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

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GEOL 5240
REMOTE SENSING DATA ANALYSIS
Spring 1993

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This course is designed as a follow-on to GEOLOGY/GEOGRAPHY 4093/5093 and, as such, will assume a familiarity with remote sensing concepts. Refer to the 4093/5093 text, *Remote Sensing Principles and Interpretation* by F.F. Sabins, Jr., or "*Introduction to the Physics and Techniques of Remote Sensing*"' by Charles Elachi for background.

The text is: *Remote Sensing Digital Image Analysis* by John A. Richards with supplemental reading to be assigned. The purpose of this course is to make the student familiar with information extraction from digital images taken from aircraft and spacecraft platforms. The technique is digital image processing, but beyond the technique, the student should develop an understanding of what kind of information can be extracted and, most importantly, what the limitations are.

The lectures will stress fundamentals, the basis for the image analysis software, and the labs are centered on hands-on use of the computers in the Center of the Study of Earth from Space (CSES). This year we are moving the class computing from canned software packages to a more flexible system based on IDL, a high-level image processing language. This will allow the more adventurous students to write their own routines without having to be C Language buffs. There is no requirement in this course to write software. We also have several commercial software packages available for those interested.

The labs have been rewritten and may contain bugs. Bear with us as we work them out. IBM 6000 workstations will be available on campus in CIRES room 236 and

Excellent job, well written
With more time and some field checking this could be a publishable paper. Not much has been done with DCPA because it is not well known.
100
90

Determination of Soil Types and Delineation of Soil Boundaries in Areas with Significant Vegetation Cover Using Landsat TM Multispectral Remote Sensing Data and Directed Principal Component Analysis

*With **more time** and **field checking** this **could** be a publishable paper.*

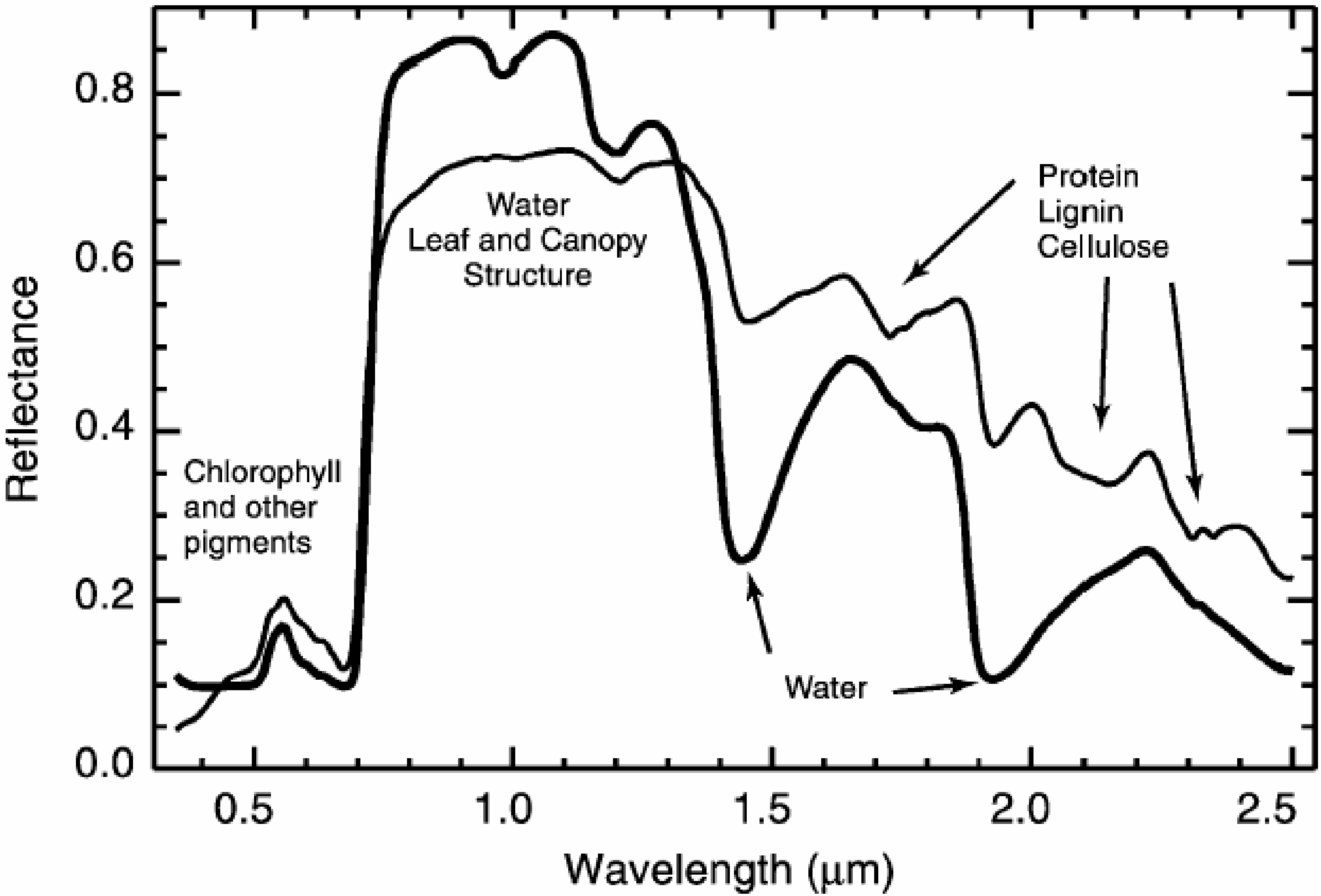
Spring 1993

Trends in Quantifying non-pigment leaf biochemistry

- Greater understanding of lab, field and remote sensing level spectra in relation to biochemical composition
- Increased use of full spectrum or specific biochemical absorption features to characterize vegetation
- Greater application of imaging spectroscopy to understand ecosystem processes

Understanding vegetation spectra in relation to biochemical composition

- Water
- Nitrogen (in chlorophylls and proteins)
- Lignin and Cellulose
- Non-Photosynthetic Vegetation

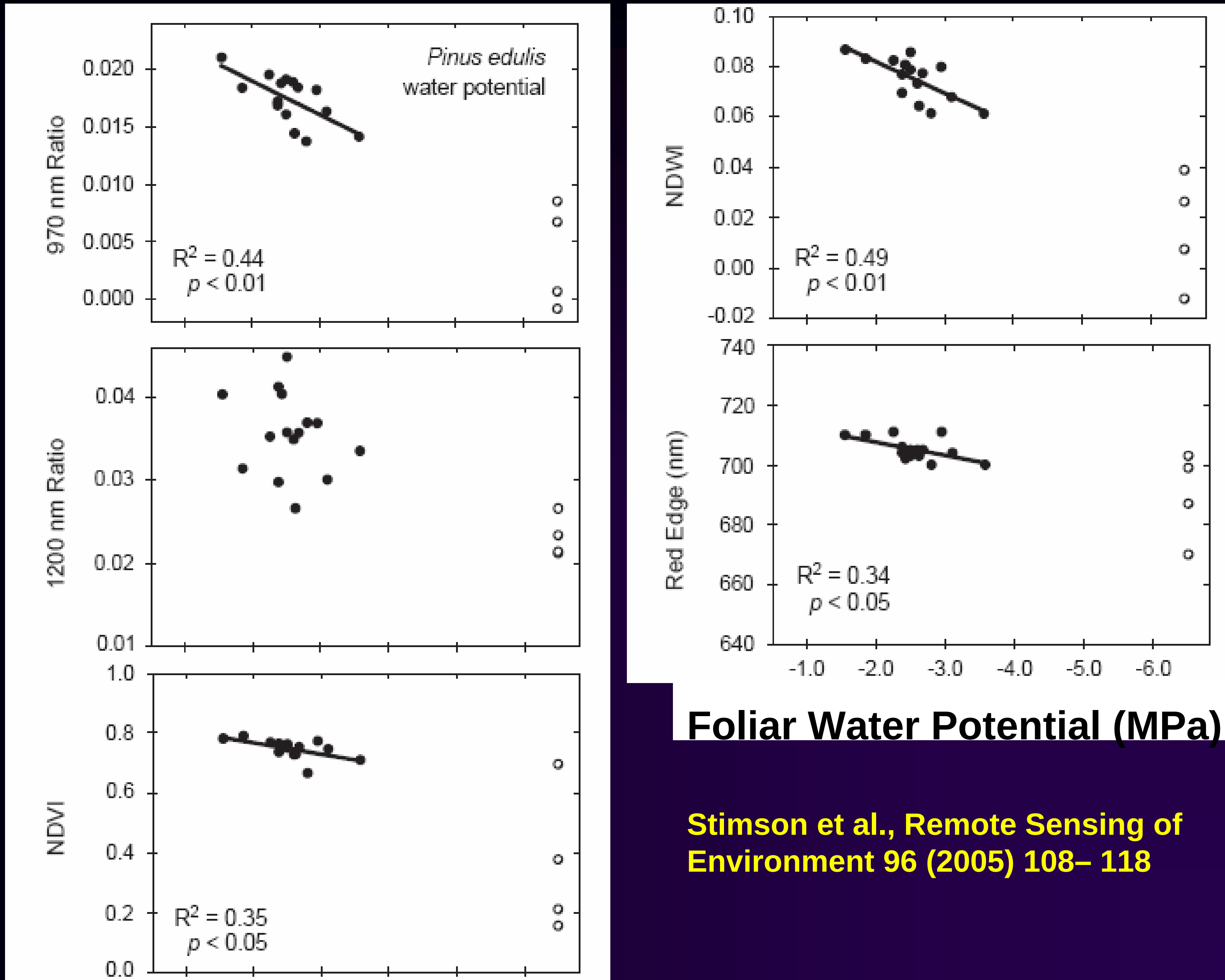


Reflectance
0.8
0.6
0.4
0.2
0.0
Water
Leaf and Canopy
Structure
Protein
Lignin
Cellulose
Chlorophyll
and other
pigments
Water
0.5
1.0
1.5
2.0
2.5
Wavelength (μm)

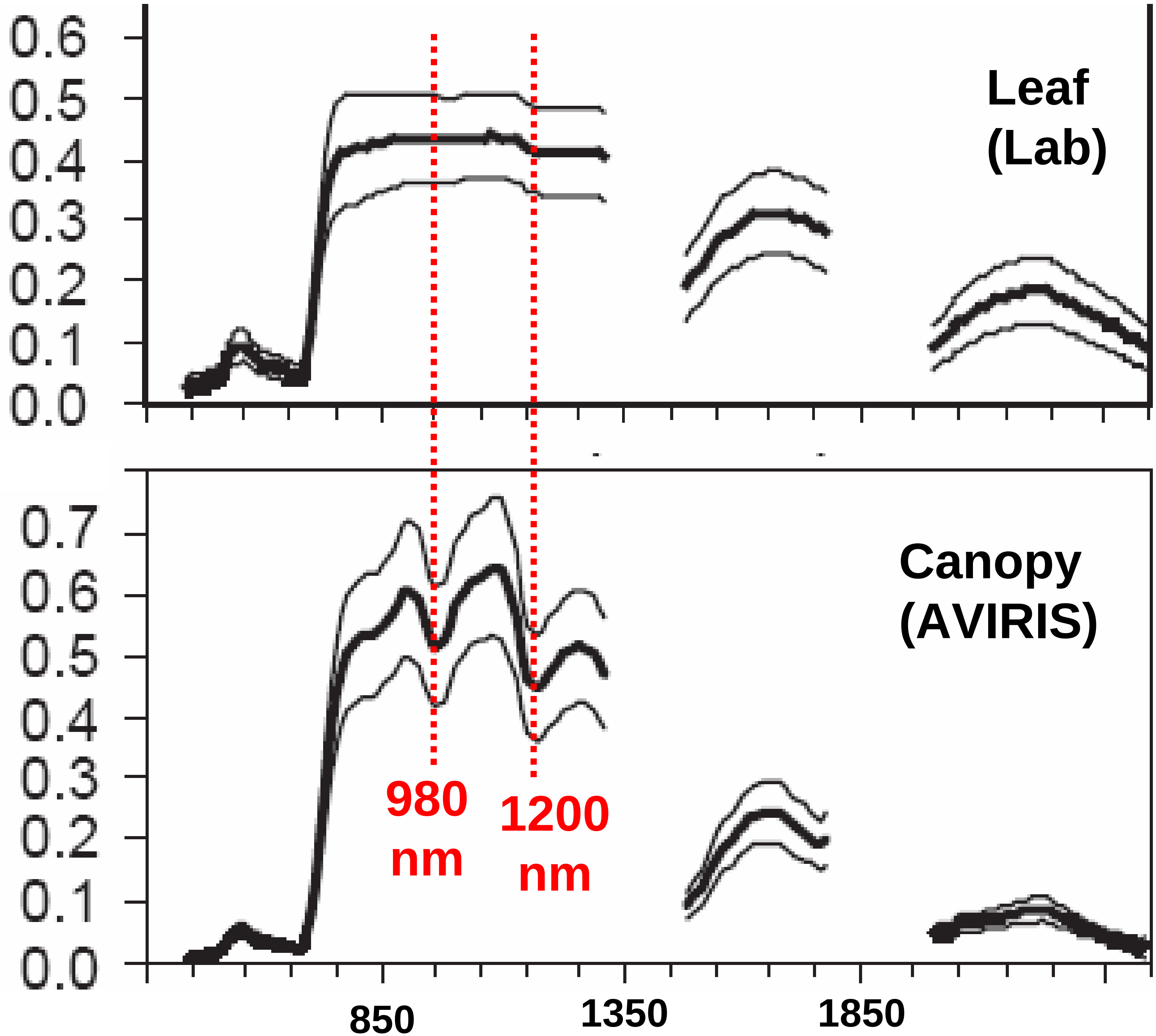
Water

Spectroscopic Estimates of Leaf/Canopy Water

- Leaf/Canopy Liquid Water Thickness
  - Gao & Goetz, 1994
- Canopy Equivalent Water Thickness
  - Green et al., 1991 & Roberts et al. 1997
- Canopy Relative Water Content
  - Serrano et al. 2000
- Foliar Water Potential
  - Stimson et al. 2005



