POTENTIALITY FOR OBTAINING PORIA DISEASE SIGNATURES IN THE OREGON CASCADES FROM ORBITAL ALTITUDES

by

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INTRODUCTION

A significant step upward is the discovery of a prime photographic signature indicator of an important forest disease in valuable Douglas-fir stands of the Pacific Northwest. The new disease signature has been verified by a multidisciplinary team of scientists to be the direct result of the *Poria weirii* root-rot syndrome in the Douglas-fir and hemlock stands of the high Cascades in Oregon. It is readily discernible on small-scale suborbital photography and has good potential for detection from earth-orbiting satellites or remote sensing platforms. Let us look at the estimated disease impact on the forest resources, the problem from the ground level, the remote sensing study methodology, and the appearance of the discrete signature on various photo scales.

DISEASE IMPACT

Protecting our forest resources from the depredations of forest diseases, forest insects, and forest fires is a continuous struggle involving man and the environment. On the basis of total impact (Table I), diseases rank first, insects second, and fire third. The spectacular and destructive forces of fire always excite public attention while the slow insidious activity of forest diseases and forest insects are of lesser concern. However, this attitude is changing with the ever-increasing need for more natural resources to meet public demand and the more intensive management of forest lands by Federal, State, and private agencies. We cannot afford to ignore timber losses in the United States, regardless of the cause.

Poria weirii (Murr.) root-rot disease is responsible for devastating some 170 millions of board feet (Table II) of old-growth and second-growth Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) annually. This represents the amount of lumber needed to replace nearly all the homes in Houston each year.

PORIA DISEASE FACTORS

Poria root rot disintegrates the root system of trees gradually (Fig. 1) until the tree topples over or is blown over. Infection spreads radially from an infection center by mycelial fungii at the rate of approximately one foot per year, makes contact with other tree roots, and continues the cycle to fell adjacent trees. At present, there is no known chemical or fungicide that effectively controls or minimizes the spread of this root-rot disease. The disease is known to remain dormant in the soil for more than 50 years. Silvicultural research shows that red alder (*Alnus rubra* Bong.) is a good inhibitor of *Poria weirii* root rot.

SURVEY RESEARCH

Remote sensing research in the past has attempted to discriminate previsually (prior to any visible external changes) root-rot-infected Douglas-fir trees from healthy trees. Because of the slow demise of infected trees, foliar characteristics of healthy and diseased trees are so similar that aerial photographic techniques in the visible and near infrared portions of the spectrum (0.34 to 0.95 micrometer) are unable to differentiate affected trees. Some success has been attained with thermal infrared scanning techniques (8.0 to 14.0 micrometer band) operating a nonimaging radiometer from a low-flying helicopter. Temperature differences were relatively small (1° to 3° F.) so that it is highly unlikely that even the most sophisticated sensors (not currently available) could detect individually affected trees from orbiting spacecraft.

The more promising aerial survey technique that has now been discovered identifies root-rot disease centers in certain areas on aerial photographs taken from suborbital altitudes. The technique also has potential for imaging these discrete signatures from orbital altitudes. Openings in the forest canopy have distinctive characteristics that can be frequently identified on aerial photographs and may be exploited by photo interpreters and resource managers.

The major objectives of the *Poria weirii* remote sensing study during the past year were (1) to determine the criteria for detecting root-rot centers or openings, (2) to investigate the distribution of signature indicators on existing photographs covering the Douglas-fir types in Oregon and Washington, (3) to cooperate with various forestry agencies in developing an intensive survey program on selected test sites in Oregon, (4) to determine the optimum photographic scale for detecting infection centers, and (5) to compare various types of multispectral imagery, i.e., color, color infrared, and black-and-white photography, for discriminating disease infection centers or openings from healthy trees.

The primary indicator of *Poria weirii* root rot was discovered in the high Cascade Mountains of Oregon on 1:15,840 scale panchromatic photographs. The signature consists of an unusual phenomenon of bare ground in a half round circular shape surrounded by trees. A small signature (early Poria stage) may be from 100 to 150 feet in diameter and range upward to 700 feet. A conglomerate of openings gives the appearance of a ringworm pattern and may range upward to 3,000 feet. Determining the cause of the openings in the forest canopy involved a multidisciplinary group of scientists and foresters. Openings can be the result of insect or disease activity, unusual geomorphological features such as rock outcrops, or soil and water deficient strips. The team ground checked several openings in different age classes of the Douglas-fir-hemlock type. The preliminary interpretation that the openings were caused by root-rot disease was verified and has been further substantiated by ground surveys of many plots in 1971.

