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Title: STOCKING LEVELS AND SEEDLING HEIGHTS ON CLEARCUTS IN RELATION TO HABITAT TYPE IN THE WESTERN CASCADES OF OREGON

Abstract approved: Signature redacted for privacy.
William K. Ferrell

Stocking characteristics and heights attained by tree seedlings at ages five and seven were measured on 45 study units, representing five habitat types, established on clearcuts in the Abies amabilis zone in the Western Cascades of Oregon. The study units ranged from six to 30 acres in size, seven to 15 years in age (time elapsed since harvest), and occupied a variety of slope aspects, inclinations, and topographic positions. A restricted random sampling procedure and circular one-milacre plots were employed to collect data.

Mean post-harvest stocking levels (on a one-milacre basis) ranged from 14.4% in the Abies amabilis-Tsuga mertensiana/Xerophyllum tenax habitat type to 48.3% in the Abies amabilis/Rhododendron macrophyllum-Vaccinium alaskaense/Cor-

nus canadensis habitat type, and mean advance stocking levels ranged from 2.0% in the *Abies amabilis*/*Vaccinium membranaceum*/*Xerophyllum tenax* habitat type to 16.5% in the *Abies*/*Rhododendron*-*Vaccinium*/*Cornus* habitat type. Differences in mean post-harvest stocking among the habitat types were found to be inversely correlated with differences in mean radiation indices and mean elevations. Differences were also found among the habitat types in the comparative stocking levels of individual tree species. *Abies procera* (noble fir) stocking was generally less than or equal to that of *Pseudotsuga menziesii* (Douglas-fir) in habitat types typically positioned on lower-to mid-slopes, but much greater than that of *Pseudotsuga menziesii* in habitat types which are typically located on or near ridgetops.

Mean heights of tree seedlings were found to vary considerably among tree species and habitat types. *Pseudotsuga menziesii* seedlings generally grow to roughly equivalent or to greater heights than do *Abies procera* seedlings in all habitat types. Both *Pseudotsuga menziesii* and *Abies procera* seedlings attained greatest heights in the *Abies amabilis*/*Achlys triphylla* habitat type, and lowest heights in an undocumented *Abies amabilis*/*Rhododendron macrophyllum*-*Vaccinium membranaceum* habitat type.

The structure and composition of successional plant communities which developed following clearcutting was also found to vary considerably among habitat types. Clearcuts in habitat types typically located on lower-to mid-slopes were occupied by plant communities often dominated by shrubs, whereas plant communities dominated by herbs usually occupied clearcuts located in habitat types typically positioned on or near ridgetops.

The results of this research imply that each habitat type seems best suited for specific silvicultural practices. Habitat type classification and mapping can be a productive tool for foresters involved with the regeneration management of *Abies amabilis* zone forests of the Western Cascades of Oregon.

Stocking Levels and Seedling Heights on Clearcuts in Relation to Habitat Type in the Western Cascades of Oregon

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I. INTRODUCTION

Habitat type classification and mapping of forest land identifies land units of equivalent environment, upon which many site characteristics can be predicted. In the northern and in portions of the central Rocky Mountains, where habitat type classification has been accomplished and mapping of habitat types has been undertaken, many silvicultural properties of forest land, including regeneration characteristics, have been shown to be well-correlated with habitat type (Layser 1974). In the Pacific Northwest, the implementation of forest habitat type classification has not reached a level of development comparable to that in the Rocky Mountain region (Pfister 1972b). Preliminary habitat types have only recently been identified by Dyrness et. al. (1974) in the Western Cascades of Oregon.

The forests of the Western Cascades fall within two major vegetation zones which are defined by their dominant climax tree species. These zones are the *Tsuga heterophylla* zone and the *Abies amabilis* zone. Regeneration problems are generally more acute in the *Abies amabilis* zone (Franklin 1965a); seedling environments on clearcuts are often harsh and regeneration is often a crucial phase of silvicultural operations. The purpose of this study was to relate stocking levels and tree seedling growth to habitat type on clearcuts in the central portion of the Western Cascades of Oregon. The results of this research will provide: (1) a first evaluation of the utility of habitat type classification to regeneration management in the *Abies amabilis* zone of the region; (2) further insight into regeneration problems characteristic of clearcuts within the *Abies amabilis* zone of the region.

II. REVIEW OF LITERATURE

The concept of habitat type is directly related to and based upon vegetation classification. As defined by Daubenmire (1952, 1968a): (1) habitat type is the collective land area which one plant association occupies, or potentially will occupy in the absence of disturbance; (2) a plant association is an abstract unit which represents all climax stands in which the dominant species of corresponding vegetative layers are essentially the same; plant associations (and their corresponding habitat types) are usually named after the major climax dominants of each vegetative layer; (3) a stand is designated as climax if it is self-regenerating and appears to have permanent occupancy (barring disturbance) of the site.

Daubenmire (1952) described 15 habitat types in northern Idaho and eastern Washington. Subsequently, this classification was refined to 22 habitat types (Daubenmire and Daubenmire 1968b). Other researchers have since extended the description of habitat types to other forests within the Rocky Mountain and Intermountain regions, and to forests of adjacent regions. Within the Rocky Mountain region, habitat types have been defined by Reed (1969) for the forests of the Wind River Mountains of Wyoming, Pfister (1972a) for the subalpine forests of Utah, and by Wirsing (1973) for the forests of southeastern Wyoming. According to Pfister (1972b), the Intermountain and Northern Regions of the United States Forest Service have been engaged in a cooperative effort to extend habitat type classification throughout the forests of the northern Rocky Mountains, with completion scheduled for 1975.

In neighboring regions, habitat types have been identified by Bailey (1966) for a portion of the southern Oregon Coast Range, Franklin (1966) for the subalpine forests of the southern Washington Cascade Range, Dyrness and Youngberg (1966) for a portion of the pumice region of central Oregon, Hall (1967) for the Ochoco and Maury Mountains of central Oregon, and Dyrness et. al. (1974) for the central portion of the Western Cascades of Oregon, where five seral communities and 18 climax communities were recognized. Eleven of the 18 climax communities occur within the *Tsuga heterophylla* zone and seven occur within the *Abies amabilis* zone.

Since Daubenmire's original development of the habitat type concept, many researchers have studied relationships between habitat types and a wide variety of important physical and biological characteristics of the vegetation occupying these types. Layser (1974) has noted that: site index, susceptibility of some tree species to insect attack and to various diseases, regeneration requirements, stocking limitations, forage production potential, small mammal populations, and other characteristics have all been found to be correlated with habitat types. However, the number of published studies which have examined the relationship between forest regeneration characteristics and habitat types is rather limited. Dyrness and Youngberg (1966) suggested that on the basis of their field observations, certain regeneration practices be used on particular habitat types of the central Oregon pumice region. Similarly, Hall (1967) briefly commented on the suitability of regeneration practices to different habitat types of the Ochoco and Maury Mountains. Pfister (1972a, 1972b) analyzed four subalpine habitat types and formulated some general guidelines for regeneration which included suitability of species, site preparation requirements, and acceptable harvest systems. General regeneration guidelines similar to those developed by Pfister were developed for the forest habitat types of southeastern Wyoming by Wirsing and Alexander (1975).

To my knowledge, only two papers have been published concerning studies which have quantitatively measured regeneration characteristics (e. g., seedling survival, stocking levels, etc.) and attempted to relate them to habitat type. The first, by Boyd (1969), examined the stocking history subsequent to harvest of seven experimental cuttings on the Decption Creek Experimental Forest, located in central Idaho. Study plots were stratified by habitat type. Two habitat types existed on the study units, an Abies grandis/Pachistima myrsinites type and a Thuja plicata-Tsuga heterophylla/Pachistima myrsinites type. Boyd found that the two habitat types differed appreciably in rate of stocking through time, and in the importance of individual tree species (in a regenerative sense). The Abies grandis/Pachistima myrsinites type restocked less rapidly, but contained more Douglas-fir than did the Thuja plicata-Tsuga heterophylla/Pachistima myrsinites type.

Kittams and Ryker (1975) compared the survival and growth performance of planted 3-0 Douglas-fir in central Idaho for two two planting methods, two degrees of site preparation, and four habitat types. Results showed that site preparation greatly affected seedling survival on only the coolest habitat type (the Abies lasiocarpa/Acer glabrum habitat type). Site preparation also seemed to affect seedling growth differently on the four habitat types. Little growth response occurred on the cool Abies lasiocarpa/Acer glabrum type, but a greater response (not statistically significant) occurred on two warmer habitat types. The results of Boyd's (1969) and Kittam and Ryker's (1975) studies show that quantitative differences in regeneration characteristics often do exist on different habitat types, at least in the northern Rocky Mountains.

Interestingly enough, both Boyd's and Kittams and Ryker's studies were done for purposes other than the study of regeneration-habitat type relationships, i.e., they originated before habitat type classification was available. Thus habitat type classification was subsequently superimposed on the experimental plots, and data was then stratified by habitat type. The research reported in this paper is different in that from the outset its purpose was to compare stocking levels and seedling growth among specific habitat types; thus the initial stage of the study consisted of the establishment of study units within specific habitat types.

III. DESCRIPTION OF STUDY AREA

Location and General Characteristics

The study area is located within the Willamette National Forest approximately 72km (45 miles) east northeast of Eugene, Oregon. The area is irregular in shape (Figure 1) and lies between 122°4' to 122°20' west longitude and 44°12' to 44°25' north latitude. The area encompasses 375km^2 (145 square miles), and falls within the administrative jurisdiction of three Willamette National Forest Districts: the Sweet Home, the Blue River, and the McKenzie. The H. J. Andrews Experimental Forest and the Wildcat Mountain Research Natural Area are also located within the study area.

Topography

The area is in the mature stage of landform development, possessing strongly dissected ridge and valley topography. Slopes are generally steep but some areas at higher elevations possess immature, rolling topography. Elevations range from 460 to 1750m (1500 to 5750 feet).

