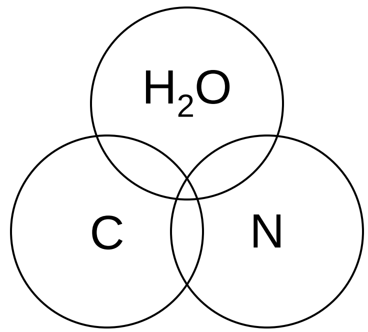
VQ3. Biogeochemical Cycles

Scott Ollinger, Susan Ustin

(presented by J. Gamon)



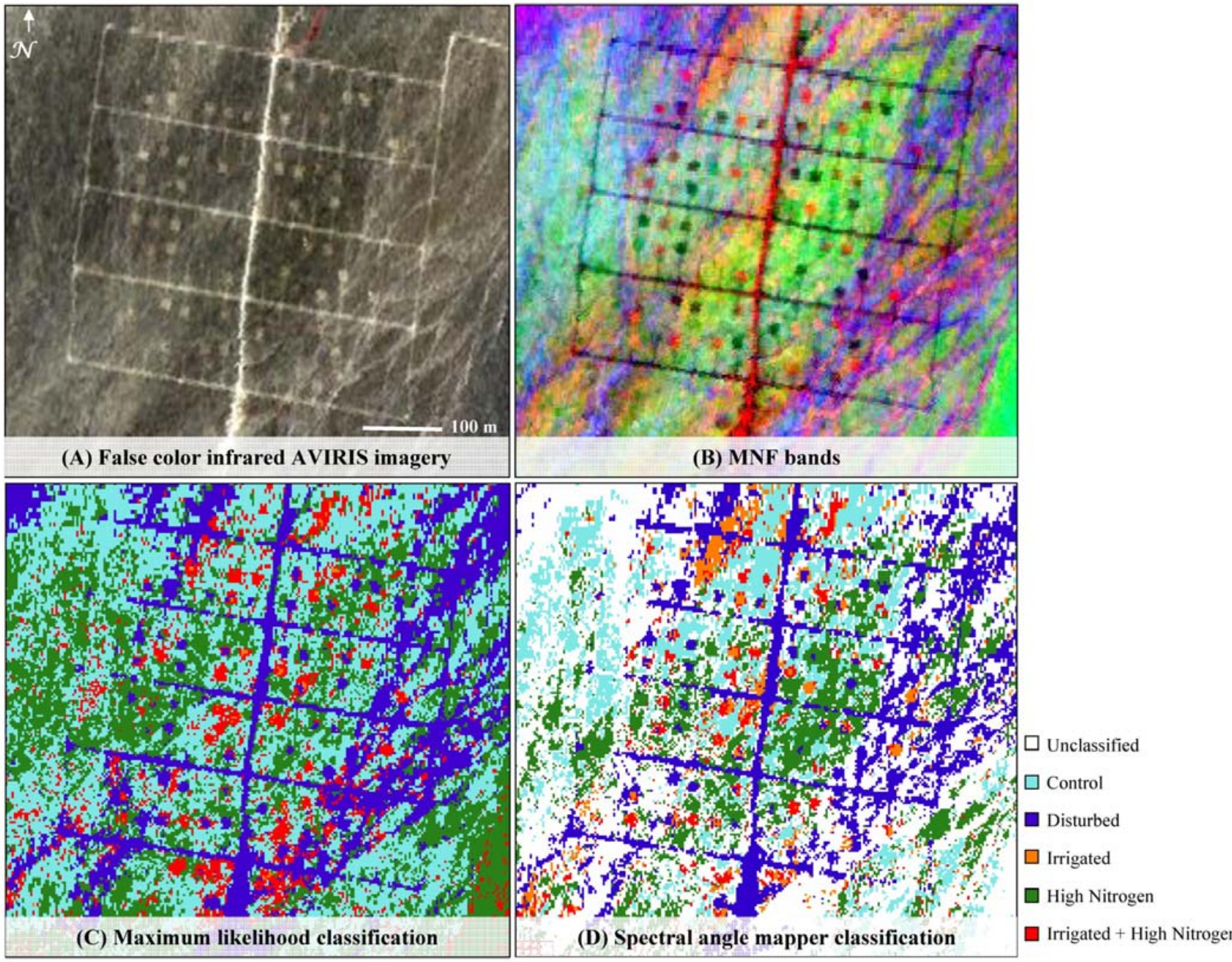
Overarching Question:

How are the biogeochemical cycles that sustain life on Earth being altered/disrupted by natural and human-induced environmental change? How do these changes affect the composition and health of ecosystems and what are the feedbacks with other components of the Earth system? [DS 195]

Sub-questions:

- How do changes in climate and atmospheric processes affect the physiology and biogeochemistry of ecosystems? [DS 194, 201]
- What are the consequences of uses of land and coastal systems, such as urbanization and resource extraction, for the carbon cycle, nutrient fluxes and biodiversity? [DS 196, 197]
- What are the consequences of increasing nitrogen deposition for carbon cycling and biodiversity in terrestrial and coastal ecosystems? [DS 195, 196]
- How do changes in hydrology, pollutant inputs and sediment transport affect freshwater and coastal marine ecosystems? [DS 196]
- How do changing water balances affect carbon storage by terrestrial ecosystems? [DS 196]
- What are the key interactions between biogeochemical cycles and the composition and diversity of ecosystems? [195, 196]
- How do changes in biogeochemical processes feed back to climate and other components of the Earth system? [DS 190, 192, 195]?

Sub-questions 1 & 3 - Atmospheric-biospheric interactions & N deposition
(deposition effects on soil crusts)

