# Structure of Mature Douglas-fir Stands in a Western Oregon Watershed and Implications for Interpretation of Disturbance History and Succession

by

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Title: Structure of Mature Douglas-fir Stands in a Western Oregon Watershed and Implications for Interpretation of Disturbance History and Succession

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The structure of a mature Douglas-fir (Pseudotsuga menziesii) forest in a watershed in the western Cascades of Oregon was examined. Two age classes were detected in the stand, the oldest originating about 1855 after an extensive fire and the younger following a second fire about 1895. Although the trees in the older age class had statistically greater diameters and heights, only open grown individuals mixed with the younger age class could be readily distinguished. Because reburns at young ages are common and may not leave firescars, great care is be required to distinguish between slow regeneration and patchy reburns.

The early stand history varied greatly between the two age classes. More than 70% of the trees in the younger portion of the stand were established within a 15 year period while comparable establishment in the older areas required over 35 years. The broad range of ages in older age class, combined with significantly lower stocking density and mortality, resulted in a nearly flat diameter distribution compared with a bell-shaped distribution for the younger age class.

The stand is heavily dominated by Douglas-fir which accounts for about 90% of the trees in the younger age class and 77% of the trees in the older portions of the stand. The older portion of the drainage has significantly more western hemlock (*Tsuga heterophylla*) and western dogwood (*Cornus nuttallii*). The younger portion of the drainage contains more early successional hardwoods including the remnants of a considerable population of bitter cherry (*Prunus emarginata*). Currently, almost no western redcedar (*Thuja plicata*) is found in the drainage although old redcedar logs or snags are still present on one quarter of the plots. The abundance of western hemlock and redcedar is much less than similar aged stands in the nearby H. J. Andrews Experimental Forest. The slow regeneration of the site following the first fire probably reflects a shortage of seed due to a hot burn and dispersal distances four to ten times greater than those reported by Issac (1943). The low abundance of western hemlock and virtual elimination of redcedar are attributed to even greater dispersal distances, low mobility of redcedar seed, and harsh establishment conditions.

The rapid regeneration following the second fire suggests efficient seed dispersal or storage with young trees and the potential importance of the understory exclusion phase of stand development on regeneration.

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# Structure of Mature Douglas-fir Stands in a Western Oregon Watershed and Implications for Interpretation of Disturbance History and Succession

## INTRODUCTION

The study of forest stand development or dynamics is a necessary bridge between tree physiology and the the studies of succession, ecosystem analysis, and silviculture (Oliver 1982). The study of forest stand dynamics has lead to an appreciation for the importance of disturbance, as well as a better understanding of forest age structure and of stand response to silvicultural thinning. In the future, work on stand development promises to reduce silvicultural costs, increase stand productivity, and provide a better understanding of the mechanisms by which desirable stand characteristics such as species composition and old-growth structure may be achieved.

While the Tsuga heterophylla Zone is the most extensive vegetation zone in western Oregon and Washington (Franklin and Dyrness 1973), studies of forest stand dynamics in these forests have been quite limited. This lack may result partly from the belief that the major stand development work has already been done by Hofmann (1924), Munger (1930, 1940), Issac (1943) and others. While these works provide an important contextual framework, substantial work is still required in early succession, processes associated with canopy closure, dynamics of natural thinning, responses to many different types and sizes of disturbances, the dynamics of interspecific competition, the characteristics of old-growth forests, and many other phenomena.

While the dwindling supply of old-growth forests is triggering a flurry of research activity into their structure (Franklin and Waring 1979, Franklin et al. 1981), little work has been done on natural mature stands. Most descriptions of these forests have been either anecdotal accounts or the results of phytosociological studies using subjective sampling methods. While both of these are useful, they fail to provide a complete and unbiased description of the forests.

In addition to the need for stand structure information on natural mature forests, the examination of mature stands is useful because they still retain clues about their origins. This is important because the conditions under which a stand is established can have a strong influence on the later development of a stand (Grubb 1977). Historically, fire is the primary catastrophic disturbance mechanism in the forests of the Pacific Northwest (Martin et al. 1974). Regeneration following a catastrophic fire in a mature or old-growth forest on modal sites is generally quite rapid, usually within the first one or two years, resulting in a narrow range of ages (Hofmann 1917, Issac 1936, Volland and Dell 1981, Chandler 1983). However, several studies have indicated that the age structure of dominants in old-growth Douglas-fir (Pseudotsuga menziesii) forests have a very broad range of ages, often well over 100 years (Hemstrom 1979, Franklin and Waring 1980, Stewart 1984). While harsh environmental conditions are certainly important in the slow regeneration of hot, dry sites (Means 1981) and exposed upper-elevation areas, they do not account for the broad range of ages on modal sites. Several potential factors have been proposed to account for these broad age differences including competing vegetation, elimination of seed source resulting from extremely extensive fires requiring gradual recolonization, and multiple small disturbances opening portions of the stand. Since the theory of uniformity applies to ecology as well as geology, the factors which created the broad range of ages in old-growth stands should still be active today although perhaps at different rates. The differences in rates may be very important since the apparent size of the fires originating the major age classes of old-growth forests appear to be larger than historical fires.

This study examines the stand dynamics of a mature Douglas-fir forest of fire origin at the Hagan Research Natural Area (RNA) in the central western Cascades of Oregon. In addition to reporting baseline information on stand structure for use by future researchers at the RNA, the objective of the study is to reconstruct the development history of the stand and place it in a successional context. This would provide needed information on mature stands and help future researchers at the RNA to interpret their results. Of particular interest in this study are the implications of disturbance timing and extent on forest regeneration, development, and the broad range of ages found in many old-growth forests.

# DESCRIPTION OF STUDY AREA

The study area consists of the 1430 hectare Hagan Creek drainage with most plots in the 470 ha. North Fork which contains the Hagan Research Natural Area (RNA). The drainage is located 56km ENE of Eugene, Oregon at 44$^{o}$ 11' N latitude and 122$^{o}$ 25', 13km west of the H. J. Andrews Experimental Forest (Figure 1). The soils, geology, and landforms of the study area are typical of the western Oregon Cascades. The land is deeply dissected with steep slopes averaging 66% (33.5$^{o}$) on the plots. The elevation ranges from 520 m at the stream bottom to 1070 m at the ridgetops. The climate is characterized by mild wet winters and relatively dry summers. The average July temperature is 17.1 $^{o}$C and the average January temperature is 3.9 $^{o}$C, about 1.5 $^{o}$C milder during both periods than comparible H. J. Andrews reference stands. Although measurements are unavailable, rainfall probably exceeds the the 234 cm reported at the H. J. Andrews Experimental Forest as moist air moving up the McKenzie drainage is forced into the Gate and Hagan Creek drainages. In addition these relatively narrow valleys result in more low clouds and fogs than at the H. J. Andrews Forest.

The vegetation in the study area is a mature growth Douglas-fir forest typical of the lower elevations of the western Cascades. Douglas-fir (*Pseudotsuga menziesii*) is the dominant tree species accounting for over 90% of the basal area in the study area. Western hemlock (*Tsuga heterophylla*), bigleaf maple (*Acer macrophyllum*), golden chinquapin (*Castanopsis chrysophylla*), and Pacific yew (*Taxus brevifolia*) cottonwood (*Populus trichocarpa*) are common in seeps and riparian areas. A few bitter cherry (*Prunus emarginata*) trees still persist on

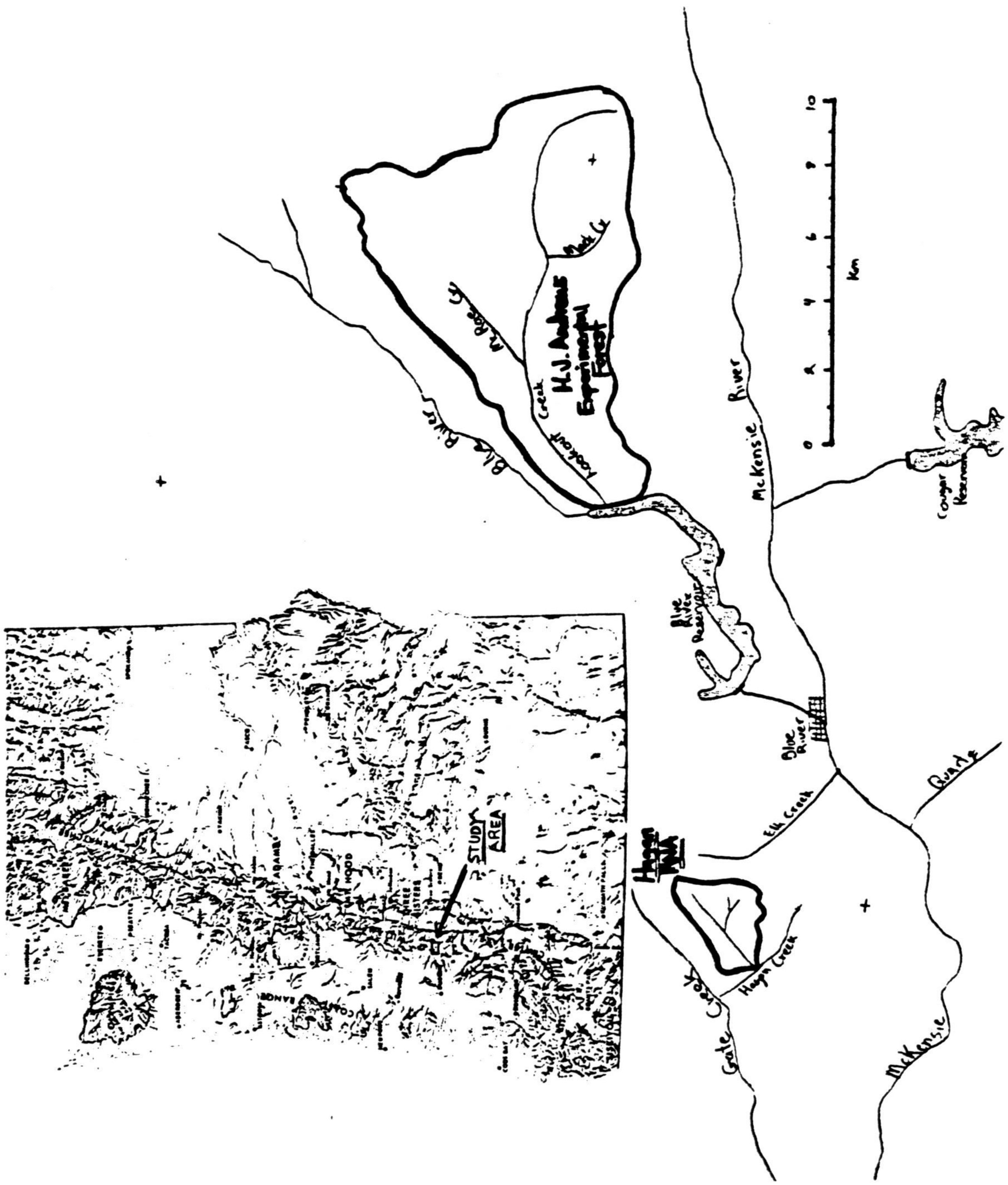



Figure 1. The location of the Hagan Creek study area relative to the H. J. Andrews Experimental Forest and major Oregon Landmarks.

are relatively minor associates. Red alder (Alnus rubra) and black or near ridgetops and the bark from old cherry boles is a common sight in much of the forest. Although little western redcedar (Thuja plicata) was found, abundant snags and logs indicate that it was once an important species.

The vegetation changes dramatically along a moisture gradient. Extremes are represented by the Tsuga heterophylla/Oplopanax horridum (POMU/OPHO) communities in seeps and riparian areas with understories dominated by sword fern (Polystichum munitum), deer fern (Blechnum spicant), lady fern (Athyrium felix-femina), and maiden-hair fern (Adiantum pedatum), and the Pseudotsuga menziesii/Holodiscus discolor/Grass (PSME/HODI/GRASS) communities on dry sites, which are dominated by ocean spray (Holodiscus discolor), serviceberry (Amelanchier alnifolia), hairy manzanita (Arctostaphylos columbiana), beargrass (Xerophyllum tenax), and grasses. Most of the landscape is dominated by less extreme western hemlock climax vegetation. North aspects and toeslopes are occupied by mesic communities, especially the Polystichum munitum (TSHE/POMU), Oxalis oregana (TSHE/OXOR), and Berberis nervosa/-Oxalis oregana (TSHE/BENE/OXOR) communities. With the exception of a few dry sites most of the rest of the area is dominated by modal vegetation types. Vine maple (Acer circinatum) is the most important tall shrub in the study area with an average cover of 30% on the plots. Rhododendron (Rhododendron macrophyllum) was present on about half of the plots but seldom in great abundance. Oregon grape (Berberis nervosa) and salal (Gaultheria shallon) are the most important low shrubs, with both species occurring at nearly identical abundances. As a result (TSHE/BENE) and Berberis nervosa-Gaultheria shallon (TSHE/BENE-

GASH) communities are common.

# METHODS

Information on the study area was collected from three sources: plots stratified on the basis of environmental factors, systematically located plots, and 1 to 2.2 ha reference stands selected to typify certain vegetation types. In the first a full range of environmental conditions was sampled by stratifying the study area on three slope positions (top, middle, and bottom) and eight aspects. At least 3 replicates of each strata were selected on a map. The locations for the 1/10 ha circular plots were identified in the field by selecting the first site in the desired area with the proper aspect which was large enough to hold a plot (without regard to vegetation). Several identical plots were subjectively located in nearby residual patches of old-growth. The systematic sample, designed to provide an unbiased estimate of stand characteristics, consisted of 94 1/10 ha permanent plots placed at 100 m intervals along transects crossing the drainage every 400 m. The first plot on each transect was placed a random distance between 0 and 100 m from the ridgeline.

