LIDAR INTEGRATED AIRBORNE IMAGING SPECTROSCOPY FOR ROOT DISEASE DETECTION AND MEASUREMENT OF FOLIAR CHEMISTRY

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ABSTRACT

Root disease is a serious concern for the softwood timber industry. The fungal pathogen *Phellinus sulphurascens* is responsible for the root disease known as laminated root rot. This disease alone is estimated to cost the North American economy $486 million US dollars of lost revenue each year [1]. These losses are attributed to reduced growth rates and mortality caused by windthrow in Douglas-fir (*Pseudotsuga menziesii*) stands. *Phellinus sulphurascens* like many other forest pathogens is considered a natural agent of forest disturbance that supports increased biodiversity and the health of forested ecosystems [2]. In unmanaged forest stands, the anchor systems of contiguous colonized trees are compromised and ultimately, canopy gaps are created as increased wind velocities topple the infected trees. Early seral species are established within these gaps, which are resistant to infection. Resistant tree species outlive the fungus which does not live much beyond fifty years saprophytically or without a live host [3]. Conversely, in managed stands, harvested plots are replaced by the most economically viable species, unfortunately Douglas-fir is also the most susceptible tree species to the disease [1]. Therefore the disease is more likely to spread between rotations and continue to reduce timber volumes and financial profits. Multispectral efforts to map root disease were not effective at discriminating between healthy and infected canopies and produced many false positives [4]. Previous studies suggested that foliar chemistry was affected by the infection of the root pathogen, especially for foliar pigments [5]. Given the current imaging spectroscopy research focused on the estimation of foliar biochemistry modulated through biotic and abiotic stressors [6], it was considered feasible that hyperspectral technologies could be applied to distinguish root disease infected areas from healthy forest canopies. A study was conducted to asses the potential for estimating chemistry from laboratory reflectance data and for the separation of infected from otherwise healthy samples by means of chemical signatures. The following study reports on the methods and results of a canopy level assessment for root disease detection thorough hyperspectral and three dimensional spatial data.

The Greater Victoria Watershed District (GVWD) was selected as the study area; located ~30km northwest of the city of Victoria, British Columbia, Canada. The GVWD is a protected, 350km^2 watershed largely composed of Douglas-fir forests. Other species that inhabit the area include: Western Red Cedar (*Thuja plicata*), Western Hemlock (*Tsuga heterophylla*), Lodgepole Pine (*Pinus contorta*), Red Alder (*Alnus rubra*), Grand Fir (*Abies grandis*), Western White Pine (*Pinus monticola*) and some spruce (*Picea*) species. *Phellinus sulphurascens* is optimized for colonizing Douglas-fir trees and is much less virulent in other coniferous species, while deciduous species are immune to its effects [1]. Logging activity, local research and silvicultural assessments have contributed to the identification of a significant population of *P. sulphurascens* within the GVWD.

In June of 2008 a field campaign was conducted to sample the upper canopies of selected Douglas-fir trees. Four sites were selected based on evidence for the presence of the pathogen, including windthrown trees, root balls with setal hyphae, laminated roots and other above and below ground indicators. From each site twelve trees were chosen to be sampled. The positions of the selected trees were registered and differentially corrected in post-processing. Lateral roots, less than 0.5m from the litter surface and 1m from the stem, were excavated to determine if the selected tree had been colonized by the fungal mycelium. From each selected sample tree, four samples were collected from the upper portion of the canopy. From each sample, three sub-samples were taken to supply material for pigment, moisture and spectroscopic analysis. In a laboratory dimethylformamide solvent was used in the determination of chlorophylls and carotenoid concentrations [7]. Moisture content was determined through fresh and dry mass measurements and projected needle area measurements were conducted. Ultimately sample chemistry was expressed both as content, a proportion of fresh weight, and as concentrations, mass relative to needle area.

Shortly after sample acquisition was complete, the airborne campaign was carried out. The AISA hyperspectral sensor was flown to acquire data over the four study plots as well as various calibration and validation sites. The AISA sensor samples the spectral range of 395-2503nm with 492 channels every 2.37nm within the VNIR and every 6.30nm within the SWIR. The hyperspectral sensor, integrated with a discrete return lidar system was flown on a Navajo platform. The resulting posting density of the lidar data was ~1.2/m^2. In preprocessing the AISA data were geometrically corrected with the aid of an inertial measurement unit, precision GPS navigation files and a lidar derived top-reflected-surface model, producing two meter spatial resolution hyperspectral data. The AISA data were atmospherically corrected with ATCOR4. The radiometric adjustment of the hyperspectral data were complete after applying an empirical line calibration using ASD fieldspec Pro spectrometer measurements acquired from a large area of relatively new asphalt and a large concrete calibration site.

