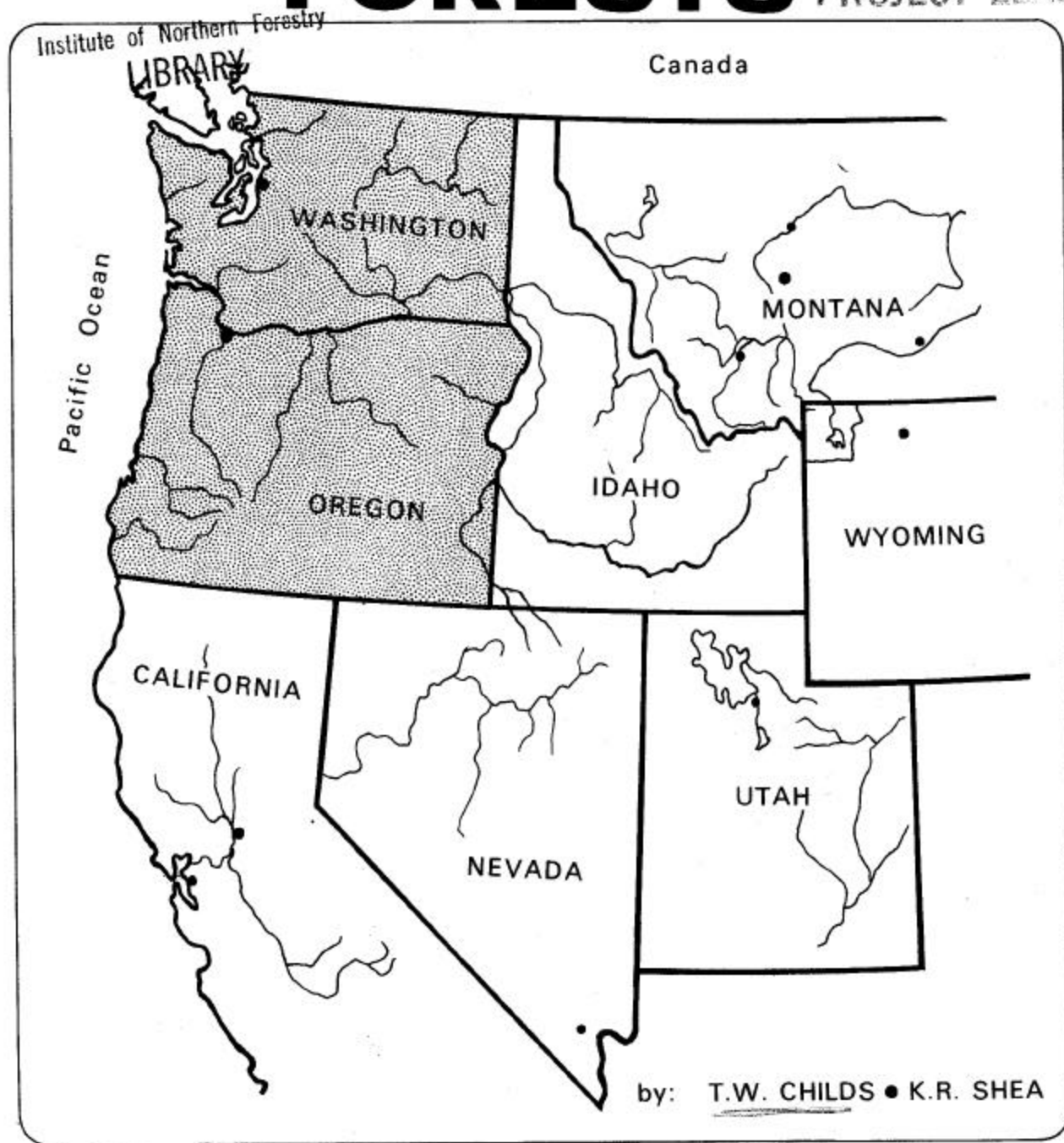


ANNUAL LOSSES FROM DISEASE IN PACIFIC NORTHWEST FORESTS

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FOREWORD

Increasing demands are being made on Oregon and Washington forests for timber and forest-derived products and benefits. To meet these demands, factors influencing the productivity and use of this forest resource must be evaluated. This report was prepared to meet current needs for estimates of losses caused by one of these factors—forest diseases. Precise data on disease-caused losses are not yet available and the authors have relied on a variety of sources and their experience to provide this information. Although more precise estimates are badly needed, this report represents the best available evaluation of disease losses at this time. It should answer an urgent need until more precise estimates can be obtained.

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SUMMARY

This report presents current estimates of annual disease impact on forest productivity of Oregon and Washington. It is concerned exclusively with losses of timber volumes and of potential timber growth in today's forests.

Annual loss from disease in this region is estimated at 3,133 million board feet or 403 million cubic feet. This is about 13 percent of the total annual growth including the mean periodic growth ~ of seedlings and saplings.' Of this loss, 162 million cubic feet is potential growth prevented by disease, 129 million is mortality, and 112 million is cull. West of the Cascade Range, annual loss is 234 million cubic feet, of which 92 million is cull from heart rots. East of the Cascades, annual loss is 169 million cubic feet, of which 91 million is growth loss and only 20 million is cull. More than half of the growth loss east of the Cascades is caused by dwarfmistletoes.

Greatest losses occur in Douglas-fir (139 million cubic feet annually), western hemlock (88 million), true firs (62 million), and ponderosa pine (40 million). Principal causes of loss are dwarfmistletoes (148 million cubic feet), root rots (115 million), and heart rots (110 million).

Cubic-volume losses are now about equally divided between young growth and old growth. As young stands replace old ones, cull from heart rots will decrease but growthreducing diseases will become more important. Effective controls for some diseases are now or will soon be available, but most diseases will continue to cause heavy losses indefinitely unless research efforts are made proportionate to the values at stake.

INTRODUCTION

Diseases seriously reduce forest productivity. Information on the kind and extent of their effects is essential for good forest management.

Losses caused by the various groups of diseases in Pacific Northwest forests were estimated in 1954 for the Timber Resource Review (U.S. Forest Service 1958). Since then, more accurate measurements have been made of forest volumes and growth rates, and some additional data have been obtained on disease effects. This report, prepared at the request of the Northwest Forest Pest Action Council, presents revised estimates of volume loss from diseases from which their economic impact can be calculated.

Estimates in this report represent the consensus of four forest disease specialists familiar with the region: L. F. Roth, Oregon State University; and D. P. Graham, T. W. Childs, and Ii. R. Shea, U.S. Forest Service.

This report is concerned exclusively with impact of the various diseases on timber volumes, actual and potential, in the principal forest types and two major subregions of Oregon and Washington. Estimates do not include, for example, losses from Christmas tree diseases, decay of forest products, increased logging costs in highly defective stands, or restrictions imposed by disease upon management.

Estimates do not include damage (1) where involvement of disease is not fairly certain—for example, rapid deterioration of residual crowns after partial cuttings; or (2) where disease is only a minor factor in losses caused primarily by such things as environmental stress on senile stands—for example, Pacific silver fir decadence during the early 1950's in northern Washington. On the other hand, disease is a primary factor in part of the mortality often attributed to bark beetles, and some of this mortality is accordingly included in the estimates (but none of the

damage caused to reasonably healthy trees by beetle broods that originate in diseased trees).