The plots used in the first two sampling strategies were virtually identical. On each plot environmental variables--slope, aspect, slope position, landform, and soil characteristics--were measured and plant covers were estimated for all species of trees, shrubs, and herbs. Within each plot the species and diameter were recorded for all live trees greater than 5 cm and snags greater than 10 cm in diameter. Because plots in the systematic sample were designed to be permanent, all of the trees were tagged for annual mortality surveys and future remeasurement. The species and size of all tree seedlings and sapling

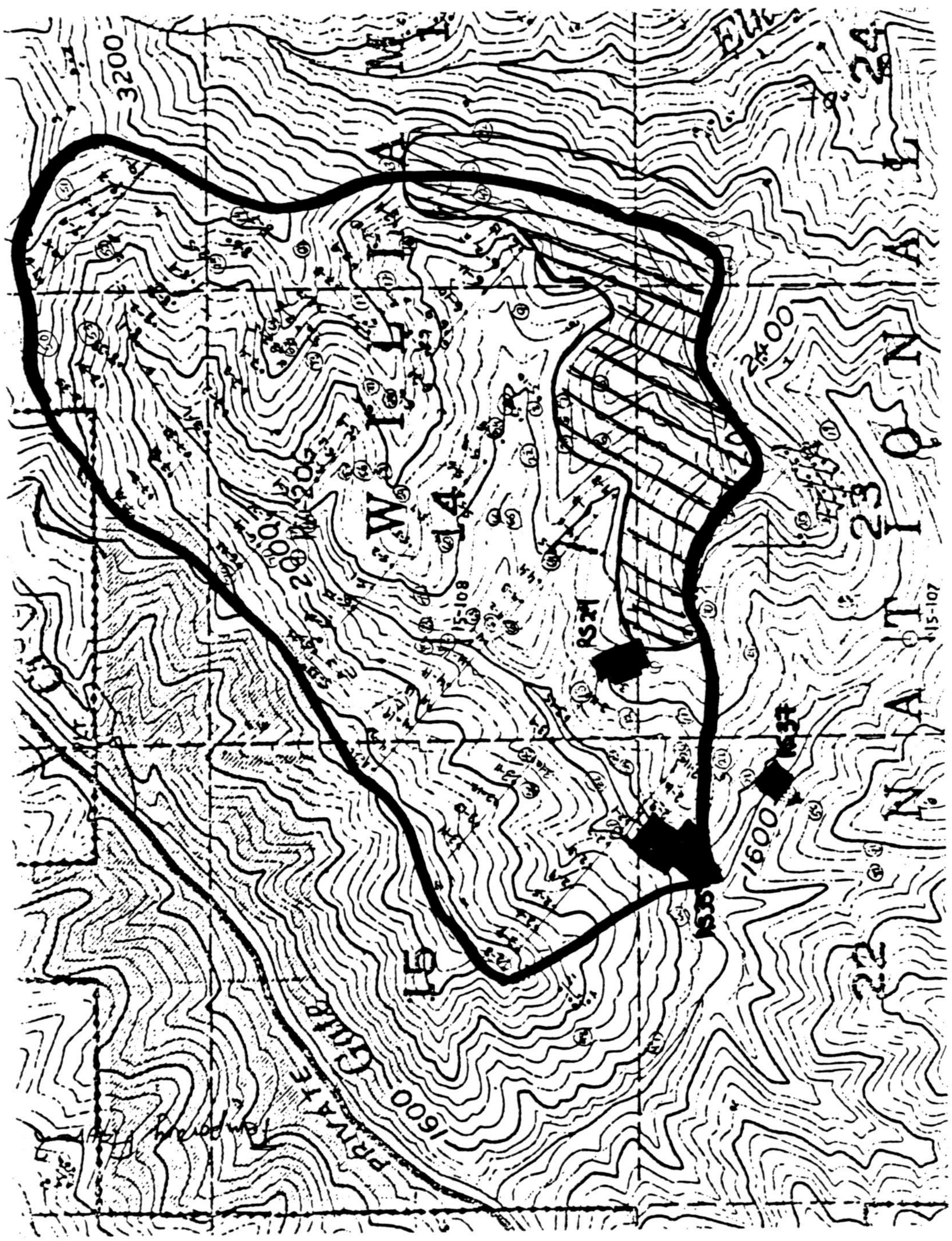



Figure 2. The location of the sample plots within the Hagan Creek Drainage. The circled numbers represent plots in the stratified sample. The dots on the lines represent the transect plots. The three reference stands are represented by solid blocks.

were recorded on four 12.5 m subplots. The location of these subplots was marked with a PVC stake on the transect plots for future remeasurement. Detailed measurements including height, crown length and breast height age were made on four trees per plot. The trees were selected so that at least one tree represented a dominant, usually the largest tree in the plot. The remaining trees were selected from those adjacent to the dominant to provide some insight into the variation within the plot and make measurement more convenient. Ages were measured by coring the tree and counting the rings using a hand lens in the field. If the center of the tree was not reached the age was estimated by extrapolating the inner growth rate to the hypothetical center of the tree. The large woody debris was mapped on every other plot in the transect study. These crude maps indicate the species, size, and decay condition for all woody debris greater than 10 cm in diameter.

The vegetation information was used to classify each plot to community according the the classification proposed by Hemstrom (1984). Because most communities had too few plots for adequate comparisons, the communities were lumped into three classes based primarily on moisture (Zobel et al. 1979) for most subsequent analyses. The moist communities consisted of those generally dominated by sword fern (TSHE/-OPHO, TSHE/OXOR, TSHE/POMU, TSHE/BENE/OXOR). The moderate group consisted of those sites dominated by vine maple, salal, and Oregon grape (TSHE/BENE, TSHE/GASH, TSHE/BENE-GASH, TSHE/RHMA-BENE, and TSHE/RHMA-GASH). The final group consisted of a small assortment of drier sites (TSHE/RHMA/XETE through PSME/HODI/GRASS). Some of these sites, particularly the TSHE/RHMA/XETE, may represent substrate differences which are only partially caused by moisture (Zobel et al. 1979).

Three reference stands were established in the study area. Reference stand #24 (1 ha) was located in the TSHE/BENE-OXOR community type. Reference stands #35 and #37 were located in riparian areas. Reference stand #35 covers 2.2 ha along the North Fork of Hagan Creek and reference stand #37 covers 1 ha along the South Fork. In each stand all the trees greater than 5 cm were tagged, mapped, and their species, diameter, canopy position and vigor were recorded. Large woody debris was recorded and mapped as on the circular plots. The transect plots and reference stands are checked annually for mortality as a part of the Long Term Ecological Research Program (LTER).

Aerial photos and ground reconnaissance were used to examine the age structure of the surrounding area. In addition to aging trees with increment cores, the rings on stumps in recent clearcuts were examined.

# RESULTS

## Fire History

Aerial photographs and ground reconnaissance indicate that about 1855 a catastrophic fire burned at least 6000 ha including nearly the entire Hagan Creek drainage and large portions of both the Elk and Gate Creek drainages (Figure 3). A few pockets of trees survived along Gate Creek and in the southern end of the South Fork of Hagan Creek. Even these surviving patches of trees may have experienced underburning during the fire because western hemlock or western redcedar trees older than 130 years are rare except in very protected areas. The fire in the North Fork drainage containing the Hagan RNA must have been intense to kill all the trees even those in the riparian zones. The ages of dominant Douglas-fir in nearby the residual patches of old-growth are about 450 years suggesting that the burned stand was about 300 years old. This age is supported by a ring count greater than 290 years in a nearly intact Douglas-fir snag within the study area.

The large woody debris maps and reconnaissance indicate many large snags and logs from the previous forest are still present in the drainage. Most are well decayed Douglas-fir ranging from class 3 (heartwood intact) to class 5 (rotted throughout, oval shaped) according to the classification by Fogel et. al (1972). One quarter of the plots mapped for large organic debris contained either western redcedar logs or snags indicating it was a substantial component of the previous forest. Additional redcedar may have been present but has either burned or decomposed beyond recognition. No hemlock snags or logs were discovered but since hemlock decays rapidly (Graham 1981) a substantial

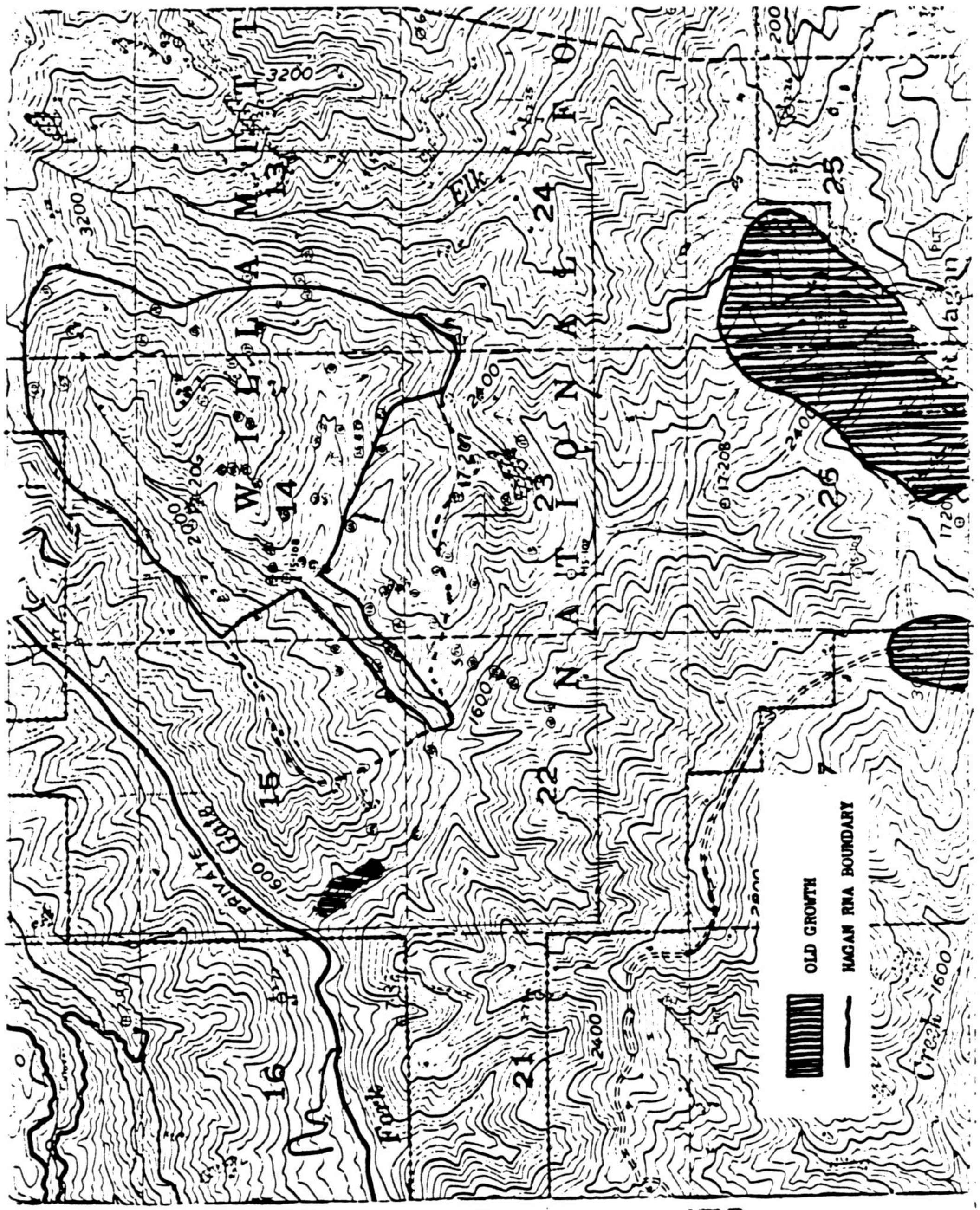



Figure 3. The extent of the ca. 1855 fire in the Hagan, Elk and Gate Creek Drainages. Surviving pockets of old-growth trees are marked with crosshatches. The residual patches closest to the Hagan RNA showed signs of underburning.

population of hemlock is likely to have completely disappeared.

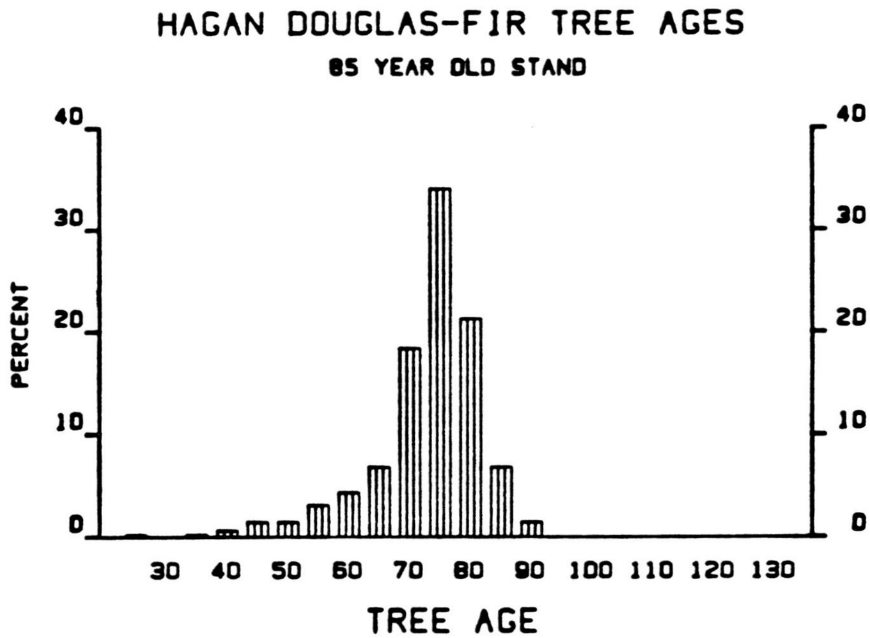
Although the stand initially appeared quite uniform, isolated individuals were found with a distinctive open-grown structure reflected in a long crown and the stubs of large branches near the ground. Cores indicated these trees were 20 to 30 years older than the surrounding stand. The age structure of the stand was then examined by counting the rings on stumps along the road at the western edge of the RNA. The stumps on the south side of a small draw averaged 94.7 rings while those on the north side had only 78.3 a difference significant at the .01 level. The trees adjacent to the stump count exhibited few characteristics to distinguish the two age classes. The older trees appeared only slightly larger than the younger trees and because they represented a closed stand, they lacked the open grown form characteristic of lone individuals.

