AN ABSTRACT OF THE THESIS OF

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Title: EARLY PLANT BIOMASS TRENDS FOLLOWING FOREST SITE PREPARATION ON THE OREGON COAST RANGE

Abstract approved: ______________________
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The vegetation following forest site preparation was examined in ten clearcut units located in the western Oregon Coast Range. The site preparation techniques used in these units included scarification, slash burning, and chemical spraying. The ages of the clearcut units studied varied from one to nine growing seasons for the scarification treatment, two to ten for the slash burning treatment, and two to six for the spraying treatment. The survey of the vegetation was executed during the summer of 1976. Herbaceous and shrub vegetation were characterized by biomass and cover measurements together with the identification of the three principal species in each vegetation layer. In addition, the influence of the density of the previous conifer stand on the occurrence and abundance of shrub individuals following site preparation and the activity of browsers on both planted coniferous transplants and shrub stems were examined.

Results were evaluated in relation to the rate of reoccupancy of

the site by herbaceous and shrub vegetation. This was used in an attempt to conceptualize the relative roles of both components of the system in the early stages of succession, and to determine the strategies of these vegetation components as secondary plant succession progresses.

The vegetation on a clearcut unit is made up of several small vegetative units as a consequence of the different intensities of the site preparation method used and is, therefore, variable in structure and composition. Findings indicate that early successional trends are characterized by an increasing abundance of both herbaceous and shrub species in proportions related to the particular set of site conditions imposed by the method of site preparation. In the initial stages of succession, microenvironmental factors under the influence of herbaceous species appear to control the establishment of conifers while by the fourth year increasing influence from the sprouting shrubs usurps a controlling influence on further succession.

The suppressive effect of coniferous overstory on understory development of shrubs indicates that intense brush recovery is more likely to happen on sites previously supporting conifer stands of low density. Such a trend, although variable, identifies the desirability of high stand densities on brush threat sites.

Selective feeding on coniferous seedlings and on brush sprouts by deer and rodents appears to be an important consideration in long term succession. Animal populations are high in habitats conditioned by site preparation; the vegetation following scarification and slash burning appeared especially attractive to browsers while that after spraying appeared attractive to rodents.

Over all, composition of perennials shortly after disturbance, especially sprouting woody species, has a major effect on long-term community development. Selective consumption by deer and rodents can delete components of low abundance, such as conifers, during the early stages of succession. Choice of site preparation method can affect both the composition and the density of woody cover and the apparent degree of animal use.

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Early Plant Biomass Trends Following Forest Site Preparation on the Oregon Coast Range

by

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EARLY PLANT BIOMASS TRENDS FOLLOWING FOREST SITE PREPARATION ON THE OREGON COAST RANGE

INTRODUCTION

Initial establishment of forest regeneration is one of the most important phases in a reforestation program. It is the phase which deserves most attention from land managers in terms of the analysis and prediction of the environmental factors acting upon tree seedlings or germinants. The regeneration phase is the beginning of a chain of events in which forest management objectives are at stake in the face of biotic and abiotic pressures.

Successful regeneration depends on the early establishment and rapid juvenile growth of the new forest crop which, in turn, depend on the easy access of seedlings or new germinants to an adequate amount of water, light, and nutrients present on the site. The amount of these site resources necessary to maintain seedling growth is often small when compared to the available quantity present in a site. However, the available supply of these growth factors in a system is limited because there is normally a variety of other plants growing simultaneously with the crop seedlings. Consequently, the site has to be disturbed in some manner to discourage unwanted vegetation from being severely competitive.

After any disturbance, the natural replacement of a community by another (i.e. plant succession) is so easily observed that the existence of this general phenomenon has long been recognized. Since the particular type of disturbance exerts one or a group of characteristic pressures upon the environment, it is useful to be able to predict the subsequent quantity and composition of plant communities following such a disturbance as a function of the intensity and type of the disturbance.

The general objective of this study was to evaluate the relative roles of shrubs and herbs in the secondary plant succession, and to assess the manner in which woody plants exert their dominance following three different site preparation techniques. Such information is sought for an understanding of how these techniques and the conditions where they are used affect the point where herbaceous and shrub species begin to displace each other for site occupancy and dominance. Beyond this point, changes in competition for habitat resources take place which directly influence the success of the introduced coniferous seedlings. Prior to this, there is a community convergence during which site occupancy has not reached the point of excluding species. It is therefore anticipated that the pattern of community development prior to full occupancy will have a marked effect on changes after convergence occurs. It is toward a characterization of this convergence that this thesis is directed.

To work within a time constraint, a side by side comparison of successional time slices was used in this study. Clearcut units subjected to different site preparation methods at various ages from the time of the operation were used instead of the preferred procedure for study of succession patterns which uses subsequent measurements of permanent plots.

The understanding of plant succession following vegetation management is not only of basic ecological interest but also is important in the evaluation of the effectiveness of the techniques used to accomplish control of unwanted vegetation previous to seeding or planting operations. Plant succession studies have dealt with change in cover and composition following slash burning and brown and burn techniques (Roberts, 1975), but little attention has been given to the quantitative aspect (biomass) of these changes. Furthermore, the mechanical type of treatment (scarification) has not been included in the studies although a considerable area has been treated by this method.

Sampling plots were established on several clearcut units under the administration of the U.S. Forest Service and State Forestry Department in the Oregon Coast Range. Field measurements of biomass and cover of herbaceous and shrub vegetation were taken to determine the reoccupancy of the sites by plant communities at different periods of time from the accomplishment of site preparation. Since site preparation is an operation aimed at reducing the dominance potential of vegetation other than desirable species, trends in the biomass of the early stages of plant succession were evaluated with respect to the impact of site preparation techniques on the reduction in the odds of coniferous seedling establishment in the Oregon Coast Range ecosystem. This approach led to a conceptualization of which species were emerging from early successional stages with high dominance potential, and how site preparation can influence the long-term community trajectory in this regard.

LITERATURE REVIEW

Site Preparation: Considerations and Constraints

Rapid, successful reforestation is essential in meeting rising demands now and in the future for more timber and wood products. As the supply of old-growth timber diminishes, the dependence upon second-growth stands become increasingly important to meet the physical and economic needs of human society. Successful regeneration is the first important step in a program of intensive forest management. However, the regenerating forest is plagued with numerout constraints which can provide impediments to successful seedling establishment. Vegetative competition, animal damage, insect damage, disease, soil movement, falling debris, and high insolation are all important considerations in reforestation strategies.

Site preparation is any operation used to prepare the site for either natural or artificial regeneration of a forest stand. In that process, logging slash and other debris are cleared, mineral soil is exposed, compaction of surface and upper soil horizons are reduced, favorable microsites on harsh sites are created, and interference by unwanted vegetation through allelopathy, competition or improved animal habitat can be reduced.

Logging slash, other debris, and residual vegetation quite often hinder the establishment of natural regeneration and provide a physical barrier for planting (Edgren and Stein, 1974; Miller et al, 1974). Mineral soil is a favorable seedbed for the establishment of many forest species from seed. On newly logged sites, the exposed forest floor consists quite often of unincorporated organic matter. An operation to expose sufficient mineral soil may therefore be required particularly for natural regeneration or artificial seeding. Exposed mineral soil is not normally important for planting; it is important to prevent the incorporation of organic matter into the planting hole on dry sites (Stewart, 1977). On landings, soil compaction after logging may reduce the infiltration of water and roots so as to affect the height growth of seedlings (Froehlich, 1974). On exposed and dry sites, trenching, weed control, or any other method that ameliorates temperature and soil moisture stress may be necessary.

In the Pacific Northwest, four major methods of site preparation are considered: mechanical, burning, chemical, and combination of the three. The objectives achieved in each method can be summarized in the following format (modified from Wellner, 1962):

Method	Removing debris	Reducing competition	Preparing mineral soil	Reducing compaction	Creating favorable microsite
Mechanical	X	X	X		X
Burning	X	X	X	X	X
Chemical		X		X	X
Combination	X	X	X	X	X

Mechanical site preparation can be accomplished during logging or as an independent and planned operation. In logging, the effectiveness of the operation is severely hampered because it is only a by-product of logging and not organized as an objective in the logging plan. Dyrness (1965) reported that about 23 percent of a clearcut unit may be slightly disturbed and only 9 percent deeply disturbed after high-lead or tractor logging. As a planned operation, scarification and piling or windrowing are the techniques most used in the Pacific Northwest. Gratkowski (1974) has cited other techniques used in the PNW such as crush, disc plow, and masticate with hammermill-type choppers. All can be used effectively when practical. However, since slopes higher than 30 percent do not offer safety or soil protection in the use of mechanical equipment, these techniques have been used only on a limited scale in the Oregon Coast Range. High operational costs and poor control of sprouting brush species are the major disadvantages of any mechanical technique. Debris left on the site after mechanical treatment interferes with planting, reduces control over spacing of seedlings, and provides protective cover for rabbits and other small mammals unless windrows are built and burned (Stewart, 1977). Compaction may occur on wet soils or soils with high clay content (Froehlich, 1974). Animal damage can be reduced by clearing large areas with greater than 120 feet between windrows (Gratkowski and Anderson, 1968).

The use of fire for preparing sites for a new stand in the PNW is the most wide-spread technique. The amount of information on fire in the literature is more extensive than any other method of site preparation. Gratkowski et al. (1973) have listed several advantages of fire use as on steep slopes, for treatment of large areas, and requiring smaller investment than mechanical treatment. On the other hand, the same researchers have cited smoke pollution, the necessity of well-trained personnel, the lack of control of shrub resprouts, and germination induction of some brush-species seeds as the common disadvantages of prescribed burning. The use of fire does not harm a significant amount of soil, since broadcast burning of logging residues in the PNW may leave 42 percent of the clearcut unburned and only 5 percent severely burned (Dyrness and Youngberg, 1957; Tarrant, 1956).

The very characteristic of herbicides--the selective kill of unwanted vegetation with the focusing of site resources in support of desirable species--has stimulated an increase in acreage treated by chemical site preparation. The planting operation is, however, likely to be more expensive because slash and debris are not removed. Chemical treatments are quite often the least expensive method of site preparation (Gratkowski et al., 1973). A great deal of information is available concerning the choice of herbicides, the season of application, the choice of carrier, and the susceptibility of several shrub species (Stewart, 1977). Chemical site preparation has the advantage of minimum disturbance since it does not compact, loosen or move top soil. Furthermore, it can be used in all terrain and requires a minimum amount of manpower. On the other hand, herbicides may not be applied near "sensitive" areas, do not expose mineral soil for artificial or natural seeding, and may need respraying to control hard-to-kill brush species. Fire hazard can also be a serious drawback with this technique (Parker, 1971). Since animals require specific types of vegetation for food and cover, herbicides can be used to alter the carrying capacity of areas by selectively favoring or denying habitat conditions (Lawrence, 1967; Nelson, 1975). The non-removal of slash and other debris may actually improve habitat for small mammals and birds (Dimock, 1974). However, Dimock (1974) cited studies by Swanson (1970) and Wallmo (1969) in which the use of the area by deer and elk was impeded by the presence of slash residues.