Mortality and cull estimates consist entirely of losses in trees 11 inches in diameter at breast height (d.b.h.) and larger. All damage to smaller trees is classified as growth loss—that is, reduction of productivity on areas nonstocked, or stocked with smaller or otherwise inferior trees, as a result of disease. Salvaged mortality has not been charged against disease. Cull refers to volume made unusable by disease (principally heart rots and stem cankers); it does not include such things as sweep, sound breakage, or frost cracks. Decay of killed timber has been charged against the cause of death—for example, losses in fire-killed timber are not included here, and losses in windthrows are included only to the extent that root rots contributed to the windthrow.

Five groups - heart rots, root rots, dwarf mistletoes; foliage diseases, and cankers and stem rusts - include most of the parasitic diseases and all of those now causing serious damage in this region. A few others, such as *Verticillium* wilt of maple, occasionally attack forest trees but cause little damage.

Forest productivity is decreased by physiological disturbances which not only cause injury directly but also predispose trees to attack by parasitic diseases. Estimates of physiological disease impact, however, depend on where the line is drawn between normal and abnormal environmental conditions. No site is ideal and the range of most growth-influencing factors is continuous from the best to the worst conditions. Even if standards of normality are arbitrarily established, the quantitative effects of most physiological diseases are too poorly known to permit reliable estimates of losses; accordingly, we have not attempted to estimate their impact. ("Wetwood" is included in losses from heart rots, even though it may be of physiological origin.)

Names and dates in parentheses refer to literature listed in "Sources of Information," p.11.

Foliage diseases are almost the only ones that fluctuate widely and rapidly, but mortality from many other diseases tends to be appreciably higher during climatic periods unfavorable to trees than during favorable periods. We have tried to estimate the averages of fluctuating losses, but assumptions about the frequency of periods of damage -for example, by outbreaks of *Elytroderma* needle cast - are obviously little better than guesses.

Even though our estimates are based on all available information, both published and unpublished, they cannot be considered precise. Quantitative data on impact are still fragmentary, even for the most important heart rots and dwarfmistletoes, and are entirely lacking for some diseases. Where we have had to depend largely on personal observations and vague, qualitative information, we have estimated loss at the lowest probable figure. Disease losses in forests of Oregon and Washington are almost certainly not less, and may be considerably more, than here estimated.

In absolute volumes, the largest errors are probably in estimates of growth loss from root rots. Chronic infections of large roots are common and undoubtedly reduce growth of many trees that survive indefinitely. Agricultural experience gives some grounds for belief that inconspicuous diseases of fine roots may cause about as much growth loss as all other root pathogens combined. But we have very little information on growth impact of chronic infections and none at all on fineroot diseases of forest trees. Accordingly, we ignored fine-root diseases and restricted our growth-loss estimates almost entirely to loss from killing of trees less than 11 inches d.b.h.

Unless specifically stated otherwise, estimates in this report are of average annual losses from disease. Most estimates in the text are given in cubic footage but are summarized in both board and cubic footage in appendix tables 1, 2, 3, and 4. Examples of computations are in the appendix.

REGIONWIDE LOSSES FROM DISEASE

Diseases reduce the annual productivity of Oregon and Washington forests by an estimated 3,133 million board feet (Scribner scale), or 403 million cubic feet. This total annual loss equals about 13 percent of the annual growth, including mean periodic-growth of seedlings and saplings. The loss consists of 162 million cubic feet of growth loss, 129 million of mortality, and 112 million of cull (fig. 1). Growth loss is caused principally by dwarfmistletoes and root rots (75 and 62 million cubic feet, respectively). Mortality is also caused principally by dwarfmistletoes and root rots (72 and 53 million cubic feet). Heart rots cause all but 2 million cubic feet of the cull.

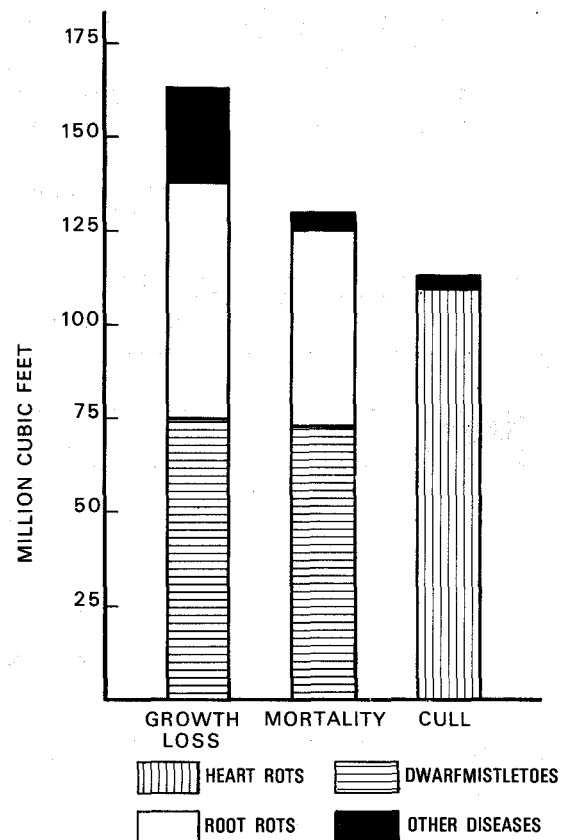


Figure 1.—Total annual losses from disease by form of loss and disease group.

In terms of cubic feet, losses are equally divided between young growth (seedlings, saplings, poles, and sawtimber less than 17 inches d.b.h.) and old growth (trees 17 inches d.b.h. and larger). In board feet, three-fifths of the loss occurs in old growth (deductions for cull are proportionately much greater in board-foot than in cubic-foot scale). Loss of potential growth occurs principally in young-growth stands, and mortality and cull losses principally in old-growth stands (fig. 2),

Most of the loss is caused by dwarfmistletoes (148 million cubic feet), root rots (115 million), and heart rots (110 million). Other diseases (foliage diseases and cankers including stem rusts) cause an annual loss of 30 million cubic feet.

Of 153 million cubic feet of potential growth lost each year in young growth, 67 million is from dwarfmistletoes and 61 million from root rots (fig. 3). In old growth, dwarfmistletoes cause more than nine-tenths of the 9 million cubic feet of growth loss.

Figure 2.—Growth loss is greatest in young-growth stands; mortality and cull in old-growth stands.