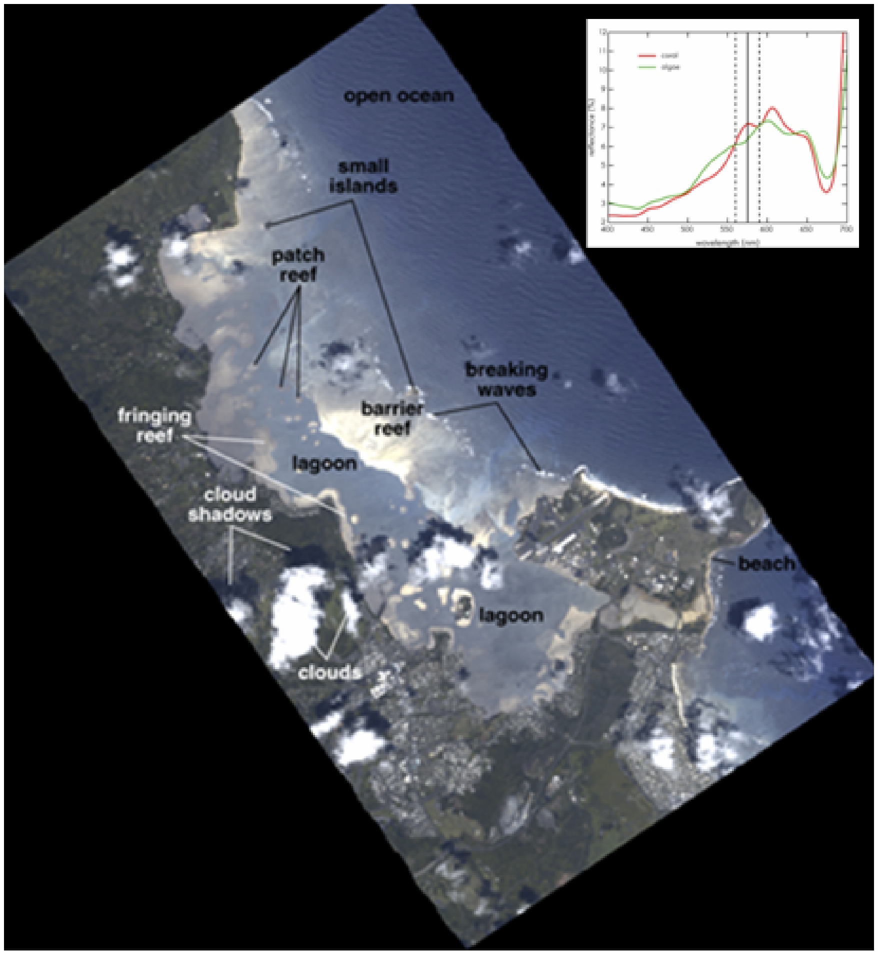


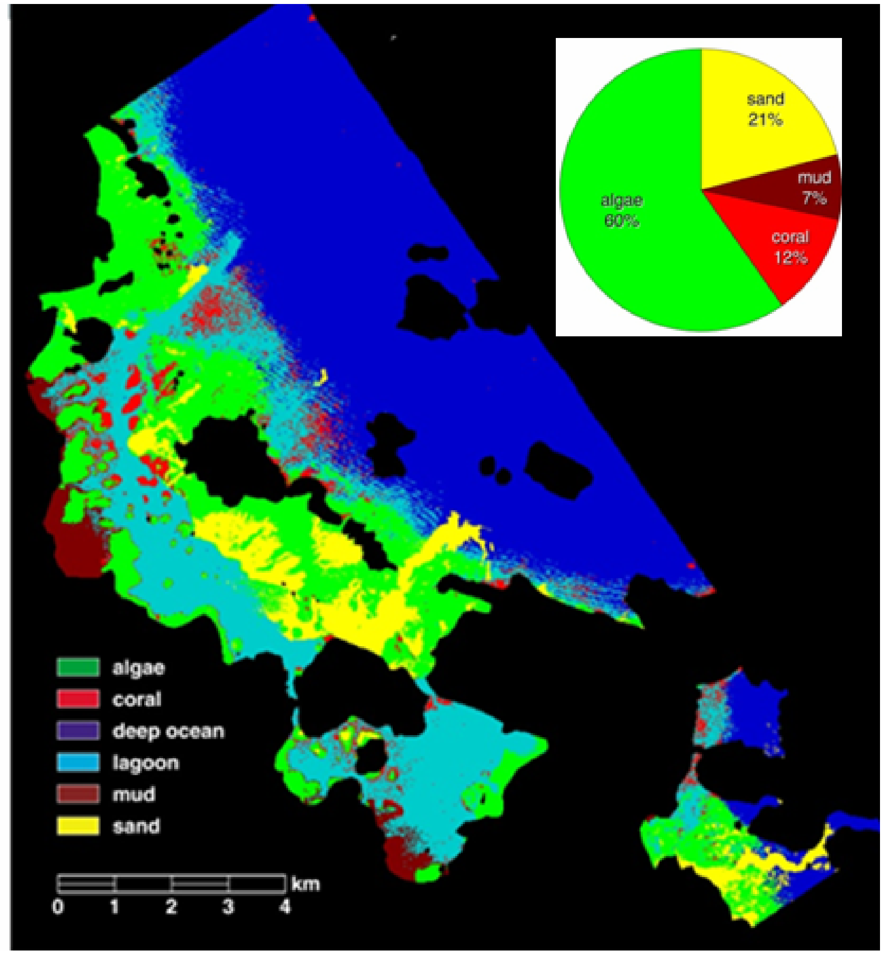
Nevada Desert Global Change Experiment. Each plot is 14 m x 14m and is a multifactorial experiment with disturbance, N addition (two levels) and summer irrigation. In the second summer of the experiment, AVIRIS was flown over the site, which clearly shows effects of some treatments on the desert soil crust (primarily) as no detectable changes were observed in shrub community. Ustin et al. RSE in press

Subquestion 2: Nutrient levels affect coastal community composition.

Kaneohe Bay, HI

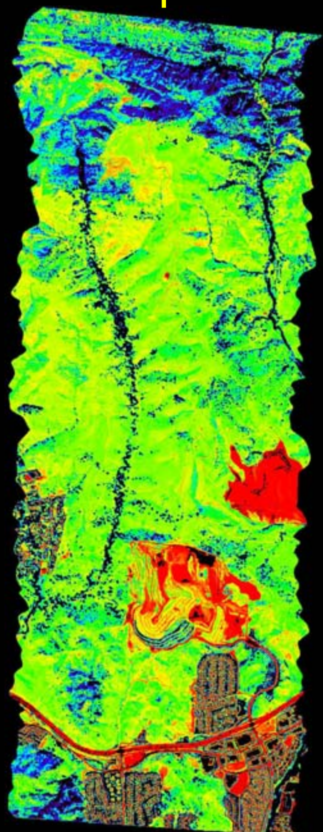
Algal replacement of coral reefs is an indicator of runoff & eutrophication



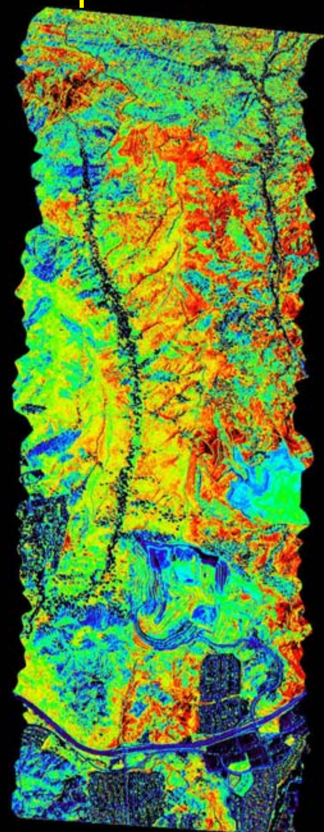


(Hochberg et al. 2003)

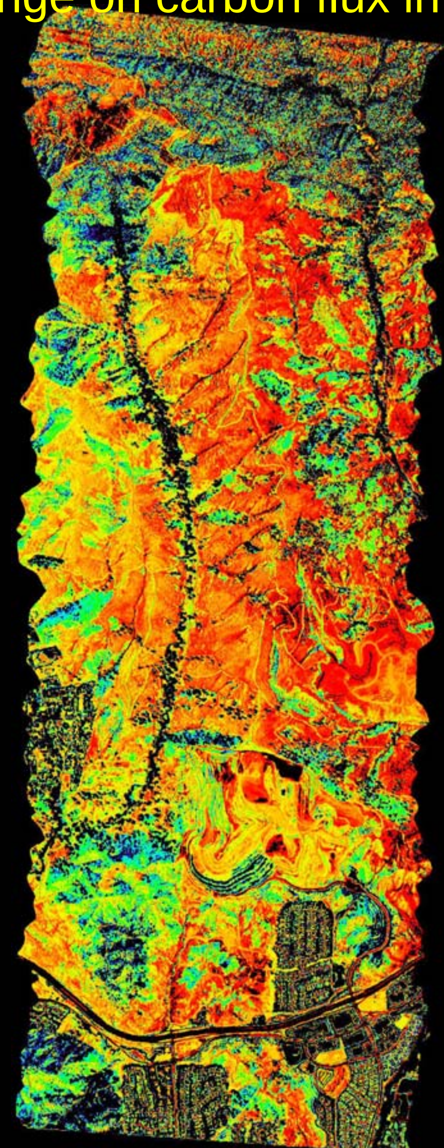
Subquestion 2: impact of land-use change on carbon flux in southern California