Utilizing a lidar derived canopy height model, the sample specimen GPS vector file and a local maximum algorithm, a simple protocol was developed for the careful selection and extraction of individual tree top spectral responses. Chemistry measurements originating from the same tree were averaged to achieve representative canopy chemistry values. Reflectance spectra were applied in correlation, band depth and vegetation indices analysis, the results of which were compared and contrasted against the leaf level results. Reflectance attributes determined to be significantly associated with chemistry in laboratory analysis were assessed for similar relationships with canopy level responses. The red edge position and continuum removal shape attributes such as depth, symmetry and areas were assessed for the ability to estimate pigment concentrations through simple linear regression (R^2 >0.8). A partial least squares and principal component regression were also applied. Model comparisons were made and the best predictors of chemistry from canopy responses were observed. Applying the selected best estimator to the hyperspectral dataset, chemistry maps were generated. Based on the extracted chemistry data distributions for colonized and healthy samples threshold values were selected to maximize the discrimination between the two health classes. These thresholds were applied to the chemistry maps to identify canopies of likely infected trees (figure 1). An additional investigation was conducted to determine if incorporating a lidar three dimensional spatial component increased the accuracy of diseased canopy detection.

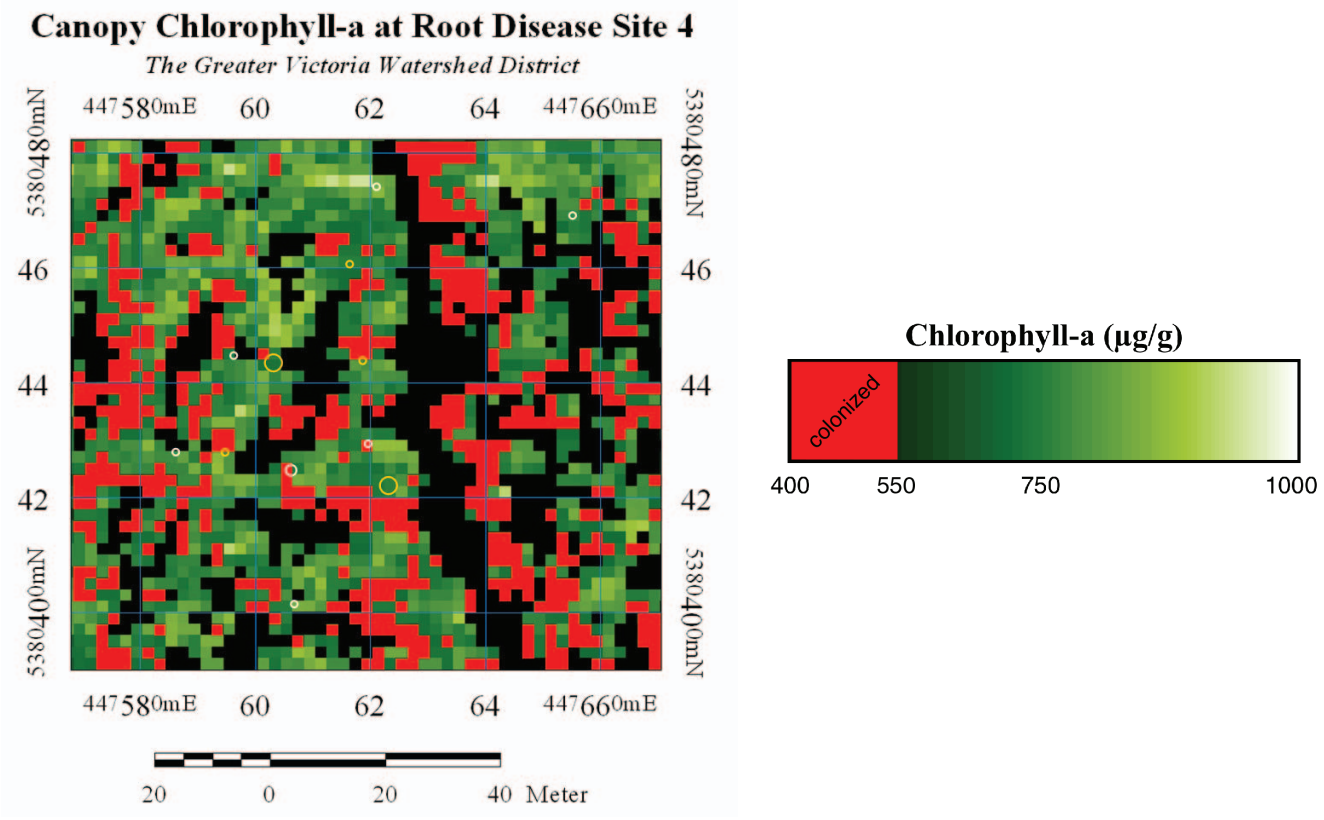

Figure 1: Chemistry identifies canopies likely experiencing the effects of root disease. Sample trees identified by circles whose radii are proportional to GPS accuracy (<±3m). yellow: colonized, white: healthy

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