Geology

The study area is part of the major geologic province known as the Western Cascades and is characterized by mas-

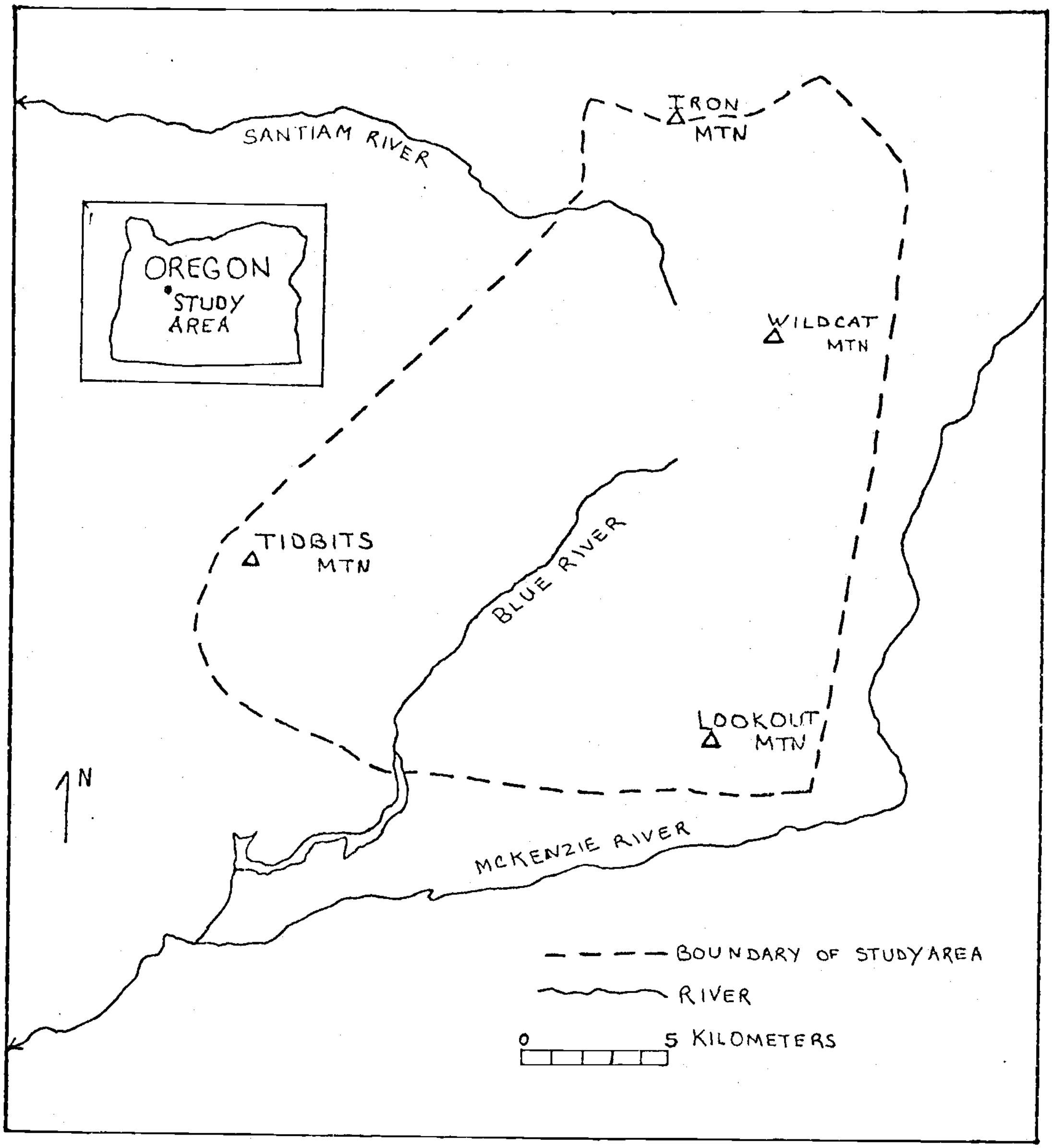

Figure 1. Location of study area.

sive accumulations of volcanic material of Eocene through Miocene origin (Williams 1969). Peck et. al. (1964) defined and mapped three major geologic formations within the study area: the Little Butte Volcanic Series, the Sardine Formation, and the Volcanic rocks of the High Cascade Range.

The Little Butte Volcanic Series ranges in age from early Oligocene to early Miocene and is chiefly composed of andesitic and dacitic tuffs, flows and breccias of basalts and andesites, and domes and flows of dacite and rhyodacite. The Sardine Formation is of middle to late Miocene origin and was deposited upon the material of the Little Butte Volcanic Series. It is mostly composed of andesitic flows and of massive tuff breccias and lapilli tuffs.

The material identified by Peck et. al. as the Volcanic rocks of the High Cascade Range, composed of basaltic and andesitic flows and breccias, is now considered to be of Pliocene age and of Western Cascades origin (Taylor 1968, Swanson and James 1975).

As mapped by Peck et. al., it appears that most of the land within the Abies amabilis zone of the study area is composed of parent material of the Sardine Formation and of Pliocene-aged material, and that exposed material of the Little Butte Volcanic Series chiefly occurs at lower elevations.

Soils

Dyrness et. al. (1974) reported that soils at the higher elevations of the H. J. Andrews Forest could be grouped into three associations: andesitic soils found in deep landslide material, weakly developed and loam to sandy loam textured, Ando-like soils derived from andesite and basalt and loam to silt loam textured, and Brown Podzolic soils derived from andesite and basalt and loamy in texture. They also characterized the general soil properties of each habitat type and in addition described soil properties of each study plot. Some general soil characteristics of the seven habitat types of the Abies amabilis zone have been extracted from Dyrness et. al. and presented in Table 1.

Climate

The climate of the study area is characterized by relatively mild, wet winters and warm, dry summers. However, the winter climate of the Abies amabilis zone is considerably more severe than that of the lower elevations of the study area, where climatic data are usually monitored. In this upper-elevational zone, the winter snowpack commonly ranges from one to three meters in depth, and recently gathered data indicate that mean January air temperatures (mea-

TABLE 1. SOME GENERAL CHARACTERISTICS OF THE SOILS OF THE *ABIES AMABILIS* ZONE HABITAT TYPES.

Habitat Type	Soil Group	Texture	Stone Content	Rooting Depth
Aa-Tm/Xt	Brown Podzolic	sandy loam	stony	1m
Aa/Vm/Xt	Brown Podzolic	loam to sandy loam	moder. stony	1-2m
Aa/Rm-Va/Cc	Brown Podzolic	loam to sandy loam	moder. stony	1.5-2.5m
Aa/Va/Cc	Brown Podzolic	loam	stony	1-3m
Aa/At	Brown Podzolic	silt loam to sandy loam	moder. stony	1-2m
Aa/Tu	Brown Podzolic	silt loam	moder. stony	1-3m
Cn/Oh	Ando-like	loam	stony	1-2m

sured under forest canopies one meter above the forest floor) range from about -.7 to -2.4°C and mean July air temperatures range from about 14 to 15.5°C.[1] Annual precipitation is estimated to range from 2470 to 3460mm (100 to 140 inches) at the higher elevations (Legard and Meyer 1973). Clear atmospheric conditions and low precipitation usually prevail during the summer months. These conditions commonly

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[1]Unpublished data, for the years 1973 and 1974, on file at the Forest Research Laboratory, Oregon State University, Corvallis, Oregon. The data reported here was gathered from four *Abies amabilis* zone reference stands, two located in the H. J. Andrews Experimental Forest, and two located in the Wildcat Mountain Research Natural Area.

result in the rapid drying of the uppermost soil layer on clearcuts in the study area, and the establishment of a high transpirational demand on tree seedlings.

Vegetation

The study area falls within the Willamette ecologic province (Franklin 1965a) of the true fir-hemlock forests, and is characterized by the extensive but often insular occurrence of *Abies amabilis* habitat types, which are typically confined to the higher portions of the ridge systems and summits. A mosaic of *Abies amabilis* zone forest stands, varied in structure and composition, exists within the study area. Past wildfires have occurred frequently enough to prevent, in most instances, the development of forest stands to the full climax state. As a result, *Pseudotsuga menziesii* and *Abies procera*, distinctly seral species, are often the overstory dominants of forest stands in the study area. A list of tree species common to the *Abies amabilis* zone of the study area, each species rated in importance, is presented in Table 2.

The characteristics of climax or near-climax stands which are representative of the seven *Abies amabilis* zone plant associations may be briefly described as follows:

(1) Stands of the *Abies amabilis*-*Tsuga mertensiana*/

TABLE 2. TREE SPECIES OF THE ABIES AMABILIS ZONE OF THE STUDY AREA.

Tree Species	Importance[a]
Abies amabilis (Pacific silver fir)	M
Abies procera (noble fir)	M
Pseudotsuga menziesii (Douglas-fir)	M
Tsuga heterophylla (western hemlock)	M
Tsuga mertensiana (mountain hemlock)	m
Pinus monticola (western white pine)	m
Chamaecyparis nootkatensis (Alaska-cedar)	m
Thuja plicata (western redcedar)	m
Abies grandis (grand fir)	m
Libocedrus decurrens (incense cedar)	m
Picea engelmannii (Engelmann spruce)	i
Pinus contorta var. latifolia (lodgepole pine)	i
Pinus ponderosa (ponderosa pine)	i
Abies lasiocarpa (subalpine fir)	i

[a]Symbols denote the following: M = major importance, m = minor importance, i = insignificant.

Xerophyllum tenax association (Aa-Tm/Xt) occur on or near ridgetops at elevations of 1400 to 1620m (4600 to 5300 feet). Codominant overstory tree species are Abies amabilis and Tsuga mertensiana, the climax trees of this association. Seral species include Abies procera, Pinus monticola, and Pseudotsuga menziesii. The understory, almost monospecific, is dominated by Xerophyllum tenax(Figure 2).

(2) Stands of the Abies amabilis/Vaccinium membrana-

Figure 2. Interior of Aa-Tm/Xt stand positioned on ridge-top. Note dense cover of Xerophyllum tenax.

Figure 3. Interior of Aa/Rm-Va/Cc stand. Rhododendron macrophyllum prominent in foreground.

ceum/*Xerophyllum tenax* association (Aa/Vm/Xt) occur on or near ridgetops at elevations of 1280 to 1430m (4200 to 4700 feet). The dominant canopy layer tree species are the climax *Abies amabilis* and the seral *Abies procera*. *Vaccinium membranaceum* is the only important shrub species of a poorly developed shrub layer, and *Xerophyllum tenax* dominates an herbaceous layer richer in species than that of the Aa-Tm/Xt association.

(3) Stands of the *Abies amabilis*/*Rhododendron macrophyllum*-*Vaccinium alaskaense*/*Cornus canadensis* association (Aa/Rm-Va/Cc) occur on many slope types at elevations of 910 to 1220m (3000 to 4000 feet), and are dominated in the canopy layer by *Pseudotsuga menziesii* and *Tsuga heterophylla*. The shrub layer is well developed and dominated by *Rhododendron macrophyllum* and *Vaccinium alaskaense* (Figure 3), while the poorly developed herb layer is dominated by *Cornus canadensis* and *Xerophyllum tenax*.

(4) Stands of the Abies amabilis/*Vaccinium alaskaense*/*Cornus canadensis* association (Aa/Va/Cc) occur on a variety of landforms and on moister sites than those of the Aa/Rm-Va/Cc association, at elevations of 880 to 1160m (2900 to 3800 feet). The canopy layer is similar in character to that possessed by stands of the Aa/Rm-Va/Cc association. The shrub layer is dominated by *Vaccinium alaskaense*, the

herb layer by Cornus canadensis.

(5) Stands of the Abies amabilis/Achlys triphylla association (Aa/At) occur at mid- to upper-slope positions, usually on south and west aspects, at elevations of 1190 to 1430m (3900 to 4700 feet). Pseudotsuga menziesii and Abies procera usually dominate the canopy layer; the shrub layer is poorly developed, and dominated by Acer circinatum and Vaccinium membranaceum, while the well developed herb layer is dominated by Achlys triphylla. Stands of the Abies procera/Achlys triphylla community (Ap/At), which will be replaced in succession by stands of the Aa/At association, possess overstories dominated by Abies procera and understories dominated by Achlys triphylla and Smilacina stellata.

