Title: Soil Moisture Depletion Trends Under Five Plant Species Present on the Douglas-fir Clear-cuts of Marys Peak, Oregon

Abstract approved: Redacted for Privacy

W. W. Chilcote

Soil moisture depletion trends under five plant species growing on the clear-cuts of the Marys Peak Watershed near Corvallis, Oregon, were followed during the summers of 1963 and 1964. The species were Holcus lanatus, Lotus crassifolius var. subglaber, Gaultheria shallon, Berberis nervosa, and Acer circinatum; and were dominant plants of several stages in a successional sere occurring on the clear-cuts.

Sampling of the moisture trends was limited to two clear-cut areas in order to reduce the variability due to location. On one area, Gaultheria, Berberis, and Lotus were growing in individual, pure stands. On the other, Acer was growing in closely grouped clumps and Holcus occupied the areas in between.

The soil moisture was measured by an electrical resistance method. Plaster-of-paris blocks were installed at 6-, 12-, and
24-inch depths at nine locations in each species. The measurements were taken two or three times a week with an ohmmeter and expressed as an average in terms of atmospheres of tension for each day and depth.

Supporting information on the precipitation, root distribution, and soils was also obtained. A root count for roots less than two millimeters in diameter was made from the face of a trench dug in each species. Soil descriptions made of the trench profiles, a particle size analysis, and 15 atmospheres determinations indicated that the soils of the two clear-cuts were similar.

Each species had characteristic moisture depletion trends during the two years. Trends for Gaultheria indicated slow rates of moisture loss at all three depths and very little influence of precipitation. Gaultheria, an evergreen shrub, has thick, leathery leaves (characteristics which are generally associated with few stomata) and has a long period during which new stems emerge. The roots were concentrated near the surface just under the one and half to two inches of litter, and a few were growing inside large, dead roots of Douglas-fir.

Depletion trends associated with Berberis were similar to Gaultheria except moisture losses at the 6-inch depth were more rapid. Berberis plants are also evergreen shrubs and have thick, leathery leaves but grow during a short period in the spring. Most
of the roots developed in the top few inches of soil. Litter accumulation was slightly less (one to one and a half inches) and was not as uniformly distributed.

Under *Lotus*, moisture trends at 6 and 12 inches fluctuated considerably. Depletion rates were rapid at all three depths. *Lotus*, a herbaceous species, grew quickly and flowered in the spring, then died back in mid-summer, evidently allowing increased infiltration of the rainfall. The rhizomes penetrated throughout the profile. Litter accumulation was about an inch, and the soil surface was somewhat rocky.

*Holcus* trends at 6 and 12 inches showed an early and rapid moisture loss but a slightly delayed and slower loss at 24 inches. *Holcus*, a perennial bunch grass, also grew rapidly in the spring and then died back about mid-summer. Regrowth occurred following a substantial rainfall. The erect culms and dense mat of grass leaves (about two inches) surrounding the base of each plant created high air temperatures which may have caused high evapotranspiration rates. Root concentration was greatest near the surface and decreased sharply with depth.

Moisture losses under *Acer* were rapid at all three depths and very consistent without any fluctuations. *Acer* clumps grew during the spring and maintained their leaves throughout the summer. Such comparatively large plants (six to seven feet high) evidently
had a high transpirational stress, and along with the one to two inches of litter, intercepted most of the precipitation. Root concentration decreased gradually with depth.

This study provides a partial explanation for the replacement of Holcus by Lotus. It appears that Lotus is able to invade Holcus by producing rhizomes which grow underneath the dense root system of Holcus and utilize the moisture there. Lotus then increases in dominance by sending up shoots from the rhizomes.

Possible explanations for the replacement of other species were not evident; however, there were some interesting correlations of the results with the sequence. With each advancing stage the depletion trends became more consistent. And, except for Lotus which had the smallest number of roots, the root count decreased with each advancing stage. The decrease was a reflection of an increase in the relative size of the roots.

Results of this study are applicable to forest regeneration problems. In terms of influence upon soil moisture Acer stands would be very competitive with tree seedlings. Holcus and Lotus stands would also be competitive, Lotus perhaps more so at the deeper levels. Gaultheria and Berberis stands, on the other hand, would not be nearly as detrimental to tree seedling establishment.
Soil Moisture Depletion Trends Under Five Plant Species Present on the Douglas-fir Clear-cuts of Marys Peak, Oregon

by

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Soil Moisture Depletion Trends Under Five Plant Species Present on the Douglas-fir Clear-cuts of Marys Peak, Oregon

I. INTRODUCTION

The orderly replacement of one species of plant by another as vegetation develops to some degree of stability following disturbance, has been observed almost from the beginning of the study of botany as an organized science. The reason for this phenomenon appears straightforward and logical. The total environment involves more than the physical aspects of the local climate and soil. The environment includes also biological influences, with the result that the modifying effect of plants themselves plays a dominant role. These plant influences create a changing series of environments adapted to a changing series of plants. Finally a point in time is reached when the influence created by the plants is compatible with the self-perpetuation of a certain combination of plants. At this time a relatively stable plant community is obtained.

For a number of years Chilcote (1962) and his students have followed the successional changes on a series of clear-cut and burned areas of the Corvallis Watershed approximately eight miles west of Corvallis. A unique set of conditions resulted in a
consistent successional sequence involving rapid shifts in plant composition during the first ten years following cutting and burning. Although a large number of plants are involved in the sere, it has been found that only a limited number of plants species play a dominant role in the community during a particular year.

From the standpoint of understanding the successional process a knowledge of the ecological role of the dominant species involved is helpful. Robinson (1964) has described the influence which certain of these dominants exert upon the temperature environment. This study is concerned with the influence of some of these plants upon the soil moisture environment.

Although total annual precipitation for the area ranged up to 80 inches per year, nearly all of this precipitation falls during the winter. The plants are, therefore, largely dependent upon this "reservoir" of soil moisture to carry them through the dry months. Although the deep-rooted evergreen trees and under-story shrubs characteristic of later stages of succession appear to withstand this dry period easily, it is postulated that limited summer moisture may be one of the limiting factors contributing to the replacement sequence observed. Those plants dominating successional stages and exhibiting marked shifts over a short period of time were selected with the object of characterizing the
manner in which each of these species influenced the soil moisture profile.

It is hoped that some knowledge of this influence may be helpful in a better understanding of the successional sequence and the environmental conditions characteristics of these several communities. In addition, it is hoped that some insight into the ecology of these plant species may be obtained. From the practical point of view this information has immediate application in forestry where summer drought is a problem in establishment of Douglas-fir seedlings.
II. DESCRIPTION OF THE STUDY AREA

The clear-cut areas chosen for study are located on the east slope of Marys Peak in the Corvallis Watershed (Figure 1). Marys peak is part of the Oregon Coast Range and rises to a height of 4,097 feet above sea level. The Watershed includes some 6,000 acres with the principal physiographic features involving three ridges extending in a northeast direction with three intervening drainage systems. Over-all, the topography is quite dissected with moderately steep slopes. The soils of the area have been classified by the U. S. D. A. Soil Conservation Service into several soil series.

The climate of the Watershed is typically marine (Trewartha, 1954). Prevailing westerly winds pick up moisture from the Pacific Ocean, creating a humid, mesothermal climate, with precipitation concentrated during the winter. During the summer, the influence of the Hawaiian high pressure system off the coast results in a marked reduction in precipitation.

Approximately 40 to 50 percent of the total precipitation occurs during the winter, 20 to 35 percent in the spring and autumn, and less than 6 percent in the summer. Marys Peak creates a rain-shadow effect so that the Watershed receives more precipitation along the higher, western boundary than along
Figure 1. Map of the Corvallis Watershed
the lower eastern boundary. The average annual precipitation recorded by the Corvallis Water Bureau Station at a location near the eastern boundary is 68 inches. Up to 90 inches of precipitation have been recorded near the top of the Peak.

Temperature records are not available for the Watershed, but the mean annual temperature, 50 degrees Fahrenheit, is somewhat less than the average for Corvallis (approximately eight miles east of the Watershed). Records from the Corvallis station give the January minimum range as 31 to 34 degrees Fahrenheit and the July maximum as 78 to 84 degrees Fahrenheit (U. S. Weather Bureau, 1936).

