Reprinted from PROCEEDINGS, SOCIETY OF AMERICAN FORESTERS, *Denver, Colorado, 1964*
Purchased by U.S. Forest Service for Official Use.

Ecology and Silviculture of the True Fir-Hemlock Forests of the Pacific Northwest

Jerry F. Franklin

THE TERM "true fir-hemlock forests" characterizes the complex of forest types which occur at middle to high elevation in the Cascade and coastal mountain ranges of Oregon and Washington. These forests are typified by such species as Pacific silver fir (*Abies amabilis*), noble fir (*Abies procera*), Shasta red fir (*Abies magnifica* var. *shastensis*), subalpine fir (*Abies lasiocarpa*), mountain hemlock (*Tsuga mertensiana*), and western white pine (*Pinus monticola*). True fir-hemlock forests, covering in excess of 3,000,000 acres, constitute one of the Pacific Northwest's most important forest resources. This acreage excludes low-elevation coastal stands of western hemlock and the mixed-conifer stands dominated by grand fir (*Abies grandis*) found on the eastern slopes of the Cascade Range.

The important multiple resource aspects of these forests are indicated by a timber volume exceeding 100 billion board feet and by their occupancy of upper reaches of major watersheds, summer range for big game, and prime recreation sites.

Until recently, this complex of forest types was relegated to relative obscurity by the Douglas-fir forests on western slopes and ponderosa pine forests on eastern slopes of the Cascade Range. In the past decade, this situation has changed dramatically, however; true fir-hemlock forests now command major attention from practicing foresters and scientists in the Pacific Northwest. Several factors have contributed to the change, including increasing accessibility, increasing demand for species previously considered "weeds," and decreasing quantities of old-growth timber available at lower elevations.

Today I would like to introduce you to the true fir-hemlock forests, the environment they occupy, management systems presently in use, and some problems encountered in management and utilization of this resource.

The Resource

Environmental features.—Let's look first at the environment within which true fir-hemlock forests grow. Please keep in mind that it is difficult to generalize habitat conditions for any complex of forest types which occurs in four major mountain ranges and which covers 7° of latitude and elevational spans as great as 5,000 feet.

True fir-hemlock forests occupy the highest, forested zones in mountains of the Pacific Northwest. Elevational limits are lowest in the north and on western slopes of the ranges. The elevational span occupied is also greatest in the north. For example, on the western slopes of the northern Cascade Range in Washington, true fir-hemlock forests occur from 1,500 feet to timberline at about 6,500 feet. In the western Cascade Range of Oregon, they occupy a narrower elevational band extending from 3,500 feet to nearly 7,000 feet.

True fir-hemlock habitats occupy six areas of broad geologic and physiographic uniformity (Fig. 1): Northern Cascades, Western Cascades, High Cascades, Olympics, Coast Ranges, and Siskiyous. The Northern Cascades of Washington are extremely rugged with deeply dissected topography. The Northern Cascades are basically nonvolcanic in origin, contrasting sharply with the remainder of the Cascade Range which is composed almost entirely of volcanic materials—andesitic, basaltic, and pyroclastic rocks. The Western Cascades include most of the range in southern Washington and the western flank of the range in Oregon. Topography is rugged with peaks and ridges separated by profound canyons because the volcanic accumulations composing this part of the range date back to Eocene times.

The High Cascades includes a small portion of the range in southern Washington (around Mt. Adams) and the crest of the Cascade Range throughout Oregon. Since the High Cascades are much younger than the Western Cascades, dating back only to Pliocene times, original land forms have been little modified by erosion. Thus, the region is a gently rolling or sloping plateau with poorly defined drainage patterns and little precipitous topography. Surface deposits of pumice and other unconsolidated volcanic ejecta cover much of the landscape. The Olympic and Siskiyou Mountains are rugged mountain systems with complex patterns of valleys and canyons separating high peaks and ridges. Their complex geologic histories result in an abundance of different rock types. The Coast Ranges are low mountains with a mature topography and few areas sufficiently elevated to support true fir-hemlock forests.