Crushing or clearing is combined with spraying or burning to achieve a more complete control of vegetation and easier access. Spray expenditures are compensated by the reduced costs of subsequent mechanical site preparation (Gratkowski, et al., 1973). The combination of spraying and burning are termed "brown and burn" which uses contact herbicides to desiccate leaves and twigs prior to the burning or "spray and burn" which uses translocated herbicides to defoliate and control competing vegetation before burning (Stewart, 1977).

Succession Following Site Preparation

Tansley (1920) has defined succession as "the gradual change which occurs in the vegetation of a given area of the earth's surface on which one population succeeds the other." Soon after the formation or devegetation of a terrestrial surface, a pioneer plant community may become evident. The invasion of new plants usually continues and the already-present species may reproduce and become more abundant. Thus, a species enrichment may be observed on the same habitat that is associated with an increase in the number of individuals or an increase in the cover of certain species. Concurrently with species enrichment and structural complexity some early invaders may disappear. These events usually are the result of competitive replacement among species. Animals as well as plants are involved in this process. Changes in fauna, however, more often follow than lead changes in vegetation.

Different types of community have different effects upon the introduction of coniferous seedlings in the same habitat. Herbaceous plants are very effective in depleting moisture from the top portion of the soil profile. Where these communities are stable it is often necessary for the coniferous seedlings to survive through a period of negligible available moisture during the summer. The removal of this type of competing vegetation will release a very large amount of the potential moisture storage capacity of the soil for the use by the seedlings (Newton, 1964). Preest (1975) found that first year devegetation bore significant effects on height and diameter growth of seedlings in each of the four subsequent years. Chetock (1976) found that first year treatment with herbicides enhanced seedling survival on droughty sites. Another effect of the detrimental influence of competing herbaceous vegetation on conifer seedling establishment is the increase in air temperature of the seedling crown when herbaceous species concentrate in the vicinity of the seedlings. This increase in temperature, in turn, increases seedling moisture stress by increasing transpiration rate (Greaves, et al., 1977). In addition, herbaceous species provide improved rodent habitat and may have allelopathic effects on crop seedlings.

Shrub communities impose different types of pressure upon the seedling environment such as shade, animal damage, and litterfall. The heavy shade cast by brush reduces wood growth in seedlings which grow more slowly and are subjected to damage from the falling litter of the overstory. The reduction of growth decreases the competitive potential of the seedling with respect to the rapid brush development and, thereby, results in its permanent suppression. Seedling mortality due to a lack of moisture in brushfield is likely to occur later than in herbaceous dominated sites because conifer seedlings will experience moisture stress when roots reach soil moisture zones already occupied by brush roots.

Several investigators have mentioned the animal pressure associated with brush habitats (Ruth, 1956; Allen, 1969; Roberts, 1975). Deer, elk, and rodents (in order of importance) present the most serious problem hampering survival of conifer seedlings (Dimock and Black, 1969). Density, weather conditions, elevation, and forage availability have been associated with the change of browsing pressure of deer upon reforestation in the PNW (Crouch, 1969). Mountain beaver damage has been related to areas of deep soil, abundance of ferns, and proximity of damp places (Scheffer, 1929). Plantations established on salmonberry-dominated sites can be threatened by rabbits as concluded by Allen (1969). The concept of brush as a nurse crop with effects such as decrease in air and soil temperature, decrease in transpiration by the reduction of solar radiation, temperature and wind velocity, and increase in soil fertility by the fixation of nitrogen, seldom offset the more detrimental effects of light reduction, improved animal habitat and moisture depletion (Greaves, et al., 1974; Zavitkovski, et al., 1969).

Isaac (1940) noted the importance of fire on natural succession in the Oregon Coast Range. He observed that ground cover species killed by slash fire can determine the frequency with which invading communities of herbaceous and shrub species appear in the succession that follows that disturbance. Isaac (1940) concluded that the cover is complete by the third growing season and reaches its maximum during the first eight years of secondary succession. Total herbaceous cover declined after about the fourth year while brush cover increased.

Sabhasri and Ferrell (1960) studying plant succession on the eastern edge of the Oregon Coast Range found a much greater cover of brush species in natural forest openings than in the adjacent forest.

Nieland (1958) comparing species composition of a forest and adjacent burn area in the northern Oregon Coast Range found that some species occurred only in the forest, some only in the burn, and some others in both forest and burn. Of the species that occurred in both forest and burn, some were abundant in the forest but rare in the burn, some showed an opposite distribution, and still others showed no preference.

Bailey (1966) described observations by Mueller-Dombois (1959) who, on the Vancouver Island, found that remnant forest vegetation left after logging is still largely governed by habitat conditions. He felt that weedy vegetation, which indicated the cut-over plant communities, was indicative of the kind, degree, and time of disturbance. Mueller-Dombois (1959) noted that the relative dominance of the weed flora is temporary and confined to the initial stages of secondary succession. In addition, he noted that by 10 to 13 years after logging, there was found to be a shift in structure to a more shrubby vegetation than in the original forest.

Morris (1958, 1970) comparing burned and unburned plots located on cut-over areas in Oregon and Washington found that brush cover remained significantly less on burned plots than on unburned for five seasons in the Cascades, and three seasons on the Coast Range. In the Oregon Coast Range, Morris (1958) found that thimbleberry (Rubus parviflorus) prevailed over other species on burned plots while salmonberry (Rubus spectabilis) prevailed on unburned plots. In addition, he observed that swordfern (Polystichum munitum) survived more frequently on unburned than on burned plots. Salal (Gaultheria shallon), red huckleberry (Vaccinium parvifolium), fireweed (Epilobium angustifolium), western pearl everlasting (Anaphalis margaritacea), sedge (Carex sp.), and trailing blackberry (Rubus ursinus) were also recorded as frequent species in some plots.

Yerkes (1958, 1960) found, studying cut-over areas of various ages located within the H. J. Andrews Experimental Forest on the west side of the Cascade Range, that surviving and invading woody species increased slowly after harvesting while surviving herbaceous species were infrequent and decreased rapidly.

Brown (1963), studying early succession following logging and

and burning in units located on the Mary's Peak Watershed, concluded that there was a general increase in total number of plant species with the average total vegetative cover rising abruptly the third, fourth, and fifth seasons. This same researcher observed that south exposed plots had the greatest vegetative cover the first five years after burning as compared with east and north slopes.

Both Brown (1963) and Chilcote (1962) found that during the first five years after burning, Senecio sylvaticus dominated on the clearcut during the second year, Lotus crassifolius var. subglaber and Circium vulgare dominated during the third, and Lotus together with Holcus lanatus dominated the fourth and fifth years. It was further noted by Brown (1963) and Chilcote (1962) that in the early stages of succession relatively few species dominate, while in the later stages other species play an increasingly important role.

One must remember when manipulating plant species composition on forest lands that success is dependent upon a knowledge of the ecology of competing vegetation and its influence on the crop individuals. The direction of forest development is largely determined by initial site characteristics combined with conditions brought about by plant and animal communities. Newton (1973) has developed the dominance potential concept by which, using a simplified ecosystem model, he showed that unassisted removal of an ecosystem component as merchantable trees can lead to a radical change of resource status of other components which will severely hamper the regeneration and growth of a new coniferous crop.

METHODS

Approach Used

Mueller-Dombois and Ellenberg (1974) have listed two general categories for study of vegetation succession: (a) studies on the same area and (b) side by side comparisons. The first, more reliable than the second, can be based on studies of permanent plots, exclosures, air photos taken at different times, historical and file records or evidences of change found in the present community. In side by side comparisons, successional trends are usually observed from a study of contemporary communities occurring side by side (i. e. in geographically separate places). The reasons for the wide utilization of this approach is that few investigators have the opportunity to follow the changes occurring in the same habitat for any length of time.

This study examined forest succession with the side by side method mentioned because of a time constraint in the author's scholarship program. The dates of the disturbance (in this case site preparation) in which clearcut units had been prepared for planting were arranged in a time sequence. The successional time span sought was up to five growing seasons after the occurrence of the disturbance.

Criteria for Selection of Study Areas

Clearcut units under the State Forestry Department and U. S. Forest Service administration were chosen for study because these agencies have a uniformity of procedures and goals. In order to be included in this study, a clearcut unit had to meet the following criteria: 1) had supported a commercial coniferous stand prior to harvesting; 2) had been exposed to one or more of the following site preparation techniques: scarification, burning, or spraying; and 3) had been planted with coniferous seedlings. No limitations on acreage or logging system were imposed. Since brown and burn is not a site preparation technique used on a large scale by those agencies, clearcut units that had been burned and sprayed with phenoxy herbicides were considered in this study. In addition, the period of five years had to be extended.

Sampling Scheme

Biomass and cover measurements were executed to evaluate the distribution and composition of the vegetation growing in the selected units. The sampling scheme for field data collection was systematic with a random start. In each unit, thirty points spaced ten meters apart were marked. These points were divided into groups to sample different aspects and slopes within the unit. The choice of aspect or slope was based on the relative importance of each to the total area of the unit. Each group of sampling points was composed of ten points located on two parallel lines of five points each. These lines ran parallel to the major aspect or slope of a unit. The points on the line were located at least ten meters from the unit boundaries or any logging road. At each point, two concentric circles (0.56 and 1.13 meters of radius for herbaceous and shrub plots, respectively) were used for measurement and estimation of biomass and cover.

Biomass Measurement

Biomass was measured because it quantifies the productivity of a site by major species. Frequency of herbaceous species was not determined. Biomass was observed because it provides a good indication of the competitive relations among species, and clipping and weighing are relatively straightforward. A drawback of this procedure is the necessity of transforming green weight to dry weight when sampling is executed after precipitation or during different seasons. In this study, all field data collection was done during the summer of 1976. The variation of biomass measurements, mainly herbaceous species, during the sampling period (mid to late summer season) was not expected to be large enough to confuse the results. The standing biomass of herbaceous layer--here defined as the above-ground mantle of any herbaceous species, independent of height, or of any other species up to one meter above the ground--was measured by clipping all green material in a circular plot of one square meter and weighing it on an Ohaus spring scale (error ± 25g). The reason for such definition is that any woody species in this herbaceous layer was assumed to act upon the environment temporarily as a herbaceous species. For shrub layer--here defined as the above-ground mantle of any shrub species with at least one stem higher than one meter above the ground--the standing biomass was measured by clipping all the green material in a circular plot of four square meters and weighing it in a Chantillon spring scale (error ± 1 lb). These last values were converted to grams. At the same time, the composition of herbaceous and shrub plots was recorded by identifying the three principal species in each plot with an estimation of the biomass contributed by each species using the Klapp method (Mueller-Dombois and Ellenberg, 1974). Also, the length, to the nearest centimeter, and number of shrub stems were recorded.