Not all openings in the forest canopy are caused by root-rot disease. Good interpretative judgments are required to identify Poria openings in different parts of the Douglas-fir subregion. The striking appearance of the circular bare ground indicator in the high Cascades of Oregon was the primary criterion for identifying root-rot centers in other forested areas of the Pacific Northwest. In the early stages of development, a Poria signature appears on the aerial photo as a circular opening in the forest stand, or as a "hole," with dead and downed trees jackstrawed in the center and standing trees in various stages of deterioration at the edges of the opening. Stand openings increase radially from the center of infection. Where brush and other vegetative species do not invade the bare areas rapidly the circular bare ground signature is readily discerned. At lower elevations and on better timber sites, small trees (primarily hardwoods) and brush invade rapidly to obscure downed trees and increase the problem of positively identifying root-rot disease centers. Both large and small pockets of bark beetle-killed trees in various stages of deterioration in the forest stand may also confuse interpretation. Considerable field experience is needed by the photo interpreter to delineate root-rot disease-caused openings.

ESTABLISHING TEST SITES

As a first step in establishing test sites to develop the survey methodology to detect Poria weirii root-rot centers in the Douglas-fir subregion, we needed to know where (based on the general distribution of root-rot signature indicators) tree mortality was in progress. Existing photographs covering approximately 30 million acres on 12 National Forests in Oregon and Washington were carefully scrutinized by two interpreters for the presence or absence of discrete Poria indicators. Interpretations on some 8,200 panchromatic photographs at scales ranging from 1:10,000 to 1:15,840 indicated disease signatures on four National Forests and likely disease signatures on eight others.

From this broad photographic overview of root-rot disease in the Northwest, three test sites were selected (Fig. 2) for more detailed examination, photographic coverage, and analysis. Each test site encompasses 9 square miles (3-mile x 3-mile block) of pole and sawtimber stands. A variety of disease, stand, and climatic conditions, slope and elevations, and forest types were sampled.

1. The Waldo Lake test site (Willamette N. F.) is in the high Cascades of Oregon. It has some brushy areas and moderate to easy terrain accessibility.

2. The Olallie Lake test site (Mt. Hood N. F.) is in the Oregon Cascades. It is brushy with areas of dense reproduction and moderate terrain accessibility.

3. The Divide Lookout test site (Siuslaw N. F.) is in the Coast Range of Oregon. It is brushy with extensive understory of vine maple (*Acer circinatum* Pursh), *Rhododendron* sp., and red alder. It has extremely rough terrain with deeply dissected slopes of 80 to 90 percent.

INTERAGENCY COOPERATION

Forest resource managers from Federal, State, and private forestry groups have shown a great interest in the new root-rot disease signature. This has stimulated a strong cooperative research and development program to evolve a survey method for detecting and evaluating the impact of root-rot disease on the forest resources of the Northwest. Several Federal and State agencies (listed in the ACKNOWLEDGMENTS section) are contributing manpower and/or financial help to assist in the collection of ground truth and in obtaining aerial photography. This interagency cooperative effort will materially increase the likelihood of gathering extensive and intensive ground truth and of developing a practical airborne survey sensing system in the shortest possible time. A well-developed survey system (orbital or suborbital) can dramatically assist in protecting one of our most valuable natural resources in the Pacific Northwest--our National Forests.

AERIAL PHOTOGRAPHY

Photographic interpretations of 1967-69 panchromatic photos at the three test sites indicated a wide range of terrain, vegetative conditions, and appearance of suspected root-rot disease openings. A preliminary ground evaluation of the different sites was necessary to determine the feasibility of testing minimum and maximum photographic scales. The vegetative complexity of the Coast Range test site clearly indicated the need for maximum ground detail to delineate root-rot openings. Consequently, photo scales larger than 1:15,840 were considered essential for the initial tests in the Divide Lookout test site of the Coast Range (Fig. 3, 4). Because of the more easily discerned signature indicators in the high Cascades of Oregon (Waldo Lake and Olallie Lake), much smaller scale photography (Fig. 5, 6) (including orbital imagery) may be adequate to detect *Poria weirii* disease centers.