The natural vegetation of the Watershed is predominantly old-growth Douglas-fir with vine maple (Acer circinatum), salal (Gaultheria shallon), and dwarf Oregon grape (Berberis nervosa) as predominant understory plants. Anderson (1967) has classified this vegetation into five different communities which he has distinguished principally on the basis of understory shrubs and herbaceous species.

Wind-fallen trees from a severe winter storm in 1949 and 1952 and subsequent Douglas-fir bark beetle infestation resulted in a decision to cut a series of areas with the purpose of salvage and reduction of the fire hazard. Between 1953 and 1959 some 44 clear-cuts, 10 to 30 acres in size, had been made on the
Watershed. Another windstorm in 1962 (the Columbus Day storm) resulted in the initiation of another series of clear-cuts. Chilcote (1962) has described the general successional sequence during the first 10 years following logging and burning. Some six plant species appear to play a particularly dominant role with Senecio sylvaticus dominating the clear-cut area the second year, Circium vulgare the third and fourth years, Holcus lanatus the fifth and sixth years, and Lotus crassifolius var. subglaber the seventh and eighth years. Berberis nervosa with increasing amounts of Gaultheria shallon form the dominant cover by the tenth year with the new Douglas-fir forest emerging through these evergreen shrubs. Widely spaced Acer circinatum occur in some areas, particularly those not burned after logging. Numerous less conspicuous plants occupy a consistent position in the successional sere.

The consistency of the pattern described has been attributed to the environmental similarities of the clear-cut areas and to the uniformity of disturbance, the latter being related to the similar method of timber removal (the "high-lead" method of cable logging). In addition, the practice of spreading rye grass straw with grass seed and nitrogen fertilizer on all road cuts leading to new clear-cuts resulted in a consistent introduction of plant species typical of the Willamette Valley rye grass fields.
Robinson (1964) has described the above and below ground temperatures associated with this successional pattern, concentrating on the influence of some of the more dominant plants. As stated previously, the study presented in this thesis includes a description of the influence of some of these plants upon soil moisture depletion during the summer months when this factor exerts a strong control in the plant community. The study was conducted during the summers of 1963 and 1964 and involves five different plants: Holcus lanatus, Lotus crassifolius var. subglauber, Berberis nervosa, Gaultheria shallon, and Acer circinatum.

Holcus is a perennial grass and was introduced as a contaminant in rye grass straw used to stabilize the road banks. Lotus is a native perennial herb present to a limited extent in the natural openings of the forest. Gaultheria, Berberis, and Acer are woody shrubs occurring in the forest understory before timber removal.

In order to minimize differences among the clear-cuts due to elevation, slope, and soils; the study was confined to two clear-cuts. The successional stages mentioned above are characteristic of the clear-cuts as a whole, but because there are localized differences in species' distributions and because the stages overlap, it was possible to sample more than one dominant species on the
same clear-cut.

The two clear-cuts chosen were numbers 12 and 31 (Figure 1). These numbers are part of a numbering system used by the United States Forest Service to designate the cutting sequence. Both clear-cuts were made in the community described by Anderson (1967) as the *Acer circinatum/Gaultheria shallon* community, *Corylus californica*-*Holodiscus discolor* subtype.

Clear-cut No. 12 is located at an elevation of 1,700 feet in section 22, Township 12 South, Range 7 West, Willamette Meridian, and is approximately 25 acres in size. Two small tributaries of the South Fork of Rock Creek run from the northwest to the southeast through the clear-cut and merge at the southeast boundary. The ridge between the two tributaries supported a relatively pure stand of *Lotus* about one and one-half feet high on the south aspect. The south aspect has a 33 percent slope. Along the north boundary, the slope supported individual pure stands of *Gaultheria* and *Berberis* which were about one and one-half feet and one foot in height, respectively. The slope is 29 percent and faces toward the south-southeast. All species sampled were located in the upper slope position, thereby avoiding marked water seepage influences.

Soils of the clear-cut are fine-textured, moderately deep, and well drained; and have developed from coarse-grained, intrusive,
igneous rock. Profile descriptions for soils under Gaultheria and Lotus are given in Tables 1 and 2 of the Appendix. The soils are tentatively classified in the Klickitat, gravelly clay loam series by the U. S. D. A. Soil Conservation Service, and are designated as Typic Haplohumult in the 7th Approximation Classification System (U. S. Soil Survey Staff, 1960).

This area (clear-cut No. 12) was cut and burned in 1955, thus being eight years old in 1963. Both 1963 and 1964 were peak years for Lotus. This plant occurred in a particularly pure and dense stand at the upper slope position where burning had been moderate to intense. Gaultheria and Berberis stands sampled were in more advanced states in succession. The presence of these understory shrubs appeared to be related to a lighter burn at the time of tree removal.

Approximately one mile north of clear-cut No. 12 is clear-cut No. 31 which is located in section 15 of Township 12 South, Range 7 West, Willamette Meridian. This clear-cut is about 1,500 feet in elevation, and approximately 35 acres in size. It has an east-facing slope of 22 percent and in 1963 supported vigorous stands of Acer and Holcus. Acer was growing in dispersed clumps (approximately six and one-half feet high) with Holcus (approximately three feet high) occupying the space in between.

The soil is fine-textured, moderately deep and well drained;
and has developed from tuffaceous sedimentary rock. A profile
description made under Acer, is given in Table 3 of the Appendix.
The soil is tentatively placed in the Honeygrove clay, variant
series by the Soil Conservation Service and is classified according
to the 7th Approximation System as a Typic Haplohumult (U. S.
Soil Survey Staff, 1960).

Clear-cut No. 31 was logged and burned in 1958 and, hence,
was five years old in 1963. Holcus was at its peak cover in 1963
but showed a definite decline the following year. The early peak
of Holcus in the fifth rather than in the sixth year appeared related
to the early availability of seed from the adjacent straw-covered
roadbank of an access road. The clumps of Acer were the result
of resprouting from a particularly dense patch in the original
tree stand. Such patches are generally located in small openings
of the forest canopy.
III. SAMPLING PROCEDURE

Soil Moisture

In order to sample the soil moisture depletion patterns under the five species, an electrical resistance method of measuring the moisture was used. This method allowed many measurements to be taken over a period of time, with little disturbance to the study areas.

The method involves the use of electrical resistance units, which are electrodes buried in a medium of plaster-of-paris or fiberglass, and a meter for measuring the amount of current. The units are buried in the soil at various depths with lead wires extending to the surface. By connecting each wire to a meter the amount of current passing through a unit at any given time is determined. The meter readings are then converted from current to resistance values and may be further related to soil moisture tension values. A low current reading indicates high resistance and, in turn, a high value of moisture tension.

For this study, two types of plaster-of-paris electrical resistance units were used. A Rayturn block having a concentric-screen electrode and two-foot lead wire was installed at the 6- and 12-inch depths. A Delmhorst block having a concentric-wire electrode and three-foot lead wire was placed at the 24-inch depth.
The meter used was an ohmmeter Model No. 300 manufactured by Beckman Instruments, Inc., and gave readings in microamperes.

Nine soil moisture stations were located in stands of each of the five plant species. A station consisted of a stack of moisture blocks at the three levels. The stations were located where the species were in vigorous stands and were well removed from large shrubs, remaining logs, and tree margins. Periodically, the stations were weeded of contaminating species. Because of the close proximity of Holcus and Acer stands, trenches removing root contaminations were dug and refilled at the beginning of each growing season.

During April and May of 1963, the stations were established. Prior to installation, all of the blocks were checked for their individual variability by placing them in a pan of distilled water and taking readings after 12 hours. The variability was found to be negligible for both types of blocks. The blocks were then installed at each station in the following way: A small-diameter hole was dug to a depth of slightly greater than 24 inches. A Delmhorst block was inserted into the wall of the hole at 24 inches, and a loop was made in the lead wire in order to prevent moisture from flowing down the lead wire to the block. The hole was backfilled with soil to the 12-inch depth and packed to
approximately the original bulk density. A Rayturn block was inserted into the wall at 12 inches and a loop made in the lead wire. The hole was then backfilled to six inches and another Rayturn block installed in a similar manner. The remainder of the hole was filled to the top and the litter replaced.

