paying who and when competing vegetation is actually forage.

The more buoyant the lamb market is, the higher the forage-competing vegetation ratio, the lower the cost per hectare, the more applicable to silviculture are sheep, and the more land area available for grazing. There are possibilities that no money would change hands in a number of scenarios, but only if there exists either local sheep or good market conditions for lamb and wool. While it is interesting to note that the exact agroforestry methodology is dependent somewhat on markets, the highest prices and highest cost-benefit situations have reached a ceiling and it is obvious in some areas that they are too expensive. The good news is that markets have nowhere else to go but up and silviculture costs have nowhere else to go but down as more is learned. Individuals and agencies are working on all aspects.

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Cattle Grazing in Conifer Plantations of Southcentral Oregon: 11 Years of Successes and Problems¹

JOHN D. MONFORE

Introduction

Since 1910, Weyerhaeuser Company has owned and operated Klamath Tree Farm, a 657,000-acre timberland in southcentral Oregon. This acreage is intermingled with USDA Forest Service and USDI Bureau of Land Management (BLM) lands. Since the first purchase in 1904, this tree farm has been managed by a combination of partial cuts, diameter-limit harvests, marked selective cuts, even-aged clearcuts, and commercial thinning, creating an unequaled diversity of timber stands.

Since 1910 these lands have been leased on an annual basis to local ranchers, many of whom also had grazing permits from the federal government. Grazing for the most part was confined to the meadows and riparian areas. By the late 1970s this grazing appeared to be causing major problems. Many of the meadows and riparian areas on the national forests suffered declines in carrying capacity and forage yields, and Weyerhaeuser conifer plantations were receiving severe and recurrent browse from livestock.

In 1979, Weyerhaeuser Company requested Western Range Services of Elko, Nevada, to conduct a comprehensive range study and recommend a method of livestock management compatible with the growing of even-aged plantations of ponderosa (*Pinus ponderosa*) and lodgepole pine (*P. contorta*) (Korpela 1983, Monfore 1983, Monfore and Steninger 1984). This paper summarizes those recommendations as well as the successes and problems that have resulted over the subsequent 11 years.

Results of the Forest/Range Study

After 3 years of the range study, several findings were revealed which proved to be the key for a largely successful management approach:

- There was no correlation between consumption of forage and browsing of tree seedlings. Browsing did *not* occur as a result of consuming all of the forage and then eating the seedlings.
- Browse damage occurred between June 15 and July 15 of each year, when the shoots of tree seedlings were tender and succulent and the ungrazed forage was starting to cure or enter its reproductive stage. No browsing occurred after July 15.
- Year-round study of individual herds revealed that browsing did not result from a nutrient deficiency. All herds were nutritionally sound.

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

- One herd was found to be dietarily conditioned to pine as a result of winter feeding under a stand of ponderosa pine.
- Through a graduate study from Humboldt State University (Korpela 1983), the quantity and quality of forage in each plantation age class was documented. Parts of this study provided the insight for changing the system of grazing management.
- Study of the coordination of grazing allotments revealed that livestock entry had to occur before budbreak of the seedlings. On the average, this meant late May or early June. Livestock had to be placed directly on the plantations, and the herds had to be controlled by riding to maintain the proper distribution and prevent entry into the riparian areas and meadows. Additional water development was needed for livestock distribution, and allotment planning had to be coordinated with government agencies.

Application of Study Results

The recommendations of this study were followed for 11 years on 25 different range leases covering over 650,000 acres of Weyerhaeuser Company ownership. The key management elements were as follows:

- Livestock was turned out early on Weyerhaeuser Company timberlands. Depending on the allotment, this was as early as April 20 on low elevations west of Klamath Falls. The goal was to have all stock out by June 1. Dates changed because of seasonal variation in any given year.
- During turnout, riders were necessary to move the stock directly to the plantations and hold them there in a well-distributed pattern. This action was vital to ensure that forage was cropped uniformly. As the tender shoots of forage regrew, the livestock would then give their full attention to this highly palatable feed. This grazing was also timed to coincide with the onset of the highest nutritional value in the transitory forage of the plantation (i.e., forage that occupies the site for a short period, after which it is replaced by other vegetation). Without riding and herd control, livestock would naturally congregate in the meadows and riparian areas and severely overgraze them while leaving the plantation forage unused. The use of trained riders cannot be over-emphasized for achieving safe, uniform plantation grazing as well as deferred meadow grazing. Meadow forage retains high nutritional value later in the season and thereby contributes to weight gains in livestock. Grazing plantations early and meadows late effectively prolongs range use.
- Numbers of livestock had to be increased to achieve uniform removal of vegetation and subsequent utilization of regrowth on the plantations. This aim was achieved on nearly all of the lease areas, and plantation damage was almost completely eliminated. Numbers were increased by 25%-600% on the various leases. Forage production increased dramatically during the first 6 years of plantation establishment, thus providing the vegetation base for increased livestock numbers.

- Water developments were made in key areas to aid in maintaining livestock distribution and minimizing the use of riparian areas. Between 1980 and 1991, over 190 water developments were built on the tree farm.
- USDA Forest Service and BLM plans for managing allotments had to be modified to accomplish the previously noted changes. After numerous tours and demonstrations, these plans were modified so that plantation grazing occurred early every year on Weyerhaeuser Company lands while grazing on major meadows and riparian areas occurred late on government lands. Before 1979, forage yields had declined on government lands, but by the third year after the study recommendations were imposed this trend was totally reversed.

11 Years of Success

Since the recommendations were imposed, many of the objectives of the extensive grazing system were fully achieved. Although the system was not administratively perfect, the results were biologically satisfactory at least for the first 11 years. It is fairly accurate to say that, on any given year on any allotment, the program was 75%-90% of what a perfectly administered grazing program could be. The cost of achieving the last fractional gain would escalate beyond a profitable margin. The four major areas of success are outlined below.

Benefits of Plantation Grazing

From 1980 through 1991, plantation browse was nearly eliminated on 160,000 acres of plantations. Less than 1% of the plantation acres received any appreciable browse damage during that period. Because of extremely dry conditions in 1988, some 400 acres received damage from cattle and big game during early September of that year—the only instance of this type of browsing. It occurred on new plantations that had no forage and on others when the forage on an entire allotment was consumed. In retrospect, the livestock should have been removed by September 1 of that year. During that same year, one small portion of a plantation was damaged by a small herd (50 head) of sheep. This herd was not part of the major band (2,000 head) and was left unattended for approximately one month.

These damaged plantations have recovered and are moving toward crown closure. Currently, there are over 130,000 acres of formerly grazed plantations at crown closure or that have been precommercially thinned. In addition, there are some 30,000 acres of plantations moving toward crown closure. These 160,000 acres are the proof of largely successful plantation grazing.

In terms of conifer growth enhancement from vegetation removal, Weyerhaeuser Company has, in the past, demonstrated a growth enhancement from herbicides in almost every timber type. At Klamath Falls, livestock exclosures were constructed in 1980 on many plantations and growth enhancement due to vegetation removal via grazing is visible,

but the magnitude of these growth increases has not yet been quantified. In addition, grazing benefits to tree growth should be compared to those achieved from the use of herbicides.

In early stages of plantation growth, grazing effectively fireproofed the plantations. This was graphically demonstrated during and after three fires that occurred in this period. In 1987 (a bad fire year), one of the worst fires occurred on an allotment that was ungrazed that year. Spot fires in the cured grass were very difficult to stop, and the fire burned some 1,600 acres of Weyerhaeuser lands. On no other allotment during this period did a fire start and spread so rapidly because of unused forage. The other fires were controlled when they reached grazed plantations due to the lack of fuel on the ground.

Improvement of Riparian Areas and Meadows

Grazing of plantations early and meadows late resulted in a dramatic turnaround on major riparian areas and meadows. Forage production on these areas for BLM and national forest allotments increased immediately. Because Weyerhaeuser Company lands contain fewer of these areas, the reversal was less dramatic there. During the last 3 years, the smaller riparian areas have not fared well, as will be discussed later.

In general, deferment of riparian areas and meadows has not only allowed deer fawning and elk calving to occur without interference but also has benefitted the soil and vegetation there. In the last 3 years (1988-91), several programs to enhance riparian areas have begun on company lands:

- The Bear Creek enclosure was constructed with some 7 miles of fence. Three seasons without livestock followed by flash (high intensity, short duration) grazing for 1 month each year with first-calf heifers (i.e., 2-year-old cattle with their first calf) is planned. The flash grazing will pay for the fence as well as keep the vegetation healthy.
- The Spencer Creek Coordinated Resource Management Plan is well under way and involves a variety of fencing, deferment, and flash grazing.
- The enclosure at Long Creek has been moderately successful in reducing livestock use on a highly visible portion of this stream.

Success with Livestock

The first 7 of the past 11 years were economically depressed for the entire livestock industry. A few allotments on and around the Klamath Tree Farm underwent some bankruptcies. Such failures, however, were minimized by increasing the carrying capacities on these allotments: a cost benefit was thereby realized by the owners even after added expense for riders. The increased numbers of livestock provided the margin.

Perhaps of equal importance were the increased gains in calf weights. These gains resulted from early grazing of the forage at optimum nutri-

tional value on plantations and saving forage on meadows for later use. The ZX Ranch reported an average increase of 40 pounds per calf over those associated with traditional rest/rotation systems. Furthermore, the count of "leppy" (orphan) calves was reduced to almost zero. Riding and herding costs were reduced by \$5,000 annually. Although not all allotments accrued these same total benefits, this general trend prevailed on many of them.

Other Benefits to the Landowner

In addition to the fire-proofing of grazed areas and the reduction in vegetative competition and browsing, other benefits were associated with the grazing system. Over the last 11 years, 15,800,000 Animal Unit Days of use have accrued on the area. The amount of organic fertilizer (manure) deposited over this period has been more than 197,500 tons. The grazing fees collected have totalled over \$1.2 million (net) for the period and have thus contributed toward paying other costs of land management such as fire assessments and property taxes.

Problems and Opportunities

While there have been major successes as previously noted, this extensive grazing program has not occurred without problems and opportunities for improvement. Its application depends on a uniform and confident approach to forest management. A series of events—most notably the 1982-84 depression in the wood products market—changed forest management practices, principally by reducing plantation acreage. This disruption in distribution of age classes and in forage production has reduced the tree farm's livestock carrying capacity.

- Crown closure and subsequent forage loss in the plantation has all but eliminated a cost-effective or economically viable grazing program on some allotments. All allotments will undergo dramatic declines in carrying capacity. For example, in 1985 a peak of 17,000 Animal Units were grazing transitory forage. But in 1991 only 6,800 Animal Units were permitted. In the future these numbers will be further reduced.
- Furthermore, the rush by many government agencies and departments to regulate forest activities has caused a direct reduction in grazing flexibility and may before long completely eliminate livestock as an effective tool in vegetation management. The uncertain regulation of forest management will continue to have a negative impact on forest grazing.
- The perceived favoring of wildlife over livestock in management programs will continue to depress livestock grazing in forest settings. It is interesting to note that this particular program has actually benefitted Roosevelt elk (*Cervus elaphus roosevelti*) populations. In comparison, elk historically used the prairie range east of the Rocky Mountains after bison (*Bison bison*) grazing had prepared the forage. The buffalo removed the coarse vegetation, which encouraged a greater diversity

of forage species and tender regrowth for elk. Livestock grazing has prepared the forage for elk in the same way. The water developments, salt, and mineral blocks have also benefitted the elk, and as a result these herds have dramatically increased on the tree farm. Range conditions throughout the summer were also improved for mule deer (*Odocoileus hemionus hemionus*). Furthermore, conflicts with fawning were reduced by early deferment of grazing in riparian areas (Monfore 1986).

- Notwithstanding this action, the needs of wildlife will be used by preservationists to effect a challenge to forest grazing of livestock. It is also a fact that hunters object to the presence of livestock in the woods. A major goal of management is to have all livestock removed from the tree farm by September 15. However, when conditions are warm and dry during early fall, such as they have been for the last 6 years, reluctance of livestock to being herded makes their gathering difficult and costly. On the average, 75% of the animals have been removed by October 1 during this period, and this rate must be increased to 95% or more if range conditions are to be improved and hunters' objections defused.
- Because the past 6 years have been exceptionally dry, the constructed water sources have not always been adequate in reducing use of riparian areas on Weyerhaeuser Company lands. Far too many of the small riparian areas and small meadows have been damaged by livestock. (Note: These are not the same as the major deferred riparian areas discussed earlier.) A system for ensuring better livestock distribution and lighter use of these small riparian areas is needed. Simple herd reduction is not always the answer—the economics of maintaining viable herds quickly aggravates this issue further. More water development may be a partial solution. A shorter season of use may also be appropriate for some lease areas. The issues of protecting riparian areas and maintaining associated water quality are the greatest challenges to successful grazing of forest lands today.
- From a social perspective, a major hindrance to the acceptance of livestock as a forest management tool is the aesthetics of the animals. Many people (especially many foresters, for some reason) just do not like the looks of cows in the woods. They especially do not like the smell of cows, even though cows can mean increased cycling and availability of nutrients to conifers. This reluctance represents a major threat to the future of forest grazing. Minimizing the use of riparian areas, salting away from roads, and maintaining uniform distribution of livestock are all actions that can reduce this conflict over aesthetics.
- The resistance to change by the livestock industry, and by a few ranchers in particular, must be overcome. Livestock owners must become more attuned to social changes in attitude. Long-standing customs and management practices must be changed or grazing in forests and on other public lands may be lost entirely.
- More stable and longer term employment in federal land management agencies is needed so that their managers can attain an understanding of extensive range programs at the local level.

Conclusions

For the past 11 years, livestock have been used successfully on a 657,000-acre tree farm in southcentral Oregon as a tool in managing vegetative competition in ponderosa and lodgepole pine plantations while providing revenue to the landowner. Controlling herds for early grazing of transitory forage and late grazing of major meadows and riparian areas can enhance total forest and range conditions.

However, aesthetic objections on the part of an ever-increasing urban population as well as abuse of riparian areas and livestock owners' resistance to change are problems that must be addressed in the near term if forest grazing is to continue. For the long term, forest management must attain a certainty and a balance so that continuity in range use for forest grazing is assured.

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Grass and Legume Seeding in Forest Vegetation Management: A Case Study in the Oregon Coast Range¹

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Introduction

Grass is often regarded as a severe obstacle to reforestation in conifer plantations, but there is some evidence to suggest that under certain conditions grass-legume seeding may be beneficial. A literature review by B. Peterson et al. (Siuslaw National Forest, Corvallis, OR, unpublished data, 1981) cited benefits to the soils, including reduced surface erosion and a short-term increase in soil nitrogen fixation. West of the Oregon Coast Range summit, where the average annual precipitation commonly exceeds 100 in., G.E. Klingler (Siuslaw National Forest, Corvallis, OR, unpublished data, 1982) reported reductions in the amount of red alder (*Alnus rubra*) and other woody vegetation, big game damage, and mountain beaver (*Aplodontia rufa*) activity in Douglas-fir (*Pseudotsuga menziesii*) plantations seeded with grass-legume mixtures. Reductions in woody vegetation have also been observed in Coast Range clearcuts seeded with grasses and legumes for enhancement of elk (*Cervus elaphus roosevelti*) forage (B. Cleary, Oregon Department of Fish and Wildlife, Corvallis, OR, personal communication, 1984).

In western Washington, Wolff (1987) found that seeded grasses effectively controlled early successional vegetation in Douglas-fir plantations. The density and height growth of salmonberry (*Rubus spectabilis*) were reduced in dense thickets near Tillamook, Oregon, that were slashed, burned, and grass-seeded (J. Heinz, USDI Bureau of Land Management, Tillamook Resource Area, Tillamook, OR, personal communication, 1984). In northwestern British Columbia, Coates et al. (1993) reported that blade-scarified sites seeded with grasses had substantially less re-establishment of thimbleberry (*Rubus parviflorus*).

Big game browsing of conifers may be reduced by seeding palatable alternative forage species. Elk have demonstrated a preference for seeded grasses and legumes over Douglas-fir, bentgrass (*Agrostis* spp.), and native forbs (B. Cleary and I.M. Mereszczak, Oregon Department of Fish and Wildlife, Corvallis, OR, unpublished data, 1978; Mereszczak 1979). V.C. Morris (Siuslaw National Forest, Corvallis, OR, unpublished data, 1981) reported 18% less mountain beaver activity in seeded than in unseeded areas.

Grass-legume seeding, however, may also have negative effects on conifer regeneration. Even on sites that have relatively high moisture

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

regimes, herbaceous plants have been shown to reduce growth of young conifers (Newton and Preest 1988, Wagner 1989, Coates et al. 1993). Damage by voles (*Microtus* spp.) to planted conifers has been observed in the fourth year after grass seeding, particularly if the seeded grasses were not used by big game animals (B. Cleary, Oregon Department of Fish and Wildlife, Corvallis, OR, personal communication, 1984). Vole populations may increase following seeding, especially in low, wet areas.