Cooperative efforts of the Remote Sensing Work Unit, Pacific Southwest Forest and Range Experiment Station, U. S. Forest Service; Pest Control, Timber Management Division, Region 6, U. S. Forest Service; and NASA, through the use of their RB-57 aircraft, were to provide photographic coverage (Table III) of the three 9-square-mile test sites with three types of photography and a wide variety of photo scales. Each test site was photographed with Aero color negative film (2445) which provides either color or black-and-white prints and with color infrared film (2443) using a Wratten #15 filter.

The Forest Service used Zeiss 8 1/4" focal length cameras for all film and scale combinations. The multiscale photography was provided by the PSW Forest and Range Experiment Station's Aero Commander and by the U. S. Forest Service Region 6 Cartographic Section's twin Beechcraft. NASA had planned to use two RC-8 cameras (6" and 12" focal lengths) and four 70 mm cameras, 1.57" (40 mm) focal length to 6" focal length (2 1/4" x 2 1/4" format), from an RB-57 or U-2 jet-type aircraft. However, tight scheduling for the NASA aircraft in 1971 prevented the photographic missions anticipated. The photo mission has been rescheduled for NASA aircraft for July 1972.

COLLECTING GROUND TRUTH

Based on criteria developed during preliminary ground inspection of Poria weirii root-rot openings, two photo interpreters scrutinized the available 1:15,840 scale panchromatic photos taken in 1967-69 of each 9-square-mile area selected for the study. Openings and type areas suspected as indicative of root-rot centers were classified into two categories--good Poria signatures and possible Poria signatures. Each suspect area was circled and numbered on a frosted acetate overlay attached to each photo. Areas of timber that did not appear infected with Poria were also marked on the photos to serve as control checks.

From this interpretation data, 75 or more areas on each test site were selected for ground visitation. Areas to be checked were chosen largely on the basis of accessibility. The extremely adverse terrain on the Divide Lookout test site (Siuslaw N. F.) necessitated that plots be within a few chains of a road. Presence or absence of Poria root rot was determined by the examination of several living, dead, and downed trees for diagnostic signs of the fungus, including ectotrophic mycelium, setal hyphae, and laminated decay. Check plots were 1/5 acre or more in size and located at least 2 chains from known Poria centers. Two 2-man teams under the direction of a trained forest pathologist visited all designated plots on the three test sites in 1971.

PHOTO INTERPRETATION

Photo interpretation on this study consists of four phases: (1) a comprehensive overview of the Douglas-fir-hemlock timber areas of the Pacific Northwest for Poria root-rot signatures and selecting three test sites, (2) photo interpretation selection of plots for collecting ground truth on each test site, (3) preliminary interpretation of 1971 photography for determining relative accuracy of photo scales for detecting disease centers, and (4) intensive and detailed interpretations of specific plots within each of three selected test sites by five interpreters. Phase one was the interpretation of some 8,200 panchromatic photos covering approximately 30 million acres to detect any type of signature indicators in the forest types of Oregon and Washington that might be caused by a root-rot forest disease and to establish the three test sites.

The second phase was the intensive photo interpretation on 1:15,840 scale black-and-white photographs of the three test sites in Oregon to identify plots for field visitation. The three test sites include indicators ranging from simple to complex. Two experienced photo interpreters received field training on different types of openings in forest areas of the high Cascades and Coast Range before interpreting Poria signatures on photos of the three test sites. More than 75 plots were chosen for field examination in each test site. Good accessibility was the primary concern for final plot selections.

The third interpretation phase developed toward the end of the summer as new photo coverage was obtained on each test site with black-and-white, color, and color infrared photography and at different photo scales. The two most experienced interpreters examined all test site area photos--first on small scale and then progressing to large scale with a random selection from the available film types (Table IV).

Unfortunately, color prints, panchromatic prints, and color IR film were not available for interpreting all photo scales and test sites before the end of the field season so that the results do not show the complete photo interpretation potential.

The fourth and final phase of the photo interpretation for the 1971 photography is in progress. A more detailed analysis of all film-filter and scale combinations is needed to make statistically valid and meaningful comparisons that can be utilized in establishing sound aerial photographic survey procedures.

The large number of plots selected and field checked on each test site provided a sound basis for using a randomized block design with a factorial feature at each of the three test sites. Nine combination treatments are possible at each test site--three types of photography with each of three photo scales. From a total of 72 plots in each test site, eight were randomly selected for each film-scale combination. Each of the 72 plots will be interpreted once by each of five interpreters, thus removing a possible source of interpreter bias. Tests of significance will be performed for film types, photo scales, and the photo-scale film interaction.