At the end of the sampling period in late September, the blocks were removed from the study areas as a precaution against possible deterioration during the winter months. In April and May of 1964, they were re-installed. Because the blocks at 24 inches were difficult to remove intact, several new blocks were installed. The variation between the new and used blocks was negligible.

The procedure for sampling the soil moisture during the two seasons involved taking readings two or three times a week. These readings, in microamperes, were converted to electrical resistance in ohms with the aid of a calibration curve supplied with the meter. The resistance values of the nine stations were then averaged for each sampling day and depth.

In order to express soil moisture in more familiar terms and to make it easier to relate the readings to available moisture, the average resistance values were converted to atmospheres of tension. This conversion was made by constructing a calibration curve for each type of block (Figure 2).
Figure 2. Calibration curves for the Rayturn and the Delmhorst blocks.
The values for constructing a curve of the Delmhorst type were obtained from a conversion table prepared in a publication by Marvin Shearer, Extension Irrigation Specialist at Oregon State University (Shearer, 1963). The values for constructing a curve of the Rayturn type were taken from a conversion table prepared by Dr. Daniel Evans of the Soils Department at Oregon State University. Since Dr. Evans had prepared the table from tests made on blocks manufactured several years ago, the values were checked by calibrating 12 Rayturn blocks in a pressure membrane apparatus. The values given in his conversion table and those obtained from testing the blocks were in close agreement.

Precipitation

Even though the climate is relatively dry during the summer months, during certain years there may be enough precipitation to influence the soil moisture depletion trends. To account for this influence, precipitation was collected in rain gauges made from No. 10 cans equipped with funnels of aluminum foil, and measured by pouring the water into a 100-milliliter graduate cylinder (Berry, 1955).

On each clear-cut, two rain gauges were placed on stumps a wide distance apart. The measurements, taken at the same time as the soil moisture readings were converted from milliliters
to inches of water and averaged for each clear-cut.

Root Distribution

Root distribution was examined from the face of a trench dug in a stand of each species and was determined quantitatively from this face by making a root count. Investigation of the root distribution from a trench rather than from soil cores provided to be the best method because the soil was comparatively rocky.

In the summer of 1965, trenches 7 feet long and 30 inches deep were dug in stands of the five species. The trenches were oriented in a direction which took advantage of sunlight striking the whole profile, and, in the case of Acer, the trench was located equal-distant from the root collars.

To make the root count, each trench face was marked off with twine in a grid pattern, the pattern being a modification of that used by Aldrich, Work, and Lewis (1935). Twine was strung across the face at 4 and 8 inches, 10 and 14 inches, and 22 and 26 inches which made three bands of four inches in width encompassing the 6-, 12-, and 24-inch depths. The bands were divided by vertical lines of twine into four-inch squares to assist in keeping a tally.

The root count of live roots, or those which did not break off when disturbed, was tallied according to species for roots less
than two mm. in diameter. Even though the trenches were located in as pure stands as possible and "weeding" performed, the presence of other species made it necessary to identify all the roots. Characteristics used for identification included color, odor, separation of xylem and phloem, and various surface features (Appendix Table 4).

Soils

Soils descriptions were made on the two clear-cuts. Also, the amount of moisture remaining in the soil at 15 atmospheres tension (permanent wilting point) and the particle size distribution were determined from a laboratory analysis.

The profile descriptions were made at the end of the trenches in Gaultheria, Lotus, and Acer stands. These trenches were chosen to give an adequate sample of the soil characteristics on the two clear-cuts. Each profile was dug to a depth of 60 inches or to bedrock and described according to the procedure given in the Soil Survey Manual, Agricultural Handbook No. 18 (U. S. Survey Staff. 1951). Dr. C. T. Youngberg, Forest Soils Specialist at Oregon State University, confirmed the descriptions.

To determine the amount of moisture remaining in the soils at 15 atmospheres, combined samples were used, from which previous determinations of the amounts of moisture remaining in
the soils at the time of maximum depletion had been made. The sampling procedure for determining the amount of moisture at the time of maximum depletion was as follows: Prior to the fall rains, pits were dug approximately two feet from alternate soil moisture stations in each species (stations 1, 3, 5, and 7). From each pit samples were obtained at 6, 12, and 24 inches by driving the head of a three-inch Ulin sampler into the wall at each depth. The amount of soil moisture present at the time of sampling was determined gravimetrically.

For determining the amount of moisture remaining in the soils at 15 atmospheres tension, these same soil samples were used. Since fewer samples were needed for this determination, samples from pits one and three were combined and those from five and seven were combined. The amount of water remaining in these soils at 15 atmospheres tension (suction force) was determined by the O. S. U. Soils Department, Soil Testing Laboratory, using standard pressure membrane techniques.

Particle size distribution was determined from the combined samples taken under the Gaultheria, Lotus, and Acer. These determinations were made in order to verify the texture as described in the field and involved using the pipette method of analysis (Day, 1965).
IV. RESULTS

Soil Moisture

The data from the soil moisture study are presented on semi-logarithymic graphs with the tension in atmospheres on the vertical axis and the time in days on the horizontal axis. Below the horizontal axis, precipitation is shown in inches for the season. Trends are indicated by curves connecting the tension values, with steep slopes giving rapid rates of depletion or accretion.

On some graphs the curves are discontinuous as they approach the 15 or 20 atmospheres point, thus indicating that the average readings in ohms resistance were above the calibration curve limits during the period of discontinuity. For the curves of the 6- and 12-inch depths, these readings were above 20 atmospheres; and for the 24-inch depth, the readings were above 15 atmospheres.

The curves are presented in two ways: one, to show the moisture depletion trends for the individual species; and two, to compare the trends among the species. In each of the two ways, the text follows with results of soil moisture trends for 1963 presented first and those for 1964 next. Finally a comparison between years is made.

Each of the two years had a characteristic precipitation pattern which played a major role in influencing soil moisture
depletion trends. In 1963 most of the rainfall occurred during the month of June, while in 1964 it occurred at intermittent times throughout the whole season.

**Moisture Depletion Trends for the Individual Species**

**Gaultheria.** The trends of the three depths for 1963 (Figure 3) indicate no moisture depletion prior to August 5. After August 5 the three depths began to lose moisture with the 6- and 12-inch levels losing it at about the same rate and more rapidly than at the 24-inch depth. The 6-inch depth reached a maximum tension of 3.2 atm. on August 30, the 12-inch reached 3.4 atm. on September 16, and the 24-inch depth also attained 3.4 atm. on September 16.

During the 1964 season (Figure 4) the 6- and 12-inch levels had three depletion periods, the 6-inch having more rapid rates of depletion and accretion than the 12-inch. The 24-inch level lost moisture at a steadily increasing rate up to August 26, then gained moisture slightly, but continued at a fairly steady rate of loss thereafter. On August 26, the 6- and 12-inch depths attained their highest peaks of 5.5 and 4.0 atmospheres, respectively, and on September 24, the 24-inch depth attained its highest peak of 2.9 atm.
Figure 3. Moisture depletion trends for Gaultheria in 1963.
Figure 4. Moisture depletion trends for *Gaultheria* in 1964
A comparison of the trends for both years shows consistently higher soil moisture depletion in the upper positions of the soil profile. Losses as well as gains in soil moisture were also markedly related to soil depth. The gradual upward slope of the 24-inch curve suggests moisture loss continued beyond the last sampling dates. Although total precipitation was somewhat greater during the 1964 season than in 1963, the intermittent distribution of this rainfall allowed greater soil moisture depletion in 1964.

In terms of cover, the Gaultheria stands were observed to be about the same during both years. Growth of new shoots was not confined to spring nor to early summer but occurred throughout the season.

Berberis. Soil moisture losses for Berberis in 1963 (Figure 5) show little increase in soil moisture tension prior to August 5. During the remainder of the season both 6- and 12-inch depths had relatively rapid depletion rates while the 24-inch depth was much less. The peak tensions attained were 4.9 atm. at the 6-inch depth on August 30, 6.4 atm. at the 12-inch on September 16, and 2.5 atm. at the 24-inch on September 16.