The climate of true fir-hemlock habitats is cool and moist. The few climatic records available for higher elevations indicate an annual precipitation of 55 to 111 inches on west slopes and 33 to 70 inches on east slopes of the Cascade Range. Precipitation normally increases rapidly with elevation on western slopes; there is a marked rain-shadow effect, even at high elevations on eastern slopes. Rainfall is markedly seasonal. Minimal quantities of rain occur from June through August—5 to 12 inches in moister regions and 2 to 4 inches in drier regions of true fir-hemlock forests. Winter precipitation often occurs as snow, as much as 550 inches in some parts of the Cascade Range.

Zonal soils in true fir-hemlock forests are generally Podzols, although Brown Podzolics are common along the eastern and southern fringes of these forests. Podzols attain maximal development under old-growth true fir-hemlock stands at middle elevations on the western slopes of the North Cascades. Matted organic layers 10 to 14 inches thick and A2 horizons 2 to 4 inches thick are sometimes encountered under these circumstances. However, many soils supporting true fir-hemlock forests are immature, Lithosols or Regosols, because of precipitous topography or recent deposition of volcanic ejecta.

Distribution of soil parent materials is closely correlated with the geologic units previously outlined. For example, Northern Cascades' soils are developed in colluvium, glacial till, and residuum weathered from igneous intrusive, metamorphic, and sedimentary rock types. Almost all soils in the High Cascades are developed in deep, relatively undisturbed deposits of volcanic ejecta including lapillii, ash, pumice, and cinders. Western Cascades' soils are developed in colluvial and residual materials, which were weathered from basalt, andesite, and pyroclastic rocks, usually in mixture with considerable quantities of volcanic ash and pumice.

The species.—Seven species characterize the true fir-hemlock forests of the Northwest: Pacific silver fir, noble fir, Shasta red fir, subalpine fir, west-

THE AUTHOR is a research forester, Division of Timber Management Research, Pacific Northwest Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, Portland, Oregon.

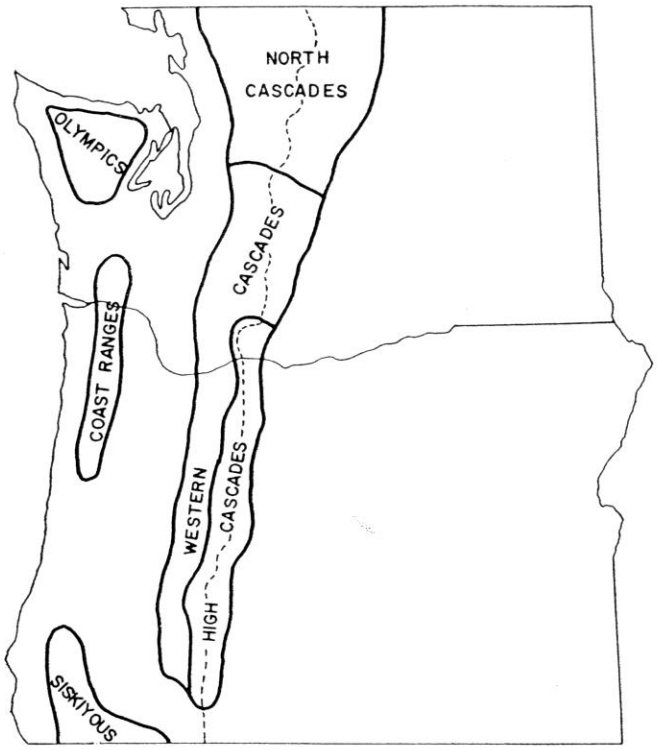

FIG. 1.—The six major geologic areas in which true fir-hemlock forests occur. Crest of the Cascade Range indicated by a dotted line.