RESULTS AND CONCLUSIONS

An inspection of the preliminary photographic interpretation data (Table IV) shows that larger photo scales did not materially improve accuracy. Relatively small differences in accuracy are indicated between photo scales for each of the high Cascade test sites. It is apparent that a high degree of survey accuracy should be attainable in detecting *Poria* centers in the Waldo Lake test site area. Somewhat less accuracy is attainable in the Olallie Lake test site area. With sampling techniques currently available, there should be no problem in promulgating a statistically sound aerial photographic survey design such as double sampling with stratification. Further research in remote sensing survey techniques is needed for the forest conditions of the Coast Range.

Even though the signature was first observed in the Pacific Northwest, there is good likelihood that similar characteristic patterns of root-rot diseases should be evident in various forested areas of the United States, Canada, and the world at large. Detecting this type of characteristic signature on photography and relaying this information to forest managers, pathologists, or timber owners will draw attention to distressed areas and help reduce timber losses from forest diseases.

FUTURE REMOTE SENSING RESEARCH

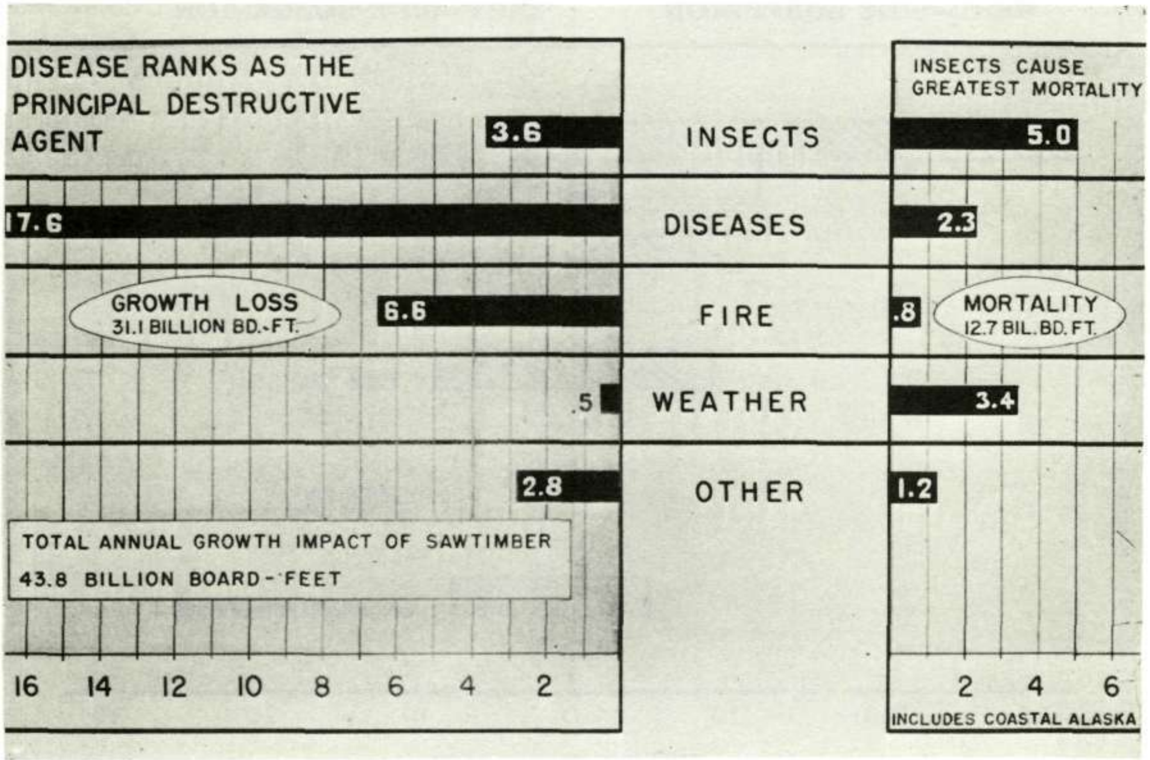
The promising results of the preliminary interpretations in the high Cascades of Oregon are sufficiently encouraging to attempt an aerial photographic trial survey in 1972 to estimate *Poria* root-rot impact in and adjacent to the Waldo Lake test site. Aerial photography is contemplated for approximately 1,000 square miles using either total coverage at 1:31,680 scale (Fig. 3) or on a sampling basis at 1:15,840 scale.

