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TECHNIQUES AND PROBLEMS OF STEM ANALYSIS OF OLD-GROWTH CONIFERS IN THE OREGON-WASHINGTON CASCADE RANGE

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INTRODUCTION

Stem analysis studies of the growth characteristics of true fir, hemlock and other Cascade Range coniferous tree species have been underway since the summer of 1965. This work in both Oregon and Washington has been done jointly by the U.S. Forest Service and Oregon State University. The studies were especially aimed at collection of growth data from old-growth noble fir (**Abies procera** Rehd.). However, similar data were also collected from species associated with noble fir and will be used later in comparative growth studies.

THE PROBLEM

To develop site quality and other growth information essential for proper management of the complex forests of the Cascades, we explored the basic interrelated growth patterns of the species involved. Knowledge of growth patterns of individual species was required so that the most desirable conifer or conifers should be selected for comprehensive stem analysis studies. As a result of this exploratory research, noble fir was selected for the first intensive work. Our primary objective in the quest for forest productivity information for noble fir was some measure of growth quality. Site index curves for the species were nonexistent, so to give us some relative measure of growth, we began collecting height-age information via stem analysis.

The case for selecting noble fir for the initial effort was clear:

1. It was found to have the best form and growth characteristics of all the Cascade upper-slope species. Nearly always, noble fir trees are **strong** dominants in relation to associated species and are the tallest trees within their stand environment — even-aged or multi-aged.

2. In contrast with many of its associates, no dominant noble fir tree has been observed to experience a period of early growth suppression followed by a growth release. Because of noble fir's simple growth pattern, it is a good standard for interrelating the growth characteristics of associated species.

Natural forest stands containing noble fir are found in the Pacific Northwest Cascade Range mountains roughly between Stevens Pass in northern Washington and Willamette Pass in central Oregon (Figure 1). In Oregon, it intermixes with Shasta red fir (**A. magnifica** var. **shastensis** Lemm.) north of Crater Lake. Because the genetic relationship between noble fir and Shasta red fir is disputed, the area south of McKenzie Pass in the Willamette National Forest was excluded from this study to avoid confusing growth variation possibly caused by hybridization. Shasta red fir and its relative, California red fir, will be studied later.

We have been asked why we have employed stem analysis. Even with such widespread species as Douglas-fir, research workers have had trouble selecting equal numbers of stands for all ages over an equal number of potential growing sites. In spite of the inherent disadvantage of dependence among successive measurements on the same sample tree, stem analysis does provide a solution to the problem of unequal selection. Stem analysis also permitted us to use very large, overmature stands to gain young-tree growth information for particular sites, where such information would otherwise be unavailable.

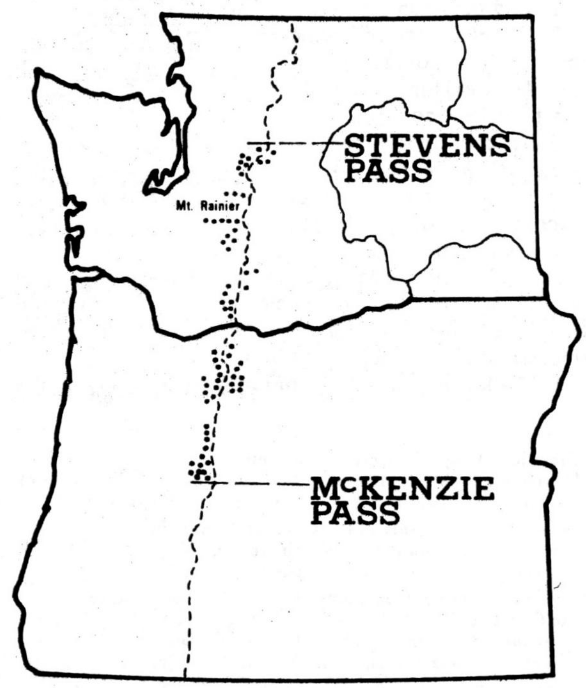

FIGURE 1. Stem analysis study locations within the natural range of noble fir in Oregon and Washington.

Last, but certainly not least, stem analysis is very efficient in number of trees required to provide sufficient data for height-age regression curve construction.

Field Study Method

Since study inception, we have evolved an increasingly efficient method of stem analysis study for large, mature, and overmature trees scattered on many locations in the true fir-hemlock forest. Old-growth trees in unmanaged stands were selected because no well-distributed population of young trees, either managed or unmanaged, was available for sampling. Only a relatively few young-growth stands were available as a result of recent, scattered, catastrophic events such as fire and windthrow. Such stands were not believed to be scattered randomly and therefore could not be considered to represent the potential population of young-growth on all possible growing sites.