(6) Stands of the Abies amabilis/Tiarella unifoliata association (Aa/Tu) occur on a variety of landforms at elevations of 1000 to 1310m (3300 to 4300 feet). Abies procera, Pseudotsuga menziesii, and Tsuga heterophylla dominate the overstory canopy layer, while the poorly developed shrub layer is dominated by Vaccinium membranaceum and Acer circinatum. The well developed herb layer is dominated by Tiarella unifoliata, Achlys triphylla, and Cornus canadensis. Stands of the Abies procera/Clintonia uniflora community (Ap/Cu), which will be replaced in succession by those of the Aa/Tu association, possess overstories dominated by Abies procera

and herbaceous understories dominated by _Clintonia uniflora_ and other herbaceous species.

(7) Stands of the _Chamaecyparis nootkatensis/Oplopanax horridum_ association (Cn/Oh) occur on steep north slopes, at elevations of 1160 to 1370m (3800 to 4500 feet). Tree layers are dominated by _Pseudotsuga menziesii_, _Abies amabilis_, _Chamaecyparis nootkatensis_, and _Tsuga heterophylla_. Moderately developed shrub layers are dominated by _Oplopanax horridum_, and well developed herb layers are dominated by _Smilacina stellata_, _Tiarella unifoliata_, _Cornus canadensis_, and _Montia sibirica_.

In the climax and near-climax stands described above, tree regeneration is typically dominated by _Abies amabilis_. The forest stands of the study area generally exist in various stages of successional development leading to these climax or near-climax states.

History of Logging Activities

Logging activity in the study area is of comparatively recent origin. The area began to be logged in the early 1950's, and during this period some stands at lower elevations of the _Abies amabilis_ zone were clearcut harvested. Since its inception, logging activity has steadily increased and at present a fairly intensive network of access roads crisscross the area and timber harvest activities have been conducted throughout the *Abies amabilis* zone. With the exception of the area (approximately 20% of the study area) within the H. J. Andrews Experimental Forest, the Wildcat Mountain Research Natural Area, and the highest elevations of some scenic ridge systems, it can be said that the study area is intensively managed for timber production.

IV. METHODS

Reconnaissance and Choice of Study Units

A field reconnaissance was conducted prior to the establishment of study units. Prior to the reconnaissance, a detailed examination was made of Forest Service regeneration records to determine the general nature of clearcuts within the study area. The age, elevation, slope characteristics, site preparation and regeneration histories were recorded for each clearcut thought likely to be located on *Abies amabilis* zone habitat types. A decision was made to limit field reconnaissance to clearcuts of age seven to fifteen years (clearcuts created between 1960 and 1968). This provided that each clearcut to be examined had ample time to regenerate, and also resulted in the inclusion of a sufficient number of clearcuts for reconnaissance purposes.

A total of 121 clearcuts was examined in the field. Using a key developed by Dyrness et. al. (1974), the habitat type of each clearcut was determined[2] by examining the vegetation of both the clearcut and surrounding, undisturbed

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[2]Several authors have confirmed that habitat types can be identified in the field during most stages of plant succession; i.e., the presence of a climax stand is generally not required for habitat type identification (Daubenmire 1973, Pfister 1972b, Roe 1967).

stands thought to possess environments similar to that of the clearcut. The following information was gathered on each clearcut unit: habitat type(s), a rough sketch of the unit and its adjacent stands, a description of competing vegetation on the unit, slope relief (degree of smoothness), slope position, and slope azimuth and inclination as determined by a compass and Abney level.

Of the 121 clearcuts examined in the field, 52 were discarded from further consideration as unsuitable for study. Criteria for dismissal were: clearcut not on *Abies amabilis* habitat type; edge effects judged too strong (clearcut too small); slope relief of clearcut highly irregular; clearcut inordinately influenced by roads or earth movement. This left 69 clearcuts, representing 96 habitat type units, for further consideration.[3] The distribution of the 96 units by habitat type is shown in Table 3.

Due to a limited amount of time available for sampling, my initial intention was to choose three habitat types (the three with the greatest number of potential study units) for further study, 15 study units to be chosen in each type.

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[3]More than 69 habitat type units were identified because two or more habitat types, or two or more units of the same habitat type which possess different slope characteristics, often occur on one clearcut.

TABLE 3. DISTRIBUTION OF POTENTIAL STUDY UNITS BY HABITAT TYPES.

Habitat Type	Number of Potential Study Units
Aa-Tm/Xt	14
Aa/Vm/Xt	13
Aa/Rm-Va/Cc	29
Aa/Va/Cc	5
Aa/At	26
Aa/Tu	8
Cn/Oh	1
	96

The Aa/Rm-Va/Cc and Aa/At habitat types were clearly dominant in clearcut occurrence and were immediately chosen for study. The Aa-Tm/Xt and Aa/Vm/Xt habitat types, typically located on ridgetops, ranked third and fourth, respectively, in number of potential study units. Rather than choose only one of the two ridgetop habitat types for study, both were chosen. The four (rather than three) habitat types finally chosen for study, and the number of study units established in each, were as follows:

Aa/Rm-Va/Cc	15 study units
Aa/At	15 study units
Aa/Vm/Xt	8 study units
Aa-Tm/Xt	7 study units

The study units of each of the habitat types were chosen at random from the groups shown in Table 3. In almost all cases the study units were not entire clearcut units but were portions thereof (ranging from one-quarter to three-quarters of the entire clearcut and from six to 30 acres in size) on which habitat type and slope aspect and inclination were consistent. Forty-two of the 45 study units were slash burned (93%), 36 were planted (to Douglas-fir, noble fir, or western white pine) at least once (80%), 10 units were seeded (to Douglas-fir, noble fir, or western white pine) at least once (22%), and 41 of the units were planted and/or seeded at least once (91%). None of the units had been treated with herbicides or fertilized.

Four of the 15 units (located on two clearcuts) chosen for study in the Aa/Rm-Va/Cc habitat type were among a small group of clearcut units and adjacent stands whose floristics and physiographic characteristics were similar but not identical to those reported by Dyrness et. al. (1974) to be characteristic of the Aa/Rm-Va/Cc habitat type. In particular, within the plant communities both on and adjacent to clearcut units of this type, _Vaccinium membranaceum_ was present rather than _Vaccinium alaskaense_, which was absent from three of the study units and present, but of minor importance, on the fourth study unit. _Xerophyllum tenax_ was prominent in the herbaceous layer of these communities.

At the time, the author believed that these units were minor variants of the Aa/Rm-Va/Cc type, and classified them within that type. Subsequent to the field sampling phase of this research, it was learned that another *Abies/Rhododendron* habitat type, which is limited by nutrient status and characterized by the presence of *Vaccinium membranaceum* rather than by *Vaccinium alaskaense*, occurs within the study area but does not occur within the H. J. Andrews Forest where Dyrness et. al. (1974) sampled forest vegetation.[4] The four study units discussed above have been tentatively assigned to this habitat type, hereafter referred to as the Aa/Rm-Vm habitat type.

The slope and elevational characteristics of the study units within each habitat type are noticeably similar to those of the study plots established by Dyrness et. al. (1974) with the exception of the study units of the Aa/Rm-Va/Cc habitat type. The study units of this habitat type possess somewhat higher elevations and more northerly aspects than do the study plots of Dyrness et. al. (1974). The pertinent characteristics of the 45 study units are summarized in Appendix I.

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[4] Personal communication, Jerry F. Franklin, Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon.

Collection of Data

A restricted random sampling procedure was employed to sample stocking levels and seedling[5] height on individual study units. This procedure entailed the use of parallel transects with fixed plot intervals (40 to 100 feet depending on the study unit sampled) oriented perpendicular to the slope. A random numbers table was used to randomly select plot location by walking a random number of paces (one to ten) perpendicularly right or left (odd number indicated left, even number indicated right) from the fixed plot interval along the transect line. This procedure established the center of each circular, one-milacre plot. The intensity of sampling on individual study units ranged from 0.5 to 1.5% of study unit area.

The following data were collected on each milacre plot: stocking condition (stocked or not stocked)[6]; number and

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[5]Seedlings are live trees less than one inch in diameter at breast height (USDA Forest Service 1973).

[6]Stocking was weighted by seedling age; a plot was stocked if it contained one of the following:

at least five one year-old trees
at least three two year-old trees
at least two three year-old trees
at least one four year-old tree

species of trees present; height[7] at ages five and seven of each tree seedling present, measured to the closest half-centimeter; percent cover of selected shrub and herbaceous species, as estimated by the canopy coverage method (Daubenmire 1959).[8]

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[7]Height was determined as follows: the age of the tree seedling was estimated by carefully counting the number of branch whorls and bud scale scars; height was then measured at those points corresponding to ages five and seven.

[8]Cover was estimated for all shrub species except trailing species such as *Rubus ursinus*, *Rubus lasiococcus*, *Rubus nivalis* and *Ribes binominatum*. These shrubs and sub-shrubs typically contribute little to the total shrub cover of the units sampled. Due to time limitations, cover was estimated for only two herbaceous species, *Xerophyllum tenax* and *Pteridium aquilinum*. These two species were among the most important herbaceous species, in terms of presence and cover, on the 45 units selected for study.

V. RESULTS AND DISCUSSION

Stocking Levels in Relation to Habitat Type

Differences in Stocking Between Habitat Types

The mean and median one-milacre stocking levels (of all coniferous species combined) of the habitat types are presented in Table 4.[9] Stocking levels of post-harvest regeneration are presented separately from stocking levels of advance regeneration.[10]

TABLE 4. MEAN AND MEDIAN STOCKING LEVELS OF CLEARCUT STUDY UNITS STRATIFIED BY HABITAT TYPE.

Habitat Type	Post-harvest Stocking Levels (%)		Advance Stocking Levels (%)	
	Mean	Median	Mean	Median
Aa/Rm-Va/Cc	48.3	48.9	16.5	8.9
Aa/Rm-Vm	44.1	41.6	14.0	5.4
Aa/Vm/Xt	20.1	19.1	2.0	1.3
Aa/At	18.7	17.1	2.7	2.3
Aa-Tm/Xt	14.4	8.5	3.1	1.4

[9]As used in this paper, the term stocking level is synonymous with stocking percentage. The stocking level of an individual study unit = $\frac{\text{number of plots stocked}}{\text{number of plots established}} \times 100$

[10]Post-harvest regeneration is composed of individuals which were established on study units after clearcutting had taken place. Advance regeneration is composed of individuals which were established on study units prior to clearcutting.