Because of the relatively large size of root-rot infection centers (100-700 feet singly to 3,000 feet in groups), there is a good possibility that the Earth Resources Technology Satellite (ERTS) imagery may detect the incidence of *Poria* disease in the forest environment. The three *Poria weirii* test sites in Oregon are included in the Oregon State University ERTS proposal for 1972. Plans have been made to scrutinize

ERTS imagery of these test sites for Poria centers when it becomes available and to collate the data with suborbital photography taken in 1971.

Aerial photographic support has already been requested from NASA overflights (RB-57 or U-2) in July 1972 for the three Oregon test sites. This photography will simulate orbital and suborbital photo scales not currently available for analysis and improved disease survey methodology. These data should indicate success-ratio likelihood for aerial surveys of forest diseases from both orbital and suborbital altitudes. Analysis of the integrated ERTS and suborbital imagery should corroborate the feasibility of using space platforms for securing valuable information to help forest managers detect and analyze critical forest problems. NASA and the Earth Resources Technology Satellite program can make a substantial contribution to improvement of forest management techniques.

TABLE I. - ANNUAL MORTALITY AND GROWTH LOSSES
TO FOREST RESOURCES IN THE UNITED STATES.*



* Timber Resources for America's Future. Forest Service, U. S. Department of Agriculture, Report No. 14. January 1958. pp. 193.