Woody competition can be intense on many Oregon Coast Range sites, and may threaten the growth and survival of young conifers. Many competing species can be effectively controlled with herbicides. The case study presented in this paper assessed an alternative vegetation management technique, grass-legume seeding, in two clearcut sites in the Oregon Coast Range over a 5-year period.

Methods

Two clearcut sites, Diamond Drifter and Sampson Creek, were selected for study. The sites were located on Bureau of Land Management land approximately 10 mi southeast of Lincoln City, Oregon, on the western slopes of the Coast Range. Because annual precipitation averages 120 in. at each site, soil moisture was not considered to be the most limiting factor for conifer growth. The average elevations of Diamond Drifter and Sampson Creek were 700 and 1,250 ft, respectively. Salmonberry and thimbleberry were the major competing shrubs.

The sites were broadcast burned in the fall of 1984. Prior to seeding, a uniform 1- to 2-acre portion of each site was selected for the study area. Half of each study area was seeded and fertilized by helicopter in October 1984. The other half was not treated and served as the control. Table 1 shows the seed and fertilizer mixtures applied to the study areas. Both seed mixes contained 11 lb/acre of grass and 9 lb/acre of legumes and were considered suitable for elk forage. The sites were planted with 2-0 Douglas-fir seedlings during January 1985.

Data on vegetation development was collected during late summer in the first, second, third, and fifth years (1985-87, 1989) after seeding. Frequency and percent canopy cover were measured for vegetation in twenty 3- by 3-ft permanent plots in each control and seeded area. Cover estimates were divided into six classes as described by Daubenmire (1970): 0%-5%, 5%-25%, 25%-50%, 50%-75%, 75%-95%, and 95%-100%. The mid-point of each cover class interval was recorded for each species.

Annual height growth, animal damage, and survival were recorded for 25 permanently marked Douglas-fir seedlings in each control and seeded area. Total height was measured in 1987 and 1989. If a terminal shoot was damaged, growth measurements were taken on the lateral shoot most likely to become dominant.

Total height was recorded for 25 permanently marked salmonberry and thimbleberry stems in each control and seeded area. Stem heights were measured from ground level to the base of the uppermost leaf. Because the previously measured salmonberry and thimbleberry stems were difficult to locate at the fifth-year measurement date, another 25

Table 1. Seed and fertilizer mixtures applied to Diamond Drifter and Sampson Creek sites.

Mixture	Contents	Site	
		Diamond Drifter	Sampson Creek
		---(lb/acre)---	
Seed	Annual ryegrass (<i>Lolium multiflorum</i>)	4	2
	Perennial ryegrass (<i>L. perenne</i>)	2	2
	Orchard-grass (<i>Dactylis glomerata</i>)	5	4
	Pubescent wheatgrass (<i>Agropyron trichophorum</i>)	0	3
	Subterranean clover (<i>Trifolium subterraneum</i>)	5	5
	New Zealand white clover (<i>T. repens</i>)	2	2
	Big trefoil (<i>Lotus uliginosus</i>)	2	2
	Fertilizer Total	232	252
		---(%)---	
	Nitrogen	0	12
	Phosphorus	28	11
	Potassium	0	15
	Sulfur	8	12
	Boron	<1	<1

stems of each species were selected in the vicinity of the original stems. All height measurements were made to the nearest 0.25 in.

Results and Discussion

Effects of Seeding on Competing Vegetation

Frequency of salmonberry and thimbleberry was lower in the seeded areas than in the controls for each year of the study (Table 2). Most of the differences were statistically significant ($p < 0.05$). Mean cover values for salmonberry, thimbleberry, and swordfern (*Polystichum munitum*) are shown in Table 2. Swordfern cover was used as a possible indicator of mountain beaver habitat quality.

Salmonberry cover was generally much lower in the seeded areas than in the controls for the first 3 years. After 5 years, however, salmonberry cover was slightly higher in the seeded area at Diamond Drifter, but still much lower in the seeded area at Sampson Creek. Thimbleberry cover generally tended to be lower in the seeded areas at both sites for each year of the study. Red alder was relatively unimportant at both sites; therefore, data were not collected for this species. At Sampson Creek, swordfern cover was significantly higher ($p < 0.05$) in the seeded area than in the control area at three of the four measurement dates, but such differences were not detected at Diamond Drifter.

Table 2. Frequency, canopy cover, and total height of salmonberry, thimbleberry, and swordfern at Diamond Drifter and Sampson Creek sites.

Variable	Site	Species	Treatment	Measurement year					
				1985	1986	1987	1989		
				----- (%) -----					
Frequency	Diamond Drifter	Salmonberry	Control	60a ¹	75a	75a	85a		
			Seeded	20b	30b	30b	45b		
		Thimbleberry	Control	10a	35a	40a	60a		
			Seeded	0a	10a	25a	20b		
	Sampson Creek	Salmonberry	Control	35a	55a	40a	56a		
			Seeded	0b	5b	0b	5b		
		Thimbleberry	Control	50a	70a	65a	88a		
			Seeded	25a	20b	25b	15b		
Canopy cover	Diamond Drifter	Salmonberry	Control	11.1a	13.3a	23.4a	12.4a		
			Seeded	5.9a	7.3a	8.5b	14.1a		
		Thimbleberry	Control	0.3a	1.5a	1.0a	4.0a		
			Seeded	0.0a	0.3a	1.3a	2.2a		
		Swordfern	Control	0.8a	2.3a	1.4a	3.4a		
			Seeded	1.8a	0.9a	1.8a	1.0a		
		Sampson Creek	Salmonberry	Control	6.4a	7.4a	15.3a	19.2a	
				Seeded	0.0b	0.1b	0.0b	0.1b	
	Thimbleberry		Control	2.5a	4.3a	9.4a	27.7a		
			Seeded	1.3a	1.1b	2.4a	2.8b		
	Swordfern		Control	1.6a	1.1a	1.6a	2.3a		
			Seeded	7.4b	0.9a	9.4b	11.9b		
					----- (in.) -----				
	Total height		Diamond Drifter	Salmonberry	Control	12.1a	18.3a	24.2a	39.2a
		Seeded			15.0b	19.0a	20.1a	43.0a	
		Thimbleberry		Control	—	—	—	31.6a	
Seeded				—	—	—	17.6b		
Sampson Creek		Salmonberry	Control	15.3a	21.9a	31.6a	47.1a		
			Seeded	12.5b	14.2b	19.4b	24.1b		
		Thimbleberry	Control	23.0a	26.8a	43.2a	37.4a		
			Seeded	14.9b	17.2b	24.4b	26.5a		

¹For a given site, species, and year, treatment means followed by the same letter are not significantly different at the 0.05 level.

Heights of salmonberry and thimbleberry are presented in Table 2. The effect of seeding on salmonberry height varied by site. Except for the first year, salmonberry height was essentially unaffected by seeding at Diamond Drifter. The majority of the salmonberry in the seeded portion of this site, however, occurred in strips where the grass density was somewhat less than average.

In contrast, salmonberry height at Sampson Creek was consistently shorter in the seeded area than in the control. These differences were

statistically significant ($p < 0.05$). At the fifth-year measurement date, salmonberry height in the seeded area was 49% less than in the control. The soils on this site probably have a lower water-holding capacity than those at Diamond Drifter because they are shallower and contain more coarse fragments. The grasses, therefore, probably competed more with salmonberry for the available soil moisture on this site.

Table 3. Number of forb species per plot (excluding ferns and seeded legumes) at Diamond Drifter and Sampson Creek sites.

Site	Treatment	Measurement year			
		1985	1986	1987	1989
Diamond Drifter	Control	2.8a ¹	5.6a	4.7a	6.6a
	Seeded	2.1a	1.8b	2.8b	4.5b
Sampson Creek	Control	4.1a	4.7a	4.8a	3.1a
	Seeded	1.9b	1.9b	2.5b	3.7a

¹For each site and year, treatment means followed by the same letter are not significantly different at the 0.05 level.

Sampson Creek was the only site with a substantial amount of thimbleberry. Thimbleberry height in the seeded area was consistently shorter in the seeded area than in the control. For the first 3 years, the differences were statistically significant ($p < 0.01$). After 5 years, thimbleberry height in the seeded area was 29% shorter, but the difference was not statistically significant ($p \geq 0.1$).

The number of forbs (excluding ferns and seeded legumes) was significantly less ($p < 0.01$) in the seeded areas for the last 3 years of the study at Diamond Drifter and for the first 3 years at Sampson Creek (Table 3). By the fifth year at Sampson Creek, the number of forbs was nearly equal in the seeded areas and the controls.

Effects of Seeding on Douglas-fir Seedlings

Annual height growth of Douglas-fir seedlings is shown in Table 4. Seeding had no effect on Douglas-fir growth the first year. During the second year, however, current-year growth in the seeded areas at both sites averaged 42% less than in the controls. These differences were statistically significant ($p < 0.05$). Cover of seeded grasses on the sites averaged 34%. It seems likely that Douglas-fir and grasses competed most strongly for soil moisture during the second year when the grass roots were probably well-established in the upper part of the soil profile, and most Douglas-fir roots had not yet penetrated beyond the grass-root zone. In addition, the very dry summer during 1985 (precipitation was 50% of normal in the Coast Range) may have increased the moisture competition between Douglas-fir and grasses. By the third year, however, height growth of Douglas-fir in the seeded areas was nearly identical to that in the control at both sites. Fifth-year height growth of Douglas-fir averaged 24% less in the seeded areas than in the controls, but the differences were not statistically significant ($p \geq 0.1$). Initial reduction of Douglas-fir height growth and subsequent recovery were also observed on seeding trials in western Washington (Wolff 1987).

Total height of Douglas-fir in the controls was very close to that in the seeded areas after 3 years (Table 4). After 5 years, Douglas-fir height in the seeded areas averaged 19% less than in the controls, but the differences were not statistically significant ($p \geq 0.1$). Douglas-fir survival

Table 4. Measurements of Douglas-fir seedlings at Diamond Drifter and Sampson Creek sites.

Variable	Site	Treatment	Measurement year			
			1985	1986	1987	1989
			----- (in.) -----			
Current-year height growth	Diamond Drifter	Control	2.4a ¹	7.5a	10.6a	25.2a
		Seeded	2.7a	4.4b	10.3a	21.2a
	Sampson Creek	Control	1.9a	5.1a	7.9a	16.6a
		Seeded	2.0a	2.9b	7.5a	10.6a
Total height ²	Diamond Drifter	Control	—	—	32.5a	88.3a
		Seeded	—	—	27.3a	73.5a
	Sampson Creek	Control	—	—	23.9a	54.5a
		Seeded	—	—	23.1a	42.4a
			----- (%) -----			
Cumulative survival	Diamond Drifter	Control	96a	83a	83a	74a
		Seeded	96a	96a	92a	92a
	Sampson Creek	Control	92a	72a	65a	63a
		Seeded	92a	64a	64a	62a
Current-year browsing damage	Diamond Drifter	Control	0a	76a	5a	7a
		Seeded	12a	82a	0a	36b
	Sampson Creek	Control	13a	22a	46a	8a
		Seeded	0a	19a	25a	23a

¹For each variable, site, and year, treatment means followed by the same letter are not significantly different at the 0.05 level.

²Total height measured after three and five growing seasons.

in the control and seeded areas was not significantly different ($p \geq 0.1$) at either site during any year of the study (Table 4).

Big game browsing damage of Douglas-fir varied by site and did not show a consistent relationship with seeding, except that damage levels tended to be higher in the seeded areas at the fifth-year measurement date (Table 4). Douglas-fir seedlings in both the seeded areas and controls at Diamond Drifter, however, experienced very high levels of elk browsing damage in late fall or early winter of the first year (1985). This damage was recorded at the second-year measurement date. Elk may have fed on the palatable seeded grasses during the spring and summer months. As the season progressed and the grasses began to decline in palatability and nutritive value, elk browsing on Douglas-fir likely increased. In addition, reduced shrub cover in the seeded portion of the site may have further increased browsing pressure on Douglas-fir. Browsing at Diamond Drifter had declined by the third year in both the control and seeded areas. No damage from mountain beaver or voles was detected at either site.

Differences in total height between Douglas-fir and competing brush species over the 5-year period are presented for Diamond Drifter and Sampson Creek in Figures 1 and 2, respectively. Since total height for Douglas-fir was not measured until the third year, heights for the first

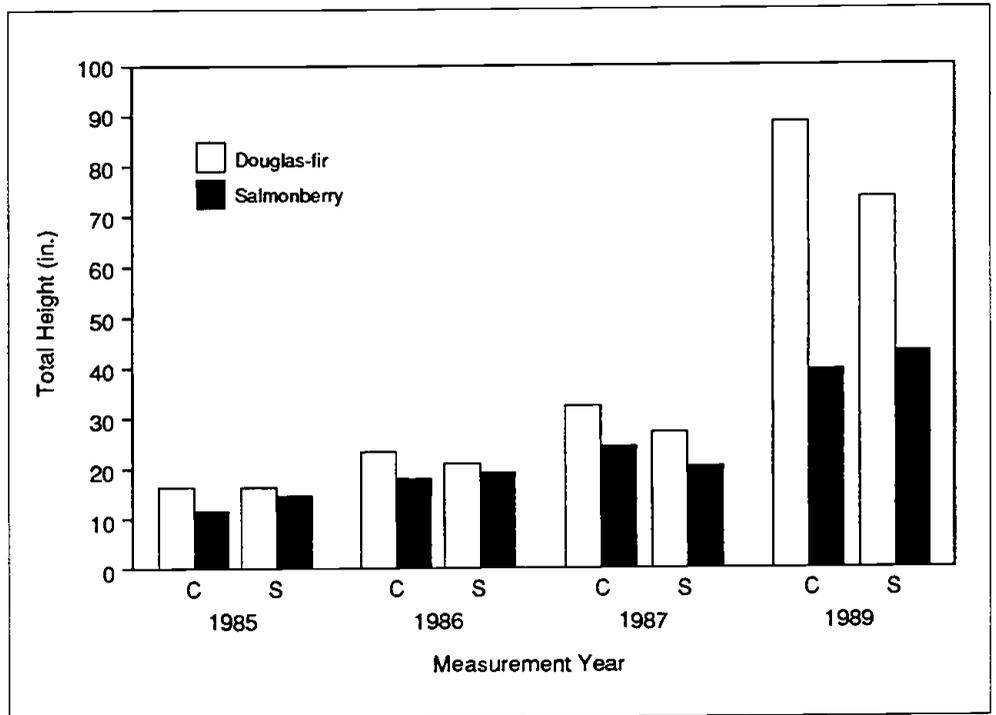


Figure 1. Total height of Douglas-fir and salmonberry at Diamond Drifter. C = control; S = seeded.

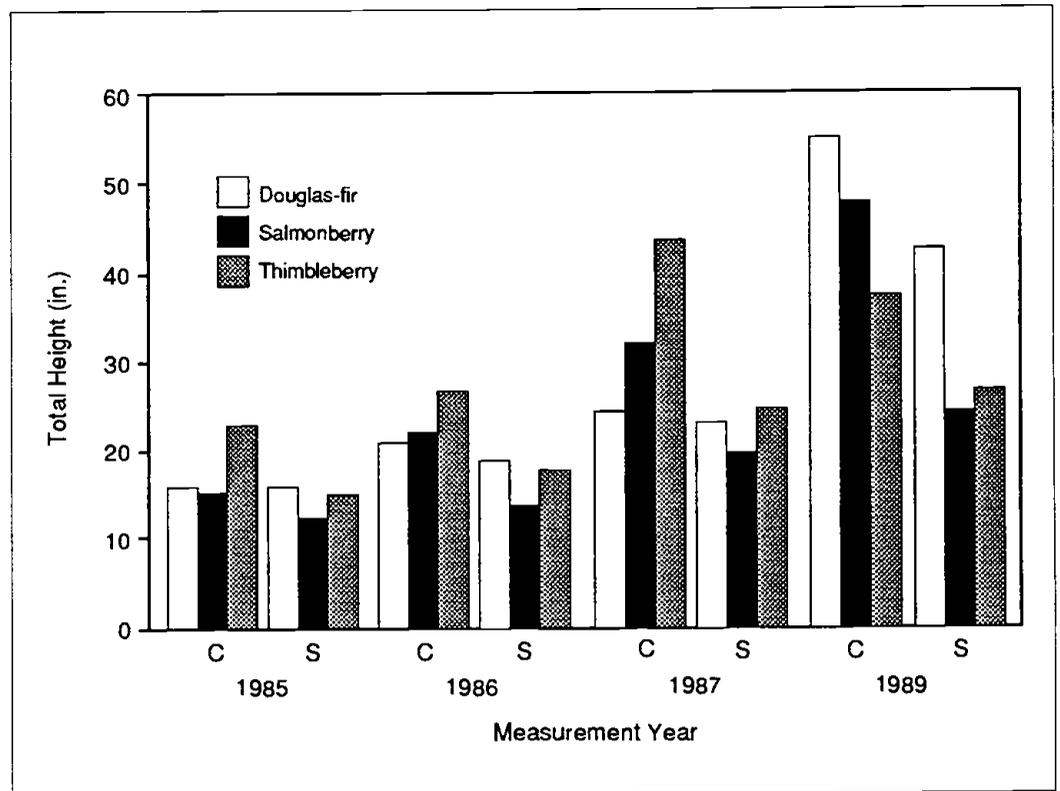


Figure 2. Total height of Douglas-fir, salmonberry, and thimbleberry at Sampson Creek. C = control; S = seeded.

and second years were estimated by assuming an initial height of 14 in. at the time of planting and adding the leader growth for those 2 years.