To further investigate the age patterns, plots were divided into two classes based on the age of the oldest dominant tree. An age of 95 years was selected as a natural dividing point because it was greater than the oldest trees in the young portion of the stand and few trees in the older portion of the stand fell into this age range. The average age of trees examined in the older plots was 98.1 while the average age of trees in the younger age class was 74.8. Even if the oldest dominant trees were excluded, the age classes are significantly different well below the .0001 level even though a few of the plots in the older age class represented a lone older tree among younger individuals. The variation of ages among all the trees in the two ages classes was also significantly different, the younger stand having a standard deviation of 9.1 years compared to 16.6 for the older stand.

This indicates the younger (*ca.* 90 year old) age class colonized more quickly with most regeneration occurring within 10 years while the older age class required at least 25 years for trees to become fully reestablished (Figure 4). The existence of two distinct age classes is further supported by displaying the distribution of the plots in the two age classes (Figure 5). The younger age class dominates the North Fork drainage while the older age class is found only along the stream and on portions of the south side of the watershed. While the younger age class is primarily found on southerly aspects, it extends across some very protected sites with north aspects. Very little variation in age was found among the different community groups.

Plot distribution and field surveys were used to reconstruct the extent of the second fire (Figure 6). The *ca.* 1895 fire burned about 700 ha. including most of the North Fork drainage and parts of the South Fork drainage and Gate Creek. About 60 ha. in the North Fork drainage were only partially reburned and contain patches of trees dating from the first fire. Careful examination often revealed distinct boundaries between the different age classes, such as in the stump count area or the upper edges of the riparian reference stand #35 (Figure 7). In other places, such as reference stand #24, small patches or individuals of the two age classes are intermixed and difficult to separate. Trees on several plots were less than 60 years old. At least one of these plots appears to be the slow regeneration of a raveling, south-facing site and another represents a spot fire (Burke 1979).

No fire scars were found on trees of the older (*ca.* 1855) cohort. However, unlike the snags among the older portion of the stand, snags in the younger areas are generally charred suggesting they may have experienced a fire after their insulating bark was removed.



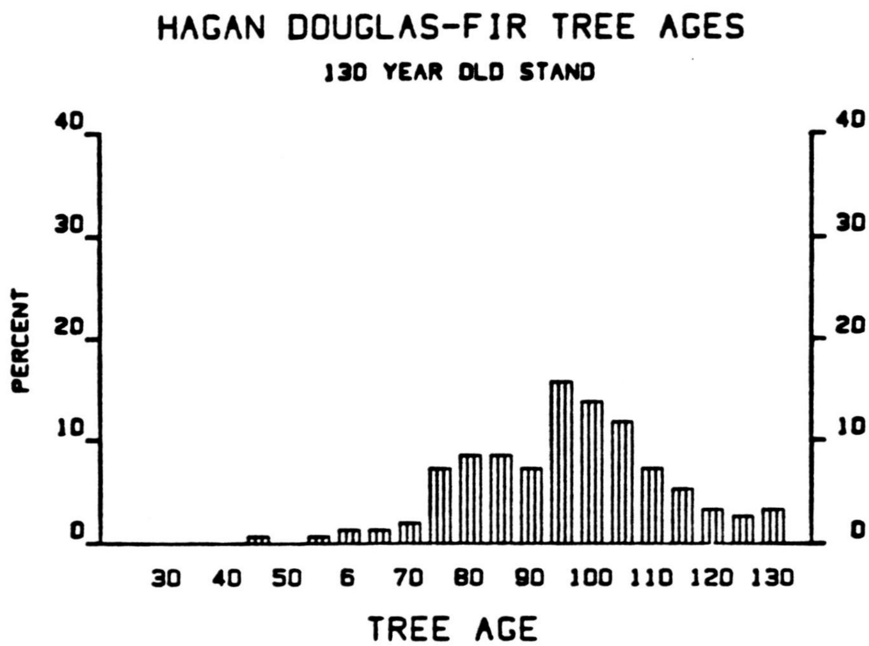




Figure 4. Age class distribution for all sampled trees divided into two age classes based on the age of the plot dominant. The age structure of the older age class is much broader then that of the younger.

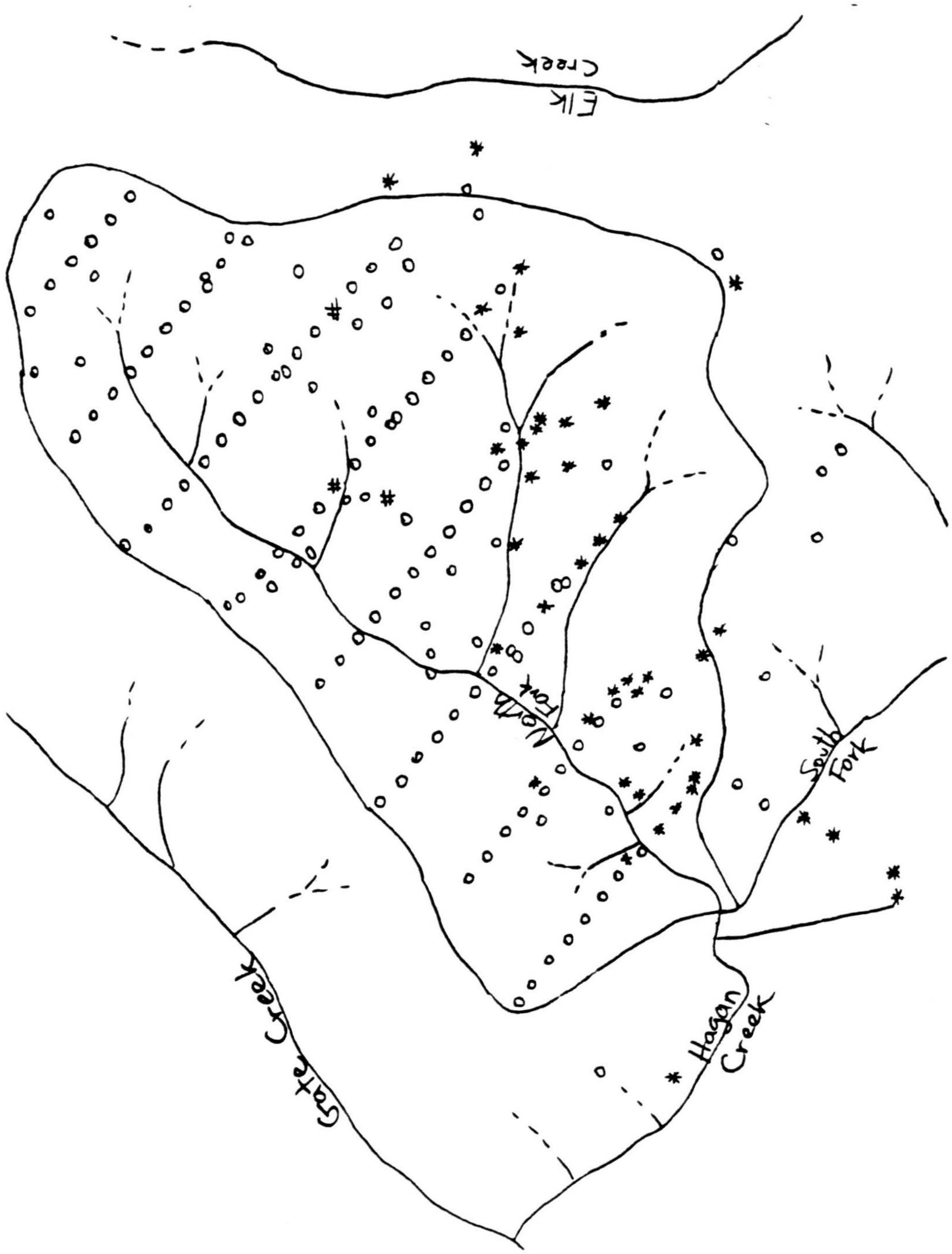



Figure 5. Map showing the distribution of older and younger plots within the Hagan study area. Older plots are represented by a "*", younger plots by a "o" and very young (<60 years) by a "#".

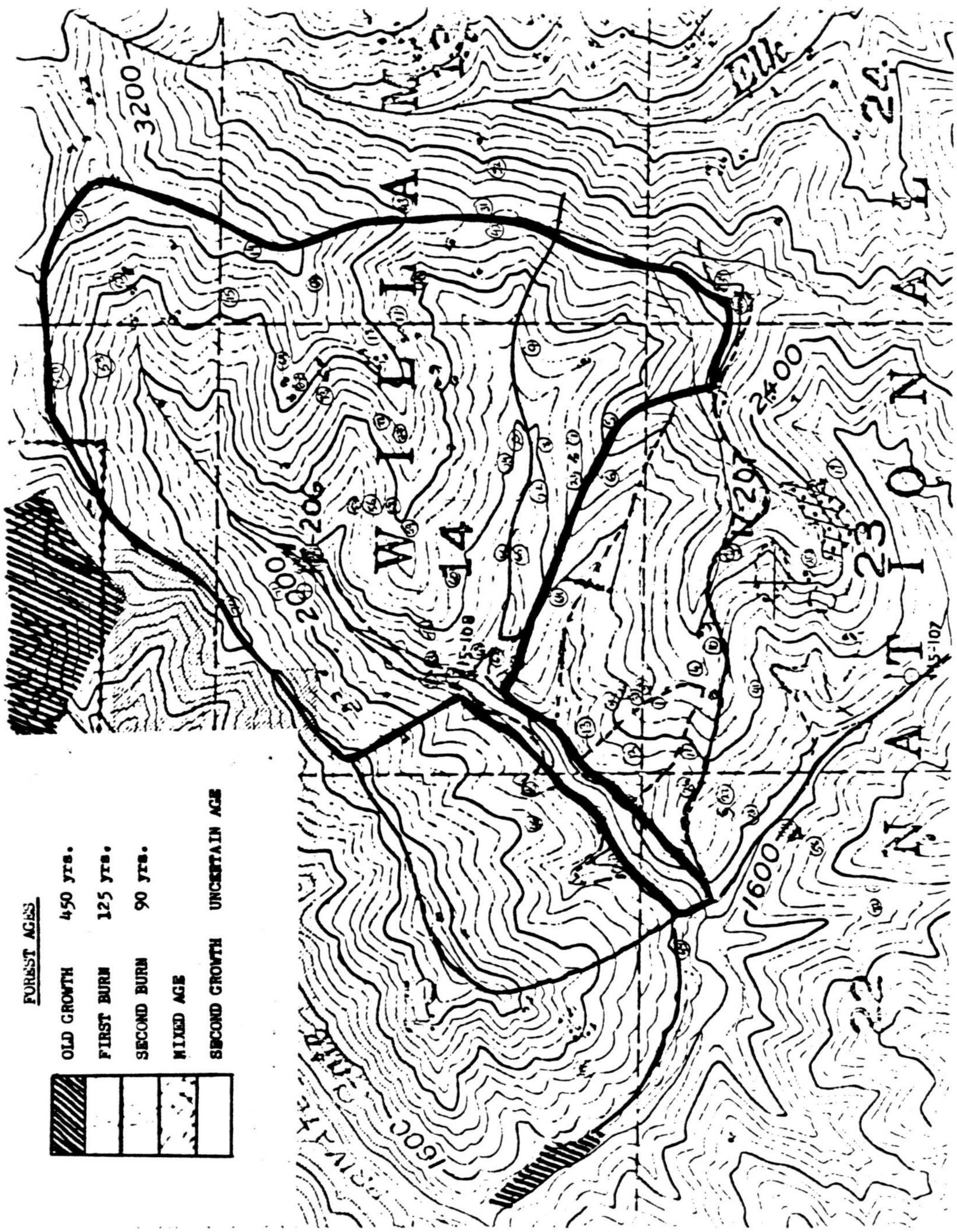



Figure 6. Map showing the extent of the two major Hagan fires as reconstructed from plot information and reconnaissance. The residual old-growth are solid black, the older Hagan age class (130 year) has diagonal hatching, and the younger (90 year) age class is unshaded.

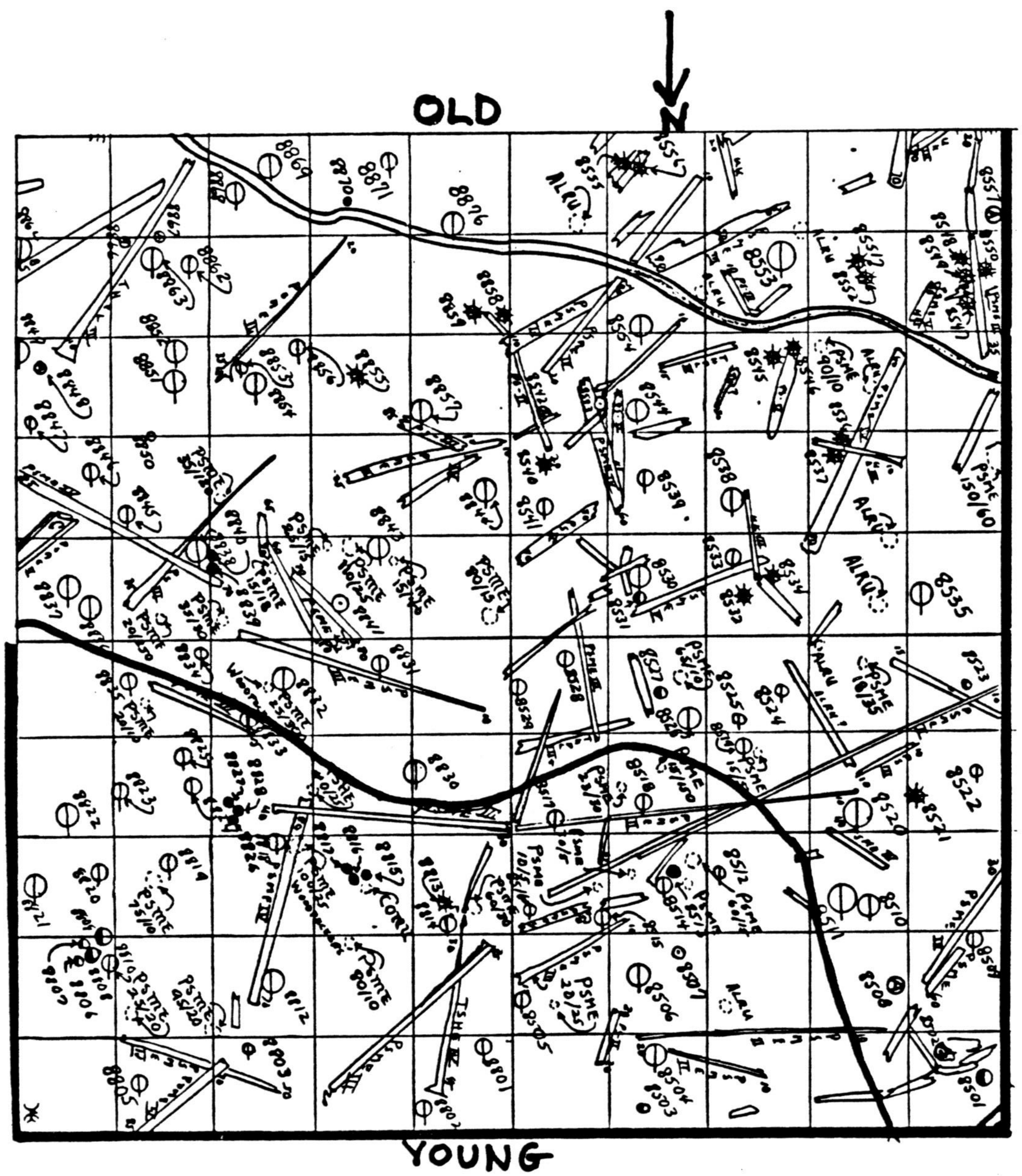



Figure 7. Map showing a portion of riparian reference stand #34. A relative sharp boundary exists between the older trees near the stream (10 m North of this map) and the younger trees on the south end.