TABLE II. - ANNUAL TIMBER LOSSES FROM
PORIA WEIRII ROOT ROT IN PACIFIC NORTHWEST

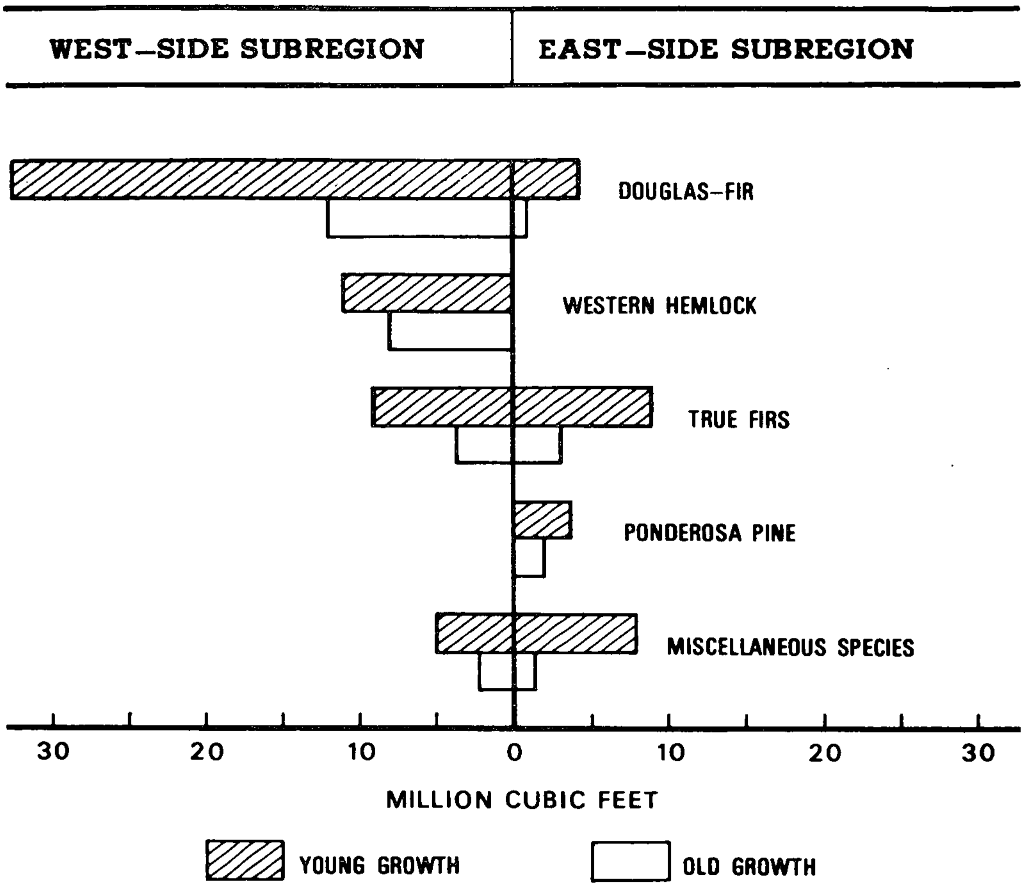


TABLE III. - *PORIA* ROOT ROT TEST SITES IN OREGON AND PHOTOGRAPHIC SCALES PLANNED FOR 1971

Divide Lookout (Coast Range)	Waldo Lake (Cascades)	Olallie Lake (Cascades)
1:4,000 (USFS)		
1:8,000 (USFS)	1:8,000 (USFS)	1:8,000 (USFS)
1:15,840 (USFS)	1:15,840 (USFS)	1:15,840 (USFS)
	1:30,000 (USFS)	1:30,000 (USFS)
	1:60,000 (NASA)	1:60,000 (NASA)
	1:125,000 (NASA)	1:125,000 (NASA)
	1:250,000 (NASA)	1:250,000 (NASA)

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TABLE IV. - PHOTO INTERPRETATION ACCURACY IN DETECTING ROOT-ROT DISEASE ON THREE TEST SITES IN OREGON

Type of Photography	Scale	Waldo Lake	Olallie Lake	Divide L.O.
Panchromatic	1:15,840	93%	80%	64%
Color	1:31,680	87%	73%	---*
Color	1:15,840	---*	---*	61%
Color	1:8,000	89%	76%	62%
Color	1:4,000	---*	---*	50%

* Not included in the photographic coverage

Figure 1.- Ground view of Poria weirii (Murr.) root-rot disease showing disintegrated root system of Douglas-fir trees and downed logs. Infection spreads radially to attack and fell adjacent trees. Detection of root-rot disease centers will help to minimize losses of salvable timber and minimize spread.