Cover Measurement

Cover on both shrub and herbaceous sampling plots was estimated using the following Braun-Blanquet classification:

Class	Cover percentage	Middle point
1	up to 5	2.5
2	5 to 25	15
3	25 to 50	37.5
4	50 to 75	62.5
5	75 to 100	87.5

Cover--defined here as the projection of the ground occupied by perpendicular projections of the aerial parts of individuals on the plot in consideration--is a good measure of relative plant abundance when used for side by side comparisons. The drawback of this estimator is that it tends to be biased for absolute values because of personal error. Cover was estimated to help identify plots where biomass would have shown similar values but with a different number of individuals and species due to differences in leaf area.

Slope Measurement

The slope, or slopes, of the unit was measured with a clinometer or Abney level and classified in the following categories:

Level	up to 10%
Moderate	10 to 40%
Steep	40 to 70%
Very steep	above 70%

Slope bears an important role in vegetation composition because of the effect on soil depth, erosion potential, and solar radiation.

Recording of Aspect

The aspect, or aspects, of the units used in this study was recorded with a Silva compass and classified as North, South, East, or West. Exposure was recorded because of its effect on solar radiation which subsequently affects soil temperature and moisture.

Assessment of Browsing Activity

Signs of browsing activity in each unit was assessed by recording: 1) the number, height, to the nearest centimeter, and evidence of browsing on conifer seedlings in three 20 meter-diameter plots, and 2) browse marks (deformation or clipping signs on stems up to 1.5 meters above the ground) on shrub stems in three belt transects of 50 by 1 meter. Only damage to the leader of conifer seedlings was considered since this damage is the most detrimental to the normal height and form development. The 20 meter-diameter plots and the belt transects were located within the slope or aspect sampled for biomass. Presence and frequency of browsing is an important factor in vegetation composition and biomass. However, it is difficult to know when browsing occurred and how intensive it was. Other methods of assessing animal use activity, such as pellet count and spotlight count, were discarded. The former is time-consuming in addition to the fact that pellets under the moist climate of the Oregon Coast Range suffer rapid deterioration, while the latter depends on road access around the clearcut unit.

Measurement of Basal Area

Density of previous coniferous stands was investigated for its effect on shrub occurrence and biomass. Basal area of each unit was assessed by counting and measuring dimater of stumps, to the nearest centimeter, located on the same three 20 meter-diameter plots used for assessment of animal activity on coniferous seedlings. This method was based on high correlation often reported between stem diameter and crown spread. Such a correlation implies a corresponding correlation between basal area and crown area.

STUDY AREAS

The study areas in this project lay within the either Picea sitchensis Zone or Tsuga heterophylla Zone of Franklin and Dyrness (1973). In the Picea sitchensis Zone, these authors have cited sword fern, wood sorrel (Oxalis oregana), wild lily-of-the-valley Maiathemun bifolium), miner's lettuce (Montia sibirica), cool-wort (Tiarella trifoliata), violet (Viola sp.), and red huckleberry as typical understory species on site of medium environmental conditions. In the Tsuga heterophylla Zone, Franklin and Dyrness (1973) have cited whipple vine (Whipplea modesta), deerfoot vanillaleaf (Achlys triphylla), evergreen violet (Viola sempervirens), sword fern, twinflower (Linnaea Borealis), salal, vine maple (Acer circinatum), red huckleberry, and Oregon grape (Berberis nervosa) as typical herbaceous and shrub species. Red alder (Alnus rubra), frequently associated with salmonberry, sword fern, and trailing blackberry, is abundant on disturbed sites in the Picea sitchensis Zone. In the Tsuga heterophylla Zone, disturbed sites are invaded by species different from those naturally occurring in the area such as woodland groundsel (Senecio sylvaticus), autumn willowweed (Epilobium paniculatum), fireweed, and common thistle (Circium vulgare).

Soils in the Oregon Coast Range belong predominantly to the Tyee formation (Franklin and Dyrness, 1973). The climate is characterized by wet winters and dry summers. Climatologic data recorded by Johnsgard (1963) for the closest stations to the study areas used in this project indicated an average annual temperature of 50.1^{o}F and an average annual precipitation of 124.1 in. for the Valsetz Station while on the Toledo Station records indicated an average annual temperature of 51.8^{o}F and an average annual precipitation of 75.6 in.

Hatchery Study Area

The Hatchery study area is located on state-owned land on the west side of the Coast Range approximately 12 kilometers north-northwest of Nashville, Oregon (portions of sections 5 and 6 of T10S, R8W, W.M., Polk and Lincoln counties). The area was logged in 1967, site prepared in the same year, and planted in the 1967-1968 season. Most of the area is flat with a small and moderate slope on the west portion of it.

Beaver Study Area

This study area is on state-owned land located 8.8 kilometers north-northwest of Nashville, Oregon (portion of section 9, T10S, R8W, W.M., Polk and Lincoln counties). The Polk-Lincoln line runs through this unit which was harvested in 1972, site prepared in 1974, and planted in the 1974-1975 season. The unit consists of rolling topography and steep south-facing slope.

Cline Study Area

The Cline study area is located on state-owned land 4 kilometers west of Burnt Woods, Oregon (portions of sections 17, 19, and 20, T11S, R8W, W.M., Lincoln County). This unit was logged in 1972, site prepared in the same year, and planted in the 1972-1973 season. The area is partially flat and partially steep. The steep slopes show north and east aspects (Figure 1).

Wolf Study Area

The Wolf study area is located on state-owned land 9.6 kilometers west of Burnt Woods, Oregon (portions of sections 30 and 31, T11S, R8W, W.M., Lincoln County). The unit was harvested and site prepared in 1971, and planted in the 1971-1972 season. This unit presents part of its area with gentle topography and part with steep slopes which are west or north-facing (Figure 2).

Powerline Study Area

This study area is located on state-owned land 3.2 kilometers west of Burnt Woods, Oregon (portion of section 16, T11S, R8W, W.M., Lincoln County). The unit was logged in 1968, site prepared in 1974, and planted in the 1974-1975 season. The entire site consists of a rolling north-facing exposure.

Long Haul Study Area

The Long Haul study area is located on state-owned land 5.6 kilometers west of Burnt Woods, Oregon (portion of section 29, T11S, R8W, W.M., Lincoln County). This unit was harvested and site prepared in 1975, and planted in the 1975-1976 season. The entire area consists of a gentle east-facing exposure.

Lasky Study Area

This area is located on state-owned land 5.8 kilometers west of Blodgett, Oregon (portion of section 31, T11S, R7W, W.M., Benton County). The unit was logged and slash burned in 1966, and planted in the 1966-1967 season. The topography of this unit is composed of a moderate north-facing slope.

Toledo Study Area

This study area is located on federally-owned land 9.6 kilometers south of Toledo, Oregon (portion of section 2, T12S, R10W, T.W., Lincoln County). The area was harvested in 1966, slash burned in 1967, and sprayed and replanted in 1975. Between 1967 and 1975, two replanting operations were executed but none succeeded due to animal damage (Jim Warner, personal communication). The spray operation used a mixture of 1.1 kg of 2, 4, 5-T, (2, 4, 5-trichlorophenoxy) acetic acid, and 1.1 kg of 2, 4-D, (2, 4-dichlorophenoxy) acetic acid, per hectare in water at a rate of 93.5 l/ha. The unit consists of a steep east-facing slope.

Benner Study Area

This study area is located on federally-owned land 12.8 kilometers south-southwest of Alsea, Oregon (portion of section 23, T14S, R9W, W.M., Lincoln County). The unit was harvested and burned in 1967, and planted in the 1968-1969 season. Since the planting operation was a failure, the area was sprayed and replanted in 1972. The spray operation consisted of a mixture of 1.1 kg of 2, 4, 5-T and 1.1 kg of 2, 4-D per hectare in water at a rate of 93.5 l/ha. The topography of this unit consists of moderate to steep slopes with east or north aspect.

Lobster Study Area

This study area is located on federally-owned land 12.9 kilometers southwest of Alsea, Oregon (portion of section 26, T14S, R9W, W.M., Lincoln County). The unit was harvested and burned in 1967, planted in 1968, and sprayed in 1970 with a mixture of 1.1 kg of 2, 4, 5-T and 1.1 kg of 2, 4-D per hectare in water at a rate of 93.5 l/ha. The entire area consists of a moderate to steep east-facing slope (Figure 3).

Table 1. Conifer Volume Harvested (Mbf/ha), Year of Disturbance, Area (ha), and Type of Disturbance of the Selected Study Areas.

Name	Volume Harvested	Year of Disturbance	Area	Type of Disturbance
Hatchery	21382.8	1967	8	scarification
Wolf	53599	1971	21.7 40	scarification burning
Cline	63479	1972	13.7 62.9	scarification burning
Powerline	13757.9	1974	4	scarification
Beaver	51870	1974	12.1 12.2	scarification burning
Long Haul	17290	1975	8	scarification
Toledo	27170	1975	23.5	burning and spray
Benner	36432.5	1972	8.1	burning and spray
Lobster	30875	1970	10.1	burning and spray
Lasky	34580	1966	10	burning

Figure 1. Slash-burned slope of Cline Study area.

Figure 2. Scarified part of Wolf study area.

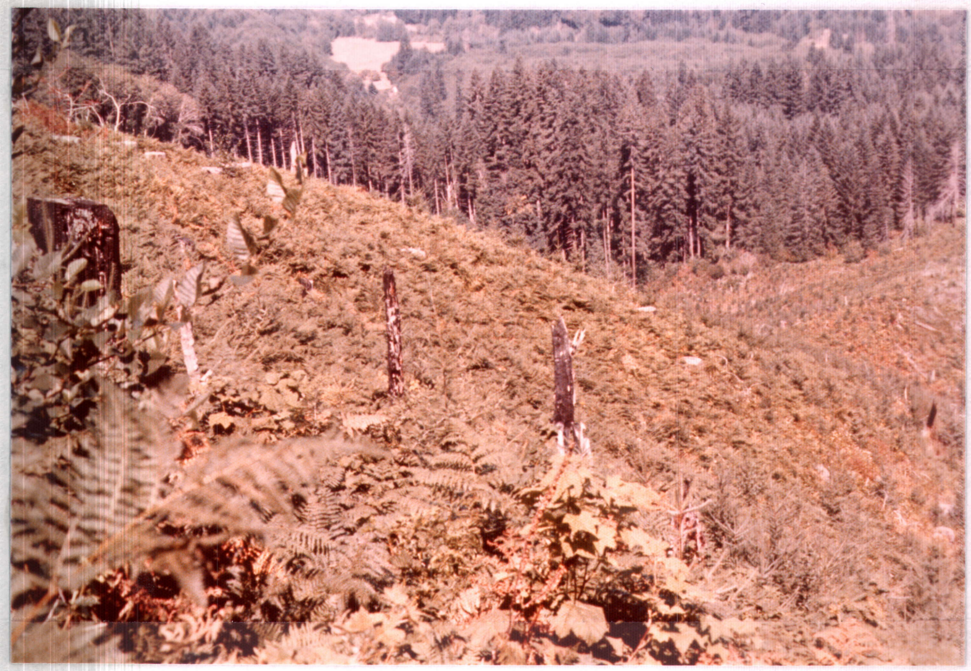

Figure 3. Chemical sprayed Lobster study area.

