Evaluation of Hyperspectral Requirements for Remote Estimation of Forest Ecosystem Composition and Function

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Field studies among diverse biomes demonstrate that nitrogen concentration (% N) at leaf- and canopy-scales is strongly related to carbon uptake and cycling (Figures 1 and 2). Combined field and airborne imaging spectrometry studies demonstrate the capacity for accurate estimation of forest canopy % N and other biochemical constituents at scales from forest stands to small landscapes. The objective of this study was to evaluate the performance of the first space-based imaging spectrometer, the EO-1 Hyperion, for estimating temperate forest canopy % N, and to compare results achieved with the airborne, high altitude imaging spectrometer, AVIRIS.

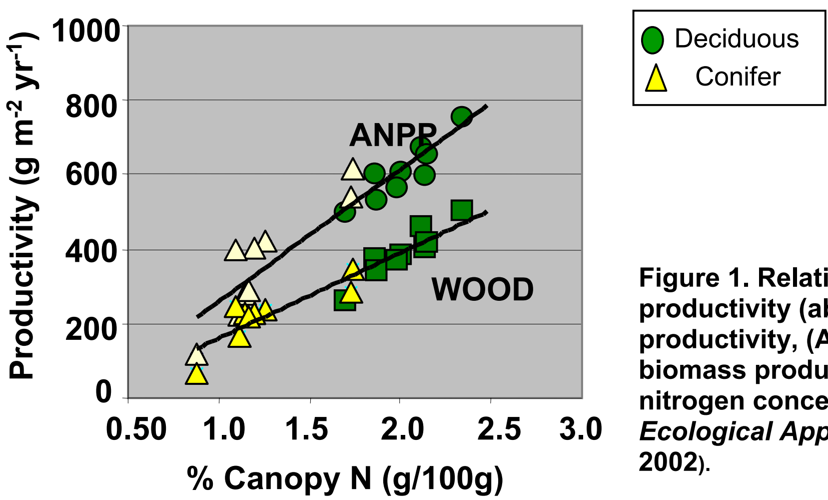

Figure 1. Relationships among forest productivity (aboveground net primary productivity, (ANPP) and aboveground woody biomass production (WOOD) and whole canopy nitrogen concentration (g/100g). (Smith et al. *Ecological Applications* vol 12, pp. 1286-1302, 2002).

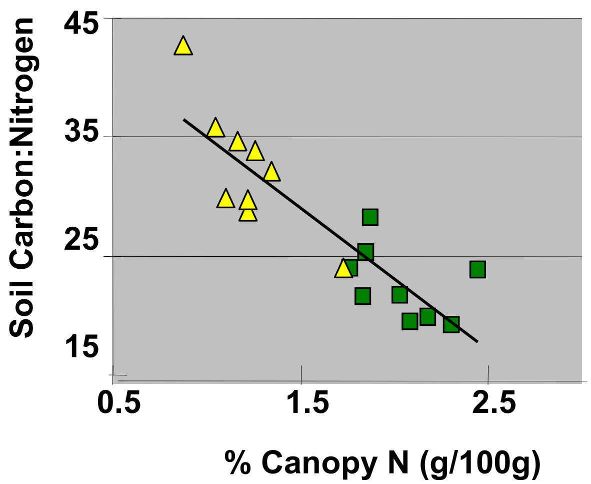

Figure 2. Relationship between foliar %N and soil C:N ratio. Soil C:N ration, in turn, is closely related to rates of both nitrogen mineralization and nitrification. (Ollinger et al. *Ecology*, vol 83, pp. 339-335, 2002).

The study was conducted at the Bartlett Experiment Forest (BEF; W 71.30^{o}, N 44.05^{o}) located in central New Hampshire, USA, and within the White Mountain National Forest. Established in 1932 by the USDA Forest Service, the BEF is a 1052 ha tract of secondary successional broad-leaved deciduous and needle-leaved evergreen forest types. Hyperion data, collected on August

29, 2001, were corrected to surface reflectance using the ACORN atmospheric correction program and related to plot-level field measurements of foliar nitrogen concentration. Plot-level reflectance spectra (*R*) were transformed to absorbance (*A*) ($A = \log_{10}(1/R)$) prior to a partial least squares (PLS) regression analysis. Overall accuracy of Hyperion estimates of canopy % N as compared with field measurements were within 0.25% dry mass and AVIRIS-based estimates were within 0.19% dry mass (Figure 3), each well within that required to distinguish among forested ecosystems in nitrogen status.

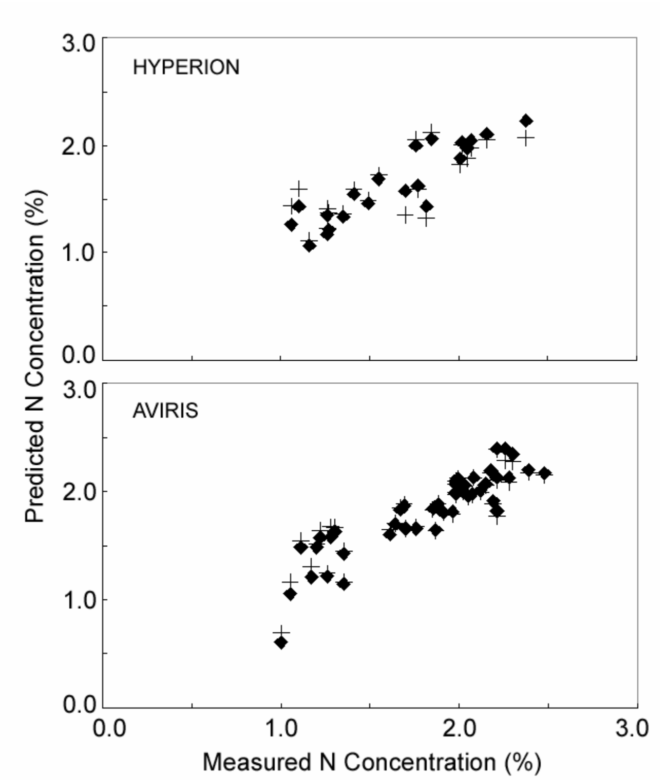

Figure 3. Predicted versus observed canopy nitrogen concentration based on PLS regression models using (top) Hyperion and (bottom) AVIRIS absorbance data. In both panels, closed symbols represent the calibration model and open symbols represent the validation model. (Smith et al. submitted to IEEE)

Conclusions:

Forest canopy % N is strongly related to forest growth in temperate forests and provides, in some cases, better predictive ability than other canopy properties examined, e.g., LAI and canopy mass.

Soil N status is reflected in foliar chemistry indicating that carbon and nitrogen dynamics and nutrient cycling dependent on these dynamics are closely coupled in temperate forests.

Hyperspectral remote sensing from both airborne (AVIRIS) and spaceborne sensors (Hyperion) can provide robust estimates of canopy %N (within 0.25% or better by mass) across large forested landscapes useful in estimation, modeling, and monitoring of forest ecosystem dynamics. This ability provides an important “stepping-stone” between field-based measurements and coarse-resolution estimates (kilometer-scale) derived from broad-scale sensors.