Stimson et al., Remote Sensing of Environment 96 (2005) 108– 118



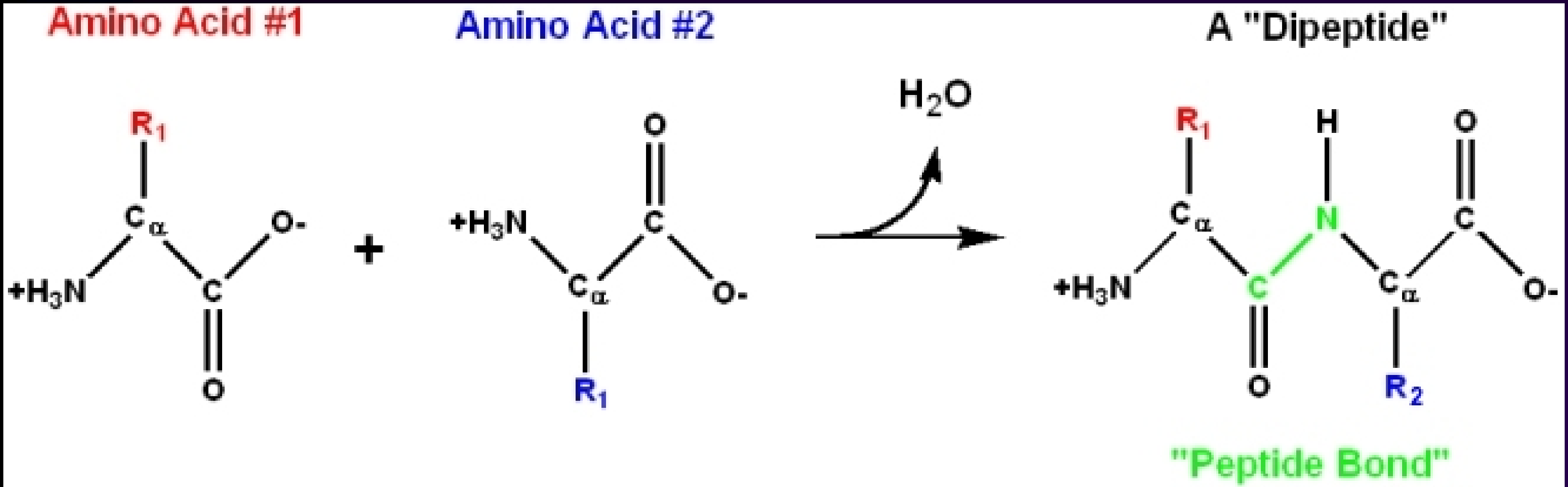
Clark et al., Remote Sensing of Environment 96 (2005) 375 – 398

Nitrogen

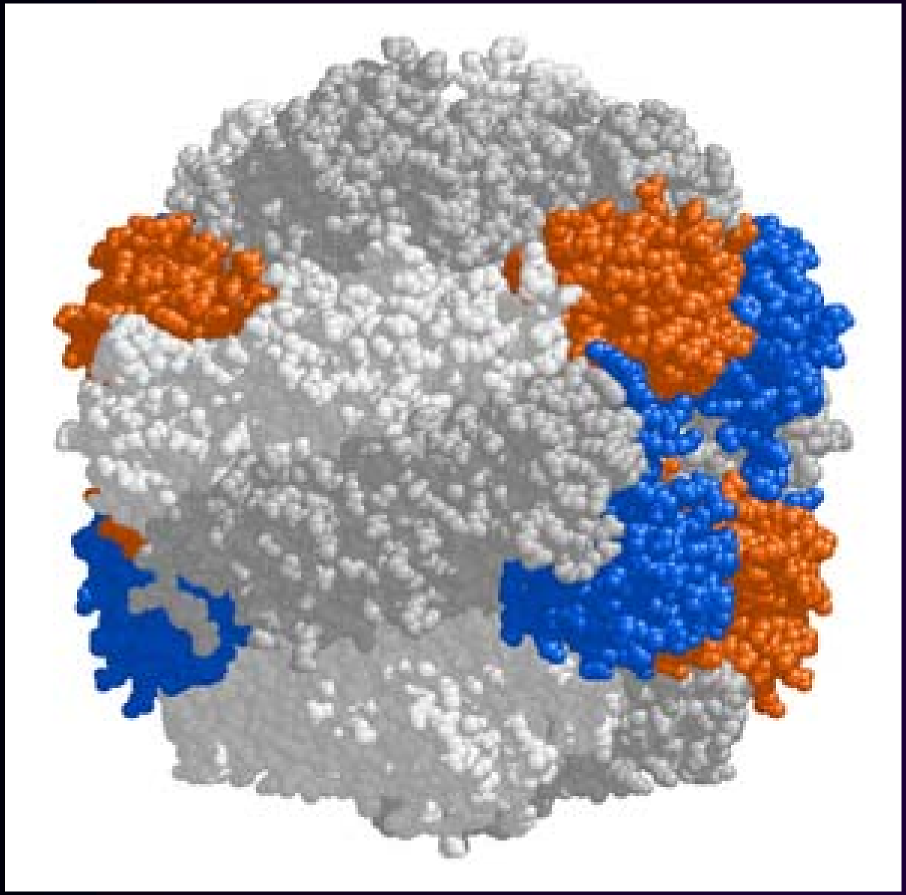
- By dry weight, very low abundance in leaves, only 0.5 to 4%
- Present in important biochemical constituents of plants
  - Chlorophyll
  - Protein
- Linked by field studies to rates of ecosystem functioning (carbon fixation) and widely used in ecosystem models

Nitrogen in Proteins

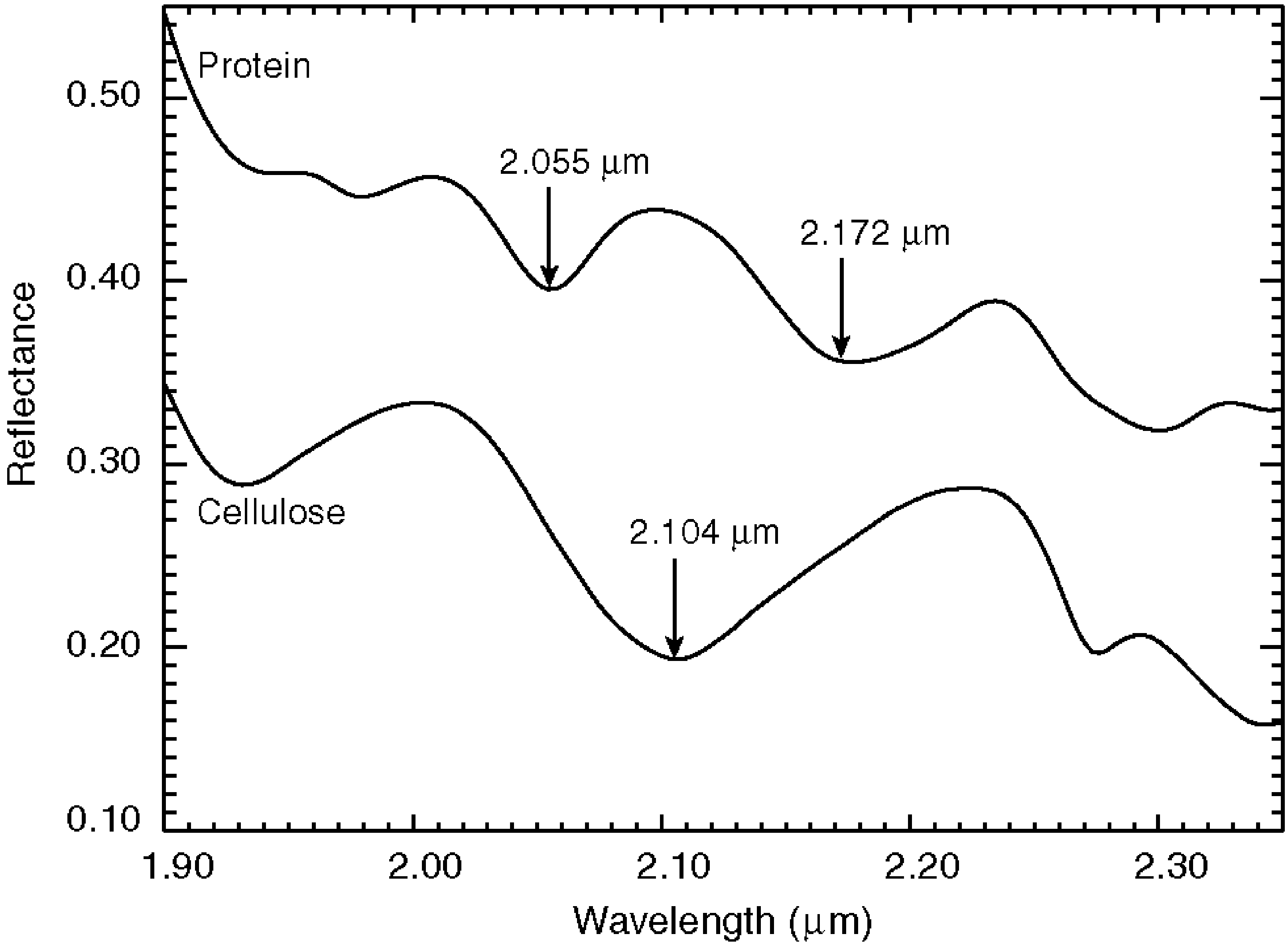
- Proteins composed of amino acids ranging from a 100 to 100,000 in number