RESULTS

Total Biomass Trend

The relationship between total biomass and time following disturbance denotes the increase in utilization of the site by primary producers which appear to occupy every available niche. Nevertheless, the relationship does not separate which type of producers make the use of such resources, nor does it discriminate as to their development. It is necessary to bear in mind that the result of site preparation is a mosaic of small areas subjected to different intensities of disturbance rather than a large uniform area. Observations were therefore variable.

All clearcut units subjected to scarification and spraying showed an increase in total biomass with increasing time after the disturbance (Figure 4) indicating a direct relation between total biomass and time from disturbance (here counted in growing seasons after the site preparation). Slash-burned units, on the other hand, showed total biomass values for the four- and five-year-old units smaller than the value recorded for the two-year-old unit. After the fifth season, however, total biomass increased again but with a lesser intensity than the other two treatments. The significance of the difference in this pattern could not be tested because of the confounding identified after the initiation of the study. Such difference could be the result of the location of the study areas in different vegetation zones.

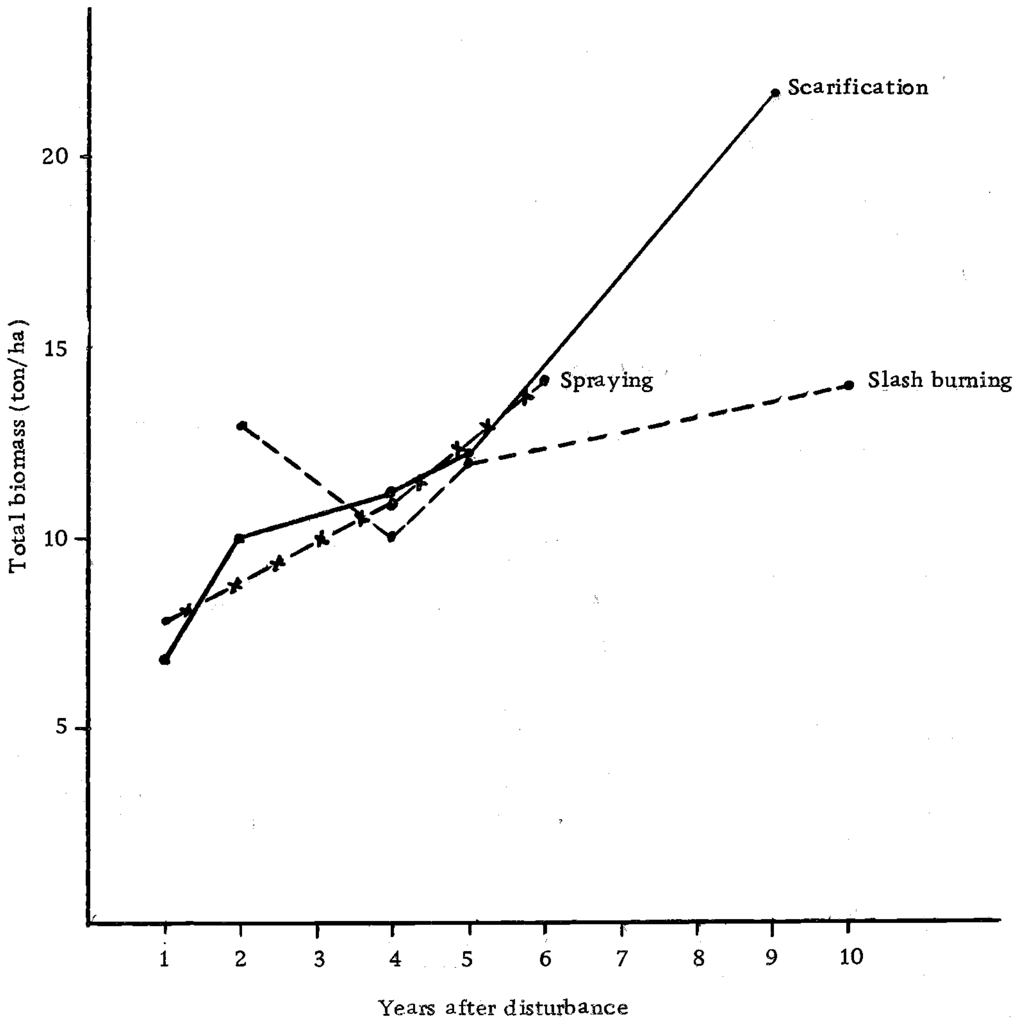

Figure 4. Total biomass (ton/ha).

Herbaceous Biomass Trend

Herbaceous species comprise a large number of the invading species in newly disturbed areas. Being able to grow, mature, and seed in a short period of time, these species are capable of maintaining a very stable community. In addition, many of such plants have a high relative preference in the food habits of several mammals and birds. Wind-disseminated seeds and plentiful vectors help the quick invasion and occupancy of bare areas. The short-term dominance potential of these primary producers can be high when compared with shrub and tree species such as red alder, especially in conditions of dry spring weather or heavy animal use (Newton, personal communication). Figure 5 illustrates that clearcut units treated by scarification showed an increase in herbaceous biomass from the first to the second season and a decrease thereafter even though some variation occurred. The same general trend of decrease in herbaceous biomass with increase in time from the disturbance was also observable in slash-burned units. However, the decrease in herbaceous biomass recorded for slash-burned units is smaller than the decrease recorded for scarified units. In both cases, the absolute value of herbaceous biomass in the two year old units was greater than any other value. Units treated with herbicides showed an increase in herbaceous biomass up to the oldest unit sampled which was six years old.

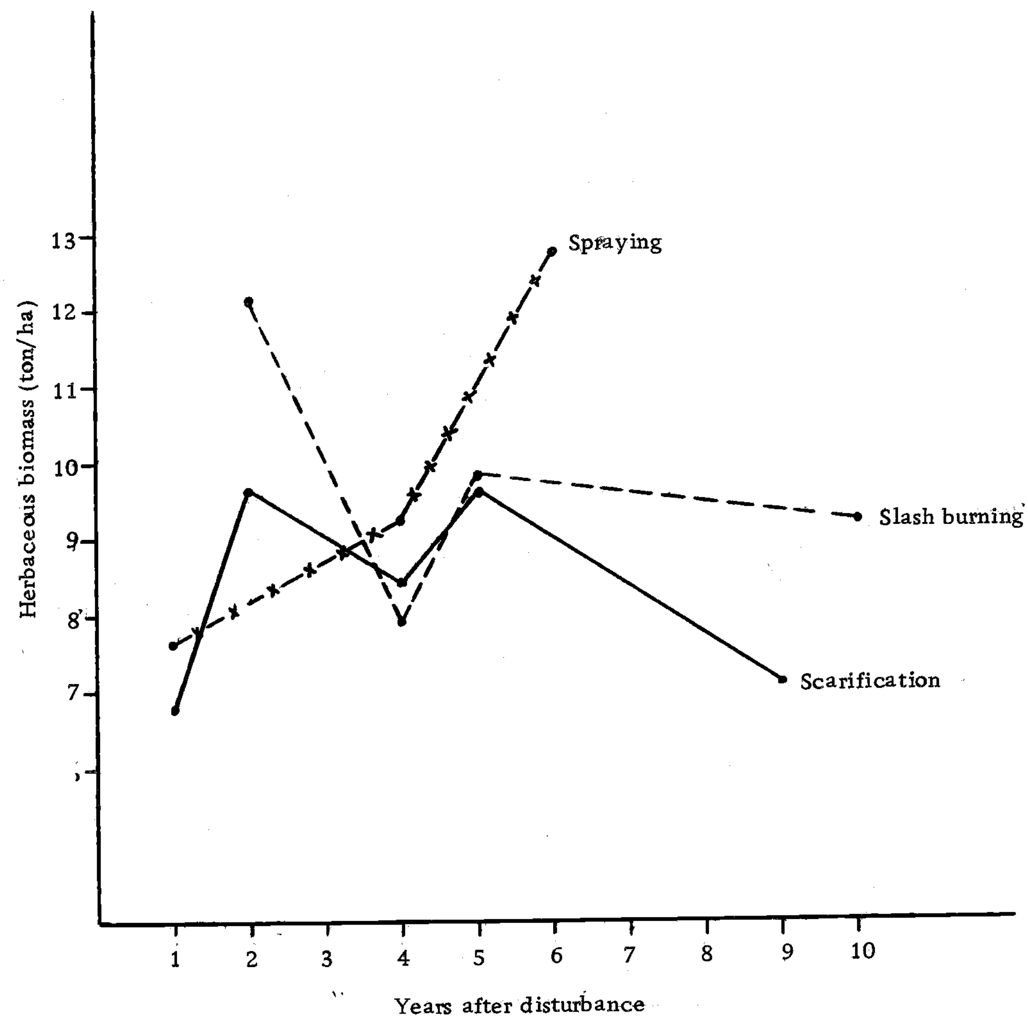

Figure 5. Total herbaceous biomass (ton/ha)

Shrub Biomass Trend

Shrub species comprise the other large component of the primary producers in a forest ecosystem. The appearance of many of these species in a disturbed area is mainly the result of vegetative reproduction rather than by seeds (Roberts, 1975).

Figure 6 illustrates that units treated by scarification are likely to support a remarkable increase in shrub biomass, up to the maximum value recorded among all the units from a nine-year-old scarified unit. Such an increase in shrub biomass with age was also noticeable in slash-burned units but to a lesser degree. Units which were treated partly by scarification and partly by burning showed that the mechanical operation yielded significantly higher shrub biomasses for the two-year-old unit and the four-year-old unit while the five-year-old unit did not show significant difference between the two treatments (Table 2).