The data indicate that distinct differences exist among the stocking levels of the different habitat types. The Aa/Rm-Va/Cc and Aa/Rm-Vm habitat types possess considerably higher mean stocking levels than do the other habitat types. This situation holds for both post-harvest and advance stocking. Large variances in advance stocking exist within the Aa/Rm-Va/Cc and Aa/Rm-Vm habitat types and are reflected in the non-convergence of their mean and median stocking levels. The variable nature of advance stocking on these habitat types may be largely due to unit to unit differences in the degree of disturbance caused by logging and site preparation activities. The mean post-harvest stocking level of the Aa-Tm/Xt habitat type is misleadingly high, due to the inclusion of one anomalous study unit which possesses a 50% stocking level.[11] The median stocking level of 8.5% is a much better estimator of the stocking potential of clearcuts in this habitat type.

F-test analyses of variance were made to test the significance of the differences observed in both post-harvest and advance stocking among the habitat types. The results

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[11] Field observations strongly suggest that the study unit with 50% stocking is an anomaly. With very few exceptions, the stocking of clearcuts in the Aa-Tm/Xt habitat type can be classified as poor to very poor.

of these analyses are summarized in Tables 5 and 6. With respect to both post-harvest and advance stocking, the differences are significant at the 0.01 probability level.

TABLE 5. ANALYSIS OF VARIANCE OF POST-HARVEST MEAN STOCKING LEVELS.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-value
Among Habitat Types	4	8653.21	2163.30	9.64 ($p<.001$)
Within Habitat Types	40	9142.56	228.56	

TABLE 6. ANALYSIS OF VARIANCE OF ADVANCE MEAN STOCKING LEVELS.

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-value
Among Habitat Types	4	1778.79	444.70	4.04 ($p<.01$)
Within Habitat Types	40	4398.38	109.96	

Multiple range tests were employed to test the significance of differences in mean stocking among the various pairs of habitat types. The results of these tests are shown in matrix form in Tables 7 and 8. The data of Table 7 reveal that when the post-harvest mean stocking levels of the Aa/Rm-Va/Cc and Aa/Rm-Vm habitat types are individually compared with those of any of the other three habitat types, the

TABLE 7. SIGNIFICANCE OF DIFFERENCES IN POST-HARVEST MEAN STOCKING LEVELS OF PAIRED HABITAT TYPES.

	Aa/Rm-Va/Cc	Aa/Rm-Vm	Aa/Vm/Xt	Aa/At	Aa-Tm/Xt
Aa/Rm-Va/Cc		NS	**	**	**
AA/Rm-Vm			*	**	**
Aa/Vm/Xt				NS	NS
Aa/At					NS
Aa-Tm/Xt					

* indicates significance at the 0.05 probability level.

** indicates significance at the 0.01 probability level.

NS indicates non-significance.

TABLE 8. SIGNIFICANCE OF DIFFERENCES IN ADVANCE MEAN STOCKING LEVELS OF PAIRED HABITAT TYPES.

	Aa/Rm-Va/Cc	Aa/Rm-Vm	Aa/Vm/Xt	Aa/At	Aa-Tm/Xt
Aa/Rm-Va/Cc		NS	*	**	**
Aa/Rm-Vm			NS	NS	NS
Aa/Vm/Xt				NS	NS
Aa/At					NS
Aa-Tm/Xt					

* indicates significance at the 0.05 probability level.

** indicates significance at the 0.01 probability level.

NS indicates non-significance.

differences are significant; the small difference in post-harvest stocking between the Aa/Rm-Va/Cc and the Aa/Rm-Vm habitat types is not significant; none of the post-harvest stocking levels of the Aa/At, Aa/Vm/Xt, and Aa-Tm/Xt habitat types is significantly different from the other. The significance of the differences in advance stocking between habitat type pairs (Table 8) mirrors the relationships shown in Table 7, with the exception that the Aa/Rm-Vm advance stocking level is not significantly different from that of any other habitat type.

Factors Affecting Differences in Stocking Between Habitat Types

The mean radiation indices,[12] mean elevations, and mean shrub cover percentages of the habitat types were compared with their mean stocking levels in the hope that correlations might be found which would link the differences in mean stocking among habitat types to differences in their environments. The means of these parameters are summarized in

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[12]The radiation index is a theoretical parameter which integrates the effects of slope inclination and aspect, latitude, and seasonality on the radiation environment of a site. The radiation index of each study unit was computed from field measurements of slope azimuth and inclination and from tables prepared by Frank and Lee (1966).

TABLE 9. MEAN VALUES OF SELECTED PARAMETERS OF CLEARCUT STUDY UNITS STRATIFIED BY HABITAT TYPE.

Habitat Type	Post-harvest Stocking (%)	Radiation Index	Shrub Cover (%)	Elev. (feet)
Aa/Rm-Va/Cc	48.3	.3789	36.3	3810
Aa/Rm-Vm	44.1	.3814	22.0	4250
Aa/Vm/Xt	20.1	.4391	25.4	4275
Aa/At	18.7	.4982	44.5	4267
Aa-Tm/Xt	14.4	.4621	10.9	4700

Table 9. Correlation coefficients between mean stocking level and mean radiation index, mean elevation, mean shrub cover, and a radiation index-elevation interaction product are shown in Table 10.

TABLE 10. CORRELATION COEFFICIENTS SQUARED (R^2) BETWEEN MEAN STOCKING AND THE MEANS OF SEVERAL VARIABLES.

	Radiation Index	Elevation	Shrub Cover	Rad. Index X Elevation
Mean Stocking	.825	.604	.047	.916

Both elevation and radiation index correlate relatively well, in an inverse manner, with stocking, and furthermore a fairly strong inverse correlation exists between the interaction product of elevation and radiation index and stocking. The lack of correlation between shrub cover and stocking may indicate that unit to unit differences in total plant cover before and after logging may be more important than differences in shrub cover alone in assessing the impact of vegetative competition on seedling stocking levels.

In light of the above correlations, the following hypotheses are advanced. The inverse correlation between radiation index and stocking may primarily represent a warm season effect on seedling mortality -- high radiation levels during the warm season may result in lower seedling survival (lower stocking) and vice-versa. Habitat type differences in solar radiation input may also affect seedling mortality during the cold season. If, early in the winter, soils freeze prior to the development of a snowpack, the incidence of seedling mortality due to dessication may be greater on clearcut habitats which receive high radiation levels than on those subjected to lower radiation levels. In effect, the comparatively low radiation levels characteristic of the <u>Rhododendron</u> habitat types probably result in seedling mortality rates which are much lower than those of the other habitat types. The inverse relationship between mean elevation and mean stocking could be the result of several interactions. For example, elevation may be directly correlated with the average annual number of freeze-thaw cycles, or inversely correlated with the amount of soil moisture available to first year tree seedlings. As a result, the incidence of seedling mortality due to frost heaving and to drought may generally increase (and stocking decrease) with increasing elevation within the _Abies amabilis_ zone.

It was anticipated that clearcuts of the cold, and relatively dry, ridgetop habitat types would possess low mean stocking levels, but the magnitude of the difference between the mean stocking level of the Aa/Rm-Va/Cc (or the Aa/Rm-Va) habitat type and that of the Aa/At habitat type was somewhat unexpected. The Aa/At habitat type characteristically occurs on south and west slopes which are subject to high summer solar radiation loads, whereas the Aa/Rm-Va/Cc type often occurs on more northerly aspects on which direct solar radiation loads are much less. The difference in the mean radiation indices between the study units of these habitat types (Table 7) emphasizes this fact. This large difference suggests that much of the difference in mean stocking levels between these habitat types may be explained by the environmental implications (discussed above) for young seedlings of that factor alone. Many other factors may be involved, however, including biotic ones.

Mortality and damage to tree seedlings as a result of pocket gopher activities is considered to be a major problem in the study area.[13] During the field phase of this research it was observed that pocket gopher activity seemed to be much higher on clearcuts in the Aa/At habitat type than on those in the Aa/Rm-Va/Cc (and Aa/Rm-Vm) habitat type. The incidence of deer browsing on tree seedlings also seemed noticeably higher on Aa/At clearcuts than on Aa/Rm-Va/Cc and Aa/Rm-Vm clearcuts. Seedling mortality due to biotic agents may be significantly greater on clearcuts in the Aa/At habitat type than on clearcuts in the Rhododendron types and may, in part, account for the large difference in mean stocking between these habitat types.

Obviously, any attempt to explain the observed differences in mean stocking among the habitat types is confounded by the fact that many environmental variables which have not been accounted for (measured) in this study may strongly influence stocking -- some of these variables may be closely correlated with the variables accounted for in this study, and some may not. However, the results of this study clearly imply that the stocking levels of the Aa/Rm-Va/Cc and Aa/Rm-Vm study units are generally superior because, other factors being equal, they possess comparatively favorable abiot-

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[13] Personal communication with members of the regeneration staffs of the Blue River, McKenzie, and Sweet Home Ranger Districts of the Willamette National Forest.

ic seedling environments, whereas the abiotic seedling environments of the study units of the other three habitat types are generally more extreme.

Factors Affecting Differences in Stocking Within Habitat Type

Considerable variation in stocking was observed among the study units within each habitat type. Five factors which may affect study unit stocking were amenable to measurement. They are: radiation index, vegetative cover, elevation, the number of regeneration operations conducted, and the age (time elapsed since harvest) of each study unit. A multiple linear regression equation was developed for each habitat type, with one-milacre post-harvest stocking as the dependent variable, and the five factors listed above as independent variables, in an attempt to account for the variation observed in stocking within each habitat type. Due to general similarities in total (all species combined) stocking and in other measured characteristics, the data of the Aa/Rm-Va/Cc and Aa/Rm-Vm study units were combined for purposes of this regression analysis. The regression equations and their respective R^2 values are presented below:

Y = one-milacre post-harvest stocking level

X_1 = radiation index

X_2= percent shrub cover[14]

X_3= elevation in hundreds of feet

X_4= number of regeneration operations conducted

X_5= age in years (time elapsed since harvest)

Rhododendron habitat types (Aa/Rm-Va/Cc and Aa/Rm-Vm combined:

$$Y = 149.454 - 99.160X_1 - .472X_2 - 2.346X_3 + 6.124X_4 + 3.210X_5$$

R^2= .381

Aa/At habitat type:

$$Y = 86.845 - 3.973X_1 + .1173X_2 - 1.466X_3 - 7.018X_4 + .567X_5$$

R^2= .709

Aa/Vm/Xt habitat type:

$$Y = - 119.36 - 258.55X_1 - .53X_2 + 6.107X_3 + 5.403X_4 - .41X_5$$

R^2= .943

Aa-Tm/Xt habitat type:

$$Y = 348.855 - 284.262X_1 - .274X_2 - 4.453X_3 + .38X_4 + 2.698X_5$$

R^2= .976

With the exception of the Rhododendron habitat types, the R^2 values of the regression equations indicate that the

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[14]For the Aa-Tm/Xt regression, X_2= percent shrub cover plus percent cover of Xerophyllum tenax and Pteridium aquilinum. This gave the best multiple correlation coefficient for the regression equation. In the regression equations of all other habitat types, X_2= percent shrub cover, because this parameter gave the best correlations for these equations.

five independent variables account for a considerable portion of the total variation observed in stocking level within each habitat type. This suggests that either a better expression must be found for these variables or that factors not taken into account in this study may significantly affect stocking on clearcuts of the Rhododendron habitat types.