## Stand Structure

The systematic plots indicate the current forest is heavily dominated by Douglas-fir (Table 1). Few hemlock or western yew and almost no redcedar are found in the drainage. Redcedar was not found on any of the transect plots because it is rare in all but one location within the watershed. The forest contains a substantial amount of hardwoods primarily golden chinquapin, flowering dogwood (Cornus nuttallii), bigleaf maple and cascara buckthorn (Rhamnus purshiana). The riparian reference stands (Table 2) and other studies (Campbell 1979) indicate that red alder and black cottonwood are common in the riparian areas.

The two mature age classes differ slightly in tree composition (Table 3). The younger age class contains slightly more early successional hardwood species, the most notable being bitter cherry. Although only six live trees were found on the transect plots, cherry logs or bark sheaths are common throughout the younger portions of the stand but are not found anywhere in the older portions. Reduced number of bigleaf maple, golden chinquapin, and cascara buckthorn were also noted although none are statistically significant. The stocking levels of Douglas-fir are also significantly lower in the 130 year old age class, while western hemlock and flowering dogwood are statistically more abundant. Pacific yew is more abundant in the older age class, and the only occurrences of western redcedar are found there.

Although strong differences in the size of Douglas-fir are not obvious in the field, the 130 year old age class has significantly larger diameters and heights than the 90 year old portion of the stand (Table 4). The trees in the older stand also had a slightly deeper

Table 1. Hagan systematic transect stocking level and average diameter in cm

| Species | Number/Hectare | Average Diameter |
|---|---|---|
| *Abies procera* | .12 | 19.60 |
| *Acer macrophyllum* | 6.00 | 22.21 |
| *Alnus rubra* | .75 | 35.80 |
| *Castanopsis chrysophylla* | 16.75 | 19.30 |
| *Cornus nuttallii* | 7.50 | 10.85 |
| *Prunus emarginata* | 1.62 | 12.62 |
| *Pseudotsuga menziesii* | 339.88 | 44.25 |
| *Rhamnus purshiana* | 3.50 | 9.80 |
| *Taxus brevifolia* | 1.00 | 9.32 |
| *Tsuga heterophylla* | 10.88 | 14.92 |

Table 2. Stocking levels for all tree species found in Hagan Reference Stands expressed in number of trees per hectare. All three reference stands are located in moist sites either BENE/OXOR communities or riparian locations.

| Species | Reference Stand | | |
|---|---|---|---|
| | RS24 BENE/OXOR | RS35 Riparian | RS37 Riparian |
| *Acer macrophyllum* | 0.0 | 28.2 | 43.0 |
| *Alnus rubra* | 9.0 | 28.2 | 40.0 |
| *Castanopsis chrysophylla* | 1.0 | 0.0 | 0.0 |
| *Cornus nuttallii* | 5.0 | 19.8 | 7.0 |
| *Pseudotsuga menziesii* | 293.0 | 202.8 | 103.0 |
| *Rhamnus purshiana* | 0.0 | 40.0 | 26.0 |
| *Taxus brevifolia* | 4.0 | 4.7 | 11.0 |
| *Thuja plicata* | 1.0 | 0.5 | 0.0 |
| *Tsuga heterophylla* | 31.0 | 22.1 | 8.0 |

Table 3. Hagan stocking for all plots by community group and age class.

| Species | Number of Trees per Hectare | | | | | |
|---|---|---|---|---|---|---|
| | Mesic | | Modal | | Xeric | |
| | 90 | 130 | 90 | 130 | 90 | 130 |
| *Acer macrophyllum* | 16.8 | 5.8 | 4.3 | 10.4 | 4.7 | ----- |
| *Alnus rubra* | 2.5 | 4.4 | 0.0 | 0.0 | 0.0 | ----- |
| *Castanopsis chrysophylla* | 0.7 | 0.5 | 25.3 | 12.2 | 33.5 | ----- |
| *Cornus nuttallii* | 2.9 | 7.1 | 5.1 | 21.0** | 14.8 | ----- |
| *Prunus emarginata* | 0.0 | 0.0 | 0.8 | 0.0 | 18.8 | ----- |
| *Pseudotsuga menziesii* | 327.2 | 234.1*** | 391.7 | 265.8** | 393.3 | ----- |
| *Rhamnus purshiana* | 0.0 | 1.2 | 1.9 | 0.0 | 9.7 | ----- |
| *Taxus brevifolia* | 1.3 | 11.2 | 0.1 | 0.6 | 0.0 | ----- |
| *Thuja plicata* | 0.0 | 0.4 | 0.0 | 0.6 | 0.0 | ----- |
| *Tsuga heterophylla* | 11.7 | 30.7 | 10.2 | 42.3*** | 11.4 | ----- |

Table 4. Average age, height, and percent of tree length in crown for the Hagan age classes and community groups.

| Stand | Mesic | | Moderate | | Xeric | |
|---|---|---|---|---|---|---|
| Parameter | 90 | 130 | 90 | 130 | 90 | 130 |
| Average Age | 74.1 | 100.5*** | 75.7 | 94.6*** | 68.1 | ---- |
| Average Dominant Height | 47.6 | 57.1*** | 43.9 | 52.9*** | 38.9 | ---- |
| Average % Crown | 41.7 | 48.2* | 42.1 | 52.2*** | 49.6 | ---- |

Level of significance for the difference between the young and old age classes.
* = .05
** = .01
*** = less than .001

crown. While the difference in crown length with age is significant, crown length is not strongly linked to communities but rather is related to canopy position and other factors. The diameter distributions (Figures 8,9 and 10) for the older age class were broader and flatter than those for the younger age class. This corresponds with the results reported by others for even aged, shade-intolerant species (Baker 1923, Lorimer and Krug 1983). Diameter growth rate was determined from the increment cores on 493 trees (Figure 11). No significant differences existed between the growth rates on wet and moderate community groups, but growth rates were slighter slower for older trees than younger trees of the same size. Larger trees of both age classes had significantly higher growth rates.

Neither Hagan age class had much regeneration when compared with the old-growth in WS2 at the H. J. Andrews Experimental Forest (Table 5). Regeneration in the 90 year old portion of the stand was dominated by of chinquapin and cascara seedlings although Douglas-fir, flowering dogwood, and hemlock seedlings were comparatively common. The 130 year old stand has significantly less cascara and more hemlock regeneration.

Many of the hardwood species are being overtopped and eliminated from the stand. Our mortality survey of the transect plots indicated that nearly all the bitter cherry trees died the next year. When the riparian reference stand #35 was established in 1981 recently fallen red alder logs were common. In 1982 and 1983 the mortality surveys indicated ten percent of the remaining red alder in that stand died. Because stand mortality measurements are only available for three years (Table 6), snag and uproot tallies (Table 7) were used as an indication of recent mortality. Since snag decay is diameter dependent (Graham

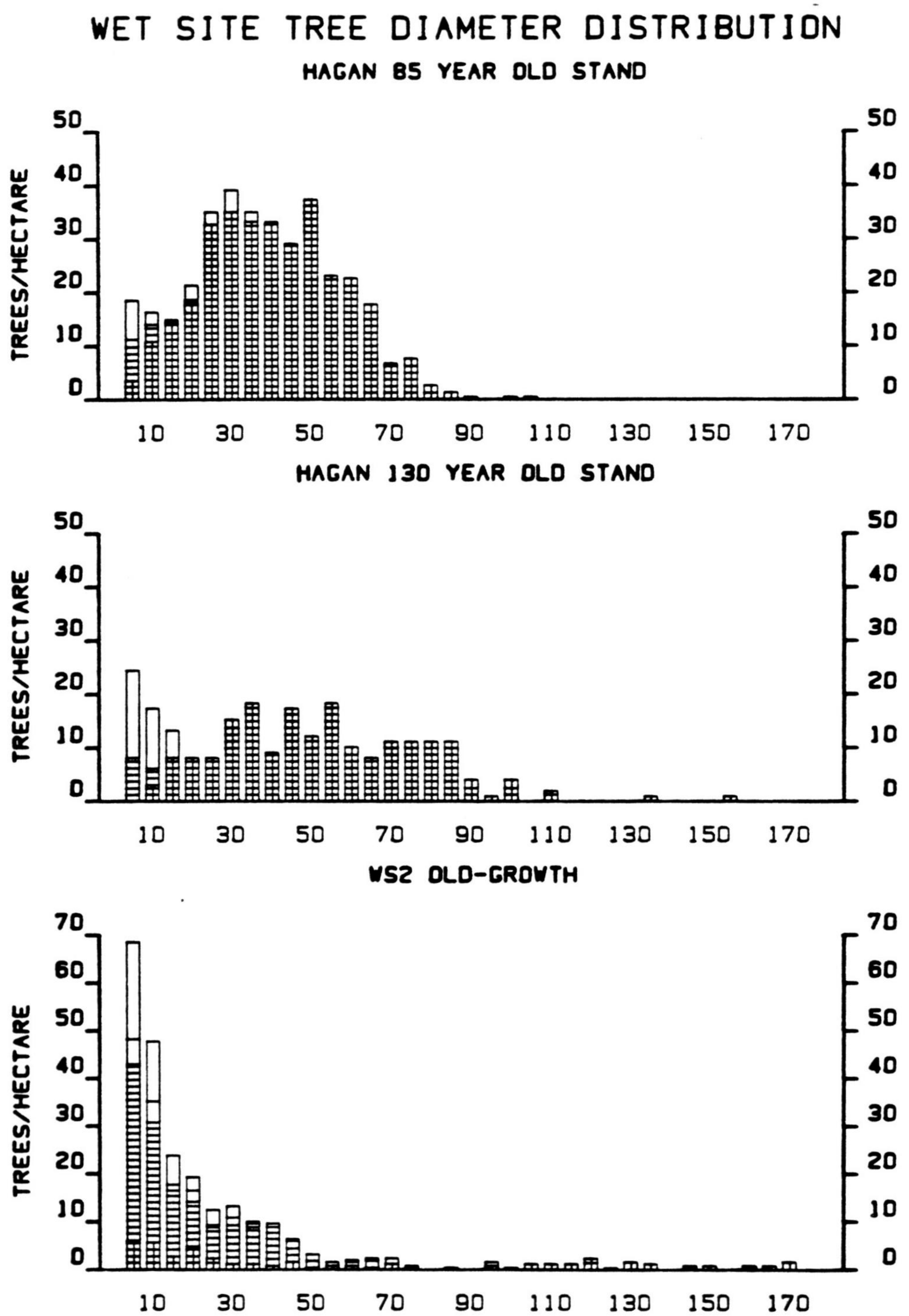



Figure 8. Diameter distributions for trees in the moister communities in the 90 and 130 year age classes at the Hagan and Watershed #2 old-growth at the nearby H. J. Andrews Experimental Forest.