Table 2. T-tests of Shrub Biomass Values Between Units Partly Site Prepared by Scarification and Partly by Slash Burning

Unit	Year of Disturbance	t Calculated	t Table (= 0.05)	Level of Significance
Beaver	1974	-4.91	2.77	S
Cline	1972	-2.59	2.16	S
Wolf	1971	-0.98	2.09	NS

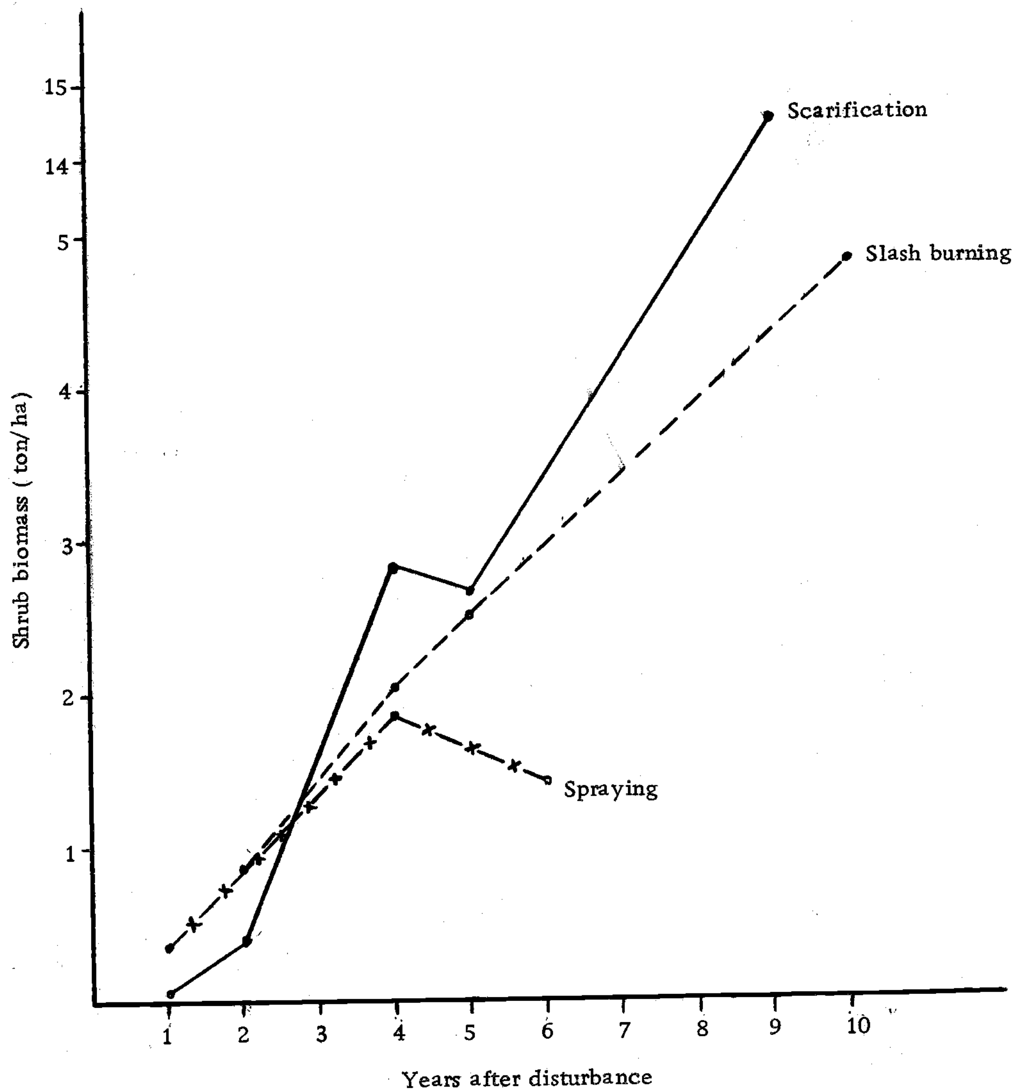

Figure 6. Total shrub biomass (ton/ha).

On units subjected to chemical treatment, there was an increase in shrub biomass from the one-year-old unit to the four-year-old unit and a decrease from this unit to the six-year-old unit.

Herbaceous Cover Trend

The mean herbaceous cover, calculated by using the middle point of the cover classes, recorded on scarified units was higher than the means calculated for either slash-burned or sprayed units on the first six years following the disturbance. The four-year-old unit of each treatment yielded the highest mean herbaceous cover (Figure 7). The decrease in herbaceous cover after the initial six years following disturbance is greater for scarified than for slash-burned units since the mean herbaceous cover for the nine-year-old scarified unit was smaller than the mean herbaceous cover for the ten-year-old slash-burned unit. In both treatments, the mean herbaceous cover of the oldest unit was lower than the mean calculated for the youngest one. Mean herbaceous cover from units chemically treated showed overall low values in comparison to the values obtained from the other two treatments. The greatest difference was during the first year following disturbance after which development was rapid. Like the trend observable with scarified and slash-burned units, the mean herbaceous cover decreased after the fourth year.

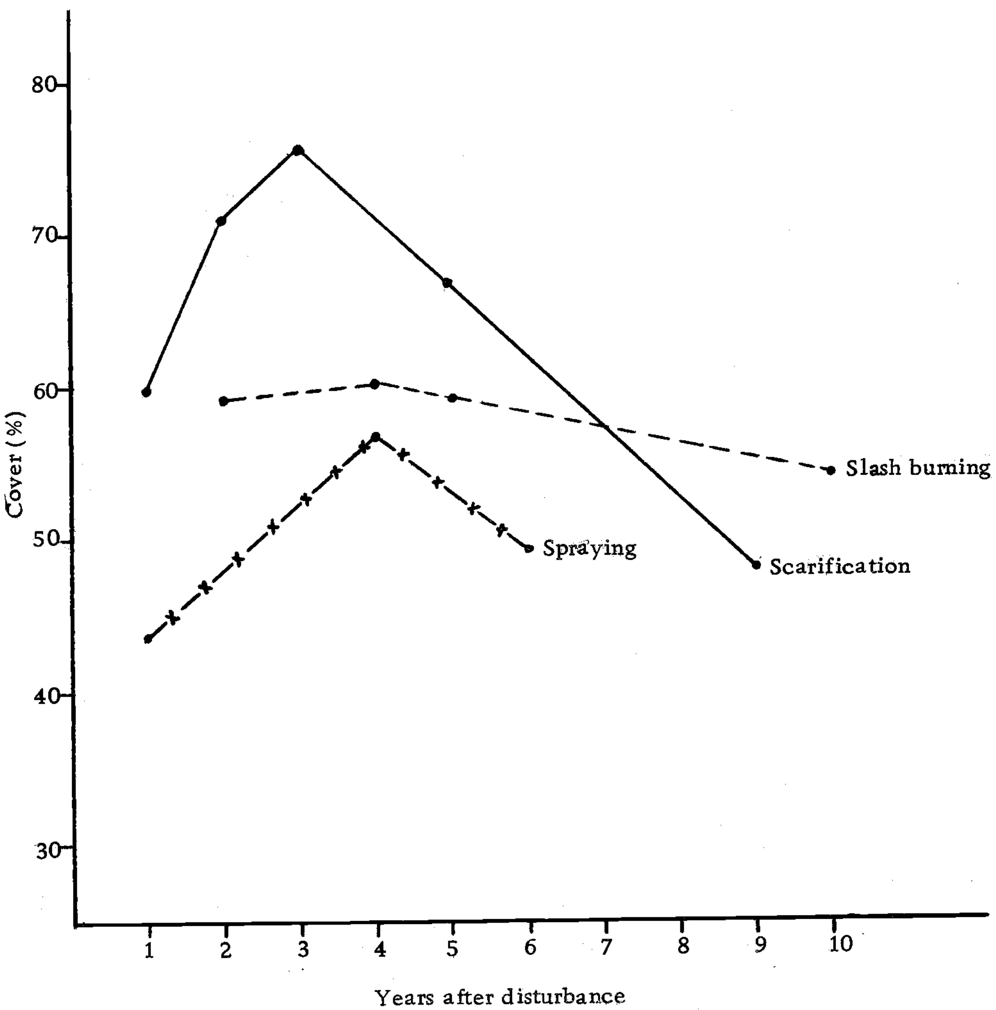

Figure 7. Average herbaceous cover (percentage).

Shrub Cover Trend

Even though cover estimation is very susceptible to human error, the variation in shrub cover obtained in units subjected to all site preparation methods precluded good evaluation of relative changes with time. The values of mean shrub cover, calculated by using the middle point of the cover classes, for scarified units increased rapidly from the first to the second season, decreased from this to the fourth and fifth season, and increased again to the highest value calculated for the nine-year-old unit. The mean shrub values calculated for the slash-burned and sprayed units increased from the youngest units to the four-year-old units. From this point, the sprayed units showed a tendency of decreasing shrub cover while the slash-burned units showed a decrease, to the five-year-old unit, followed by an increase in the oldest unit sampled. The calculated shrub cover means for scarified areas were higher than their counterparts calculated for the slash-burned and sprayed units at the first two years and after the fifth year following disturbance (Figure 8).

The variation of shrub cover is in the low range of the possible range and therefore subject to wide proportional variation without necessarily implying significance.

Effect of Exposure and Slope Steepness on Vegetation Development

The effect of exposure and slope steepness on shrub and herbaceous biomass could not be determined conclusively in this study because of the small number of units selected which did not have a sufficient

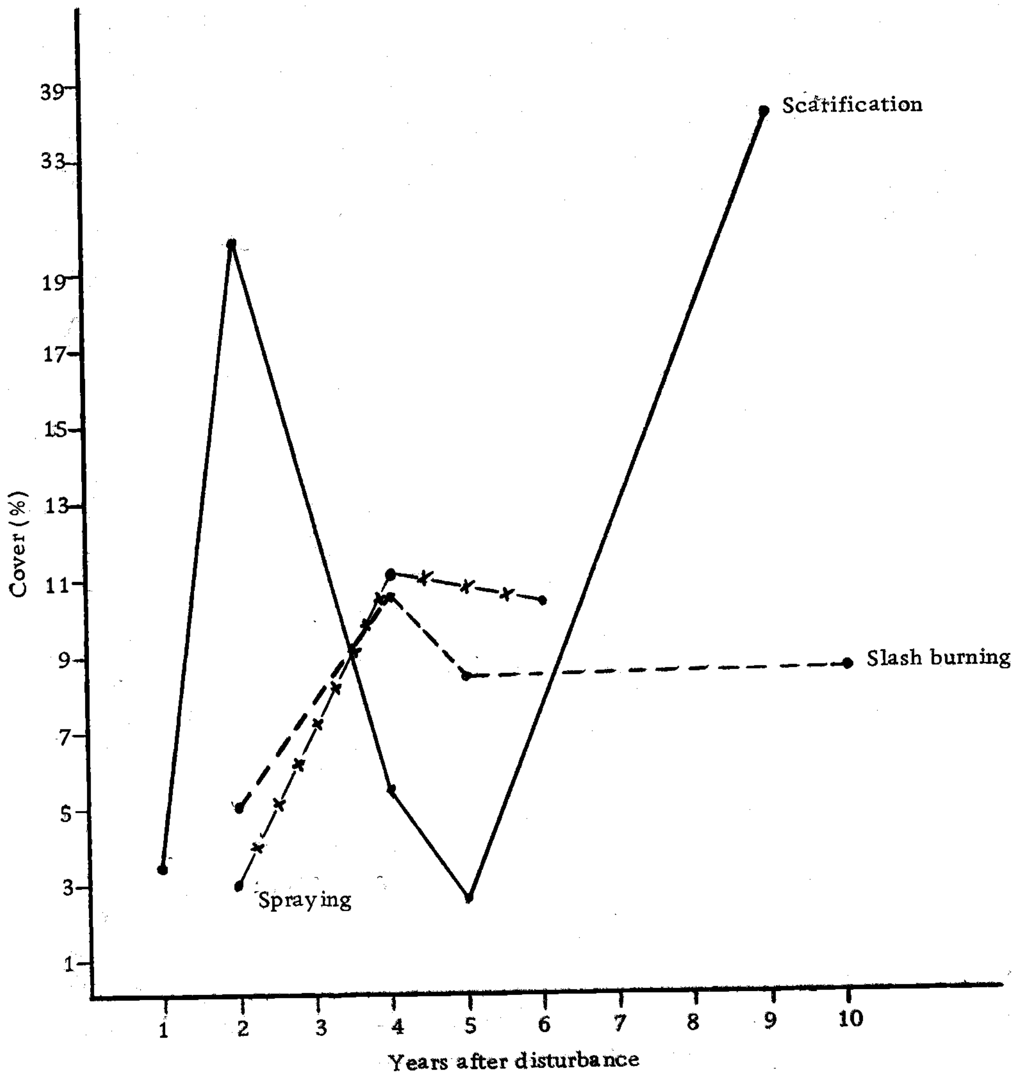

Figure 8. Average shrub cover (percentage)

number of comparable exposures or slopes. Therefore, the conclusions drawn from numerical data are limited in scope and in reliability.