In both the seeded area and control at Diamond Drifter, Douglas-fir and salmonberry heights were nearly equal for the first 2 years. In the third year, Douglas-fir began to increase in height over salmonberry, and by the fifth year, the trees were about twice as tall as salmonberry. Also, height of Douglas-fir in the control tended to be greater than in the seeded area after 5 years.

During the first 2 years at the Sampson Creek control, Douglas-fir was about equal in height to salmonberry, but was slightly shorter than thimbleberry. In the third year, both salmonberry and thimbleberry were taller than Douglas-fir. By the fifth year, however, Douglas-fir was taller than both salmonberry and thimbleberry.

In the seeded area at Sampson Creek, Douglas-fir, salmonberry, and thimbleberry heights were nearly equal until the fifth year, when Douglas-fir was taller. As was the case at Diamond Drifter, Douglas-fir height in the control tended to be greater than in the seeded area after 5 years.

Additional Observations

The following are some additional observations on using grass-legume seeding for forest vegetation management in the Coast Range:

- An ash seedbed or mineral soil appears to be important for establishing a stand of grasses and legumes dense enough to provide control of woody vegetation. Establishment of seeded species was poor in portions of sites where an adequate burn was not achieved.
- Cover of ryegrass (*Lolium* spp.) appeared much lower and cover of orchard-grass (*Dactylis glomerata*) appeared much greater by the fifth year than during the first 3 years of this study. An increase in orchard-grass cover and a decrease of ryegrass cover following seeding was also reported in northwestern British Columbia (Coates et al. 1993).
- Pubescent wheatgrass (*Agropyron trichophorum*) was included in the seeding mixture applied to Sampson Creek. This species was not observed in any of the plots until the third-year measurement date when it was only found in very small quantities throughout the seeded area.
- Legumes generally accounted for less than 5% of the total cover of seeded species and, therefore, were probably not important for control of woody vegetation. Big trefoil (*Lotus uliginosus*) was the only legume that seemed to increase in abundance by the fifth year.
- Less than 10% of the current-year annual production of seeded species was consumed by big game animals.
- Fertilizer does not appear to be necessary for establishment of seeded grasses on many sites in the Coast Range. Equally dense stands of grass have been established without the use of fertilizer in many other clearcut sites in the northern Coast Range.

- Future studies of this nature should include measurement of stem diameter as well as height of Douglas-fir. Stem diameter growth of young Douglas-fir is a more sensitive indicator of competition than height growth (Chan and Walstad 1987, Wagner 1989). Also, the height/diameter ratio provides a useful index of the degree of overtopping competition experienced by young Douglas-fir (Cole and Newton 1987, Wagner 1989).
- Future research on forage seeding should include replicated plots of seeded and unseeded areas on each site or it should utilize sites as replications and include more than two sites. In addition, research is needed to separate the effects of seeding and associated fertilization.

Summary and Conclusions

Seeding with a mixture of grasses and legumes reduced the frequency of salmonberry and thimbleberry. Cover of salmonberry was generally much less in the seeded areas for the first 3 years. Thimbleberry cover tended to be less in the seeded areas after 5 years. The effect of seeding on salmonberry height varied by site. At Diamond Drifter, salmonberry height did not appear to be affected by seeding. At Sampson Creek, however, salmonberry was shorter in the seeded area. Height of thimbleberry tended to be less in the seeded areas at both sites.

Douglas-fir in the seeded areas had notably less height growth during the second year. By the third year, both height growth and total height were nearly equal for Douglas-fir in the control and seeded areas. After five growing seasons, however, Douglas-fir height in the seeded areas averaged 19% less than in the controls, but the differences were not statistically significant. Survival of Douglas-fir was not significantly affected by seeding.

The average height of Douglas-fir was greater than that of both salmonberry and thimbleberry after 5 years, even in the controls. On similar sites, broadcast burning for site preparation, planting large vigorous seedling stock, and protecting trees from animal damage may be sufficient to allow conifers to grow taller than salmonberry and thimbleberry without grass-legume seeding.

Big game browsing of Douglas-fir did not appear to be significantly related to seeding for the first 3 years. There seems to be a potential, however, for attracting large numbers of big game animals into seeded areas, which may result in a higher level of browsing damage even in untreated portions of sites. After 5 years, no vole damage was observed on Douglas-fir in the seeded areas. There was no evidence to suggest that mountain beaver habitat quality was reduced by seeding since swordfern cover was not consistently less in the seeded areas. In addition, because no mountain beaver damage was detected in either the seeded areas or the controls, we could not demonstrate that mountain beaver damage was reduced by seeding.

Seeding clearcut sites with grasses and legumes has been recommended for a variety of management objectives, including visual enhancement, forage production for wildlife and domestic livestock, soil stabilization, and control of competing vegetation. The results of this

study indicate that a careful site-specific evaluation should be performed to determine a seed mix and application rate that will both achieve the desired results and minimize potential adverse impacts to conifer regeneration.

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Grass and Legume Seeding for Big Game Forage in Conifer Plantations of Western Oregon¹

STEVEN P. SMITH

Introduction

My topic, under the broad heading of grazing and seeding, is competition release. I hesitate to use the word release; the emphasis here is on managing competition from seeded and natural herbaceous vegetation to make enhancement of big game forage compatible with regeneration of Douglas-fir (*Pseudotsuga menziesii*).

My work with the Oregon Department of Fish and Wildlife (ODFW) is primarily in two geographic provinces; we are interested in using grass and forb seeding as a vegetation management tool in both. The first is the Cascades province, and the second is the Oregon Coast Range, from Mary's Peak to the coast. This area probably has the longest history of work to benefit big game populations. Timber management, of course, is the primary objective that has been emphasized historically and will continue to play a very important role throughout these two provinces.

Early Research on Grass and Legume Seeding

One of the problems with timber management, more on the coast than in the Cascades I think, is the amount of residue that is left on site after harvest operations. A traditional way to deal with this residue was to spray, burn, and then spray again to keep the sites pretty open. This created several problems in the Coast Range; one is the potential for erosion. Gene Klingler, silviculturist on the Alsea Ranger District, recognized that in areas of soil disturbance, such as cat roads which had been seeded with grasses to prevent erosion, there was significantly less invasion of red alder (*Alnus rubra*). As the use of herbicides became restricted in the late 1970s, he began to look at grass seeding as a potential vegetation management technique. To many wildlife biologists, Klingler was a breath of fresh air because he allowed us to look at other techniques. To many silviculturists, his program of grass seeding was perceived as a threat to conifer regeneration.

Gene Klingler initiated some of the first field research on grass seeding. In hindsight, his study design had some limitations (Klingler 1986). The objective of the research was to evaluate Douglas-fir survival and growth, as well as the aggressiveness and longevity of seeded nonnative species of grasses and legumes. As with many administrative studies, this one introduced too many variables. For example, Klingler's study had alternating seeded and unseeded strips, and each seeded strip contained a different species of grass. Rather than replications within sites, several

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

sites had this arrangement of treatments which made statistical analyses highly subject. However, this study did allow us to look at general trends, which provided the basis for applying these techniques on a broader scale across the Alsea Ranger District. The results from Klingler's study on the Alsea District (Klingler 1986) were very similar to those reported by Walt Kastner (this proceedings). We began to see loss in Douglas-fir growth by the third year. This competitive effect was significant for some but not all grass species, which indicated that grasses interact differently with conifers. Bentgrass (*Agrostis* spp.), for instance, appeared to have the least impact, whereas red fescue (*Festuca rubra*) significantly reduced survival and growth of Douglas-fir.

By the fifth year, seeded species, particularly rye (*Lolium* spp.) and wheat grasses (*Agropyron* spp.), disappeared from the stands. Big trefoil (*Lotus uliginosus*) and orchard-grass (*Dactylis glomerata*) were the most tenacious. Woody vegetation in the unseeded strips was taller than that in the seeded strips by year 5. By year 7, conifers in most of the unseeded strips were in need of release from overtopping woody vegetation.

At about year 7, several individuals involved with this grass-seeding project left the Alsea District and we lost track of monitoring those particular sites. There is potentially a wealth of data available but agencies have a very limited capacity to track long-term studies. Thus, I support the concept of contracting with a university to conduct research and monitoring of long-term projects, as Steve Sharrow (this proceedings) has been doing on the sheep study at Alsea.

ODFW's Forage Seeding Program

Rationale for Forage Seeding

What is the role of the ODFW in grass- and legume-seeding programs? We have primary concerns for habitat. The remainder of this paper will focus on Roosevelt elk (*Cervus elaphus roosevelti*) and black-tailed deer (*Odocoileus hemionus columbianus*) habitat. Timber management directly affects four significant things that habitat provides: cover, forage, security, and calving areas. During a series of public meetings in the early 1980s and again in 1991, Oregon hunters reaffirmed that habitat quality for game species is a primary concern. They strongly endorsed the concept of forage seeding and vegetation management techniques to enhance big game habitat.

Biological Basis for Forage Seeding

Seeding of grass and legume species provides forage of high nutrition and energy content that helps big game to survive stressful periods during winter and early spring. It is believed that forage seeding also promotes growth of the game population by increasing both cow fecundity and calf survival. However, research on those topics is somewhat limited.

We knew from previous research that the annual reproductive rates of Roosevelt elk are significantly lower than those of the Rocky Mt. elk (*Cervus elaphus nelsoni*). We also had data on black-tailed deer from the Cedar Creek study in Tillamook County (Hines 1973), in which we followed deer herds and closely monitored their energy reserves, measured as the amount of stored kidney fat. Energy reserves for deer and elk populations follow a similar trend, with minimum values occurring from January to March. This is a critical period because fawn and calf fetal growth rates are fastest during this time of year and the young animals need the high nutrition. Forage nutrition levels do not increase in the Coast Range until May, when they reach a peak and then decline again. The fat deposits follow a similar trend. ODFW research has found a positive relationship between elk energy reserves and pregnancy rates.

We began to examine the factors that limit forage for elk and deer. Forage quantity and quality do not appear to be limiting during summer periods in western Oregon. Quantitative measurements of biomass available as forage indicate that preferred forage exceeds 2,000 pounds per acre (green weight) during summer months. Forage quality and quantity are most limiting during winter months. By December, forage quantity may be reduced eight fold. Forage quality is highest during the spring and early summer months and declines through the late summer and winter periods. Nutritional content on "unimproved" clearcuts and meadows falls below minimum maintenance requirements for deer and elk during the fall-winter period and less than 300 pounds per acre (green weight) may be available throughout the winter (Hines 1973, Ramsey and Krueger 1986).

In August, when forage is readily available, many of the species are highly preferred: vine maple (*Acer circinatum*), trailing blackberry (*Rubus ursinus*), bitter cherry (*Prunus emarginata*). Most are deciduous woody species or are forbs that are not available in the fall, winter, or late spring periods, when forage nutrition levels are most limiting to survival and reproduction of elk and deer. During the winter months, evergreen shrubs, such as Oregon grape (*Berberis nervosa*) or salal (*Gaultheria shallon*), are used considerably but are highly indigestible and have very low nutritional quality.

Effects of Nonnative Plants

In the Coast Range, rapid establishment of nonnative nonpalatable herbs, such as foxglove (*Digitalis purpurea*), groundsel (*Senecio sylvaticus*), and tansy ragwort (*S. jacobea*) can limit forage production of desirable species. We did clipping studies in a clearcut to determine how much biomass was produced by nonpalatable species after clearcutting and burning. Our results showed that 75% of the biomass was in nonnative, nonpalatable herbs. This amount has increased over time as forests have become more fragmented by timber harvesting, and more areas have been penetrated by invading species that were easily spread by wind and water dispersal from one site to another. We became concerned that the production of Roosevelt elk may be affected if nonnative, nonpalatable species were outcompeting the native grasses or forbs that the elk had

historically used. Potentially, animals simply do not recover after calving, and it takes an extra year for them to become pregnant again.

Specifications of the Forage Seeding Program

We began an operational program of seeding preferred species for big game forage in clearcuts—a program that appeared compatible with objectives for conifer regeneration. We have found that the seedbed is critical for establishment. The basic principle is that, in order for seeds to germinate and grow, they need exposed mineral soil. Prescribed fire that leaves an ash layer will facilitate seedling establishment. Hotter burns will more completely consume the biomass and create a uniform seedbed for germination of forage species. Light burns can be used to maintain a component of indigenous species that either resprout or come in from seed; the seeding rate can be manipulated as well. Machine piling or other mechanical methods are also effective for seedbed preparation.

We have a limited research base from which to evaluate the impact of these kinds of practices in the Coast Range, but it is on an order of magnitude better than what we know about the Cascades at this point. We are working with the CRAFTS (Cooperative Research on Alternative Forestry Treatments and Systems) cooperative at Oregon State University (OSU) to examine some of these techniques in the Cascades. Slash levels definitely affect seedling establishment. Generally, a site must have at least 50% mineral soil exposure before we will invest the money to seed, but the entire site does not need to have that condition.

We deal primarily with six highly palatable species, each of which has a specific purpose: annual ryegrass (*Lolium multiflorum*), perennial ryegrass (*L. perenne*), orchard-grass (*Dactylis glomerata*), New Zealand white clover (*Trifolium repens*), subterranean clover (*T. subterraneum*), and big trefoil (*Lotus uliginosus*). If we expect some form of moisture competition on a site, perhaps because of steep slopes or shallow soils, we use a heavy legume component and a light grass component. In seedings to control woody vegetation, where moisture is not a strong limiting factor in the Coast Range and our objective is to totally occupy the site, we use a very high rate of seeding. Orchard-grass will persist the longest, and this introduced species is of concern to people interested in protecting biological diversity in the native plant community.

The most important thing we discovered about seeding is that species in the seed mixes have differential spread capacities. Grass seed, which is light, has very poor aerodynamics and will be distributed out of the bucket differently than the heavier legume seed. Therefore, the bucket that is used to spread the seed must be calibrated on-site. We also use a technique called prilling. The legumes and grasses are coated with a trace-element fertilizer, inoculum, and lime. This makes the seed weights fairly equal, and results in a more uniform application of the various forage species.

We also fertilize. There are plenty of nutrients on-site to establish the species seeded for control of woody vegetation and to establish grasses. Our fertilizer regime is aimed specifically at the legume component. We fertilize with a target of 80 lb of phosphorus per acre with components

of sulphur and boron in order to promote nitrogen fixation of the legumes, which will provide fixed nitrogen for the grasses and trees. Our ultimate objective is to provide a very high quality forage base during the winter period.

Big Game Utilization of Seeded Areas

ODFW is concerned about animals moving off public lands and causing damage on adjacent private lands. Some of the public want more elk so that there are better hunting opportunities; others are trying to make a living on those same lands and conifer damage caused by elk is a problem for them. By providing high quality forage on public lands, we hope to keep the animals where they are welcome, or should be welcome.

The big game management objectives are very important from an application standpoint. Seeding entire sites will result in poor utilization in any one area because elk move rather than concentrate in a specific area. If too small an area is seeded, the site could be overgrazed, and extensive animal damage to young conifers could follow. Seeding is of primary benefit to deer and elk during the winter and spring months. In fact, by the end of July and August, grasses are lower quality forage than the woody species that would normally be available. The key to successful seeding is to just seed enough to meet management objectives. If the objective is to provide forage for a large resident population of elk (30-60 head), we recommend seeding no more than 20 acres in any given clearcut site. If the population is smaller, fewer acres should be seeded so that the animals use the forage effectively.

Besides improvement of forage quantity and quality, the other most important component of deer and elk management is to provide security for the animals to use a seeded area. As many elk may be lost to illegal harvest as to regular harvest. Significant amounts of disturbance, legal or illegal, may displace elk from using forage sites to their fullest capacity. Some kind of security, such as road closures, particularly during those critical winter months, may encourage utilization of the seeded species.

A cooperative research study by OSU and the Siuslaw National Forest examined whether elk production increased as a direct result of the seeding practices. The locations of radio-collared cows and calves were tracked over time. Elk use seeded sites extensively for calving; the sites provide good cover and forage. However, the variation in the data sets was too large to conclude that a forage-seeding program will increase productivity of elk herds.

There are indications of a positive trend in elk productivity as a result of improved forage. On the north coast of Oregon, Doug Taylor (ODFW) has been collecting aerial census data of elk herds for about 20 years and has documented herd composition based on distance from improved dairy fields in the Tillamook County area. Significantly higher cow:calf ratios are found near improved dairy fields than in any other area of his district. We have started a similar aerial census of the Alsea Ranger District and our data show the same trend. Herds with ready access to improved

ranges appear to have higher cow:calf ratios. However, this data collection is not based on a statistical design; it is simply a trend resulting from the counts we use to monitor the effects of hunting. Again, the use of these areas for calving is probably one of the most important components. High quality feed for the mother and security for the calf are available at the same site.

