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# Aerial photography for the detection of soil-borne disease

Y. Jim Lee

*Pacific Forestry Centre, Forestry Canada, 506 West Burnside Road, Victoria, British Columbia V8Z 1M5.*

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Research on the applications of aerial photography and computer-aided image analysis, for the detection of soil-borne disease, is assessed with respect to agriculture and forestry. The applications in agriculture deal with nematode on cotton, root rot of cotton, root rot of alfalfa, root rot of pecans, burrowing nematode damage on citrus orchards, and citrus tree root rot infestation. The applications in forestry deal mainly with root rot disease. Computer-aided image analysis for the detection of soil-borne disease is a recent phenomenon. Future developments are discussed briefly.

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La recherche sur les applications de la photographie aérienne et de l'analyse d'images par ordinateur pour la détection des maladies racinaires a été évaluée pour l'agriculture et la foresterie. Les applications en agriculture comprennent la détection des nématodes du cottonnier et du nématode fouisseur des vergers d'agrumes de même que de pourridiés du cottonnier, de la luzerne, du pacanier, et du citronnier. Les applications en foresterie comprennent principalement la détection des pourridiés. L'analyse d'images par ordinateur pour la détection des maladies des racines est un phénomène récent. On discute brièvement des perspectives de développement de ces techniques.

Aerial photography is extremely useful for detecting quickly and reliably the extent of damage caused by soil-borne disease. Toler et al. (1981) discussed in detail various aspects of remote sensing technology, such as spectral signature of vegetation, acquisition of aerial photography, use of color versus color infrared film, suitability of scales, timing of photography, and cost considerations. It appears that the best time for photography in northern temperate zones is around June. Color and color infrared films are most useful for the detection of foliage color changes that result from damage caused by soil-borne disease. Photographs may deal with the entire damaged area or a selection of samples.

Computer digitizing cameras have been used to digitize aerial photographs. These digital data are used for the detection of diseased agricultural crops (Bronson & Klittich 1984) and citrus orchards (Ali & Aggarwal 1977), and to detect root rots in British Columbia (Bloomberg 1987).

This report summarizes the applications of aerial photography and digital image analysis in the detection of soil-borne disease.

## Applications in agriculture

**Reniform nematode on cotton.** Using Kodak Ektachrome infrared film 2443 at scales of 1:4000 and 1:8000, Heald et al. (1972) indicated that damage from *Rotylenchulus reniformis* (Linford and Oliveira) could be detected with aerial photographs and that those areas treated with the nematocide 1,3-dichloropropene were distinguishable from those untreated. The infected cotton fields appeared much lighter in color.

**Phymatotrichum root rot of cotton.** In the Blackland region of Texas, phymatotrichum root rot of cotton which results in sudden death within 48 h of infection provided good examples of a root-borne disease amenable to detection by the use of color infrared aerial photography (Smith et al 1977a). The importance of the timing of color infrared aerial photography to coincide with the cotton-growing season before harvest, in determining the maximum extent of cotton root rot, was stressed by Smith et al. (1977a). Choosing a suitable scale of aerial photography is also an important factor in the success of detection. Smith et al. (1977a) indicated that large scale (1:3000) offered excellent resolution, with individual plants being distinguishable, but the amount of film required to cover a large area would be prohibitively expensive; on the other hand a scale of 1:120 000 did not provide sufficient resolution for the identification of small areas of infestation within a large cotton field, while a scale of 1:20 000 offered the best compromise among area coverage, film cost, and resolution. Smith et al. (1977b) further incorporated various remote sensing techniques into an integrated cotton root rot management system.

**Root rot of alfalfa.** In California Pratt et al. (1973) surveyed alfalfa fields with aerial photography for alfalfa root rot caused by *Phymatotrichum omnivorum* (Shear) Duggar. The infected area could be recognized by the roughly circular ring pattern with sinuous margins displayed in the aerial photographs. They found that oval spots were related to salt and water conditions and were confined to the irrigated areas.

**Root rot of pecans.** The use of Ektachrome 2443 color infrared film showed that pecan trees infected with clitocybe root rot (*Clitocybe tabescens* Bres.) were stunted and appeared a lighter red than healthy trees (Payne et al. 1971). The irregular canopy of infected pecan trees appeared starlike. However, stunting was the only above-ground symptom, and infected trees might appear healthy when much of the root system was already destroyed by the disease.

**Burrowing nematode damage in citrus orchards.** Norman & Fritz (1965) indicated that the burrowing nematode (*Radopholus similis* Cobb.) caused extensive damage to the root structure of infected trees. This phenomenon was wide-spread in citrus orchards in Florida. They reported that this damage was detectable with aerial photography, using Kodak Ektachrome color 2443 film. Foliage stress caused by the damage to the root system was visible in early stages of infection.

**Citrus tree root rot infestation.** Ali & Aggarwal (1977) successfully developed a system designed to convert color infrared aerial photography into digital data for computer-aided image analysis. The purpose of this analysis was to automatically interpret the digital data of citrus orchards having infestations of root rot disease. An algorithm in the analysis was used to locate the outline of each tree in the photograph, and then a cluster analysis was applied. The cluster analysis resulted in excellent classification of root rot diseased trees corresponding to the diseased trees surveyed in the field.

