Anticipated New HyspIRI Products

Examples for Ecological Applications

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2012 HyspIRI Products Symposium

New & Improved Ecosystem Products

1) Ecosystem nutrients and chemistry (nitrogen, water[‡], etc.)

2) Biodiversity (improved species[‡] and functional-type[†])

3) Ecosystem health (physiological condition)
   - *Canopy structure (improved LAI, fraction of green biomass[‡])*
   - *Canopy pigments (e.g. chlorophyll[‡], carotenoids[†], anthocyanins[†])*
   - *Canopy water[‡]*
   - *Lignin & cellulose[‡], crop residue cover**
   - *Nitrogen[‡]*
   - *General stress[†]*

4) Temperature and emissivity estimates by vegetation components (species, functional groups, vegetation health class)

5) Relationships and feedbacks between canopy composition/function and canopy temperatures; predictive relationships between **VSWIR** and **TIR** indicators

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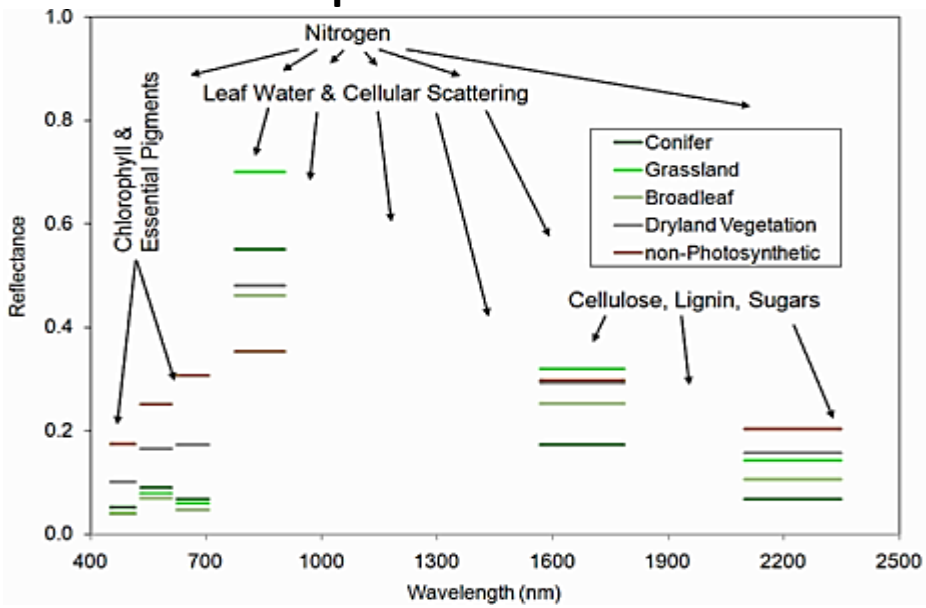
**application ready* *[‡]advanced* *[†]researched*

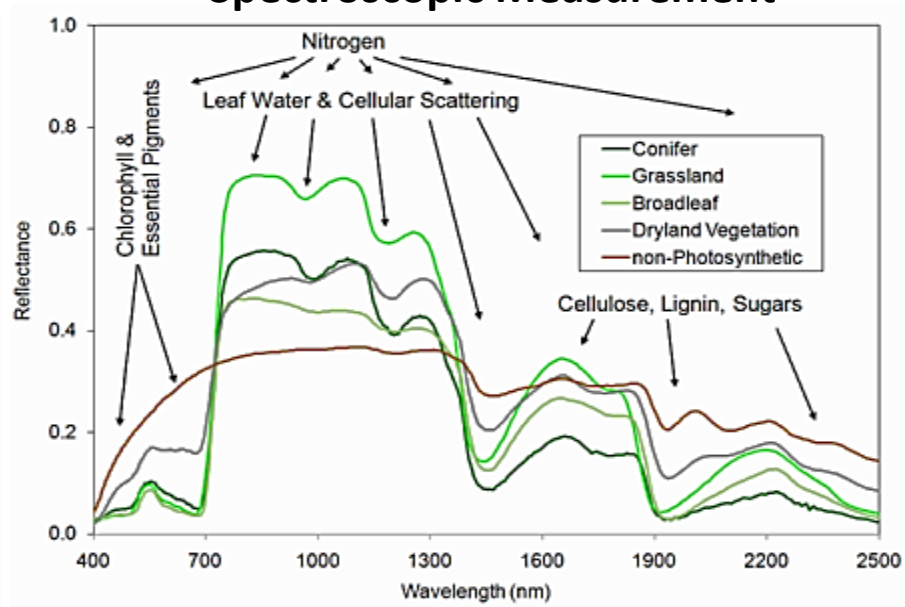
Spectroscopic Measurements are Required for Global Ecosystem Assessments

Multi-Spectral Measurements



Multi-spectral imaging is insufficient to derive the required terrestrial surface compositional parameters accurately.

Spectroscopic Measurement

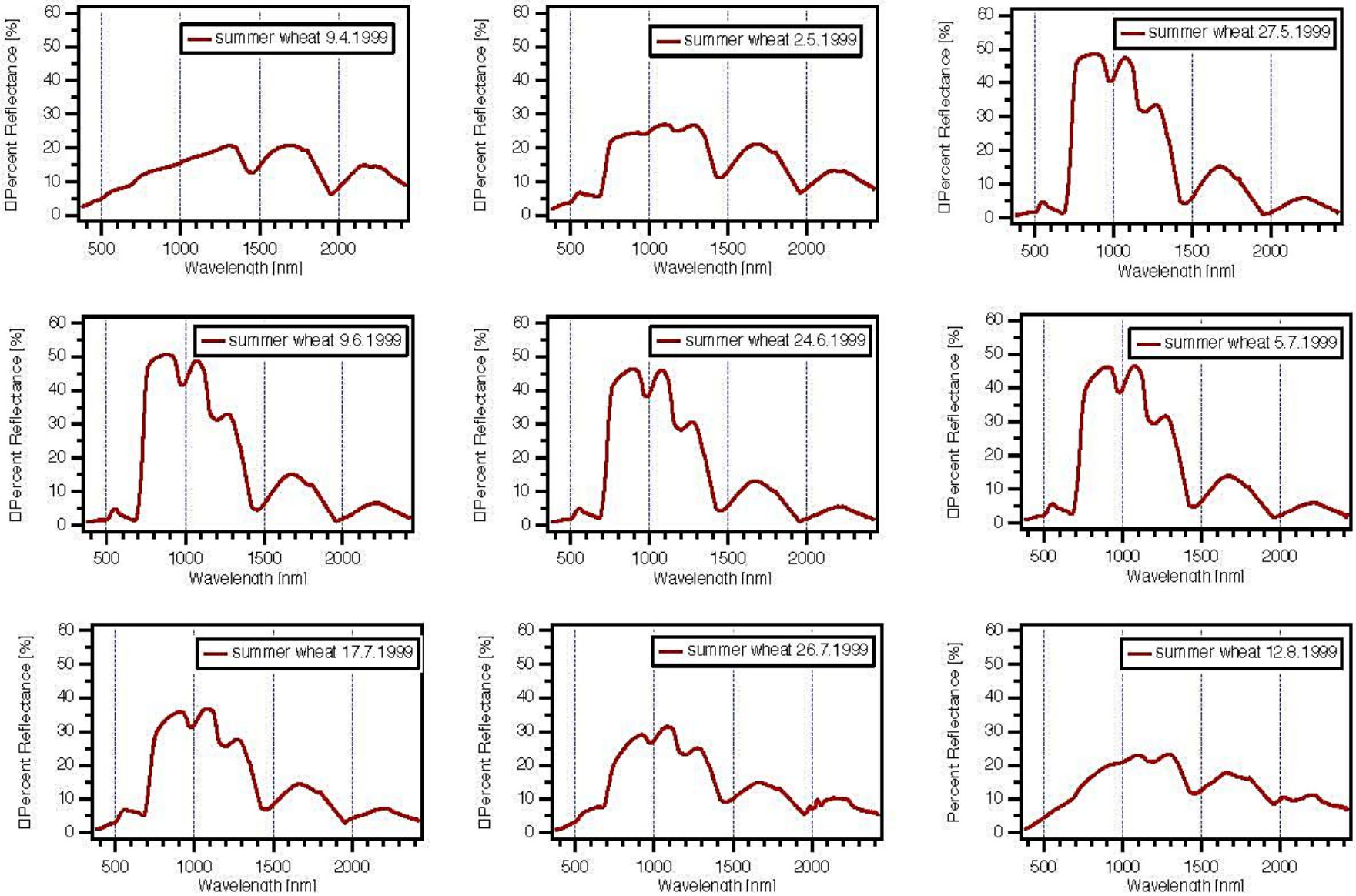


Full range imaging spectroscopy is required to measure composition, chemistry, health and change of ecosystems.

- *Plant species and functional types have biochemical and biophysical properties that are expressed as* ***reflectance, absorption and scattering features*** *spanning the spectral region from 380 to 2500 nm.*
- *Individual bands do not capture the* ***diversity of biochemical and biophysical signatures*** *of plant functional types, species or physiological condition.*
- *Changes in the chemical and physical configuration of ecosystems are expressed as* ***changes in the contiguous spectral signatures*** *related to plant functional types, physiological condition, vegetation health, and species distribution.*

Green et al.

