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Estimation of chlorophyll fluorescence under natural illumination from hyperspectral data

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ABSTRACT

This paper reports a series of laboratory and field measurements of spectral reflectance under artificial and natural light conditions which demonstrate that effects of natural chlorophyll fluorescence are observable in the reflectance red edge spectral region. These are results from the progress made to link physiologically-based indicators to optical indices from hyperspectral remote sensing in the Bioindicators of Forest Sustainability Project. This study is carried out on twelve sites of Acer saccharum M. in the Algoma Region, Ontario (Canada), where field measurements, laboratory-simulation experiments, and hyperspectral CASI imagery have been carried out in 1997, 1998, 1999 and 2000 campaigns. Leaf samples from the study sites have been used for reflectance and transmittance measurements with the Li-Cor Model 1800 integrating sphere apparatus coupled to an Ocean Optics Model ST1000 fibre spectrometer in which the same leaves are illuminated alternatively with and without fluorescence-exciting radiation. A study of the diurnal change in leaf reflectance spectra, combined with fluorescence measurements with the PAM-2000 Fluorometer show that the difference spectra are consistent with observed diurnal changes in steady-state fluorescence. Small canopies of Acer saccharum M. have been used for laboratory measurements with the CASI hyperspectral sensor, and under natural light conditions with a fibre spectrometer in diurnal trials, in which the variation of measured reflectance is shown experimentally to be consistent with a fluorescence signature imposed on the inherent leaf reflectance signature. Such reflectance changes due to CF are measurable under natural illumination conditions, although airborne experiments with the CASI hyperspectral sensor produced promising but less convincing results in two diurnal experiments carried out in 1999 and 2000, where small variations of reflectance due to the effect of CF were observed.

INTRODUCTION

The objective of the *Bioindicators of Forest Sustainability Project* [Mohammed *et al*, 1997; Sampson *et al,* 1998] is to develop links between physiologically-based bio-indicators from field and laboratory data and optical indices from hyperspectral remote sensing data for assessing forest condition. Previous work [Zarco-Tejada *et al*, 1999a; 1999b] showed that optical indices calculated from single leaf reflectance data, infinite reflectance models from optically-thick simulation formulae, and canopy reflectance models, progressively more closely represented the observed above-canopy reflectance spectra. Optical indices calculated from modelled canopy reflectance through infinite and canopy reflectance models were shown to be able to be used for estimation of pigment content over closed deciduous canopies of *Acer saccharum* M, and showed high correlations with ground truth chlorophyll fluorescence (CF). The strong correlation relationships obtained between selected optical indices calculated in the 690 and 750 nm spectral region from airborne CASI hyperspectral data with ground measured CF were studied in detail in Zarco-Tejada *et al* [2000a, b]. Experiments were carried out at different levels of study in the laboratory and through the development of a radiative transfer model (FRT) that simulates the effect of the fluorescence signal superimposed to the reflectance spectrum. This paper reports on further research carried out in this research theme, in which experiments with a fibre spectrometer were carried out using small canopies of seedlings under natural illumination conditions, and with CASI-airborne campaigns over *Acer saccharum* M. study sites in 1999 and 2000 with specific bandsets to investigate the ability to detect CF from an airborne sensor

LEVELS OF STUDY

The effects of the CF signature on vegetation apparent reflectance were studied in a series of experiments in 1997, 1998, 1999 and 2000 at different levels of scale. Four different levels of study were carried out, from the leaf level to the canopy, in order to investigate whether the effects of CF on apparent reflectance are measurable in spite of increasing complexity: i) at leaf level, with data collected from *Acer saccharum* M. study sites to develop relationships between leaf reflectance and CF; diurnal studies were also carried out at leaf level to study the effects of changes in leaf apparent reflectance due to diurnal CF patterns; ii) at canopy simulation level in the laboratory using the CASI hyperspectral sensor and