Since clearcut units subjected to scarification were located on rolling topography, they did not show large variation in terms of either herbaceous or shrub biomass according to exposure or slope (Table 3). On the other hand, units which were treated by slash burning or spraying and which were located on slopes varying from moderate to very steep showed a more luxurious vegetation, especially shrubs, growing on north-oriented slopes than on south-oriented slopes (Table 4). Tables 5 and 6 illustrate t-tests used to determine significant differences among herbaceous and shrub biomass data collected on different slopes and aspects within units treated by slash burning and spraying respectively.

Recorded and personal observations between west and east exposures showed a small advantage in terms of biomass for the former (Table 4). On the other hand, the observations were not conclusive for the evaluation of the vegetation structure and composition in different sections of a slope (i.e. upper, middle and lower).

Herbaceous Species Composition

The three principal species in the herbaceous layer were recorded at the time of biomass measurement. These species were arranged using an importance value which is a combination of abundance

Table 3. Tests (t-test) for Detection of Significant Differences of Herbaceous and Shrub Biomass Between Groups of Sample Points Located on Different Exposures or on Different Sections in a Slope Within Scarified Units.

Unit	Year of disturbance	Group 1, 2 and 3	Group I (1)	Group 2 (1)	Group 3 (1)
Hatchery	1967		W level	E level	E level
		W level	xxxxxxx	0.92/ --	-1.14/ --
		E level	0.92/ --	xxxxxxx	-1.17/1.82
		E level	-1.14/ --	-1.17/1.82	xxxxxxx
Wolf	1971		E level	E level	N level
		E level	xxxxxxx	1.41/-0.91	0.63/1.58
		E level	1.41/-0.91	xxxxxxx	-0.94/2.55* (2)
		N level	0.63/ 1.58	-0.94/2.55*	xxxxxxx
Cline	1972		N level	W level	W level
		N level	xxxxxxx	0.92/ --	-1.14/ --
		W level	0.92/ --	xxxxxxx	-1.77/1.82
		W level	-1.14/ --	-1.77/1.82	xxxxxxx
Powerline	1974		N level	N level	N level
		N level	xxxxxxx	0.81/ --	1.85/ --
		N level	0.81/ --	xxxxxxx	0.83/ --
		N level	1.85/ --	0.83/ --	xxxxxxx
Beaver	1974		N level	N level	W level
		N level	xxxxxxx	-1.17/ --	-1.59/ --
		N level	-1.77/ --	xxxxxxx	-0.29/ --
		W level	-1.59/ --	-0.29/ --	xxxxxxx
Long Haul	1975		E level	E level	E level
		E level	xxxxxxx	-0.34/ --	-1.02/ --
		E level	-0.34/ --	xxxxxxx	-0.69/ --
		E level	-1.02/ --	-0.69/ --	xxxxxxx

(1) a double dash sign denotes the impossibility of testing due to a lack of sufficient points with shrub biomass per group.

(2) the asterisk denotes a level of significance at $\alpha = 0.05$.

Table 4. Herbaceous and Shrub Biomass Values (kg/ha), Exposure, and Slope Steepness per Group of Sample Points of Clearcut Units Used in This Study.

Unit	Year of disturbance	Type of disturbance	Aspect	Steepness	Herbaceous biomass	Shrub biomass
Hatchery	1967	scarified	north	moderate	3091	2801
			north	level	2191	7122
			north	level	1841	4673
Wolf	1971	scarified	east	level	3691	435
			east	level	2650	1554
			north	level	3300	677
Cline	1972	scarified	north	level	2708	--
			west	level	2341	1891
			west	level	3363	962
Powerline	1974	scarified	north	level	3433	--
			north	level	3066	70
			north	level	2666	362
Beaver	1974	scarified	north	level	2734	307
			north	level	3635	37
			west	level	3859	22
Long Haul	1975	scarified	east	level	2133	--
			east	level	2225	83
			east	level	2466	--
Lasky	1966	slash-burned	north	moderate	1683	783
			north	moderate	4283	--
			north	moderate	3300	4043

Table 4. (Continued)

Unit	Year of disturbance	Type of disturbance	Aspect	Steepness	Herbaceous biomass	Shrub biomass
Wolf	1971	slash-burned	west	very steep	3066	618
			north	very steep	3366	1718
			west	very steep	3425	197
Cline	1972	slash-burned	east	steep	2325	141
			north	steep	2783	1947
			north	steep	2866	--
Beaver	1974	slash-burned	south	steep	4199	--
			south	steep	4366	--
			south	steep	3608	863
Lobster	1970	sprayed	east	moderate	2841	747
			east	steep	2916	314
			east	moderate	3275	377
Benner	1972	sprayed	east	steep	3500	342
			east	steep	3391	343
			east	moderate	2591	1387
Toledo	1975	sprayed	east	steep	2975	--
			east	steep	2075	350
			east	steep	2583	--

Table 5. Tests (t-test) for Detection of Significant Differences of Herbaceous and Shrub Biomass Between Groups of Sample Points Located on Different Exposures or on Different Sections in a Slope Within Slash-burned Units.

Unit	Year of disturbance	Group 1, 2 and 3	Group 1 (1)	Group 2 (1)	Group 3 (1)
Lasky	1966		N moderate	N moderate	N moderate
		N moderate	xxxxxxx	3.25*/ --	1.12/ --
		N moderate	3.25*/ --	xxxxxxx	-2.182*(2)/ --
		N moderate	1.12/ --	-2.82*/ --	xxxxxxx
Wolf	1971		W very steep	N very steep	W very steep
		W very steep	xxxxxxx	-0.52/-0.30	-0.74/1.33
		N very steep	-0.52/-0.30	xxxxxxx	-0.12/2.68*
		W very steep	-0.74/1.33	-0.12/2.68*	xxxxxxx
Cline	1972		E steep	N steep	N steep
		E steep	xxxxxxx	-0.95/ --	-2.28*/ --
		N steep	-0.95/ --	xxxxxxx	-0.17/ --
		N steep	-2.28*/ --	-0.17/ --	xxxxxxx
Beaver	1974		S steep	S steep	S steep
		S steep	xxxxxxx	-0.22/ --	0.81/ --
		S steep	-0.22/ --	xxxxxxx	1.37/ --
		S steep	0.81/ --	1.37/ --	xxxxxxx

(1) a double dash sign denotes the impossibility of testing due to a lack of sufficient points with shrub biomass per group.

(2) the asterisk denotes a level of significance at $\alpha = 0.05$.

Table 6. Tests (t-test) for Detection of Significant Differences of Herbaceous and Shrub Biomass Between Groups of Sample Points Located on Different Exposures or on Different Sections in a Slope Within Chemically Treated Units.

Unit	Year of disturbance	Group 1, 2 and 3	Group 1 (1)	Group 2 (1)	Group 3 (1)
Lobster	1970		E moderate	E steep	E moderate
		E moderate	xxxxxxx	-0.14/1.15	-0.90/0.95
		E steep	-0.14/1.15	xxxxxxx	-0.68/-0.55
		E moderate	-0.90/0.95	-0.68/-0.55	xxxxxxx
Benner	1972		E steep	E steep	N moderate
		E steep	xxxxxxx	0.29/ --	2.17*/-2.67* (2)
		E steep	0.29/ --	xxxxxxx	2.41*/-2.68*
		N moderate	2.17*/-2.67*	2.41*/-2.68	xxxxxxx
Toledo	1975		E steep	E steep	E steep
		E steep	xxxxxxx	1.95/ --	0.78/ --
		E steep	1.95/ --	xxxxxxx	1.26/ --
		E steep	0.78/ --	1.26/ --	xxxxxxx

(1) a double dash sign denotes the impossibility of testing due to a lack of sufficient points with shrub biomass per group.

(2) the asterisk denotes a level of significance at $\alpha = 0.05$.

and frequency of occurrence. Abundance was considered by placing a weighting factor on the occurrence depending on the partial contribution of the species to the total biomass measured per plot (i.e. a factor three for a partial biomass above 50 percent, a factor two for biomass between 50 and 25 percent, and a factor one for biomass below 25 percent).

Table 7 lists clearcut units treated by scarification and respective principal species with the calculated importance values. Trailing blackberry was the most abundant and frequent species during the first season following disturbance. Isaac (1940) found this species to be the most common invader on freshly logged areas declining in cover as it is crowded out by taller species. Velvet grass and tansy ragwort (Senecio jacobaea) were the most important species on all other scarified units. Bracken fern (Pteridium aquilinum) had a high importance value on the one-year-old unit and on one of the two-year-old units declining in importance thereafter.

On slash burned units (Table 8) either bracken fern or sword fern was the most important on every unit. Contrary to the findings of Isaac (1940), trailing blackberry did not have a high importance value even on the two-year-old unit. Velvet grass never attained a very important place on these units, while tansy ragwort showed high importance values on the old units. On the other hand, there was more evidence of vine maple (Acer circinatum) and bitter cherry (Prunus

Table 7. Principal Herbaceous Species and Importance Values Recorded on Scarified Units.

Unit	Year of disturbance	Herbaceous species	Importance value
Long Haul	1975	blackberry	46
		bracken fern	45
		bromus	23
		tansy ragwort	17
		sword fern	17
		velvet grass	9
Powerline	1974	velvet grass	55
		thimbleberry	34
		tansy ragwort	30
		bracken fern	19
		blackberry	8
		bromus	5
Beaver	1974	bracken fern	39
		tansy ragwort	25
		velvet grass	20
		bromus	13
		fox glove	10
		curly dock	9
Cline	1972	velvet grass	61
		salmonberry	41
		bent grass	17
		thimbleberry	17
		pearly everlasting	9
		sword fern	6
Wolf	1971	velvet grass	40
		tansy ragwort	28
		bracken fern	23
		salal	19
		fox glove	12
		thimbleberry	10
		sword fern	10
Hatchery	1967	tansy ragwort	31
		velvet grass	19
		miner's lettuce	12
		thimbleberry	9
		sword fern	8
		bent grass	7

Table 8. Principal Herbaceous Species and Importance Values Recorded on Slash-burned Units.