Spectral Time Series - *Phenology of Summer Wheat*

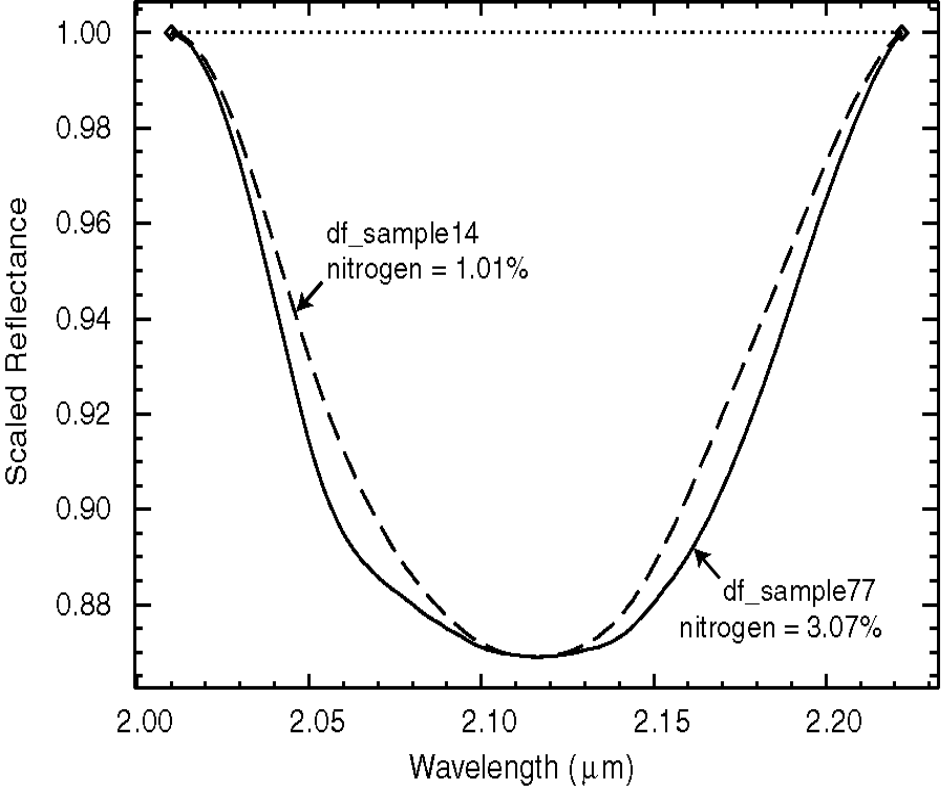


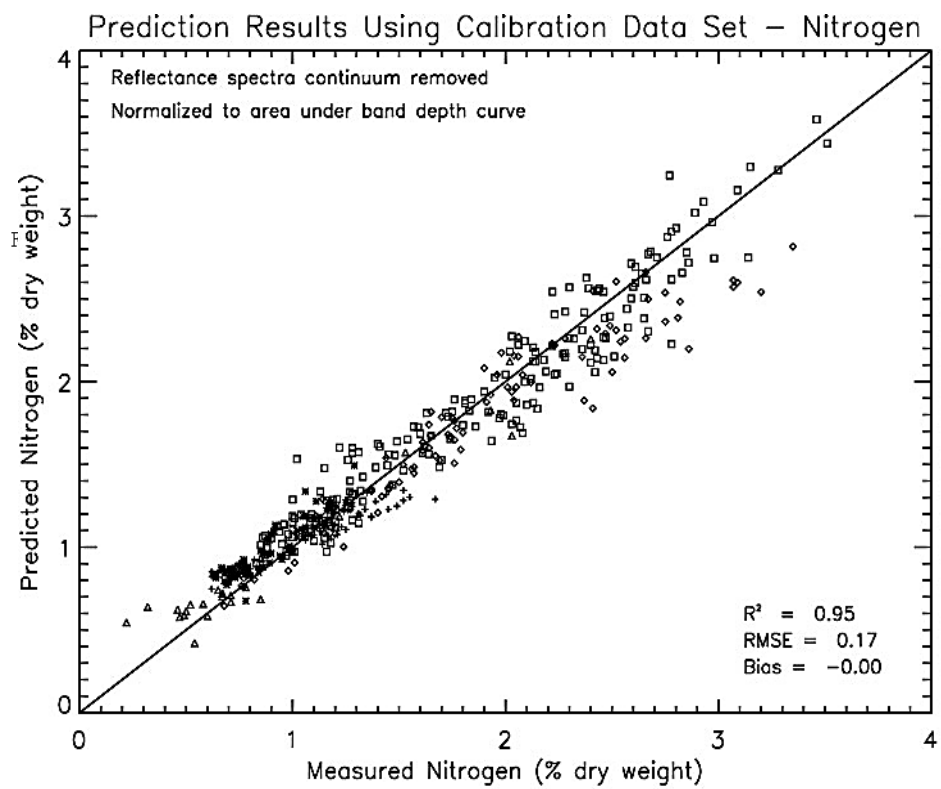
Kneubuhler , 2002

Methods For Hyperspectral Analysis

Acronyms		VSWIR Methods	Objective / Use	Required
1	ACORN	Atmospheric CORrection Now	radiometric calibration and atmospheric correction	Spectral Hypercubes
2	FLAASH	Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes	radiometric calibration and atmospheric correction	Spectral Hypercubes
3	SS&R	Spectral sensitivity & relationship to *in situ* measurements	knowledge of important spectral information	contiguous spectra
4	CR &FD	Continuum Removal & Feature Depth	analysis on specific absorption features	contiguous spectra
5	SI, P-VI	Physiological Vegetation Indexes (P-VI)	reduce the number of bands but retain the most important spectral information	Spectral Hypercubes, SS&R
6	MNF	Minimum noise fraction (two-stage PCA)	reduce wavelength specific noise and dimensionality of data	Spectral Hypercubes
7	SAM	Spectral Angle Mapper of spectral cubes	comparing spectra of image pixels to the spectra of reference endmembers	Spectral Hypercubes
8	SMA, SUM, MESMA	Spectral Mixture Analysis and Unmixing Methods	derive apparent fractional abundance of specific endmember in a pixel	a priori known endmembers (b-1)
9	MF	Matched Filters	maximizes target-to-background contrast	Spectral Hypercubes, known signatures to match
10	MTMF	Mixture Tuned Matched Filtering	combines the strength of MF with physical constraints imposed by mixing theory	Knowledge of the target species endmembers
11	MLc of MNF	Maximum Likelihood classification of MNF transformed images	species identification	MNF
12	MLc of P-VI	MLc of P_VI Images	identification of physiological state	Physiological Vegetation Index Images