## Applications in forestry

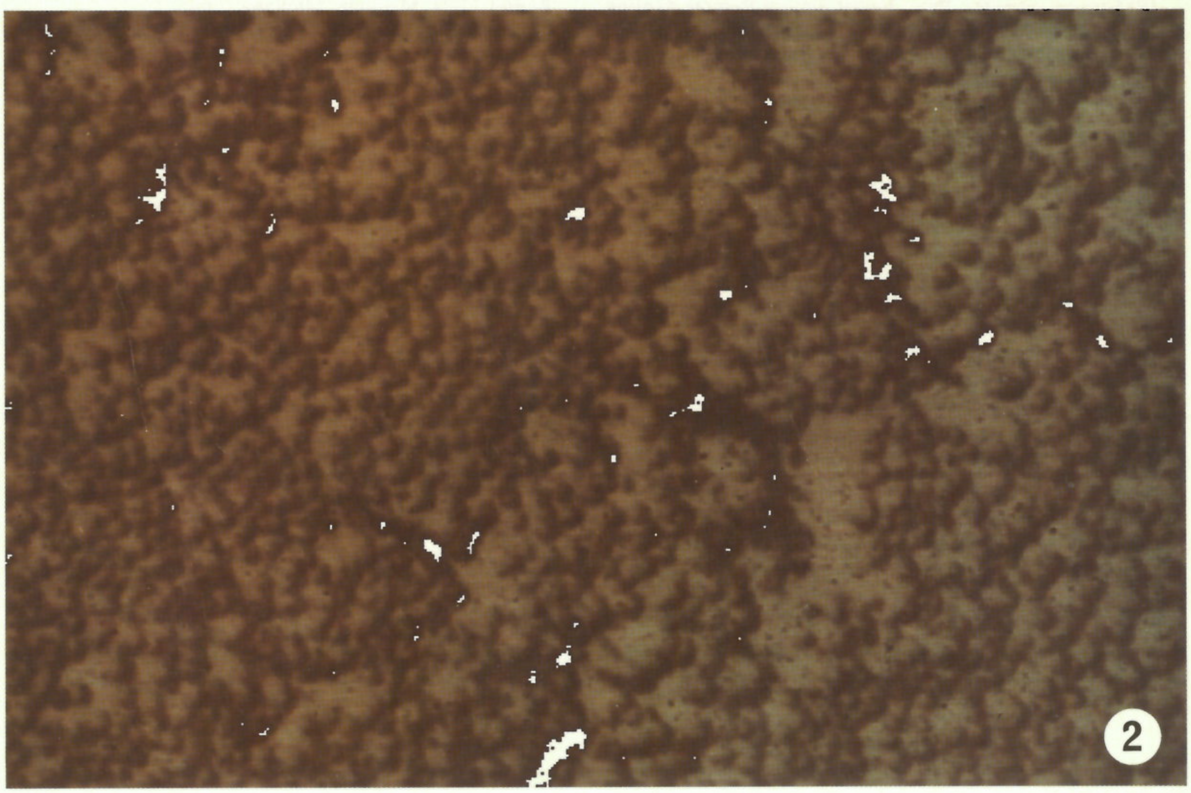
Aerial photography in the detection of soil-borne disease deals mainly with root rot in forestry. An early study on the effect of *Fomes annosus* was conducted by Hanson & Lautz (1969). Using a scale of 1:4000 for color infrared transparencies, they could identify *Pinus echinata* (Mill) trees 35 years old and 15 m in height in a plantation killed by *Fomes annosus.* Wear (1971) found that small-scale color infrared transparencies of 1:32 000 were useful in detecting *Poria weirii* Murr. damage on Douglas-fir in Oregon, because of the unusual shape of openings of ringworm-like circular patterns. Williams (1973) found that in the Coeur d'Alene National Forest root disease centers with definite margins and in various states of decline could be interpreted with nearly 100% accuracy from aerial photographs at film scales of 1:4000 and 1:1200. Other reports of successful root disease detection using aerial photographs vary considerably, especially for coastal stands. Johnson and Wear (1975) reported the best identification accuracy with a scale of 1:31 680, black and white aerial photography, in the central Cascade area, and the poorest with a scale of 1:8000, color aerial photography, in coastal forests. Wallis & Lee (1984) recommended that color infrared aerial photography be used where atmospheric haze was present or when it was desirable to observe ground details. In northern Idaho, Williams and Leaphart (1978) identified well-established root disease centers with 92% accuracy, using color infrared film at a scale of 1:4000. Wallis & Lee (1984) indicated that a scale of 1:6000 provided adequate information for the detection of root disease centers in stands 15 to 20 years old, whereas scales of up to 1:15 000 were satisfactory for locating most root disease centers in 100-year-old Douglas-fir stands. They also reported that the primary character contributing to successful detection was the presence of at least one infected or killed tree within each root disease center (Fig. 1). Bloomberg (1987) reported that remote sensing applications to forest disease detection are developing rapidly, through the combination of advances in imagery and image analysis. The use of computers to digitize images transmitted from aerial photographs by video-camera is being applied to root rots in British Columbia (Fig. 2). Using a supervised classification process, spectral patterns unique to disease centers were selected for pixel-by-pixel classification as photographs were scanned. Pixels producing the unique patterns were displayed on the monitoring screen, and their cumulative number was used to estimate the total area infected.

## Future developments

As the advanced technology of the 1990s becomes a reality, pathologists will be taking advantage of the high-technology and innovative approaches in dealing with the detection of soil-borne diseases. Photo interpretation is an effective tool for detecting such diseases, but it is time-consuming and costly. Computer-aided photo-interpretation of digitized aerial photographs, using an image analysis system (Lee 1988), may

**Figure 1.** Kodak Ektachrome 2443 color infrared positive aerial photography with root disease polygons.

**Figure 2.** Example of digitized image from color aerial photography, showing classified pixels of root disease damage using computer supervised classification algorithm.



allow scientsts to deal with the detection of soil-borne disease more effectively. Results from the computer classification of the damaged areas delineated can be transferred directly to agricultural and forestry maps, and can be used to simultaneously update an attribute database, using a geographic information system on a microcomputer.

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