We monitor elk use and species composition in a subset of our forage sites every year. Any site with significant use is fertilized to promote an active legume component throughout early stand development. After about 7 years, the seeded forage species disappear with canopy closure. Except for orchard-grass, they are not long-lived species.

Other Approaches for Improving Forage

There is more to wildlife management and certainly more to habitat management than deer and elk, but their management has been the main interest of our funding source historically. However, public preference is very strong to promote wildlife diversity in Oregon. Among the ways to achieve wildlife diversity while also managing for deer and elk is to use native plants in the seed mixes.

In 1983 the Oregon Forest Protection Association in cooperation with ODFW pursued Dan Campbell's (U.S. Fish and Wildlife Service) research on seeding native forbs for black-tailed deer. We tried to propagate several palatable species: false dandelion (*Agoseris* spp.), deervetch (*Lotus* spp.), varileaf phacelia (*Phacelia heterophylla*), and fireweed (*Epilobium angustifolium*). Our results were interesting and indicate a need for more research. We initially planted about an ounce of seed of each species. The grower harvested and replanted the seed crop each year. By the third year we thought we had enough seed to plant about 300 acres of each species. However, the third generation of the seed was sterile. It was a total loss; none of the seed was viable and interest faded. We have not revisited that subject since, but it is an area that I think deserves some key research. Propagation of native species for use in seed mixes, particularly in the Coast Range if clearcut harvesting and burning continue, may help combat the problem with invasion of nonnative, nonpalatable species. Providing a competitive edge for native species probably would be a good practice in maintaining biodiversity.

The other option we have for elk management is to maintain permanent forage areas such as on old homesteads. Most of the old homesteads have not been plowed, limed, fertilized, or otherwise worked in over 40 years. They are dominated by tansy ragwort in the summer and have very little biomass production in the winter. Most of the vegetation on these sites is bentgrass, which is one of the lowest quality grasses for elk forage. Our program is to maintain as many of these old homesteads as we can and dedicate permanent forage sites for elk management. Elk prefer these sites, which tend to be flat; they congregate naturally on them in the winter, and utilization is significantly higher than on other sites. We also consider other treatments to establish forage species on clearcuts in which constraints on burning limit our ability to conduct successful programs of forage seeding.

We have tried to evaluate other benefits to seeding, although we had not been very successful. Vole (*Microtus* spp.) or mice (*Peromyscus* spp.) populations may increase as a direct result of seeding, which is often interpreted as a problem. However, natural predators of rodents, such as foxes (*Vulpes* spp.) and coyotes (*Canis latrans*), may follow, so diversity increases. High-density legume stands may be important for production of mountain quail (*Oreortyx pictus*), a species that appears to be declining significantly. Quail are one of the species that will use legumes very early in the spring to increase protein in their diet, which favors their reproduction.

We have very poor information on other trade-offs of nongame wildlife use. Some inherent habitat relationships are important. Within-stand diversity is higher if seeding is not conducted on entire sites over an entire landscape. This yields a variety of vegetation communities: grasslands, forbs, and the more typical forb-brush component in unseeded areas. Short-term diversity can be increased within any given area. The key questions that we have are which species should be used, how long-lived are they, and what kind of seed bank do they store. We think that big game management and forage seeding will work in the long term with the different techniques available, and that they are compatible with both silviculture and wildlife objectives.

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Manual Techniques for Managing Woody Competition: An Overview¹

STEVEN A. KNOWE

Manual methods for competition release have a number of advantages and disadvantages, as noted by Mahoney (1986). These methods are socially acceptable, and there are very few, if any, environmental constraints. The manual treatments have fewer macrosite changes, but there may be extreme microsite changes. Another advantage is that manual treatments are highly selective and can be incorporated with precommercial thinning. An advantage that may become more important in the future is the potential for providing a lot of local jobs.

The disadvantages of manual release methods are that they require a large, skilled crew, they generally result in more injuries to work crews, and they are more complex to administer. If treated areas are relatively small (<5 acres), Mahoney (1986) estimated that manual treatments have a lower cost per acre than herbicide treatments. However, with increasing size of the treated area, the time required to accomplish the work increases dramatically, resulting in higher costs per acre. Also, because manual treatments are so time-expensive, it is difficult to schedule time to treat those areas that were not completed in previous years. Mahoney (1986) listed snow as a constraint to reaching a site and cutting the trees. Also, since most of the woody competitors will resprout, manual treatments often have a lower efficacy of vegetation control than that for herbicide treatments. In addition, the conifers must be capable of responding to drastic changes in their light environment, such as that which results from manual cutting of dense overtopping vegetation.

The papers in this section on competition release will discuss treatments of mulching, grubbing, and manual cutting. The objectives of mulching and grubbing treatments are to spread a material at the base of a desirable plant in order to control undesirable plants, prevent soil moisture loss, reduce extreme temperatures, and possibly enhance soil structure. Grubbing usually involves physically removing the undesirable plants by severing them just below the root crown. The research section will deal with topics such as how much area around a crop tree needs to be treated to get a response and cost of treatments. The application section will discuss paper mulching for controlling herbaceous vegetation, and the hand-pulling and grubbing of ceanothus (*Ceanothus* spp.).

The objectives of manual cutting treatments are to temporarily reduce the size of undesirable plants by cutting off the aboveground parts. The research section will discuss timing for the manual cutting of red

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

alder (*Alnus rubra*), salmonberry (*Rubus spectabilis*), and tanoak (*Lithocarpus densiflorus*). The application section will discuss timing of the cutting operations, some of the species that have been controlled with these manual methods, limitations on size of vegetation to ensure reasonable levels of control, the radius around the crop trees in which to control vegetation, and the cost of the treatments.

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Mulching and Grubbing Techniques in Forest Vegetation Management: A Research Synthesis¹

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Introduction

Our topic is current research by the Pacific Southwest Research Station on mulching and grubbing to release conifer seedlings. We began our research program in vegetation management in 1979 and have been busy ever since. Our main study objectives were to: (1) test and evaluate the five classical competition-release techniques—manual, chemical, animal, mulches, and mechanical (big machines); (2) quantify treatment costs; (3) determine conifer seedling growth/vegetation quantity relationships for both natural (control) and manipulated (treated) conditions; and (4) determine most effective treatments in terms of cost, survival, and growth. Objective (3) is mostly ecological and concerns gaining knowledge on both individual species and plant communities.

For presentation at this workshop, we were asked to concentrate on two of these release treatments: the grubbing part of manual release and mulching. For each we will give a little background and then present results. Because the manual release treatments were generally part of multiple-treatment comparison studies, and not all of our studies began at the same time, our results vary by the number of years of data that we have collected. Consequently, the best way to portray our information is to present the grubbing results together, but to use a case history framework for the mulching. We then bring everything together at the end.

Background

Grubbing is simply the manual removal of the complete plant or the severing of it below the groundline, at or below the root crown. It is hard, dirty, and potentially dangerous work. Mulching is the spreading of material around the base of a plant to mitigate adverse temperatures and moisture loss, control weeds, or enhance soil moisture and fertility.

The climate where our studies are installed is characterized by long, hot, dry summers and cool, moist winters. We often have no rain from the middle of May to the end of September and about 30 days in which temperatures reach at least 100°F. Many of the plants—shrubs, grasses, and forbs—have the strategy of growing while the moisture is available, then after 60 days or so, at least at mid-elevations, ceasing to grow.

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From then on their strategy is simply to survive the heat and wind and loss of critical moisture from transpiration.

The typical site quality where we work is generally average or better. None of our sites are excessively good or poor. Our study sites have treatment plots with subplots for sampling the vegetation. The treatment plots are small and range from 0.14-0.25 acre. The subplots are either circles with specific radii or of milacre (0.001 acre) size. They are always centered around a conifer seedling. Number of subplots typically ranges from 25-35 seedlings per replication. We have three or four replications of each treatment (including the control) per study, and occasionally up to six.

No matter how good the job of site preparation, there are always plenty of undesirable plants that interfere with our best silvicultural prescriptions and release methods. Mother Nature makes sure that bare ground does not stay bare for long. Consequently, competition release is almost always necessary.

Grubbing

From about 1980 to 1990 we began 40 vegetation management studies; 16 involved grubbing on seven national forests. We do not even attempt grubbing in several plant communities. These include forb, shrub, and fern communities where the aboveground portion of the plants originates from belowground structures like root crowns or rhizomes. We grub many of these plants, but only if they originate from seed. Grass is a perplexing kind of vegetation. We generally do not grub plant communities where grass predominates, although once in a while we will grub a grass community in the spring. We learned the hard way about grubbing in the fall. In one instance, we planted more grass plants than we grubbed.

In almost all of our studies we test different plot sizes and intensities of grubbing. We often install a range of different radii around sample conifer seedlings (2, 3, 4, 5, or even 6 ft) and grub them one, two, or three times, usually at 2-year intervals. Sometimes we enlarge the radius as part of the treatment: in one study, we began with a 2-ft radius and after 2 years expanded it to a 4-ft radius. We did the same for a 4-ft radius—expanding it to 6 ft after 2 years. We also do what we call a 100% or whole-plot grubbing. Rarely do we grub more than once per year, and then only when we want to create a relatively competition-free condition for treatment comparison.

Results from our studies indicate that grubbing works well if it is done on plots with a radius no smaller than 5 ft, and if it occurs within the first year or two after planting. Grubbing works best if the competing plants are removed during the first year—that is, when they are young and tender, or not fully recovered from damage incurred during site preparation.

Grubbing has some problems. It is expensive, costing anywhere from \$100-\$2,000 per acre for grubbing several times per year in a sprout community. Finding available manpower is another problem. Our experience indicates that the availability of crews for grubbing will be limited in the near future (Fiddler and McDonald 1990). Plenty of people are will-

ing to manually release seedlings with chainsaws, but few become excited about grubbing.

The effect of grubbing on the soil is beginning to receive attention. We have been informed that on the Tahoe National Forest there will be no more 100% grubbing on steep slopes, and that grubbing only a small radius around conifer seedlings will be allowed. Possible losses of soil organic matter, disrupted soil structure, and spread of propagules of rhizomatous species are the concerns. On the Sierra National Forest, we have been informed that all grubbing will cease because of perceived soil problems.

Another problem with grubbing is that if it is done in the second or third year after planting, the competing vegetation may be twice as tall as the conifer seedlings, and some seedlings may inadvertently be grubbed out or damaged as the work progresses. On steeper slopes and with taller shrubs, potential injury to crew members increases.

Grubbing probably will become more expensive in the future, not only because of lack of crews, but also because of the way that it is paid for. In the past, payment often was by the acre; in the future it will be by the number of seedlings that are released.

Mulching

The objective of mulching is to give the conifer seedling enough time to get its roots into, and stay in, a zone of available soil moisture. When the rains cease, the soil dries rapidly. Not only does it dry from evaporation, but roots from surrounding vegetation also use tremendous amounts of soil moisture. The key to mulching is to have a big enough mulched area to provide a zone of available moisture to the conifer seedling.

The history of mulching in the western United States is relatively short. Although mulching has been associated with horticulture in Europe for the past 300 years, it has been applied in forestry in the western United States for only about 30 years (McDonald and Helgerson 1990). In Oregon and California, the size of mulches has ranged from a few inches to 3 by 3 ft. Mulches most often were made of materials that had a short life-span. They neither were large enough nor lasted long enough to enhance the growth of conifer seedlings. Increased survival for 1 or 2 years was all that was expected.

Silviculturists have tried an amazing variety of products for mulching: sheets of plastic, plywood, and newspaper; various thicknesses of bark, sand, and sawdust; and all kinds of straw—from grass straw to pine straw. Silviculturists have sprayed on petroleum emulsions and have even tried tacking large plastic buckets over tanoak (*Lithocarpus densiflorus*) stumps in an effort to contain the sprouts. While this idea had merit, it did not recognize that tanoak sprouts arise not only on the upper surfaces of the root crown, but also on its lower extremities. Although upper sprouts were contained, lower sprouts grew up outside the buckets. Before long the technique was judged a failure.

In our studies, we wanted to see if mulching could be used to enhance conifer seedling growth. We also wanted to develop a mulch that

suppressed ferns and sprouts of hardwoods and shrubs. Both of these desires expanded mulching beyond traditional use (enhance seedling survival, apply only in herbaceous plant communities).

Our first mulching study involved the use of an early version of Terra-Mat® polyester, which was compared to manual release. The research site, on the Plumas National Forest in California, had deep soil, a 40% slope, and a northeast aspect. Annual precipitation averaged 65 in. Site preparation was by broadcast burning. Healthy 2-0 Douglas-fir (*Pseudotsuga menziesii*) seedlings were planted in augured holes. The competing vegetation was abundant shrub tanoak (*Lithocarpus densiflorus* var. *echinoides*). We applied 5- and 10-ft squares of Terra-Mat® and compared vegetative responses to two manual releases with a chainsaw. We also had two unreplicated controls: in one, the vegetation was kept down so that the Douglas-fir seedlings were relatively free to grow (maximum growth); in the other, the vegetation was left to develop naturally (minimum growth).

After 4 years, we had 1,150 clumps of shrub tanoak per acre, with an average of 32 stems per clump. These clumps occupied 58% of the ground surface and were about 59 in. tall. They constituted extremely heavy competition. After 4 years, there was no significant difference among treatments for Douglas-fir stem diameter or height. However, the shrub tanoak sprouts had died under the mulches.

The cost was high: a 10-ft square of Terra-Mat® cost \$6.39, the 5-ft square was \$1.65; installation was \$1.74; maintenance, including repinning the mulches or throwing logs and other debris on them to hold them down, was \$0.90 per year for 4 years, or \$3.60. The total cost of material, installation, and maintenance was \$11.73 per large mulch over the 4-year period. At a stocking rate of 222 seedlings per acre, the large mulch would have cost \$2,600 per acre, and the small one \$1,550 per acre. The cost of manual release over the 4-year period (we grubbed only twice but we would have had to grub a third time) would have been \$1,050 per acre.

What did we learn? First, that both sizes of this polyester mulch were ineffective for stimulating Douglas-fir seedling growth. Soil moisture data indicated a miniature desert existed beneath the large mulches. Apparently, water traveled through the mulches internally and then wicked off at the lower end—never reaching the ground beneath. Had the mulches been able to mat to the ground, instead of being suspended by the stubs of burned tanoak sprouts, this might not have happened. The most important finding was that for the first time, we were able to demonstrate that a vigorously sprouting shrub species could be killed with a sheet-type mulch.

The second case history on mulching involved trials of various mulch materials on the Eldorado National Forest in California. In this study, we were not so much concerned about conifer seedling performance as we were desirous of learning how the mulches performed. We tested six mulches, all standardized at 4 by 4 ft, with an untreated control. The study site was in snow country at an elevation of 6,400 ft on a south slope. The area was planted with 1-0 Jeffrey pine (*Pinus jeffreyi*).

One of the mulches that we tested is called Hortopaper®, which is used extensively in Hawaii for propagating pineapple plants. It is made of

pressed peatmoss and other materials. It breaks up easily, and deer love its taste. It disappeared or was broken up to the point that it was judged ineffective after the first year. Another tested mulch material was standard black polyethylene. It cracked and broke in the strong sunlight and did not last long in our trials. A standard paper sandwich with outer layers of kraft paper and inner materials of fiberglass strands and tar also was evaluated. It tended to shrink and the outer layers to disintegrate. Consequently, the 4- by 4-ft mulches soon became smaller and had disappeared within 2 years. The fourth material, Terra-Mat® "E," is a heavy fabric manufactured from light gray polyester. It was advertised as being resistant to ultraviolet light and being able to last at least 4 years. Some surface deterioration and shrinkage was noted for this durable material. Pacific Weave, or "Pac-weave®," is a material manufactured from polypropylene that we tested. It was easy to install, did not shrink, was durable, and quite effective overall. The sixth material, Duon®, marketed by Phillips Petroleum, also was tested. It forms a tough, heavy, fibrous mat with an "x" cut in the center for installation over the conifer seedling. We found that this material actually rubbed the bark off the conifer seedlings, killing a number of them.

Of all the mulches tested, Pacific Weave seemed best. Its cost, which included material, hold-down pins, installation, and maintenance, was \$327 per acre.

Another relatively new study involved large (10- by 10-ft) and small (1-by 1-ft) mulches on a site with adequate soil, but tough to regenerate because of its steep slope, west exposure, incessant wind, and complex herbaceous plant community. The study was located on USDI Bureau of Land Management land along California's central coast. The study area received about 125 in. of precipitation annually. The mulch material that we tested consisted of polypropylene with a thin layer of polyester underneath. The latter helps transfer water from the mulch surface to the soil. We examined the permeability of this mulch in late July one year by pulling up one of the mulches (secured by nine 9-in. pins) and noting the degree of soil moisture beneath. We also noticed something important: the layer of dead vegetation beneath the mulch. The mats had been placed over a fully developed plant community that had died and formed a thick layer of organic material on top of the soil. This layer soaked up moisture that had passed through the mulch and in effect formed a second mulch. In mid-summer, the soil beneath was dark and moist, whereas that away from the mulches was bone dry.