During the following year (Figure 6) moisture was extracted from the 6-inch depth in three depletion periods; however, from the 12-inch level moisture was extracted in one long rather erratic period without as much fluctuation at the times of rainfall.
Figure 5. Moisture depletion trends for Berberis in 1963
Figure 6. Moisture depletion trends for Berberis in 1964
Moisture was removed gradually from the 24-inch depth in one period beginning about July 16. The highest tensions reached were 12.4 atm. for the 6-inch depth on August 24, 10.8 atm. for the 12-inch on August 31 through September 24 and 7.3 atm. for the 24-inch on September 24.

Comparing the data of both years, it is evident that greater depletion took place during 1964; however, there are similarities between the two years. The 6- and 12-inch levels had somewhat similar moisture loss patterns with 12-inch showing less fluctuations. The 24-inch level fluctuated little and the lag or time taken to attain the same tension as another depth was large. The shape of the 24-inch curve indicates that moisture loss continued beyond the final sampling dates.

As was the case with Gaultheria, the cover of Berberis changed little from 1963 to 1964. Growth occurred mostly during the late spring and early summer.

Lotus. The curves for Lotus in 1963 (Figure 7) indicate the 6- and 12-inch depths had similar moisture depletion trends. About the middle of June some moisture was removed, and not until the last half of July did an appreciable amount of moisture removal occur. The 24-inch depth had a very gradual moisture loss up to the middle of July, resulting in tension values slightly higher during the precipitation period that those of the 6- and
Figure 7. Moisture depletion trends for Lotus in 1963.
12-inch depths. After the middle of July the moisture was lost more rapidly and at nearly the same rate as the 6- and 12 inch depths, but was lagging behind them. The driest points reached were 17.3 atm. at the 6-inch level on August 19 through 22, 17.3 atm. at the 12-inch on August 22 through August 30, and greater than 15 atm. at the 24-inch after August 19.

For 1964 (Figure 8) the curves reveal rather distinct moisture trends related to the times of rainfall. At the 6-inch level there were considerable fluctuations in moisture throughout the season. Both moisture depletion and addition were rapid. At 12 inches the depletion and especially the accretion rates were not as rapid; however, there were three definite periods of depletion with peaks coinciding with those of the 6-inch level. At 24 inches the curve shows moisture removal began later than the other depths and had a fairly high rate comparable to that of the 12-inch level. The maximum tension values achieved were 13.0 atm. by the 6-inch level on August 26, 17.2 atm. by the 12-inch on August 31, and greater than 15 atm. by the 24-inch after August 21.

It is evident that moisture loss was greater in 1963 than in 1964. Furthermore, the 6- and 12-inch depths had considerable fluctuations in moisture, the 6- more than the 12-inch. The 24-inch depth had little fluctuation and probably remained at a high tension for a time after the last sampling dates. All three depths
Figure 8. Moisture depletion trends for Lotus in 1964
apparently approached the wilting point at about the same time. In 1963, the time was approximately August 22. In 1964, the time was approximately August 24.

*Lotus* did not change noticeably in cover during the two years. New leaves and stems emerged each year about the time the sampling was begun, and the plants began to die back during mid-summer.

*Holcus*. Soil moisture losses for *Holcus* (Figure 9) show marked withdrawal of moisture from the 6- and 12-inch levels during the first part of the 1963 season. Thereafter, moisture increased at both levels, the 6-inch more than the 12-inch, and then was withdrawn again during a second depletion period. The slopes of the curves in the second period indicate depletion was much faster at 6 inches than at 12 inches. At 24 inches, moisture loss was gradual, but during the second period the loss was much faster and approximately equaled the 12-inch level. The peak tension values were 18.2 atm. on August 22 for the 6-inch level, 10.8 atm. on September 16 for the 12 inch, and 15 plus atm. on September 16 for the 24-inch.

Figure 10 shows moisture depletion in *Holcus* stands continuing over one, long period in 1964. Depletion at 6 inches was rapid with slight fluctuations. At 12 inches depletion was also
Figure 9. Moisture depletion trends for Holcus in 1963
Figure 10. Moisture depletion trends for *Holcus* in 1964
rapid with little fluctuation, but depletion began much later than at the 6-inch depth. The 24-inch depth was parallel to the 6- and 12-inch in depletion rate but the depletion period began much later than the 12-inch and was of shorter duration. Maximum tension values attained were greater than 20 atm. at the 6-inch depth between August 21 and 31, 11.5 atm. at the 12 inch on August 31, and 4.7 atm. at the 24-inch on September 24.

From observing the trends of both years it can be seen that moisture loss was greatest during 1963. This loss is particularly evident at the 24-inch depth, which continued to lose moisture throughout the sampling period. The trends are similar for 1963 and 1964 in that the losses of moisture from the 12-inch depth occurred considerably later than for the 6-inch, and likewise the 24-inch lagged behind the 12-inch depth. Both 12- and 24-inch depths had about the same depletion rates but were somewhat slower than the 6-inch.

Holcus plants grew rapidly in the spring and then began to die back about mid-summer. New leaf blades sprouted soon after a substantial rainfall and generally remained green all season. In 1964 Holcus stands had thinned out considerably (a phenomena consistent with successional patterns on these clear-cuts), and regrowth following the rains was proportionally less.
Acer. For Acer in 1963, (Figure 11) the moisture trends at 6- and 12-inches were somewhat similar. There was a rapid loss rate of short duration followed by an increase in moisture, then a long period of moisture loss. During the time of moisture increase and long period of loss, the 6-inch level had faster rates of accretion and depletion. The trend at 24-inches shows that moisture depletion was gradual prior to July 23, and afterwards, rapid and constant. Each depth reached the following maximum tension values: 13.0 atm. by the 6-inch on August 19, 11.0 atm. by the 12-inch on August 30, and greater than 15 atm. by the 24-inch after August 14.

During the following year (Figure 12) the trends were very similar. Both the rates and the times of initiation of depletion were approximately the same. At the 6-inch depth moisture depletion rates were slightly less each period following times of rainfall. The 6-inch level attained its driest point of greater than 20 atm. between August 19 and 31, the 12-inch level reached a tension of greater than 20 atm. after August 12, and the 24-inch attained its highest tension of greater than 15 atm. after August 7.

Comparing the trends of both years, it is evident that the two deeper levels lagged only slightly behind the 6-inch. All three levels lost moisture at rapid rates and were little affected by the small additions of moisture. They approached the wilting point
Figure 11. Moisture depletion trends for *Acer* in 1953
Figure 12. Moisture depletion trends for Acer in 1964
at approximately the same time, which was near August 14 in 1963, and August 7 in 1964. Of the two years, the greater depletion occurred during 1964.

In terms of development, *Acer* plants completed their growth early in the season and maintained their leaves until fall. The plants were one to two feet taller in the second year.

Comparison of the Moisture Depletion Trends among the Species

Figures 13 through 18 illustrate the relative trends in soil moisture depletion of the various species for the three depths sampled over the two-year period.

Six-inch depth. From Figure 13 showing the trends of all five species in 1963, the following relationships are evident: *Gaultheria* and *Berberis* were very similar in their moisture loss. They had no initial peak on June 19, began their depletion later, and attained lower maximum tensions than the other three species. The trends of *Lotus* and *Acer* were also similar throughout the season. *Holcus* had a more rapid rate of depletion and accretion during June than *Lotus* and *Acer* but thereafter had a trend parallel to them.

Moisture depletion trends for 1964 (Figure 14) follow a somewhat different pattern. *Gaultheria* and *Berberis* were much
Figure 13. Moisture depletion trends for the five species at the 6-inch depth in 1963.
Figure 14. Moisture depletion trends for the five species at the 6-inch depth in 1964.
alike throughout the season and had lower tension values on corresponding dates than the other three species. Lotus was similar to the Gaultheria and Berberis trends but had much greater rates of depletion and accretion. The Holcus and Acer trends were similar to one another and appeared less affected by the precipitation pattern.

From a comparison of Figures 13 and 14 some generalizations can be made about the moisture relationships among the five species. Gaultheria and Berberis had the slowest rates of depletion and therefore the lowest peak tensions. In terms of moisture addition they had intermediate rates. Lotus showed the fastest rates of depletion as well as moisture addition except for June, 1963, when Holcus showed the most rapid rates. Holcus and Acer were intermediate in their rates of depletion and slowest in their rates of addition.