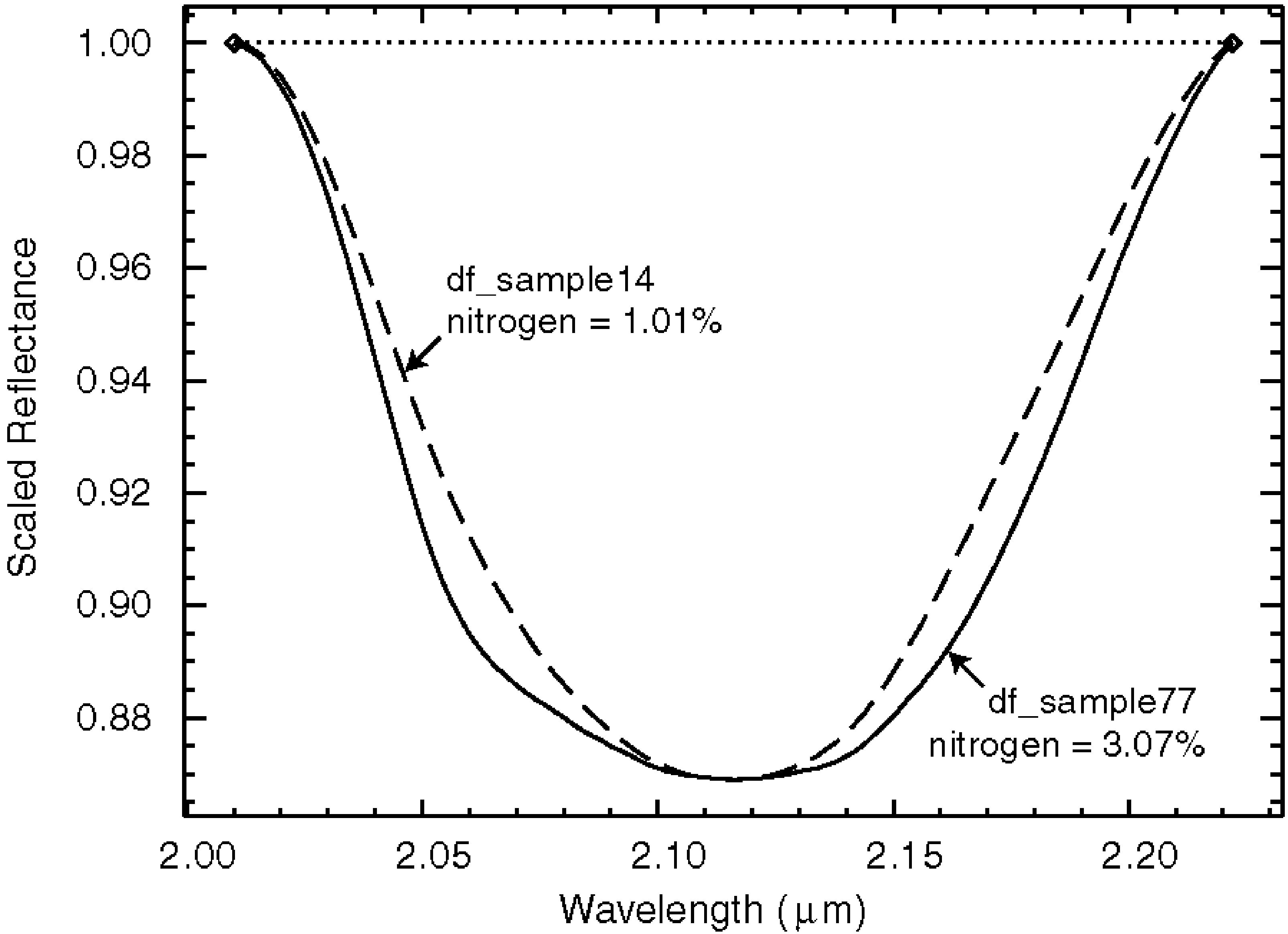
RuBisCO



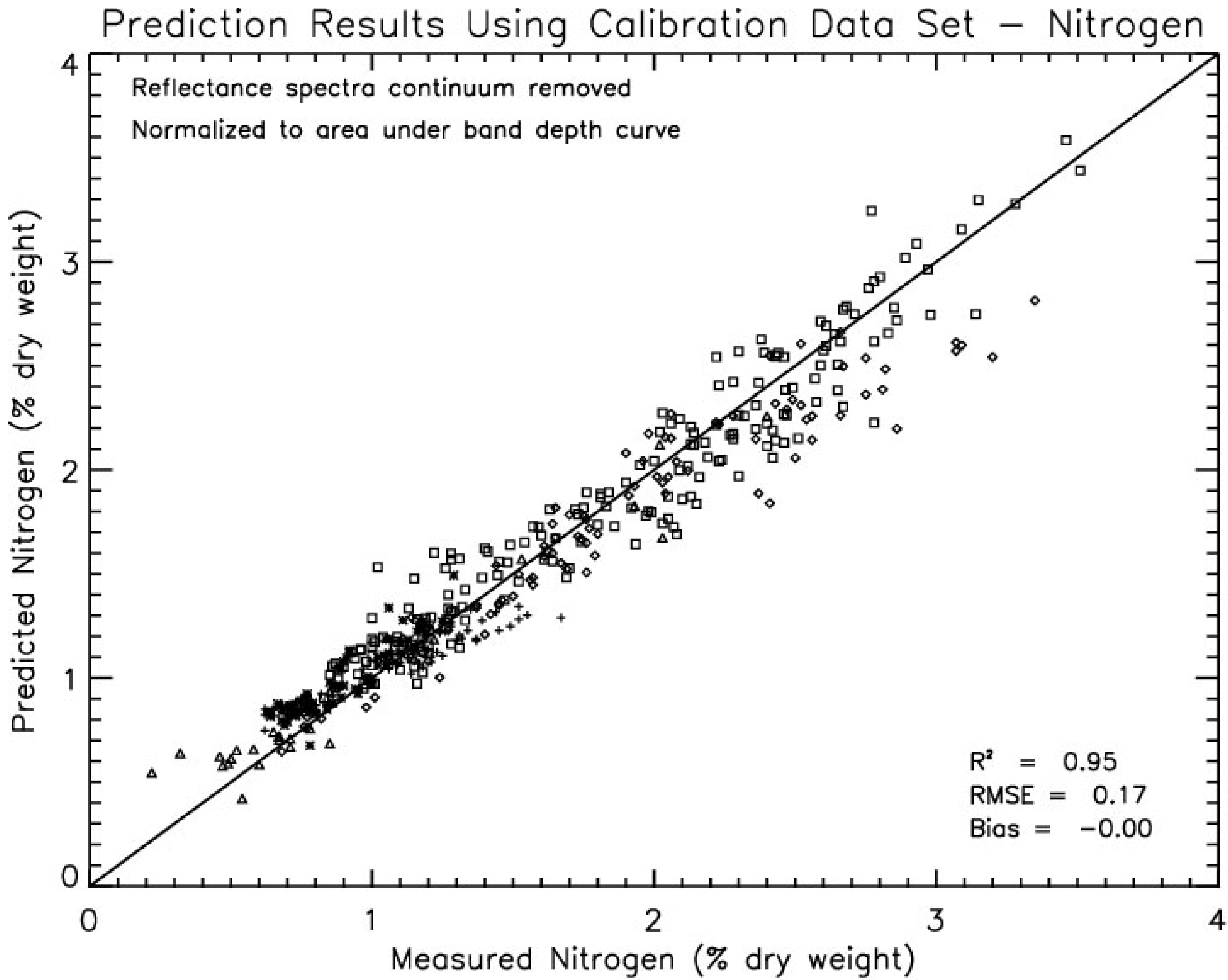
- **Ribulose-1,5-bisphosphate carboxylase/oxygenase**, catalyzes the first major step of carbon fixation
- RuBisCO is the most abundant protein in leaves (maybe the most abundant on Earth).



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

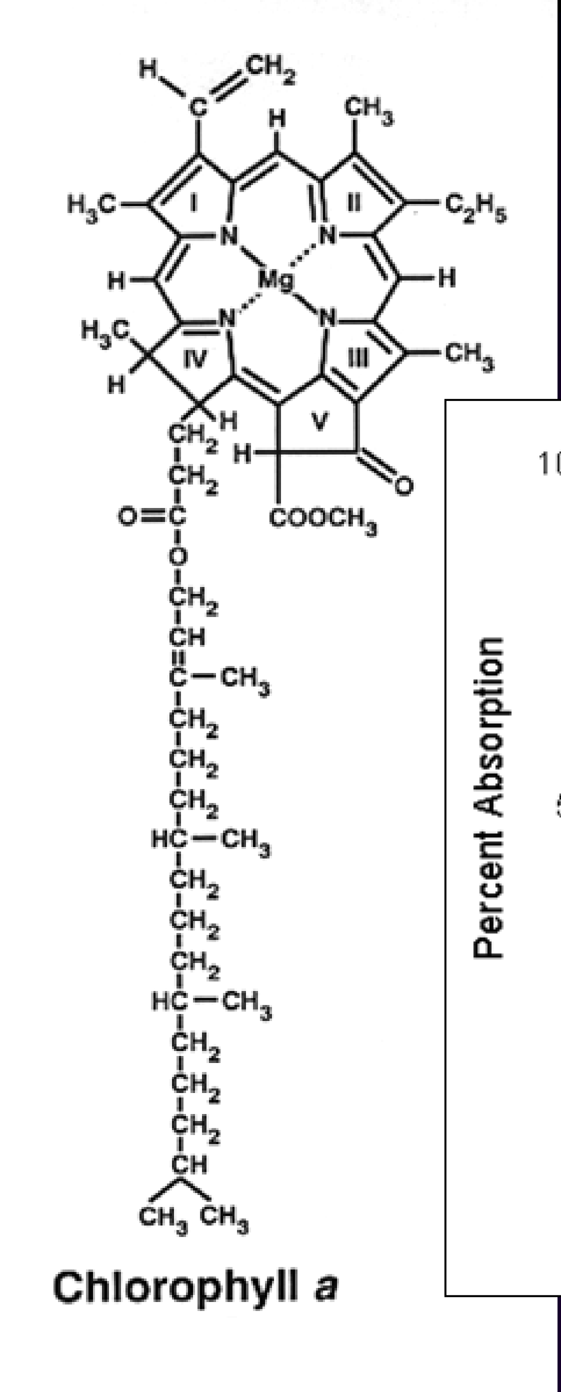


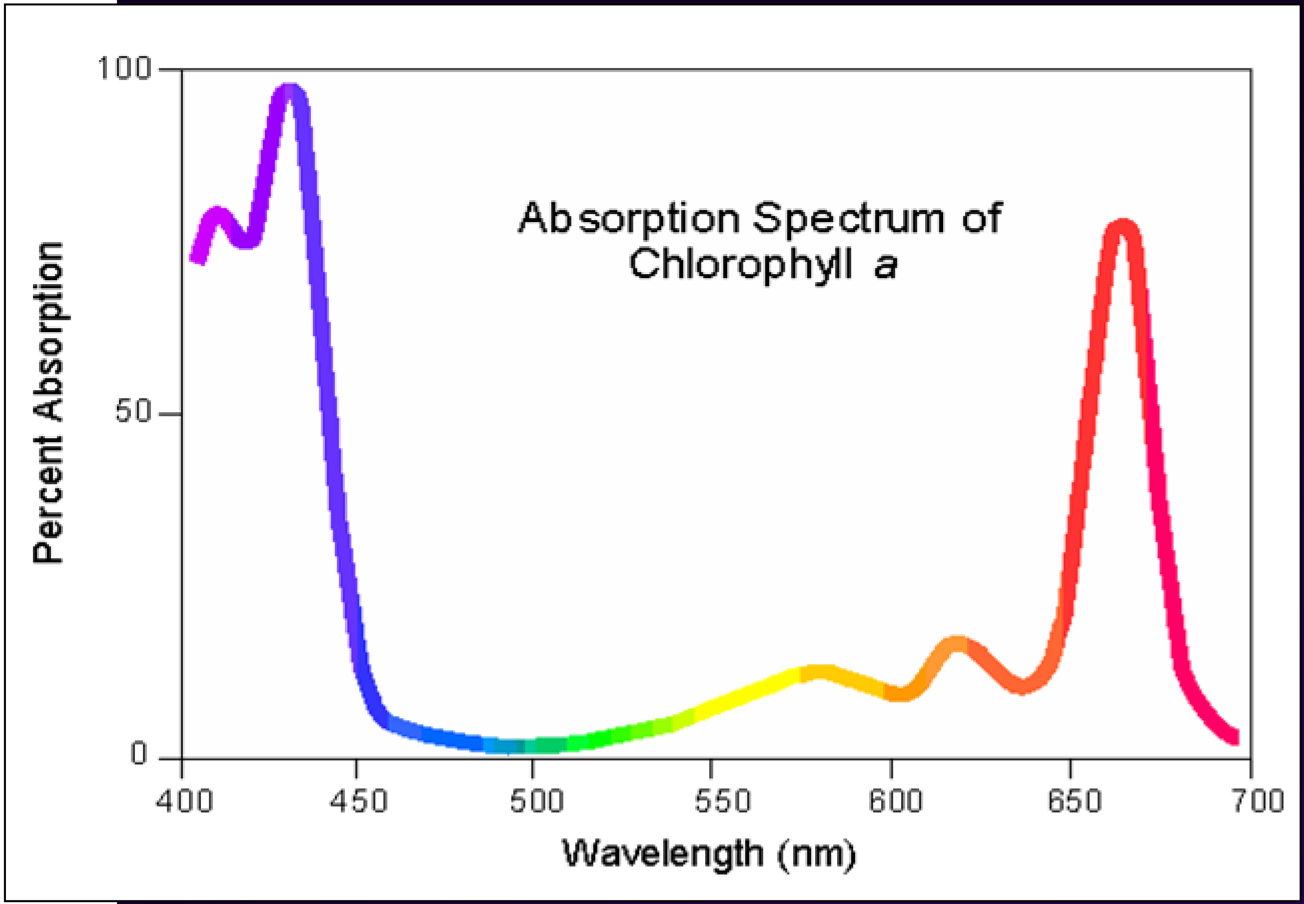
Kokaly, REMOTE SENS. ENVIRON. 75:153–161 (2001)

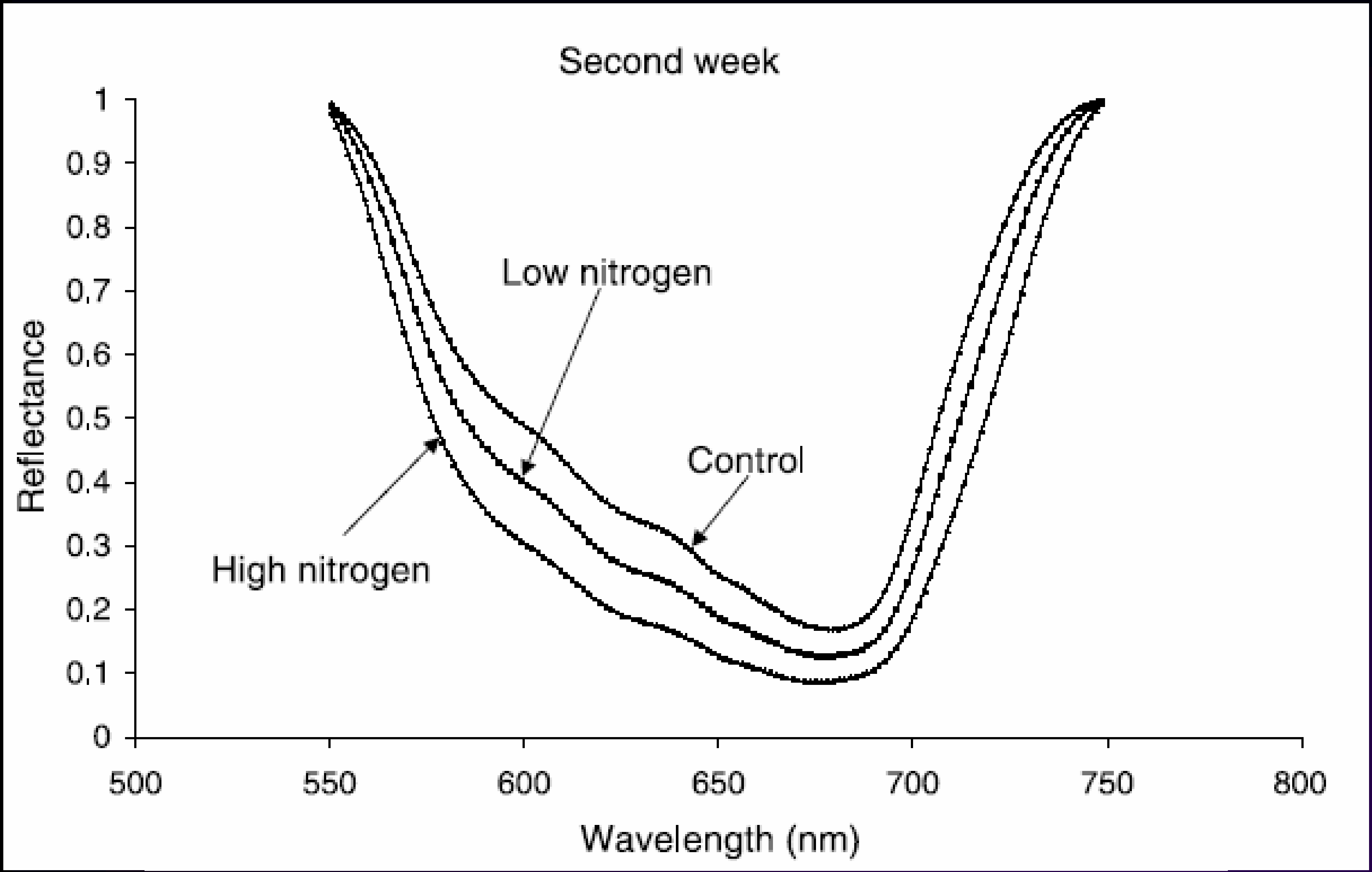


Kokaly and Clark, REMOTE SENS. ENVIRON. 67:267–287 (1999)