The small mulches were ineffective and resulted in many dead Douglas-fir seedlings. Of importance is that, on a site as harsh as this, a fairly drastic treatment—large mulches—was the only way to achieve conifer seedling establishment.

The next case history involves the use of polyester and paper mulches on the Sequoia National Forest in central California. This was a good site; the soil was about 5 ft deep; the slope was 30%; the aspect was southwest; and annual precipitation, mostly as snow, averaged about 36 in. Site preparation was by pile and burn with very little soil placed in the piles. Competing vegetation consisted of 8 shrubs including gooseberry (*Ribes roezlii*), Sierra currant (*Ribes nevadense*), greenleaf manzanita (*Arctostaphylos patula*), and mountain whitethorn (*Ceanothus cordulatus*); about 20 forbs; 4 grasses; and the ever-present bracken fern (*Pteridium*

aquilinum). All told, this was a plant community that rated as medium competition to ponderosa pine (*Pinus ponderosa*) seedlings.

Treatments were: 10-ft squares of two thicknesses of 100% polyester made by Foss Manufacturing Company of Hampton, New Hampshire—a material used primarily for controlling soil moisture beneath railroad tracks; 4-ft squares of kraft paper sandwich with tar and fiberglass between outer paper layers; manual release over the whole plot (one time); and a control.

The kraft paper sandwiches were found to be short-lived and ineffective. Because of the size and weight of the heavy polyester “blankets,” and the steepness of the slope, special care had to be taken to keep the mulches in place. Shallow trenches were dug where the upper edge of each mulch would be, a few inches of the mulch were placed in the trench, and the trench was then backfilled and packed. This procedure worked well; the mulches stayed in place, but it was expensive.

After 5 years, pine height and stem diameter in the large mulch treatment were significantly larger than for seedlings with kraft paper mulches or in the control. This finding demonstrated for the first time that big heavy mulches could significantly enhance conifer seedling growth, thus providing silviculturists with another effective treatment alternative. Again, they were expensive. The large heavy mulches cost \$9.90 per seedling, which included maintenance for 5 years.

Seedlings with either the polyester mulches or the 100% grubbing grew at the biological potential of the site. If the big mulches last 10 years (as the heavy ones were supposed to), will they be considered cost-effective? That, of course, is a management decision, but it may be decided in the affirmative.

On a per-acre basis, material, installation, and maintenance costs (5 years) were \$1,985 per acre for the big mulches and \$305 per acre for the sandwiches; cost of the 100% grubbing was \$410 per acre. Results of the latter method certainly were as statistically impressive as those for the big, heavy mulch—and the cost was much less. Nevertheless, this trial provided an important finding—big mulches can significantly improve conifer seedling growth.

Conclusions

Results from our studies show the strengths and weaknesses of grubbing and mulching for increased conifer seedling growth. One method—grubbing—has a proven track record, complete with data on biological and economical effectiveness. The other method—mulching—has a very limited track record for enhancing growth, and the cost factor is daunting.

Grubbing definitely has a place in the silviculturist’s repertory of release treatments, but its application is limited to mostly herbaceous plant communities and those where the shrubs are from seed. If done in at least a 5-foot radius around conifer seedlings and performed within a year or two after planting, grubbing is an effective treatment and, although costly, not prohibitively so. The perceived damage to the soil surface layer needs to be studied and resolved.

As for mulching, it is safe to say that this release alternative is going to receive more emphasis than ever before. Our studies have demonstrated that mulching shows promise for application in nearly all plant communities, and we are optimistic that the cost of mulching can be lowered. Certainly, an economy of scale will apply as the number of acres treated with this method increases. Another reason for increased application is that results from our work, and from others 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 a little and, in turn, add to growth.

On a broader scale, there is a new national working group on mulches headquartered in Mississippi. Some of its members are from Oregon and California. Several researchers at the equipment development center at Missoula, Montana, and at the Forest Products Laboratory at Madison, Wisconsin, also are involved. Some of this work entails blowing various plant materials into preset shapes and solidifying them so that they can be installed on the ground.

The hope is that a mulch will be developed specifically for silvicultural purposes. Materials in mulches today have been borrowed from many industries: from the pineapple industry, horticultural work, greenhouse work, and, as mentioned earlier, from railbed construction. A recent development is use of mulches in highway construction. They are proving to be well-suited for controlling drainage and reducing soil erosion.

Looking ahead, there will probably be two classes of silvicultural mulches. One will be a general mulch, which will be relatively inexpensive, probably of a fixed size and color, and have a predetermined durability that will last for about 5 years. The second class of mulch will be special, perhaps "tailor-made" to specific situations. It will be more expensive but have the attribute of varying in size, thickness, and durability. It might even be camouflaged to blend into the natural environment.

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Paper Mulches for Herbaceous Weed Control in Conifer Plantations of the Roseburg BLM District¹

CRAIG L. KINTOP

Introduction

Paper mulching to control herbaceous vegetation around conifer seedlings has been used operationally since the early 1960s on the Roseburg District of the USDI Bureau of Land Management (BLM)(Hermann 1964). However, this tool has not been used continuously. Because of their cost effectiveness and efficiency, herbicide treatments essentially replaced mulches after the mid-1960s. Public concerns about herbicide use revived interest in alternative methods of vegetation control in the late 1970s. However, large-scale operational use of paper mulches did not occur on the district until the federal courts banned all herbicide use on BLM lands in 1984. Since that time, mulching has been the principal method of controlling herbaceous weeds in the district's reforestation sites.

Rationale for Mulching

Roseburg BLM District is in southwestern Oregon. Boundaries of the district are roughly Cottage Grove on the north, Azalea on the south, Umpqua National Forest on the east, and the crest of the Coast and Siskiyou Ranges on the west. The district is bisected by Interstate Highway 5. The district is comprised of 428,000 acres of public lands, mostly lands revested from the Oregon and California (O & C) railroad that are arranged in a checkerboard fashion among private, state, and USDA Forest Service lands.

The summer climate of most of the district is hot and dry with rain normally ending abruptly by mid-June. Significant precipitation does not usually begin again until October. Competition for water by herbaceous vegetation on southerly aspects in certain plant communities can deplete available soil moisture from the rooting zones of conifer seedlings. Lack of sufficient moisture results in high mortality of such seedlings. Mulches are installed to reduce evaporation and to prevent transpiration by competitors around the rooting zone of conifers.

Mulching Materials

At present we are using a mulch composed of two sheets of kraft paper with a sheet of asphalt sandwiched in the middle (Figure 1A). The mulch is reinforced with a cross-hatching of fiberglass scrim for added resistance to tearing. An X-shaped slit is cut in the center of each mulch to allow placement over the seedling. Mulches are shipped in bundles of

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

100 with about 40 bundles per pallet. A bundle of 100 mulches weighs about 40 pounds. Current cost is \$165-\$180 per thousand mulches.

We are also using sod staples for anchoring mulches on some sites. Sod staples made of 12-gauge wire are 6 in. by 1 in. (Figure 1B). Current cost is \$11-\$15 per thousand. Four staples are used to anchor each mulch.

Installation Specifications

Current specifications for installation are as follows:

- The mulching spot should be prepared so that the paper mulch square can be laid flat on the surface of the ground around the seedling. All movable slash or rigid vegetative matter that would cause a loose or lumpy installation should be removed.
- Mulch sheets should be placed so that seedlings are centered in the middle of the X-shaped slit or in the downhill portion of the slit.
- Install one sheet per seedling and place it so as not to damage or cover any portion of the seedling's live limbs.
- Each mulch should be secured by burying the four corners or by use of staples.
- For the burial method, all four corners of the mulch should be buried to a depth of 4 in. (Figures 1C and 1D). At least 6 in. measured from corner to center should be secured. All corners shall be firmly set in the ground.
- For the staple method, mulches should be installed by securing each corner with a staple (Figures 1E and 1F). On all four corners, 6 in. of the corner measured from corner to center should be folded underneath the sheet. Each staple shall be set firmly in 6 in. of soil by placing the staple at least 3 in. from the folded edge and passing it through both layers of the mulch.
- Mulches may be folded for placement next to immovable objects such as logs or stumps, as long as the mulch has at least half of its effective area around the seedling.

Factors Affecting Application

A mulching crew is generally made up of spreaders who distribute the mulches next to seedlings and by installers who then prepare the mulching spots, place the mulches over the seedlings, and anchor the corners. The following factors affect the difficulty and success of mulch application.

Slope

Steep slopes affect crew production by increasing the difficulty of keeping seedlings centered in the mulch slits while securing the corners.

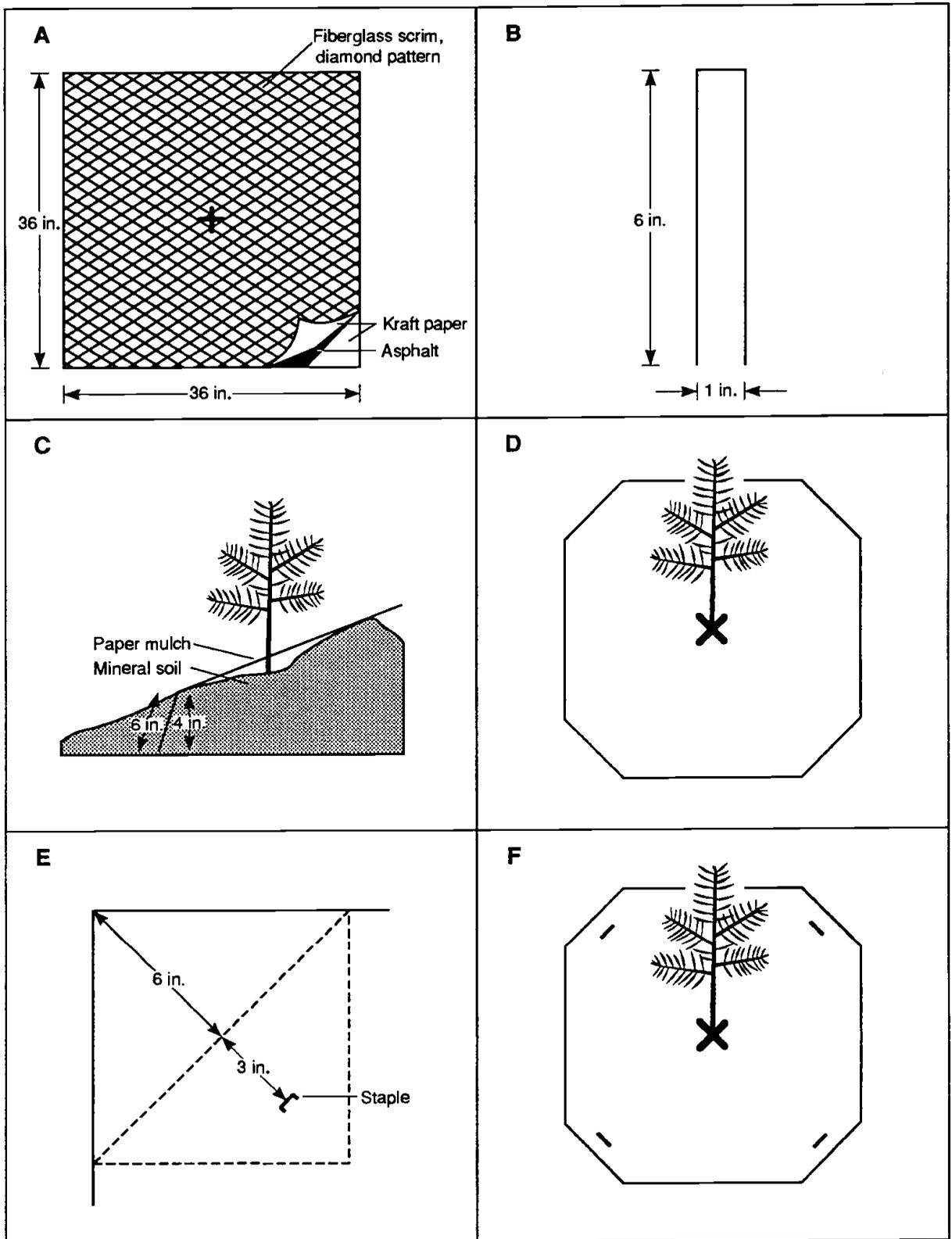


Figure 1. (A) kraft paper mulch with asphalt sandwiched between; (B) sod staple of 12-gauge wire; (C) buried corner of paper mulch; (D) seedling centered in paper mulch with buried corners; (E) corner of paper mulch to be folded underneath and then stapled; (F) seedling centered in paper mulch with folded and stapled corners.

The difficulty is greatest on steep slopes when corners are buried rather than pinned. So far, no upper limit on slope steepness for successful mulch installation has been encountered. Sites with sizable areas containing slopes of 80% or more have been successfully mulched. Steeper slopes slow down the distribution of mulches within the sites and often necessitate the spreaders placing individual mulches over the seedlings, thereby decreasing production time.

Road Access

Distances that mulches must be moved from all-weather roads affect production rates significantly. In extreme cases, we have had to transport mulches by helicopter to sites with poor access to roads.

Soil Type

Skeletal, rocky, and ravelly soils can make anchoring difficult. Staples often work better than burying corners. It is sometimes necessary to use rock found on the site for anchoring.

Slash Loading and Distribution

As with tree planting, amount and distribution of slash affects production and feasibility of mulching. It was originally assumed that sites need to be cleared by tractor or broadcast-burned to make mulching feasible. Increasing smoke management constraints required us to question this belief and to experiment on unburned sites. In general, we have found that a high proportion of those unburned sites considered plantable without burning can also be mulched, although at more cost. Key factors are amount of exposed ground and ability to displace light slash around seedlings with hand tools. It is not necessary that the mulch be installed over slash-free mineral soil; only that slash that prohibits a relatively flat installation needs to be removed or knocked down.

Existing Vegetation

Existing vegetation and its developmental phase at the time of mulch installation are factors that affect how much clearing of the mulch spot or anchoring is necessary. Again, it is not necessary that the mulch be installed over vegetation-free mineral soil; only that vegetation that prohibits a relatively flat installation needs to be removed or knocked down. Existing root systems and resprouting brush can make burying corners extremely difficult. Staples work best in these situations.

Soil Moisture

Mulches should be applied while soil moisture is high. Delay until competing vegetation has reduced soil moisture limits the effectiveness of mulches. Once the mulch is installed, no precipitation can penetrate it except through the slit. As a goal, we try to have our mulching done by April 1 of each year.

Weather

As with herbicides, too much wind can halt mulching operations by blowing unanchored mulches away from seedlings. Mulches cannot be installed when snow is present.

Crew Experience

Experienced mulchers are often difficult to find. Most crew members and some contractors swear that they would never mulch again after having done it once. It is typical for our project inspectors to spend the first few days of any mulching contract doing unofficial training and advising of contractors.

Benefits and Liabilities

Seedling Survival, Vegetation Control, and Soil Effects

The obvious benefit of mulching when used appropriately is increased survival of conifer seedlings. Mulching is as effective as herbicide treatments in assuring conifer survival but significantly more costly (unpublished data on file at Roseburg BLM district). It is relatively effective in suppressing herbaceous vegetation during the first growing season, although some competing vegetation often grows up through the mulch slit immediately adjacent to the seedling. Mulches begin to shrink and disintegrate after the first growing season. Rate of decomposition is variable. Often mulches are still 50% or more effective for a second growing season. By the third growing season, they are decomposed beyond the point of providing any vegetation control. The effect of mulching on soil organisms is unknown.

Damage from Installation Errors

Conifers can be damaged if mulching is delayed until after budbreak, when tender young shoots are easily broken off. Further, if improperly anchored, mulches can slide down or a loose end can flop over and smother the seedling.

Animal Damage

When former pastureland or extremely grassy backlog sites are reforested, mulching can create hiding cover for various species of small rodents. Without protection, trees can often be girdled by these rodents. Managers must evaluate their potential rodent problem and plan appropriate protection. Deer, elk, and even cattle can cause localized damage, but we have noted no serious problems.

Logistics

The greatest logistical problem in this procedure is moving mulches both to the work site and within it. Ideally, the easiest way to move mulches to the site is by a banded pallet. A pallet of mulches weighs about 1,600 pounds and, as indicated previously, contains 40 bundles of 100 mulches. A 40-acre site with 400 trees per acre to be mulched would require about 3 1/4 short tons of mulches.

To date, no one has devised a better way to move mulches within sites than by human transport. Several contractors have tried "skylining" (i.e., an aerial cable system) mulches into sites, but they usually fall back on human transport. Production rates range from about 200 to 300 mulches per crewmember per day.

Table 1. Average costs for 1992 mulching project.

Planting spacing (ft x ft)	Site treatment	Cost (\$/acre)
8 x 8	Broadcast burned, first-time planting	260
8 x 8	Not broadcast burned, first-time planting	320
8 x 8	Additional trees planted	363
10 x 10 or 9 x 9	Mix ¹	249
8 x 8	Mix	375

¹Mixture of sites that are either being planted for the first time or those having additional trees planted; includes various types of initial site preparation.