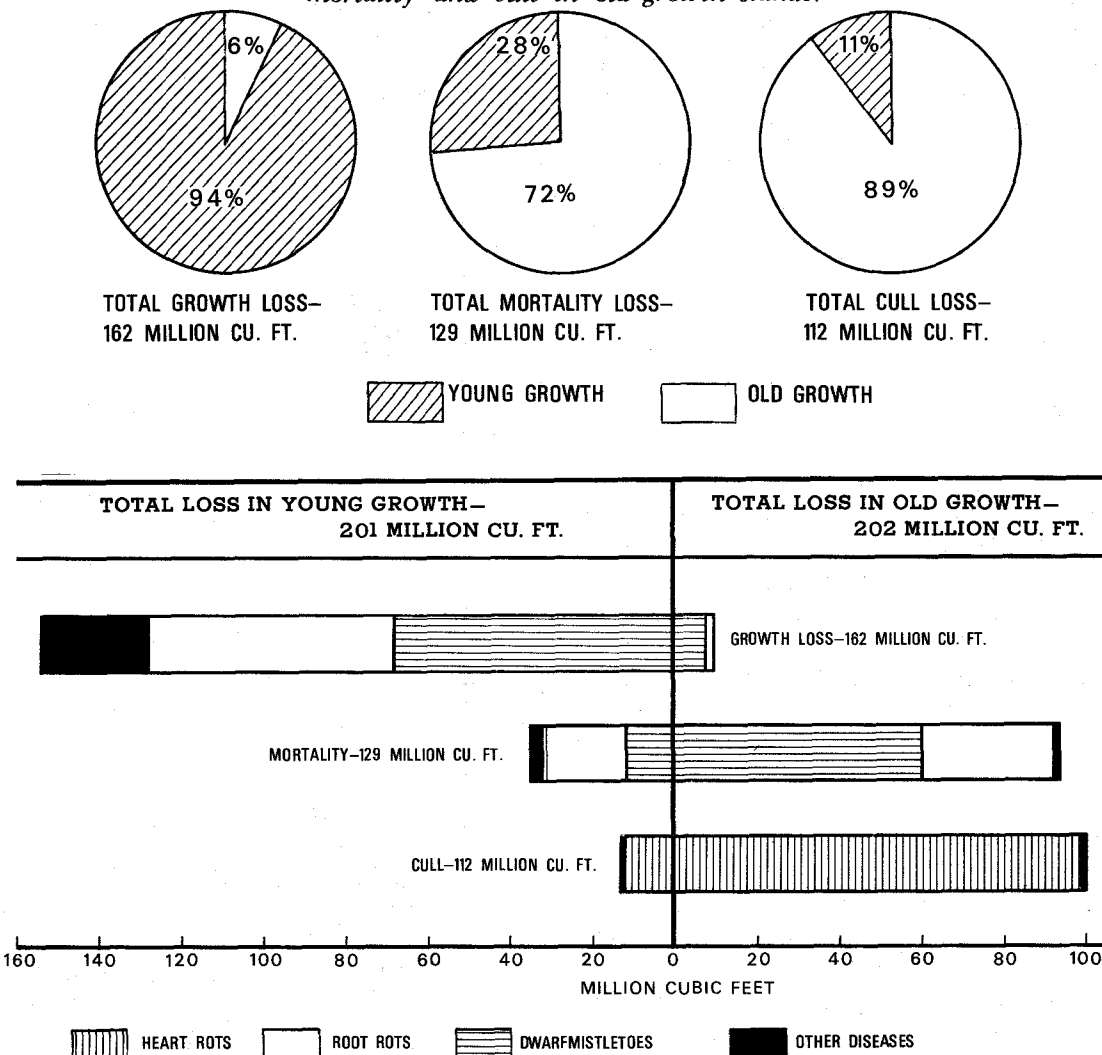


Figure 3.—Principal forms and causes of disease loss in young growth differ from those in old growth.

Young-growth mortality (36 million cubic feet) is caused principally by root rots (20 million) and dwarfmistletoes (12 million). In old-growth mortality (93 million cubic feet), loss to dwarfmistletoes exceeds that to root rots (60 million and 33 million, respectively).

Annual cull losses amount to 12 million cubic feet in young growth (11 million from heart rots) and 100 million in old growth (99 million from heart rots).

LOSSES BY SUBREGIONS AND TREE SPECIES

The Cascade Range divides Oregon and Washington into two subregions that differ markedly in climate, forest types, and disease conditions: the Douglas-fir subregion to the west of the range and the ponderosa pine subregion to the east. To avoid confusion, these subregions will be referred to as "west side" and "east side" instead of by the names of their principal tree species. Noticeable differences in forest types and disease conditions also exist between Oregon and Washington, but we have not estimated losses separately by States.

Total annual loss from disease is 239 million cubic feet on the west side and 169 million on the east side. Volumes and growth rates are considerably lower on the east side than on the west side, however, and disease impact relative to the total subregional forest resource is accordingly greater on the east side (0.4 percent of present cubic-volume inventory, or 23.2 percent of current growth) than on the west (0.2 percent of volume, or 11.6 percent of growth).

Average annual loss per stocked acre is 7.4 cubic feet in young growth and 16.0 in old growth on the west side, and 7.3 in young growth and 12.8 in old growth on the east side.

West of the Cascades, growth loss and mortality are about equal, and cull causes more loss than either (fig. 4). On the east side, growth loss is more than half again as great

as mortality, and cull causes considerably less loss than either. In both subregions, growth loss is much greater in young than in old growth, and mortality and especially cull are greater in old growth.

Losses are summarized by tree species in figures 5 and 6. Largest losses occur in Douglas-fir (91 million cubic feet) and western hemlock (88 million) in the west-side subregion and in Douglas-fir (49 million) and ponderosa pine (40 million) in the east side.

Heavy losses also occur in true firs (32 million cubic feet on the west side and 29 million on the east), and in miscellaneous species (23 million on the west side and 51 million—mostly in lodgepole pine and western larch—on the east). In view of the rapidly increasing importance of these so-called minor species, such losses must be considered a serious drain on the forest resources of the region.