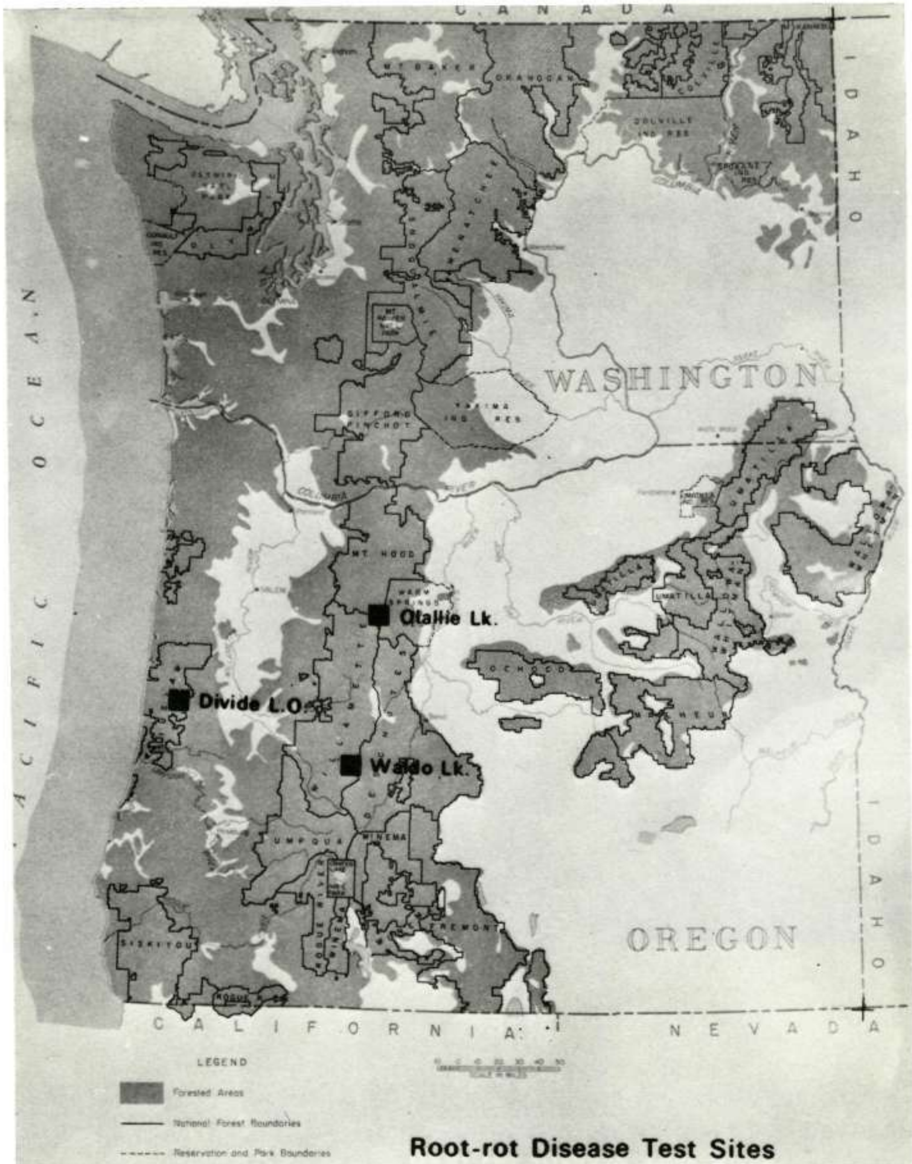

Figure 2.- Map of Oregon and Washington showing distribution of Douglas-fir-hemlock types and location of three test sites--Waldo Lake and Olallie Lake in the high Cascades and Divide Lookout in the Coast Range. Each test site is 9 square miles (3 miles x 3 miles) and covers a variety of vegetation and terrain conditions.