Table 2. Weighted costs for 1992 mulching project.

Type of cost	Weighted cost (\$)	
	Per acre	Per tree
Average installation	265	0.72
Average material ¹	76	0.21
Total	341	0.93

¹Mulches and staples.

Costs

Costs for both materials and installation are high when compared to herbicide application. Material costs have shown a slight overall decrease over the past 3 years. Installation costs fluctuate because of factors related to site type and competition among contractors from year to year.

In 1992 the district purchased 1,755,000 mulches and 1,722,000 staples at a total cost of \$461,800. Installation costs were approximately \$741,300. A total of 3,900 acres were scheduled for mulching. Bid prices ranged from \$249-\$375 per acre.

It is difficult to come up with an average cost per acre or per tree because contracts have differing percentages of site types—i.e., degree of site preparation, slope, number of trees to be mulched. Theoretically, if the district provides staples for anchoring, our material cost per tree should increase but installation would be cheaper because it would be faster.

Tables 1 and 2 summarize the 1992 application costs for the 3,900 acres to be mulched at various spacings and types of sites. In most instances, staples are used for anchoring, although corners are buried in some cases. For comparison,

cost of mulching is approximately 4 to 5 times more than that of an herbicide treatment.

Conclusions

Mulching is an effective albeit expensive tool for vegetation management. Conifer survival on mulched sites can be as high as on herbicide-treated sites if the mulches are installed appropriately. Mulches will probably be an important management tool on the Roseburg BLM District in the future even if herbicides become available again.

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Hand Removal of Snowbrush in Conifer Plantations of the Cascade Range¹

DENNIS G. BECKNER

Early Vegetation Management Techniques

Site preparation and reforestation methods used on the Willamette National Forest prior to the mid-1970s created favorable conditions for reproduction of snowbrush (*Ceanothus velutinus*), which can be highly competitive with conifer seedlings. Specifically, site preparation that included burning in the fall, when conditions were relatively dry and hot, stimulated the germination of snowbrush seeds and intensified that component in the plantation. Late planting or poor stock and inadequate tree handling allowed snowbrush to dominate a site early. Such stands were referred to as brushfields or backlog. The primary treatment for these prior to the herbicide injunction was aerial spraying. With the high densities and rapid growth rates of snowbrush, grubbing (digging plants out with a tool) or handpulling was not feasible. Attempts to release conifers by manual cutting of snowbrush had mixed results that were plagued by vigorous resprouting and high labor costs.

Administrative Studies

Farr (1979) conducted two trials in 1978 on the feasibility of handpulling snowbrush for conifer release on the McKenzie Ranger District. The first trial compared the production rates and costs of three treatments with different specifications on how much snowbrush to remove:

Treatment 1: all snowbrush removed within a 3-ft radius around conifers

Treatment 2: all snowbrush 8 in. or taller removed

Treatment 3: 100% pull - all snowbrush removed

Release work was done by district personnel. Production rates were higher and costs per acre were lower with treatment 1. Per-acre costs for treatments 1, 2, and 3 were \$16.87, \$28.95, and \$43.58, respectively. A production rate of 1 acre per 8-hr worker-day could be attained if less than 2,300 snowbrush plants per acre were to be removed.

The second trial was to contract handpulling on three sites totaling 75 acres. All snowbrush between 6 and 48 in. tall were to be pulled. The average cost per acre was \$37.47. The contract was successfully completed by the Hoedads and Groundwork, Inc. (Groundwork, Inc., is a subsidiary of the reforestation company, Hoedads). Horowitz (1978) stated that handpulling snowbrush was an effective release method because it selectively removed competitive vegetation without a direct impact on nontarget species. However, brush pulling was not feasible on old brushfields

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

in which the brush is too large and deeply rooted. Five-year-old sites were about the oldest for performing handpulling treatments; 3- to 4-year-old sites seemed ideal (Horowitz 1978).

The Hoedads and Groundwork, Inc., started using a new handpulling tool designed by Steve Gibbs (International Reforestation Suppliers, Eugene, OR) and found it to be somewhat effective in removing the larger root systems of the 48 in. snowbrush. Farr (1979) suggested that this treatment method could be used for roadside brush removal in specific situations. He stated that a single handpulling would be a lot less expensive than the multiple treatments required by mechanical brushing (i.e., mowing or manual cutting). Also, the costs for handpulling were comparable to herbicide applications and the results were more effective (Farr 1979).

Wilson (1985) developed an administrative study from these two trial areas. Twelve individual plots, each measuring 124 by 124 ft, were installed in the stands; within each plot, a 0.25-acre internal subplot was established to minimize edge influences. Each plot was surrounded by a 30-ft buffer. The treatment specifications were: remove all snowbrush 8 in. or taller, remove all snowbrush in a 3-ft radius around individual conifers, remove all snowbrush, and an untreated control. Growth in height and stem diameter of the released conifers were measured for 8 years after the handpulling. The study demonstrated that Douglas-fir (*Pseudotsuga menziesii*) release from snowbrush may be unnecessary if a conifer stand is established quickly and if juvenile height growth is rapid; also, complete removal of all snowbrush is not required to achieve release objectives.

Manual Release of Conifer Seedlings from Snowbrush on the Willamette National Forest

The McKenzie Ranger District continued handpulling snowbrush throughout the 1980s; the specifications were to remove all snowbrush that were between 6 and 48 in. tall. Other districts also used this treatment with the same specifications. Results from the McKenzie and other ranger districts showed that the handpulling specifications needed to be changed. Contract prices were increasing and quality of work was decreasing because of the difficulty of removing 100% of the snowbrush. Stand exams and empirical observations indicated that the release objectives could be met without having to remove so much vegetation. Also Youngberg et al. (1979) showed the benefits of nitrogen fixation from snowbrush to plantations of Douglas-fir.

Releasing only those conifers or crop trees with the best form, vigor, and size at the required spacing (which depends on site capacity) was instituted in late 1980s. Timber Stand Improvement exams showed that the released trees remained dominant and were left after precommercial thinning. Most handpulling that is currently done on the Willamette National Forest specifies that for release of each crop tree located at a spacing of 12 by 12 ft, all snowbrush will be removed in a 4-ft radius. This treatment releases about 300 trees per acre. Since 1978, a total of 3,200 acres of conifer plantations have been released by hand removal of snowbrush on the Willamette National Forest.

Recommendations for Manual Release of Conifer Seedlings from Snowbrush

The following information is an aggregate of management strategies, procedures, and recommendations from the various ranger districts on the Willamette National Forest that have conducted contracts for hand removal of snowbrush.

Knowledge that a dense snowbrush community will occur on a given site can aid in reforestation planning. Planning includes setting priorities for which sites to treat in a given year, developing unique and cost-effective contract specifications, and developing workshops which would inform prospective contractors on this competition release method. The grand fir/prince's pine (*Abies grandis*/*Chimaphila umbellata*) plant association (Hemstrom et al. 1985) is prone to storing heavy seed banks of snowbrush; therefore, silvicultural operations that encourage snowbrush germination and growth should be avoided in this plant community.

The density and size of snowbrush seedlings following timber harvest can be greatly reduced by modification of the seedbed to disfavor the species' germination and growth. The inclusion of alternate harvest methods other than clearcutting, such as shelterwoods or logging methods with the least amount of soil disturbance, will reduce the intensity of site disturbance. Seedbed conditions following timber harvest, including amount of incoming solar radiation and fluctuations in soil temperatures, will be more like those of the undisturbed forest, and therefore less conducive to the scarification and subsequent breaking of dormancy for snowbrush seed. If broadcast burning is used to reduce woody debris, a spring burn of low intensity will release fewer snowbrush seeds from dormancy.

Handpulling of snowbrush is most effective when it is accomplished in the fourth season after timber harvest. This treatment timing gives the snowbrush seed time to germinate and reach a size that is highly visible and easily grasped. The ideal plant height for handpulling is 1 to 2 ft, but occasionally hand-removal contracts include plants up to 4 ft. Complete removal of the plant is most successful when pulling is conducted in the spring and early summer, during which the soil moisture is near field capacity and the soil crumbles easily. Handpulling is easiest for the pumice and nonplastic soil types (e.g., SRI soil types 66, 61, and 161; Legard and Meyer 1973).

Several tools have been used for grubbing of snowbrush. The ribes tool (Figure 1A) was developed in the 1930s to remove *Ribes*—a shrub that is the alternate host for white-pine blister rust. A tool having claws similar to those on a carpenter's hammer has been developed specifically for snowbrush grubbing by Steve Gibbs (International Reforestation Suppliers, Eugene, OR) (Figure 1B). The Pulaski axe and Hazel hoe (Figures 1C and 1D), tools commonly used in wildfire suppression by the USDA Forest Service, have been used for grubbing snowbrush.

Typical contract specifications for hand removal of snowbrush on the Willamette National Forest include the following: (1) A minimum of 300 crop conifers per acre (i.e., trees at an approximate spacing of 12 by 12 ft) are to be released. (2) All snowbrush (height \leq 48 in.) that occur within a 4-ft radius of a crop conifer are to be removed. (3) The contractor has the option of either handpulling entire plants or grubbing the

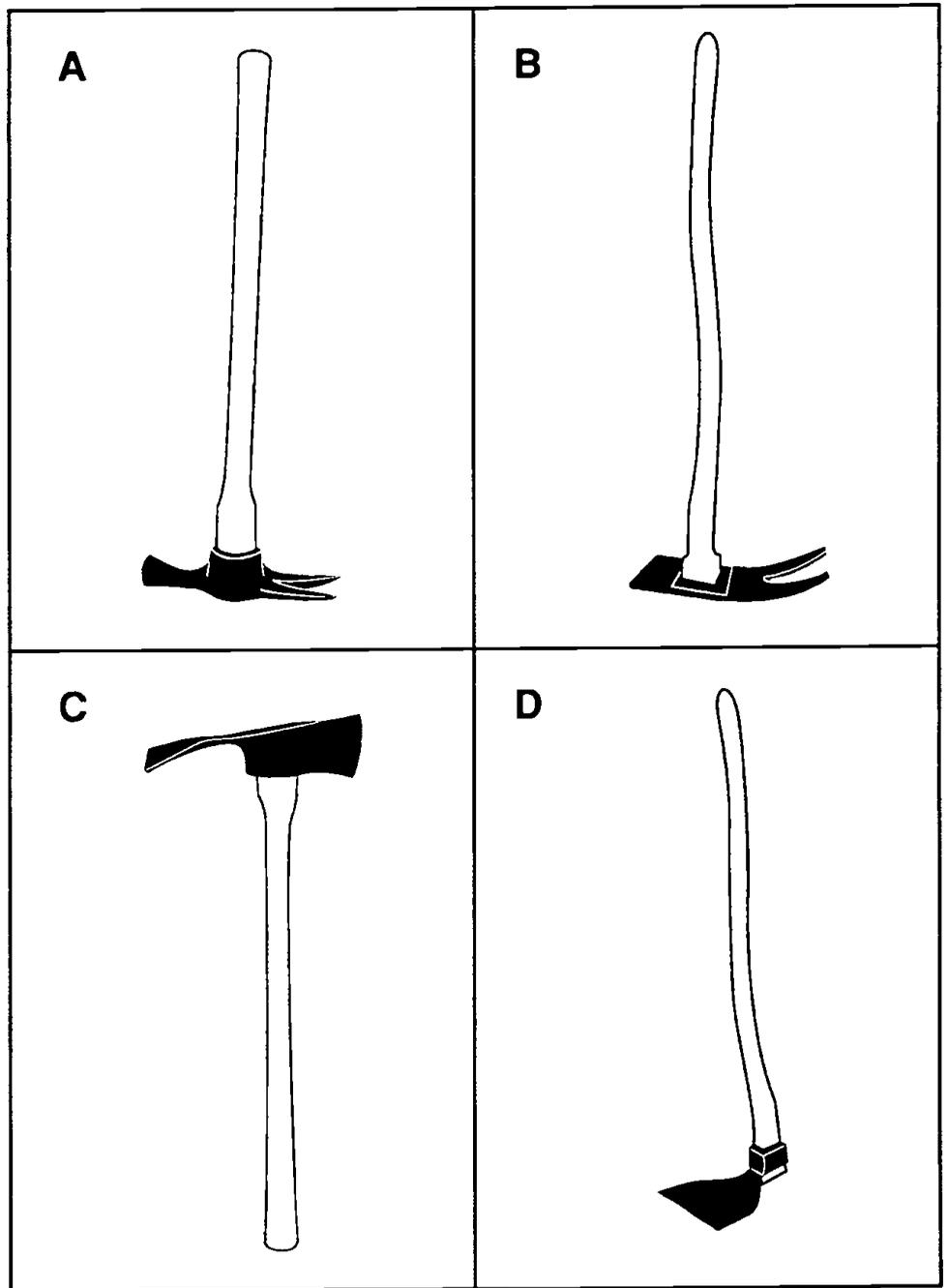


Figure 1. Grubbing tools for hand removal of snowbrush and other shrub seedlings: (A) ribes tool; (B) snowbrush grubbing tool; (C) Pulaski axe; and (D) Hazel hoe.

top portion of plants to a depth of 2 in. below the root collar or soil surface. (4) Removed snowbrush plants are to be kept away from moist soil or standing water to prevent them from re-rooting. (5) If soil is removed from around a crop conifer during release operations, then it shall be repacked around the tree.

Comparisons of Grubbing, Handpulling, and Herbicide Treatments

For snowbrush stands of identical density and size, grubbing has the advantages over handpulling of being less labor intensive and costly, of being a more generic treatment and thus permitting the inclusion of both seedling and sprout removal in contract specifications, and of allowing larger plants to be removed. In contrast, the advantages of handpulling over grubbing are that less damage to crop conifers typically occurs and that the greater labor requirements of handpulling create more employment which is critical in areas that are economically depressed.

When compared to herbicide treatments, hand removal of snowbrush has the advantages of being highly selective (i.e., causing little or no damage to crop conifers), of maintaining some snowbrush on site for species diversity and nitrogen fixation, and of following the guidelines for the 1989 Mediated Agreement to the Final Environmental Impact Statement for Managing Competing and Unwanted Vegetation (i.e., herbicides must be used as a last choice and the selected treatment must have minimal impacts to nontarget species) (USDA Forest Service 1988, U.S. District Court 1989). In addition, hand removal treatments are currently more socially acceptable on public lands than are herbicide treatments.

Some districts remove redstem ceanothus (*Ceanothus sanguineus*) and hairy manzanita (*Arctostaphylos columbiana*) as well as snowbrush. Hairy manzanita is quite easy to pull because of its shallow root system. Redstem ceanothus is difficult to pull because it seems to break off at the root collar; therefore grubbing is preferred as a removal method.

A common problem in high elevation sites with heavy snowpack is mechanical damage to conifers from compaction of the snowbrush, which either breaks the conifer bole or causes deformity. Impacts from this are either severe growth loss or mortality.

Summary

Hand removal of snowbrush has been found to be a successful method for competition release of young conifers on the Willamette National Forest. The McKenzie Ranger District administrative study gave some insights on optional methods of brush removal. However, empirical observations, stand exams, and the application of snowbrush handpulling has provided the majority of information. I recommend continued ecological research on relationships between snowbrush and conifers.

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Manual Cutting in Forest Vegetation Management: A Research Synthesis¹

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Introduction

Manual cutting is the silvicultural practice of severing noncrop vegetation that could overtop crop vegetation. The cutting is accomplished by hand-operation of a tool that is either motorized (chainsaw, rotary saw) or unmotorized (saw, machete, Pulaski). When a 1984 court injunction banned herbicide use on federal lands in Oregon and Washington, manual cutting became one of the few treatments available for releasing conifer regeneration from the severe competition associated with tall woody vegetation, such as red alder (*Alnus rubra*) and tanoak (*Lithocarpus densiflorus*).

In 1989, a mediated agreement was reached which stated that herbicides could be used as a "last-choice" alternative on USDA Forest Service lands (U.S. District Court 1989). Although herbicides became available several years after the agreement, strong reliance on manual cutting continues. Therefore, prior to discussing efficacy research on manual cutting, it seems prudent to analyze the rationale supporting its use. Two philosophical approaches appear to guide practices in forest vegetation management today, the "agricultural" versus "ecological" paradigms. In the agricultural paradigm, emphasis is placed on maximizing commodity (i.e., fiber) production and minimizing cost—an approach that relies on intensive practices to suppress natural processes, such as forest succession. In contrast, the ecological paradigm places more emphasis on the sustainability of forest resources with less regard for cost—an approach that relies on low-intensity practices that prevent or avoid problems with competing vegetation.