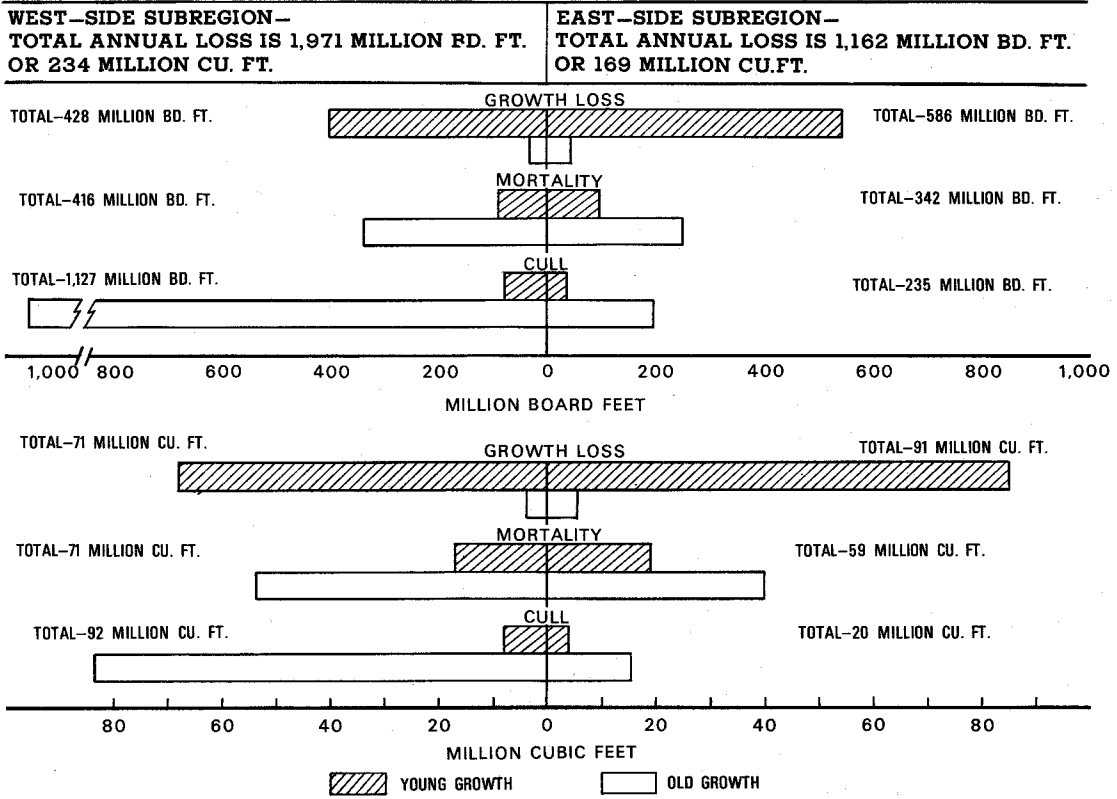


Figure 4.—Annual losses in young growth and old growth by subregion, form of loss, and age class.

LOSSES BY DISEASE GROUPS

Regionwide, heart rots cause more boardfoot loss than any other group of diseases but dwarfmistletoes cause more cubic-foot loss (fig. 7). Regardless of unit of measurement, the largest loss in old growth is caused by heart rots. In young growth, dwarfmistletoes and root rots cause about equally heavy losses, and heart rots, foliage diseases, and cankers (including stem rusts) are of much less importance.

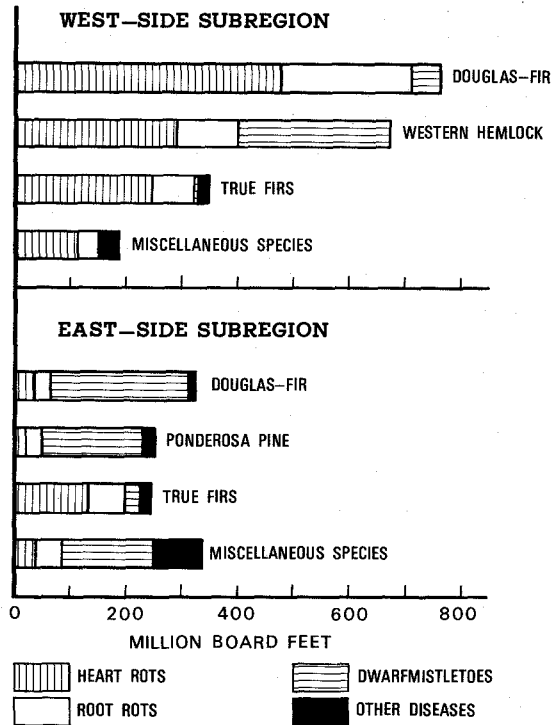


Figure 5.—Annual board-foot losses by subregion and tree species.

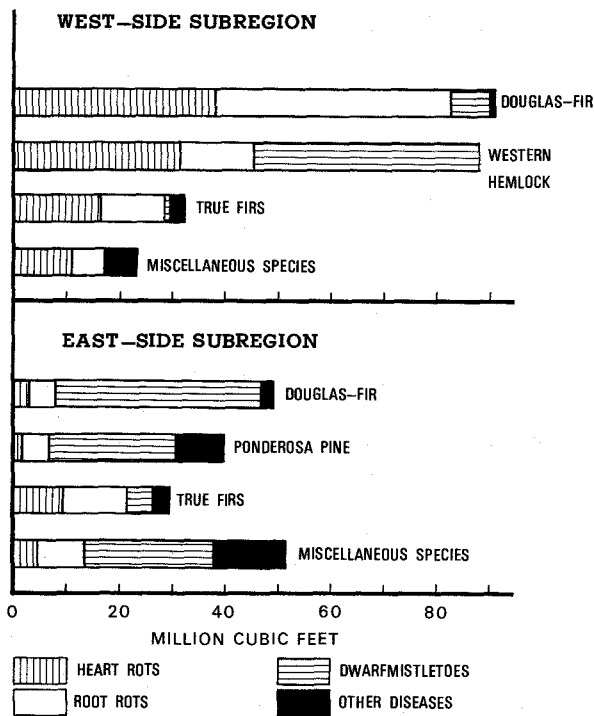


Figure 6.—Annual cubic-foot losses by subregion and tree species.

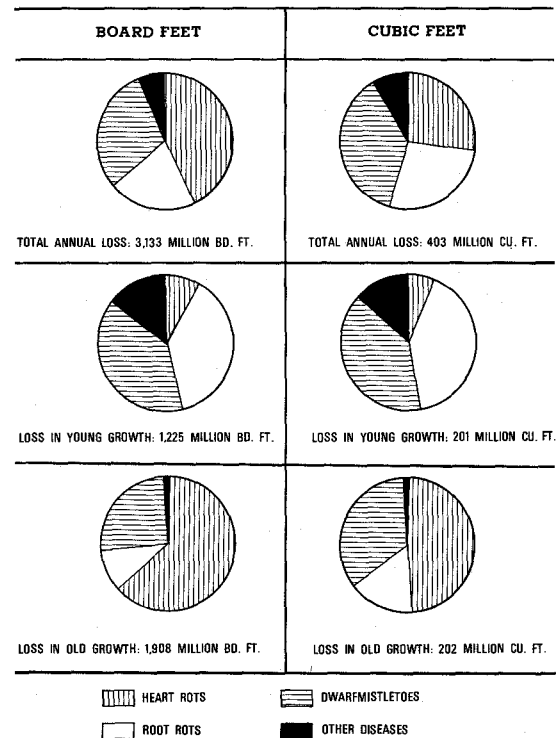


Figure 7.—Relative importance of disease groups by total annual loss and by loss in young growth and old growth.

Subregionally, largest losses on the west side are caused by heart rots and on the east by dwarfmistletoes (fig. 8).

Heart rots.-A few heart-rot fungi also attack sapwood of living trees to some extent, slowly weakening and occasionally even killing their hosts. Loss from heart rots, however, is almost entirely in the form of cull. *Fomes pini* (mostly in Douglas-fir) and *Echinodontium tinctorium* (mostly in western hemlock and true firs) are the most important of the numerous heart-rot fungi in the Pacific Northwest.

Annual board-foot losses from heart rots are greatest in Douglas-fir (511 million), true firs (380 million), and western hemlock (292 million). Ponderosa pine and most of the miscellaneous species are relatively sound (fig. 9).

Dwarf mistletoes -Dwarfmistletoes cause 75 million cubic feet of growth loss annually, 72 million mortality, but only negligible cull. Losses are almost twice as great on the east side of the Cascades (97 million cubic feet) as on the west side (50 million), and are somewhat greater in young growth (79 million) than in old growth (68 million).

Most of the coniferous species in the region are attacked by dwarfmistletoes, *Arceuthobium* spp. (west of the Cascades, Douglasfir is attacked only in southwestern Oregon). Losses are greatest in Douglas-fir (46 million cubic feet), western hemlock (42 million), and ponderosa pine (29 million), and are relatively small in true firs (fig. 10). Losses in miscellaneous tree species are principally in lodgepole pine and western larch.