For study purposes, the lack of younger trees growing on a complete range of sites was unfortunate. Because of this deficiency, stem analysis procedures became increasingly more complicated as tree size and age increased. Also, little information was available concerning the range of noble fir growth variability.

Information and methods used to select noble fir study locations representing the range of its response to growing conditions included:

1. Habitat type and understory vegetation differential[1,2] between altitudes at same geographical latitude and between latitudes at similar altitudes.
2. Careful reconnaissance of known true fir-hemlock stands containing noble fir to discover and sample in existing site continuums — as from ridgetop to valley bottom.
3. Inspection of true fir-hemlock forest sites suspected to have noble fir of unknown growth capabilities and stand associations. Areas of this sort were discovered through contacts with foresters on ranger districts and management units.

After location was determined, at least one noble fir plus one tree of each species associated with noble fir was selected to be felled and sectioned[3]. Each tree selected had to meet the following criteria:

1. **Tallest dominant or codominant in stand.** While noble fir was the tallest tree in more than 90 percent of the stands studied, representatives of other species often also were dominant, or at least codominant, because of the natural spacing within old-growth stands.
2. **Free of visible breaks, large forks, or other growth interruptions.** Trees with such minor defects as small forks near top, or simple sweep or lean, were selected where better stems were unavailable. Trees with identifiable defects, such as rot and scars that might possibly influence growth or complicate analysis, were avoided.
3. **Same chronological age.** Where trees of the same chronological age were not available, as in two- and multi-aged stands, trees of the same or similar physiological age were chosen.
4. **Same or similar site.** Individual trees of all species selected were estimated to be on same or similar sites according to field evaluation of:
   a. Understory vegetation
   b. Soils
   c. Moisture conditions
   d. Slope
   e. Contour position
   f. Aspect

Even though care in felling was taken to minimize stem breakage, such breakage nearly always occurred. The broken stems from stump to tip were carefully reassembled to permit accurate length measurement, and disks one to two inches thick were cut at selected stem intervals. No log lengths longer than 18 feet—mostly shorter—were used. A cut was made at breast height, and the butt log often was halved to strengthen information about early growth. For consistent understanding of early growth, the butt log should always be cut at midpoint. Sectioning in the tops beyond merchantable diameter was performed at internodal intervals and at points along the stem 1 to 10 feet apart.

From each disk cut from the stem, a transverse "representative" radial section was selected and cut. These rectangular blocks of wood were transported to the laboratory and formed the bases for the stem analysis studies. Except for sequential radial growth measurement at stump and breast height, field measurement and ring counts were unnecessary and were delayed for later laboratory investigation. For this study, only one "representative" radius per section was used to provide required sequential radial growth and age data. Better growth information was obtained from a single, carefully selected radius than would have been obtained from either mechanically selected or current average radii. The radius selected for each section was one that approached the average in breadth and was representative of the total radial accretion at each point of observation. Radii crossing difficult-to-count rot, pitch pockets, and aberrant annual ring configurations were avoided. Calculations later converted radial growth at all stem section points to an average radial growth by proportional addition and reduction. Basis for designation of an

[1] Franklin, Jerry F. 1962. Study plan for development of a habitat-type classification of the true fir-hemlock forests of the southern Washington Cascades. 51 pp. (Processed)

[2] ————. 1966. Vegetation and soils in the subalpine forests of the southern Washington Cascade Range. Ph.D. dissertation. 132 pp., illus. (Processed)

[3] Tree species other than noble fir that also were studied include Pacific silver fir (*Abies amabilis* (Dougl.) Forbes), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), western white pine (*Pinus monticola* Dougl.), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), western larch (*Larix occidentalis* Nutt.) subalpine fir (*A. lasiocarpa* (Hook.) Nutt.), mountain hemlock *T. mertensiana* (Bong.) Carr.), grand fir (*A. grandis* (Dougl.) Lindl.), western redcedar (*Thuja plicata* Donn), and lodgepole pine (*P. contorta* Dougl.).

average figure was current diameter inside bark as obtained by diameter tape.

Among the recommendations that might be made for future studies of this kind is the need for more than one radial measurement and age count at least at stump and breast height points. This is especially true where the pith is a considerable distance from the geometric center and where the stump is strongly fluted and out of round. At stump, the sequential radial growth of at least three "representative" radii should be measured. At breast height, only two need be measured. For the stump, selected radii should be spaced approximately 120 degrees apart. At breast height, two radii about 180 degrees apart provided good data. Again, calculations can be made to convert radial growth at all stem section points to an average radial growth by proportional addition or reduction.