Clearly, the ecological paradigm is guiding the selection of manual cutting and the prevalence of its use on federal lands. By acknowledging this fact, it is imperative that we judge the efficacy of manual cutting under a different set of standards than we use to judge herbicide treatments. Thus, treatment objectives for manual cutting may be defined as the attainment of a conifer-dominated stand within a reasonable time frame, given the availability of funds to accomplish this task. Rapidity, magnitude, and duration of crop response to treatment need not be maximal (as they must in the agricultural paradigm); rather, they must be sufficient to accomplish this objective. With these definitions in place, it is possible to judge fairly the merits of manual cutting.

Because most woody species are adapted to sprout when cut, the duration and magnitude of vegetation control from manual cutting is generally less than that from an effective herbicide treatment. Neverthe-

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

less, by modifying the treatment specifications, it is possible to increase the level of vegetation control achieved by manual cutting. A manual cutting treatment is likely to provide the greatest vegetation control if it reduces plant leaf area when demand for photosynthate is high (i.e., during the growing season) *and* if the plant has a limited ability to re-grow leaf area because of low carbohydrate reserves and limited availability of light, soil water, and nutrients.

Hart and Comeau (1992) recently reviewed the published and unpublished research on techniques, efficacy, and costs of manual cutting as it has been applied in the Pacific Northwest. Numerous studies have been conducted in which a given manual cutting treatment was unsuccessful—it had little or no effect on both noncrop and crop vegetation. In this paper, we will focus our discussion on the specifications of manual cutting treatments that have been successful, those that have been shown to increase the control of noncrop vegetation and the performance of young conifers. These specifications pertain to the timing, frequency, and technique of cutting, as well as the competitive status of noncrop and crop vegetation at the time of cutting.

Effects of Timing, Frequency, and Technique of Manual Cutting

The timing of manual cutting can affect both the ability of noncrop vegetation to recover, as well as the ability of crop vegetation to respond to release. In general, manual cutting limits the recovery of woody vegetation the most when it is applied after the new foliage has expanded—usually in mid to late summer. During this period, levels of starch and soluble sugars, which had peaked at budbreak, are in a state of decline (S.D. Hobbs, Oregon State University, Corvallis, unpublished data), indicating that the plant has exhausted some of its energy reserves.

DeBell and Turpin (1989) found that the optimal timing for manual cutting of red alder depends on tree phenology. They recommended that cutting be initiated 8-10 weeks after budbreak and completed about 8 weeks later. In the central Coast Range of Oregon, this is the period from late May to late July. Research by Pendl and D'Anjou (1990) suggests that the optimal timing may be as late as August for alder growing on relatively dry sites in southwestern British Columbia.

First-year crown volume of bigleaf maple (*Acer macrophyllum*) clumps was lowest when manual cutting occurred in August, although clump size did not vary significantly ($p \leq 0.05$) from those in which cutting was conducted when vegetation was dormant or soon after budbreak (R.G. Wagner, Ontario Forest Research Institute, unpublished data). Sprouting ability for salmonberry (*Rubus spectabilis*) was lowest when manual cutting occurred in June or July (J.C. Zasada, USDA Forest Service, Rhinelander, WI, and J.C. Tappeiner II, National Biological Survey, Corvallis, OR, unpublished data). There is some evidence that sprouting ability of red alder declines with increasing plant water stress (Hoyer and Belz 1984, Pendl and D'Anjou 1990).

Increased frequency of manual cutting may reduce sprouting ability, particularly if treatments are applied over several growing seasons. In research conducted in the Oregon Coast Range, two cuttings during each

of two successive growing seasons greatly reduced cover and height of salmonberry growing in an alder understory (J.C. Tappeiner II, National Biological Survey, Corvallis, OR, and J.C. Zasada, USDA Forest Service, Rhinelander, WI, unpublished data). Big-game browsing on the tender regrowth contributed to the reduced sprout development of salmonberry. Young, succulent sprouts of bigleaf maple also are vulnerable to big-game browsing (Roberts 1980).

Stein (1986) found that fourth-year cover of coastal woody vegetation was about the same following one (61%), two (57%) or three (56%) successive annual cuttings, but each of these values was less than the untreated control (78%). However, a marked reduction in fourth-year vegetation height was observed, relative to the untreated control (280 cm), for one (197 cm), two (146 cm), and three (135 cm) successive annual cuttings.

A variety of cutting techniques to reduce the sprouting ability of red alder have been tested. Harrington (1984) found that sprouting was least when saplings of red alder were cut to leave a level stump with a height of 10 cm or less. She hypothesized that less water drains from stumps with a level surface, and that the retained water would promote activity of decay organisms and possibly increase stump mortality.

In general, stump height should be minimized during manual cutting, otherwise new sprouts that originate from aboveground portions of the stump will have a distinct height advantage over young conifers that are growing nearby. For bigleaf maple that originated from sprouts and were up to 12 years old, there was a significant ($p \leq 0.05$) correlation between clump height and height of the stump(s) from which sprouts originated (T.B. Harrington, University of Georgia, Athens, unpublished data).

Effects of Competitive Status of Noncrop and Crop Vegetation

Competitive status and vigor of noncrop vegetation determine its response to injuries from manual cutting. Tappeiner et al. (1991) found that the vigor of vegetative reproduction from salmonberry declines with increasing basal area of overstory trees. Their results suggest that, following a severe disturbance such as clearcutting or burning, sprout vigor of salmonberry would be greatest for populations that had developed under alder-dominated stands, which typically have lower basal areas than those dominated by conifers.

Hardwood trees that survive a disturbance that kills the aboveground portions of the plants, such as cutting or burning, go through a dynamic period of decline and recovery. Immediately after such a disturbance, the large residual root system of a tree must begin drawing on stored carbohydrates for its sustenance. Many growing seasons must pass before the tree will recover the leaf area it had prior to the disturbance. Because the newly recovering leaf area is unable to sustain the belowground portions of the parent tree, the root system undergoes a period of decline and eventual recovery. When the root system reaches its maximum state of decline, it can be hypothesized that plant capacity for vegetative reproduction is severely restricted.

Ahrens (1989) studied root biomass of tanoak in pure stands that either originated from sprouts (2-9 years since clearcutting) or were in a 75-year-old undisturbed forest. The maximum root biomass was in the undisturbed forest (6,500 kg/ha); the minimum was in 6-year-old sprout stands (2,900 kg/ha). Root biomass had begun to recover in the 9-year-old sprout stands (3,650 kg/ha). Thus, control of tanoak is likely to be greatest when manual cutting is delayed until the stand is about 6 years old.

Growth rate and number of sprouts from manually cut red alder declined with age of the parent tree, and the best level of vegetation control occurred when trees were at least 5 years old (Harrington 1984, DeBell and Turpin 1989). In contrast, growth rate and number of sprouts increased with dbh of the parent tree for tanoak, Pacific madrone (*Arbutus menziesii*), giant chinkapin (*Castanopsis chrysophylla*), and bigleaf maple (Tappeiner et al. 1984, Harrington et al. 1992, T.B. Harrington, University of Georgia, Athens, unpublished data). For these species, size of the parent tree apparently is an indicator of the number and vigor of basal buds.

Equally important as information about noncrop vegetation is knowledge about the competitive status and vigor of the crop vegetation. Unfortunately, limited research has documented responses of young conifers to manual cutting in which effective yet feasible treatment specifications were tested. Much of the research has demonstrated the obvious—that manual cutting of overtopping woody vegetation during the dormant season leads to little or no growth responses and possibly injury to young suppressed conifers. The following three studies demonstrate how the responses of Douglas-fir (*Pseudotsuga menziesii*) to manual cutting are highly dependent on the treatment specifications.

Stein (1986) studied growth responses of coastal Douglas-fir to one, two, and three manual cuttings applied between May and July in successive years. The red alder were entering their fourth growing season when the first manual cutting was applied. Stein found that average stem diameter of Douglas-fir saplings 4 years after a single cutting (79 mm) was significantly ($p \leq 0.05$) greater than that for saplings in the untreated control (47 mm). No additional gain in stem diameter of Douglas-fir was observed from the second (74 mm) and third (71 mm) cuttings, probably because in neither case did the competing vegetation overtop Douglas-fir.

Growth of Douglas-fir in southwestern Oregon was studied following the application of three treatments to a tanoak brushfield: no treatment, a single manual cutting, and complete weed control with herbicides (T.B. Harrington, University of Georgia, Athens, unpublished data). In the fifth year after treatment, stem diameter (at 15-cm height) differed significantly ($p \leq 0.05$) among each of the three treatments and was ranked in descending order by treatment as follows: complete weed control (45 mm) > manual cutting (31 mm) > no treatment (20 mm). It is important to note that the timing of manual cutting (July of the third growing season after tanoak sprouting) coincided with: (1) a period of decline in parent-root biomass (Ahrens 1989); (2) probably some current-year depletion of tanoak carbohydrate reserves associated with active shoot growth; and (3) minimal overtopping or suppression of the Douglas-fir.

Research by Pendl and D'Anjou (1990) indicates that incorrect application of manual cutting to red alder (i.e., during the dormant season to

alder seedlings less than 3 years old) can result in greater competition with Douglas-fir than would be expected from no treatment at all. Responses of Douglas-fir growing with alder seedlings of the same age (4 years) was compared to that for Douglas-fir growing with alder sprouts that originated from a fall manual cutting 2 years previously. At study initiation, sprout stands had much higher densities (51,600 stems/ha) than did seedling stands (4,400 stems/ha). Five years later, Douglas-fir in the sprout stand were smaller (height = 360 cm; stem diameter = 52 mm) than trees in the seedling stand (height = 440 cm; stem diameter = 65 mm), illustrating negative impacts from manual cutting in the fall.

Conclusions

Treatment specifications that can be modified to increase the levels of vegetation control from manual cutting include timing, frequency, and cutting technique. Responses to manual cutting vary considerably by species, but several generalizations are possible. First, a manual cutting treatment is likely to be most effective if it is timed to reduce leaf area when the plant needs it the most but is unable to recover it—usually during mid to late summer. Second, repeated manual cuttings probably do little to further improve resource availability to crop vegetation beyond that achieved by the first cutting, unless noncrop vegetation continues to overtop the crop at the time of each treatment. Third, stump height should be cut as low as possible for all species because this will limit sprouting from aboveground buds which would likely have a height advantage over the crop trees.

In addition to the treatment specifications described above, the competitive status and vigor of noncrop and crop vegetation should be considered when scheduling a manual cutting treatment. Manual cutting of vegetation that originated from seedlings should be applied when age, vigor, or size of the plant are most limiting to the viability of basal buds and the growth rate of sprouts that may develop from them. Manual cutting of vegetation that originated from sprouts should be applied when the parent root system is in a maximum state of decline. Probably the most important concept to remember is that a manual cutting treatment should be applied *before* crop trees become overtopped and suppressed.

Clearly, there is some research evidence to indicate that manual cutting is a viable treatment for competition release of young conifers. Regardless of the management paradigm to which one subscribes, it is wise to have a good understanding of the biology of both noncrop and crop vegetation. Knowledge about the presence of dormant seed or bud banks, sprouting ability, relationship between sprouting ability and size of parent stem, and tolerance to shade can be used to innovate new treatments and approaches. With the aid of computers and good research information, someday it may be possible to accurately predict levels of competing vegetation following a disturbance and, perhaps, to design stands in which noncrop vegetation is less problematic and more mutualistic.

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Manual Cutting of Competing Vegetation in Conifer Plantations of the Illinois Valley Ranger District, Siskiyou National Forest¹

CHIP WEBER

Introduction

The vegetation management program of the Illinois Valley Ranger District, Siskiyou National Forest, consisted of 1,500-2,500 acres per year of herbicide applications in the 1970s and early 1980s. Following the USDA Forest Service administrative ban on use of herbicides in 1984, the program shrunk to about 200 acres of manual release per year.

This level of activity did not meet the district's needs for plantation maintenance and growth enhancement. To meet these needs, the manual cutting program grew to 2,000-3,000 acres per year in 1990 and 1991. The administrative ban on herbicides was lifted in 1991 with the acceptance of the USDA Forest Service Region 6 Vegetation Management Environmental Impact Statement (1988) and the signing of the Mediated Agreement (U.S. District Court 1989), but the criteria for their application are more stringent than in the past. In the meantime, district foresters have become quite proficient in the application of manual methods for competition release of young conifers.

As a public agency, the USDA Forest Service is responsive to political and social pressure applied by constituents and their representatives. Manual methods of vegetation management continue to enjoy wider acceptance than either chemical or mechanical methods.

Among the advantages of manual release compared to aerial or ground-based application of herbicides is that manual methods can selectively target individual stems. Species diversity objectives can thereby be fulfilled while still releasing the conifers in each stand. Another advantage is that manual release can occur in riparian areas without concern for water contamination and with no cost for water monitoring. Also, manual cutting is not climatically restricted unless the site is simply inaccessible or snow creates unsafe footing. Finally, treatment and contract administration costs can be reduced on some sites by combining release with precommercial thinning.

Treatment Specifications

Vegetation management work in the Illinois Valley Ranger District is accomplished primarily by contractors but the treatment specifications are the same regardless of who does the work. Most of the species we

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

treat are hardwood trees. They strongly compete for moisture, which is the most limiting resource to survival and growth of conifers on most of our sites. They are able to sustain rapid growth and compete with our crop conifers for a number of years. Tanoak (*Lithocarpus densiflorus*), madrone (*Arbutus menziesii*), chinkapin (*Castanopsis chrysophylla*), manzanita (*Arctostaphylos* spp.), and ceanothus (*Ceanothus* spp.) all resprout after cutting; therefore many of our sites require more than one release. We have tried a variety of treatment specifications with varying success. The specifications presented below have proven effective over several years.

Treatment Timing

On sites with heavy competition, primarily lower elevation tanoak sites, we expect to conduct two release treatments. The first release is usually 2 or 3 years after the stands are planted to conifers; the timing varies with the preharvest level of site occupancy by hardwood trees and shrubs, and with the type and intensity of site preparation. The second release is conducted when stands are ready for precommercial thinning; such stands are generally 8-15 years old. Higher elevation sites may only need one release, which typically occurs at stand ages of 5-8 years.

Season of Application

We would prefer to cut the brush during mid-May to early July, which is the period immediately after rapid spring growth in our area. By this time the plants would have expended a lot of their carbohydrate reserves on growth and would not have sufficient reserves to also produce and sustain resprouting stems. However, we seldom operate under ideal circumstances. Contracting delays, workload scheduling conflicts, lack of available administrators, and fire shutdowns have forced changes in scheduling; we have performed manual release treatments from as early as April to as late as December.

Cutting Radius

We use the crop tree as the center of a circle and cut everything within a given radius. We originally specified a 16-ft radius. The current specification is an 8-ft cutting radius, which produces satisfactory release but does not require as much work or cost. With this cutting radius, all the woody vegetation will be cut in an area that was planted at a spacing of 9 by 9 ft (538 trees per acre) and has good survival. The woody vegetation is not cut in unstocked or understocked portions of the plantation. This 8-ft cutting radius helps us meet our species diversity and wildlife habitat objectives as well as our silvicultural objectives. A 4-ft cutting radius has been used on adjacent lands and it was ineffective.

Height of Woody Vegetation to Cut

Our specifications state that any shrub or hardwood tree taller than 1 ft is to be cut to a 6 in. stump. By reducing the leaf surface area, we hope to reduce moisture competition which can be significant, even from low-growing species like manzanita and Sadler oak (*Quercus sadleriana*).

If light competition is a more significant problem, half or two-thirds of crop-tree height could be used as a guideline for cutting woody vegetation. We have tried these specifications in past treatments but were less pleased with the results than when woody vegetation taller than 1 ft was cut.

Diameter Limit

Hardwood trees are cut if they are less than 8 in. at dbh. We usually treat our plantations well before hardwoods reach that size, but this specification allows us to treat trees in older plantations and during precommercial thinning that would compete with conifers for a long period.

Species to Treat

We have a list of species that shall not be cut and a list of species that need not be cut. All other species are treated. The "shall not be cut" species are those that we wish to promote or maintain for various reasons: bigleaf maple (*Acer macrophyllum*), dogwood (*Cornus* spp.), willow (*Salix* spp.), elderberry (*Sambucus* spp.), and Pacific yew (*Taxus brevifolia*). They are not significant competitors on most of our lands because they do not occupy much area. The "need not be cut" species are those that are difficult to treat with a chainsaw: salal (*Gaultheria shallon*), blackberry (*Rubus* spp.), poison oak (*Rhus diversiloba*), rose (*Rosa* spp.), and huckleberry (*Vaccinium* spp.). They may either be cut or left on-site; we do not want to incur extra costs by requiring that they be cut.

Slash Treatment

We used to require that any cut wood longer than 6 ft be bucked, lopped, and scattered to achieve a 2-ft deep fuel bed. Coastal districts did not require this slash treatment and their bids were \$50-\$100 lower than ours. We abandoned these requirements in 1991 because the hazard level was not reduced enough to justify the extra expense. Other contract specifications prohibit hazards such as hang-ups or buried trees.

Inspection

After treatment is complete, we visually inspect each site. Flagging is hung in locations where the work does not meet contract specifications.

We can require retreatment of any unsatisfactory work, but use a measure of reasonableness to guide us. If there are only a few flags scattered in a site, we do not require retreatment.