Root rots attack trees of all ages, causing growth loss of 62 million and mortality of 53 million cubic feet annually. (Cull from invasion of butt logs is classed as loss from heart rots.) The most important root-rotting fungi are probably *Paria weirii* (we estimate that this fungus causes an annual loss of about 32 million cubic feet in west-side Douglas-fir alone), *Armillaria mellea*, and *Domes annosus*.

West-side losses from root rots (83 million cubic feet) are considerably greater than

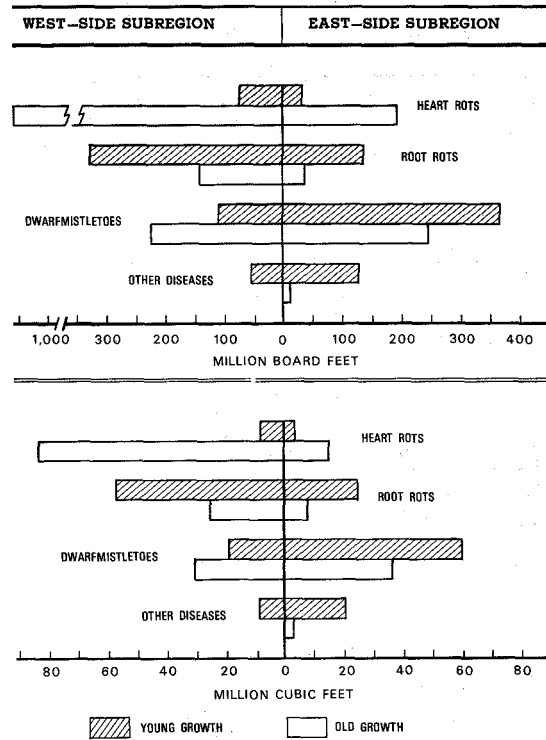


Figure 8.—Annual disease losses by subregions and disease groups.

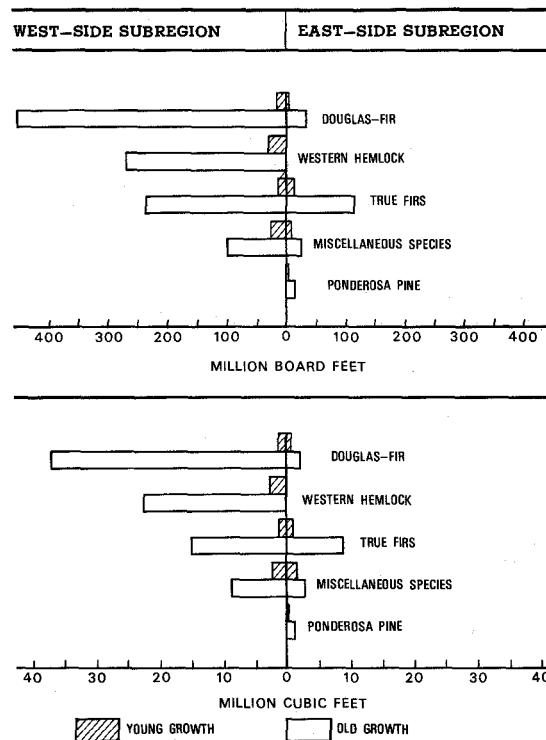


Figure 9.—Annual losses from heart rots by subregion, tree species, and age class.

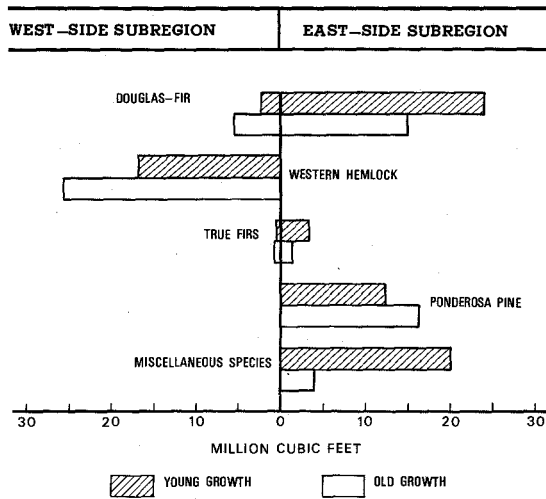


Figure 10.—Annual losses from dwarf mistletoes by subregion, tree species, and age class.

east-side (32 million), and young-growth losses (82 million) exceed old-growth (33 million).

Losses are greatest in Douglas-fir (50 million cubic feet), true firs (25 million), and western hemlock (19 million), and are relatively small in ponderosa pine (fig. 11).

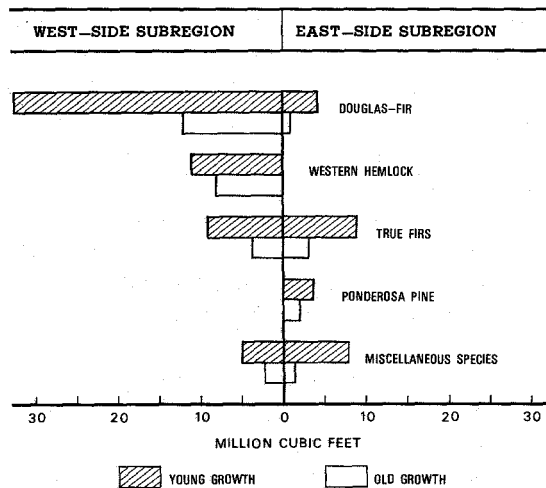


Figure 11.—Annual losses from root rots by subregion, tree species, and age class.

Foliage diseases occur on all tree species throughout the region, but severe damage is usually confined to relatively small localities and to occasional periods following weather conditions exceptionally favorable for infection. Almost all damage is in the form of growth loss.

Annual losses are about 2 million cubic feet in the west-side subregion and 15 million in the east-side. Losses are greatest in lodgepole pine, western larch, and true firs (4 million cubic feet each), and in ponderosa pine and Douglas-fir (2 million each).

Several different fungi cause damaging foliage diseases of lodgepole pine and true firs. On western larch, the most important foliage fungus is *Hypodermella laricis*; on ponderosa pine, *Elytroderma deformans*; and on Douglas-fir, *Rhabdocline pseudotsugae*.

Cankers and stem rusts annually cause losses of 9 million cubic feet of potential growth, 3 million of mortality, and 2 million of cull. Only about 1 million cubic feet of the total loss is in old growth.

By far the most important of these diseases are the stem rusts: white pine blister rust, *Cronartium ribicola*, (5 million cubic feet annually) in west-side forests, and western gall rust, *C. harknessii*, and comandra rust, *C. comandrae*, of lodgepole and ponderosa pines (6 million) in east-side forests.

DISCUSSION

Extension of road systems and improvement of logging equipment will permit increased salvage of scattered mortality. Replacement of old-growth stands by young-growth will reduce losses from heart rots. Intensive management will recover some of the potential productivity of growing space now occupied by diseased trees.