NDVI



PRI



$C0_2$ flux

0 40 $\mu mol\ m^{-2}\ s^{-1}$

Landcover	CO_2 flux
Riparian	100%
Chaparral	16.6
(post-fire)	-1.0
Coastal sage	13.2
Grassland	-2.6
Homes	48.7%
New homes	- 4.9
Landfill	- 0.6

$C0_2$ flux = f_{APAR} * PAR* LUE

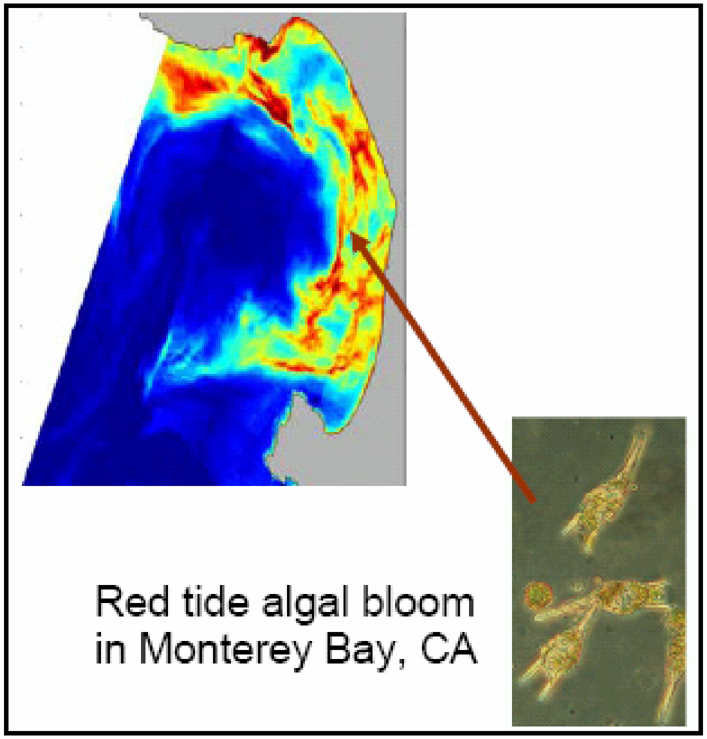
f_{APAR} = (NDVI * 1.25) – 0.135

Midday PAR for Sept. 9 = 1740 $\mu mol\ m^{-2}\ s^{-1}$

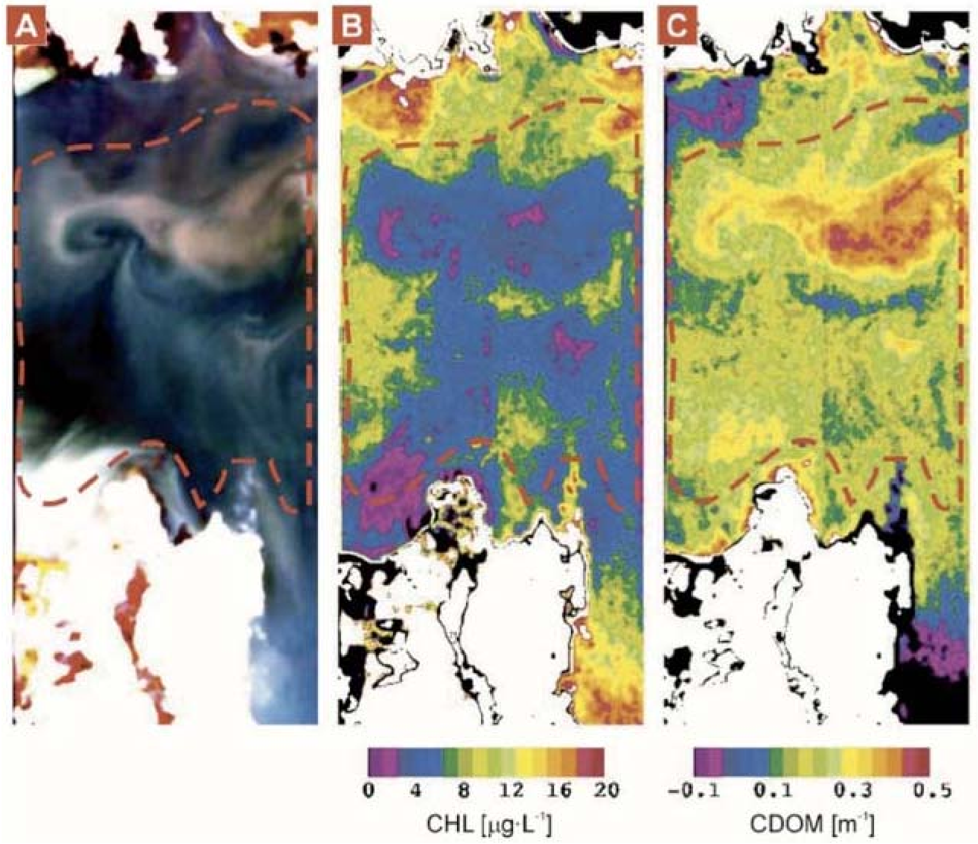
LUE = 0.034 + (PRI * 0.447)

Gamon et al.

Sub-questions 2-4 Coastal activity and algal blooms



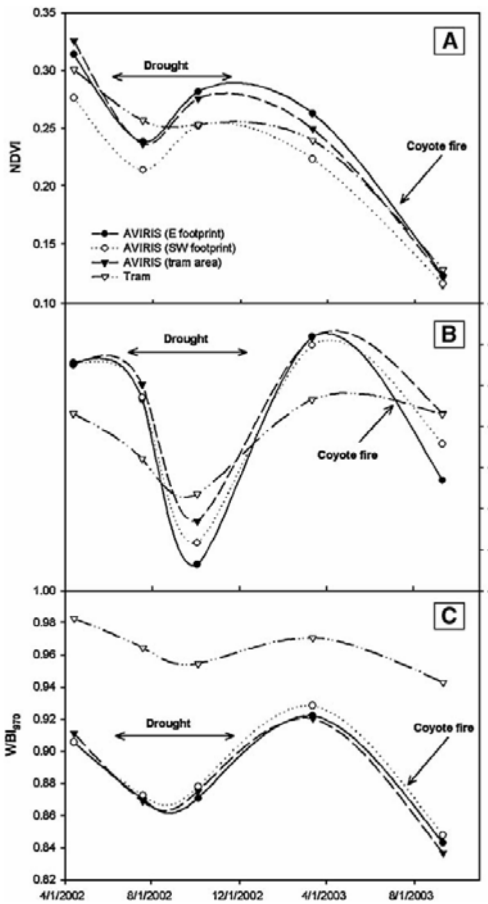
A dense algal bloom or red tide in Monterey Bay measured from the AVIRIS airborne imager at 20 m resolution (Dierssen et al. 2006)