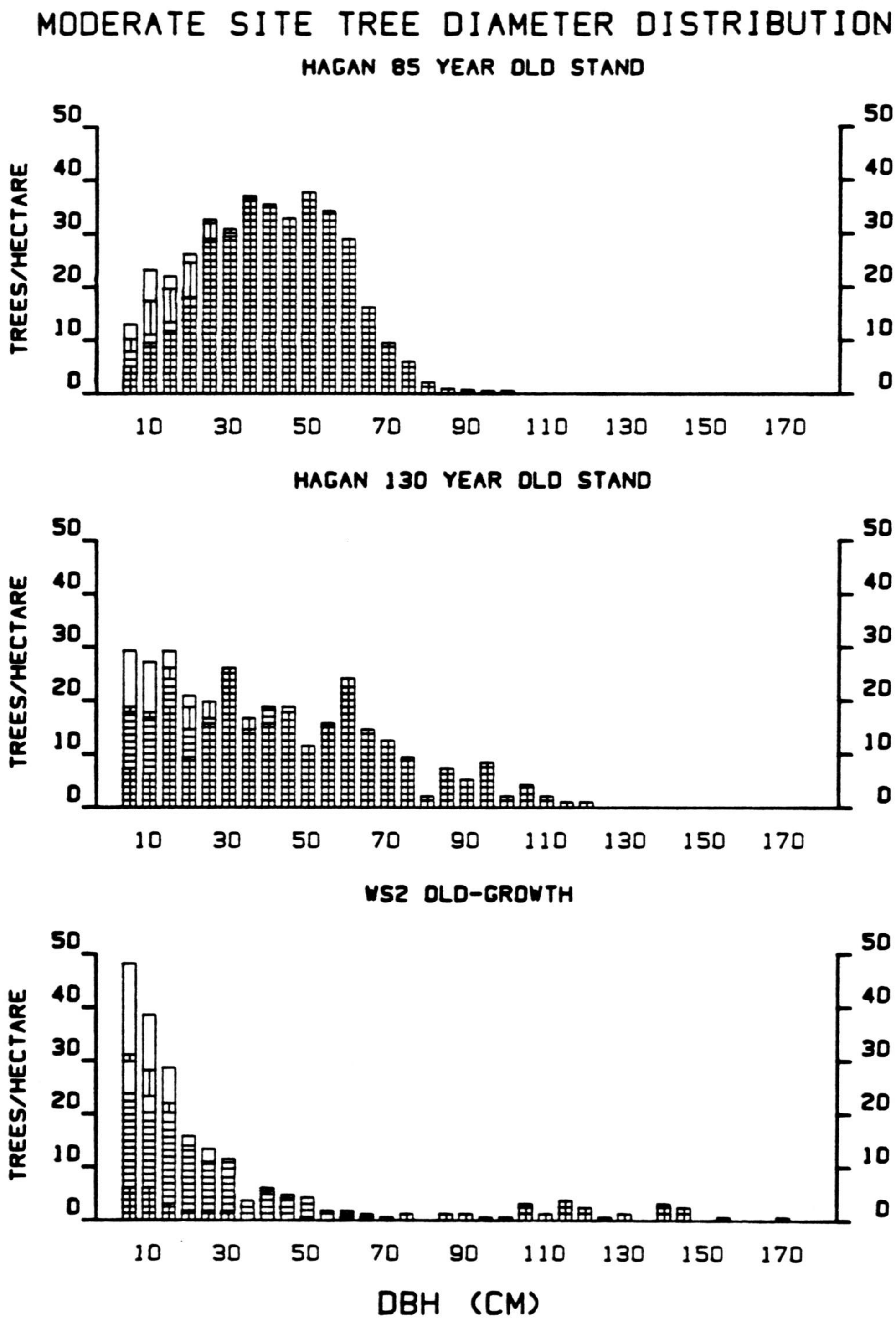



Figure 9. Diameter distributions for trees in the modal communities in the 90 and 130 year age classes at the Hagan and Watershed #2 old-growth at the nearby H. J. Andrews Experimental Forest.

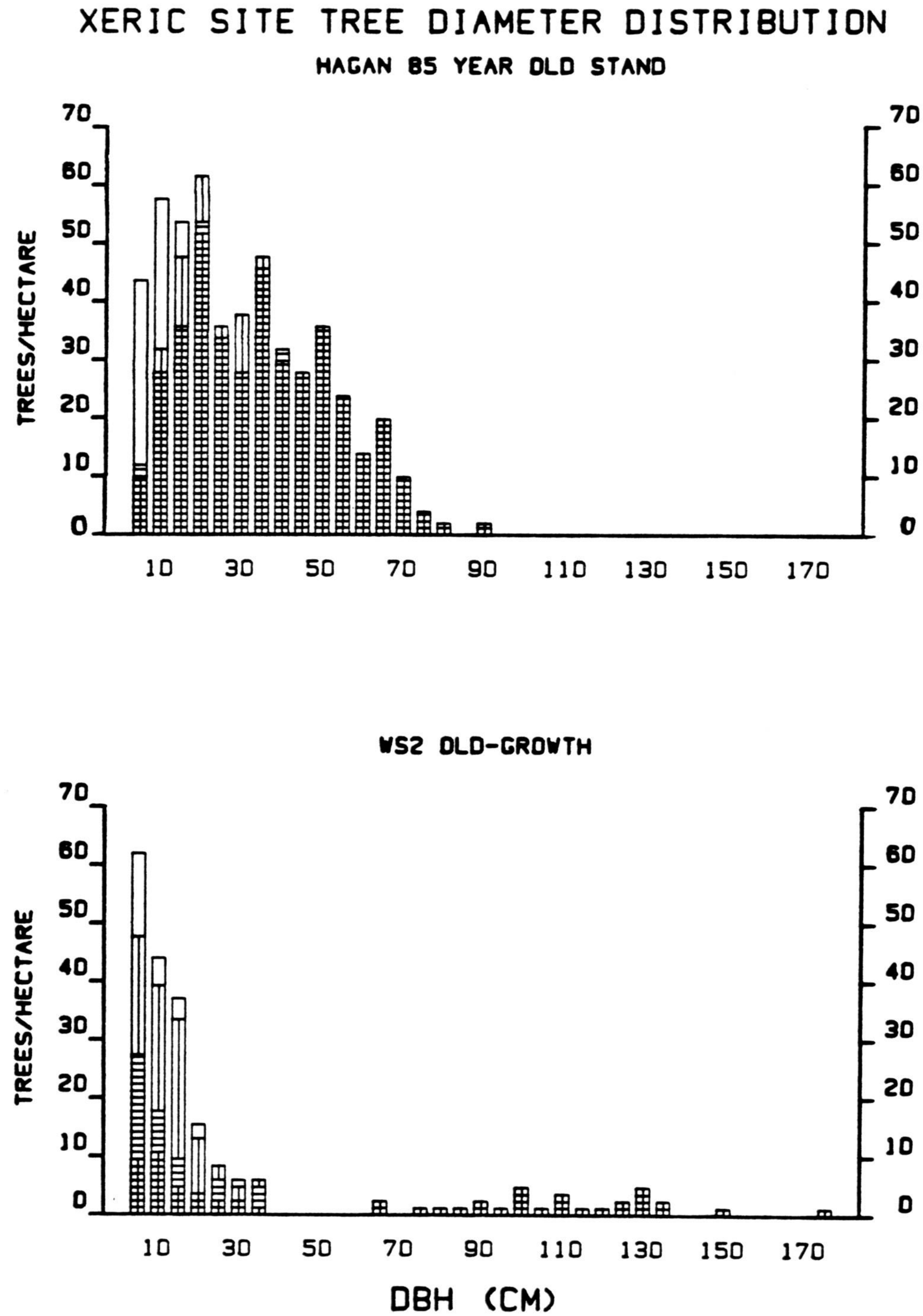



Figure 10. Diameter distributions for trees in the more xeric communities in the 90 and 130 year age classes at the Hagan and Watershed #2 old-growth at the nearby H. J. Andrews Experimental Forest.

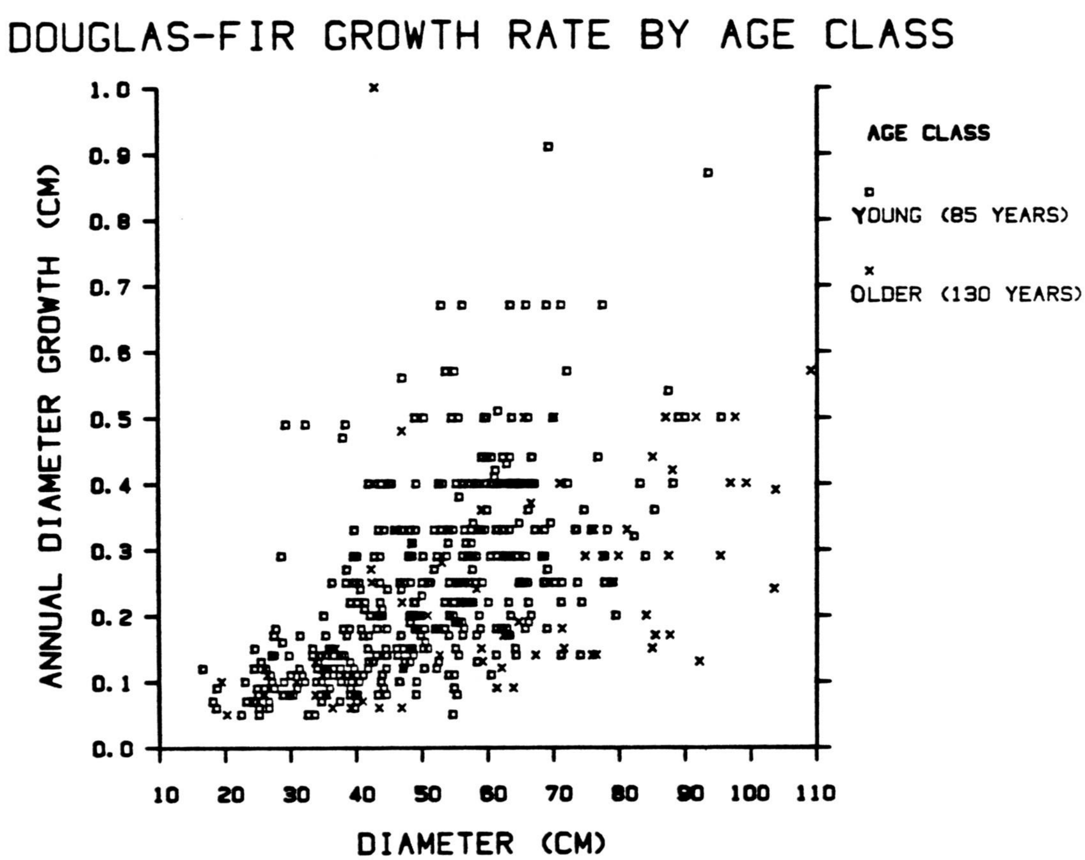



Figure 11. Annual diameter growth rate for trees in the Hagan study area plotted against diameter. While there is a substantial amount of variation the diameter growth rate still increases significantly with size (although the increase may be slightly less amoung the older age class).

Table 5a. Seedling regeneration in seedlings per hectare for community groups and age classes at the Hagan with Watershed 2 old-growth at the H. J. Andrews provided for comparison. For this analysis seedlings were defined as regeneration older than one year but less than 1 cm basal diameter.

| Species | Mesic 90 | Mesic 130 | Mesic 450 | Moderate 90 | Moderate 130 | Moderate 450 | Xeric 90 | Xeric 450 |
|---|---|---|---|---|---|---|---|---|
| *Acer macrophyllum* | 0 | 0 | 66 | 16 | 0 | 11 | 0 | 80 |
| *Castanopsis chrysophylla* | 105 | 100 | 47 | 179 | 75 | 533 | 325 | 1360 |
| *Cornus nuttallii* | 11 | 0 | 53 | 26 | 0 | 67 | 50 | 280 |
| *Pseudotsuga menziesii* | 5 | 50 | 227 | 12 | 38 | 33 | 50 | 80 |
| *Rhamnus purshiana* | 174 | 33 | 0 | 70 | 12 | 0 | 800 | 120 |
| *Taxus brevifolia* | 5 | 8 | 67 | 2 | 0 | 55 | 0 | 120 |
| *Thuja plicata* | 0 | 0 | 120 | 0 | 0 | 278 | 0 | 0 |
| *Tsuga heterophylla* | 11 | 75 | 8793 | 14 | 112 | 1967 | 0 | 680 |

Number of Seedlings per Hectare

90= 90 Year Old Portion of the Hagan Stand
130= 130 Year Old Portion of the Hagan Stand
450= Watershed 2 Old Growth

Table 5b. Sapling regeneration in saplings per hectare for community groups and age classes at the Hagan with Watershed 2 old-growth at the H. J. Andrews provided for comparison. For this analysis saplings were defined as regeneration greater than 1 cm basal diameter but less than 5 cm dbh.

| Species | Mesic 90 | Mesic 130 | Mesic 450 | Moderate 90 | Moderate 130 | Moderate 450 | Xeric 90 | Xeric 450 |
|---|---|---|---|---|---|---|---|---|
| *Acer macrophyllum* | 0 | 0 | 13 | 2 | 0 | 11 | 0 | 0 |
| *Castanopsis chrysophylla* | 11 | 8 | 13 | 28 | 12 | 100 | 0 | 320 |
| *Cornus nuttallii* | 0 | 0 | 7 | 2 | 0 | 0 | 0 | 0 |
| *Pseudotsuga menziesii* | 0 | 0 | 40 | 7 | 0 | 67 | 0 | 0 |
| *Rhamnus purshiana* | 11 | 0 | 20 | 2 | 0 | 0 | 0 | 0 |
| *Taxus brevifolia* | 0 | 0 | 67 | 0 | 0 | 33 | 0 | 60 |
| *Thuja plicata* | 0 | 0 | 113 | 0 | 0 | 200 | 0 | 0 |
| *Tsuga heterophylla* | 5 | 75 | 587 | 2 | 25 | 289 | 25 | 140 |

Number of Saplings per Hectare

90= 90 Year Old Portion of the Hagan Stand
130= 130 Year Old Portion of the Hagan Stand
450= Watershed 2 Old Growth

1981), snag tallies are only crude estimates of mortality. The size and number of uprooted trees was estimated from the subset of plots with course woody debris maps representing several hectares of young stand but only 0.5 hectares of the 130 year old age class. Uproots represented only 8.4 percent of the dead trees in the 90 year old portion of the stand and 13.2 percent in the older stand. The younger stand had significantly more snags and uproots suggesting it is undergoing a wave of mortality particularly among the suppressed individuals in the smaller size classes.

The lower stocking densities of the older stands may also be reflected in the understory species. Despite the fact that the stands are generally located in modal to mesic sites they contained a substantial component of species such as ocean spray which are usually associated with dry open sites. These could be remnants of a an earlier period when the stand was more open and shrubs were more important.