Unit	Year of disturbance	Herbaceous species	Importance value
Beaver	1974	bracken fern	70
		salal	22
		blackberry	13
		thistle	11
		Oregon grape	7
		tansy ragwort	6
Cline	1972	bracken fern	38
		sword fern	32
		velvet grass	21
		tansy ragwort	17
		bitter cherry	7
		thimbleberry	6
Wolf	1971	sword fern	37
		tansy ragwort	30
		velvet grass	27
		thimbleberry	19
		salmonberry	16
		vine maple	8
Lasky	1966	bracken fern	56
		tansy ragwort	26
		sword fern	24
		velvet grass	23
		bromus	22
		bitter cherry	9

emarginata) on slash-burned units than on scarified units.

Sword fern was the most frequent and abundant species recorded on units treated by chemical spraying (Table 9). Pearly everlasting, bracken fern and thimbleberry were also recorded with high importance values.

Shrub Species Composition

The shrub species recorded on the shrub biomass plots were tallied by number and height of stems. Among the three treatments, scarification yielded the largest number of stems per unit when comparisons were possible. Chemical treatment, on the other hand, yielded the smallest number of shrub stems. The average height of shrub stems in each unit increased with time since disturbance, but did not show any relation to the method of site preparation used (Table 10). Red alder, ocean spray (Holodiscus discolor), and red elderberry (Sambucus callicarpa) were the species with the tallest stems, while salmonberry and thimbleberry showed the largest number of stems. The occurrence of shrub stems, recorded as frequency in Table 10, indicates that scarification is more likely to yield a wider distribution of shrubs throughout the area than the other two techniques.

Animal Damage to Conifer Seedlings

In each unit, planted coniferous seedlings were sampled in three circular plots of 20 meters in diameter. Most of the planted conifers

Table 9. Principal Herbaceous Species and Importance Values Recorded on Sprayed Units.

Unit	Year of disturbance	Herbaceous species	Importance value
Toledo	1975	sword fern	30
		bracken fern	26
		pearly everlasting	22
		tansy ragwort	17
		salmonberry	14
		fox glove	9
		hazel	9
Benner	1972	sword fern	58
		thimbleberry	31
		salmonberry	23
		pearly everlasting	11
		liliaceae	8
		vine maple	7
Lobster	1970	sword fern	39
		thimbleberry	27
		pearly everlasting	14
		bracken fern	14
		blackberry	14
		velvet grass	12

Table 10. Shrub Species With Calculated Density (no. /ha), Average Height (meters) and Frequency of Occurrence (Percentage based on 30 sample points per unit) of Shrub Stems.

Unit	Disturbance		Shrub species	Shrub stems		
	Year	Type		Density	Average height	Frequency
Long Haul	1975	scarified	salmonberry	416	1.63	6
Beaver	1974	scarified	red alder	666	1.66	22
			salmonberry	2500	1.15	3
Powerline	1974	scarified	red alder	250	2.15	6
			thimbleberry	1333	1.34	3
Cline	1972	scarified	thimbleberry	1333	1.32	3
			salmonberry	10000	1.39	36
			elderberry	666	1.74	6
Wolf	1971	scarified	red alder	250	2.18	3
			salmonberry	4750	1.45	9
			ocean spray	750	1.37	3
			thimbleberry	833	1.27	3
Hatchery	1967	scarified	salmonberry	33916	1.53	45
			elderberry	2333	1.74	15
			vine maple	583	1.55	3
			thimbleberry	916	1.25	3
			red alder	583	3.45	9
Beaver	1974	burned	elderberry	2083	1.10	6

Table 10. (Continued)

Unit	Disturbance Year	Disturbance Type	Shrub species	Shrub stems Density	Shrub stems Average height	Shrub stems Frequency
Cline	1972	burned	salmonberry	9416	1.75	10
			elderberry	83	1.52	3
			hazel	250	1.66	3
Wolf	1971	burned	salmonberry	2666	1.55	6
			elderberry	1000	1.77	12
			hazel	666	1.67	3
			bitter cherry	416	1.61	6
Lasky	1966	burned	vine maple	1500	2.47	13
			elderberry	333	3.50	6
Toledo	1975	sprayed	hazel	166	1.72	3
Benner	1972	sprayed	vine maple	3916	1.70	29
			salmonberry	1750	1.85	3
			red alder	83	2.27	3
			thimbleberry	666	1.72	3
Lobster	1970	sprayed	vine maple	1083	2.77	13
			hazel	1166	1.66	9
			salmonberry	833	1.62	3
			thimbleberry	333	1.51	3
			ocean spray	166	1.59	3

were said to have been three-year-old transplants. Intact seedlings smaller than 15 centimeters were not recorded since these were probably the result of natural regeneration. Observations for signs of damage were restricted to the leader since this type is the most detrimental to the normal height growth and form of the future tree.

The number of conifer seedlings sampled per unit varied widely. Units treated by chemical means showed a greater number of seedlings per total area sampled than units treated by the other two methods. The percentage of seedlings with browse signs seemed to decrease as the period from site preparation increased independent of the type of site preparation. The difference in average height between seedlings not submitted to animal interference and those with evidence of browsing increased slightly with time since the disturbance (Table 11).

Browsing Activity on Shrub Stems

Clearcut units treated by both scarification and burning showed the same variation of the percentage of browsed shrub stems (Table 12). Percentage values peaked at units on the second growing season following site preparation and decreased thereafter. Even though the number of sampled shrub stems on scarified units was greater than the one on slash-burned units, the calculated percentages did not vary greatly. No stems were recorded on the one-year-old sprayed unit although the other two chemically treated units yielded percentage

Table 11. Total Number of Seedlings Surveyed, Total Number of Seedlings Presenting Leader Damage Surveyed, Percentage of Browsed Seedlings, Mean Height of Intact Seedlings (centimeters), and Mean Height of Damaged Seedlings (centimeters).

Unit	Disturbance		Total no. seedlings		Mean height		Percentage
	Year	Type	intact	damaged	intact	damaged	browsed
Long Haul	1975	scarif.	52	24	38.2	28.0	46
Beaver	1974	scarif.	77	49	65.4	52.4	64
Powerline	1974	scarif.	42	27	49.3	37.2	64
Cline	1972	scarif.	48	12	106.7	89.1	25
Wolf	1971	scarif.	100	63	72.9	47.8	63
Hatchery	1967	scarif.	64	15	118.2	84.5	23
Beaver	1974	burning	56	29	77.2	69.0	52
Cline	1972	burning	17	4	101.3	84.7	23
Wolf	1971	burning	46	6	149.2	114.3	13
Lasky	1966	burning	79	15	195.2	122.4	19
Toledo	1975	spraying	107	28	99.2	96.9	26
Benner	1972	spraying	137	18	126.2	102.3	13
Lobster	1970	spraying	97	22	95.9	62.9	23

Table 12. Total Number of Shrub Stems Recorded on Transects, Number of Shrub Stems Bearing Browsing Activity Signs, and Percentage of Browsed Shrub Stems.

Unit	Year of disturbance	Type of disturbance	Total no. of stems	No. of stems w/browse marks	Percentage
Long Haul	1975	scarification	4	1	25
Beaver	1974	scarification	17	6	35.3
Powerline	1974	scarification	10	3	30
Cline	1972	scarification	36	10	27.8
Wolf	1971	scarification	24	5	20.8
Hatchery	1967	scarification	49	10	20.4
Beaver	1974	burning	12	4	33.3
Cline	1972	burning	25	6	24
Wolf	1971	burning	18	3	16.7
Lasky	1966	burning	9	2	22.2
Toledo	1975	spraying	--	--	--
Benner	1972	spraying	17	5	29.4
Lobster	1970	spraying	11	3	27.3

values similar to the ones from units treated by the other two techniques.

Effect of Previous Stand Density on Shrub Vegetation

The effect of basal area of previous stand on the abundance of shrub vegetation following site preparation seems to be inverse, but weak (Table 13). Linear regression equations were used to verify the above mentioned relationship. Since only three measurements of basal area per unit were executed, pooled equations (i.e. shrub biomass and basal area values of all units treated by a given method) of shrub biomass on basal area per treatment were used (Table 14). The calculated coefficients of determination were very low despite the fact that the relationship was consistent within all units independent of the site preparation method used. Only 10 to 14 percent of the variation of shrub biomass could be statistically explained by the models used. On the other hand, it is interesting to note that all equations presented a negative value for the slopes of the curves indicating that an increase in basal area corresponds to a decrease in shrub biomass. It is also noteworthy that some of the units had been allowed to revegetate for a period prior to site preparation. Such an opportunity for shrub to develop would tend to mask the original effect of overstory density on understory development of sprouting shrubs.

Table 13. Clearcut Units With Respective Estimated Shrub Biomass Values (kg/ha) and Prior Conifer Basal Area (m^2/ha).

Unit	Year of disturbance	Type of disturbance	Aspect	Shrub biomass	Basal area
Hatchery	1967	scarification	west	2801	18.13
			east	7122	12.2
			east	4673	14.4
Wolf	1971	scarification	east	435	66.5
			east	1554	13.0
			north	677	57.65
Cline	1972	scarification	north	--	148.62
			west	1891	12.36
			west	962	28.31
Powerline	1974	scarification	north	--	27.35
			north	70	15.4
			north	362	14.65
Beaver	1974	scarification	north	307	14.51
			north	37	24.23
			west	22	24.61
Long Haul	1975	scarification	east	--	16.36
			east	83	19.47
			east	--	23.32
Lasky	1966	burning	north	783	35.65
			north	--	62.23
			north	4043	17.49
Wolf	1971	burning	west	618	51.52
			north	1718	25.37
			west	197	57.37
Cline	1972	burning	east	141	25.15
			north	1947	9.35
			north	--	82.95
Beaver	1974	burning	south	--	10.30
			south	--	55.04
			south	863	14.26
Lobster	1970	spraying	east	747	60.17
			east	314	63.86
			east	377	193.54
Benner	1972	spraying	east	342	91.56
			east	343	88.04
			north	1387	59.31
Toledo	1975	spraying	east	--	67.84
			east	350	58.05
			east	--	45.12

Table 14. Linear Regression Equations of Shrub Biomass on Basal Area With Coefficients of Determination and F Tests.