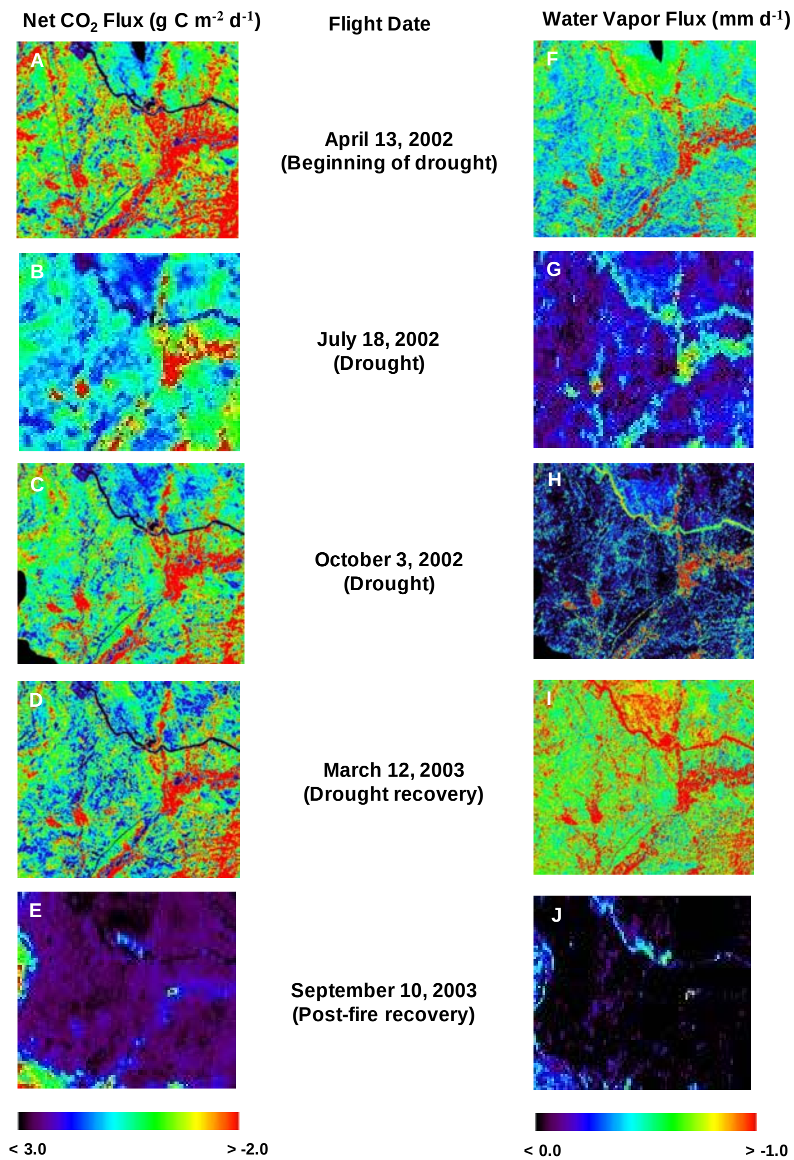


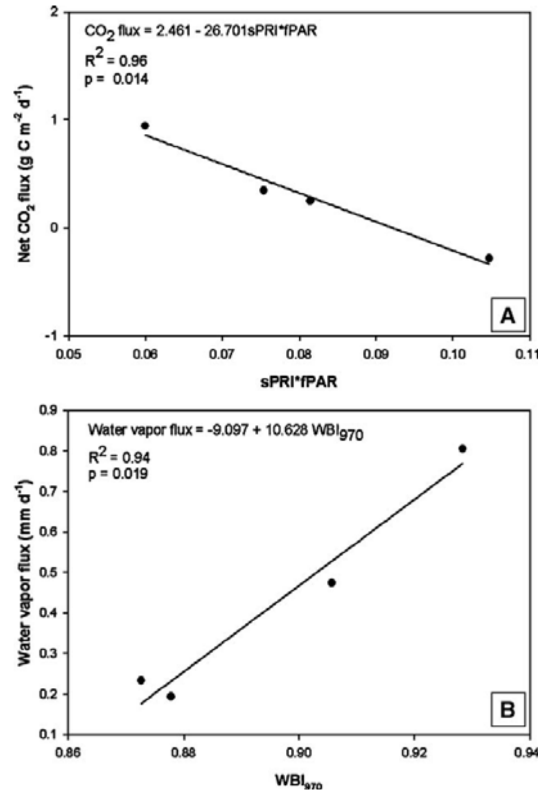
Hyperion scene over Deception Bay showing chl and disolved organic matter (Brando & Dekker 2003)