Nitrogen in Chlorophyll







Mutanga et al., Remote Sensing of Environment 96 (2005) 108– 118

Biochemical Components of Plants

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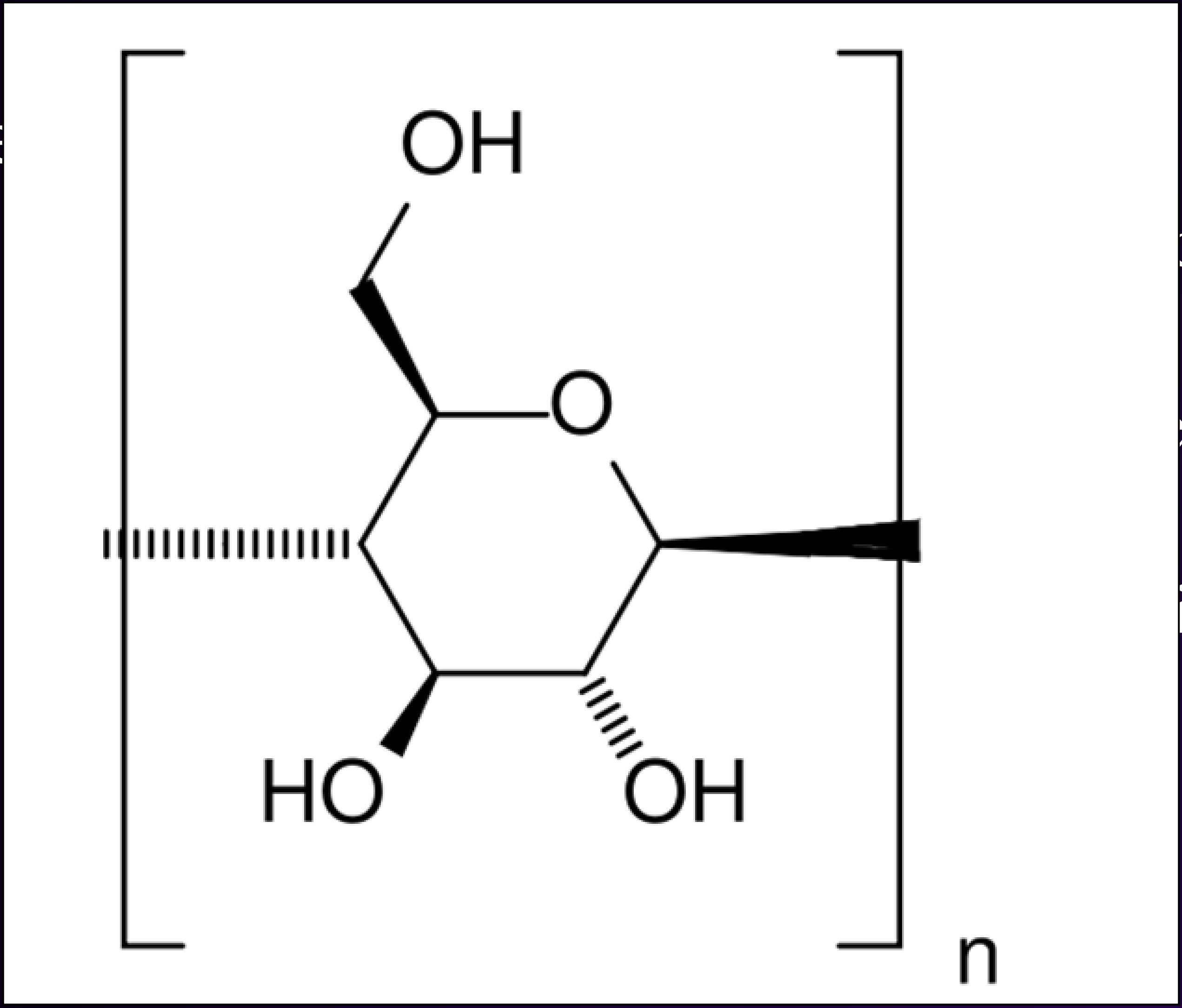
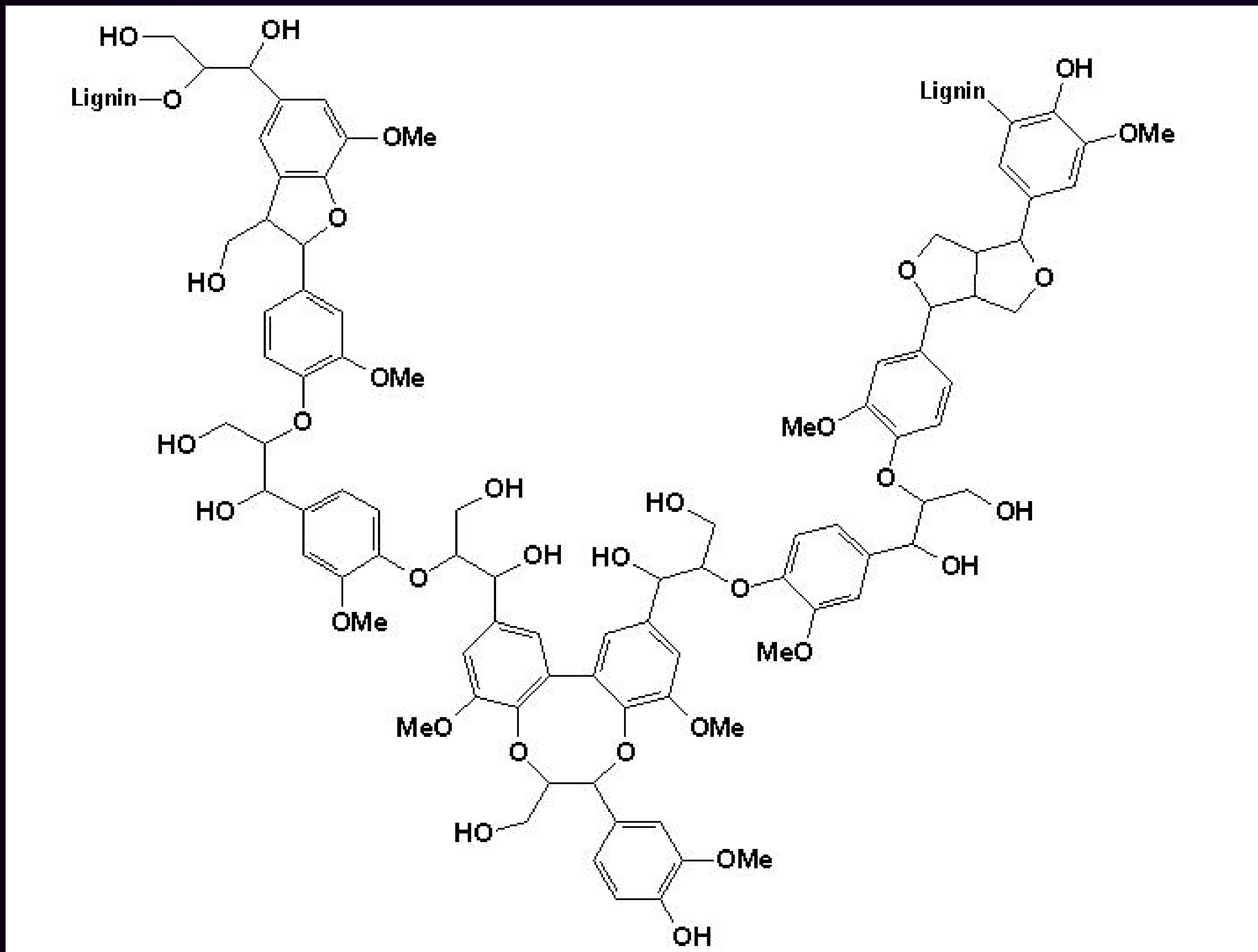


Biochemical Components of Plants



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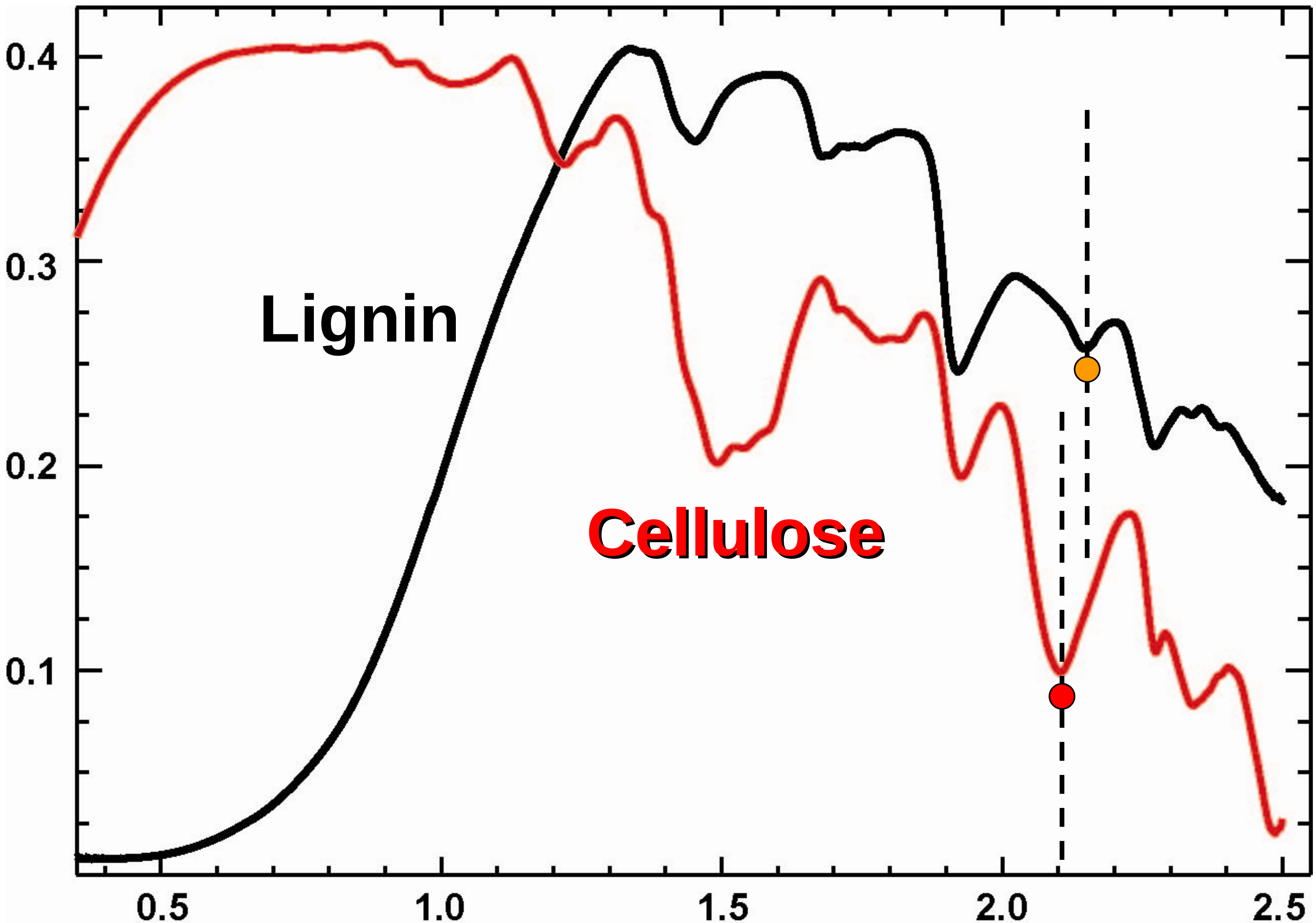
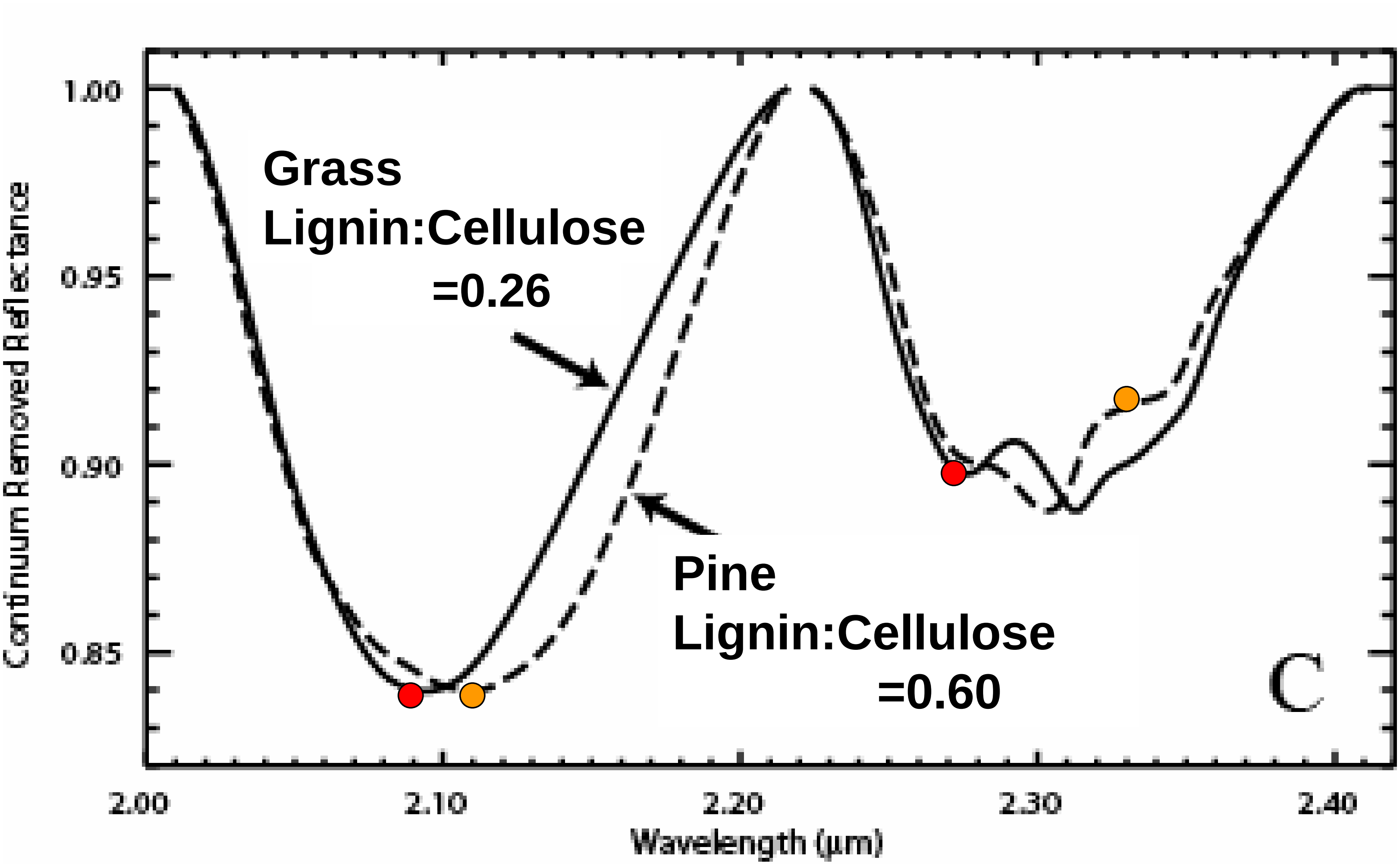
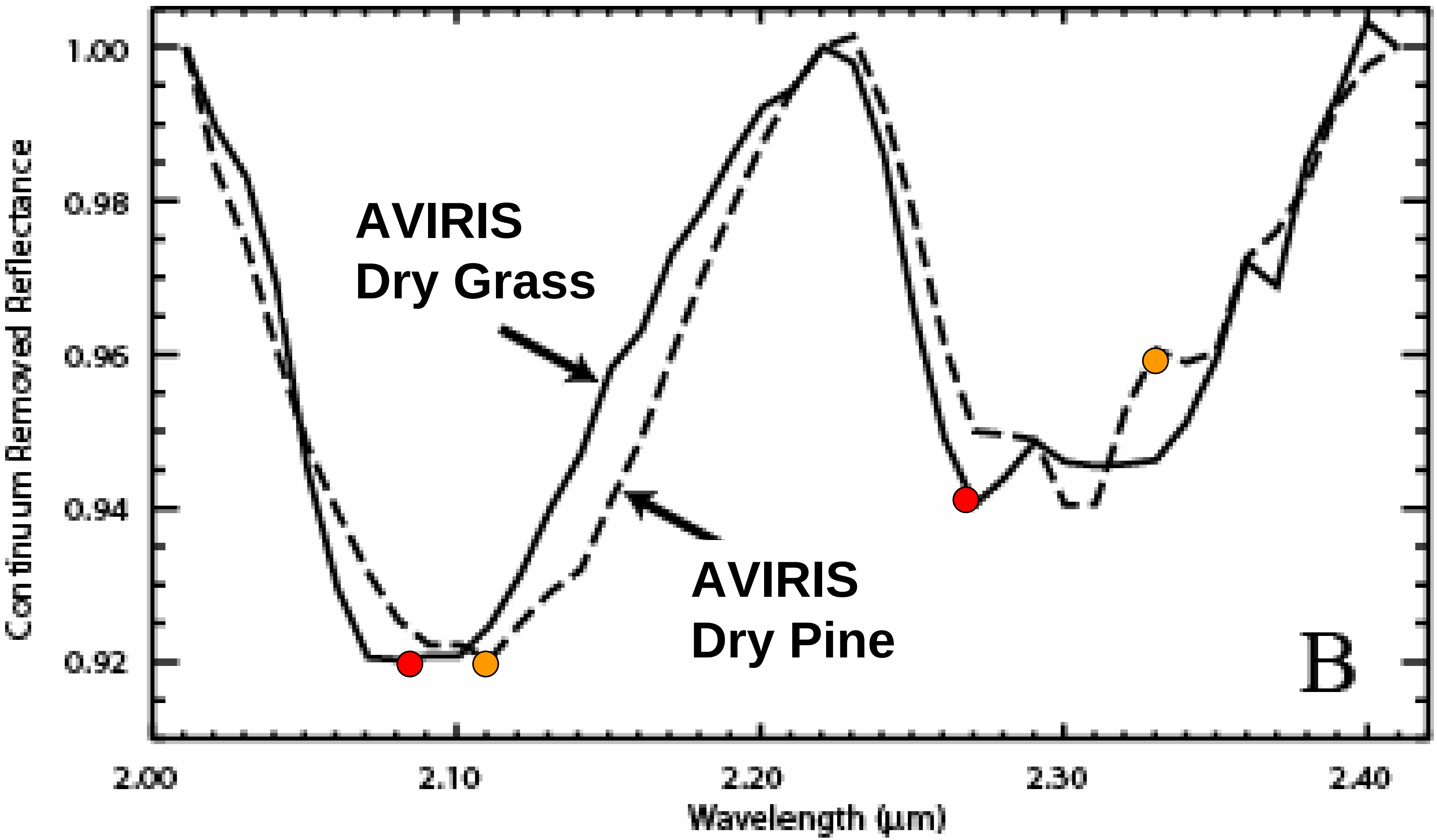


