Bioindicators of sustainable forestry: Scaling up physiological indicators using remote sensing

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Abstract

The Bioindicators of Forest Sustainability Project is developing optical indices from hyperspectral remote sensing data that are linked with ground-based physiological bioindicators of forest condition. Physiological indicators were used because they have been shown to give quick and reliable assessments of tree condition. Scaling up leaf-based physiological indicators to canopy and stand levels required the assembly of a multidisciplinary team. A series of experiments, designed to show the linkages of the physiological indicators between levels, were performed at the leaf, laboratory canopy simulation, and field canopy and stand levels to scale up leaf-based physiological indicators using canopy reflectance models. A field plot network of twelve sugar maple sites representing a range in tree condition (chosen from existing provincial plot networks) was assessed by a leaf data collection for physiological and spectral analysis and measurement of stem electrical resistance. A Compact Airborne Spectrographic Imager (CASI) was used to collect data of high spatial, hyperspectral and full spectral image with up to 288 channels in the visible and near-infrared region. Single leaf reflectance and transmittance, chlorophyll fluorescence, and chlorophyll *a* and *b* levels were measured from leaves of five trees per site. Optical indices derived from CASI data were found to correlate well with chlorophyll concentration and chlorophyll fluorescence measured from individual leaves and averaged for entire stands. Leaf and laboratory canopy simulation levels revealed the contribution of chlorophyll fluorescence to spectral apparent reflectance signals from which new indices were developed. Stand average stem electrical resistance, a ground measurement of tree vigour, was significantly correlated with CASI optical indices. Our results suggest that hyperspectral sensors may indicate changes in chlorophyll and chlorophyll fluorescence in forest canopies and the vigour and stress levels of forest stands. Future challenges include developing operational hyperspectral methods that can deal with issues related to canopy structure and species and scaling up the indicators from the aerial remote sensing level to the satellite level.

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