Sub-question 5: Water-carbon interactions

Spatial and temporal patterns of carbon and water vapor fluxes, Sky Oaks, CA

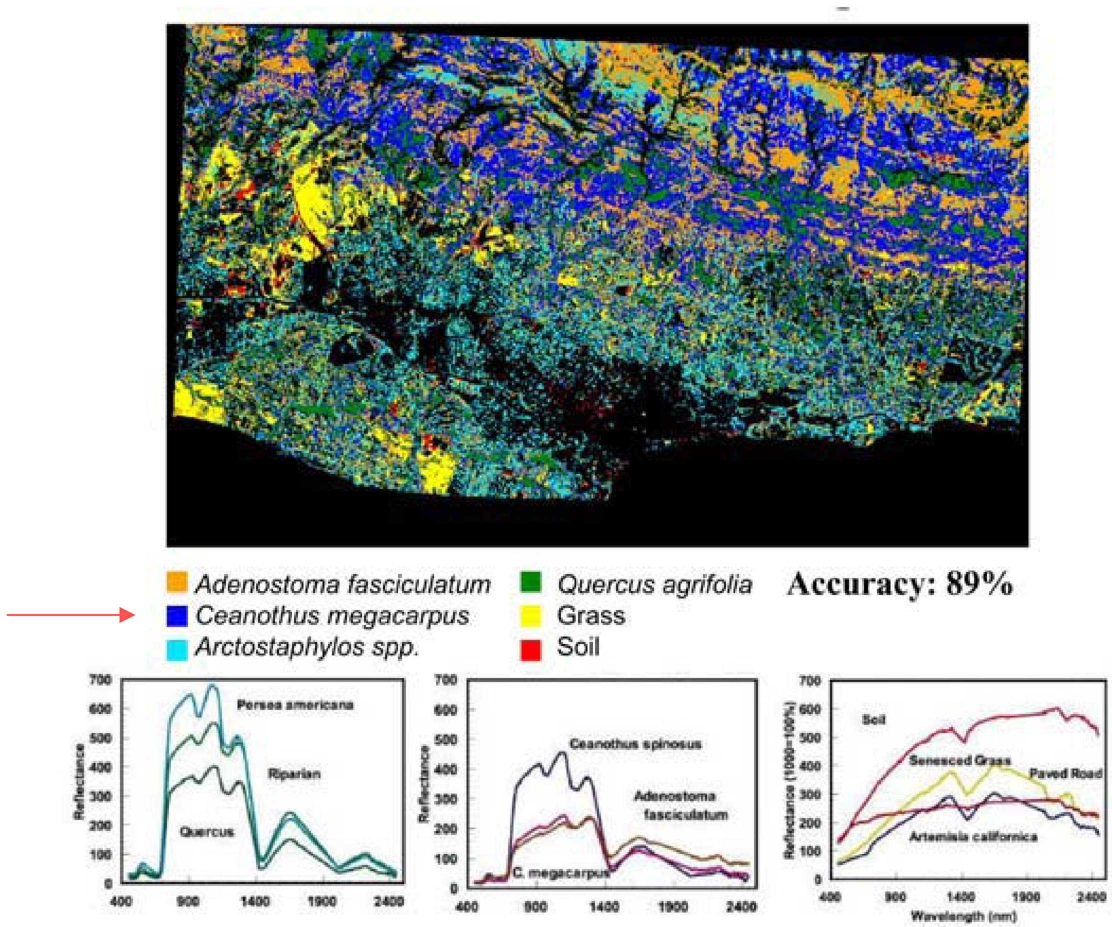






Fuentes et al. 2006

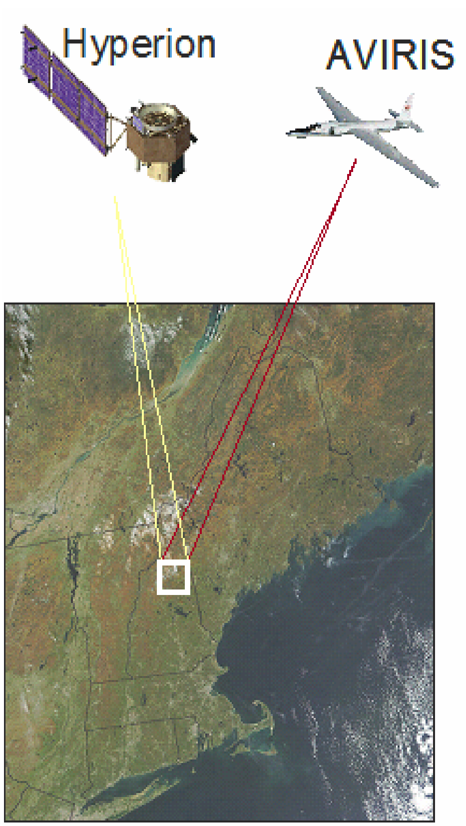
Subquestion 6: Ecosystem composition and biogeochemistry

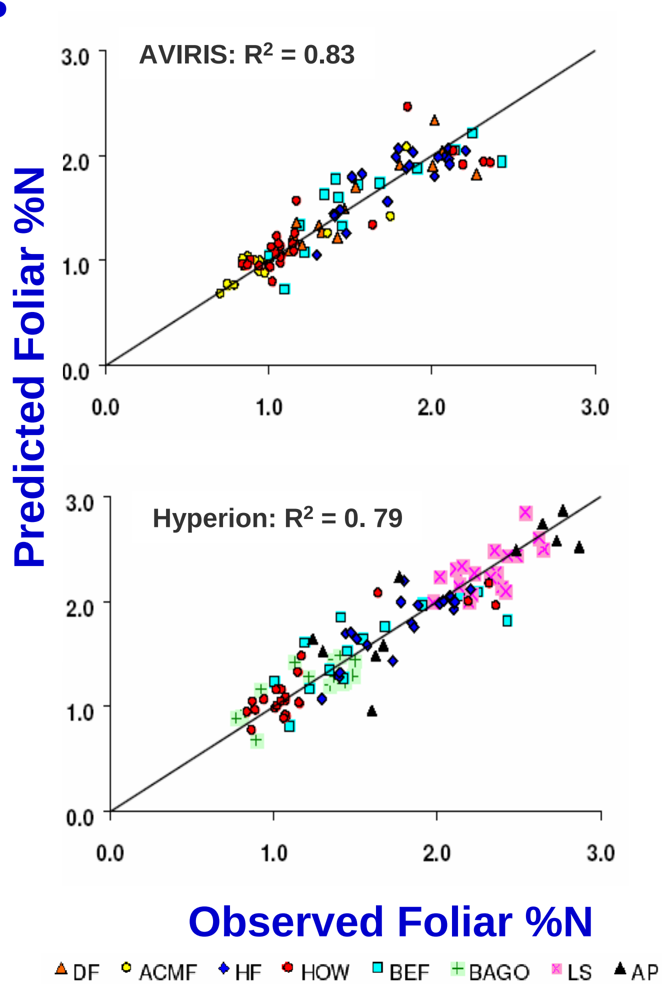


Dennison & Roberts 2003

Subquestion 6: Ecosystem composition and biogeochemistry

A Generalized Method of Foliar Nitrogen Detection Across a Range of Forest Ecosystems

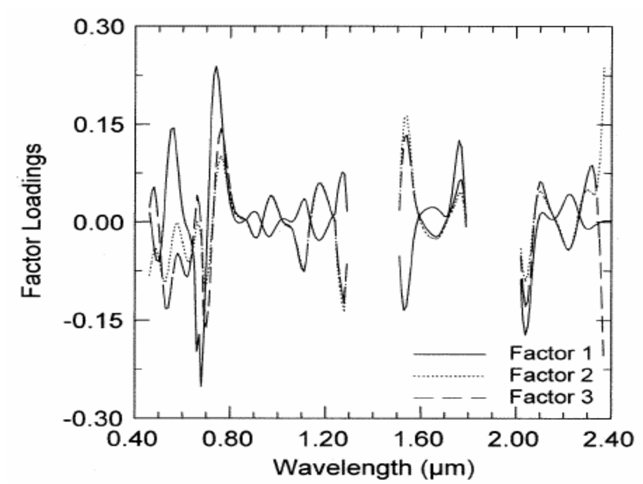




Field Sites

LEFT: Predicted versus observed foliar N, derived from cross-calibration of a 3 factor PLS model to 123 plots across a diverse set of forested research sites in the U.S., Australia and Central America.

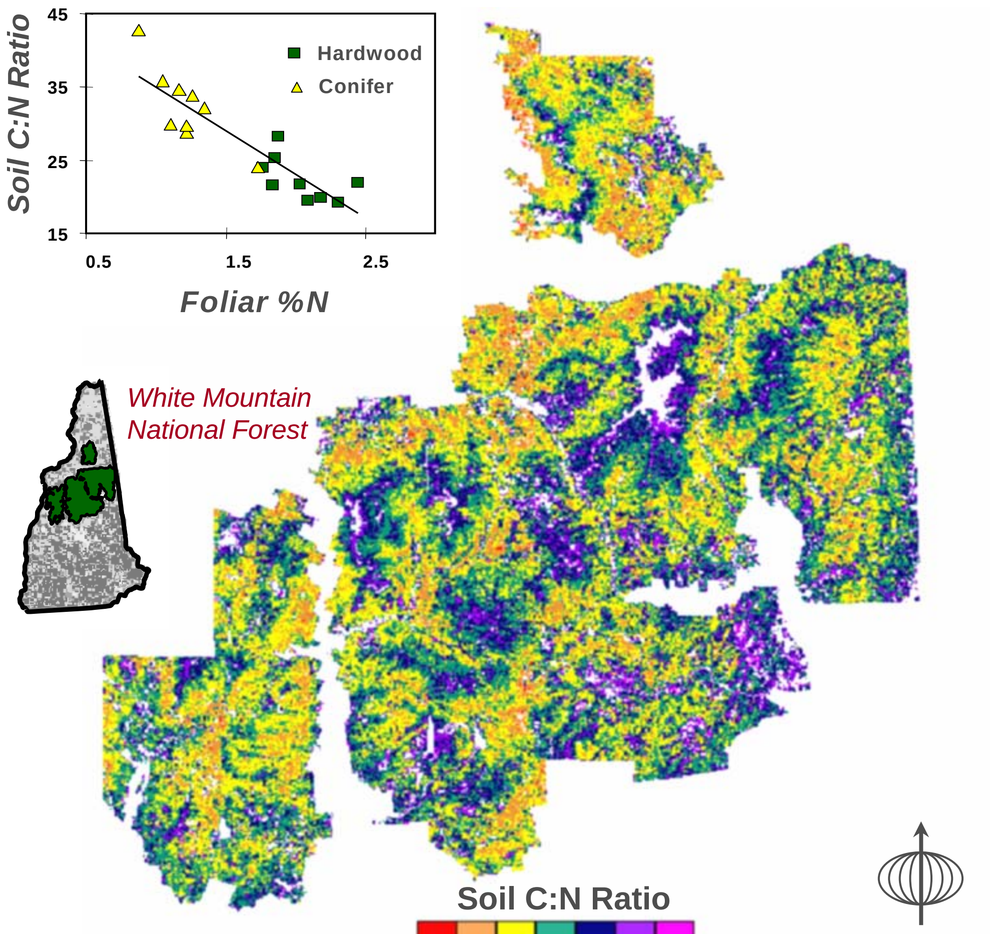
BELOW: Importance values, or factor loadings, for image spectra as derived through Partial Least Squares (PLS) Regression.