Continuum Removal & Feature Depth Analysis

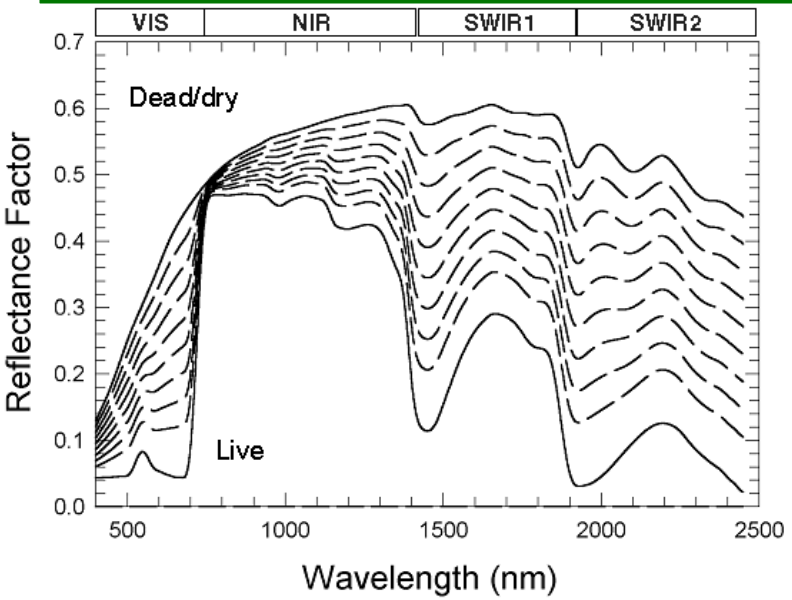


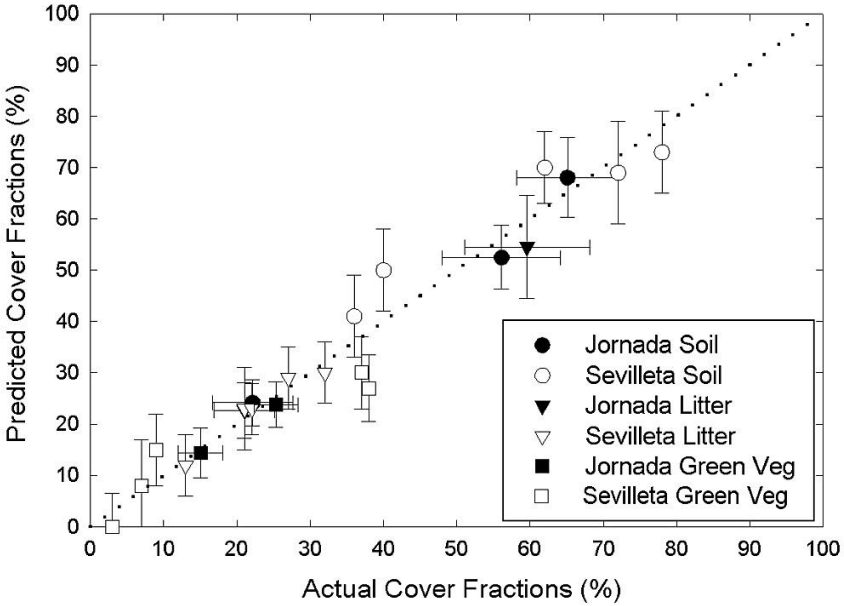


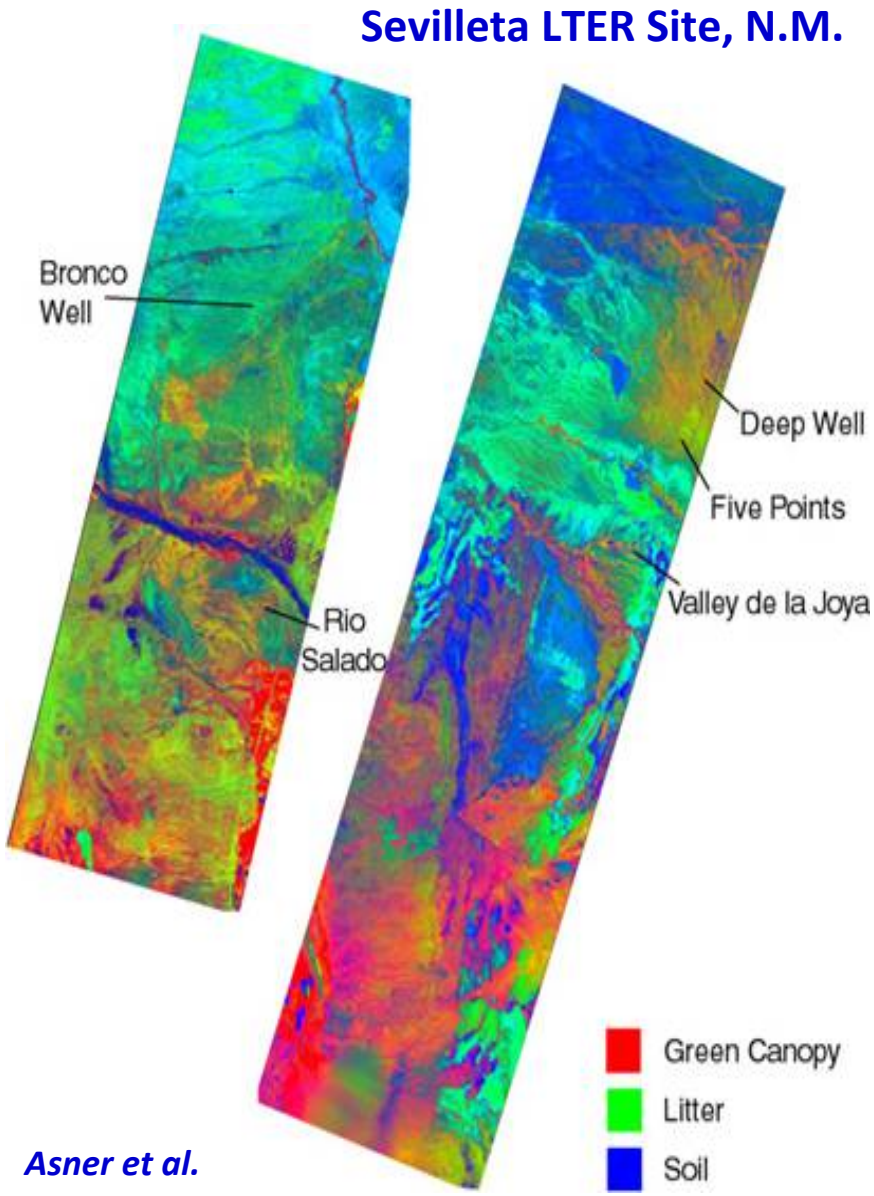
- *N determination*

Kokaly, REMOTE SENS. ENVIRON. 75:153–161 (2001)

Cover Fractions in Transition from Live/Green to Dry/Dead

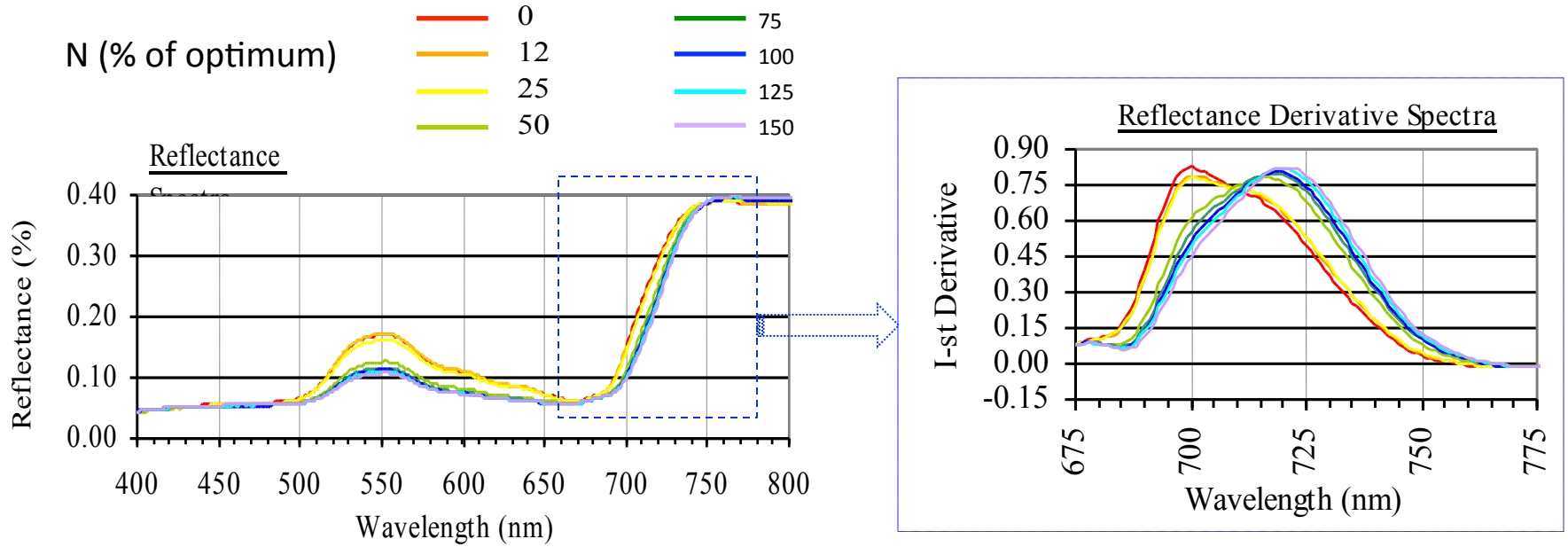






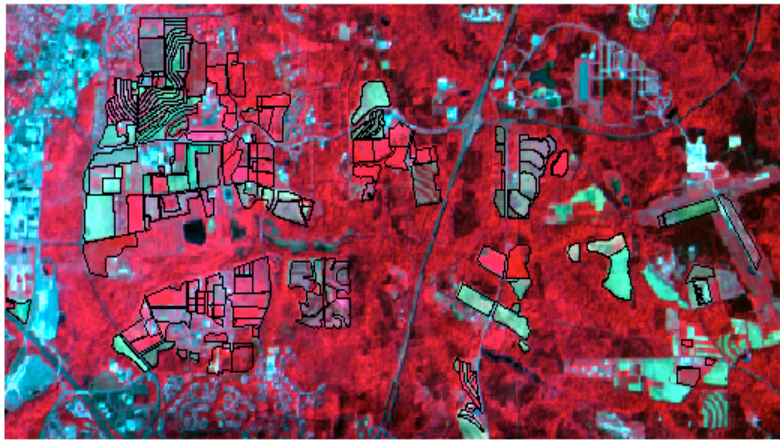
Asner et al.

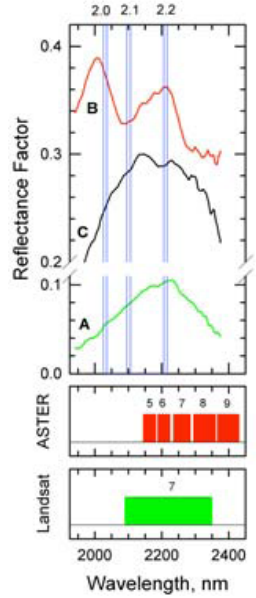
Reflectance and Derivative Analysis

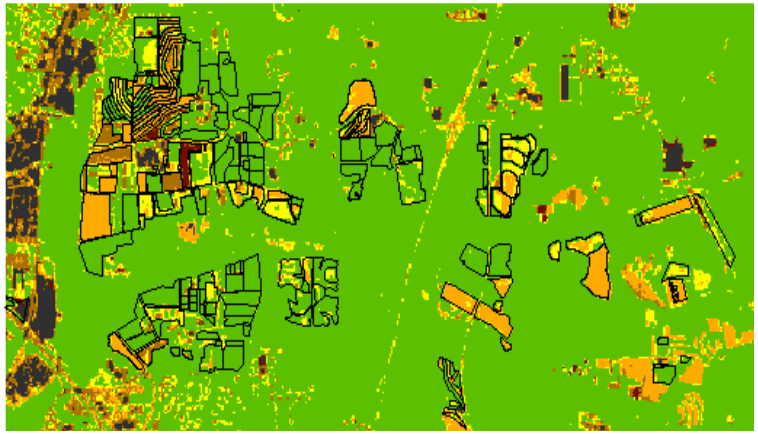


Vegetation Indices of function, structure and foliar chemistry

- **REIP** = wavelength (in nanometers) of the maximum slope **Dmax** of the reflectance spectrum at wavelengths between 690 and 740 nm; $D = (R_n - R_{n-1})/(w_n - w_{n-1})$; in the 690-740nm range
- Chlorophyll (Gitelson) = $(R_{NIR}/ R^{-1}_{720-730}) - 1$; Function, *PRI = (R531 - R570)/(R531 + R570); NDWI=(Rnir-R1240)/(Rnir+R1240), etc.*
- *TVDI = (Ts – Ts_min)/(a + bNDVI – Ts_min); WSVI=NDVI/Ts, where Ts is the brightness temperature at ~11 µm*



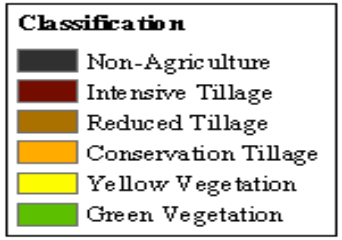




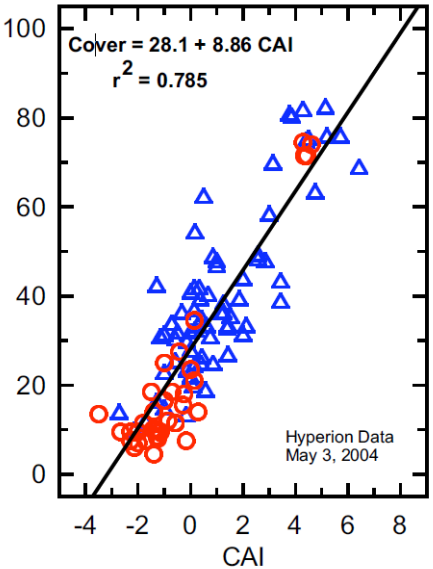
Color Infrared composite AVIRIS image with field boundaries.