But changes in forest conditions and practices must be expected to aggravate rather than lessen damage by disease. Growth-reducing diseases, especially, will become more important as young stands replace old ones and gross growth increases. Substitution of more or less artificial environments and vegetative successions for natural ones will increase losses from many diseases unless effective countermeasures are taken.

Losses from heart rots in young growth can be largely avoided in the future through prevention of wounds, discrimination against infected trees during cuttings, and shortening of rotations where necessary. Annual losses in old growth, although totaling hundreds of millions of board feet, are so small in relation to the gross volumes in which they occur that they can seldom be given much weight in determining the order of harvest of old-growth stands. The huge volumes of cull now present in old-growth forests are accumulations from many decades of slow deterioration; economic loss from this existing cull can be substantially reduced through better utilization (development of new products and improved milling methods) and through more accurate determinations of cull volumes in stands and location and extent of decay in individual trees.

Much of the heart-rot information needed for both young-growth and old-growth management is already available. Additional information is needed principally on wetwood in true firs and associated species, extent of cull associated with various external indicators in a few of the major commercial tree species, and relationships of heart rots to environmental conditions in young stands.

Dwarfmistletoes will almost certainly be the first group of diseases effectively controlled at reasonable cost, even if no selective herbicide is developed. Recent studies suggest that dwarfmistletoe on ponderosa pine and probably on several other hosts can be controlled by changes in logging and thinning practices. Since control by such methods is practicable only during one or two brief periods in the rotation, and since several million acres must be treated, immediate and drastic reduction of losses is unlikely. However, there is good reason to expect that losses from dwarfmistletoes can be practically eliminated within the next century.

Information most urgently needed at present is (1) How much infection can we leave in sapling stands and still get a satisfactory crop at the end of the rotation? (2) What is the cheapest way to reduce infection to an acceptable level? (3) To what extent are the research results obtained from ponderosa pine dwarfmistletoe also applicable to dwarf mistletoes on western hemlock, Douglas-fir, and other conifers?

The root rot problem is much more difficult, even if we consider only the known diseases of coarse roots and ignore the probable great importance of fine-root diseases. Losses will increase considerably in the next several decades, not only because of increase in quantity of young growth but also because certain cultural practices tend to increase damage by root rots. For effective control, it will be necessary to eliminate the pathogens, or at least keep them from invading new hosts, on persistent infection centers that in the aggregate total thousands of acres now largely nonproductive. Direct control methods are often ineffective and, in any event, far too costly for general use. Experience in agriculture indicates that satisfactory control is most likely to be obtained by indirect methods—that is, by modifying environmental conditions, especially the soil microflora, to make them unfavorable for the pathogens. This is obviously a long-term effort, but the values at stake more than justify the effort.

For immediate use, we need more accurate measurements of damage rates and better methods for distinguishing local hazard zones; these will facilitate salvage and prevent waste of funds in cultural operations where adequate returns are unlikely. For eventual control, we need detailed information on the complex relationships between root pathogens, their hosts, associated vegetation, and other biological and physical factors of the environment.

Although foliage and canker diseases are less damaging than the other three disease groups, they cause substantial losses, most of which must be tolerated until more serious problems have been solved. As with other diseases, some losses could be prevented by ordinary good management. For example, plantations of nonlocal stock are often destroyed by foliage diseases; when nonlocal plantations survive, large-scale introduction of undesirable genes into the local races may eventually be even more damaging.

A breeding program, now in progress, will soon produce white pine and sugar pine planting stock resistant to blister rust, thereby permitting the production of a valuable crop on thousands of acres where other species are far less productive. Arid rust control by ribes eradication is too expensive to be practical. Little else is being done at present to reduce losses caused by foliage and canker diseases, but research on fungicides would probably yield worthwhile results. For example, a systemic fungicide effective against *Elytroderma* needle cast of ponderosa pine would eliminate the need for heavy salvage cuts on severe outbreak areas and save much of the million-plus cubic feet lost annually to this disease.

Control of agricultural diseases, almost entirely a result of research during the last century, indicates the benefits obtainable from comparable progress in forestry. Control of forest diseases, even if only moderately effective, will prevent many undesirable side effects of intensive management and reduce current losses from disease by at least one-half.

But control methods cannot be developed overnight, and chances to apply them to a given acre ordinarily occur only at long intervals. Even with present progress, large volumes of valuable timber will be lost annually to disease for several decades to come. Unless development of control measures is hastened, heavy losses will continue indefinitely.

SOURCES OF INFORMATION

To strengthen our basis we sometimes used data from other parts of western North America, modified as necessary to fit the situation in the Pacific Northwest. For example, having little information on foliage diseases of western white pine, we relied to some extent on Shaw and Leaphart's (1960) study, but reduced their estimate of impact because the two diseases they discuss appear less common and probably less damaging here than in Idaho.

Unpublished data and observations by Pacific Northwest Forest and Range Experiment Station personnel and others were used in addition to the following reports:

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APPENDIX

Calculations of Losses from Disease

Basic forest resource data were taken from "Forest Statistics for Southwest Oregon" (Hazard and Metcalf 1964), "Timber Resource Statistics for the Pacific Northwest as of January 1, 1963" (U.S. Forest Service 1965), and from timber resource statistics in the Bonneville Power Administration's "Pacific Northwest Economic Base Study for Power Markets" (Gedney et al. 1966). Some adjustments of these data were made to meet special requirements of this report—for example, percentage of acreage in seedlings and saplings east of the Cascade Range was increased because much of the area typed as sawtimber is actually occupied by small groups of young trees.

Necessary breakdowns of basic resource data were made by pro rata apportionment whenever possible. For example, acreage was apportioned among species and among old sawtimber, young sawtimber, and poles on the basis of cubic volumes by species and size classes as given in table 13 of Resource Bulletin PNW-9 (U.S. Forest Service 1965). Definitions and assumptions used in such calculations are as follows:

1. Old sawtimber includes all trees 17 inches d.b.h. and larger; young sawtimber, all trees 11.0 to 16.9 inches d.b.h.
2. West of the Cascade Range, acreage of seedlings and saplings is about equal to that of poles; east of the Cascades it is about half that of poles.
3. Cubic volume per acre of young sawtimber is about half and cubic volume per acre of poles is about one-quarter that of old sawtimber.
4. Growth percent of young sawtimber (in both cubic and board feet) is about four times that of old sawtimber.
5. Mean periodic growth is average annual growth during the rotation (if a stand now 10 years old will yield

40,000 board feet per acre at a rotation age of 100 years, mean periodic growth is 0.4 thousand board feet per acre.)

6. Mean periodic growth per acre of coniferous seedlings, saplings, and poles is about the same as that of young sawtimber, except that board-foot growth of lodgepole is about half that of young sawtimber. Mean periodic growth of small hardwoods is about half that of young sawtimber in cubic-foot volume and about one-quarter that of young sawtimber in board-foot volume.