Martin et al. 2008.

Subquestion 6: Ecosystem composition and biogeochemistry

Nitrogen Cycling and Nitrification in Soils of the White Mountain National Forest, NH. linked to foliar chemistry



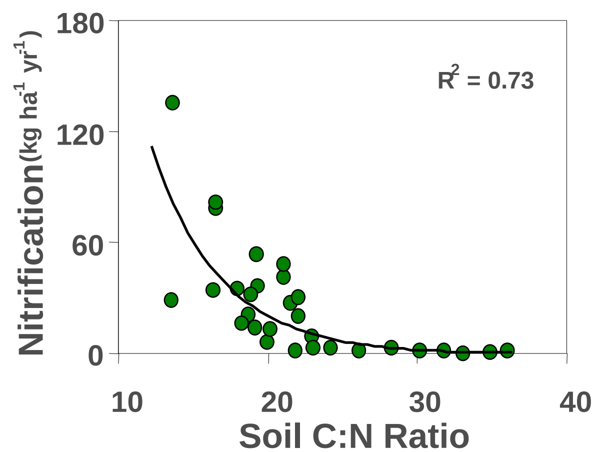
Ollinger et al. 2002

Nitrate (NO_3^-) leaching from soils to streams is an important concern for aquatic ecosystems in areas of high nitrogen deposition.

In Northeastern U.S. forests, nitrate production is inversely related to soil C:N ratios and positively related to the abundance of sugar maple in watersheds.

Soil C:N and NO_3^- leaching have been predicted for the White Mountains of New Hampshire using remote sensing of foliar nitrogen and estimates of sugar maple abundance derived from spectral unmixing.

Predictions have been used to explain observed patterns of stream NO_3^- and to highlight areas vulnerable to elevated N deposition



Sub-question 6: ecosystem composition and biogeochemistry

"Functional vegetation mapping" in the boreal forest

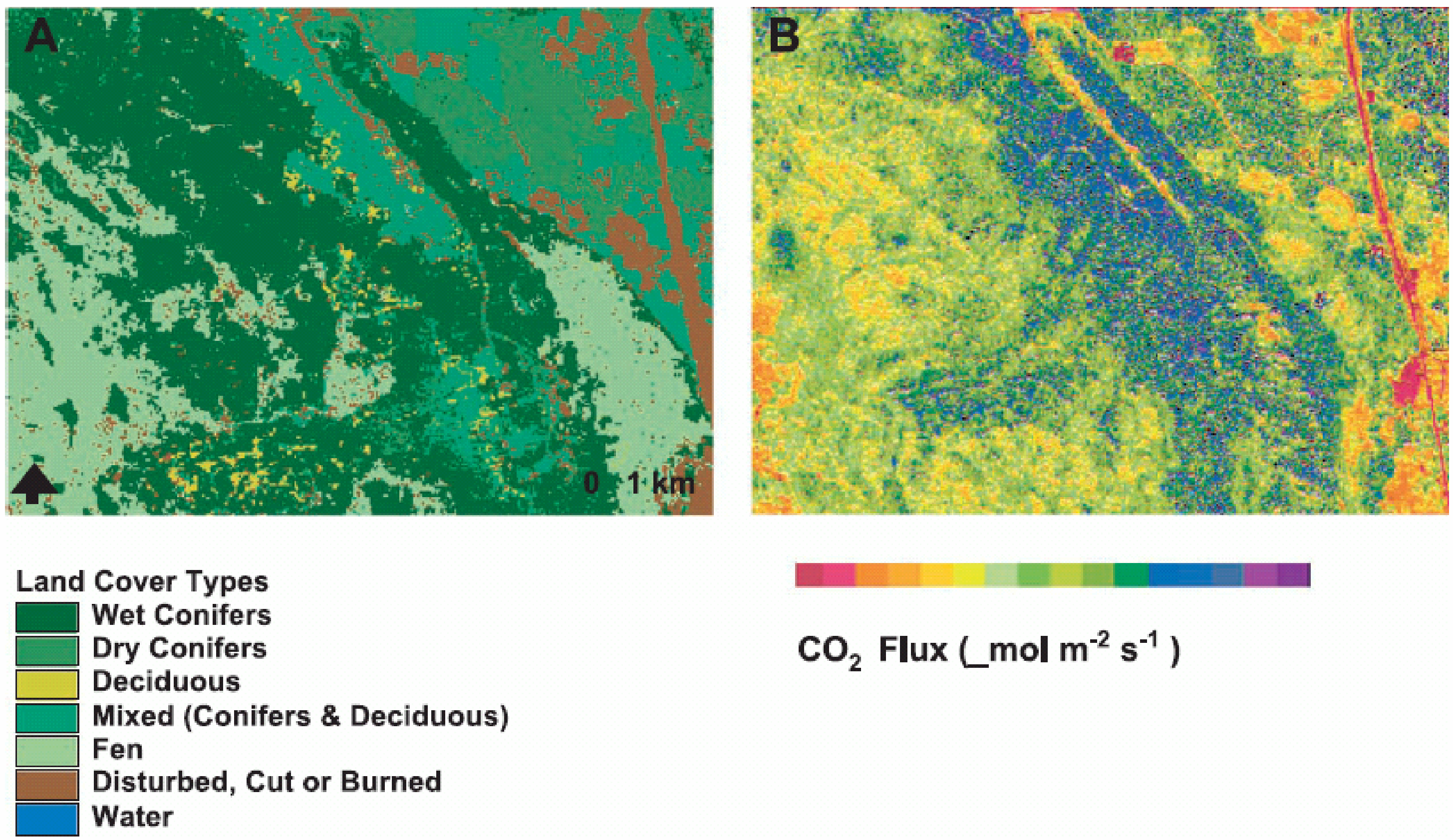
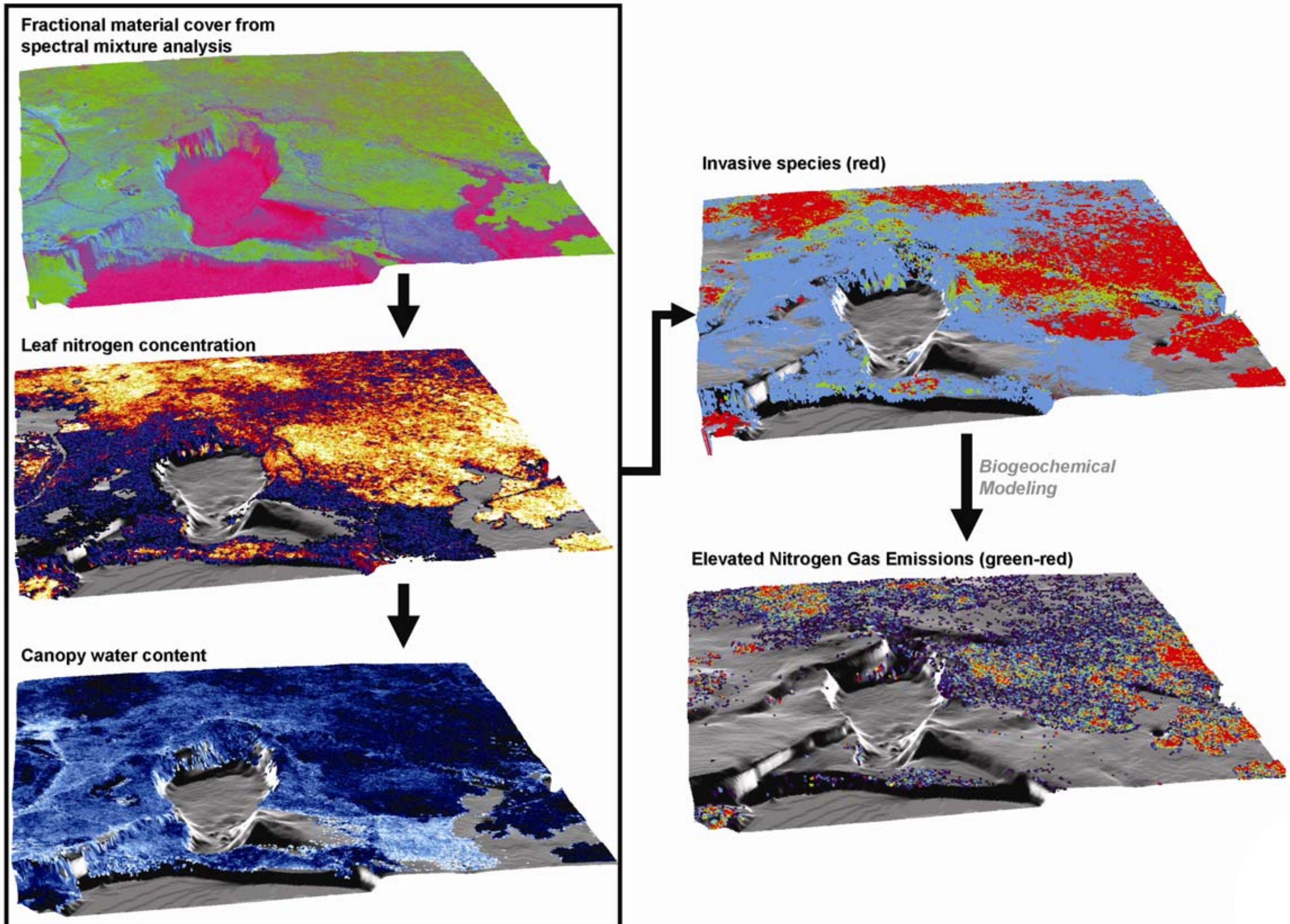