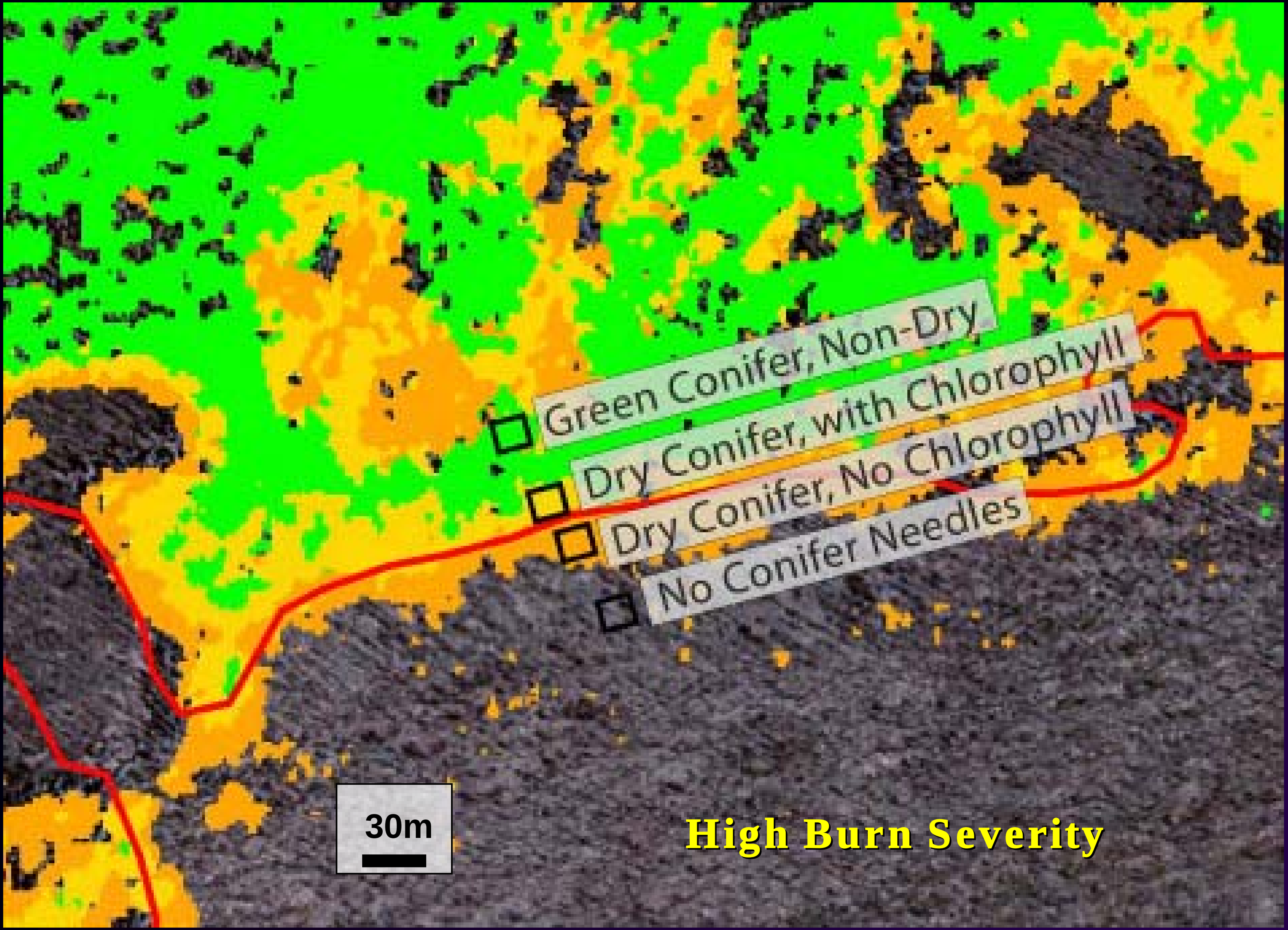
0.4
0.3
0.2
0.1
0.5
1.0
1.5
2.0
2.5
Lignin
Cellulose



Kokaly et al., Remote Sensing of Environment, submitted



Kokaly et al., Remote Sensing of Environment, submitted



Kokaly et al., Remote Sensing of Environment, submitted

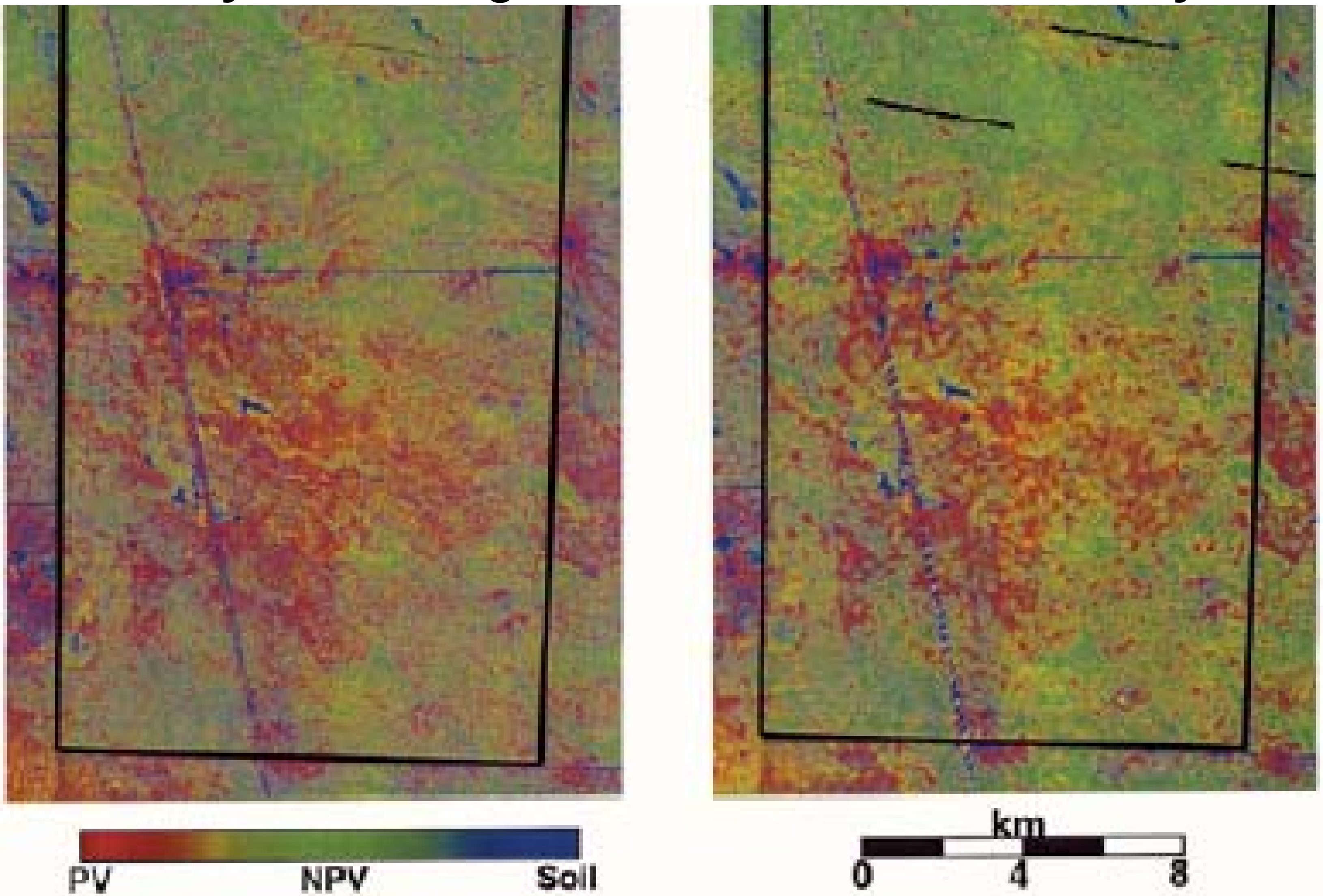
Analysis of spectral shape (full spectrum and/or absorption features) for vegetation characterization

- Multiple Endmember Spectral Mixture Models:
  - Roberts, et al. (1998) Remote Sens. Environ. 65:267–279
- Monte Carlo spectral unmixing model:
  - Asner and Heidebrecht (2002) Int. J. Remote sensing 23: 3939–3958
- Tetracorder:
  - Clark, et al. (2003) . J. Geophys. Research 108 (E12): 5-1 to 5-44