FIG. 2.—A typical true fir-hemlock stand in the western Oregon Cascade Range. Mature tree species present are noble fir (left of center), Douglas-fir (center), and Pacific silver fir (foreground and poles and young veterans in background). Advance regeneration of Pacific silver fir is abundant.

ern hemlock, mountain hemlock, and western white pine. There are many important associated species, including Douglas-fir (*Pseudotsuga menziesii*), Engelmann spruce (*Picea engelmannii*), lodgepole pine (*Pinus contorta*), Alaska-cedar (*Chamaecyparis nootkatensis*), western redcedar (*Thuja plicata*), western larch (*Larix occidentalis*), and grand fir (*Abies grandis*).

Pacific silver fir is presently the most important species ecologically and economically, accounting for almost half of the volume present in true fir-hemlock forests. Silver fir attains heights of 150 to 180 feet and diameters of 3 to 5 feet in favorable situations. Although widespread, it attains maximum development on the western slopes of the Cascade Range in Washington and in the Olympic Mountains. The only available yield data indicate volumes per acre in overmature stands of Pacific silver fir and western hemlock may run over 70,000 board feet per acre (*7*).

The most important ecologic feature of Pacific silver fir is its tolerance. Seedlings are readily established in shade and on thick layers of duff and litter (Fig. 2). Resultant advance regeneration is responsive to release to very old ages (*19*). Pacific silver fir is a climax species wherever it occurs in upper-slope forests, and there is good evidence it is more tolerant than any associated hemlocks or cedars (*14*).

Several major insect and disease problems are associated with Pacific silver fir. Silver fir bark beetles (*Pseudohylesinus grandis* and *P. granulatus*) have caused extensive mortality in northern Washington. Balsam woolly aphid (*Chermes piceae*) is presently epidemic on silver fir in some areas although mortality of infested trees is limited (*17*). Several butt and trunk rots may cause extensive decay (*3, 4, 9*).

Noble fir is the largest and most valuable tree (on an individual basis) found in true fir-hemlock forests. It has been described as ". . . magnificantly tall and symmetrically formed . . . often clear of branches for 100 feet or more . . ." (*22*). Noble fir is found as far north as the Stevens Pass area in the Cascade Range and in the Coast Ranges (*10*). In southern Oregon, it merges with the morphologically similar Shasta red fir.

Noble fir is a relatively intolerant species and does not usually become established under a closed canopy (*21*). It is commonly found in even-aged stands, usually in mixture with other species, although small areas of pure stands are common (*10*). Noble fir is a very productive species individually (*13*) and in stands. Nearly pure old-growth stands containing gross volumes of over 300,000 board feet per acre have been encountered (*10*). Noble fir is free of any major insect or disease pests.

Shasta red fir, found in the southern Oregon Cascade Range and the Siskiyou Mountains, has been a center of controversy among taxonomists and foresters (*10, 18*). Some individuals consider the populations present to be noble fir while others call them Shasta red fir. Additional study may prove this fir is an ecotype or variation of noble fir, but for the present I refer to it as Shasta red fir.

In many ways Shasta red fir is like noble fir, forming dense even-aged stands which are highly productive. However, they appear to be ecologically distinct. Shasta red fir grows well on soils and under a climatic regime evidently not suited to the "typical" noble fir encountered in the northern two-thirds of the Cascade Range. Yields in 200-year-old stands of Shasta red fir probably equal or exceed the 140,000-board-feet-per-acre yields reported for California red fir (*Abies magnifica*) in northern California (*12*).

Western hemlock is often considered to be a low-elevation species but, in fact, it is second in abundance only to Pacific silver fir in true fir-hemlock forests of the northwest. It is most important on western slopes of the Cascade Range in Washington and northern Oregon and in the Olympic Mountains.