Fig. 4. Comparison of land-cover types (A) with midday gross carbon uptake rates (2-h averages near solar noon) derived from AVIRIS imagery for a portion of the SSA. The land-cover types were derived from pigment and water absorption features using a combination of spectral mixture analysis and a maximum likelihood classification (Fuentes et al., 2001). The CO_2 flux image (B) was derived from NDVI and scaled PRI using a light-use efficiency model and provided an empirically calibrated regional image of midday fluxes for September 16, 1994. This method yielded a strong agreement ($r^2 = 0.8$) with fluxes determined by eddy covariance from five different boreal ecosystems (Rahman et al., 2001).

Gamon et al. 2004

Sub-questions 6 (composition) and 7 (Climate feedbacks)

Canopy chemistry and Soil Nitrogen Emissions

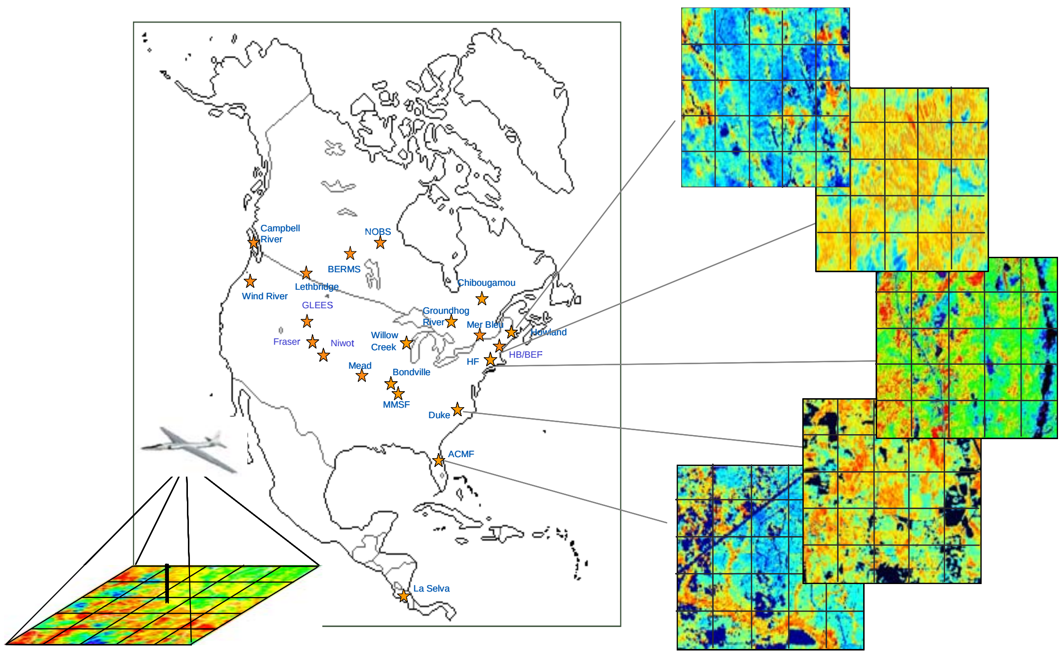