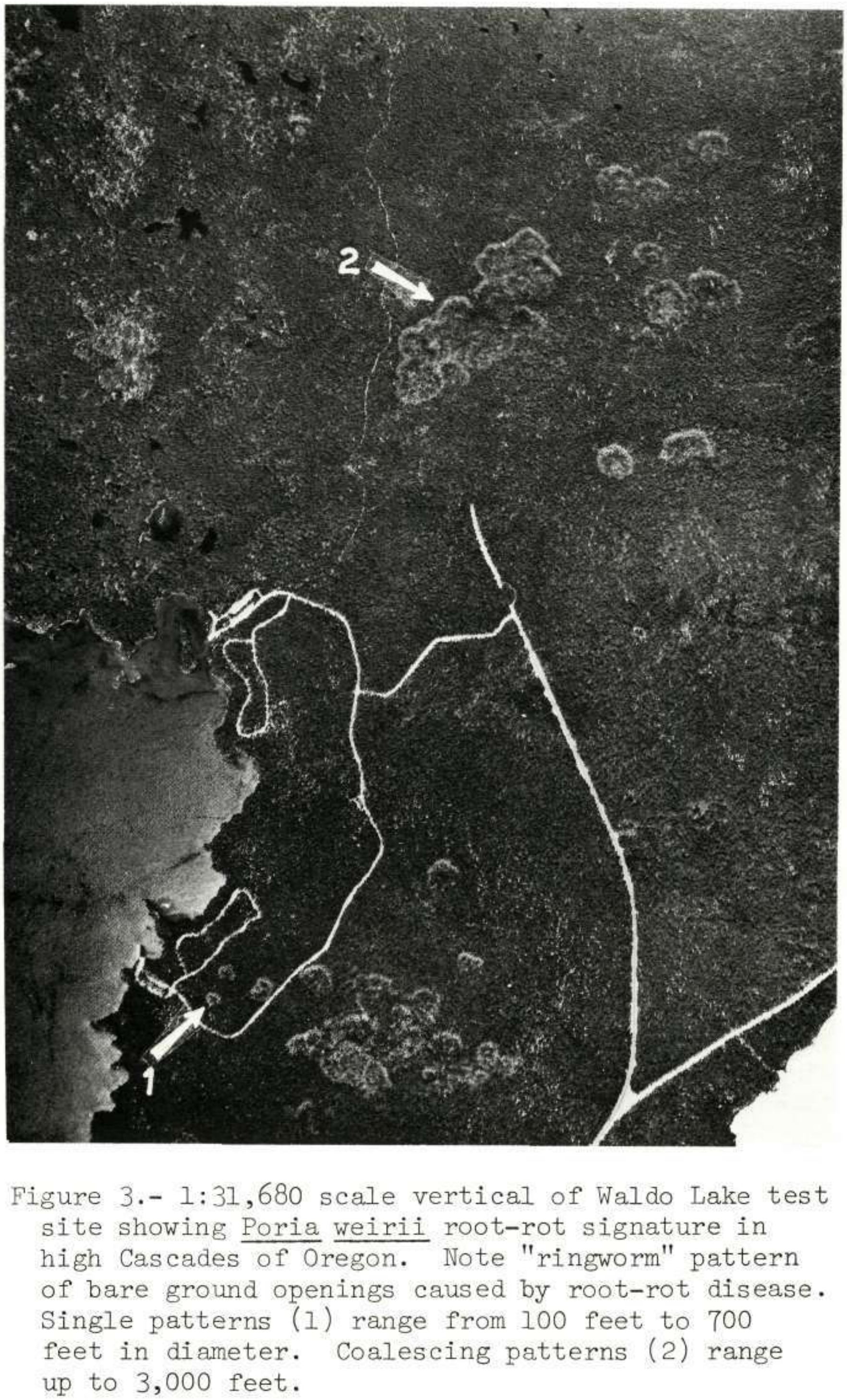

Figure 3.- 1:31,680 scale vertical of Waldo Lake test site showing Poria weirii root-rot signature in high Cascades of Oregon. Note "ringworm" pattern of bare ground openings caused by root-rot disease. Single patterns (1) range from 100 feet to 700 feet in diameter. Coalescing patterns (2) range up to 3,000 feet.

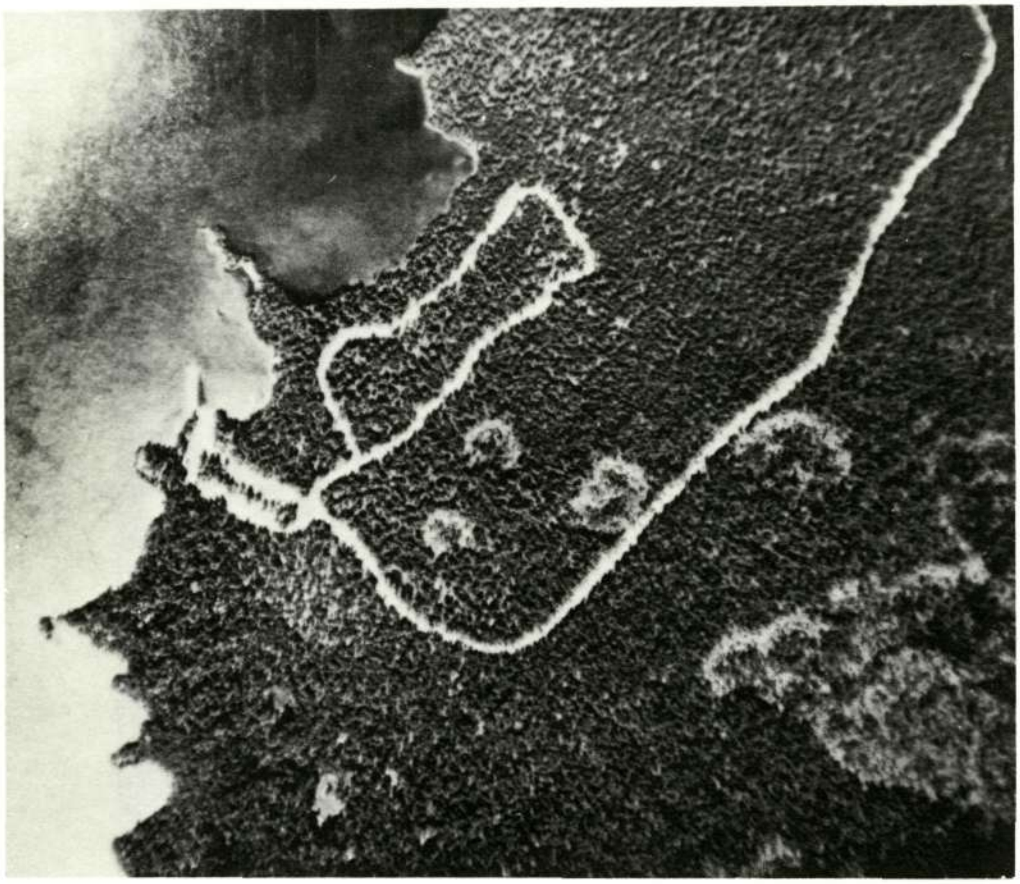

Figure 4.- 1:8,000 scale vertical of Waldo Lake test site showing typical root-rot pattern. Some disease-resistant herbaceous trees and plants are encroaching into the center of the openings but will eventually succumb to the root rot.

Figure 5.- 1:15,840 scale oblique of the Divide Lookout test site shows land-use pattern, periodic logging, Poria centers, and steepness of terrain (80 to 90% slopes).

Figure 6.- 1:4,000 scale oblique of the Divide Lookout test site shows Poria center below lookout. Some standing dead trees around edges of the opening and some downed logs are visible. Brush and hardwood species are rapidly filling in the openings.

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Oregon State Board of Forestry.