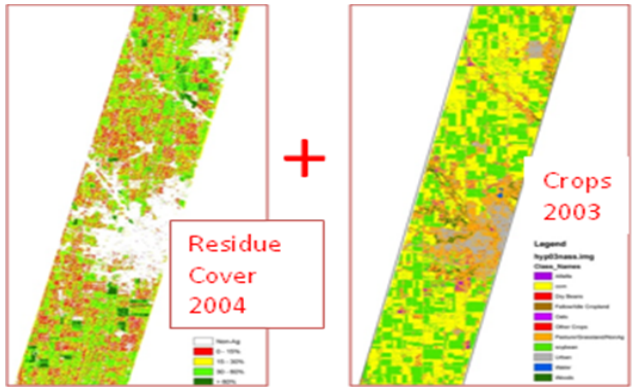
549 nm -- blue
646 nm – green
827 nm – red

Tillage intensity classification using CAI and NDVI (overall classification accuracy = 92%).



$$CAI = 0.5(R_{2000} + R_{2200}) - R_{2100}$$



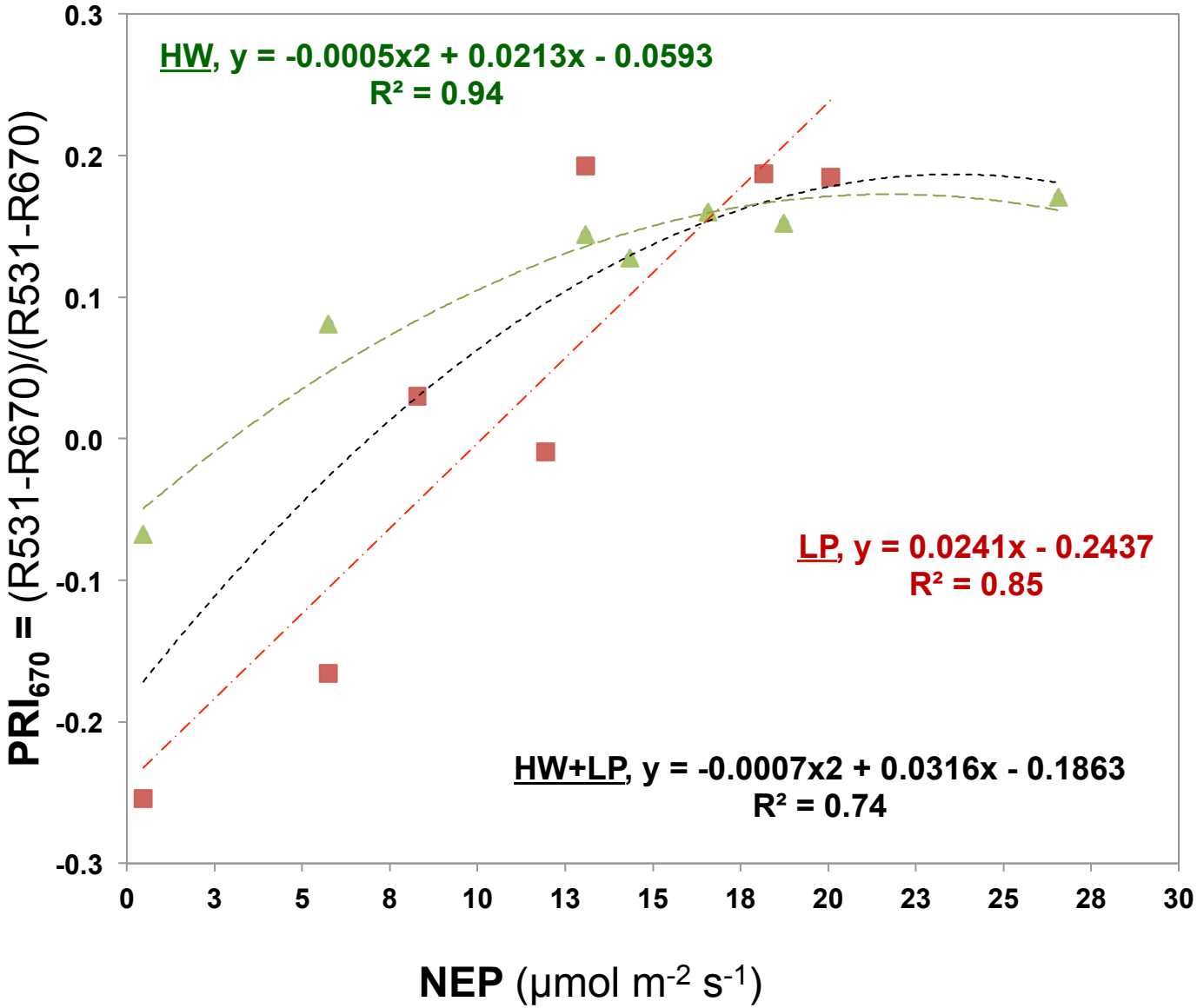


Crop Residue Cover vs. CAI for Hyperion Image Iowa – May 3, 2004

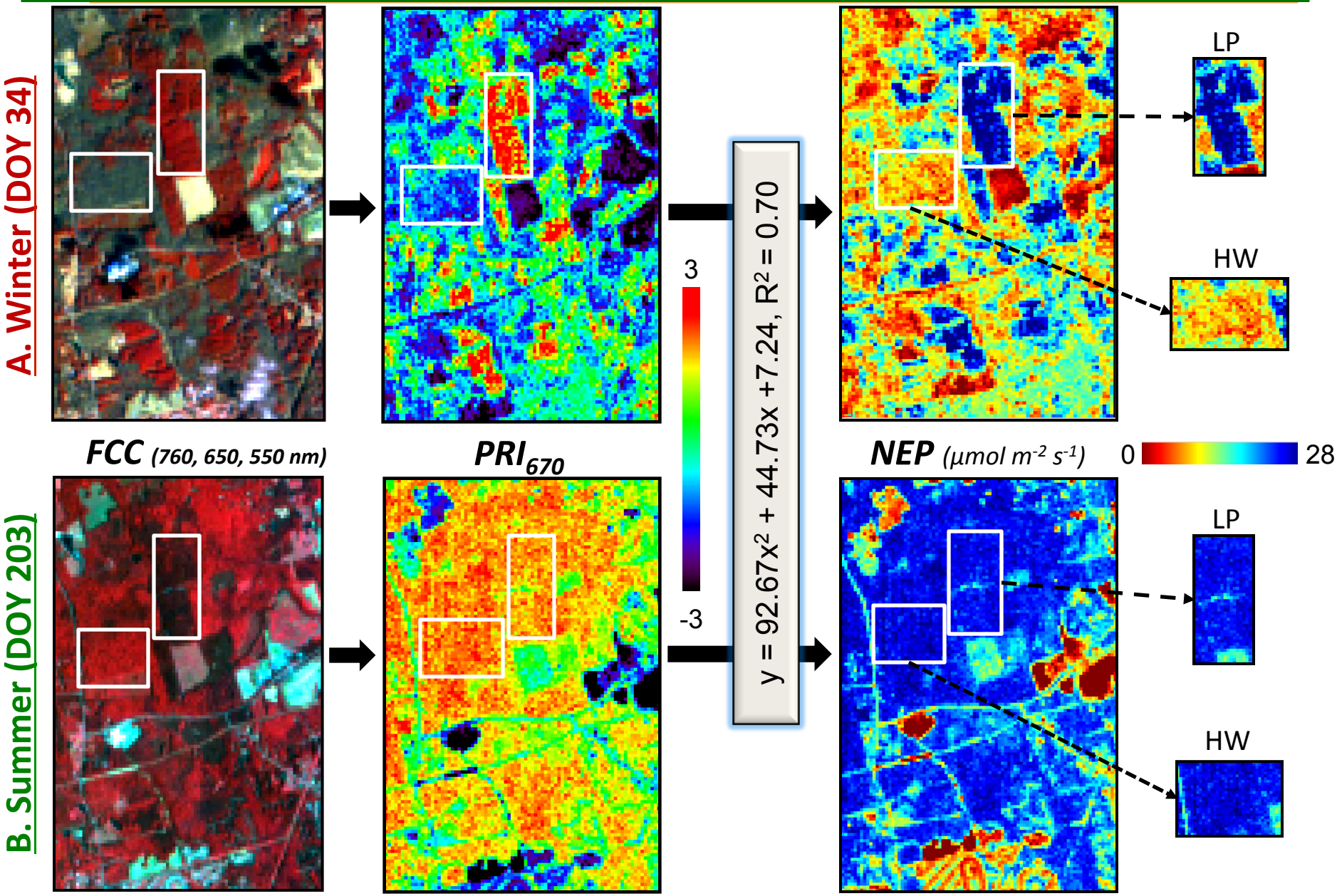
For dry and moist conditions CAI is adequate for assessing crop residue cover.