Table 6. Hagan transect plot mortality since establishment (2 to 3 years depending on year of establishment) adjusted to a annual mortality per hectare. The sample sizes for both the 130 year age class and the xeric site data is only about 0.5 hectares so considerable variability should be expeced.

| Species | Mortality Trees/Hectare/Year Mesic 90 | Mesic 130 | Moderate 90 | Moderate 130 | Xeric 90 |
|---|---|---|---|---|---|
| *Acer macrophyllum* | 0.00 | 0.00 | 0.09 | 0.00 | 0.00 |
| *Castanopsis chrysophylla* | 0.00 | 0.00 | 0.64 | 0.00 | 0.83 |
| *Cornus nuttallii* | 0.00 | 0.00 | 0.27 | 0.00 | 0.83 |
| *Prunus emarginata* | 0.00 | 0.00 | 0.09 | 0.00 | 5.00 |
| *Pseudotsuga menziesii* | 3.67 | 5.00 | 2.02 | 1.25 | 1.67 |
| *Rhamnus purshiana* | 0.00 | 0.00 | 0.09 | 0.00 | 0.83 |
| *Tsuga heterophylla* | 0.17 | 0.00 | 0.00 | 0.00 | 0.00 |
| Total for all species | 3.84 | 5.00 | 3.20 | 1.25 | 9.16 |

90= 90 Year Old Portion of the Hagan Stand
130= 130 Year Old Portion of the Hagan Stand (Small Sample Size)

Table 7. Hagan Snag and Uproot tallies by Age class

| Diameter Class | Young (90yr) Stand Snag/ha. | Young (90yr) Stand Uproot/ha. | Older (130yr) Stand Snag/ha. | Older (130yr) Stand Uproot/ha. |
|---|---|---|---|---|
| 10 | 19.6 | 0.3 | 4.1 | 0.0 |
| 15 | 19.1 | 0.3 | 2.6 | 0.0 |
| 20 | 25.7 | 1.4 | 4.1 | 2.0 |
| 25 | 16.0 | 1.2 | 4.1 | 2.0 |
| 30 | 9.0 | 1.7 | 4.6 | |
| 35 | 3.4 | 0.9 | 4.1 | |
| 40 | 1.1 | 0.0 | 1.0 | |
| 45 | 1.4 | 0.9 | 0.5 | |
| 50 | 0.7 | 0.9 | | |
| 55 | 0.0 | 0.9 | | |
| 60 | 0.3 | 0.0 | | |
| 65 | 0.0 | 0.3 | | |
| 70 | 0.0 | 0.3 | | |
| 75 | 0.1 | | | |
| 80 | 0.1 | | | |
| Total | 96.4 | 8.8 | 26.3 | 4.0 |

## DISCUSSION

The wide range of ages reported in some modal old-growth Douglas-fir stands are probably the result of several factors including age dependent fire behavior, species dependent differences in seed storage and dispersal, species dependent regeneration requirements, and the behavior of competing vegetation. The current study provides some insights into the interactions of these factors.

Fire behavior is related to the nature and orientation of fuels and environmental conditions. Stand age and history are directly linked to these fuels and, therefore, fire behavior. In the years shortly after a fire the flammability of a stand may be increased by fine fuels from scorched canopies, herbaceous and shrub vegetation, low canopy height (Van Wagner 1978), and the presence of snags to serve as ignition points for lightning fires, ladders to aid surface fire in reaching the canopy and as a source of firebrands to aid in fire spread. These factors may be responsible for frequent occurrence of reburns with large fires. Of six major fires in the Pacific Northwest in historical time (Yaquina, Nestucca, Coos, St. Helens, Yacolt, and Tillamook) only St. Helens is not reported as suffering substantial reburns (Plummer 1912, Morris 1937, Lucia 1983). Patches of unburned trees observed in the Hagan, Sardine Creek, and other young stands suggest that although crown fires are common in young stands because of the low closed canopy (Plummer 1912), the low stature of the young forests may permit relatively smaller gaps to serve as fire breaks.

Even the most catastrophic of the historical fires experienced adequate regeneration following the initial burn (Hofmann 1925, Issac

1938). Seed for the regeneration of these sites is ascribed to residual trees (Hofmann 1917, Issac 1938), long distance dispersal from the edge of the burn (Issac 1943), surviving seed in cones of fire killed trees (Hofmann 1925, Issac 1943), and seed surviving on the forest floor (Hofmann 1917). The latter source is probably important only for rare spring burns since seed rarely survives beyond the current year on the forest floor (Issac 1935). Issac (1943) mentions that viable seed was found in Douglas-fir cones from trees killed by crown fire during the Tillamook burn in places where the fire had not been extremely hot. Regeneration is generally rapid with most occurring within the first couple of years following the fire (Issac 1936, Hofmann 1917). The later reduction in regeneration is attributed to the exhaustion of surviving propagules, the death of residual trees from exposure, injury, windthrow, or insect attack, and competition from other vegetation (Hofmann 1917, Issac 1936). The poor regeneration from reburns in the early stages of recovery is ascribed to the same factors. A thorough fire, before the regeneration reaches reproductive maturity, may destroy residual trees and destroy all the seed sources for a stand except for long-distance dispersal from the fire borders. Both the Tillamook and Yacolt fires subsequently reburned several times destroying the young trees and producing sites still not fully stocked in 1985. Repeat burns at these very young ages are often suggested as mechanisms to account for the broad range of ages, often in excess of 100 years, found in old-growth stands (Franklin and Waring 1980).

If long distance wind dispersal from known residual patches and burn boundaries was the only method for seed to reach the Hagan stands following the (*ca.* 1855) Hagan fire, regeneration was remarkably rapid and dense. Areas 2 km from the nearest patch of known surviving residual trees and at least 5 km from the fire boundary regenerated to 300 trees per ha. within 25 years (Figure 4). Issac (1943) reported that very little Douglas-fir seed dispersed further than 0.4 km from the edge of a forest into a clearcut. Thus even the 0.5 km distances from the burn boundaries common in the later (1895) fire would appear to stretch dispersal distances, yet the area regenerated to even higher densities within 10 years. With a large seed crop, favorable winds, and better than average survival condition, Issac (1943) suggests adequate regeneration may be acheived at greater distances. In rare or unusual circumstances dispersal distances of at least 16 km have been reported (Issac 1943, Hansen 1967). Still, based on the current knowledge of seed dispersal, adequate regeneration of the stand from long-distance dispersal would be unlikely even with a large seed crop and considering the increased wind across the treeless area, a possible reduction in seed predators due to the fire, and the effects of low seed density on the feeding behavior of seed predators.

If current long-distance dispersal rates are accepted, some form of on site seed storage must have occurred. Seed storage on the forest floor can be ruled out because the fire most major fires in the Pacific Northwest occur in the fall when very little viable seed would be available. The elimination of old-growth trees in the North Fork drainage, even in deep ravines and along streams, suggests the first fire was quite hot. It is unlikely the second fire destroyed many residual older trees because it primarily burned the warmer, drier, south- facing slopes and relatively few locations likely to have sheltered trees from the first fire. The charred character of the snags in the reburned area suggests that these trees had been killed in the first fire and reburned in the second fire after shedding their protective bark. Some additional trees may have survived the fire in protected areas for a few years before falling prey to fire damage, beetles, or wind. Because seed in green cones can survive a fire hot enough to kill the tree, some regeneration from seed surviving in the canopy of less severely burned trees probably occurred following both fires. The intensity of the first fire probably permitted the survival of seed only in relatively protected areas. The low density of trees and the relatively wide range of ages in suggests either the amount of seed was not adequate or environmental conditions were not favorable for initial seedling germination and survival. The second fire was less intense as indicated by the survival of trees in moist areas. The lower fire intensity, shorter dispersal distances, and, perhaps, a good seed year combined to produce the rapid regeneration following the second fire.

The favorable habitat for western hemlock and the abundance of western redcedar logs and snags indicates that these species were once important constituents of the forest. The hot initial fire destroyed nearly all of the western hemlock and western redcedar in the drainage. Currently western redcedar is limited to essentially one site and the abundance of western hemlock is low compared with other stands of similar age (Table 8). Both species are relatively susceptible to fire and are often killed by even a fairly light ground fire. Since the seeds of both species are considerably more sensitive to heating than Douglas-fir seed (Hofmann 1917), the seed for these species survived only at the edges of the burn, on the few surviving trees in protected

Table 8. The stocking levels for mature reference stands at the H. J. Andrews Experimental Forest expressed in number of trees per hectare.

| Species | Reference Stand RS19 BENE/OXOR | RS32 BENE | RS11 BENE | RS33 BENE | RS18 ACCI/WHMO |
|---|---|---|---|---|---|
| *Abies amabalis* | 0 | 0 | 4 | 4 | 0 |
| *Abies grandis* | 0 | 0 | 4 | 0 | 4 |
| *Acer macrophyllum* | 100 | 0 | 0 | 0 | 0 |
| *Calocedrus decurrens* | 4 | 4 | 0 | 0 | 0 |
| *Cornus nuttallii* | 60 | 0 | 24 | 0 | 0 |
| *Pseudotsuga menziesii* | 256 | 248 | 352 | 52 | 268 |
| *Taxus brevifolia* | 4 | 12 | 0 | 0 | 0 |
| *Thuja plicata* | 0 | 208 | 0 | 104 | 0 |
| *Tsuga heterophylla* | 84 | 184 | 336 | 388 | 32 |

areas, and possibly in the canopies of trees killed by the surface burns in some residual pockets. Due to the limited seed and the subordinate canopy position, these sources were only adequate to regenerate the residual pockets themselves. The dispersal of these species is also limited by their subordinate positions in the canopy. Although western hemlock seed is capable of traveling further than Douglas-fir seed (Siggins 1933, Issac 1935) the wind in and under the canopy is reduced and the probability of interception by vegetation is greater. Western redcedar seed falls faster than Douglas-fir and nearly twice as fast as western hemlock. This rate of fall combined with it's usual canopy position virtually prevents any substantial long-distance dispersal of western redcedar. Dispersal is further restricted because neither of these species is as adapted to the harsh early successional environment as Douglas-fir (Gashwiler 1970) reducing the survival of the few seeds which did reach the burn areas. These factors result in the slow colonization of the stand by the more easily dispersed western hemlock and the virtual elimination of western redcedar.

As stands grows toward maturity the increasing canopy height and fall of snags starts to break down the connectivity between the ground and canopy resulting in an increased chance of underburning without a canopy fire (Chandler et. al. 1983). Occasionally case-hardened snags may continue to bridge this gap for up to a century. The common occurrence of fire scars in old growth stands attests to the ability of mature and old-growth Douglas-fir stands to survive surface fires. The implication of this behavior is that the return interval of fires in the early stages of a stands development should be relatively more frequent than the average.

The Hagan fire history is interesting because the time between fires was sufficient to avoid the stocking problems usually associated with repeat burns. This stocking problem appears to be caused by either inadequate seed source, vegetation competition or both combined. If effective dispersal distances are substantially longer than currently believed then the culprit must be competition. The distances for seed dispersal from residual vegetation in the Hagan stand are comparable to the distances between known survivors of the fire episode of the H. J. Andrews 450 years ago and WS10, one of the stands with a broad dominant age class (Franklin and Hemstrom 1981). The distances from survivors to the moist, mid-elevation stand with a 60 year regeneration period reported by Means (1982) is about the same as the distances involved in the second fire at the Hagan. This suggests that the resprouting of competing vegetation may play a substantial role in the repeat burn syndrome. While a number of species may survive a fire their abundance following the burn of a mature or old-growth forest is generally too low to prevent tree species from becoming established. Once tree seedlings become established the moderate environment permits them to survive and grow even under substantial amounts of competition (Issac 1943). If competing vegetation can become established before Douglas-fir tree seedlings, the establishment period can be extended for decades. The presence of residual vegetation established after the previous burn may be enough to upset this delicate balance. If this is true then the suppression of competing vegetation by crown closure may be even more important than reproductive maturity in assuring normal regeneration following a repeat burn. The rapid regeneration of the younger Hagan stand suggests that a good seed source was available and the stocking levels of the older Hagan stands appear to have been more than adequate to prevent competition.

Fires at relatively young ages can result in the appearance of a broad age class for a variety of reasons. Scarred trees, the usual indicator of fires, are not reliable with young trees. Fires in young stands are generally crown fires resulting in the complete destruction of most trees, islands of unaffected trees, and relatively few damaged live trees. Agee and Dunwiddie (1984) suggest a similar reason for the lack of fire scars amoung young trees on Yellow Island in San Juan County, Washington. This form of fire behavior could also be seen at Sardine Creek, near Detroit, Oregon, the site of a similar multiple burn 20 years ago. Both pockets of unscarred trees and areas of partial burn were observed. All ten of the fire scarred trees found there had rotten centers, and most likely would not survive another 70 years. Second, small size differences between age classes by even 100 years makes the detection of older patches and lone individuals difficult. While the older trees on the Hagan are significantly larger than the younger trees (both in diameter and height) statistically, the differences are sufficiently small that they can easily escape notice. Stewart (1984) also identified two mature age classes on one of his plots which were undetected without aging. Finally, the boles in the reburn of a young stand are small enough that they decompose rapidly. Twenty years after the Sardine Creek burn the boles of trees killed in the fire had almost completely deccomposed. Unless the spatial pattern of ages is detected an age class may go undetected. For example, the histogram of the ages for all trees from the Hagan plots (Figure 12) appears to be a single broad age class.