Twelve-inch depth. The curves for the five species at the 12-inch depth during the first year (Figure 15) indicate the following relationships which are similar to those of the 6-inch in 1963; Gaultheria and Berberis had similar trends which differed from those of the other species by having no depletion in June, beginning the main depletion period later, and attaining lower peak tension values. Holcus had more rapid removal and addition
Figure 15. Moisture depletion trends for the five species at the 12-inch depth in 1963.
of moisture than Lotus and Acer during June but a much slower rate of removal than Lotus during August. Holcus and Acer were nearly parallel in their rates of depletion from the last of July to the end of August. The trends for Acer and Lotus during the first part of the season were somewhat similar except Acer began the main depletion period earlier than the Lotus.

In 1964 (Figure 16) the pattern of curves reveals relationships which resemble to some degree those of the 6-inch in 1964. The trends of Berberis and Holcus were close together throughout the season. They did not have as great a decrease in tension during the precipitation periods as Gaultheria and Lotus. Gaultheria had rates of depletion comparable to those of Berberis and Holcus; however, because it was more affected by the precipitation, Gaultheria had a lower peak tension. Lotus and Acer were alike in their depletion rates and began depletion earlier than the other three species.

From observing both years together, one can see that Lotus and Acer attained high moisture tensions at earlier times than the other species. Also, they had the most rapid rates of depletion with the exception of Holcus in June, 1963. In terms of moisture addition, Lotus had a greater increase than Acer. Holcus reached higher peak tensions than Gaultheria and Berberis and at about the same times. The rate of depletion for Gaultheria was
Figure 16. Moisture depletion trends for the five species at the 12-inch depth in 1964.
approximately the same as for Berberis, but the rate of addition was greater.

Twenty-four-inch depth. Seasonal fluctuations in soil moisture depletion for the five species were markedly reduced at the 24-inch level (Figure 17). Acer and Lotus removed moisture at rapid and almost equal rates. In addition, Holcus removed the moisture rapidly but decreased its rate after the middle of August. Gaultheria and Berberis extracted the moisture at about the same rates, the rates being much slower than those of the other species.

Figure 18 shows a greater amount of fluctuation in soil moisture at the 24-inch level in 1964 than in 1963. Acer and Lotus had rapid losses of moisture beginning sooner than Holcus, Berberis, and Gaultheria. During August, losses under Lotus declined some in comparison to losses under Acer. Holcus began moisture depletion at a low tension, then had a rapid loss rate until August 24. Thereafter, the loss was slight. Gaultheria and Berberis depleted the moisture about equally, and more gradually, than the other species.

Comparing Figures 17 and 18, it is evident Acer and Lotus extracted the moisture most readily, the Acer slightly faster than Lotus. Both Gaultheria and Berberis removed moisture at the
Figure 17. Moisture depletion trends for the five species at the 24-inch depth in 1963.
Figure 18. Moisture depletion trends for the five species at the 24-inch depth in 1964.
slowest rates, with *Gaultheria* having the slower rate. *Holcus* had
depletion trends intermediate between the two extremes.

**Root Distribution**

The correlation between soil moisture depletion and root
distribution is not clearly defined. Some say there is a definite
relationship. The rate is greatest where the root concentration
is greatest (Metz and Douglas, 1959), or the rate decreases with
depth (the root concentration assumed to decrease with depth)
(Fletcher and Lull, 1963). On the other hand, others say deple-
tion is at equal rates for all depths occupied by the roots (Lassen,
Lull, and Frank, 1952); or as in a study of moisture loss under
varying densities of herbaceous vegetation, the depletion on fully
vegetated plots occurred at equal rates throughout the profile
(Newton, 1964); or the root concentration is not a reliable guide
to rate or amount of water loss (Hoover, Olson, and Greene, 1953).

A laboratory study involving a simulated root distribution and
measurement of water removal rates from moist soil sheds some
light on the relationship (Vasquez and Taylor, 1958). They found
soil moisture depletion is a function of root concentration only
when the profile is uniformly moist, which would be near field
capacity. As moisture is lost and the tension increases near the
surface where the root concentration is greatest, moisture will
be extracted from a lower depth where it is more available at a lower tension. Vasquez and Taylor postulated that a soil moisture gradient would gradually be established at a point where equal amounts and rates would be extracted from all depths.

From Vasquez and Taylor's work it appears that both opinions may be correct to a certain extent, depending upon moisture content. It is, however, felt that the conditions under which the studies were made and the interpretations of the data also had a part.

Since the relationship of root concentration and moisture depletion is not definite, the value of this root distribution investigation is in determining the depth and characteristics of the root systems and the contribution of roots by other species.

Several interesting points can be learned from examining the root profiles and a root count from the trench faces. First, the observations of the root profiles will be considered and then the results of the root count.

Examination of the root systems of Holcus and Acer showed their roots were concentrated near the surface. This observation was particularly evident for Holcus, which had many fine roots and root hairs. Acer had both large and small roots near the surface and occasional large roots with smaller ones at the lower depths.
Gautheria and Berberis, which are rhizomatous species, also developed more roots near the surface. Berberis had a greater concentration of rhizomes in the mineral soil of the surface six inches while Gaultheria had more rhizomes just under the one to two inches of litter. Gaultheria rhizomes showed a preference for growing inside the rotting wood of Douglas-fir roots at depths of one to two feet.

The root system of Lotus was different. Instead of the rhizomes being concentrated near the surface, they had grown downward for some distance with laterals extending outward at intermittent depths, resulting in a more uniform distribution.

The quantitative aspects of the root distribution and the species composition are shown by the root count taken within the four-inch bands of the 6-, 12-, and 24-inch depths. Figure 19 gives the root count for each species and depth. The total count at a particular depth is divided into that contributed by the predominant species and that contributed by the other species present.

Looking at the total count, Holcus has the highest, followed by Lotus, Berberis, Gaultheria, and then Acer. With depth the total count was greatest near 6 inches, less near 12 inches, and least near 24 inches.

The contribution of the predominant species to the total root count was not the same for all trenches. Holcus, Gaultheria and
Figure 19. Root count for each of the five species at the three depths.
Acer showed little contamination of other species, while roots of other species in Lotus and Berberis were much higher than was to be expected from the appearance of these stands. Because of the successional nature involved, it may be assumed that Holcus roots (perhaps many of these being dead) were contributing heavily in the Lotus stands. Both Holcus and Lotus as remanent species and Gaultheria as an invading species contributed to those "other species" in Berberis.

Figure 19 also shows that the root count confirmed the observations made of the root systems. Holcus, Berberis, Gaultheria, and Acer had root systems which were concentrated more near the surface and less at the deeper levels. Lotus had a root system which was not concentrated near the surface. All the species had root systems extending to the 24-inch depth.

Soils

Results of the investigation reveal that the soils on the two clear-cuts are very similar. From the profile descriptions and the particle size distribution, the soils are fine-textured and moderately deep with varying degrees of rockiness (Appendix Tables 1, 2, 3, and 5). They also have about the same water-holding capacity at 15 atmospheres tension (Appendix Table VI). Since both the water-holding capacities and the particle size
distributions are similar, soil moisture tensions on the two clear-cuts may be assumed to represent nearly equal amounts of available moisture.

The soils change little with depth as the above-mentioned tables show. In the process of making the descriptions, no layers of compaction were found which would restrict root development and water movement.
V. DISCUSSION

Upon examination of the soil moisture depletion trends, it can be seen that there are definite relationships between soil moisture loss and the plant species. These relationships of rate of depletion and degree of lag with depth have held over a two-year period, in spite of differences in precipitation and changes in the vegetation, i.e., Holcus decline and Acer growth in the second year. Such overriding consistencies in the face of two very different years has in some ways provided a better basis for understanding the moisture microenvironment associated with each species than if the conditions of the two years were similar.

To understand further the moisture microenvironment associated with each species, the root count and soils data and relevant observations are of interest. By drawing together this supporting information and the pertinent features of the trends, a more complete picture of the relationships for each species can be seen.

**Gaultheria**

Moisture trends indicated slow rates of depletion at all three depths. Of the five species studied, Gaultheria appears to have the least moisture loss during any one season.