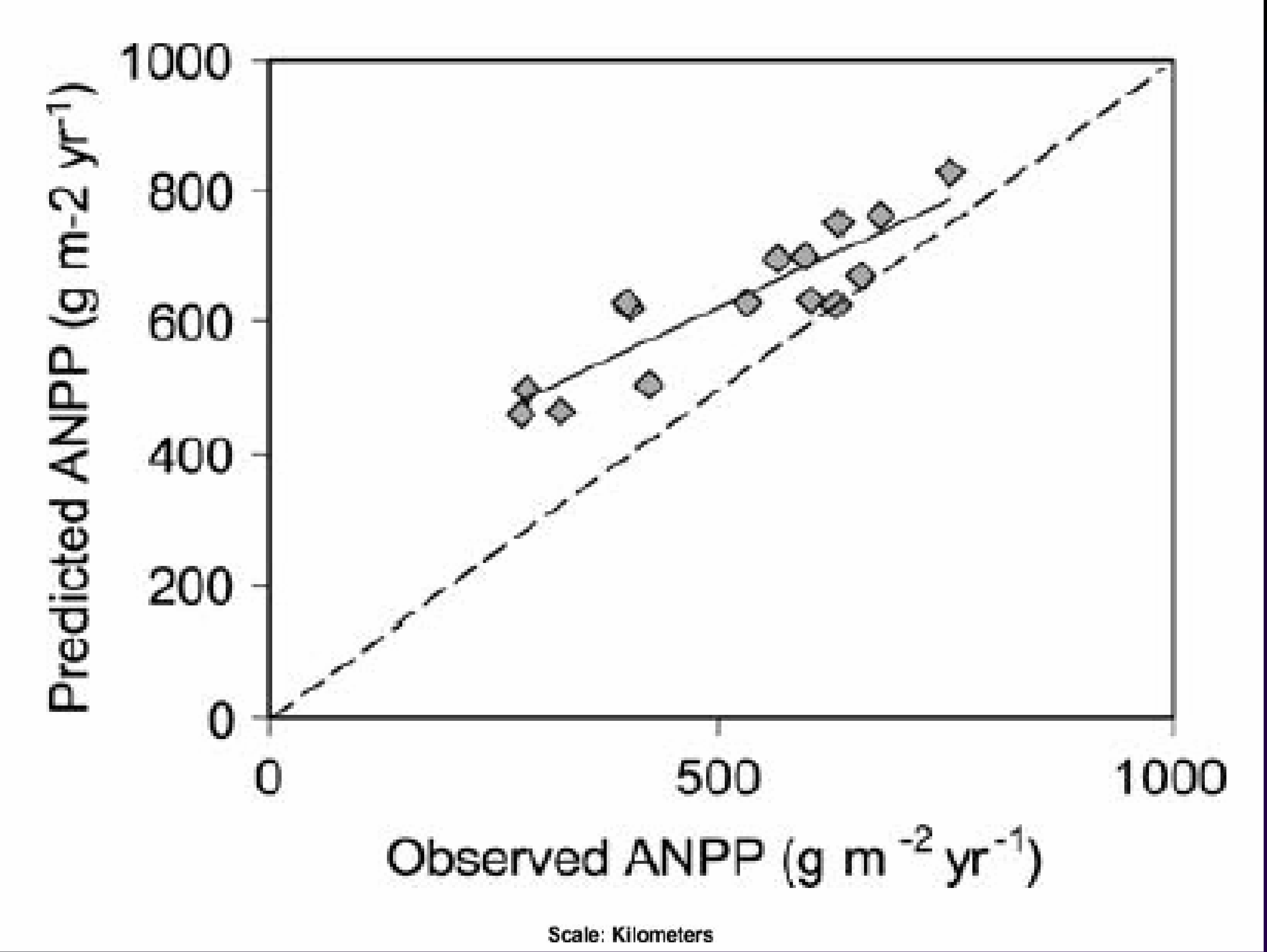
Understanding ecosystem processes by quantifying canopy biochemistry

- Wessman, et al. (1988) Nature 333:154–6.
- Asner and Heidebrecht, (2003) IEEE Trans. on Geoscience & Remote Sensing 41:1283-1296.
- Ollinger and Smith, (2005) Ecosystems 8: 760–778
- Asner et al. (2005), Remote Sensing of Environment 96: 497 – 508

Non-Photosynthetic Vegetation and Shrubland Ecosystems



Asner and Heidebrecht, IEEE Trans. on Geoscience & Remote Sensing (2003), 41:1283-1296.



Ollinger and Smith, Ecosystems (2005) 8: 760–778

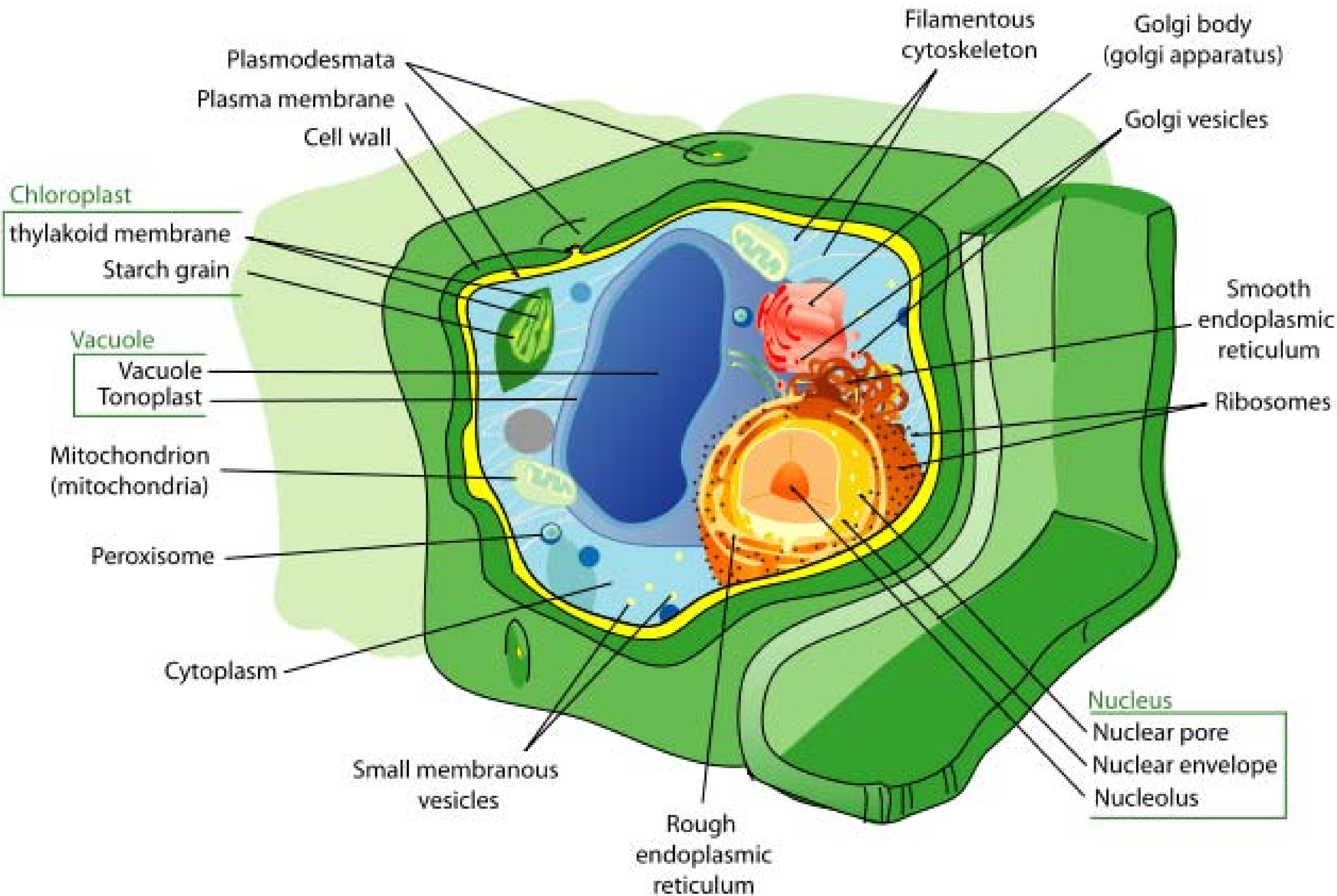
Remaining Challenges/ Future Directions

- Interaction of biochemicals
  - Leaf water masking effect
  - Nitrogen/lignin/cellulose all affect the 2.1 and 2.3 μm features
- Atmospheric correction
- Quantifying other biochemicals (phosphorous)
- Independent-site/Multi-site validation

- Multispectral statistical methods applied to spectroscopic data

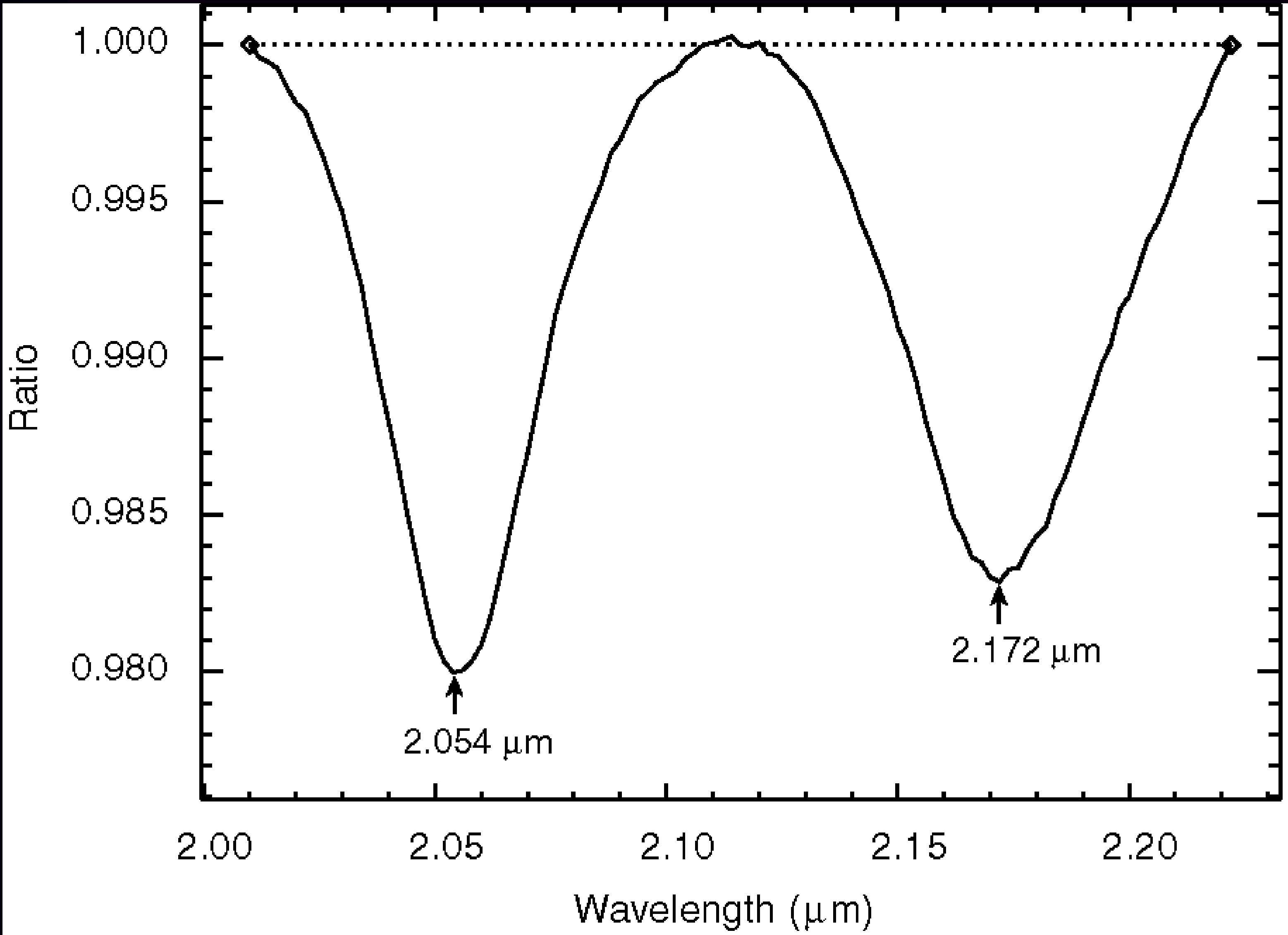
Influence on multispectral approaches via ratios and indices based on absorption features