Factors Limiting Application and Efficacy

The species requiring treatment is the greatest limitation to applying manual methods. A chainsaw is useless if the competing vegetation is herbaceous, and it is far too expensive for cutting salal, blackberry, or other flexible brush species. Production decreases as slope increases or in areas with high concentrations of slash. Weather conditions are generally not limiting factors for manual methods, but snow can make the work difficult or dangerous.

Contractors vary in reliability and skill but in general are quite good. If necessary to get a specific job accomplished, we use our own in-house crew, which can perform this work at or below contract costs.

Benefits vs. Negative Impacts

The only negative impacts we perceive are a short-term increase in fire hazard and a short-term decrease in aesthetic values. Both of these effects are imperceptible 5 years after treatment. The incidence of conifer injury from this treatment is negligible except on sites in which treatment is delayed. Conifers on such sites can develop height/stem diameter ratios of 100 to 200, and these trees tend to bend over or break when they are released. We have only seen this on one or two sites and it affected 10%-15% of the crop trees.

In addition to improved conifer growth and survival, we have observed the following benefits:

- Increased soil moisture holding capacity. The organic mulch from this treatment decreases evaporative water loss.
- Short-term increase in palatable browse available for big game which results from resprouting woody vegetation.
- Short-term increase in low cover under which birds and small mammals may hide.
- Long-term aesthetic improvement by accelerating the rate of site occupancy by conifers.

Logistics

Because most of our work is accomplished by contract, our main concern is availability of contract administrators and inspectors. Work delays, except for fire shutdowns, are the responsibility of the contractor. Sometimes a contractor will bring in so many crews that we have difficulty keeping up with inspection, but that is rare.

Approximate Costs

Contractors have become increasingly skilled and efficient at manual release. Also, there are enough of them in the workforce to create significant competition. Because of these two factors, costs have stabilized or even decreased in spite of rising insurance costs. But bidding is a variable process. Costs for manual release in young plantations range from \$175-\$280 per acre. The range for combination treatments (release and thinning) is \$190-\$310 per acre. Since precommercial thinning alone costs from \$100-\$150 per acre, there is a cost savings when the treatments are combined. Administration and contract preparation costs add about 10% on top of the contract bid.

New Tools

A new girdling machine called the L'il Beaver Power Girdler (Albertson, this proceedings) is promising for applications that previously might have used stem injection of herbicides. Treatment efficacy compares favorably with stem injection. The machine will save a lot of time when girdling large wildlife trees or mistletoe-infected trees.

Summary

Manual cutting has become an important tool for managing competing vegetation on national forests. As foresters become accustomed to its applications, its efficacy increases and cost decreases. Because this treatment is socially acceptable and has proven effective, it will continue to be widely applied on federal lands.

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Manual Cutting of Competing Vegetation in Conifer Plantations of the Siuslaw National Forest¹

EDMUND L. OBERMEYER

Location and Setting

The Siuslaw National Forest, located in the central Oregon Coast Range, contains some of the most productive lands for conifers in the world. Conifer growth is excellent over much of the Forest because of favorable moisture conditions and good soil fertility. The average Douglas-fir site index (100-year basis) is 161, a value that is generally uniform throughout the Forest. The major tree species is Douglas-fir (*Pseudotsuga menziesii*); however, the Forest also supports large volumes of Sitka spruce (*Picea sitchensis*) and western hemlock (*Tsuga heterophylla*). The principal hardwood species is red alder (*Alnus rubra*) with a smaller component of bigleaf maple (*Acer macrophyllum*). The same agents that promote favorable growth tend to complicate stand establishment: salmonberry (*Rubus spectabilis*), red alder, and other vegetation are vigorous competitors with newly planted conifer seedlings. In addition, black-tailed deer (*Odocoileus hemionus columbianus*), Roosevelt elk (*Cervus elaphus roosevelti*), and mountain beavers (*Aplodontia rufa*) find this habitat highly desirable and often browse conifer seedlings extensively.

Management Situation

The normal method of timber harvest on the Siuslaw National Forest is clearcutting. After harvest, the principal silvicultural objective is to establish new plantations that will be commensurate with other resources. We typically plant between 350 and 400 seedlings per acre with the objective of 250 to 300 uniformly spaced trees per acre (conifers alone or mixed with hardwoods) at stand age 10. Over the last 5 years, an average of 5,500 acres per year has been reforested by planting. Most of this acreage required a treatment to control animal damage. Approximately 55% of the sites were prepared by broadcast burning, and 45% required no site preparation. In addition, approximately 5,000 acres were treated each year to release seedlings from competing vegetation.

Reasons for Manual Control of Vegetation

Until 1984, the primary method of controlling vegetation during plantation establishment was with herbicides. During that year, as a result of a lawsuit, the USDA Forest Service and the USDI Bureau of Land Management were enjoined from using herbicides until a Worst Case Analysis was satisfactorily completed. Since that judgment was delivered, silvicultural

¹Proceedings of a presentation at the workshop on Forest Vegetation Management without Herbicides, Oregon State University, Corvallis, February 18-19, 1992.

tural activity on the Siuslaw National Forest has, by necessity, been completed with nonchemical methods. The last use of herbicides on the Forest occurred in fiscal year 1983.

Before the judgment, the Siuslaw National Forest had chemically treated an average of 5,150 acres each year. Treatments were primarily for site preparation and stand release. In addition, herbicides were used for maintaining the areas around facilities and road rights-of-way and for controlling noxious weeds.

Current Practices

Since 1984, all site-preparation and release treatments have been accomplished by manual means, yet the average annual percentage of acres receiving manual treatments is actually less than that of acres that were formerly treated with chemicals (Table 1).

Table 1. Comparison of acreage treatments on the Siuslaw National Forest before and after 1984 injunction on herbicide use.

Activity	Average annual percentage of acres	
	Chemically treated before 1984	Manually treated since 1984
Site preparation	40	12
Release from woody vegetation ¹	26	41
Release from red alder ¹	34	31
Total	100	84

¹All percentages include retreated acres.

Site Preparation

During site preparation, the target vegetation is usually salmonberry. This species is typically established in the existing stand before harvest and increases in vigor after harvest. Prior to burning, salmonberry is sometimes hand-slashed (the area is too steep for mechanical slashing) so that it will ignite more easily. This slashing must be done far enough in advance of burning to allow proper drying, but not so far ahead as to allow resprouting. To be cost effective, slashing is only done to a height that is necessary to "carry the fire." A successful site-preparation burn gives the plantation a 1- to 2-year head start on the competing vegetation.

Release from Woody Vegetation

Approximately 72% of the acreage planted on the Forest each year will require one or more release treatments of some kind before age 10. Release from salmonberry and other woody vegetation occurs at age 1 to 4 years. Although 41% of the total acres on the Forest will require manual release from woody competition each year, the percentage varies according to whether the site has been burned. Only 22% of the burned acres require release, whereas 95% of the nonburned acres do so. Release requires that all salmonberry and other woody vegetation within a 3-ft radius from a conifer be cut to a stump height of not more than 6 in. In addition, all vegetation less than 10 ft from the seedling is cut back if it intersects an imaginary line that originates at the base of the seedling and extends 45° up from the ground (Figure 1). Costs are minimized by releasing only those seedlings needed to meet desired stocking levels of crop trees. The success of such release treatments is often affected by

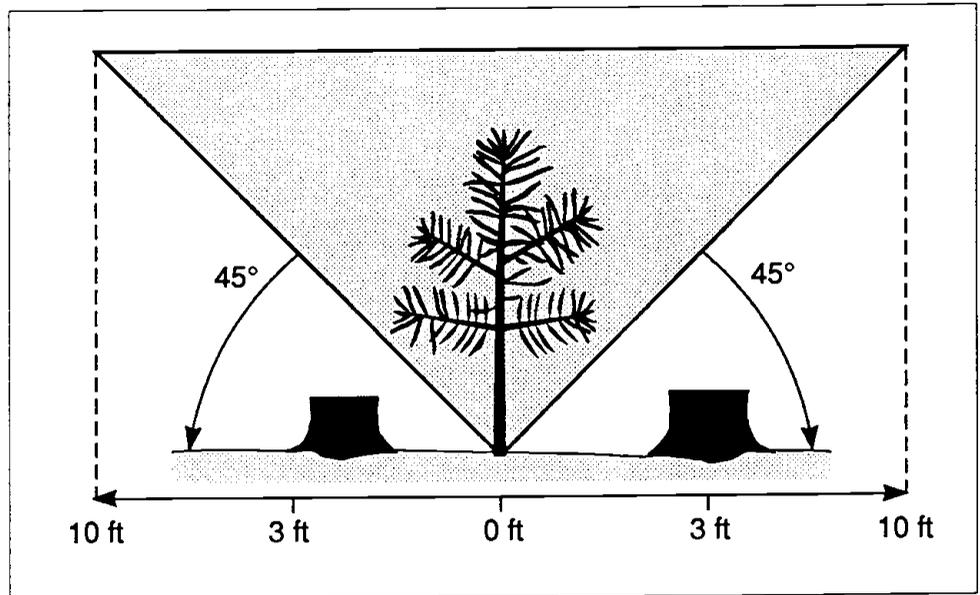


Figure 1. Zone (shaded) within which competing vegetation is cut back so that a crop conifer seedling receives adequate sunlight.

browsing from deer and elk. When animal populations are high, severe browsing can occur on released seedlings, and animal damage control and additional release treatments may be required. Successful release may require from one to three treatments.

Recently, a study to identify a "cutting window" for salmonberry was conducted by the Pacific Northwest Research Station and the Forest. Results indicate that the optimal period for hand-cutting salmonberry is from June 1 to August 15. Cutting during this period coupled with improved control of animal damage and the planting of better-quality seedlings have greatly enhanced the management of salmonberry competition.

Release from Red Alder

Red alder can overtop a plantation and severely decrease its annual growth. If the alder is left too long, conifer mortality will occur. Release from red alder usually occurs at stand ages 4 through 8 years. Conifers are released by cutting all red alder below the lowest live limb and not more than 6 in. above the ground. When conditions make it impractical to cut below the lowest live limbs, alder stems are severed above these limbs and the latter are cut from the stump. Small red alder may be pulled out instead of being cut.

Research conducted by the Pacific Northwest Research Station and the Forest indicates that conifers can be successfully hand-released from alder if the latter is cut between June 1 and August 1 while it is between 6 and 10 years old. Hand-release according to this prescription has resulted in 96% mortality of red alder. If properly timed, hand-release is

needed only once. On coastal sites, red alder may invade a site and require treatment prior to age 6. When such invasion occurs, additional treatments will probably be needed.

Results of Manual Control

The movement away from chemical treatments to manual methods has not resulted in significant changes in growth and survival of seedlings. Analysis of 3-year data collected from staked rows of conifers indicates that survival prior to 1984 (when herbicides were banned) was 81% and survival after 1984 (when manual methods were adopted) was 86%. Analysis of data from a reforestation survey indicates that 5-year height growth was 6.4 ft prior to 1984 and 6.2 ft after 1984. The average annual percentage of acres requiring replanting was 25% before 1984 and 6% thereafter. While some of these differences can be attributed to effects other than manual control treatments (e.g., better quality seedlings, less broadcast burning, reduced stocking levels), the impacts of using manual instead of chemical methods are not as great as one might have expected.

Benefits

Discontinuing the use of herbicides has provided some benefits to wildlife. The vegetation on harvested areas is recovering from harvest and site preparation much faster and is providing cover and forage sooner. These benefits are thus available more quickly for small mammals such as brush rabbits (*Sylvilagus bachmani*), snowshoe hares (*Lepus americana*), and mountain beavers. Because of increased cover, big game browse is being utilized over entire sites instead of being concentrated along plantation boundaries.

Stopping the use of herbicides has also resulted in social benefits. Contracts for both site preparation and release treatments have increased significantly, thereby creating many new jobs for unskilled labor and, of course, a wider distribution of money. Our programs of vegetation management are also more widely understood and accepted than in the past.

Costs

The contract costs in dollars per acre for manual release of conifer seedlings from woody vegetation and from red alder are as follows:

<u>Release from:</u>	<u>1984</u>	<u>1985</u>	<u>1986</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1991</u>
Woody vegetation	269	119	127	123	143	142	146	147
Red alder	125	97	54	67	90	100	76	62

While these costs might be considered excessive by some readers, they are not unreasonable in comparison with those for chemical treatments on the Siuslaw National Forest. The Final Environmental Impact Statement (FEIS) for Competing and Unwanted Vegetation (USDA Forest Service 1988) states that herbicides will only be used when other methods are not effective or their costs would be unreasonable. We have not been able to show that these costs are unreasonable for standard silviculture activities. In fact, it is realistic to believe that costs with herbicides would actually be higher because of all the requirements that would have to be met under the FEIS and the Mediated Agreement (U.S. District Court 1989).

Summary and Conclusions

Experience since 1984 indicates that the necessary site preparation, reforestation, and release treatments are being applied successfully without herbicides on the Siuslaw National Forest. A number of silvicultural techniques tailored to individual sites are involved, and we have not experienced any backlog to date. District silviculturists have had to hone their techniques and learn to apply them only where needed. Cooperative research during the last 8 years has revealed much about alternative vegetation treatments, which are now enabling us to get the job done to acceptable standards.

Discontinuing the use of herbicides has resulted in more contracts and jobs being created. Wages from these jobs tend to go into more hands and more communities than formerly.

The impact on wildlife has also been beneficial. Discontinuing chemical control has resulted in more rapid recovery of vegetation, thus providing more cover and forage.

The loss of herbicides on the Siuslaw National Forest has been less traumatic than anyone on the Forest expected. This loss required us to look at new alternatives in vegetation management that would otherwise have taken years to develop or may never have been developed at all. Unless management activities change dramatically, we are confident that we can continue to manage the Siuslaw National Forest effectively without the use of herbicides.

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CONCLUDING REMARKS¹

Timothy B. Harrington

In this workshop we learned that successful practice of forest vegetation management without herbicides requires more skill than that with herbicides because the former involves so many more questions. Herbicide treatments are generally more effective because fewer things can go wrong; they control such a broad spectrum of vegetation that even when mistakes are made, their level of vegetation control is generally acceptable. In contrast, nonherbicide treatments are generally less effective and more difficult to prescribe because a forester must know a lot more about the biology of the system (e.g., rates of vegetation recovery, developmental stage, and associated susceptibility of vegetation to control measures). For example, treatment timing is critical for manual cutting and application of mulches because the duration of vegetation control from these treatments is so brief, and because treatment during specific months can provide greater levels of vegetation control than during others. Consequently, the technology of nonherbicide treatments is not as advanced as that for herbicide treatments.

Various speakers during the workshop discussed both new practices that are being refined as well as old ones that are still being used. As a concluding statement, I would like to suggest four ways that we can accelerate the development and application of effective treatments in nonherbicide vegetation management. First, it is apparent that we should be controlling plant competitors when they are at their lowest vigor. An example of this approach is the application of prescribed fire or manual cutting prior to timber harvest, when understory vegetation is already in a state of low vigor from light deprivation. Our current silvicultural systems create the most vigorous competitors possible through clearcutting and burning. These disturbances expose the forest floor to high levels of available light, provide an ash or mineral-soil seedbed, and "prune" vegetation from the preharvest stand to stimulate their vigorous regrowth. To release conifer seedlings from such competing vegetation, we often are required to use the most intensive treatment available, yet treatment efficacy is often limited because the improved vigor of the competitor makes it resilient to additional disturbances.

Second, we must consider ways of making animals work for us to control competing vegetation. The technology for doing this requires refinement, but the concept is to conduct vegetation control prior to timber harvest by means of prescribed fire or manual cutting, and then allow one or more growing seasons for the vegetation to sprout and for big game and other wildlife to browse on the new growth. The idea of generating revenues from livestock grazing to offset the costs of conifer regeneration may or may not be viable, depending on the current markets for livestock products. But the investments we are making now in

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forest vegetation management are no doubt improving wildlife habitat, a benefit that should reap good public relations. Let us allow those animals to work for *us* a bit.

Third, we must improve the way that we diagnose competitive stress in conifer seedlings and their need for competition release. Often competition release is prescribed either unnecessarily or when growth suppression of conifers is already well under way. Indices of current vigor and potential for rapid crown development in conifers include the size and number of buds and needles, rate of growth in stem diameter, height:diameter ratio, and the abundance of neighboring woody vegetation at or above conifer height. These indices give us a measure of the imminence of conifer growth suppression and possible mortality, as well as the potential for a positive response to competition release.

Finally, we must quantify the gains in stand growth, yield, and structure that are being achieved by the often expensive treatments that we apply in forest vegetation management. In order to obtain such information, foresters must have a system in place to establish and protect side-by-side comparisons of treated and untreated stands. Such comparisons should be maintained for a sufficient period of time so that they reveal the ultimate consequences of a given treatment—which species will become the long-term dominant and how treatment has influenced this outcome. A statistically-sound experiment does not have to be complex or difficult to design and install, and universities, such as Oregon State, have the expertise to assist you in all types of problem-solving in forest vegetation management.

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