(Daughtry et al. 2001, 2006 and 2010)

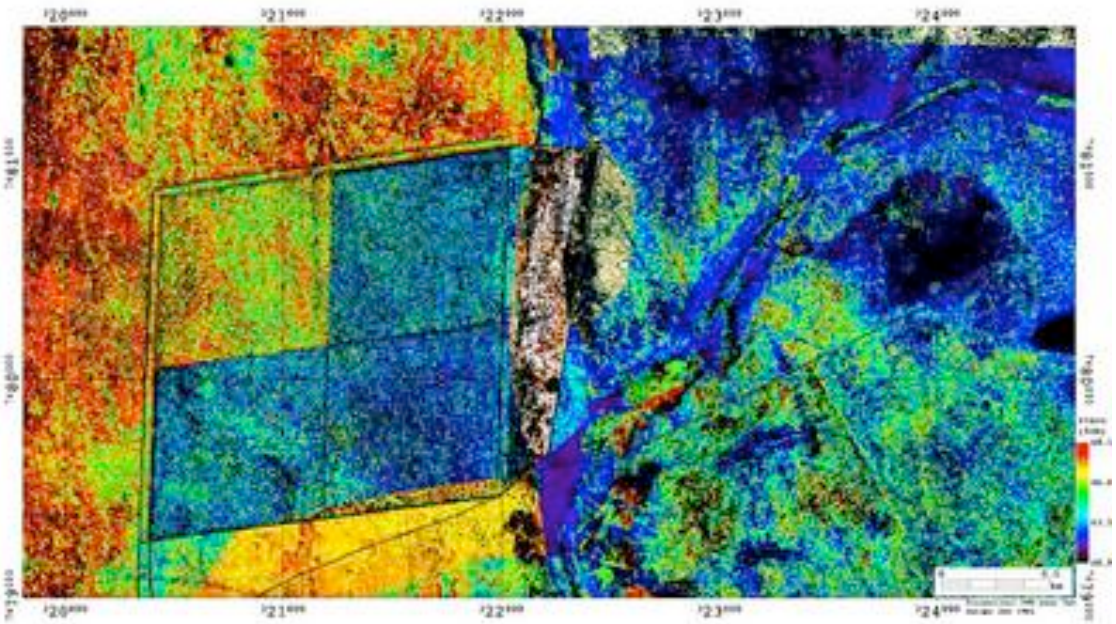
Bio-indicators of Photosynthetic Function



Duke Forest : PRI_{670} & NEP



Forage & Fiber Distribution in African Savanna



Airborne mapping of dry season forage and fiber distribution across the N'washitsumbe roan enclosure and surrounds on the Northern Plains of the Kruger National Park, South Africa.

Carnegie Airborne Observatory

Forage quality in African savannas can be described in terms of nutrients that are limiting (nitrogen and phosphorus) and constrain the rate at which herbivores take in fiber. These forage quality nutrients are particularly crucial in the African dry season when their concentrations decline.

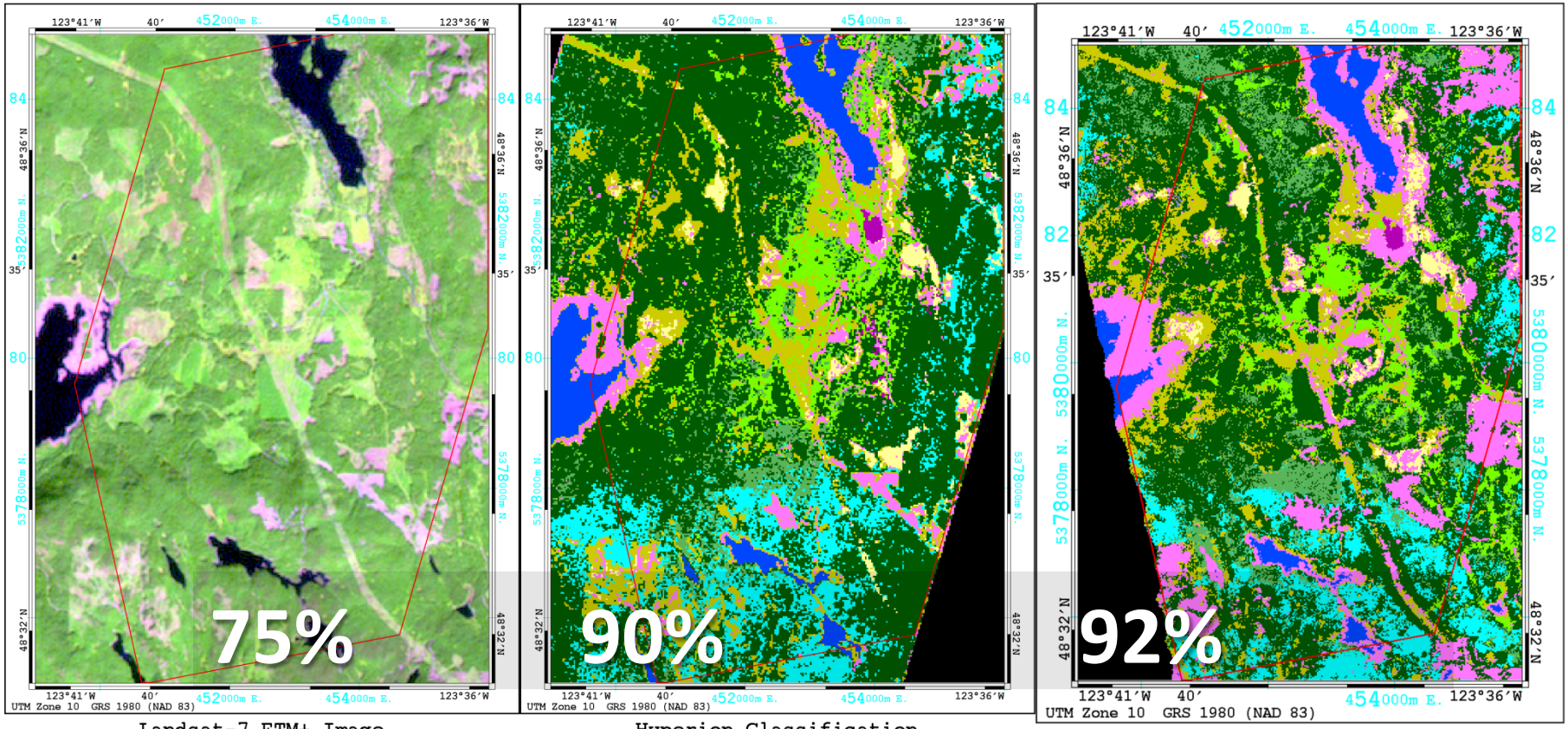
Using the Carnegie Airborne Observatory (CAO) Alpha sensor, in combination with ancillary data, researchers from ITC-University of Twente and the Carnegie Institution mapped **grass forage nutrients** in the early dry season within an African savanna.

Respectively, 65%, 57% and 41% of the variance in fiber, phosphorus and nitrogen concentrations could be explained.

In addition, for the first time, a landscape map of grassland fiber was created from CAO imagery.

Species Recognition

Landsat 7 | Hyperion | AVIRIS



Landsat-7 ETM+ Image
September 10, 2001

Hyperion Classification
September 10, 2001

AVIRIS MNF Classification
August 10, 2001

Kilometres 1 0 1 2 3
Miles 1 0 1 2

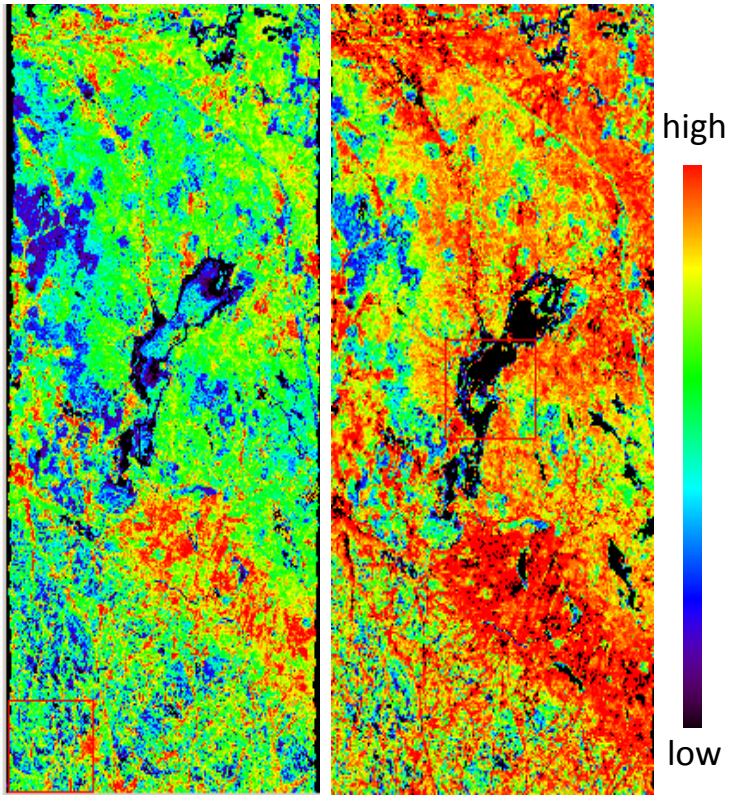
- Exposed land
- Water body
- Shrub, low
- Herb graminoids
- Swamp area
- Red alder, dominant
- Hemlock, dominant
- Lodgepole pine dominant
- Western redcedar
- Douglas-fir, dominant
- Unclassified