- NDWI
- CAI
- NDNI
- NLNI



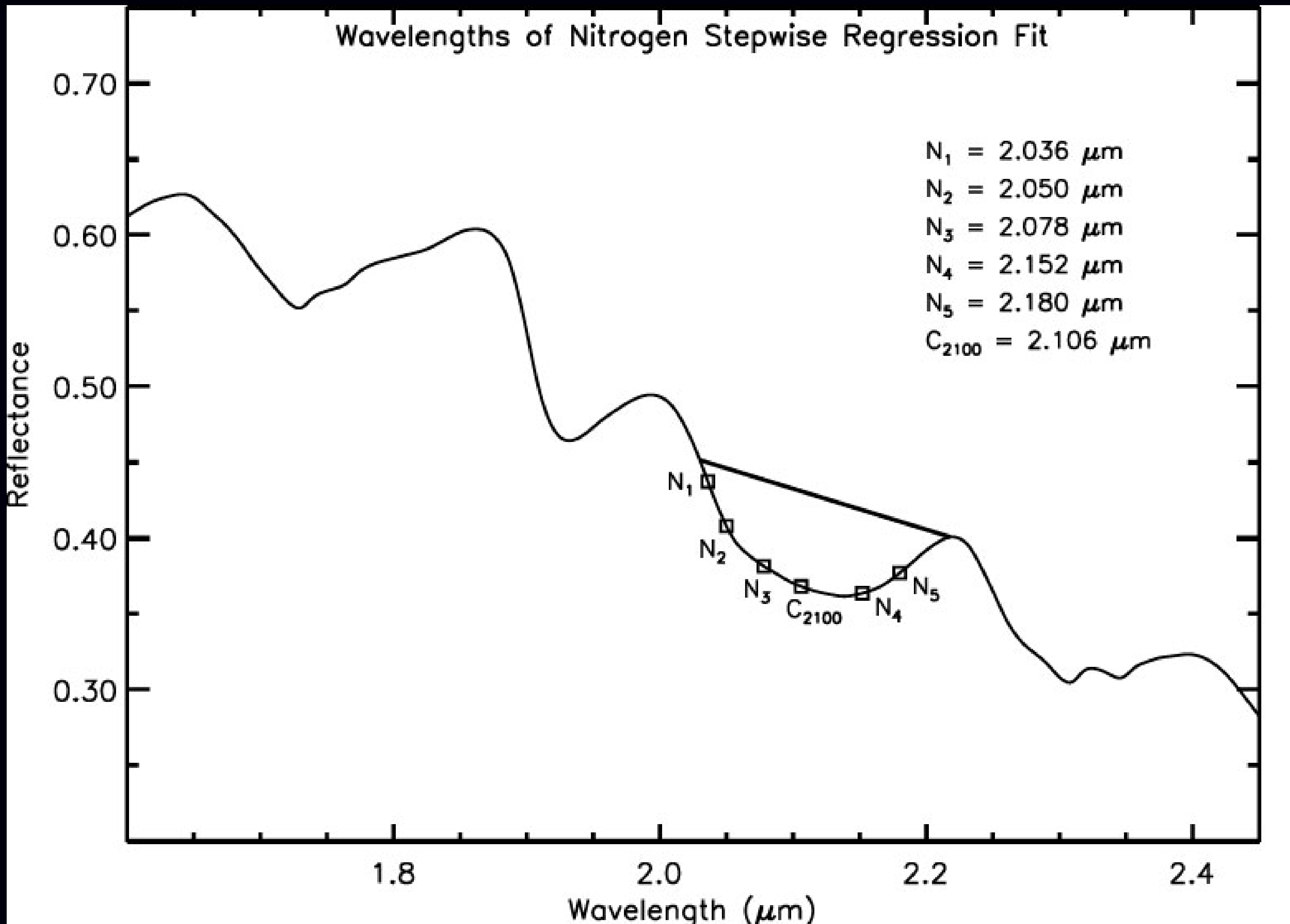
Plasmodesmata
Plasma membrane
Cell wall
Chloroplast
thylakoid membrane
Starch grain
Vacuole
Vacuole
Tonoplast
Mitochondrion (mitochondria)
Peroxisome
Cytoplasm
Small membranous vesicles
Rough endoplasmic reticulum
Filamentous cytoskeleton
Golgi body (golgi apparatus)
Golgi vesicles
Smooth endoplasmic reticulum
Ribosomes
Nucleus
Nuclear pore
Nuclear envelope
Nucleolus

- The first mention of the word *protein* was from a letter sent by Jöns Jakob Berzelius to Gerhardus Johannes Mulder on 10. July 1838, where he wrote:
  - «Le nom protéine que je vous propose pour l'oxyde organique de la fibrine et de l'albumine, je voulais le dériver de πρωτειος, parce qu'il paraît être la substance primitive ou principale de la nutrition animale.»
- Translated as:
  - "The name protein that I propose for the organic oxide of fibrin and albumin, I wanted to derive from [the Greek word] πρωτειος, because it appears to be the primitive or principal substance of animal nutrition."
- Investigation of proteins and their properties had been going on since about 1800 when scientists were finding the first signs of this, at the time, unknown class of organic compounds.



Ratio
1.000
0.995
0.990
0.985
0.980
2.054 µm
2.172 µm
2.00
2.05
2.10
2.15
2.20
Wavelength (µm)

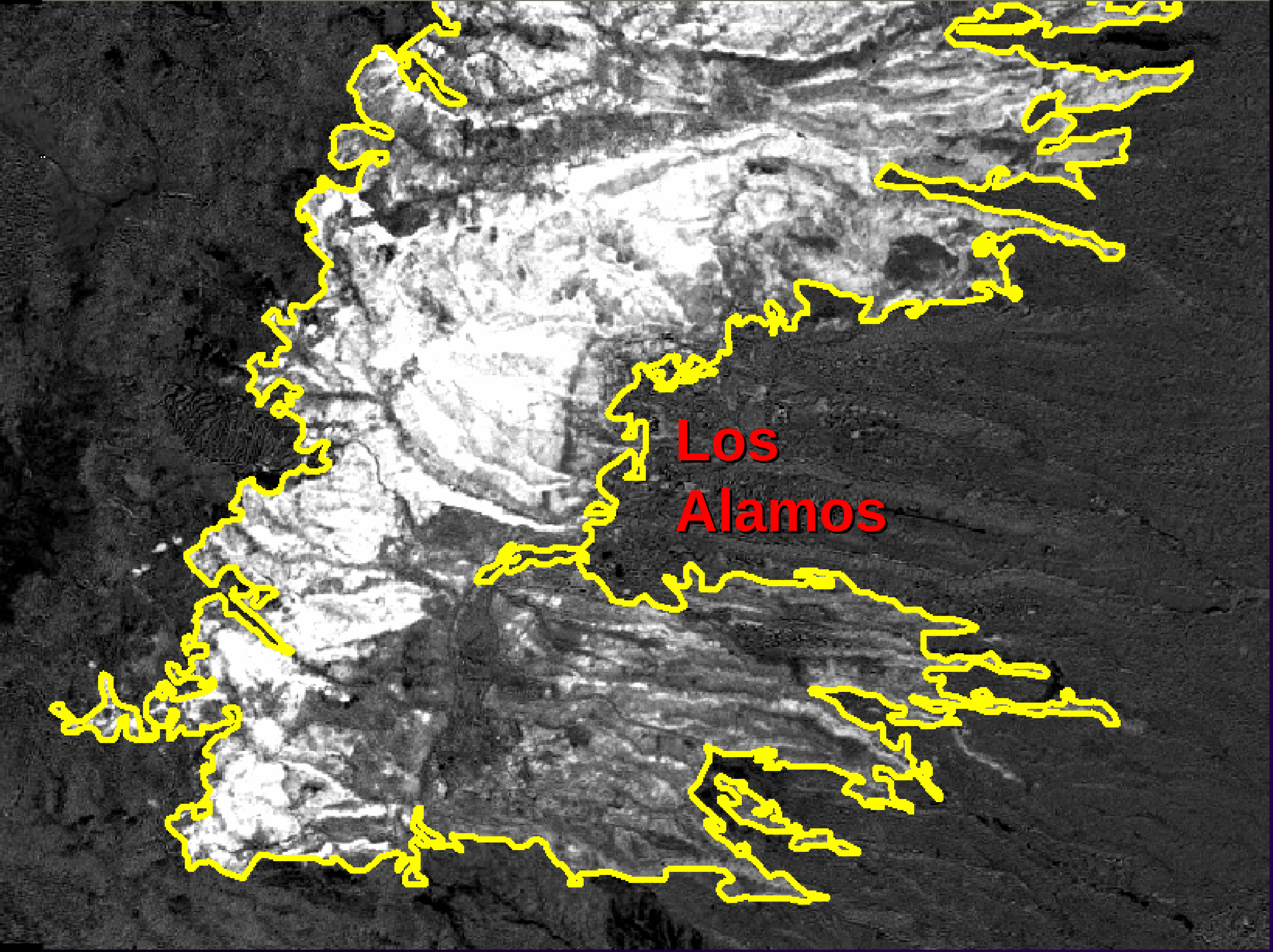
Figure 3b



Wavelengths of Nitrogen Stepwise Regression Fit
0.70
0.60
0.50
0.40
0.30
Reflectance
1.8
2.0
2.2
2.4
Wavelength (μm)
N1 = 2.036 μm
N2 = 2.050 μm
N3 = 2.078 μm
N4 = 2.152 μm
N5 = 2.180 μm
C2100 = 2.106 μm
N1
N2
N3
C2100
N4
N5

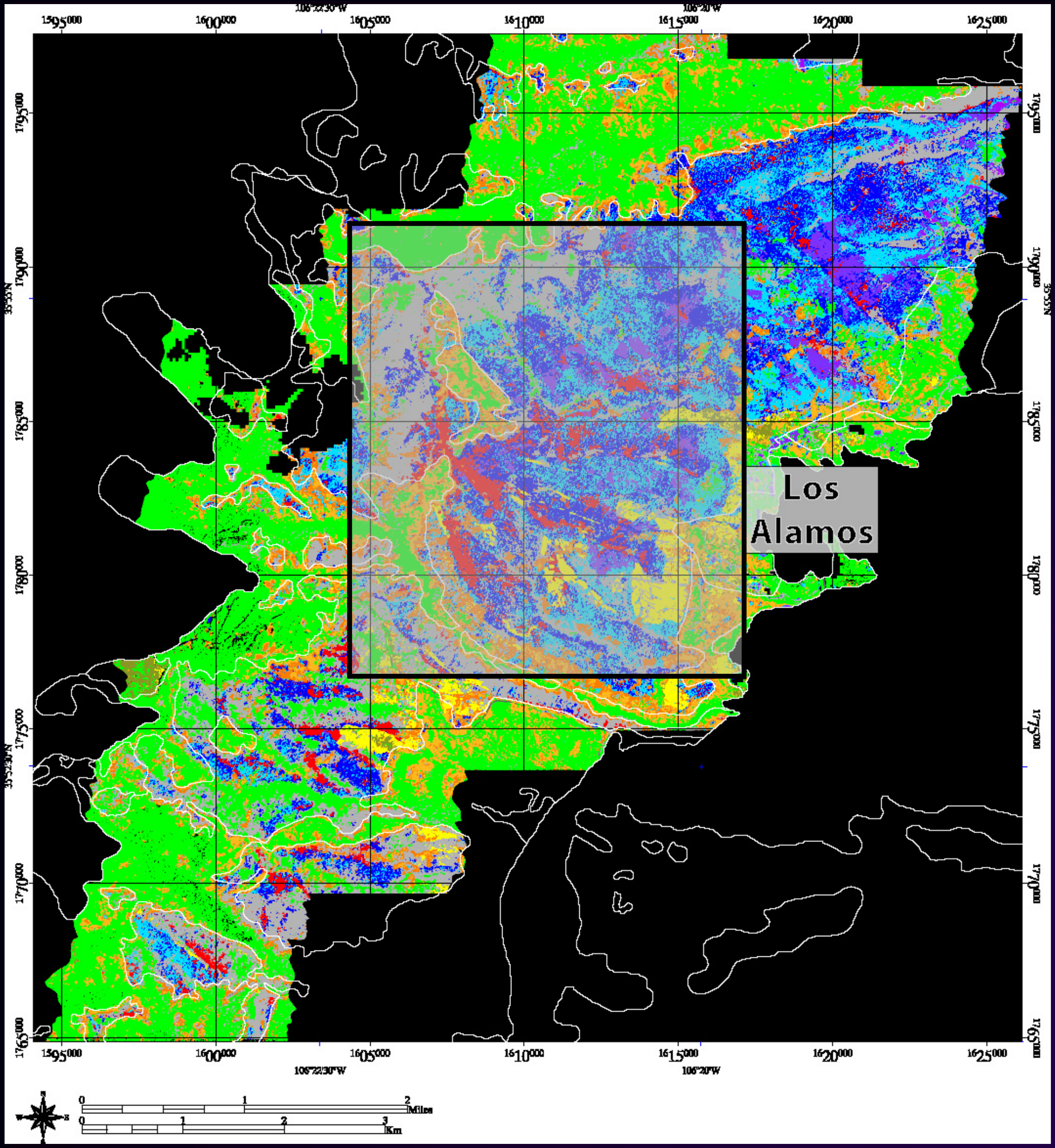
Figure 4a


nationalatlas.gov
Where We Are
FEDERAL LANDS AND INDIAN RESERVATIONS
Cerro Grande Fire
Los Alamos,
New Mexico
CANADA
WASHINGTON
OREGON
IDAHO
MONTANA
WYOMING
NEVADA
UTAH
CALIFORNIA
ARIZONA
COLORADO
NEW MEXICO
NORTH DAKOTA
SOUTH DAKOTA
NEBRASKA
KANSAS
OKLAHOMA
TEXAS
MINNESOTA
IOWA
MISSOURI
ARKANSAS
LOUISIANA
WISCONSIN
MICHIGAN
ILLINOIS
INDIANA
OHIO
KENTUCKY
TENNESSEE
MISSISSIPPI
ALABAMA
GEORGIA
FLORIDA
SOUTH CAROLINA
NORTH CAROLINA
VIRGINIA
WEST VIRGINIA
PENNSYLVANIA
NEW YORK
MAINE
VERMONT
NEW HAMPSHIRE
MASSACHUSETTS
RHODE ISLAND
CONNECTICUT
NEW JERSEY
DELAWARE
MARYLAND
DC
Lake Superior
Lake Michigan
Lake Huron
Lake Ontario
Lake Erie
PACIFIC OCEAN
ATLANTIC OCEAN
GULF OF MEXICO
MEXICO
CUBA
THE BAHAMAS
HAWAII
ALASKA
ARCTIC OCEAN
BERING SEA
GULF OF ALASKA
RUSSIA
Bureau of Indian Affairs
Bureau of Land Management
Bureau of Reclamation
Department of Defense
Fish and Wildlife Service
Forest Service
National Park Service
Tennessee Valley Authority
Other agencies
0 100 200 300 mi
0 100 200 300 km
U.S. Department of the Interior
U.S. Geological Survey
The National Atlas of the United States of America®