All units subjected to slash burning: $y = 26256.4 - 350.49x$ $R^2 = 0.14$

source	df	ss	ms	F	F table $\alpha = 0.05$	Level of significance
total	7	1669958624				
regression	1	241364029.6	241364029.6	1.01	5.99	NS (1)
residual	6	14285945594	238099099			

All units subjected to spraying : $y = 9351.7 - 31.08x$ $R^2 = 0.10$

source	df	ss	ms	F	F table $\alpha = 0.05$	Level of significance
total	6	137011442.9				
regression	1	13747983.26	13747983.26	0.56	6.61	NS
residual	5	123263459.6	24652691.92			

All units subjected to scarification: $y = 2914798$ $R^2 = 0.10$

source	df	ss	ms	F	F table $\alpha = 0.05$	Level of significance
total	13	8166554880				
regression	1	811786100.8	811786100.8	1.32	4.75	NS
residual	12	7354768779	612897398.3			

(1) Non significant

DISCUSSION

A forest is a complex community of trees, shrubs, herbs, birds, mammals, and other organisms living together in an otherwise abiotic environment of climatic and edaphic factors. These biotic and abiotic factors together form a complex ecological system in which each factor and each individual is conditioned by the others and each affects others in the system to some degree and over a time continuum.

After site preparation, the herbaceous and shrub components of the forest ecosystem increase in importance because of the availability of space and site resources until the tree component imposes its ultimate dominance over the entire area. The way in which the herbaceous and shrub components seek dominance has been schematically illustrated by Newton (1973) and reported in several studies (Isaac, 1940; Mueller-Dombois, 1959; Yerkes, 1960; Brown, 1963).

The immediate reoccupancy of the soil following a disturbance - here site preparation specifically - can be evaluated by looking at Figure 4. The increase in total biomass with the increase in time from the disturbance is clear. However, the rate of increase seems to be different depending on the type of disturbance and, consequently, on the intensity of effects of the particular method used to achieve the preparation of the terrain.

Mechanical site preparation imposes the largest degree of soil disturbance. Reoccupancy of the site by vegetation after this method is very rapid when nutrient capital is not removed. Fire, along with chemical treatment, disturbs the site in different ways but with intensities generally well below the level inherent in scarification. Consequently, areas treated by these latter two techniques are less likely to condition a rapid development of total biomass.

The rapid change of communities during the early segment of plant succession exemplifies the opportunistic and competitive strategies of individual species. In addition, the conditions created by the disturbance will enhance the appearance of one or a group of plant species at the expense of others. Another important consideration in conditioning species composition following a disturbance is the composition of the understory of the previous stand.

Herbaceous species are the most common invaders on newly disturbed areas. By comparing Figure 5 and 6, it can be seen that the variation of the herbaceous component after the third year is largely conditioned by the variation of the shrub component. Consequently, it can be deduced that the time during which herbaceous species exert their dominance is dependent on the growth habits of shrub species and on the presence of shrub individuals established in the area.

Even though the composition of the understory prior to harvesting may bear some influence on the struggle for site dominance on the early years after a disturbance, the method of site preparation itself also has substantial influence on the process as can be seen in Table 10. Scarification, depending on the amount of brush individuals initially existing, is likely to disperse reproductive plant parts throughout the area so as to increase the potential for rapid shrub resurgence. Such a pattern can be observed by the high frequency of occurrence recorded for shrub stems in scarified units and by the greater heights measured as contrasted with values obtained on slash-burned and sprayed units. Furthermore, the total herbaceous biomass recorded on exposures where shrubs were absent were, in general, considerably higher than on exposures where shrub vegetation was present (Table 4).

The change in dominance from the herbaceous to the shrub component is predicted to occur more slowly on slash-burned than on scarified units as the comparison of Figure 5 and 6 indicates. This hypothesis seems to be confirmed by the trends of the biomass and cover of herbaceous species, while for the shrub species the trend is only shown in terms of biomass (i. e., shrubs compete with herbs but herbs do not displace shrubs). The lack of patterns in the shrub cover measurements is probably due to differences in morphology and development strategy of the species which could not be accounted for during the measurements. A possible correction for this problem would be the measurement or estimation of leaf area for different shrub species at different ages.

On slash-burned units, the slow increase in the shrub component is resultant from the set back effects of fire on the aerial parts of shrub individuals. However, these same individuals are able to recuperate and resprout. Evidence for the slow rate of increase of the shrub component can be inferred from the calculated importance values of the shrub species recorded in the herbaceous layer of slash-burned units (Table 8). In general, these values were smaller than the ones recorded on scarified units.

It should be mentioned that scarification and slash burning techniques of site preparation produce a number of small areas within the units submitted to different intensities of disturbance while chemical treatment results in a more uniform treatment on the entire area. The problem with the mechanical method is resultant from physical obstacles like stumps and topographic features. The slash burning method has as its major disadvantage the heterogeneous distribution of fuels on the ground resulting in different fire temperatures. This study did not take into account in the sampling scheme such differences of intensity during the execution of the site preparation operation. Nevertheless, it was possible to recognize, by personal observations, that the amount of vegetation, primarily herbaceous, was higher on spots where scarification had produced more soil disturbance than on adjacent areas. In the case of slash-burned units, spots submitted to high temperatures produced less vegetation than on slightly burned areas.

The gradual increase in herbaceous biomass in units chemically treated (Figure 5) can be interpreted as the result of a shift in dominance due to the selectivity of the herbicide used which temporarily suppresses the shrub component. The chemical spraying technique executed in the clearcut units selected for this study can not be truly recognized as a site preparation operation since the herbicide application was not executed previously to the planting. Nevertheless, it is interesting to compare the effects of the pressure imposed by the use of herbicides in plant communities. By comparing Figure 5 and 6, it can be noted that the herbaceous component tended to remain high with the consequent low development of the shrub component. The fact that low shrub biomass was recorded on those units leads to the conclusion that the environmental conditions for the establishment of conifers were not as restrictive as observed on units treated by the other two methods.

The herbaceous biomass trend illustrated in Figure 5 shows a peak value for the two-year-old units treated by scarification and slash burning. This pattern is similar to that one noted by Brown (1963) and Chilcote (1962) in slash-burned clearcuttings located on Marys Peak. High values of herbaceous biomass presented on newly site-prepared areas can result in the attraction of consumers to these areas. Such presence of consumers brings pressure to the newly planted coniferous seedlings. Also, these consumers may help in the stabilization of herbaceous communities by keeping the shrub component down as result of heavy browsing activity and by vectoring the dissemination of herb seeds. The carrying capacity of sprayed units, on the contrary, may be increased for small rodents because of the high herbaceous component present but it appears to be less suitable for browsers because of the low contribution of the shrub component and also because of the physical obstacles.

On scarified clearcut units considered in this study, the variation of herbaceous cover as a function of time from the disturbance was larger than the ones observed for units treated by the other two methods. It is interesting to note that the calculated mean herbaceous cover per unit peaked in all four-year-old units, independent of treatment, while the herbaceous biomass peak occurred in the two-year-old units. The explanation for such an anomaly seems to rely on the increase of shrub species within the herbaceous layer with subsequent increase in the total cover estimation.

Even though the effect of previous basal area on shrub vegetation could not be well explained by the statistical model presented on Table 14, values for both variables within each unit showed a clear trend by which large shrub biomass values were recorded on areas of small basal area. Such a trend has important implications on the managerial aspects of stands since the degree of crown closure throughout the life of the stand, controlled as it is by thinning practices, will influence the potential of invasion and establishment of brush species underneath it. Understory establishment of woody species will, in turn, contribute toward a more difficult reestablishment of a new crop on those sites. In addition, a delay in planting after site preparation will compromise in an extensive form the success of a new conifer crop because of the difference in juvenile growth between conifer seedlings and sprouts of brush species which favors the dominance potential of the latter. Concurrently, costs of plantations will increase due to the expensive replanting and brush control practices.

The pressure exerted by consumers, specially browsers, on the conifer seedlings could not be connected to any particular method of site preparation since the percentage of damaged seedlings varied widely on the units selected for this study. However, it can be noted that higher percentages of damaged seedlings were obtained on units with few growing seasons from the occurrence of the disturbance. Also, it can be observed that scarified units showed the highest proportions of damaged seedlings. These last two statements can be connected to the high biomass recorded on the herbaceous layer of the young units in particular on the young scarified clearcut units.

All units included in this study, independent of the site preparation method, supported a good amount of vegetation highly ranked on the food habits of consumers in general (Tables 7, 8, 9, and 10). Consequently, such areas are able to support quite a large number of herbivorous species which are serious threats to successful regeneration in the Pacific Northwest.

CONCLUSIONS

This study has attempted to characterize the relative roles of shrubs and herbs in the early stages of plant succession following site preparation in terms of biomass and plant species composition. Plant biomass and composition were interpreted in relation to their potential effects on the effort of regenerating forest lands previously supporting commercial Douglas-fir stands.

The reaction of the forest ecosystem to the disturbance imposed by the site preparation has been shown as rapid and directional depending on the particular set of effects exerted by the method used. The resulting niches remain unoccupied for a very short period of time since the herbaceous component of the system begins to increase in importance right after the disturbance. This herbaceous component attains its maximum development two years after the disturbance caused by scarification and slash burning. After this point, the herbaceous species decrease biomass but increase their cover through the fourth year after disturbance. The decrease in herbaceous biomass with corresponding increase in cover seems to result not only from a change in the life cycle of the species, from annuals to biennials and perennials, but also from a redistribution of the growing capacity of the site among herbs, woody, and conifer saplings due to an increasing interception of light by the resprouts of woody individuals already established. The herbaceous component on units chemically treated, on the other hand, showed a steady biomass increase, up to the sixth season after disturbance, with the same herbaceous cover decline after the fourth season. Since the sprayed units did not show a considerable shrub biomass, it is concluded that besides light interception, intraspecific competition and etiolation from shrub associates play an important role on the development of the herbaceous component in areas where shrubs were present. These are both evidence of full site occupation and of unsuitability of such communities for further conifer plantings.

Scarification is more likely to favor the development of the shrub component than slash burning. The widespread occurrence of shrub individuals caused by the dissemination of reproductive parts without the set back of development originated by fire resulted in a greater number of stems per hectare. This study has shown that the effects of the shrub component became restrictive about four years after the disturbance. This suggests less than four years as the maximum permissible for the introduction of coniferous seedlings to reach establishment before being seriously threatened by shrub competition. Furthermore, the height growth of the seedlings during the initial period, often reduced for three years because of the planting check, is an important factor in the reduction of damage by animals since the large amount of food available in the first years after site preparation can support high numbers of browsers and rodents.

Although the model presented for the assessment of the relationship between basal area of previous conifer stand and shrub biomass is deficient in its prediction ability, it is useful in that it gives a first approximation to the development of woody vegetation as a function of stand density. The agreement between those variables within units was satisfactory enough to conclude that conifer crown closure bears some influence on the potential development of shrub species in the understory. This effect would logically be carried over and maximized during the establishment of a new plantation. Such a conclusion poses another concern to the management of commercial forest lands in that a prescribed thinning regime should be well adapted to the opening of the stand for the development of good form and size of the individual trees but should not enhance the development of understory sprouting species capable of excluding conifers in the next rotation.

The need for further qualification of the relationship between basal area of previous conifer stand and the potential development of shrub species is suggested through the use of study plots with controlled conditions of slope, aspect, and vegetation type. In addition, it is suggested the recording of shrub vegetation prior to harvest so that the reoccurrence of shrub vegetation could be related to the previous amount of shrubs established in the site.

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