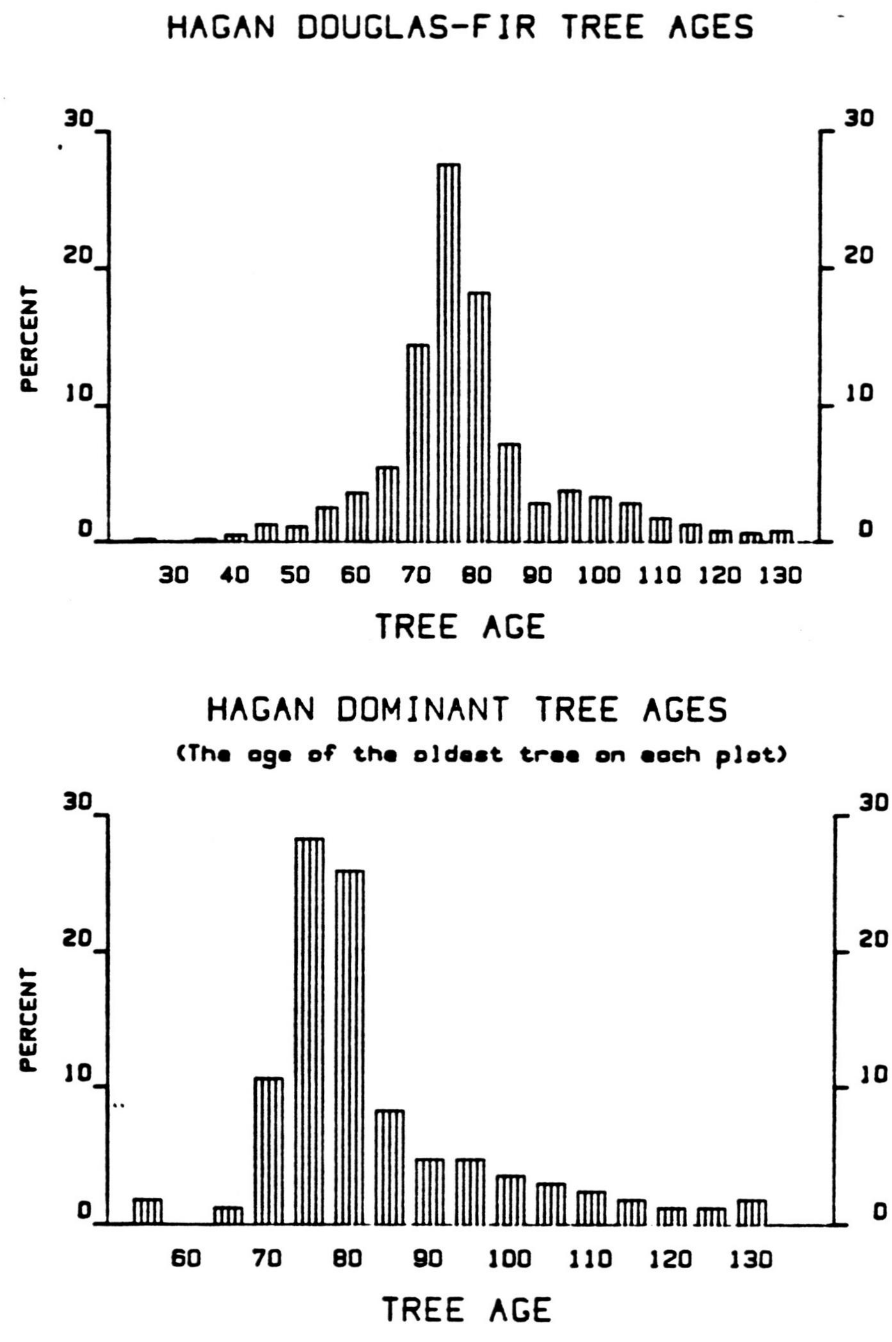



Figure 12. Age distribution for all trees from both young and old age classes in the Hagan study area.

The stand structure of the Hagan forest provides additional details about its development. Stand projections using diameter growth rates and dead tree tallies were used to compare the size class distributions for the two stands. Projections forward (or backward) were made by adding (or subtracting) diameter specific annual growth rates, subtracting (or adding) estimated size specific mortality, and adding (or subtracting) estimated ingrowth for a specified number of years. While the combination of more rapid growth among the larger trees and mortality, primarily among the smaller trees, can produce the broad flat distribution found in the older age class, these changes are not adequate to account for the differences between the stands. Projecting the older stand back resulted in a size distribution with too many small trees (Figure 13), while projecting the young stand forward failed to produce as broad a range of tree sizes as are found in the older stand (Figure 14). This suggests that the initial stocking density for the older age class was less than that of the younger.

Several reference stands have been established in mature forests around the H. J. Andrews Experimental Forest (Hawk et al 1978, Data on file with the Forest Science Data Bank). Direct comparisons of the number of trees is difficult because on several of these stands (RS11, RS18 and RS19) only trees greater than 15 cm in diameter at breast height (DBH) have been measured. Hawk et al. (1978) reports all three of these stands have substantial amounts of immature western hemlock. All the stands have substantially more western hemlock than the comparably aged older Hagan portion of the drainage (Table 8). However, Franklin (personel communication) reports that stands like the Hagan with little western hemlock and other shade tolerant species are not

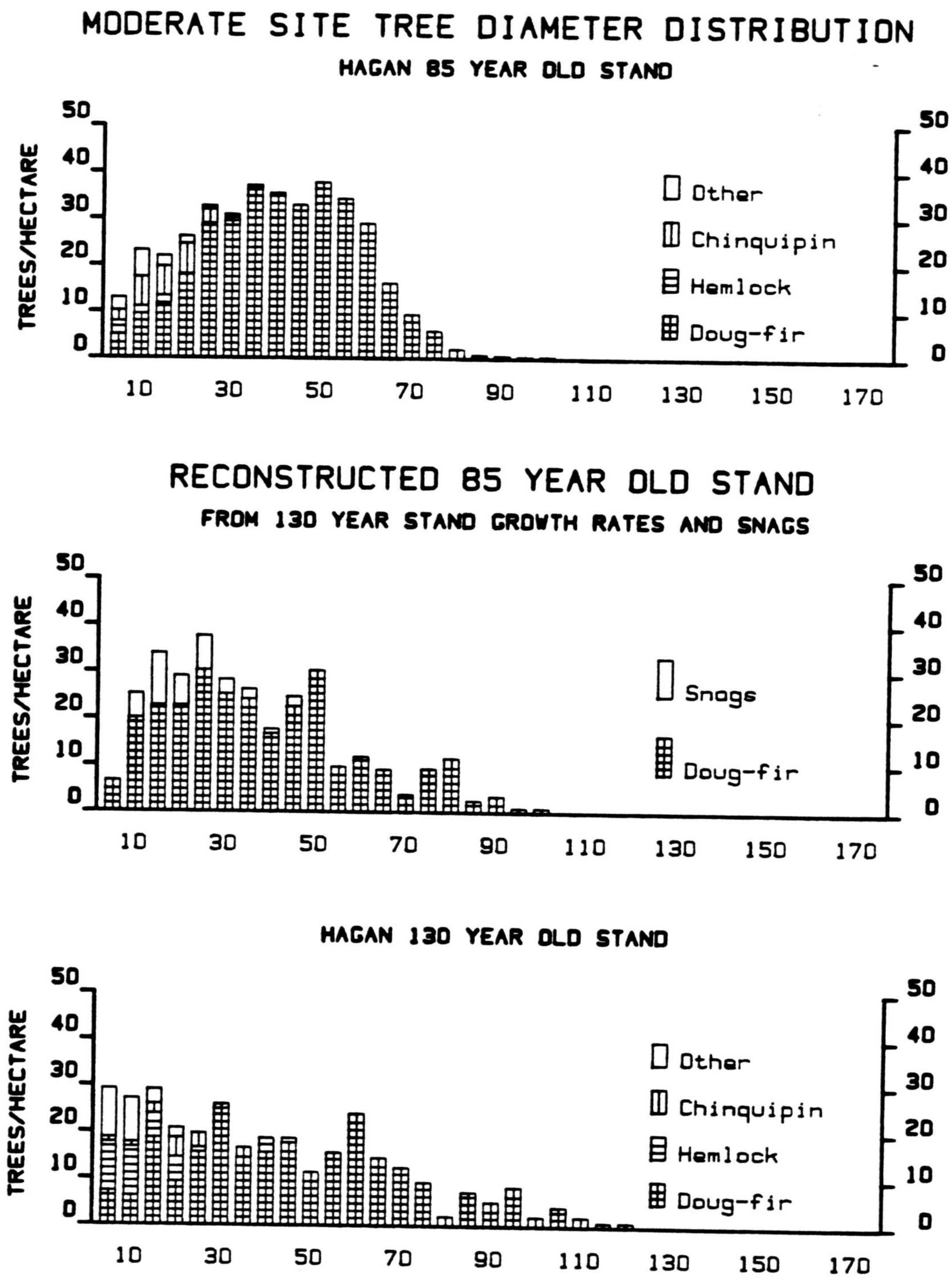



Figure 13. The species Douglas-fir diameter distributions for the young and older Hagan stands compared with the projection of the older stand back to the age of the younger stand using diameter growth rates and mortality information.

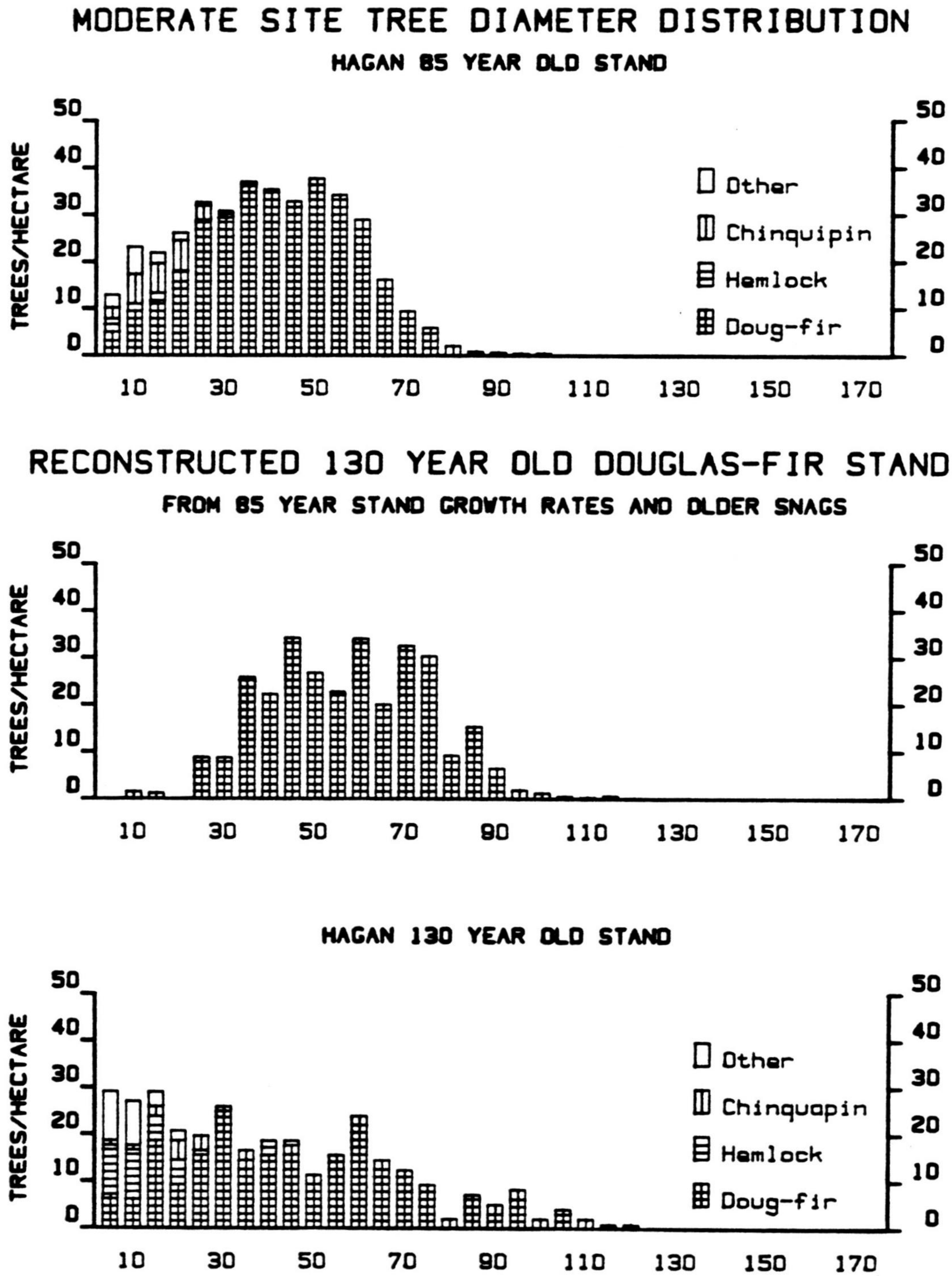



Figure 14. The species Douglas-fir diameter distributions for the young and older Hagan stands compared with the projection of the younger stand forward to the age of the older stand using diameter growth rates and mortality information.

uncommon in the central Oregon Cascades.

The stand structure at the Hagan RNA provides must be examined in its successional context. The Watershed 2 (WS2), an old-growth drainage at the H. J. Andrews Forest, was systematically sampled with a similar set of plots as part of the Long Term Ecological Research (LTER) program. Information from these plots provide an example of the stand structure of an old-growth stand in a similar environment. The adjacent Watershed 1 (WS1) was skyline logged from 1962 to 1965 before being broadcast burned in fall 1966. Several years later the site was aerial seeded and parts of it planted but most regeneration appears to be from natural regeneration. While the removal of trees and the low intensity of the broadcast burn make this site different from one originated by a wild fire, it does provide a young stand for comparison purposes. The low site disturbance from the skyline logging and the primarily natural regeneration make it a better comparison than most 19 year old clearcuts.

A comparison between the sites (Tables 9, 10, and 11) shows that the Hagan stand fits fairly well between these points. The direction of change in stocking and regeneration from the 90 to the 130 year old Hagan portions of the stand is in the direction of the old-growth WS2 plots for all species. The hardwood species which appeared to be declining in the mature stands are eliminated in the old-growth stand. The amount of western hemlock, Pacific yew, flowering dogwood and western redcedar continue to increase while the abundance of Douglas-fir declines substantially. The 19 year old WS1 fits reasonably well at the young end of the spectrum. Particularly notable is the abundance of bitter cherry. While pin cherry (<u>Prunus pensylvannica</u>) is

Table 9. Stocking levels in numbers of trees per hectare for wet sites across a chronosequence of stands from the Hagan and the nearby H. J. Andrews Experimental Forest. Watershed 1 is a large skyline logged clearcut and the Watershed 2 is an old-growth control area adjacent to it.