Several factors have a possible bearing on this limited
moisture loss pattern. In terms of transpirational loss, the morphology and growth habit of the plants may play an important role. *Gaultheria* leaves are characteristically thick and leathery, features which are generally associated with reduced numbers of stomata and reduced transpiration during certain periods. The growth of leaves and stems was not of the usual habit. Instead of emerging in one flush of growth during the spring, new stems and leaves grew throughout the season with the result that no marked period of rapid moisture loss occurred.

Reduced evaporative losses may have been related to characteristics of the *Gaultheria* site. *Gaultheria* was growing on a lightly burned portion of the clear-cut. Litter accumulation there amounted to one and a half to two inches in depth and was fairly well distributed over the sampling area.

The *Gaultheria* stand was little contaminated by other species as the root count data show (Figure 19).

**Berberis**

Moisture depletion trends were somewhat more rapid at the 6-inch depth than those for *Gaultheria*. At the deeper levels, however, the trends of both species were similar and had the slowest rates of moisture loss when compared with *Lotus*, *Holcus*, and *Acer*. 
Berberis plants are also of low stature and have thick, leathery leaves. Growth was only a small amount each year but took place during the spring rather than throughout the season.

The stand of Berberis, located a short distance from the Gaultheria stand, was also part of the original understory and had received little disturbance from logging and burning. Litter accumulation was slightly less, amounting from one to one and a half inches, and was less uniformly distributed. This reduced amount of litter probably contributed to a greater rate of depletion at the 6-inch depth.

The root count data indicates greater contamination of the stand from other species than was the case with Gaultheria. As was mentioned previously, most of the contamination could be attributed to the carry-over of Holcus roots, many of which were probably dead. A few Lotus and Gaultheria roots contributed to the count, but the influence of these species as well as the influence of Holcus was minimized by weeding.

Lotus

At the 6- and 12-inch levels, the rapid rates of depletion and addition created trends with considerable fluctuations. At 24 inches, the rates of depletion were also rapid; but moisture addition was not evident, resulting in more uniform trends each
year.

In the spring *Lotus* plants grew rapidly and formed a nearly continuous cover over most of the sampling area. About mid-summer they began to die back, which probably allowed greater rainfall infiltration. Litter accumulation was only about an inch, and the soil surface was somewhat rocky (Appendix Table 2); factors which also may have contributed to the greater infiltration as well as may have allowed rapid evaporative losses. The rapid depletion at 24 inches was probably due to the presence of rhizomes. As mentioned in the section "Results, Root Distribution" the rate of depletion might not indicate the concentration but would indicate the presence or absence of roots.

The root count data (Figure 19) shows the *Lotus* stand was heavily contaminated by other species. Almost all of this contamination was due to the presence of *Holcus* roots. The roots are very small and probably not functional for more than a year. Thus, most of the count was undoubtedly based on dead roots from previous years.

*Holcus*

Moisture depletion rates were most rapid at 6 inches, less at 12 inches, and the slowest at 24 inches, with the result that the trends showed considerable lag with depth. The 6- and 12-inch
trends showed greater fluctuations during 1963 than during 1964.

As mentioned previously, Holcus grew rapidly in the spring and died back about mid-summer. Regrowth of new leaf blades then occurred, following a substantial rainfall. Litter accumulation amounted to about two inches over most of the area.

Not only did growth influence the depletion trends, but also the rainfall distribution played an important part and may help to explain the greater fluctuations during 1963. In 1963, the rainfall was intense and concentrated during one period, which was enough to reduce the tensions at both the 6- and 12-inch levels (Figure 9). In 1964, the intermittent showers failed to affect the 6-inch depth in Holcus, whereas they influenced those trends in the Gaultheria, Berberis, and Lotus stands. The study by Robinson (1964) on the temperature relationships associated with Holcus and other species provides at least a partial explanation. He found that the erect culms (which allowed light penetration to the litter surface and restricted air movement) and dense mat of dead grass leaves surrounding the base of each plant (which reduced heat conduction) created higher air temperatures an inch and a half above the ground, than on similar bare ground areas. Higher temperatures are related to greater evaporation and transpiration rates, and, thus, only a concentrated rainfall period would be effective in reducing the soil moisture tensions.
The effect of Holcus thinning out the second year can be seen in a comparison of the 12- and 24-inch depths with other species. Holcus trends at 12 inches in 1963 were similar to Acer and Lotus while in 1964 they were similar to Gaultheria and Berberis (species with slower rates) or at least less associated with Acer and Lotus (Figures 15 and 16). At 24 inches the Holcus trends decreased in depletion rate near 4.0 atmospheres during both years, but in 1964 the rate decreased sharply, with the result that the wilting point was not reached (Figures 17 and 18).

From Figure 19, the root count for Holcus indicates there was very little contamination from other species. Lotus was invading various parts of the clear-cut but not in the vicinity of the root profile trench or the soil moisture stations.

Acer

Soil moisture depletion trends were rapid at all three depths and were the most consistent of the five species during the two seasons. The 12- and 24-inch depths lagged slightly behind the 6-inch depth, and most of the depletion each year was during one period.

Even though logging and burning of the clear-cut five years prior to 1963 has removed most of the stems, vigorous growth from the stumps created a dense canopy by 1963. Such
comparatively large plants evidently withdrew moisture rapidly from the whole profile, while at the same time intercepting most of the precipitation. Litter of one to two inches in depth probably played a minor part by reducing evaporative losses and intercepting precipitation.

The root count data indicated there was no contamination at the stand by other species. It also indicated that a relatively small number of roots were absorbing the moisture. Many roots larger than two mm. were present in the profile, but these were functional in conduction rather than in absorption and therefore were not included.

These results and explanations lead to some interesting implications. Both the soil moisture data and the root distribution data shed some light on the causes for succession on the clearcuts. The replacement of Holcus by Lotus appears to be related to the respective root distributions and associated moisture regimes of the two species. Holcus roots are extremely dense near the surface and decrease rapidly in numbers with depth. The moisture depletion, especially during the year of Holcus decline, is rapid at the surface and much less so at the deeper levels. Under such conditions Lotus may be suited to invade these stands through rhizomes penetrating below the dense root system of Holcus and taking advantage of the moisture at this
position.

It is realized that these results may provide only a partial explanation for replacement of Holcus by Lotus. For example, the decline of Holcus does not appear to be related to the invasion by Lotus. Chilcote (1962) and Brown (1964) noted Holcus continued to persist after the Lotus had become dominant. Robinson (1967), in a current study of the relationships of Holcus and Lotus and other species, has noted Holcus does not decline as rapidly when present with Lotus as when growing in pure stands.

Possible explanations for succession involving Gaultheria, Berberis, and Acer are not as evident. There are, however, some interesting correlations of the results for the five species with the succession sequence. Except for Lotus, the root distribution data shows the number of moisture-absorbing roots decreases with each advancing state. This decrease is a reflection of an increase in the relative size of roots. As noted earlier Acer had the smallest number of roots but more roots larger than 2 mm. Moisture depletion, also, becomes more consistent with each stage. Holcus and Lotus trends fluctuated considerably, Berberis and Gaultheria trends fluctuated somewhat less, and Acer trends fluctuated very little.

The results of the study have important implications for reforestation of the clear-cut areas. Isaac (1943) has pointed out
the importance of the associated species as having possible detrimental effects on tree establishment. Soil moisture and temperature are the two most important factors affecting growth of young trees in this region. Youngberg (1955) found from a plantation study in the McDonald Forest a few miles north of the Watershed that Douglas-fir seedling mortality was almost entirely due to drought conditions. Newton (1964), understanding the importance of competing vegetation on moisture availability for seedlings, undertook to study quantitatively the effects of herbaceous vegetation on soil moisture depletion in an old field of McDonald Forest. He found the severity of the drought conditions comparable to those of more arid regions, but these conditions could be ameliorated by reduction of the vegetation density.

The five species studied would vary in the competition which they would present to seedling establishment. *Acer* would present the most competitive moisture conditions for seedlings. These stands remove moisture rapidly and from a depth of at least two feet while intercepting most of the precipitation.

*Holcus* would also create unfavorable conditions. *Holcus* stands deplete the moisture rapidly near the surface and allow little moisture addition during the summer. Because of the high air temperatures near the ground surface, *Holcus* would create both conditions of high transpirational stress and of frequently
lethal temperatures.

Lotus stands would also be competitive with tree seedlings. Lotus withdraws moisture rapidly, particularly from the deeper levels.