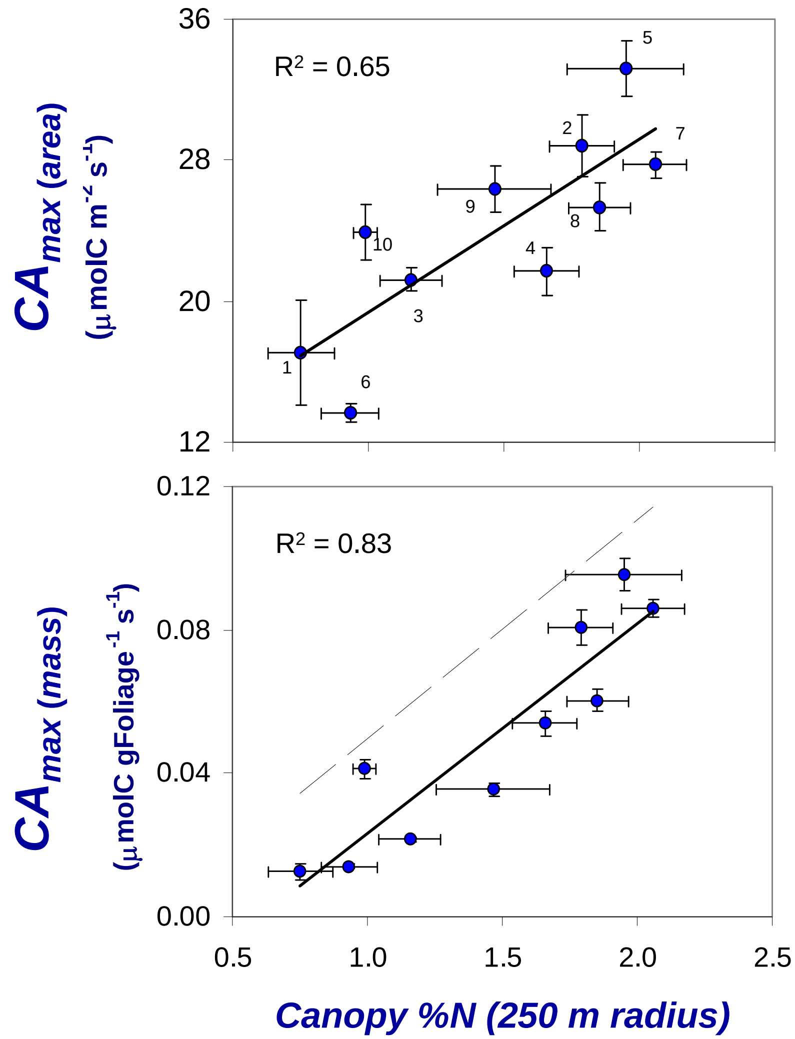
Courtesy: Greg Asner

Sub-question 7 – Climate feedbacks

Understanding Biosphere-Atmosphere CO2 exchange through coupled application of eddy covariance and imaging spectroscopy

Foliar nitrogen and photosynthetic capacity at forested sites within the AmeriFlux network





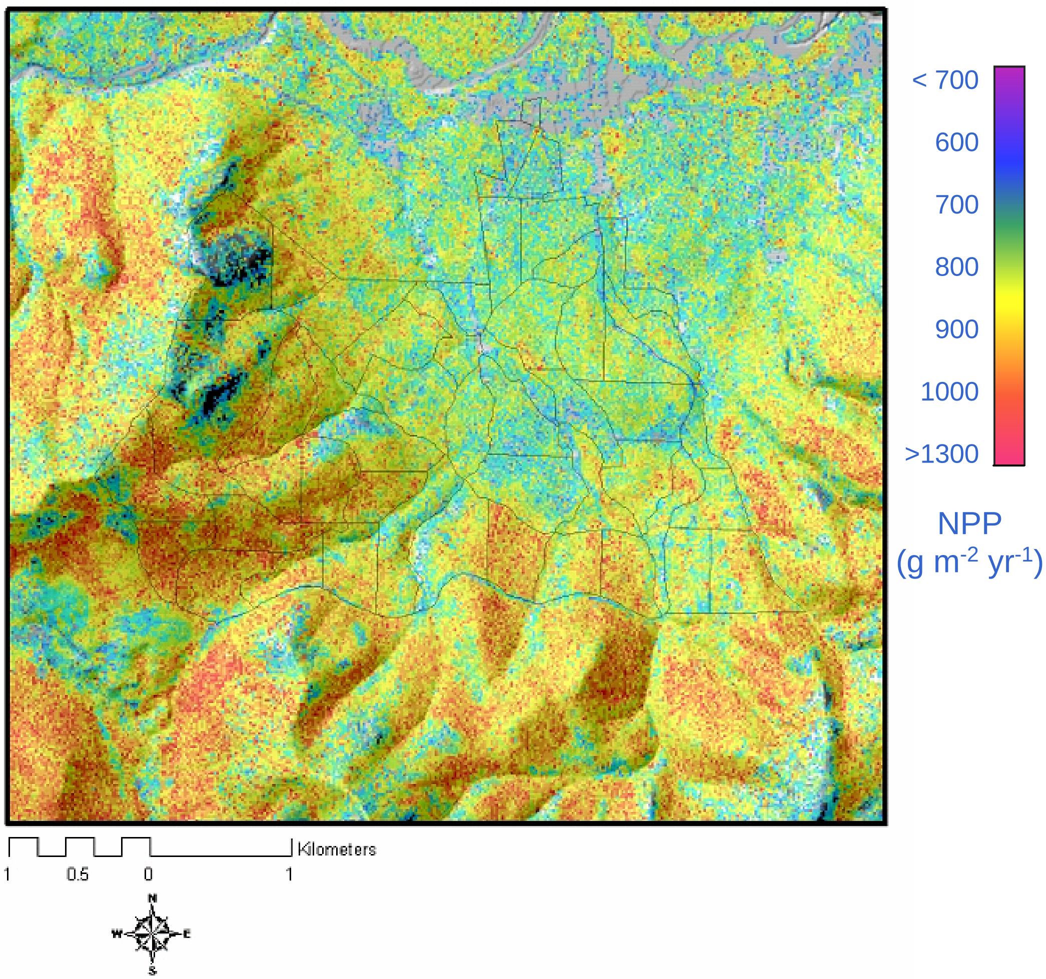
Ollinger et al. In Review

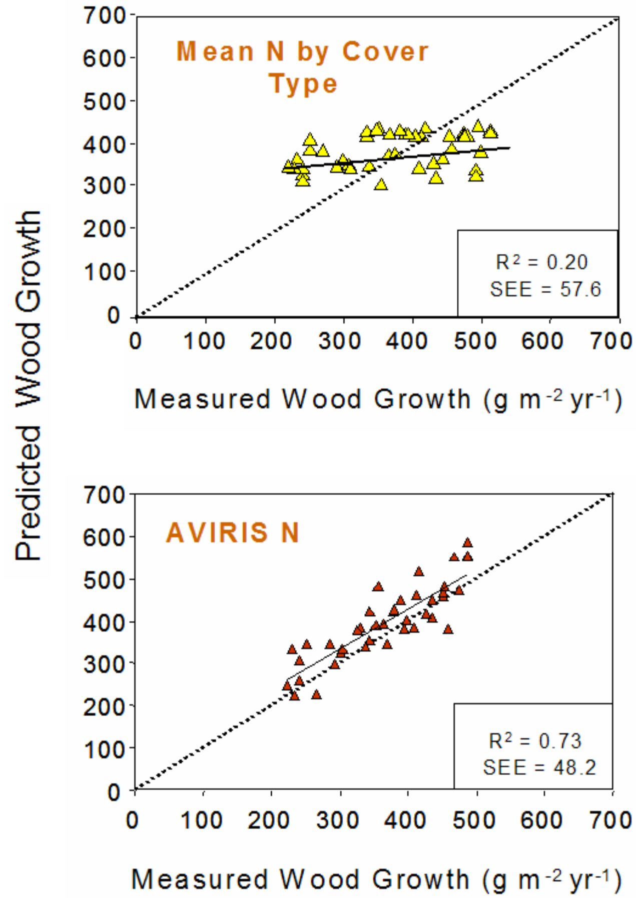
Summary

- Hyperspectral imagery offers many separate “handles” on biogeochemistry
- Integration analyses (C, N, H_2O, species composition…) provide a more synthetic understanding
- Particularly powerful when supplemented with “ecological rules”

Subquestion 6: Interactions between ecosystem composition and biogeochemistry

Local Variation in Canopy N and NPP at Bartlett, NH





AVIRIS Canopy N greatly improves the accuracy of modeled wood growth and NPP

Ollinger and Smith 2005