The silvics of western hemlock are well known (*2*) but it should be noted that western hemlock is not so tolerant as Pacific silver fir in most true fir-hemlock forests. Western hemlock

seedlings do not become established on the thick litter layers present in many true fir-hemlock forests; any reproduction is almost invariably confined to rotten logs. A successional sequence from Douglas-fir to western hemlock and, finally, to Pacific silver fir is commonly encountered. Successional relations of silver fir and western hemlock may be reversed at lower elevations (*20*).

Western hemlock suffers extensively from several pathogens at high elevations. Most important are butt and trunk rots and dwarfmistletoe (*Arceuthobium campylopodum*). Western hemlock is severely damaged by Indian paint fungus (*Echinodontium tinctorium*) in the High Cascades; cull due to this rot may run as high as 80 percent in old-growth stands. At high elevations western hemlock is, perhaps, least desirable of the important tree species present.

Mountain hemlock is an important species in higher elevation true fir-hemlock forests. It is found throughout the Cascade Range and in the Olympic and Siskiyou Mountains. Mountain hemlock attains maximum development in the High Cascades of central and southern Oregon where it forms dense, pure, even-aged forests over extensive areas.

Most ecologists consider mountain hemlock a climax species throughout its range, but my observations in the Washington Cascade Range indicate it is seral to Pacific silver fir in most closed forest stands in this area. However, mountain hemlock is the climax species at high elevations in southern Oregon where it is the most tolerant species present.

The most important pathogens attacking mountain hemlock are dwarfmistletoe and *Poria wierii* root rot, but these are of significance only in southern Oregon. Butt and trunk rots attack mountain hemlock, but it is generally a sounder species than western hemlock, especially along the crest and on the eastern slopes of the Cascade Range.

Western white pine is one of the larger, better formed species found in true fir-hemlock forests. Although it is not so abundant in the Pacific Northwest as in northern Idaho, there is a generous scattering of western white pine throughout mature forests, and it is well represented on areas burned over during the last century. White pine attains greatest importance in true fir-hemlock forests on eastern slopes of the Cascade Range in Washington and in the High Cascades of Oregon. In these areas, western white pine is often the largest tree present in mature even-aged stands and it is probably the fastest growing species present. Mountain pine beetle (*Dendroctonus monticolae*) and white pine blister rust (*Cronartium ribicola*) are presently causing extensive mortality of western white pine in the Cascade Range, especially in pole-sized stands.

The forests.—Composition, structure, and productivity of true fir-hemlock stands vary greatly, as would be expected with any wide-ranging group of forest types containing such a large variety of species. I am willing to attempt only a single generalization—the bulk of the true fir-hemlock forests consist of mature or overmature old-growth stands which often contain an abundance of advance regeneration (Fig. 2).

Four major geographic areas of true fir-hemlock forests can be recognized, however, by a uniformity in seral and climax species:[1]

1. The western slope of the Cascade Range in Washington and northern Oregon and in the Coast Ranges and Olympic Mountains. Characteristic species in mature forests are Pacific silver fir, western hemlock, and, except in the Olympic Mountains and northern Washington, noble fir. Typical Pacific-slope Douglas-fir forests occur in the true fir-hemlock zone (area in which true fir-hemlock forests are climax).

2. At high elevations on the east side of the Cascade Range in northern Washington. Forest composition is very much like that encountered in the spruce-fir zone of the northern Rocky Mountains (*6*)—subalpine fir, Engelmann spruce, western white pine, lodgepole pine, etc.

3. In the High Cascades of Southern Washington and northern Oregon. Species in mature stands are the more mesic Pacific silver fir and hemlocks but many seral species are the same as those found in the Rocky Mountain spruce-fir zone, e.g., subalpine fir. Engelmann spruce, western larch.

4. Southern Oregon Cascade Ranges and Siskiyou Mountains. Forests are composed mainly of Shasta red fir and mountain hemlock.