Gaultheria and Berberis stands, on the other hand, would present less severe conditions. Moisture removal rates are comparatively slow at all three depths.
VI. SUMMARY

Soil moisture depletion trends under five plant species growing on the clear-cuts of the Marys Peak Watershed near Corvallis, Oregon, were followed during the summers of 1963 and 1964. The species studies were Holcus lanatus, Lotus crassifolius var. subglaber, Gaultheria shallon, Berberis nervosa, and Acer circinatum; and were dominant plants of several stages in a successional sere occurring on the clear-cuts.

Two clear-cuts were chosen for study in order to reduce the variability due to location. It was possible to choose only two because the successional stages overlapped, and there were localized differences in species' distributions on the clear-cuts. Gaultheria, Berberis, and Lotus were growing in individual, pure stands on one clear-cut. On the other clear-cut Acer was growing in closely grouped clumps with Holcus occupying the area in between.

Soil moisture was sampled in each species using an electrical resistance method of measurement. Plaster-of-paris blocks were installed at 6-, 12-, and 24-inch depths at nine locations, and readings were taken two or three times a week using an ohmmeter. An average of the readings were made for each day and depth, and then each average was converted to moisture tension in atmospheres.
Supporting information on precipitation, root distribution, and soil characteristics was also obtained. The precipitation was collected in rain gauges which were placed on stumps in each clear-cut. The root distribution was examined from trenches 7 feet long and 30 inches deep dug in each species, and a root count for roots less than two mm. in diameter was made within four-inch bands encompassing the 6-, 12-, and 24-inch levels. Soil descriptions were made from trenches on both clear-cuts. The particle size distribution and 15 atmospheres moisture suction point were determined from soil samples taken at the three depths in the vicinity of every other moisture depletion station. The soil profile descriptions, particle size analysis, and the 15 atmospheres determinations indicated that soils on the two clear-cuts were similar.

Each species had characteristic moisture depletion trends during the two years in spite of differences in precipitation and changes in abundance of two species, *Holcus* and *Acer*. *Holcus* declined the second year as part of the successional process, and *Acer* clumps increased in size with growth.

Moisture depletion trends for *Gaultheria* indicated slow rates of moisture loss at all three depths. *Gaultheria*, an evergreen shrub, has thick, leathery leaves (characteristics which are generally associated with few stomata) and has a long period
during which new stems emerge. The roots were concentrated near the surface just under the one and half to two inches of litter and a few were growing inside large, dead roots of Douglas-fir.

Depletion trends associated with Berberis were similar to Gaultheria except moisture losses at the 6-inch depth were more rapid. Berberis plants are also evergreen shrubs and have thick, leathery leaves but grow during a short period in the spring. Most of the roots developed in the top few inches of soil. Litter accumulation was slightly less (one to one and a half inches) and not as uniformly distributed.

Under Lotus, moisture trends at 6 and 12 inches fluctuated considerably, and depletion rates were rapid at all three depths. Lotus, a herbaceous species, grew quickly in the spring then died back in mid-summer, evidently allowing increased infiltration of the rainfall. Litter accumulation was only about an inch, and the soil surface was somewhat rocky, factors which also may have allowed increased infiltration. The rhizomes penetrated throughout the soil profile. The root count indicated contamination of Lotus stands by residual Holcus plants. This contamination, however, is thought to be of little consequence in soil moisture removal because many of the roots were probably dead and carried over from previous years. In addition, all
contaminating species were rigorously weeded from the sampling areas.

_Holcus_ trends at 6 and 12 inches showed an early and rapid moisture loss but a slightly delayed and slower loss at 24 inches. _Holcus_, a perennial bunch grass, also grew rapidly in the spring and then died back about mid-summer. Regrowth of new leaf blades occurred following a substantial rainfall. The erect culms (allowing light penetration and restricting air movement) and the dense mat of grass leaves (amounting to about two inches and reducing heat conduction) created high air temperatures which probably caused high evapotranspiration rates. Root concentration was greatest near the surface and decreased sharply with depth.

Moisture losses under _Acer_ were rapid at all three depths and very consistent without any fluctuations. _Acer_ clumps grew during the spring and maintained their leaves throughout the summer. Such comparatively large plants (six to seven feet high) evidently had a high transpirational stress, and along with the one to two inches of litter, intercepted most of the precipitation. Root concentration decreased gradually with depth.

The results of this study suggest, at least a partial explanation for the replacement of _Holcus_ by _Lotus_. _Holcus_ roots are extremely dense near the surface and decrease in numbers with
depth. Moisture depletion, especially during the year of decline, is rapid at the surface and much less so at the deeper levels. Under such conditions, *Lotus* may be suited to invade these stands through rhizomes penetrating below the dense root system of *Holcus* and utilizing the moisture at the deeper levels.

Possible explanations for the replacement of other species were not as evident; however, there are some interesting correlations of the results with the succession sequence. The consistency of soil moisture use appears related to the successional position of the plants involved. Trends of *Holcus* and *Lotus* fluctuated considerably during both years while those of *Gaultheria*, *Berberis*, and particularly *Acer* were more consistent. Also correlated are the number of roots. Except for *Lotus* which had the smallest number, the root count decreased with each advancing state. This decrease is a reflection of a greater proportion of larger roots.

Results of this study are applicable to forest regeneration problems on clear-cut areas. One of the major problems is the influence of competing vegetation upon tree seedling establishment and growth. In terms of influence upon soil moisture, *Acer* stands would be very competitive. *Holcus* and *Lotus* stands would also be very competitive, *Lotus* perhaps more so at the deeper levels. *Gaultheria* and *Berberis* stands, on the other hand, would not be nearly as detrimental to tree seedling establishment.
BIBLIOGRAPHY


APPENDIX
<table>
<thead>
<tr>
<th>Zone</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2 to 0 inches, leaf litter</td>
</tr>
<tr>
<td>A1</td>
<td>0 to 3 inches, dark reddish brown (5YR 3/4) fine gravelly, silty clay loam, reddish brown (5YR 4/4) when dry, with 50 percent angular cobbles, 3 to 5 inches; moderate, fine granular structure; firm, slightly sticky, slightly plastic; many, fine to medium, interstitial pores; very strongly acid (pH 5.0); clear, smooth boundary.</td>
</tr>
<tr>
<td>B1</td>
<td>3 to 20 inches, dark reddish brown (5YR 3/4) silty clay, yellowish red (5YR 4/6) when dry, with 20 to 30 percent angular cobbles, 1 to 5 inches; moderate, medium, subangular blocky structure; friable, slightly sticky, slightly plastic; many, very fine, tubular pores; worm channels, 5 to 10 mm. in diameter and 5 to 10/sq. ft., filled with dark reddish brown (5YR 3/2) casts; very strongly acid (pH 4.9) clear, smooth boundary.</td>
</tr>
<tr>
<td>B2</td>
<td>20 to 38 inches, dark brown (7.5YR 4/4) silty clay, strong brown (7.5YR 5/6) when dry, with 30 to 40 percent angular cobbles, 1 to 5 inches; moderate, coarse, subangular blocky breaking to moderate, medium, subangular blocky structure; friable, slightly sticky, slightly plastic; clay skins on ped surfaces; common, very fine, tubular pores; worm channels, 5 to 10 mm. in diameter and 5 to 10/sq. ft.; very strongly acid (pH 4.9); clear, smooth boundary.</td>
</tr>
<tr>
<td>B3</td>
<td>38 to 50 inches, strong brown (7.5YR 5/6) angular cobbly silty clay, reddish yellow (7.5YR 6/6) when dry; moderate, medium, subangular blocky breaking to moderate, fine, subangular blocky structure; friable, slightly sticky, slightly plastic; clay skins on ped surfaces; few, very fine, tubular pores; strongly acid (pH 5.3).</td>
</tr>
</tbody>
</table>
Table 2. Soil profile description under Lotus