To provide permanent records of tree stump- and b.h.-annual-ring growth, ring decades were transcribed to heavy plastic overlays. For our use, we did not scribe each ring, but every tenth ring or ring decade. To provide comparable data from tree to tree and location to location, ring counts were begun at breast height from the pith toward the cambium, and cumulative measurement to every tenth ring was recorded. The final measurement to the cambium rarely had 10 rings, but some count less than 10. Counts on all other sections taken from the tree were started at the cambium with the odd number of rings being counted first.

Occasionally, rot would be encountered on a stump or breast height section. Where wood was not completely destroyed, but rot was so fragile as to prevent collection of the usual thin transverse radial section after field counts, a thicker, rectangular section was taken. This was then frozen and field counts and measurements verified by laboratory observations on the frozen sections.

To facilitate collection of satellite growth measurement data from standing trees not sectioned for stem analysis, an increment borer adapted to a double-handled ratchet was developed (Figure 2). This consisted of two flex-handled, ⅜-inch-drive ratchet handles brazed together to provide equal torque to the borer and a ⅜-inch, square-holed sleeve adapter equipped with a stainless steel clip. This arrangement worked especially well for large, mature trees, where a 26-inch-long borer of standard 0.177-inch diameter was used. A .22-caliber firearm cleaning rod and accessories were adapted to provide for efficient cleaning of the long increment borers.

Laboratory Study Methods

Where rings were closely spaced or indistinct, a dendrochronograph with a 7-to-30-power traveling binocular microscope was used. This instrument[4], although not nearly so sophisticated as the electronic counting models, nevertheless provided accurate information. This dendrochronograph is capable of measuring individual ring width to hundredths of a millimeter or of carrying a cumulative measure of radial growth, ring by ring, across a transverse radial section with the same accuracy. It was in the laboratory that the transverse radial sections containing the representative radii were measured and counted. Here again, all decadal marks were placed on plastic overlays.

From field to laboratory, the wood samples collected for measurement shrunk as they dried. A side study, utilizing the plastic overlay technique, is underway to evaluate measurement inaccuracies introduced as a result of such shrinkage. Even differential shrinkage measurements between young-growth, wide-ring wood and that of the older, narrow-ring wood will be available for evaluation. Correction factors will be provided should they be found necessary.

Since no numerical data, other than stem lengths between cuts, diameters, and bark thicknesses, are taken in the field, all sequential radial growth count and measurement information can be placed directly on computer code forms. This facilitates transfer of data to punch cards and eventually to magnetic tape.

Preliminary Site Index Curves for Noble Fir

Preliminary polymorphic site index curves (Figure 3) were developed using stem analysis data from 54 plot locations between McKenzie Pass in Oregon and Mount Rainier in Washington. Using a stepwise-regression computer program, four curvilinear regressions of the form, $\text{Age}^2/\text{Height} = a + b\,(\text{Age}) + c\,(\text{Age}^2)$[5] were produced from grouped data. A family of 11 curves was then obtained from the four polymorphic curves by interpolation and proportional methods. At a site-index reference age of 100 years, computer-produced results show that noble fir varies between 50 and 150 feet in height for that portion of the noble fir range south of Mount Rainier. These regression curves were extended from 250 to 350 years of age to provide site index values for these older age classes. Revised curves including the noble fir range north of Mount Rainier currently are being developed.

Future Use of Data

Other uses of the data include development of height/age relationships among the many species to determine their relative usefulness in evaluation of site quality. Of immediate value to forest managers will be a method of evaluating noble fir site index in terms of upper-slope Cascade Range Douglas-fir. Until specific growth and yield information for true fir-hemlock can be developed, it is hoped that existing Douglas-fir growth and yield tables can be used for some measure of true fir-hemlock productivity.

[4] Anonymous. 1959. The DeRouen dendrochronograph. Forest Sci. 5: 278, illus.

[5] Prodan, Michael. 1968. Forest biometrics. 447 pp. Oxford, London, New York: Pergamon Press. (English translation by Sabine H. Gardiner.)