Management of True Fir-Hemlock Forests

Management techniques in true fir-hemlock forests are still in an embryonic and rapidly changing state. Many techniques are being developed by practical experience and experimentation concurrently with cutting as problems not encountered in lower elevation forest types become apparent. I would like to briefly outline for you past and present management practices in true fir-hemlock forests on national forest lands and the changes I foresee in the future. Practices are somewhat different on the much smaller proportion of true fir-hemlock forests in private and Washington State ownership.

Regeneration and harvesting methods. — Until recently, the staggered-setting system of clear cutting, developed for management of Douglas-fir, was practically the only silvicultural system applied to true fir-hemlock forests on National Forest lands. With this system, clearcuts of about 40 to 60 acres are interspersed with uncut areas of at least equal extent. After logging, clearcuts are usually burned and then planted or seeded. The results of applying this clearcut system to true fir-hemlock forests have been variable. Efforts at either natural or artificial regeneration have had limited success or complete failure on many cuttings, especially in the High Cascades area. Planting has not been consistently successful, partly, perhaps, because Douglas-fir has been used too extensively in reforesting these higher elevation cuttings. In many areas, a thick, compacted layer of organic matter remaining after logging and slash burning retarded establishment of seedlings from natural seed fall or broadcast seed and made proper planting of seedlings difficult. In some areas, such as the Mt. Baker region, questions have been raised concerning the advisability of burning cutovers on which large quantities of Pacific silver fir and western hemlock advance regeneration are present.

These problems brought quick recognition that the true fir-hemlock forests constitute ecologically different forest types growing in a more rigorous environmental regime than is the case for most coastal Douglas-fir forests. In 1963, the Pacific Northwest Region of the U. S. Forest Service developed a set of special silvicultural prescriptions for the true fir-hemlock forests.[2] The new prescriptions emphasize use of shelterwood cuttings and group clearcuts as small as one-half acre in size in regeneration problem areas and use of small patch clearcuts elsewhere in true fir-hemlock types. In the field, many foresters are solving regeneration problems associated with the tough, organic layers by tractor scarification and seeding of cutover areas following slash burning.

Consideration is now being given to

[1] A more detailed breakdown of the true fir-hemlock forests into 12 ecological provinces is in preparation and will be published in the near future as a U. S. Forest Service Research Paper by the Pacific Northwest Forest and Range Experiment Station.

[2] U. S. Forest Service. Forest Serv. Manual R-6, Sup. 40, Title 2400-Timber Management. Page Code 2413.14 — 47 through 54. 1964.

preservation of advance regeneration by careful logging and by eliminating slash burning. Interest in advance regeneration has been stimulated by: (1) realization that these seedlings and saplings are capable of release (*5, 7, 19*) and are not subject to extensive rot (*1*), (2) a decreasing prejudice against the tolerant species making up advance regeneration, and (3) difficulties encountered in obtaining postlogging regeneration.

It should be recognized that silvicultural needs have had to be tempered by economic factors such as limited access, low stumpage values, and a short operating season. These factors can still be expected to have a significant effect in the future.

I believe the future will see an even greater emphasis on natural regeneration in true fir-hemlock forests. This may be accomplished by using all high-forest silvicultural systems, including shelterwood, seed tree, alternate strip clearcut, and selection methods, depending on forest and site conditions, and by better utilization of advance regeneration. In my opinion, consistently successful techniques of artificial regeneration are not yet available, and several circumstances make it possible that extensive planting of cutover areas, as practiced elsewhere in the region, will never be carried out as a standard or automatic procedure in true fir-hemlock types. These circumstances include a short undependable planting season (*11*), heavy winterkill of seedlings, difficulty in growing high-quality true fir and hemlock planting stock, and slow growth of planted trees.

Regeneration research presently in progress is aimed at providing data on regenerative habits of true fir-hemlock forest species basic to scientific selection of harvesting systems for obtaining natural regeneration. Research on artificial regeneration of upper-slope cutovers is also in progress, with a goal of developing some consistently successful techniques for regenerating problem areas.