In some instances it was necessary to estimate the aggregate effect of a group of diseases over the entire acreage occupied by a given host species and age class. For example, since mortality from root rots appears somewhat more common in old-growth western hemlock than in old-growth Douglas-fir in the west-side subregion, we estimated an unsalvaged mortality loss of 20 board feet per year from root rots on the average acre of old-growth western hemlock. In other instances, enough information was available to permit computation of impact factors for specific diseases. For example, *Polyporus tomentosus* is damaging on about 10 percent of the old-growth ponderosa pine acreage and affects about 30 percent of the trees on this infested acreage. We assumed that growth of affected trees is reduced by 20 percent. The product of these percentages is an impact factor of 0.006 (0.6 percent) which, when applied to the annual growth of old-growth ponderosa pine (52 million cubic feet), gives an estimated loss of 0.3 million cubic feet. Other examples follow

Losses from heart rots in west-side Douglas-fir old growth. About three-fourths of the remaining volume is in Oregon, where stands are more defective than in Washington, but utilization is closer now than at the time of Boyce's (1932) study. So we assumed that 14 percent of board-foot volume (or 8 percent of cubic-foot volume) is cull. Some of Boyce and Wagg's (1953) results suggest that the average tree survives

for about 100 years after infection, but theoretical analysis of data from another study indicates that infected western hemlocks and true firs survive for about 200 and 150 years, respectively, and Douglas-fir would be expected to survive at least as long. So we assumed an average survival of 200 years after infection, or an , average period, since infection, of 100 years for living infected trees. Then, (14 percent/100 years) X (327,973 million board feet of gross volume) - annual cull loss of 459 million board feet.

Losses from Douglas-fir dwarfmistletoe in southwest Oregon. Infection is present on almost every acre of Douglas-fir type on the Rogue River National Forest, and current mortality on the forest is about 45 million board feet per year (Hopkins 1958). In stands aerially mapped as damaged, 68 percent of the trees were infected and 14 percent had been recently killed; on "check" plots supposedly outside the areas of damage, 56 percent of the trees were infected and 8 percent recently killed (Aho and Anderson 1959) . We assumed that half of the Douglas fir acreage in Josephine and Jackson Counties is damagingly infected, and that average annual mortality loss per acre is 15 cubic feet in old growth and 6 in young sawtimber. (Hopkir's' data indicate considerably greater losses, but he is describing some of the most severe infection to be found anywhere; also, much of the killing on the Rogue River National Forest appears to have occurred during the decade immediately preceding the survey, which may have been a peak period for mortality.) Old-growth mortality, then, is 15 cubic feet per acre per year on 50 percent of 0.6 million acres, or a total of 4.5 million cubic feet; young sawtimber mortality is 6 cubic feet on 50 percent of 0.1 million acres, or a total of 300,000 cubic feet.

Losses from dwarfmistletoes in miscellaneous species. Lodgepole pine and western larch constitute more than half of "miscellaneous species" volume and are by far the most commonly and severely infected members of this group. Less than one-third of the lodgepole pine but more than half of

the larch stands are moderately or severely infected. Effects of dwarfmistletoe on lodge pole pine growth appear somewhat less severe, but on larch somewhat more severe, than on ponderosa pine. So we assumed that 40 percent of combined larch-lodgepole pine is on moderately or severely infected areas, that 70 percent of the trees on these areas are moderately or severely infected, and that growth of these trees is reduced 35 percent. The resulting impact factor of 0.098 (9.8 percent), applied to 6 million cubic feet of annual growth of these species, gives an estimated annual growth loss of 600,000 cubic feet.

TABLE 1 — Annual board-foot volume losses from disease by disease group, subregion, form of loss, and age class

Disease group	Mortality			Cull			Growth loss			Total		
	Old growth	Young growth	Total	Old growth	Young growth	Total	Old growth	Young growth	Total	Old growth	Young growth	Total
----- Million board feet -----												
West side:												
Heart rots	0	1.9	1.9	1,053.0	72.0	1,125.0	0	0	0	1,053.0	73.9	1,126.9
Root rots	140.0	65.0	205.0	0	0	0	0	258.0	258.0	140.0	323.0	463.0
Dwarfmistletoes	192.5	14.2	206.7	0	0	0	28.3	93.9	122.2	220.8	108.1	328.9
Other diseases	0	2.6	2.6	0	1.6	1.6	0	47.8	47.8	0	52.0	52.0
Subtotal	<u>332.5</u>	<u>83.7</u>	<u>416.2</u>	<u>1,053.0</u>	<u>73.6</u>	<u>1,126.6</u>	<u>28.3</u>	<u>399.7</u>	<u>428.0</u>	<u>1,413.8</u>	<u>557.0</u>	<u>1,970.8</u>
East side:												
Heart rots	0	0	0	194.0	30.6	224.6	0	0	0	194.0	30.6	224.6
Root rots	40.0	37.0	77.0	0	0	0	2.3	103.7	106.0	42.3	140.7	183.0
Dwarfmistletoes	208.0	43.8	251.8	0	0	0	40.8	323.6	364.4	248.8	367.4	616.2
Other diseases	2.0	10.9	12.9	3.8	6.2	10.0	3.0	112.2	115.2	8.8	129.3	138.1
Subtotal	<u>250.0</u>	<u>91.7</u>	<u>341.7</u>	<u>197.8</u>	<u>36.8</u>	<u>234.6</u>	<u>46.1</u>	<u>539.5</u>	<u>585.6</u>	<u>493.9</u>	<u>668.0</u>	<u>1,161.9</u>
Entire region:												
Heart rots	0	1.9	1.9	1,247.0	102.6	1,349.6	0	0	0	1,247.0	104.5	1,351.5
Root rots	180.0	102.0	282.0	0	0	0	2.3	361.7	364.0	182.3	463.7	646.0
Dwarfmistletoes	400.5	58.0	458.5	0	0	0	69.1	417.5	486.6	469.6	475.5	945.1
Cankers and stem rusts	1.2	13.4	14.6	3.8	7.8	11.6	0	53.6	53.6	5.0	74.8	79.8
Foliage diseases	.8	.1	.9	0	0	0	3.0	106.4	109.4	3.8	106.5	110.3
Total	<u>582.5</u>	<u>175.4</u>	<u>757.9</u>	<u>1,250.8</u>	<u>110.4</u>	<u>1,361.2</u>	<u>74.4</u>	<u>939.2</u>	<u>1,013.6</u>	<u>1,907.7</u>	<u>1,225.0</u>	<u>3,132.7</u>

TABLE 2 — Annual cubic-foot volume losses from disease by disease group, subregion, form of loss, and age class.