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1 to 0 inches, leaf and stem litter</td>
</tr>
<tr>
<td>A1</td>
<td>0 to 6 inches, dark reddish brown (5YR 3/3) fine gravelly silty clay, yellowish red (5YR 4/6) when dry, with 70 to 80 percent angular cobbles, 3 to 6 inches; moderately weak, very fine, subangular blocky structure; friable, slightly sticky, slightly plastic; many, very fine, interstitial pores, strongly acid (pH 5.4); clear, smooth boundary.</td>
</tr>
<tr>
<td>B1</td>
<td>6 to 20 inches, dark reddish brown (5YR 3/3) clay, yellowish red (5YR 4/6) when dry, with 20 to 30 percent angular cobbles, 2 to 5 inches; moderate, medium, subangular blocky structure; friable, slightly sticky, slightly plastic; clay skins on ped surfaces; common, very fine, tubular pores; worm channels, 5 to 8 mm. in diameter and 8 to 10/sq. ft., filled with dark reddish brown (5YR 3/3) casts; very strongly acid (pH 4.9); clear, smooth boundary.</td>
</tr>
<tr>
<td>B21</td>
<td>20 to 40 inches, yellowish red (5YR 4/6) silty clay, strong brown (7.5YR 5/6) when dry, with 20 to 30 percent angular cobbles, 2 to 5 inches; moderate, coarse, angular blocky breaking to moderate, medium, angular blocky structure; friable, slightly sticky, slightly plastic; clay films on ped surfaces; many, very fine tubular pores, worm channels, 5 to 8 mm. in diameter and 3 to 5/sq. ft.; very strongly acid (pH 5.0); gradual, smooth boundary.</td>
</tr>
<tr>
<td>B22</td>
<td>40 to 60 inches, yellowish red (5YR 4/6) clay, strong brown (7.5YR 4/6) when dry, with 30 to 50 percent angular cobbles, 3 to 6 inches; moderate, coarse, angular blocky breaking to moderate, medium, angular blocky structure; friable, slightly sticky, slightly plastic; clay skins on ped surfaces; common, very fine, tubular pores, very strongly acid (pH 4.8).</td>
</tr>
</tbody>
</table>
Table 3. Soil profile description under *Acer*

<table>
<thead>
<tr>
<th>Layer</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2 to 0 inches, leaf litter</td>
</tr>
<tr>
<td>A1</td>
<td>0 to 17 inches and tonguing to 27 inches, dark reddish brown (5YR 3/3) silty clay, reddish brown (5YR 4/4) when dry, with many iron-manganese concretions and pieces of charcoal, 2 to 3 mm.; moderately weak, coarse, granular structure; very friable, slightly sticky, slightly plastic; common, very fine, tubular pores; strongly acid (pH 5.1); abrupt, irregular boundary.</td>
</tr>
<tr>
<td>B21</td>
<td>17 to 29 inches, dark reddish brown (5YR 3/4) clay, yellowish red (5YR 4/6) when dry, moderate, coarse, subangular blocky breaking to moderate, medium subangular blocky structure; very friable, slightly sticky, slightly plastic; clay skins on ped surfaces; few, very fine and fine, tubular pores; very strongly acid (pH 4.7); clear, wavy boundary.</td>
</tr>
<tr>
<td>B22</td>
<td>29 to 40 inches, yellowish red (5YR 4/6) clay, yellowish red (5YR 5/8) when dry, with black flecks; moderate, coarse and medium, angular blocky breaking to medium and fine, angular blocky structure; very friable, slightly sticky, slightly plastic; clay skins on ped surfaces; many, very fine, tubular pores; very strongly acid (pH 4.6); clear, wavy, boundary.</td>
</tr>
<tr>
<td>C</td>
<td>40 to 50 inches, black coated, partly weathered rock breaking to strong brown (7.5YR 5/6) clay, reddish yellow (7.5YR 6/6) when dry; strong, coarse and medium, angular blocky structure; slightly sticky, slightly plastic; few, very fine, tubular pores, and common, very fine interstitial pores; very strongly acid (pH 4.6).</td>
</tr>
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</table>
Table 4. Root identification characteristics

<table>
<thead>
<tr>
<th>Species</th>
<th>Color</th>
<th>Odor</th>
<th>Xylem and phloem separation</th>
<th>Surface features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gaultheria</td>
<td>Brown outside white inside</td>
<td>Sweet</td>
<td>Xylem soft, not easily separated from phloem</td>
<td>Many root hairs on rhizomes, leaf scales not appressed</td>
</tr>
<tr>
<td>Berberis</td>
<td>Black outside yellow inside</td>
<td>None</td>
<td>Xylem tough, easily separated from phloem</td>
<td>Few root hairs on rhizome, leaf scales appressed</td>
</tr>
<tr>
<td>Lotus</td>
<td>Light brown outside, white inside</td>
<td>Pungent</td>
<td>Xylem tough, easily separated from phloem</td>
<td>Few root hairs on rhizome, leaf scales inconspicuous</td>
</tr>
<tr>
<td>Holcus</td>
<td>White outside, white inside</td>
<td>None</td>
<td>Not noted</td>
<td>Many very fine root hairs, roots less than two mm. in diameter</td>
</tr>
<tr>
<td>Acer</td>
<td>Brown to black outside, white inside</td>
<td>None</td>
<td>Not noted</td>
<td>Few root hairs, small roots with striations running length-wise, large roots with smooth bark</td>
</tr>
</tbody>
</table>
Table 5. Particle size distribution showing percent of each fraction. Size range for each fraction given in millimeters

<table>
<thead>
<tr>
<th>Sample location (Clear-cut No.)</th>
<th>Depth</th>
<th>Sand 2-.05</th>
<th>Silt .05-.002</th>
<th>Clay .002</th>
<th>Textural class 1/</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gaultheria</strong> (Clear-cut No. 12)</td>
<td>6&quot;</td>
<td>16.40</td>
<td>39.76</td>
<td>43.84</td>
<td>Silty clay</td>
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<tr>
<td></td>
<td>12&quot;</td>
<td>14.13</td>
<td>39.45</td>
<td>46.42</td>
<td>Clay</td>
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<tr>
<td></td>
<td>24&quot;</td>
<td>14.79</td>
<td>41.76</td>
<td>43.45</td>
<td>Silty clay</td>
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<tr>
<td><strong>Lotus</strong> (Clear-cut No. 12)</td>
<td>6&quot;</td>
<td>20.97</td>
<td>39.07</td>
<td>39.96</td>
<td>Clay</td>
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<td></td>
<td>12&quot;</td>
<td>19.89</td>
<td>38.69</td>
<td>41.42</td>
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<td></td>
<td>24&quot;</td>
<td>16.99</td>
<td>40.37</td>
<td>42.64</td>
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<tr>
<td><strong>Acer</strong> (Clear-cut No. 31)</td>
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<td>18.36</td>
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<td></td>
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<td>8.47</td>
<td>32.25</td>
<td>59.28</td>
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<td></td>
<td>24&quot;</td>
<td>5.62</td>
<td>28.99</td>
<td>65.39</td>
<td>Clay</td>
</tr>
</tbody>
</table>

1/ Determined from textural triangle in Soil Survey Manual, p. 209. (Soil Survey Staff, 1951)
Table 6. Percent soil moisture at 15 atmospheres tension

<table>
<thead>
<tr>
<th>Depth</th>
<th>Gaultheria</th>
<th>Berberis</th>
<th>Lotus</th>
<th>Holcus</th>
<th>Acer</th>
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</thead>
<tbody>
<tr>
<td>6-inch Depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>25.3</td>
<td>25.6</td>
<td>24.5</td>
<td>24.7</td>
<td>24.6</td>
</tr>
<tr>
<td>B</td>
<td>25.4</td>
<td>26.1</td>
<td>23.9</td>
<td>25.5</td>
<td>25.2</td>
</tr>
<tr>
<td>12-inch Depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>25.4</td>
<td>25.8</td>
<td>23.9</td>
<td>26.5</td>
<td>26.5</td>
</tr>
<tr>
<td>B</td>
<td>25.7</td>
<td>25.0</td>
<td>23.7</td>
<td>27.9</td>
<td>26.3</td>
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<tr>
<td>24-inch Depth</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>26.1</td>
<td>26.1</td>
<td>24.8</td>
<td>30.6</td>
<td>29.7</td>
</tr>
<tr>
<td>B</td>
<td>25.6</td>
<td>27.2</td>
<td>24.0</td>
<td>29.3</td>
<td>27.7</td>
</tr>
</tbody>
</table>

1/ Combined samples of pits 1 and 3.
2/ Combined samples of pits 5 and 7.