TABLE 11. SQUARED CORRELATION COEFFICIENTS (R^2) BETWEEN STUDY UNIT STOCKING AND SEVERAL VARIABLES.

	R^2 Values Between Stocking and:				
Habitat Type	Radiation Index	Shrub[a] Cover	Elev.	No. of Regen. Opr. Conducted	Age of Study Units
Aa/Rm-Va/Cc and Aa/Rm-Vm Combined	.006	.004	.010	.040	.165
Aa/At	.118	.108	.524	.620	.229
Aa/Vm/Xt	.479	.123	.011	.039	.014
Aa-Tm/Xt	.860	.058	.041	.012	.024

[a]For the Aa-Tm/Xt habitat type only: shrub cover plus cover of Xerophyllum tenax and Pteridium aquilinum.

Analysis of the importance of individual independent variables, summarized in Table 11, indicates that: (1) radiation index is strongly correlated with stocking on the study units of the two ridgetop habitat types -- radiation index accounts for most of the observed variation in stocking within the Aa-Tm/Xt habitat type and a considerable portion of the observed variation in stocking within the Aa/Vm/Xt habitat type; however, radiation index alone accounts for little of the variation in stocking observed within both the Aa/At habitat type and the Aa/Rm-Va/Cc and Aa/Rm-Vm habitat types combined; (2) elevation alone accounts for little of the variation in stocking observed within habitat types, with the exception of the Aa/At habitat type -- on this habitat type, the higher elevation study units possess considerably lower stocking levels than do lower elevation study units; (3) percent shrub cover correlates poorly with the stocking of individual study units within each of the habitat types; (4) the number of regeneration operations conducted correlates poorly with study unit stocking on all habitat types with the exception, again, of the Aa/At habitat type; stocking on this habitat type is inversely correlated with regeneration effort -- apparently, the units with the most severe regeneration environments have been planted frequently with little success, whereas the units with less severe regeneration environments were often planted once, with comparatively good success; (5) the R^2 values indicate that no strong correlations exist between age of study unit and stocking; this implies that only minor accretion in stocking occurs between (roughly) the seventh and fifteenth years following harvest; i.e., most stocking occurs in the years immediately following harvest.

Stocking Levels of Individual Tree Species

The mean one-milacre post-harvest stocking levels of Douglas-fir and noble fir, the two tree species which contribute most to total post-harvest stocking, are shown in Table 12.

TABLE 12. MEAN POST-HARVEST STOCKING LEVELS OF DOUGLAS-FIR, NOBLE FIR, AND ALL SPECIES COMBINED.

Habitat Type	All Species Stocking (%)	Douglas-fir Stocking (%)	Noble fir Stocking (%)
Aa/Rm-Va/Cc	48.3	31.8	16.7
Aa/At	18.7	8.8	8.7
Aa/Vm/Xt	20.1	5.6	13.2
Aa/Rm-Vm	44.1	4.8	32.1
Aa-Tm/Xt	14.4	.2	13.6

When subjected to t-test analysis, the differences in the mean stocking levels of the two species were found to be significant on the Aa-Tm/Xt habitat type ($p < .05$), and on the Aa/Vm/Xt and Aa/Rm-Vm habitat types ($p < .01$). In order to indicate unit to unit variation in species stocking performance, the comparative stocking performances of Douglas-fir and noble fir on individual study units have been summarized for each habitat type (Table 13).

TABLE 13. COMPARATIVE UNIT TO UNIT STOCKING PERFORMANCE OF DOUGLAS-FIR AND NOBLE FIR.

Habitat Type	Douglas-fir Stocking Superior[a] (No. Units)	Noble fir Stocking Superior (No. Units)	Stocking of Neither Species Superior (No. Units)[b]
Aa/Rm-Va/Cc	7	2	2
Aa/At	4	4	7
Aa/Vm/Xt	1	5	2
Aa/Rm-Vm	∅	4	∅
Aa-Tm/Xt	∅	6	1

[a]Stocking superiority on individual study units was based on a consideration of: the magnitude of the difference in stocking between the two species, the relative difference in stocking between the two species, and the magnitude of the stocking levels of the two species.

[b]Includes stocked units on which Douglas-fir and noble fir stocking are roughly equivalent, and units which are essentially not stocked.

The data of Table 12, taken in conjunction with that of Table 13, indicate that Douglas-fir stocking is superior to that of noble fir on the Aa/Rm-Va/Cc habitat type, and is equivalent to that of noble fir on the Aa/At habitat type. In contrast, on the Aa/Rm-Vm habitat type and on the Aa/Vm/Xt and Aa-Tm/Xt habitat types, noble fir stocking is far superior to that of Douglas-fir.[15]

[15]The four Aa/Rm-Vm study units occur on only two clearcut units. Comparative species stocking performance, when based on such a restricted sample, cannot be assumed representative of the habitat type as a whole.

Field observations indicate that: (1) the stands adjacent to the Aa/Rm-Va/Cc study units generally contain an abundance of seed-producing Douglas-fir but a limited number of noble fir seed sources; (2) the stands adjacent to most of the Aa/At, Aa/Vm/Xt, and Aa-Tm/Xt study units contain an adequate number of both Douglas-fir and noble fir seed sources. Thus, it seems likely that the drastic reduction of Douglas-fir stocking on the Aa/Vm/Xt and Aa-Tm/Xt habitat types cannot be attributed to a lack of natural seed source, whereas the dominance of Douglas-fir stocking on the Aa/Rm-Va/Cc habitat type may be partly a consequence of natural seed source availability.

An analysis was made of the artificial regeneration operations conducted on each study unit in an attempt to determine whether the comparative stocking performances of the two species were influenced by the selection of species, or the numbers of a species used, in artificial regeneration operations. The results of this analysis are summarized in Table 14. When the study units are grouped by habitat type, it is evident that Douglas-fir was planted or seeded somewhat more often than was noble fir on the Aa/Rm-Va/Cc and Aa/At habitat types, and at least equally as often as was noble fir on the Aa/Vm/Xt and Aa-Tm/Xt habitat types. Numbers of seedlings planted or seeded are not shown in Ta-

TABLE 14. REGENERATION HISTORIES OF STUDY UNITS.

Habitat Type	Total No. of Study Units	No. of Study Units Artif. Regenerated[a]	No. of Units Planted and Species Planted	No. of Units Seeded and Species Seeded
Aa/Rm-Va/Cc	11	10	6 DF[b] & NF[c] 3 DF only	2 DF & NF 2 DF only
Aa/Rm-Vm	4	2	2 DF & NF	-
Aa/At	15	15	12 DF & NF 3 DF only	2 DF
Aa/Vm/Xt	8	8	3 DF & NF 2 DF only	3 DF & NF
Aa-Tm/Xt	7	6	4 DF & NF 1 NF only	1 DF

[a]Neither the number of units planted, the number of units seeded, nor their sum need equal the total number of units artificially regenerated. For example: for the Aa/Rm-Va/Cc habitat type, nine units were planted and four units were seeded, but only one of the four units which were seeded was not planted as well; therefore, the total number of units on which at least one artificial regeneration operation was conducted is nine plus one = ten units.

[b]DF indicates Douglas-fir.

[c]NF indicates noble fir.

ble 14 due to the incomplete nature of some regeneration records, but all available information indicates that, for each group of study units, the numbers of Douglas-fir planted or seeded was equal to or greater than the numbers of noble fir planted or seeded. It appears that the superiority of noble fir stocking over that of Douglas-fir on the Aa-Tm/Xt and Aa/Vm/Xt habitat types cannot be attributed to differences in the selection of species, or the numbers of a species used, in artificial regeneration operations on the study units of the respective habitat types. The superiority of noble fir stocking over that of Douglas-fir on the Aa/Vm/Xt and Aa-Tm/Xt habitat types apparently reflects the superior ability of noble fir to survive and become established on these habitat types.

Mean Number of Trees Per Acre of Clearcut Study Units

The mean number of trees per acre of individual tree species and of all tree species combined (stratified by habitat type) are shown in Table 15. The number of trees per acre values shown represent the means of the study unit values within each habitat type.[16] The mean total number of

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[16]The number of trees per acre of an individual tree species on an individual study unit was obtained by dividing the total number of individuals of the species counted on

trees per acre values obtained by the use of the ratio method[16] compares favorably with those obtained by using stocking percent-trees per acre curves constructed by Bever and Lavender (1955), given that those curves were developed from stocking data collected on naturally regenerated clearcuts located at relatively low elevations in the _Tsuga heterophylla_ zone of western Oregon. The large differences in mean total number of trees per acre between those of the Aa/Rm-Va/Cc and Aa/Rm-Vm habitat types and those of the other habitat types is striking but not surprising, considering the large differences that exist in mean stocking (all species combined) among the habitat types. The mean total number of trees per acre values (post-harvest and advance trees combined) of the Aa/Vm/Xt, Aa-Tm/Xt, and Aa/At habitat types, 328, 326, and 314 trees per acre respectively, are misleading because: (1) these trees tend to be poorly distributed on the clearcuts studied; (2) the mean values are strongly affected by extreme values of a few study units; for example, on the Aa/Vm/Xt habitat type, four of eight study units have less than 300 total trees per acre, and three of eight units have less than 100 post-harvest trees per acre; on the

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all milacre plots by the total number of such plots established, and multiplying by 1000 to convert from a milacre to an acre basis.

TABLE 15. MEAN NUMBER OF TREES PER ACRE OF INDIVIDUAL TREE SPECIES.

Habitat Type	Total	[DF	NF	SF	WH	MH	WWP	WRC	GF	LPP	IC][a]
					Post-harvest Trees						
Aa/Rm-Va/Cc	1080	626	267	115	52	-	18	-	-	-	2
Aa/Rm-Vm	962	52	720	100	-	72	14	-	-	4	-
Aa/Vm/Xt	292	56	182	44	2	-	2	-	4	-	2
Aa-Tm/Xt	291	2	263	8	-	18	-	-	-	-	-
Aa/At	272	102	114	29	16	-	5	-	6	-	-
					Advance Trees						
Aa/Rm-Va/Cc	402	-	-	368	25	2	-	5	2	-	-
Aa/Rm-Vm	437	-	20	403	9	-	-	-	5	-	-
Aa/Vm/Xt	36	-	-	36	-	-	-	-	-	-	-
Aa-Tm/Xt	35	-	11	18	-	6	-	-	-	-	-
Aa/At	42	-	5	30	7	-	-	-	-	-	-

[a] DF = Douglas-fir WWP = western white pine
NF = noble fir WRC = western redcedar
SF = Pacific silver fir GF = grand fir
WH = western hemlock LPP = lodgepole pine
MH = mountain hemlock IC = incense cedar

Aa-Tm/Xt habitat type, six of seven study units have less than 300 total trees per acre, and two of seven units have less than 100 post-harvest trees per acre; on the Aa/At habitat type, ten of 15 study units have less than 300 total trees per acre, and five of 15 units have less than 100 post-harvest trees per acre.