Disease group	Mortality			Cull			Growth loss			Total		
	Old growth	Young growth	Total	Old growth	Young growth	Total	Old growth	Young growth	Total	Old growth	Young growth	Total
----- Million cubic feet -----												
West side:												
Heart rots	0	0.4	0.4	83.7	7.8	91.5	0	0	0	83.7	8.2	91.9
Root rots	25.6	13.1	38.7	0	0	0	0	44.1	44.1	25.6	57.2	82.8
Dwarfmistletoes	27.9	3.0	30.9	0	0	0	3.4	16.0	19.4	31.3	19.0	50.3
Other diseases	0	.5	.5	0	.2	.2	0	7.8	7.8	0	8.5	8.5
Subtotal	53.5	17.0	70.5	83.7	8.0	91.7	3.4	67.9	71.3	140.6	92.9	233.5
East side:												
Heart rots	0	0	0	15.0	3.2	18.2	0	0	0	15.0	3.2	18.2
Root rots	7.3	7.4	14.7	0	0	0	.3	17.1	17.4	7.6	24.5	32.1
Dwarfmistletoes	32.2	9.3	41.5	0	0	0	4.9	50.8	55.7	37.1	60.1	97.2
Other diseases	.3	2.1	2.4	.8	.8	1.6	.4	17.3	17.7	1.5	20.2	21.7
Subtotal	39.8	18.8	58.6	15.8	4.0	19.8	5.6	85.2	90.8	61.2	108.0	169.2
Entire region:												
Heart rots	0	.4	.4	98.7	11.0	109.7	0	0	0	98.7	11.4	110.1
Root rots	32.9	20.5	53.4	0	0	0	.3	61.2	61.5	33.2	81.7	114.9
Dwarfmistletoes	60.1	12.3	72.4	0	0	0	8.3	66.8	75.1	68.4	79.1	147.5
Cankers and stem rusts	.2	2.6	2.8	.8	1.0	1.8	0	8.6	8.6	1.0	12.2	13.2
Foliage diseases	.1	.03	.1	0	0	0	.4	16.5	16.9	.5	16.5	17.0
Total	93.3	35.8	129.1	99.5	12.0	111.5	9.0	153.1	162.1	201.8	200.9	402.7

TABLE 3 — Annual board-foot volume losses from disease by tree species, subregion, form of loss, and age class.

Tree Species	Mortality			Cull			Growth loss			Total		
	Old growth	Young growth	Total	Old growth	Young growth	Total	Old growth	Young growth	Total	Old growth	Young growth	Total
----- Million board feet -----												
West side:												
Douglas-fir	102.0	45.4	147.4	459.0	13.6	472.6	5.2	138.9	144.1	566.2	197.9	764.1
Western hemlock	200.0	21.5	221.5	267.0	25.0	292.0	22.5	140.0	162.5	489.5	186.5	676.0
True firs	20.5	10.2	30.7	235.0	13.0	248.0	.6	64.4	65.0	256.1	87.6	343.7
Miscellaneous species (including hardwoods)	10.0	6.6	16.6	92.0	22.0	114.0	0	56.4	56.4	102.0	85.0	187.0
Subtotal	<u>332.5</u>	<u>83.7</u>	<u>416.2</u>	<u>1,053.0</u>	<u>73.6</u>	<u>1,126.6</u>	<u>28.3</u>	<u>399.7</u>	<u>428.0</u>	<u>1,413.8</u>	<u>557.0</u>	<u>1,970.8</u>
East side:												
Ponderosa pine	109.3	15.8	125.1	19.2	2.1	21.3	19.9	86.9	106.8	148.4	104.8	253.2
Douglas-fir	87.5	22.0	109.5	34.0	4.3	38.3	18.0	158.9	176.9	139.5	185.2	324.7
True firs	23.0	17.9	40.9	117.0	15.0	132.0	2.0	69.7	71.7	142.0	102.6	244.6
Miscellaneous species (including hardwoods)	30.2	36.0	66.2	27.6	15.4	43.0	6.2	224.0	230.2	64.0	275.4	339.4
Subtotal	<u>250.0</u>	<u>91.7</u>	<u>341.7</u>	<u>197.8</u>	<u>36.8</u>	<u>234.6</u>	<u>46.1</u>	<u>539.5</u>	<u>585.6</u>	<u>493.9</u>	<u>668.0</u>	<u>1,161.9</u>
Entire region:												
Douglas-fir	189.5	67.4	256.9	493.0	17.9	510.9	23.2	297.8	321.0	705.7	383.1	1,088.8
True firs	43.5	28.1	71.6	352.0	28.0	380.0	2.6	134.1	136.7	398.1	190.2	588.3
Miscellaneous species (including hardwoods)	40.2	42.6	82.8	119.6	37.4	157.0	6.2	280.4	286.6	166.0	360.4	526.4
Total	<u>582.5</u>	<u>175.4</u>	<u>757.9</u>	<u>1,250.8</u>	<u>110.4</u>	<u>1,361.2</u>	<u>74.4</u>	<u>939.2</u>	<u>1,013.6</u>	<u>1,907.7</u>	<u>1,225.0</u>	<u>3,132.7</u>

† Except west-side western hemlock and east-side ponderosa pine.

TABLE 4 — Annual cubic-foot volume losses from disease by tree species, subregion, form of loss, and age class.

Tree Species	Mortality			Cull			Growth loss			Total		
	Old growth	Young growth	Total	Old growth	Young growth	Total	Old growth	Young growth	Total	Old growth	Young growth	Total
----- Million cubic feet -----												
West side:												
Douglas-fir	16.5	9.2	25.7	37.0	1.0	38.0	0.8	26.1	26.9	54.3	36.3	90.6
Western hemlock	31.0	4.4	35.4	23.0	3.4	26.4	2.5	23.2	25.7	56.5	31.0	87.5
True firs	4.0	2.1	6.1	15.0	1.3	16.3	.1	9.7	9.8	19.1	13.1	32.2
Miscellaneous species (including hardwoods)	2.0	1.3	3.3	8.7	2.3	11.0	0	8.9	8.9	10.7	12.5	23.2
Subtotal	<u>53.5</u>	<u>17.0</u>	<u>70.5</u>	<u>83.7</u>	<u>8.0</u>	<u>91.7</u>	<u>3.4</u>	<u>67.9</u>	<u>71.3</u>	<u>140.6</u>	<u>92.9</u>	<u>233.5</u>
East side:												
Ponderosa pine	16.1	3.1	19.2	1.9	.4	2.3	2.7	15.4	18.1	20.7	18.9	39.6
Douglas-fir	14.1	5.0	19.1	2.2	.5	2.7	1.9	25.1	27.0	18.2	30.6	48.8
True firs	4.5	3.6	8.1	8.8	.9	9.7	.3	11.3	11.6	13.6	15.8	29.4
Miscellaneous species (including hardwoods)	5.1	7.1	12.2	2.9	2.2	5.1	.7	33.4	34.1	8.7	42.7	51.4
Subtotal	<u>39.8</u>	<u>18.8</u>	<u>58.6</u>	<u>15.8</u>	<u>4.0</u>	<u>19.8</u>	<u>5.6</u> ^a	<u>85.2</u>	<u>90.8</u>	<u>61.2</u>	<u>108.0</u>	<u>169.2</u>
Entire region:												
Douglas-fir	30.6	14.2	44.8	39.2	1.5	40.7	2.7	51.2	53.9	72.5	66.9	139.4
True firs	8.5	5.7	14.2	23.8	2.2	26.0	.4	21.0	21.4	32.7	28.9	61.6
Miscellaneous species (including hardwoods)	7.1	8.4	15.5	11.6	4.5	16.1	.7	42.3	43.0	19.4	55.2	74.6
Total	<u>93.3</u>	<u>35.8</u>	<u>129.1</u>	<u>99.5</u>	<u>12.0</u>	<u>111.5</u>	<u>9.0</u>	<u>153.1</u>	<u>162.1</u>	<u>201.8</u>	<u>200.9</u>	<u>402.7</u>

^a Except west-side western hemlock and east-side ponderosa pine.

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