Los
Alamos

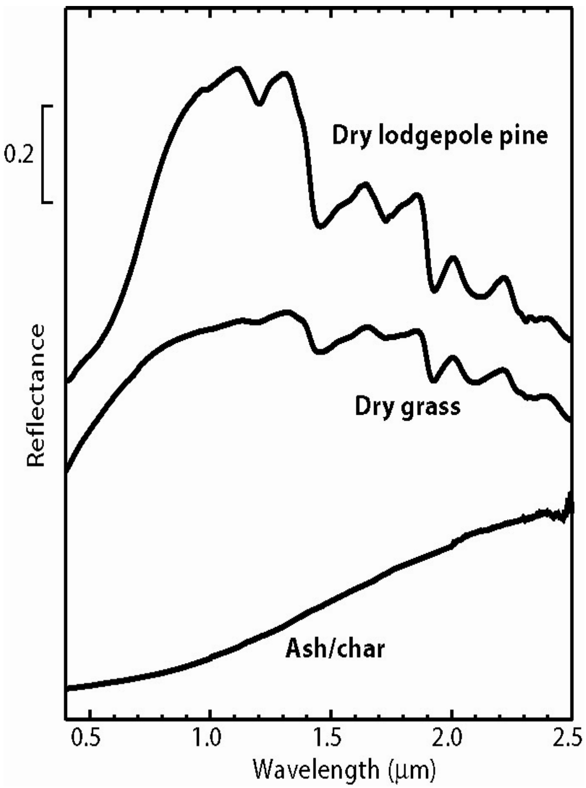
Results: AVIRIS Maps



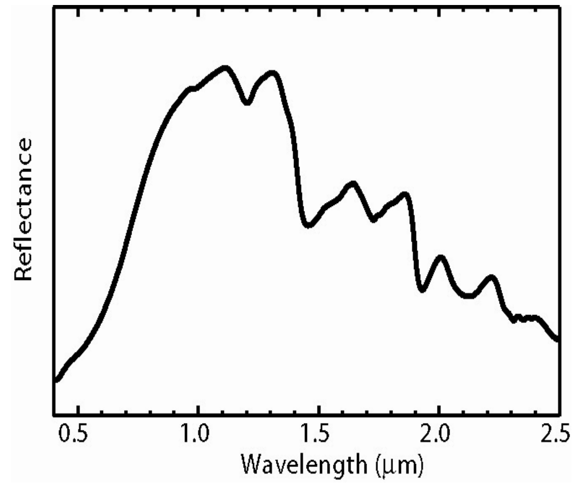
- Ash / Charcoal
- Mineral / Ash
- Mineral-1μm
- Mineral-2μm
- Dry Conifer
- Dry & Green Conifer
- Straw matting
- Straw matting & Green grass
- Green Vegetation

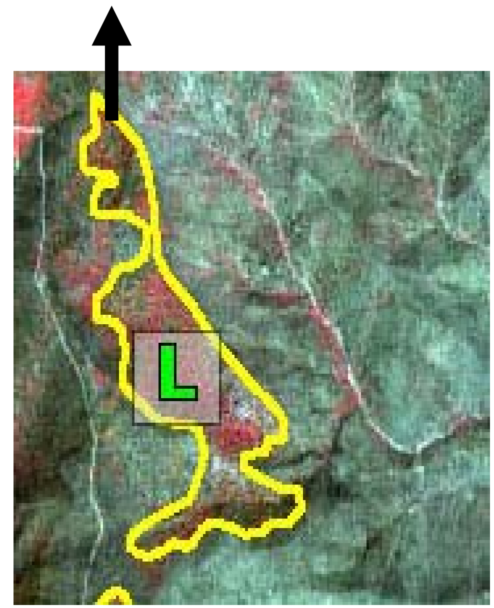
Tetracorder

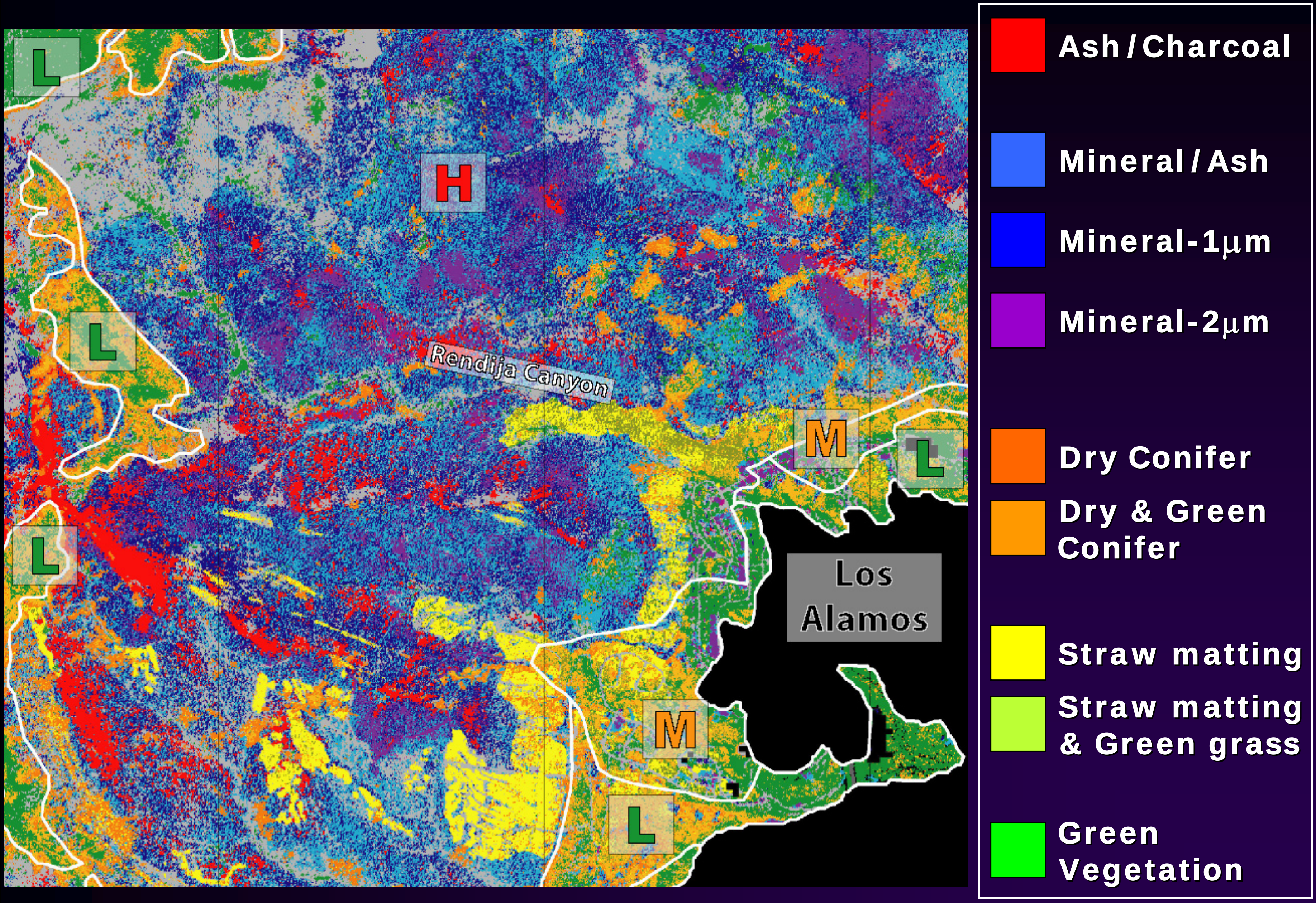
Library Spectra



Pixel Spectrum





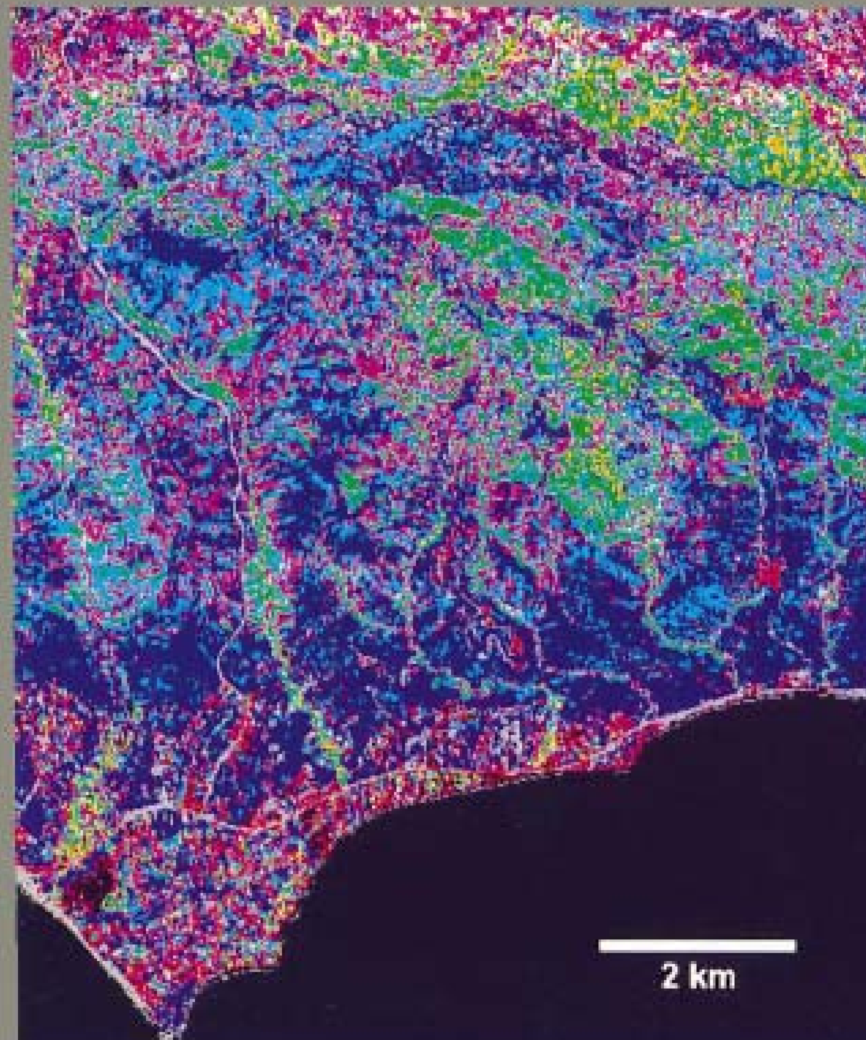


H
L
L
L
L
L
M
M
Rendija Canyon
Los Alamos
Ash / Charcoal
Mineral / Ash
Mineral-1μm
Mineral-2μm
Dry Conifer
Dry & Green Conifer
Straw matting
Straw matting & Green grass
Green Vegetation

Green Vegetation

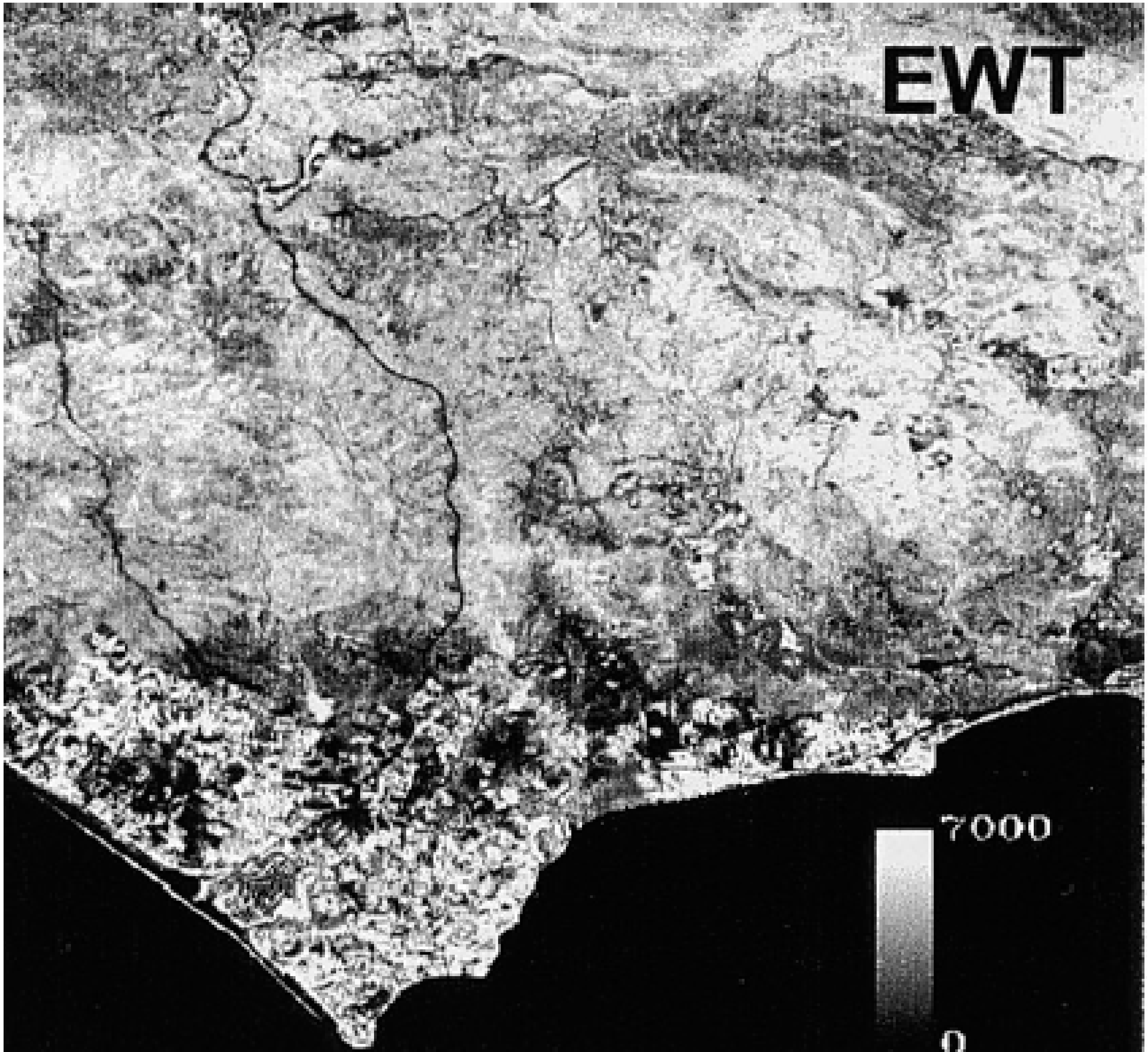
LEGEND

- (8) Sophora
- (9) Zibmala10b, (29) Wplph2-Zibmala10b
- (10) Grassme1
- (11) Qudo1stack
- Urban Vegetation (12, 28, 35)
- (13) Ogheather
- (14) Buro0
- (23) Purglan
- Roads/exposed rock & soil (15-21, 27, 33)
- Drought Deciduous and Senesced Vegetation



PV Fraction

NPV Fraction



Serrano et al., REMOTE SENS. ENVIRON. 74:570–581 (2000)