Pacific Forestry
Natural Resources Canada

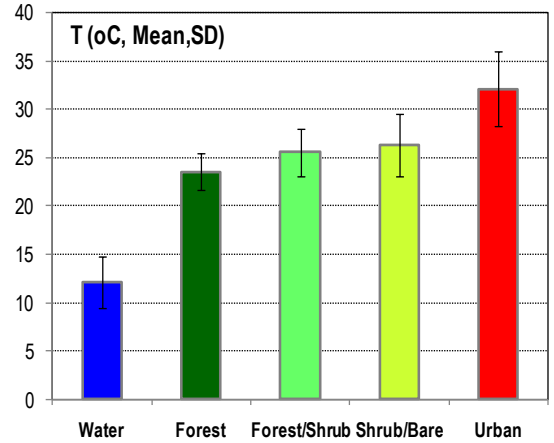
Goodenough et al. 2003

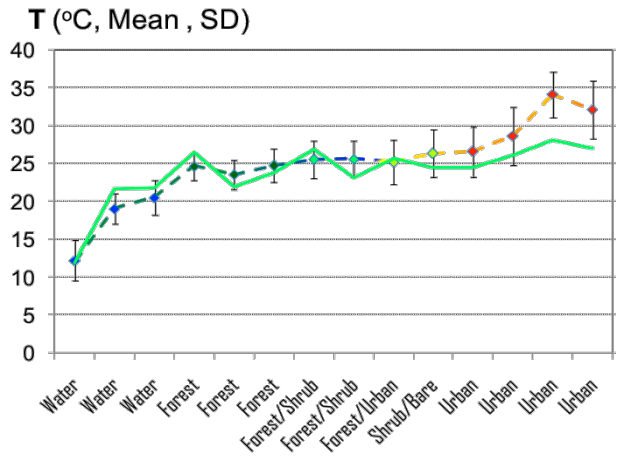
Reflectance & Temperature for Common Cover Types

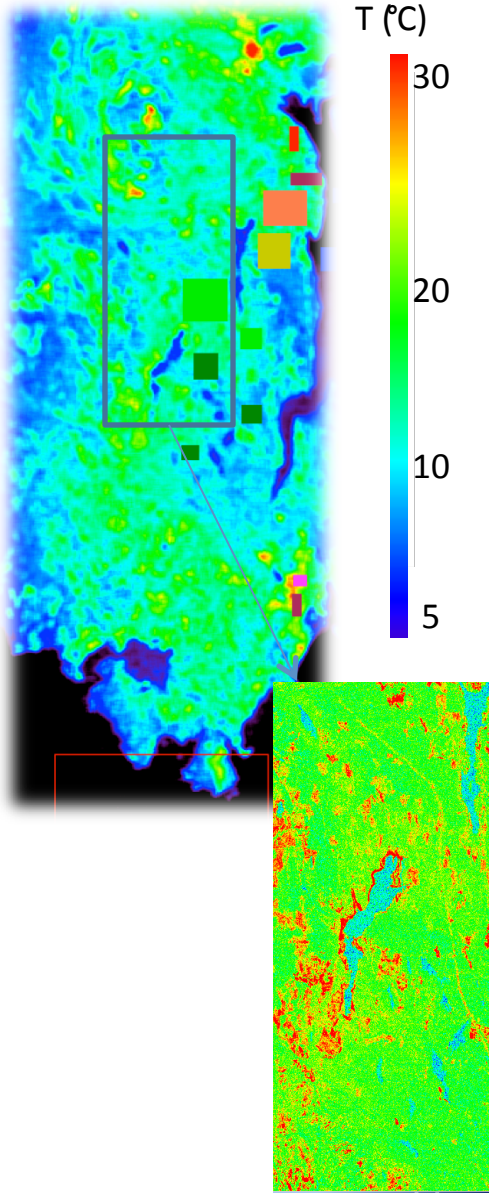
Indicators of plant function (60 m)



V1 - chlorophyll *Dmax - stress*

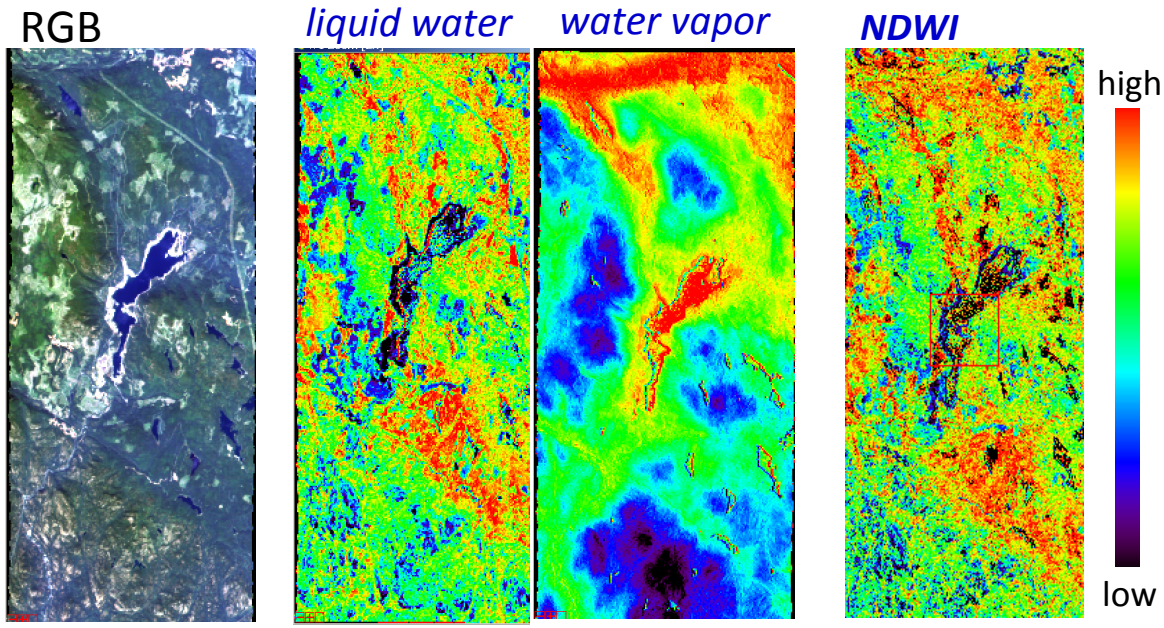


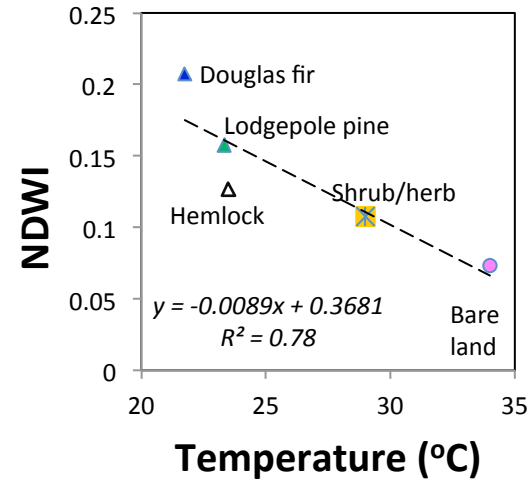


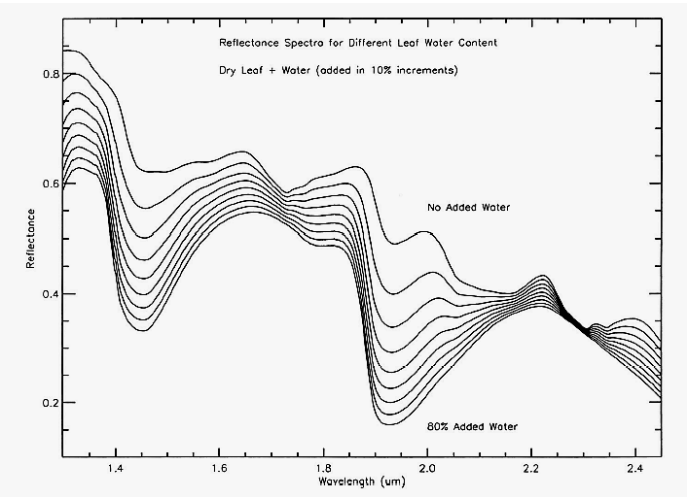


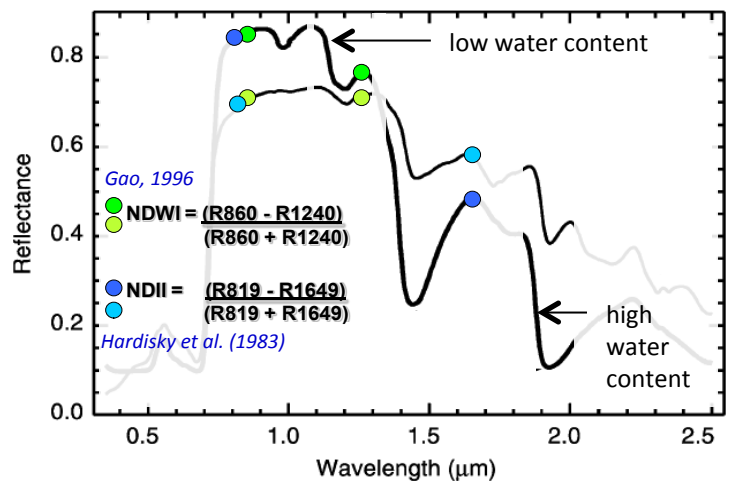
HyspIRI-like data provided range of indicators of plant function and showed temperature gradient of ~ 15° C between rural and urban areas in British Columbia.