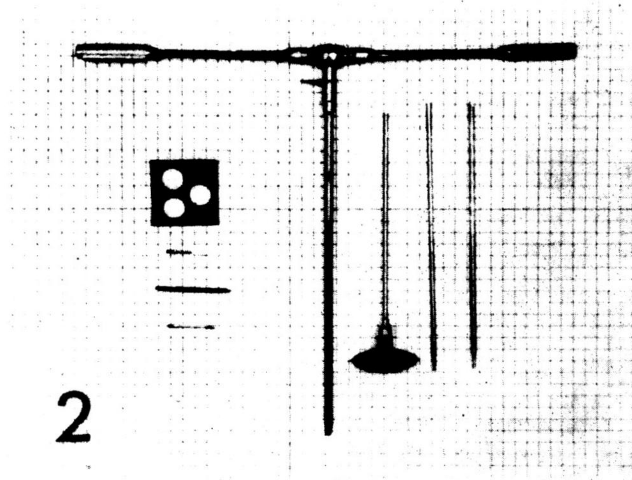

FIGURE 2. A 16-inch-long increment borer, with attached ratchet assembly, and accessory .22-caliber rifle cleaning equipment.

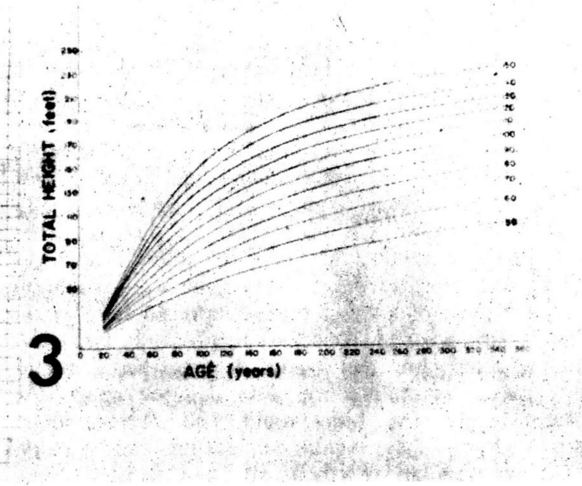

FIGURE 3. Family of polymorphic site index curves for noble fir in Oregon and Washington.

To make such an interim measure possible, growth conversion factors will have to be developed. Some of the information necessary for those factors can be provided from available stem analysis data.

Another use of the data is in refinement of stem analysis work technique. Investigation into methods of selecting the best single radius or multi-radii for definition of accurate past diameter growth patterns is possible. The influence of wood drying upon shrinkage also can be determined. Thus far, it is reasonably certain that near-green-condition configuration and dimensions are restorable when dried, split, and warped disks are soaked to saturation in water.

Perhaps one of the most important uses to which the data can and will be put is for comparison of radiolongitudinal growth among species on a given site and among sites. Much needs to be understood about the growth relationships among the many species growing together in the Cascade Range. Some of the questions concerning best tree species or combination of tree species to favor for particular sites could be answered upon future evaluation of the radiolongitudinal data now on hand.

Dendrochronological studies can be begun on the transverse radial wood sections that are currently available. Other specimens for particular locations may be collected to supplement accessible information. Perhaps the understanding of tree growth-climatological relationships in mesic areas will be strengthened.

Future Additional Work

Several additional research projects are planned using stem analysis techniques. Determination of productivity of the mixed coniferous Cascade Range forests, with their tremendous range of growing sites, conditions, and species combinations, is the ultimate objective in these studies. To provide the management tools necessary for practicing land managers, some measure of growth and yield must be made available. Studies relating environmental facets, such as understory vegetation and soils, to measures of tree growth are in the planning stages. An effort will be made to provide vegetative and soil indicators, supplemented with other environmental descriptive data, which will help to index relative site quality. Computer availability is expected to facilitate the total ecological habitat approach to site quality definition.

Attempts also may be made to use the dendrochronological approach to date recent volcanic activity in Oregon and Washington. Such investigation may be initiated in the vicinity of Mount St. Helens in southwestern Washington to date recent ash and thermally triggered mud flows.

In addition, some thought has been given to an attempt to date the frequency of past cone crops for many of the 16 coniferous species found in the Cascades of Oregon and Washington. If the influence of current cone production on radial growth can be ascertained[6], a determination of the occurrence of past good seed production years can be determined.

Apart from the narrow pathway of providing management information only for timber production, operations currently underway and those to be undertaken will be geared to furnishing environmental information useful in total land management evaluation. Rather than to have the single goal of providing information about how to grow more wood fiber, future use of available data and new information collected will be directed toward understanding of the ecology of the very complex Cascade Range forests.

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[6] Eis, S., E. H. Garman, and L. F. Ebell. 1965. Relation between cone production and diameter increment of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), grand fir (*Abies grandis* (Dougl.) Lindl.), and western white pine (*Pinus monticola* Dougl.). Can. J. Bot. 43: 1553-1559.