Seedling Height at Ages Five and Seven in Relation to Habitat Type

Introduction

Growth rates of tree seedlings seem generally slow on clearcuts within the *Abies amabilis* zone of the study area. Seedling growth seems primarily restricted by temperature regimes which are considerably less than optimum for tree growth (Zobel et. al. 1974). Other environmental factors, such as mechanical damage caused by snowpack weight (Williams 1966), frequently reduce the growth rates of tree seedlings on these habitats.

Heights of post-harvest seedlings of all tree species encountered on all milacre plots were measured at ages five and seven. Only two tree species, Douglas-fir and noble fir, occurred often enough on most study units to permit a meaningful statistical analysis of seedling growth. A total of 1643 tree seedlings was measured on the 45 study units. The data base from which Douglas-fir and noble fir height (measured at constant age) was analyzed consisted of height observations taken from 485 Douglas-fir and 784 noble fir seedlings.

Mean Height of Douglas-fir Seedlings at Ages Five and Seven in Relation to Habitat Type

The mean heights of post-harvest Douglas-fir seedlings at ages five and seven are arrayed in Table 16.[17] No data

TABLE 16. MEAN HEIGHT OF DOUGLAS-FIR AT AGES FIVE AND SEVEN ON SEVERAL HABITAT TYPES.

Age	Aa/Rm-Vm	Aa/Rm-Va/Cc	Aa/Vm/Xt	Aa/At
		Mean Height (cm.)		
Five	16.4	21.1	31.5	35.2
Seven	-	36.4	49.9	62.9

are shown for either the Aa-Tm/Xt habitat type (at ages five and seven) or for the Aa/Rm-Vm habitat type (at age seven) due to an insufficient number of observations. The differences in mean heights at age five and at age seven were subjected to F-test analyses of variance and were found to be

[17]Each mean height shown in Table 16 represents the mean of the mean heights of each study unit within a particular habitat type.

significant at the 0.01 probability level.

Multiple range tests were employed to test the significance of the differences between all pairs of habitat type means. The results of these analyses are shown in Tables 17 and 18. At age five, the mean heights of Douglas-fir seedlings on the Aa/Rm-Vm and the Aa/Rm-Va/Cc habitat types were

TABLE 17. SIGNIFICANCE OF DIFFERENCES IN DOUGLAS-FIR MEAN HEIGHT BETWEEN PAIRED HABITAT TYPES -- AGE FIVE.

	Aa/Rm-Vm	Aa/Rm-Va/Cc	Aa/Vm/Xt	Aa/At
Aa/Rm-Vm		NS	*	**
Aa/Rm-Va/Cc			*	**
Aa/Vm/Xt				NS
Aa/At				

NS indicates non-significance.
 * indicates significance at the 0.05 probability level.
** indicates significance at the 0.01 probability level.

TABLE 18. SIGNIFICANCE OF DIFFERENCES IN DOUGLAS-FIR MEAN HEIGHT BETWEEN PAIRED HABITAT TYPES -- AGE SEVEN.

	Aa/Rm-Va/Cc	Aa/Vm/Xt	Aa/At
Aa/Rm-Va/Cc		NS	**
Aa/Vm/Xt			NS
Aa/At			

NS indicates non-significance.
** indicates significance at the 0.01 probability level.

significantly less than the mean heights of the other two habitat types, whereas at age seven only the difference between the mean height of the Aa/Rm-Va/Cc habitat type and that of the Aa/At habitat type was significant.

Factors Affecting Differences in Mean Height of Douglas-Fir Seedlings Within Habitat Types.

Multiple linear regression equations of mean height (at age seven) against radiation index, percent shrub cover, and elevation were derived in an effort to account for the variation in mean height observed within each habitat type. The regression equations and their respective R^2 values are presented below:

Y = mean height (on a study unit) of Douglas-fir seedlings at age seven, measured in centimeters

X_1 = radiation index

X_2 = percent shrub cover

X_3 = elevation in hundreds of feet

Aa/Rm-Va/Cc habitat type:

$$Y = 26.374 + 53.609X_1 - 1.0035X_2 + .7254X_3$$

$$R^2 = .791$$

Aa/Vm/Xt habitat type:

$$Y = -198.446 + 248.761X_1 + .378X_2 + 3.282X_3$$

$$R^2 = .998$$

Aa/At habitat type:

$$Y = -76.66 - 148.896X_1 + .1425X_2 + 5.054X_3$$

$$R^2 = .276$$

The poorest correlation between mean height and the three independent variables clearly occurs in the Aa/At habitat type -- the habitat type on which mean height is greatest.

An analysis of the importance of individual independent variables indicates that radiation index and percent shrub cover (but not elevation) correlate fairly well with mean height on the study units of the Aa/Rm-Va/Cc and the Aa/Vm/Xt habitat types. In contrast, none of the independent variables correlate well with mean height on the Aa/At habitat type.

Mean Height of Noble Fir Seedlings at Ages Five and Seven in Relation to Habitat Type

The mean heights of noble fir seedlings, at ages five and seven, are presented in Table 19. A clear separation of

TABLE 19. MEAN HEIGHT OF NOBLE FIR AT AGES FIVE AND SEVEN ON SEVERAL HABITAT TYPES.

Age	Aa/Rm-Vm	Aa/Vm/Xt	Aa-Tm/Xt	Aa/Rm-Va/Cc	Aa/At
	Mean Height (cm.)				
Five	18.6	20.0	20.5	23.1	26.1
Seven	32.3	32.3	34.3	37.6	51.6

mean heights exists at age seven. The mean heights on the Aa/At habitat type are much greater in magnitude than those on the other habitat types. F-test analyses of variance revealed that the differences in mean heights at age five were not significant, whereas the differences at age seven were significant at the 0.01 probability level.

A multiple range test was employed to analyze the differences in mean height, at age seven, between paired habitat types. The results are shown in Table 20. The mean

TABLE 20. SIGNIFICANCE OF DIFFERENCES IN NOBLE FIR MEAN HEIGHT AT AGE SEVEN BETWEEN PAIRED HABITAT TYPES.

	Aa/Rm-Vm	Aa/Vm/Xt	Aa-Tm/Xt	Aa/Rm-Va/Cc	Aa/At
Aa/Rm-Vm		NS	NS	NS	*
Aa/Vm/Xt			NS	NS	**
Aa-Tm/Xt				NS	*
Aa/Rm-Va/Cc					*
Aa/At					

NS indicates non-significance.

* indicates significance at the 0.05 probability level.

** indicates significance at the 0.01 probability level.

height on the Aa/At habitat type is significantly different from all other means, but no other pairs of means are significantly different from each other.

Factors Affecting Differences in Mean Height of Noble Fir Seedlings Within Habitat Types

Multiple linear regression equations of noble fir mean height at age seven against three independent variables were derived in an attempt to account for the variation in mean height observed within each habitat type. The regression equations and their R^2 values follow:

Y = mean height (on a study unit) of noble fir seedlings at age seven, measured in centimeters

X_1 = radiation index

X_2 = percent shrub cover

X_3 = elevation in hundreds of feet

Aa/Rm-Vm habitat type:

$$Y = 25.807 + 42.404X_1 - .322X_2 - .061X_3$$

$$R^2 = .980$$

Aa/Vm/Xt habitat type:

$$Y = 68.016 + 64.963X_1 - .184X_2 - 1.332X_3$$

$$R^2 = .967$$

Aa-Tm/Xt habitat type:

$$Y = 136.25 + 43.407X_1 - .001X_2 - 2.542X_3$$

$$R^2 = .999$$

Aa/Rm-Va/Cc habitat type:

$$Y = 52.17 + 98.027X_1 - .328X_2 - .977X_3$$

$$R^2 = .868$$

Aa/At habitat type:

$$Y = -251.44 + 295.251X_1 + .259X_2 + 3.313X_3$$

$$R^2 = .457$$

Considerable variation in the importance of individual independent variables exists among the habitat types. For example, radiation index correlates better with seedling height on the Aa/Rm-Va/Cc habitat type than do the other independent variables, whereas percent shrub cover correlates better with height than do the the other independent variables on the Aa/Vm/Xt habitat type, and elevation correlates better with height than do radiation index and percent shrub cover on the Aa-Tm/Xt habitat type.

Differences Among Species in Mean Heights of Seedlings of Equivalent Age

The data of Tables 16 and 19 reveal that at ages five and seven, Douglas-fir seedlings clearly outgrew (on the average) noble fir seedlings on the study units of the Aa/Vm/Xt and Aa/At habitat types, whereas on the study units of the Aa/Rm-Vm and Aa/Rm-Va/Cc habitat types there was little difference (at either age) in mean height between the two species, although noble fir exhibits slightly greater mean height. Limited (in number) measurements of height of Pacific silver fir seedlings at ages five and seven indicate that on any given habitat type, Pacific silver fir mean height is roughly half that of equal-aged Douglas-fir and noble fir seedlings. In an overall sense, the data collected in this study suggest that, on a basis of height attained by seedlings at ages five and seven, the three species rank as follows: Douglas-fir $\geq$ noble fir $\gg$ Pacific silver fir. This ranking is similar to that reported by Williams (1968), who measured juvenile growth rates (at ages 15 to 20 years) of open-grown seedlings and saplings[18] of Douglas-fir, noble fir, western white pine, and Pacific silver fir on upper-slope clearcuts in the Cascades of northern Oregon and Washington.

Differences Among Habitat Types in Mean Heights of Seedlings of Equivalent Age

The data of Tables 16 and 19 also show that the mean height at ages five and seven of both Douglas-fir and noble fir seedlings is clearly greatest on the Aa/At habitat type,

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[18]Saplings are live trees one to five inches in diameter at breast height (USDA Forest Service 1973).

least on the Aa/Rm-Vm habitat type, and intermediate on the Aa/Vm/Xt and Aa-Tm/Xt habitat types. Limited data on heights attained by Pacific silver fir seedlings in relation to habitat type suggest that it follows a pattern similar to that of Douglas-fir and noble fir. The high radiation inputs characteristic of the Aa/At habitat type apparently result in heat environments which are relatively favorable for the growth of established tree seedlings. Seedling growth on the Aa/Rm-Vm habitat type may be limited by both heat and nutrients.

Plant Community Development on Clearcut Study Units

Introduction

Coverage and frequency of selected shrub and herbaceous species were collected on each study plot. This data, in conjunction with qualitative observations made during the field phase of this study, makes possible a limited characterization of the plant communities that have developed, following clearcutting, on the five habitat types. This discussion is limited, of necessity, to the characterization of successional plant communities aged seven to 15 years. Mean cover and frequency values of individual species are shown in Appendix 2. For the purposes of the following discussion, residual species are defined to be those which possess fifty percent or greater constancy in near-climax or climax stands on a particular habitat type, whereas invader species are those which possess less than fifty percent constancy in such stands. The preceding definitions are based on constancy data compiled by Dyrness et. al. (1974).