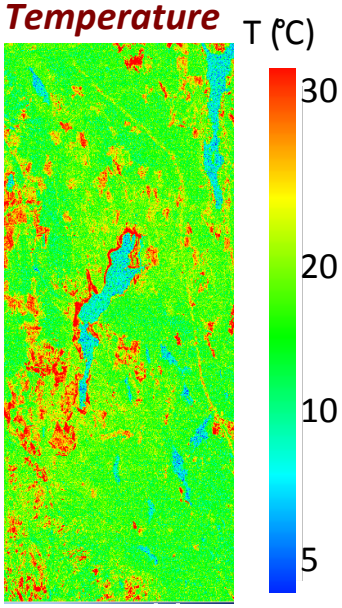
Canopy Moisture & Temperature



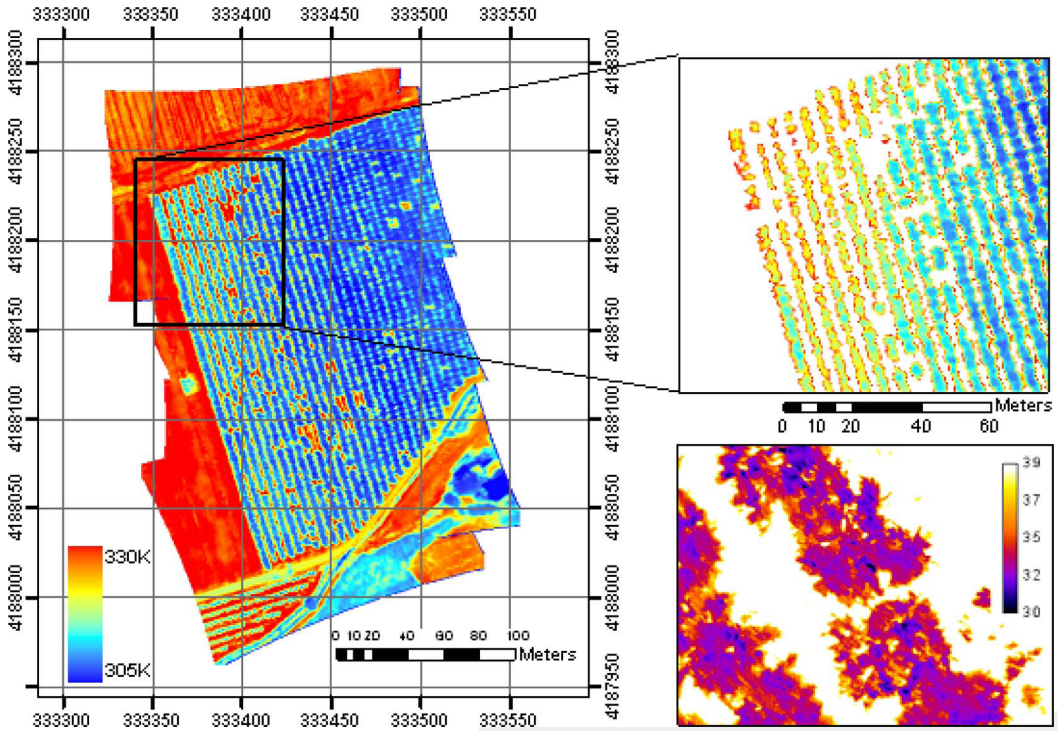




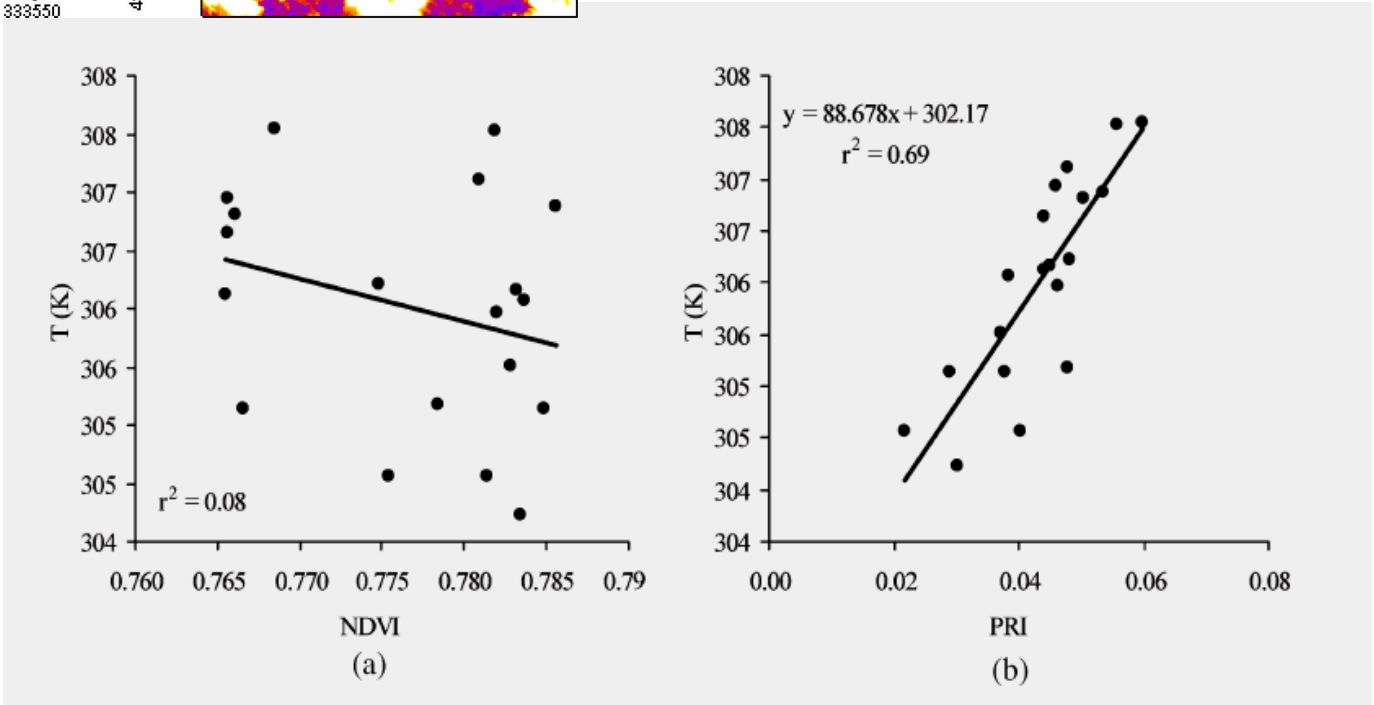




Kokaly and Clark, REMOTE SENS. ENVIRON. 67:267–287 (1999)



Canopy Structure, Function & Temperature



Zarco-Tejada et al. 2012

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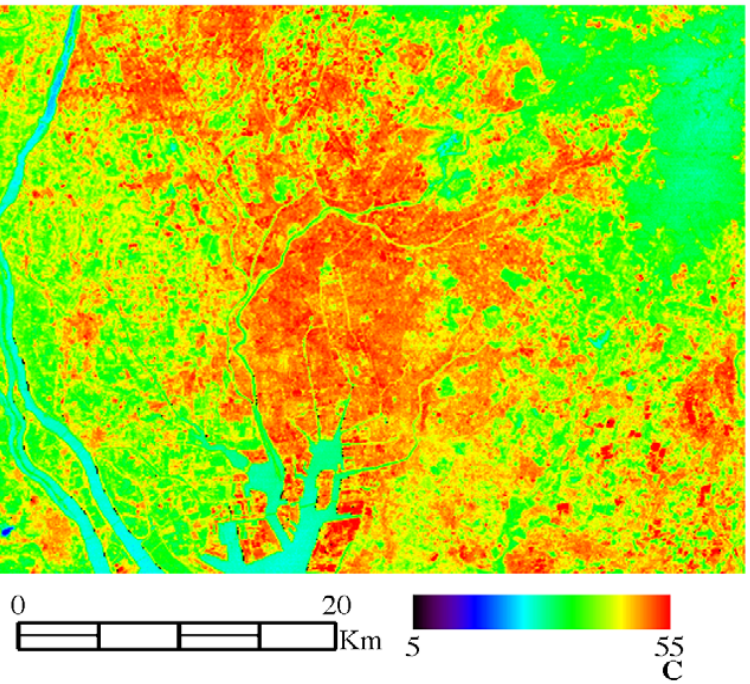
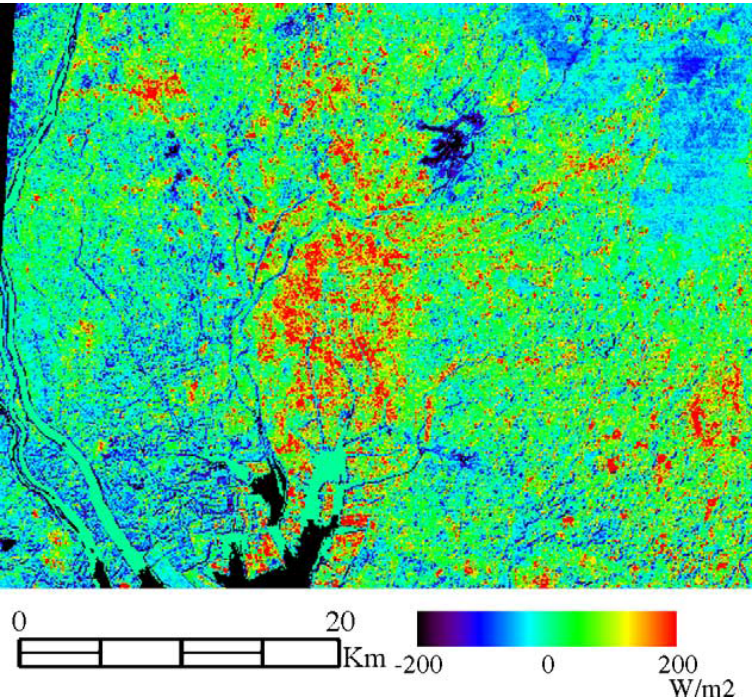
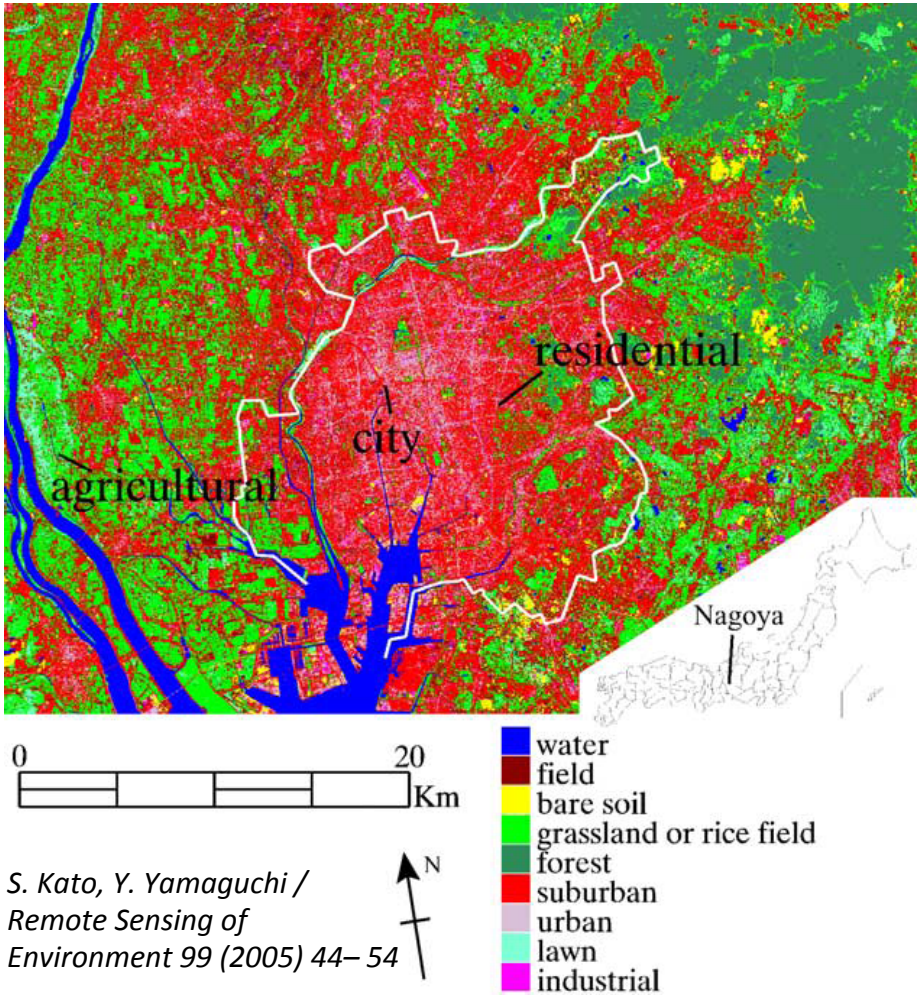




