Quantifying non-pigment plant components from imaging spectrometer data: using biochemical absorption features to study ecosystem processes.

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Since 1988, remotely sensed data from imaging spectrometers have been used to quantify non-pigment vegetation components such as water, nitrogen, protein, cellulose, and lignin. This research has been motivated, in large part, by the important role that these substances play in plant biophysical processes, such as photosynthesis, and their demonstrated relationships with ecosystem processes, such as carbon fixation, litter decomposition, and nutrient cycling. In this talk, we will focus on the two areas of research that have been pursued to improve the utilization of imaging spectrometers for examining ecosystem processes. First, we examine the fundamental understanding of vegetation spectra in relation to non-pigment biochemical constituents, and second, how the application of imaging spectrometers to map indicators of ecosystem processes contribute to our understanding of ecosystems. We will summarize relevant, recent work, look at trends in concepts and methods from those employed at the inception of imaging spectroscopy to current developments, and discuss the challenges faced and opportunities presented in the quantification of non-pigment plant constituents and their use in ecosystem studies.

Estimating canopy chemistry from imaging spectrometer data was based on earlier research that estimated the quality of animal feed and forage using statistical relationships developed between data from laboratory spectrometers and biochemical assays of nitrogen and protein. These initial studies were conducted with tightly controlled laboratory conditions. Prediction equations could not be extended to other populations of samples. More recent studies have used new statistical methods. A physically-based approach of estimating the concentration of a biochemical based on quantities derived from wavelength regions in which it is the principal absorber has given better results than past techniques. This improvement has been observed for quantifying water, nitrogen, cellulose, lignin, and non-photosynthetic vegetation. As higher correlations between spectra and biochemical concentrations are being achieved, new insights are being gained into how specific biochemical components influence the shapes of absorption features in the reflectance spectra of vegetation.

Initially, maps of indicators of ecosystem functioning were derived from imaging spectrometer data collected over forests. Continuing research has expanded on those successful studies by linking nitrogen estimates to models of forest net primary production. The most recent studies go even further by illuminating the relative impacts of topographic variables, such as elevation, slope and aspect, soil variables, such as water and nutrient content, and changing environmental conditions, such as precipitation, on vegetation growth. In mixed conifer-hardwood forests of the eastern United States, nitrogen estimates derived from imaging spectrometers revealed an unexpected increase in foliar nitrogen from low- to mid-elevation deciduous stands. This indicated moisture as a possible limiting factor in net primary production in lower-elevation forests. In rainforest canopies of Hawaii, an index of water absorption derived from imaging spectrometer data was found to be superior to the traditional chlorophyll-based normalized difference vegetation index (NDVI) in capturing spatial and linked climate-substrate driven variations in canopy structure. Following a fire in a coniferous forest of the Rocky Mountains, imaging spectrometer data was used to show the variable patterns of nutrients available for plant re-growth. Outside of forests, in a dryland region of Argentina, non-photosynthetic vegetation cover (NPV) mapped from imaging spectrometer data was found to be an important indicator of land condition and ecosystem functioning. Areas of low NPV were described as showing a chronic break in the cycling of carbon and nutrients as compared to areas of higher NPV that have more processing of litter by soils to produce plant available nutrients. These selected studies demonstrate the successful application of imaging spectrometers to mapping indicators of ecosystem processes and the corresponding increases in our knowledge of ecosystem functioning.

Challenges still remain to more widespread application of imaging spectrometers to quantifying non-pigment plant constituents for understanding ecosystems. The studies mentioned above have described challenges presented by overlapping absorption features of plant biochemical constituents, the complexity of spectral signatures in pixels of mixed vegetation and soil, and the low signal-to-noise of space-based imaging spectrometers. However, new opportunities are also arising; for example, new imaging spectrometers will be launched on future remote sensing satellites. More challenges and opportunities will materialize as people increasingly demand to know the consequences of land use, disturbance, and climate change on the world's ecosystems and communities.