Wet Sites

| Species | Watershed 1 14yrs | Hagan 90yrs | Hagan 130yrs | Watershed 2 450yrs |
|---|---|---|---|---|
| *Acer macrophyllum* | 291.3 | 16.8 | 5.8 | 19.9 |
| *Alnus rubra* | 2.9 | 2.5 | 4.4 | 0.0 |
| *Castanopsis chrysophylla* | 7.3 | 0.7 | 0.5 | 0.0 |
| *Cornus nuttallii* | ----- | 2.9 | 7.1 | 8.1 |
| *Pinus monticola* | 0.0 | 0.0 | 0.0 | 0.4 |
| *Prunus emarginata* | 5.8 | 0.0 | 0.0 | 0.0 |
| *Pseudotsuga menziesii* | 1494.6 | 327.2 | 234.1 | 60.8 |
| *Rhamnus purshiana* | 0.0 | 0.0 | 1.2 | 0.0 |
| *Taxus brevifolia* | 0.0 | 1.3 | 11.3 | 73.0 |
| *Thuja plicata* | 0.0 | 0.0 | 0.4 | 26.7 |
| *Tsuga heterophylla* | 25.0 | 11.7 | 30.7 | 233.1 |

Note: WS1 community classification was based on precutting data

Table 10. Stocking levels in numbers of trees per hectare for moderate sites across a chronosequence of stands from the Hagan and the nearby H. J. Andrews Experimental Forest. Watershed 1 is a large skyline logged clearcut and the Watershed 2 is an old-growth control area adjacent to it.

Moderate Sites

| Species | Watershed 1 14yrs | Hagan 90yrs | Hagan 130yrs | Watershed 2 450yrs |
|---|---|---|---|---|
| *Acer macrophyllum* | 93.4 | 4.3 | 10.4 | 12.2 |
| *Alnus rubra* | 3.1 | 0.0 | 0.0 | 0.0 |
| *Arbutus menziesii* | 27.7 | 0.0 | 0.0 | 0.0 |
| *Calocedrus decurrens* | 0.0 | 0.0 | 0.0 | 0.6 |
| *Castanopsis chrysophylla* | 381.5 | 25.3 | 12.2 | 8.6 |
| *Cornus nuttallii* | ----- | 5.1 | 21.0 | 14.1 |
| *Prunus emarginata* | 194.1 | 0.8 | 0.0 | 0.0 |
| *Pseudotsuga menziesii* | 928.3 | 391.7 | 265.8 | 80.2 |
| *Rhamnus purshiana* | 0.0 | 1.9 | 0.0 | 0.0 |
| *Taxus brevifolia* | 2.1 | 0.1 | 0.6 | 66.7 |
| *Thuja plicata* | 49.8 | 0.0 | 0.6 | 29.4 |
| *Tsuga heterophylla* | 145.8 | 10.2 | 42.3 | 287.8 |

Note: WS1 community classification was based on precutting data

Table 11. Stocking levels in numbers of trees per hectare for dry sites across a chronosequence of stands from the Hagan and the nearby H. J. Andrews Experimental Forest. Watershed 1 is a large skyline logged clearcut and the Watershed 2 is an old-growth control area adjacent to it.

Dry Sites

| Species | Watershed 1 14yrs | Hagan 90yrs | Watershed 2 450yrs |
|---|---|---|---|
| *Acer macrophyllum* | 250.4 | 4.7 | 4.8 |
| *Arbutus menziesii* | 17.3 | 0.0 | 0.0 |
| *Calocedrus decurrens* | 0.0 | 0.0 | 1.2 |
| *Castanopsis chrysophylla* | 287.8 | 33.5 | 139.6 |
| *Cornus nuttallii* | ----- | 14.8 | 27.4 |
| *Pinus lambertiana* | 0.0 | 0.0 | 1.2 |
| *Pinus monticola* | 0.0 | 0.0 | 1.2 |
| *Prunus emarginata* | 247.5 | 18.8 | 0.0 |
| *Pseudotsuga menziesii* | 848.9 | 393.3 | 152.7 |
| *Rhamnus purshiana* | 0.0 | 9.7 | 0.0 |
| *Taxus brevifolia* | 0.0 | 0.0 | 54.9 |
| *Thuja plicata* | 2.8 | 0.0 | 4.8 |
| *Tsuga heterophylla* | 28.8 | 11.4 | 180.1 |

Note: WS1 community classification was based on precutting data considered a common early successional species in the Northeast (Marks 1974) cherry is barely mentioned in the successional literature for the Norhtwest (Munger 1930, 1940, Dyrness 1973). The abundance of it in WS1 and the strong evidence of its presence in the Hagan suggest it deserves more attention. The clearcut has a much greater abundance of the shade-tolerant species: western hemlock, Pacific yew, and western redcedar. While some of these trees are residuals, a large proportion of the trees are probably the result of regeneration from seed from the surrounding mature and old-growth forest.

This study examined a few of the principle parameters relating to stand composition and structure, regeneration, growth, and mortality. In nearly all of these, the conditions surrounding initial establishment have had a significant impact. Species composition at the Hagan was altered by the initial fire, but regeneration appears to be slowly returning the stand toward it's prefire condition. The stand structure was affected by the differences in rates of establishment, in terms of tree density, diameter distribution, and crown length. Growth rate is strongly correlated with tree size and appears to be slowing with age. Mortality varies dramatically between age classes with the denser young stand experiencing several times the mortality of the older stand. Most of this mortality is coming from smaller "suppressed" individuals.

Although the study has revealed some interesting results, it represents just a small step in the research among mature stands. The study represents a large but unreplicated sample. The results must be compared with other sites to avoid the difficulties of unusual situations and complicating factors. If nothing else the differences between the two age classes should be a warning about the dangers of unreplicated sampling.

Among the numerous areas requiring further research is fire behavior. The fire literature is very "fuels" oriented, but the connection between fuels and stand composition, structure, and age is seldom developed. An effort is needed improve this connection and to relate fire frequency and behavior with stand composition and age. Much of the information for such an analysis probably already exists in forest service data files. Several aspects of fire behavior having special usefulness to an ecologist, are the degree of patchiness, intensity of the burn, the frequency and effects of underburning, and the types of structures which act as natural firebreaks under different conditions.

Many aspects of postfire reforestation also require further study. The degree of onsite seed storage in fertile green cones, animal caches, and in the litter needs to be quantified. While their amount may be small, these could be important early sources of seed following large fires. The dispersal distances observed at the Hagan and at Mt. St. Helens are far in excess of the common distances reported by Issac (1943) indicating dispersal distances need further examination. The distribution of trees like western redcedar should be examined on a landscape basis to determine they have been temporarily excluded from other areas.

Additional information is needed on the importance of competition during postfire reforestation. This includes further work on the survival and reestablishment of understory species following fire, as well as the amount and type of competition necessary to prevent seedling survival. The relationship between fire frequency and relative species abundance should be explored to determine which species benefit from repeated burns at various intervals. The dynamics of canopy closure and competitive exclusion needs extensive examination as does the importance of trees, like bitter cherry, in the maintaining canopy openings.

The accelerated mortality among the trees in the younger Hagan age class raises some interesting questions. How important are these waves of mortality in forest systems? What are the actual mechanisms of tree mortality and do they change with time and place? How well do the stands match the 3/2 power law? How much release do the surrounding trees experience following the death of a neighbor?

Many of these topics for future research have immediate application in forest planning or silviculture. Others would help our understanding of natural systems and might be useful in wilderness management. Areas like the Hagan RNA provide important laboratories for conducting this research.

# REFERENCES

Agee, J. K. and P. W. Dunwiddie. 1984. Recent forest development on Yellow Island, San Juan County, WA. Canadian Journal of Botany 62(10):2074-2080.

Burke, Connie J. 1979. Historic fires in the central western Cascades, Oregon. M.S. Thesis, Oregon State University, Corvallis, Oregon. 130pp.

Campbell, Alsie G. and Jerry F. Franklin. 1979. Riparian vegetation in Oregon's western Cascade mountains: composition, biomass, and autumn phenology. U.S./IBP, Ecosystem Analysis Studies, Coniferous Forest Biome, Bulletin No. 14. 89pp.

Chandler, C., P. Cheney, P. Thomas, L. Trabaud, D. Williams. 1983. Fire in Forestry: Volume 1, Forest Fire Behavior and Effects. John Wiley and Sons. New York. 450pp.

Dyrness, C.T. 1973. Early stages of plant succession following logging and burning in the western Cascades of Oregon. Ecology 54:57-69.

Dyrness, C.T., Franklin, Jerry F., and W.H. Moir. 1974. A preliminary classification of forest communities in the central portion of the western Cascades in Oregon. Bulletin no. 4, Coniferous Forest Biome, Ecosystem Analysis Studies, U.S./International Biological Program. 123pp.

Fogel, Robert, M. Ogawa, and Jim M. Trappe. 1972. Terrestrial decomposition: a synopsis. Unpublished Internal Report #135. US/IBP, Coniferous Forest Biome, Univ. of Washington, Seattle. 12pp.

Franklin, Jerry F. and C. T. Dyrness. 1973. Natural vegetation of Oregon and Washington. USDA Forest Service General Technical Report PNW-8. 417p.

Franklin, Jerry F., and Miles A. Hemstrom. 1981. Aspects of succession in the coniferous forests of the Pacific Northwest. Pages 222-229 in West, D.C., Shugart, H.H., and D.B. Botkin, editors. Forest Succession. Springer-Verlag, New York.

Franklin, Jerry F., Kermit Cromack, Jr., William Denison, Aurthur McKee, Chris Maser, James Sedell, Fred Swanson, and Glen Juday. 1981. Ecological characterics of old-growth Douglas-fir forests. USDA Forest Service General Technical Report PNW-118 48pp.

Franklin, Jerry F. and Richard H. Waring. 1980. Distinctive features of the northwestern conferous forest: Development, structure, and function. Pages 59-86 in Richard H. Waring, editor. Forests: Fresh perspecitves from ecosystem analysis. Oregon State University Press, Corvallis, Oregon.

Gashwiler, Jay S. 1970. Further study of conifer seed survival in a western Oregon clearcut. Ecology 51:5 p. 849-854.

Graham, Robin L. 1981. Biomass dynamics of dead Douglas-fir and western hemlock boles in mid-elevation forests of the Cascade range. Ph.D. Thesis, Oregon State University, Corvallis. 152p.

Grubb, P. J. 1977. The maintenance of species-richness in plant communities: the importance of the regeneration niche. Biological Review 52:107-145.

Harper, John L. 1977. Population Biology of Plants. Academic Press. New York. 892pp.

Hawk, Glenn M., Jerry F. Franklin, W. Arthur McKee, Randall B. Brown. 1978. H. J. Andrews Experimental Forest reference stand system: Establishment and use history. U.S./IBP Coniferous Forest Biome Bulletin No. 12. 79p.

Heath, James P. 1967. Primary conifer succession, Lassen volcanic National Park. Ecology 48:270-275.

Hemstrom, Miles A. 1979. A Recent Disturbance History of Forest Ecosystems at Mount Rainier National Park. Ph.D. Thesis, Oregon State University, Corvallis. 67p.

Hemstrom, Miles, S. E. Logan, W. Pavlat. 1985. Preliminary Plant Association and Management Guide, Willamette N. F. Review Draft. USDA Forest Service PNW Region Willamette N. F. 300pp.

Henry, J. D. and J. M. A. Swan. 1974. Reconstructing forest history from live and dead plant material--an approach to the study of forest succession in southwest New Hampshire. Ecology 55(4):772-783.

Hofmann, Julius. V. 1917. Natural Reproduction from Seed Stored on the Forest Floor. Journal of Agricultural Research 11(1) p.1-26.

Hofmann, Julius V. 1924. Natural Regeneration of Douglas fir in the Pacific Northwest. USDA Department Bulletin No. 1200. 59pp.

Issac, Leo A. and George S. Meagher. 1938. Natural Reproduction on the Tillamook Burn Four Years After the Fire. Pacific Northwest Forest and Range Experiment Station Unpublished Internal Report. 15pp.

Issac, Leo A. 1930. Seed flight in the Douglas fir region. Journal of Forestry 28:492-499.

Issac, Leo A. 1935. Life of Douglas fir seed in the forest floor. Journal of Forestry 33:61-66.

Issac, Leo A. 1943. Reproductive Habits of Douglas-fir. Charles Lathrop Pack Forest Foundation. 107pp.

TABLE OF CONTENTS

Lucia, Ellis. 1983. Tillamook Burn Country. The Caxton Printers, Ltd. Caldwell, Idaho. 307pp.

Marks, P. L. 1974. The role of pin cherry (Prunus pensylvanica L.) in the maintenance of stability in northern hardwood ecosystems. Ecological Monographs 44:73-88.

Martin, Robert E., Dan D. Robinson, and Walter H. Schaeffer. 1974. Fire in the Pacific Northwest-Perspectives and Problems. Proceedings of the Annual Tall Timbers Fire Ecology Conference #15. p. 1-23.

Means, Joseph E. 1982. Development history of dry coniferous forests in the central western Cascade Range of Oregon. Pages 142-158 in J. E. Means, editor. Forest succession and stand development research in the Northwest. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

Morris, William G. 1936. Forest Fires in Oregon and Washington. Oregon Historical Quarterly 34(4):313-339.

Munger, T. T. 1930. Ecological aspects of the transition from old forests to new. Science 72:327-332.

Munger, T. T. 1940. The cycle from Douglas-fir to hemlock. Ecology 1(3):451-459.

Oliver, Chadwick D. 1982. Stand development--Its uses and methods of study. Pages 100-112 in J. E. Means, editor. Forest succession and stand development research in the Northwest. Forest Research Laboratory, Oregon State University, Corvallis, Oregon.

Plummer, Fred G. 1912. Forest Fires: their causes, extent, and effects, with a summary of recorded destruction and loss. USDA Forest Service Bullitin 117. 39p.

Siggins, Howard W. 1933. Distribution and Rate of Fall of Conifer Seeds. Journal of Agricultural Research 47: 119-128.

Stewart, Glenn H. 1984. Forest structure and regeneration in the Tsuga heterophylla-Abies amabilis transition zone, central western Cascades, Oregon. Phd Thesis. Oregon State University, Corvallis, Oregon. 148pp.

Van Wagner, C. E. 1978. Age class distribution and the forest fire cycle. Canadian Journal of Forest Research 8:220-227.

Volland, Leonard A. and John D. Dell. 1981. Fire Effects on Pacific Northwest forest and range vegetation. USDA Forest Service. 23p.