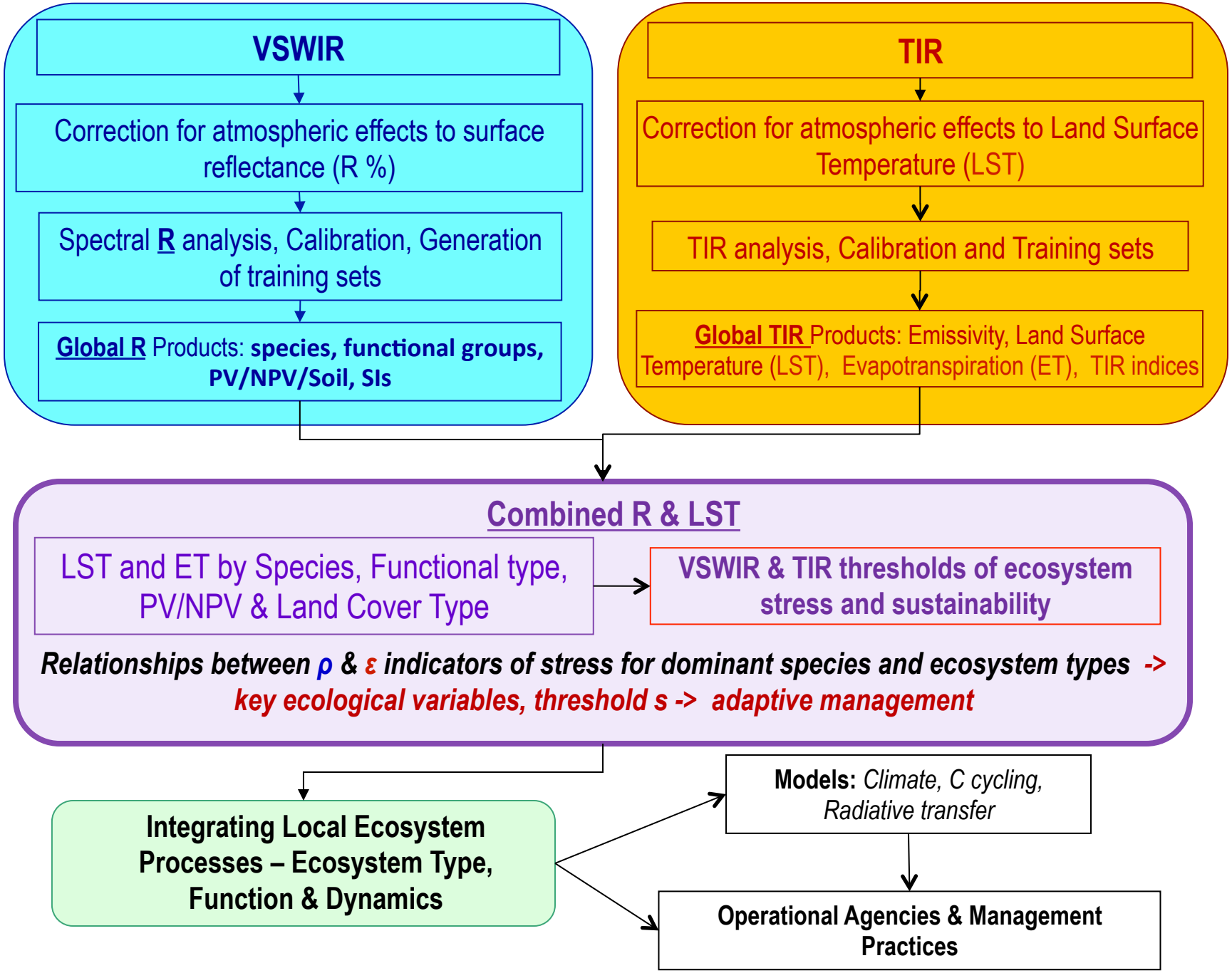
Surface temperature distribution for Nagoya, Japan on (a) July 10, 2000 1055 JST

Artificial (UHI) increase in sensible heat flux for Nagoya, Japan on July 10, 2000.

Kato et al. 2005



S. Kato, Y. Yamaguchi / Remote Sensing of Environment 99 (2005) 44– 54


VSWIR
Correction for atmospheric effects to surface reflectance (R %)
Spectral R analysis, Calibration, Generation of training sets
Global R Products: species, functional groups, PV/NPV/Soil, SIs
TIR
Correction for atmospheric effects to Land Surface Temperature (LST)
TIR analysis, Calibration and Training sets
Global TIR Products: Emissivity, Land Surface Temperature (LST), Evapotranspiration (ET), TIR indices
Combined R & LST
LST and ET by Species, Functional type, PV/NPV & Land Cover Type
VSWIR & TIR thresholds of ecosystem stress and sustainability
Relationships between ρ & ε indicators of stress for dominant species and ecosystem types -> key ecological variables, threshold s -> adaptive management
Integrating Local Ecosystem Processes – Ecosystem Type, Function & Dynamics
Models: Climate, C cycling, Radiative transfer
Operational Agencies & Management Practices

LPV Focu					SWIR / TIR
LAND CO					
Fractional					
Disturban					
SURFACE					
Surface R					
Surface A					
BIOPHYS					
Gross / Ne					
fPAR					
LAI					
Water con					
FIRE					
Detection					
Fire fuel lo					
LAND SU					
LST					
Emissivity					
Evapotranspiration					

Existing Val Methods

Research Required

J. Nightingale, 2011

HyspIRI Products for LPV

LPV Focus Group / Product	VSWIR L 2/ 3	VSWIR L4	VSWIR Global	TIR L4	SWIR / TIR
LAND COVER					
Fractional land cover / veg. cover					
Disturbance, PFT, hazard susceptibility					
SURFACE RADIATION					
Surface Reflectance					
Surface Albedo					
BIOPHYSICAL					
Gross / Net Primary Production					
fPAR					
LAI					
Water content, LUE, Pigments					
FIRE					
Detection of Fire events					
Fire fuel loads					
LAND SURFACE TEMPERATURE					
LST					
Emissivity					
Evapotranspiration					

Existing Val Methods | Research Required

J. Nightingale, 2011

Summary

Existing:

1) Many approaches / tools / applications
2) Local to regional studies & pilot projects
3) Application demand for new ecosystem products

Needed:

1) To determine their sensitivity and application extend of the existing approaches we need large scale VSWIR/TIR data-sets for variety of ecosystems
2) Calibrated spectral products (establish a network producing *in-situ* bio-physical measurements)
3) Establish seasonal VSWIR/TIR relationships for major species, functional groups, etc.
4) Long term VSWIR/TIR spectral time series to reveal normal & divergent ecosystem patterns

HyspIRI Ecosystem Products

1. Seamless global bi-directional reflectance, surface emissivity and temperature products

2. Global discrimination of species through phenology

3. Sub-pixel fractions of functional groups, species, photosynthetic & non-photosynthetic vegetation and bare soil, incl. detection thresholds

4. Seamless VSWIR suites of established stress indices (SI) - Estimations of bio-physical variables

5. Temperature and emissivity estimates by vegetation components (species, functional groups)

6. Feedbacks between changes in canopy composition and canopy temperatures –

7. Complementary T, ET and VSWIR spectral indictors as measures of function, phenology and water use

HyspIRI Ecosystem Science Questions

- *Vq1. What is the global spatial pattern of ecosystem and diversity distributions and how do ecosystems differ in their composition or biodiversity?*
- *Vq2. What are the seasonal expressions and cycles for terrestrial and aquatic ecosystems, functional groups, and diagnostic species? How are these being altered by changes in climate, land use, and disturbance?*
- *Vq3. 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?*
- *Vq5. How do changes in ecosystem composition and function affect human health, resource use, and resource management?*

- *Cq1. How do Inland, Coastal, And Open Ocean Aquatic Ecosystems Change Due To Local and Regional Thermal Climate, Land-Use Change, And Other Factors?*
- *Cq4. How do species, functional type, and biodiversity composition within ecosystems influence the energy, water and biogeochemical cycles under varying climatic conditions?*