The Aa-Tm/Xt Habitat Type

Successional communities on clearcuts of this habitat type are strongly dominated by herbaceous species and it appears that shrubs will not dominate these communities prior to canopy closure. Shrub cover on the seven study units averages 10.9%, whereas the cover of *Xerophyllum tenax*, alone, averages 32.4%. Although *Xerophyllum tenax* typically dominates on these sites, its cover is often greatly reduced from that which existed prior to logging.[19] The major invading species present on most study units seven to ten years after disturbance consist of a variety of grasses and sedges which tend to occupy the interstices between clumps of *Xerophyllum tenax* (Figure 4). *Vaccinium membranaceum* averages 2.1% cover and is the only residual shrub of any

[19] *Xerophyllum tenax* coverage averaged 64% in undisturbed forest stands on the Aa-Tm/Xt habitat type studied by Dyrness et. al. (1974).

importance on the study units. The most important invading shrub species is Ribes viscosissimum var. hallii, which averages 2.9% cover. Other shrub invaders are Rubus leucodermis which averages 1.8% cover and Ceanothus velutinus, averaging 1.1% cover. Ceanothus occurs infrequently and most individuals are of low vigor.

Aa/Vm/Xt Habitat Type

The plant communities which have developed, following logging, on the study units of this habitat type are generally dominated by herbs but shrub development is greater on this habitat type (shrub cover averages 25.4%) than on the Aa-Tm/Xt habitat type. Xerophyllum tenax averages 20.4% cover and is of major importance in the herbaceous layer. Xerophyllum cover appears to be significantly less than that which existed prior to logging.[20] One major difference in the herbaceous layer on the study units of this habitat type, as contrasted with those of the Aa-Tm/Xt habitat type, is the relative abundance of Pteridium aquilinum, an invader species, which averages 11.3% cover.

Vaccinium membranaceum is the dominant residual shrub

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[20] Xerophyllum tenax averaged 39% cover in undisturbed forest stands of the Aa/Vm/Xt habitat type sampled by Dyrness et. al. (1974).

Figure 4. Aa-Tm/Xt clearcut. Dense cover of Xerophyllum tenax and grass and sedge species.

Figure 5. Aa/Rm-Va/Cc clearcut. Domination by Rhododendron macrophyllum, Vaccinium alaskaense, and Epilobium species.

species, averaging 4.2% cover. The most important invading shrub species are Ribes viscosissimum var. hallii (6.3% mean cover) and Rubus parviflorus (4.4% mean cover), followed by Ceanothus velutinus (3.6% mean cover) and Prunus emarginata (2.1% mean cover). Shrub development seems best on study units situated on warmer aspects, whereas on cooler aspects Xerophyllum tenax and other herbaceous species are so well-developed that the occurrence of a shrub-dominated phase of successional development seems very unlikely.

Aa/Rm-Vm Habitat Type

Plant communities of the four study units of this habitat type are poorly developed. Herbaceous development is limited, with the exception of Xerophyllum tenax, which averages 20.7% cover. Much mineral soil surface remains exposed and is unoccupied by vegetative cover, even though ten to 15 years have elapsed since logging. Rhododendron macrophyllum (14.6% mean cover) and Vaccinium membranaceum (4.3% mean cover), two residual species, dominate the shrub layers of the communities studied. All invading shrub species, in terms of cover and frequency, are of minor importance.

Aa/Rm-Va/Cc Habitat Type

Two residuals, Rhododendron macrophyllum and Vaccinium alaskaense, dominate the shrub layers of the plant communities on the 11 study units established in this habitat type (Figure 5). Total shrub cover averages 36.3%, to which Rhododendron macrophyllum and Vaccinium alaskaense contribute 13.3% and 11.6%, respectively. The only invading shrub species of any importance is Ceanothus velutinus, which occurred on a little over half of the study units, and averaged 3.4% cover. Ceanothus was dominant on one study unit, codominant on another, but of little importance on the remaining study units.

Cornus canadensis was generally prominent in the herbaceous layer of the plant communities studied, as was Xerophyllum tenax, which averaged 5.9% cover. Epilobium species (abundantly present on most study units) are important invaders in the herbaceous strata.

The dominant roles played by Rhododendron macrophyllum, Vaccinium alaskaense, Xerophyllum tenax, and Cornus canadensis in these early successional communities suggest that the climax understory vegetation of this habitat type tends to reconstitute itself fairly rapidly, following disturbance.

Aa/At Habitat Type

The average shrub cover (44.5%) of the study units of this habitat type is greater than that of any other habitat type included in this study. This is interesting, because in the undisturbed state, the plant communities of this habitat type have a poorly developed shrub layer and on the other hand have the best developed herb layer of any of the habitat types included in this study. An examination of study unit data revealed that mean shrub cover has been inflated by the inclusion of two study units on which *Ceanothus velutinus* has developed vigorously and has achieved strong dominance. Although it is possible that such study units are over-represented in this sample, shrub cover still averages 38% upon the exclusion of these two units.

Four shrub species, at least three of which may be considered to be invaders, dominate the shrub layers of these plant communities -- *Ceanothus velutinus*, *Rubus parviflorus*, and *Ribes viscosissimum* var. *hallii* (the invaders) average 15.4, 6.4, and 6.1% cover, respectively, while *Acer circinatum* averages 4.9% cover. Almost without exception, one or another of the aforementioned four species is the dominant shrub (in terms of cover) on any given study unit. Invading species, *Prunus emarginata* and *Sambucus racemosa*, and residual species, *Vaccinium membranaceum* and *Pachistima myrsinities*, possess relatively high constancy and are of secondary importance in most shrub layers studied.

Herbaceous vegetation is well-developed on many of the clearcut units studied. Pteridium aquilinum is often present in abundance (10.2% mean cover) and is the dominant herbaceous species on many study units. Other residual species usually present in varying degrees of abundance include Smilacina stellata, Achlys triphylla, Asarum caudatum, Cornus canadensis, and Tiarella unifoliata. Epilobium species are present in abundance on some study units of this habitat type, but species of this genus seem, in general, to be of less importance on clearcuts of the Aa/At habitat type than on those of the Aa/Rm-Va/Cc habitat type.

The successional communities of some Aa/At study units are already in a shrub-dominated phase of development, while those of other study units may be approaching a shrub stage. However, other study units, which possess well-developed herb layers and poorly developed shrub layers, will probably never pass through a shrub-dominated phase of development.

Silvicultural Implications

Introduction

The results of this study possess silvicultural implications. Habitat type differences in overall stocking potential, stocking potential of individual species, mean heights of tree seedlings measured at common ages, and vegetational development, following clearcutting, all exist. These differences imply that different silvicultural approaches to regeneration may be desirable or even necessary on different habitat types in order to achieve regeneration success. Of primary importance is the fact that many clearcuts in the Abies amabilis zone of the Western Cascades of Oregon encompass two or more habitat types. Thus, in many instances, in order to attain maximum regeneration success on a particular clearcut unit, individual subunits (habitat types) must be managed differently, or cutting should be restricted to one habitat type at a time.

Aa/Rm-Va/Cc Habitat Type

The clearcut system seems well-suited (for purposes of regeneration) to forest stands of this habitat type. The Aa/Rm-Va/Cc habitat type possesses the most moderate seedling environment of all the habitat types studied, and adequate regeneration is usually achieved following clearcutting. Both Douglas-fir and noble fir are suitable species for artificial regeneration purposes. In most cases, the most acute problem on clearcuts of this habitat type seems to be the slow growth rates exhibited by most tree seedlings. It appears that, among other factors, low solar energy inputs during the growing season, and high competition for environmental resources from adjacent tree seedlings and shrubs severely restrict seedling growth on this habitat type.

Aa/Rm-Vm Habitat Type

This habitat type seems to possess a very similar stocking potential, following clearcutting, to that of the Aa/Rm-Va/Cc habitat type; i.e., adequate regeneration appears to be readily obtainable following clearcutting, but established tree seedlings grow very slowly, and thus are susceptible for a prolonged period of time to damage caused by biotic agents (mammals, primarily) and mechanical damage caused by debris fall and heavy snowpack accumulations. In many instances, better control of stocking density and perhaps, fertilization of tree seedlings, may shorten the long period of susceptibility to damage of the type discussed above.

Aa/At Habitat Type

This habitat type typically occurs on south- and west-facing slopes. High inputs of summer radiation and high frequency of frost heave probably are major causes of poor stocking levels often observed on clearcuts of this habitat type. Williamson (1973) has reported that shelterwood harvesting of upper-slope Douglas-fir and mixed-conifer stands on severe sites in the Oregon Cascades is feasible and results in increased seedling establishment. The shelterwood system would seem to be the most appropriate silvicultural system for stands on the Aa/At habitat type, provided that such stands are not positioned on ridgetops or on overly steep slopes. If the clearcut system is to be employed, cutting units should be kept small (except where frost problems are envisioned) to ameliorate the seedling environment. Care should be taken to protect advance regeneration, if it exists. Burning of most sites on this habitat type probably increases the severity of the seedling environment, and in addition, often destroys existing advance regeneration.

Brush development can be vigorous on some sites, but observation suggests that when regeneration is established shortly after harvest, tree seedlings can compete favorably with shrubs. On moister sites on this habitat type, dense herbaceous vegetation often develops rapidly following logging and seems to maintain its dominance over time. On such sites seedling establishment will be difficult without vegetation control. In general, large seedlings with relatively low shoot to root ratios may be best suited for planting on this habitat type.

Aa/Vm/Xt Habitat Type

Although regeneration problems often occur following clearcutting on this habitat type, no alternative even-aged silvicultural system may be suited to this habitat type. The ridgetop or near ridgetop location of Aa/Vm/Xt sites may preclude the application of the shelterwood system due to a high risk of overstory windthrow loss. Clearcuts should generally be kept small to minimize environmental extremes and enhance natural regeneration. Seedlings are established best on exposed mineral soil which has not been heavily compacted. Large-scale site preparation methods should be avoided if possible, because they often aggravate environmental extremes and destroy advance regeneration. Results of this study indicate that noble fir should be favored over Douglas-fir in planting operations. Brush competition is not a major regeneration problem on this habitat type.

Aa-Tm/Xt Habitat Type

Following clearcutting on this habitat type, adequate stocking is rarely obtained. In many instances, regeneration is almost non-existent. Due to the exposed position and shallow soils characteristic of this habitat type, the use of partial cutting methods to ameliorate the seedling environment seems infeasible. Productivity is very low on these habitats; Douglas-fir site quality averages class V (Dyrness et. al. 1974). Given the slow growth rates of tree species and the severe regeneration problems which exist, a no-harvest option on this habitat type should be strongly considered by forest land managers. If forest stands are to be clearcut, advance regeneration should be carefully protected during logging and site preparation activities. It is preferable that mineral seedbeds and seedling planting sites be created by site preparation activities other than burning. Noble fir, not Douglas-fir, should be planted on this habitat type. Given the difficulty with which seedlings are established and their subsequent slow growth, rotations on this habitat type will be considerably longer than those commonly envisioned for forests at lower elevations in the *Abies amabilis* zone.