Species to manage. — Selection of species for management is a difficult problem in true fir-hemlock forests because of the large number of species and wide variety of habitats present. Little use has been made of many species in the past, and not much consideration has been given to the diversity of habitats often present on single cutting units. For many years, silviculturists have suggested greater use of true firs in plantings at higher elevations (*8, 15, 16*). However, in many cases, foresters have tried to convert true fir-hemlock forests to Douglas-fir, or even ponderosa pine, following logging. Results have been variable, sometimes promising at lower elevations but usually less successful with increasing elevation. The only true fir which has been planted to any extent is noble fir. Some de-facto species selection has resulted from destruction of advance regeneration during logging and slash burning.

There are encouraging signs that foresters working in true fir-hemlock types are beginning to make greater efforts in utilizing the wide variety of species present. One recent development worthy of special note is a renewed interest in use of western white pine. In many parts of the Cascade Range western white pine has been difficult to market because of the small proportion of this species handled by local sawmills. Marketability should improve greatly in the future, however, if a greater volume of this species becomes available; the soft, uniform texture and good working properties of the wood make it especially desirable. It is one of the fastest growing and highest quality species present in true fir-hemlock forests, especially on low-quality sites. Western white pine has greatest potential for management in the High Cascades. Possibilities of antibiotic control of white pine blister rust and of rust-resistant planting stock has made white pine management more promising. Greater planting of western white pine and antibiotic treatment of seedlings and established stands are already being carried out. If control of the rust and mountain pine beetle can be accomplished, the Cascade Range could become a region of white pine production second only to northern Idaho.

Much greater efforts in species selection can be expected in the future if foresters working in true fir-hemlock forests favor the species best adapted to fulfill management objectives for each site. Increasing utilization should be made of the wealth of tree species available in true fir-hemlock types. Greater demand for species previously considered "weeds" will accelerate activities in this direction. I believe that a very important aspect of this work could be a "unit area" approach in regeneration which would recognize that blanket efforts to establish one or two species on a cutting may be undesirable when a large amount of habitat variability is present. Species selection can be accomplished in natural regeneration as well as artificial by paying careful attention to silvical requirements of desired species when selecting the harvesting system to be used.

The major difficulty in species selection is lack of information. Neither yield data nor site index curves are available for any major upper-slope species except western hemlock. Habitat preference and site requirements of true fir-hemlock species are not known in sufficient detail. A great deal of research is necessary before an adequate basis for making species selections is available. A major goal of vegetation-soil-site and mensurational studies presently in progress is to provide the necessary information.

Other aspects of management.—Little thought has as yet been given to management of immature stands because of the predominance of old-growth in true fir-hemlock forests. Thinnings have not been carried out, although many of the younger true fir-hemlock stands are obviously overstocked. Much attention will undoubtedly be given this phase of management in the future as the proportion of young age classes increases. An important objective of future research will be development of spacing-yield data.

Coordination of timber production with other resource values is and will continue to be a major consideration of foresters working in true fir-hemlock forests. Recreation and aesthetic values of true fir-hemlock forests are so important an appreciable proportion of their area on the National Forests has been designated as "High Mountain Area" (*23*), for which special objectives and policies have been determined. Watershed and recreation values are especially high in the high-elevation areas occupied by these forests. Resource users are quick to criticize any timber harvest activities they believe to be detrimental to the values in which they are interested. Coordination of timber production with other uses will often require application of compromise silvicultural systems. The significance of uses other than timber makes it especially important that management of true fir-hemlock forests has a broad ecological basis, since timber values are not the only major values at stake.

Literature Cited

1. AHO, PAUL E. 1960. Heart-rot hazard is low in *Abies amabilis* reproduction injured by logging. U. S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 196, 5 pp.
2. BERNTSEN, CARL M. 1958. Silvical characteristics of western hemlock. U. S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Silvical Ser. 3, 16 pp.
3. BIER, J. E., P. J. SALISBURY, and R. A. WALDIE. 1948. Studies in forest pathology. V. Decay in fir, *Abies ambilis* and *lasiocarpa*, in the upper Fraser region of British Columbia. Canad. Dept. Agr. Tech. Bul. 66, 28 pp.
4. BUCKLAND, D. C., R. E. FOSTER, and V. J. NORDIN. 1949. Studies in forest pathology. VII. Decay on west

ern hemlock and Pacific silver fir in the Franklin River area, British Columbia. Canad. Jour. Res. C. 27: 313-331.

5. DAHMS, WALTER G., rev. by JERRY F. FRANKLIN. 1963. Silvical characteristics of mountain hemlock. U. S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Silvical Ser. 11, 18 pp., illus. Revised.
6. DAUBENMIRE, R. 1952. Forest vegetation of northern Idaho and adjacent Washington, and its bearing on concepts of vegetation classification. Ecol. Monog. 22:301-330.
7. DIMOCK, E. J., II. 1958. Silvical characteristics of Pacific silver fir. U. S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Silvical Ser. 4, 12 pp.
8. DOUGLAS-FIR SECOND-GROWTH MANAGEMENT COMMITTEE. 1947. Management of second-growth forests of the Douglas-fir region. U. S. Forest Serv. Pac. NW. Forest & Range Expt. Sta., 151 pp.
9. FOSTER, R. E., J. E. BROWNE, and A. T. FOSTER. 1958. Studies in forest pathology. XIX. Decay of western hemlock and amabilis fir in the Kitimat Region of British Columbia. Canad. Dept. Agr. Pub. 1029, 37 pp.
10. FRANKLIN, JERRY F. 1964. Some notes on the distribution and ecology of noble fir. Northwest Sci. 38:1-13.
11. GRATKOWSKI, H. J. 1958. Natural reproduction of Shasta red fir on clear cuttings in southwestern Oregon. Northwest Sci. 32:9-18.
12. HALLIN, WILLIAM E. 1957. Silvical characteristics of California red fir and Shasta red fir. U. S. Forest Serv. Calif. Forest & Range Expt. Sta. Tech Paper 16, 8 pp.
13. HANZLIK, E. J. 1925. A preliminary study of the growth of noble fir. Jour. Agr. Res. 31:929-934.
14. ————————. 1932. Type successions in the Olympic Mountains. Jour. Forestry 30:91-92.
15. ISAAC, LEO A. 1956. Where do we stand with Douglas-fir natural regeneration research. Soc. Amer. Foresters Proc. 1955:70-72.
16. ————————. 1960. Leo A. Isaac on silviculture. 32 pp., illus. Oregon State College Press: Corvallis.
17. JOHNSON, NORMAN E., RUSSELL G. MITCHELL, and KENNETH H. WRIGHT. 1963. Mortality and damage to Pacific silver fir by the balsam woolly aphid in southwestern Washington. Jour. Forestry 61:854-860, illus.
18. PARKER, EUGENE L. 1963. On the geographic overlap of noble fir and red fir. Forest Sci. 9:207-216, illus.
19. SCHMIDT, R. L. 1957. The silvics and plant geography of the genus *Abies* in the coastal forests of British Columbia. Brit. Columbia Forest Serv. Tech. Pub. T.46, 31 pp., illus.
20. SCOTT, DAVID R. M. 1962. The Pacific Northwest region. *In* Regional silviculture of the United States, ed. by John W. Barrett. Pp. 503-570, illus. The Ronald Press Co., New York.
21. STAEBLER, GEORGE R. 1958. Silvical characteristics of noble fir. U. S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Silvical Ser. 5, 12 pp.
22. SUDWORTH, GEORGE B. 1908. Forest trees of the Pacific slope. 441 pp., illus. Washington, D. C.
23. U. S. FOREST SERVICE. 1962. Management objectives and policies for the high mountain areas of National Forests of the Pacific Northwest Region. U. S. Forest Serv. 8 pp.