VI. SUMMARY

The results of this study indicate that strong differences in stocking potential, following clearcutting, clearly exist among the habitat types studied. Both the Aa/Rm-Va/Cc habitat type and an undocumented Aa/Rm-Vm habitat type generally restock adequately following clearcutting (mean one-milacre post-harvest stocking levels of 44.1 and 48.3%, respectively). The mean one-milacre post-harvest stocking levels on clearcuts of the Aa-Tm/Xt, Aa/At, and Aa/Vm/Xt habitat types are quite low, ranging from 14.4 to 20.1%, and regeneration failures are commonplace. The differences in mean stocking levels among habitat types are inversely correlated with differences in mean radiation indices and mean elevations among habitat types. Variation in stocking among the study units within each habitat type is correlated with several variables, of which radiation index for the ridgetop habitat types, elevation and the number of regeneration operations conducted for the Aa/At habitat type, and the age of study units for the Rhododendron habitat types, correlates best with stocking.

Important differences were observed among the habitat types in the stocking of individual tree species. The mean stocking level of noble fir was inferior to that of Douglas-fir on the Aa/Rm-Va/Cc habitat type, equal to that of Douglas-fir on the Aa/At habitat type, and far superior to that of Douglas-fir on the Aa/Rm-Vm, Aa/Vm/Xt, and Aa-Tm/Xt habitat types. The superiority of noble fir stocking on clearcuts of the ridgetop habitat types appears to result from its superior ability to survive on these harsh sites.

The results of this study also indicate that differences among habitat types in the mean height of tree seedlings clearly exist. Both Douglas-fir and noble fir seedlings grow best on clearcuts of the Aa/At habitat type. The mean height of seedlings of both species is considerably less on the other habitat types studied, and is poorest on the Aa/Rm-Vm habitat type. The mean height of Douglas-fir seedlings is generally similar to, or greater than, the mean height of noble fir seedlings on each habitat type studied.

The nature of the early successional plant communities which develop, following clearcutting, varies considerably among the habitat types studied. Those which have developed on the Aa/Vm/Xt and Aa-Tm/Xt habitat types are, with few exceptions, herb-dominated and will in most cases remain so through canopy closure, whereas those of the Aa/Rm-Vm, Aa/Rm-Va/Cc, and Aa/At habitat types are often dominated by shrubs.

The fact that differences in regeneration characteristics among habitat types have been revealed in this study implies that habitat type classification can be of use in the regeneration management of Abies amabilis zone forests of the Western Cascades. The following are the most important silvicultural implications of the results of this study: (1) adequate regeneration is usually obtained following clearcutting on the Aa/Rm-Va/Cc and Aa/Rm-Vm habitat types; (2) on most sites of the Aa/At habitat type, shelterwood, rather than clearcut, seems to be the most appropriate silvicultural system; (3) noble fir, not Douglas-fir, should be planted on the Aa/Vm/Xt and Aa-Tm/Xt ridgetop habitat types; (4) strong consideration should be given to a no-harvest decision in forests of the Aa-Tm/Xt habitat type, where severe regeneration problems and very slow tree growth rates prevail.

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APPENDICES

APPENDIX I. GENERAL CHARACTERISTICS OF CLEARCUT STUDY UNITS.

Aa/Rm-Va/Cc and Aa/Rm-Vm Habitat types

Study unit[a]	Year cut	Aspect	Slope (%)	Elev. (feet)	Radiation index	Shrub cover (%)	One-milacre stocking (%)	Number of regeneration operations
17	65	WSW	55	3900	.5063	26.7	23.1	2
B216	66	N	50	3900	.2663	47.9	34.9	Ø
B83	66	NE	40	4000	.3504	46.6	37.3	3
FrCa2	67	NNE	35	3500	.3305	42.7	37.7	1
FrCa1	67	NNE	20	3200	.3852	41.5	40.0	1
UDC8	61	NW	35	4050	.3632	25.0	48.9	1
B83	66	N	35	4200	.3185	41.3	50.0	3
B81	60	E	25	3800	.4560	28.6	53.3	1
I5	65	NW	30	4200	.3760	36.1	57.1	1
SF1	66	ENE	25	3400	.4215	24.2	70.0	2
DC12	60	ENE	25	3750	.4215	38.5	78.6	2
S60*	61	WNW	40	4400	.4009	14.0	33.9	1
FC3*	65	ENE	20	4050	.4286	19.8	37.5	Ø
FC3*	65	E	35	4150	.4543	13.5	45.6	Ø
S60*	61	NNE	70	4400	.2316	40.5	59.5	1

* Study units which have been tentatively placed within an Aa/Rm-Vm habitat type.

[a] Each study unit is located on the clearcut possessing the indicated USFS code.

APPENDIX I. Continued. Aa/At Habitat Type.

Study unit	Year cut	Aspect	Slope (%)	Elev. (feet)	Radiation index	Shrub cover (%)	One-milacre stocking (%)	Number of regeneration operations
FrCa11	66	SSW	50	4700	.5710	67.6	∅	4
FrCa11	66	WSW	50	4700	.5048	40.4	1.7	4
WC1	67	SW	45	4500	.5408	52.0	2.9	2
B611	67	SSW	10	4300	.4899	13.9	5.4	3
FrCa10	66	WSW	40	4400	.4999	36.9	6.5	2
FrCa10	66	SSW	40	4400	.5580	47.9	14.5	2
I3	61	NW	20	4000	.4032	25.8	15.0	2
B22	67	SSW	30	4200	.5403	21.5	17.1	3
FrCa12	65	E	55	4700	.4492	28.8	19.7	2
B610	67	S	25	4200	.5344	50.0	20.0	1
FC4	65	SW	30	4100	.5218	41.6	23.1	2
B11	63	E	30	3800	.4553	89.1	32.1	1
C23	63	SW	25	4100	.5129	38.7	34.0	1
UDC8	61	NW	35	3800	.3632	26.2	39.1	1
FC1	66	SSE	25	4100	.5290	86.9	48.8	1

APPENDIX I. Continued. Aa/Vm/Xt and Aa-Tm/Xt Habitat Types.

Study unit	Year cut	Aspect	Slope (%)	Elev. (feet)	Radiation index	Shrub cover (%)	One-milacre stocking (%)	Number of regeneration operations
				Aa/Vm/Xt Habitat Type				
L306	64	SE	45	4400	.5408	34.1	2.5	3
L212	61	W	40	4150	.4533	28.7	4.5	2
FW3	68	SW	30	4300	.5218	6.4	6.7	1
L212	64	NE	25	4150	.3896	41.3	17.5	2
L709	65	WNW	40	4300	.4009	43.9	20.7	1
L707	65	NE	35	4300	.3632	19.2	34.4	1
L708	65	NE	25	4200	.3896	11.6	36.5	1
L306	61	W	40	4400	.4533	12.8	37.7	3
				Aa-Tm/Xt Habitat Type				
FrCa6	68	SE	60	4500	.5525	21.6	Ø	1
FC4	65	SW	20	4500	.5040	5.1	7.1	2
WC2	68	E	60	4900	.4476	5.7	7.5	Ø
FW3	68	SW	15	4500	.4933	1.9	8.5	2
FrCa12	65	E	60	4900	.4476	11.1	12.5	2
L710	65	W	50	4900	.4507	27.2	15.5	1
WC3	68	NE	45	4700	.3388	3.4	50.0	1

APPENDIX II. MEAN PERCENT COVER AND FREQUENCY OF SELECTED SHRUB AND HERBACEOUS SPECIES.

Species	Aa/Rm-Va/Cc		Aa/Rm-Vm		Aa/At		Aa/Vm/Xt		Aa-Tm/Xt	
Tall Shrub Layer	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.
Acer circinatum	.4	2	-	-	4.9	12	.5	2	.1	a[*]
Acer glabrum	-	-	-	-	Tr[**]	a	-	-	-	-
Alnus sinuata	-	-	-	-	.3	1	.1	1	.0[***]	a
Amelanchier alnifolia var. semiintegrefolia	.0	a	-	-	Tr	a	.0	a	.1	2
Arctostaphylos columbiana	.5	2	.8	4	.1	1	-	-	-	-
Castanopsis chrysophylla	.4	2	.0	1	Tr	a	-	-	.3	a
Ceanothus velutinus	4.3	14	.7	5	15.4	29	3.6	22	1.1	10
Holodiscus discolor	Tr	a	-	-	.2	1	.5	a	-	-
Pachistima myrsinites	.4	5	.4	2	1.2	12	.8	8	.5	7
Prunus emarginata	.4	1	-	-	2.6	13	2.1	13	.1	1
Rhodendron macrophyllum	13.3	49	14.6	52	.1	1	-	-	-	-
Ribes lacustre	-	-	.3	3	.7	5	.2	a	Tr	a
Ribes lobbii	.0	a	-	-	.8	6	.2	1	-	-
Ribes viscossimum var. hallii	.7	4	.2	2	6.1	27	6.3	34	2.9	11
Rubus leucodermis	Tr	a	Tr	1	Tr	a	.1	1	1.8	1
Rubus parviflorus	.2	1	.1	3	6.4	31	4.4	33	.2	12
Rubus spectabilis	-	-	-	-	Tr	a	-	-	-	-
Salix lasiandra	-	-	-	-	.0	a	-	-	-	-
Salix scouleriana	-	-	-	-	Tr	a	.1	a	-	-
Salix sitchensis	.2	1	-	-	.1	1	.1	1	-	-
Sambucus cerulea	Tr	a	-	-	.1	a	-	-	-	-
Sambucus racemosa	.4	1	.2	2	1.6	10	.5	4	.3	1

APPENDIX II. MEAN PERCENT COVER AND FREQUENCY OF SELECTED SHRUB AND HERBACEOUS SPECIES (CONTINUED).

Species	Aa/Rm-Va/Cc		Aa/Rm-Vm		Aa/At		Aa/Vm/Xt		Aa-Tm/Xt	
Tall Shrub Layer (continued)	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.	Cov.	Freq.
Vaccinium alaskaense	11.6	53	.3	3	.9	6	-	-	-	-
Vaccinium membranaceum	2.0	21	4.3	43	1.7	17	4.2	45	2.1	35
Vaccinium parvifolium	.0	a	-	-	-	-	-	-	-	-
Vaccinium scoparium	-	-	-	-	-	-	-	-	Tr	a
Low Shrub Layer										
Arctostaphylos nevadensis	-	-	-	-	.0	a	.0	1	.6	4
Berberis nervosa	.8	21	Tr	1	.1	2	.0	a	-	-
Juniperus communis	-	-	-	-	-	-	-	-	.2	1
Rosa gymnocarpa	.5	3	.1	1	.4	4	.4	5	.2	3
Symphoricarpos mollis var. hesperius	.2	1	.1	1	.6	3	1.3	6	.4	4
Total Shrub Cover	36.3		22.2		44.3		25.4		10.9	
Herb Layer										
Pteridium aquilinum	.7	6	1.0	8	10.2	41	11.3	55	1.6	11
Xerophyllum tenax	5.9	32	20.7	75	.3	3	20.4	64	32.4	78

*indicates that mean frequency is less than 0.5%.

**indicates that mean cover is less than 0.05%.

***indicates that species occurred in trace amounts only on all study units.