USDA-ARS HRSL
Hydrology & Remote Sensing Lab
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Vegetation Water Content using AWiFS Shortwave Infrared Band

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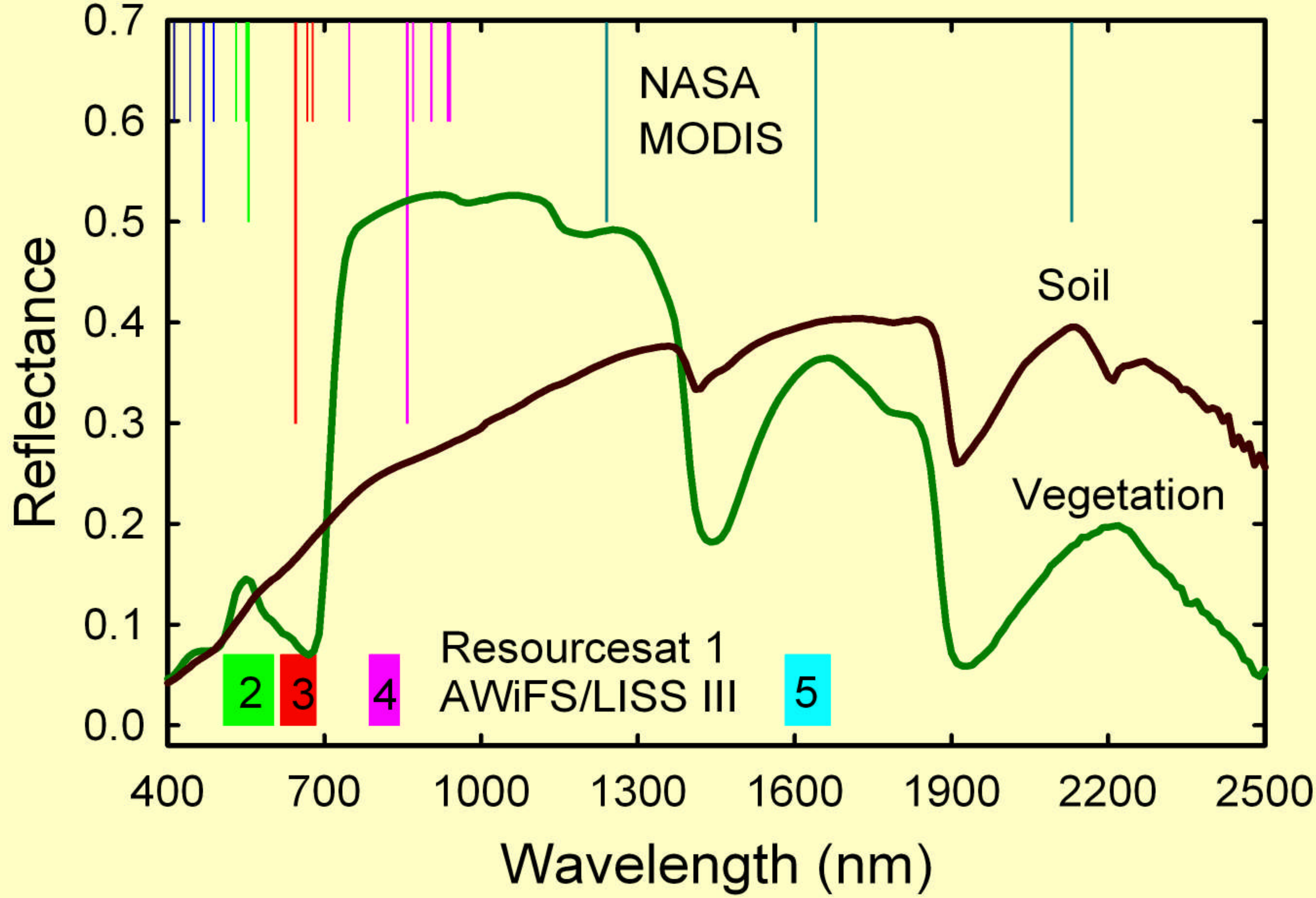
Goals for a Canopy Water Content Data Product

- Vegetation water stress/drought detection
- Potential for wildfires/vegetation dryness
- Improve estimates of soil moisture from microwave radiometers

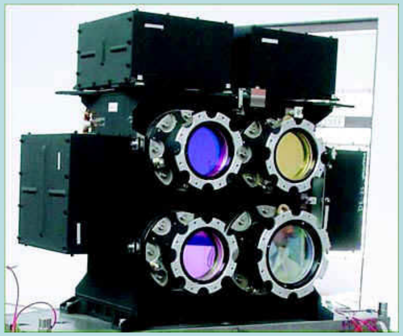
Algorithm should be compatible with other sensors (MODIS, VIIRS)



0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Reflectance
NASA
MODIS
Soil
Vegetation
Resourcesat 1
AWiFS/LISS III
2
3
4
5
400
700
1000
1300
1600
1900
2200
2500
Wavelength (nm)

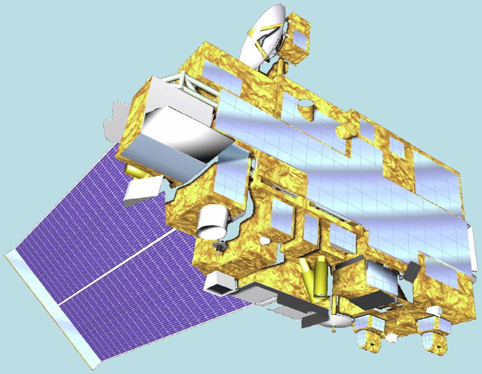
Remotely sensed indices for canopy water content:

NDII: Normalized Difference Infrared Index (Hardisky et al. 1983) defined with AWiFS bands



NDII = (R**4** – R**5**)/(R**4** + R**5**)

NDWI: Normalized Difference Water Index (Gao 1996) MODIS Bands 2 and 5



NDWI = (R**850** - R**1240**)/(R**850** + R**1240**)

No equivalent to MODIS band 5 on AWiFS

Canopy Water Content (kg m^{-2} or mm)

- Leaf EWT = (FWT – DWT) / leaf area
- Canopy water content = Leaf EWT x Leaf Area Index
- Estimated by SWIR reflectance (Hunt & Rock, 1989)

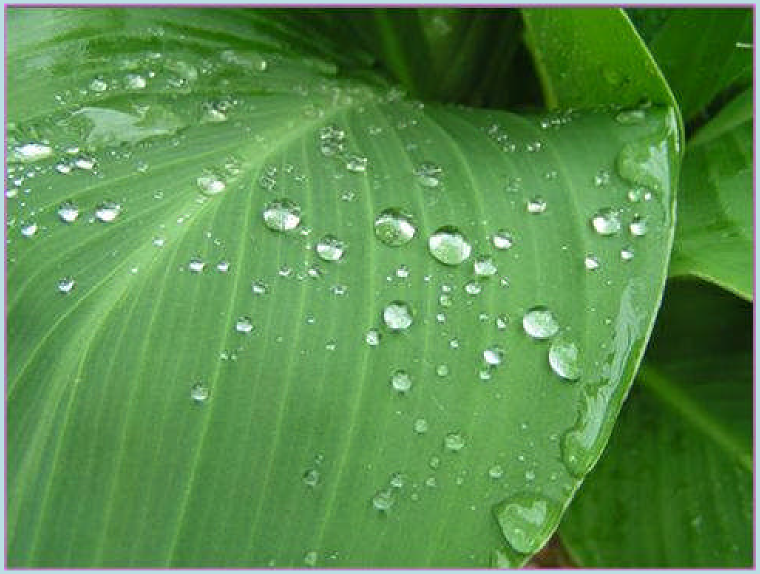
Vegetation Water Content (VWC, kg m^{-2})

- VWC = Stem water content + Canopy water content
- Estimated by Active or Passive Microwaves

Physiological Status to Remote Sensing

EWT: Leaf equivalent water thickness (volume/area in mm or kg m^{-2}) from Beer-Lambert Law

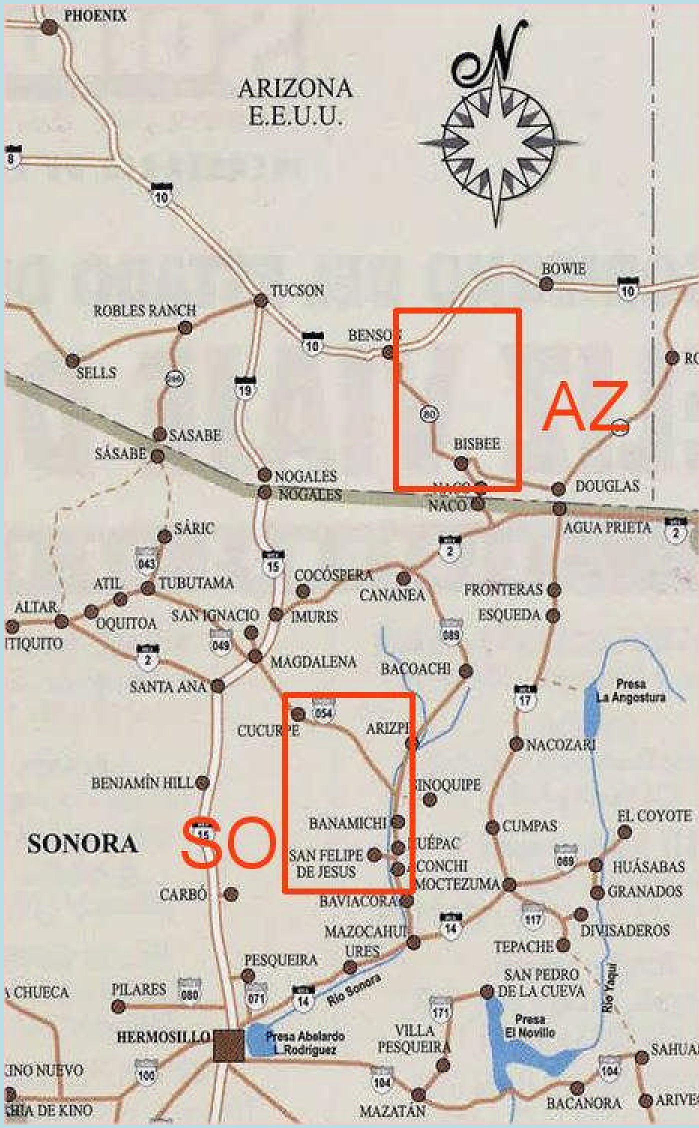
RWC: Relative Water Content (volume/volume at full turgor) or **EWT/EWT full turgor**



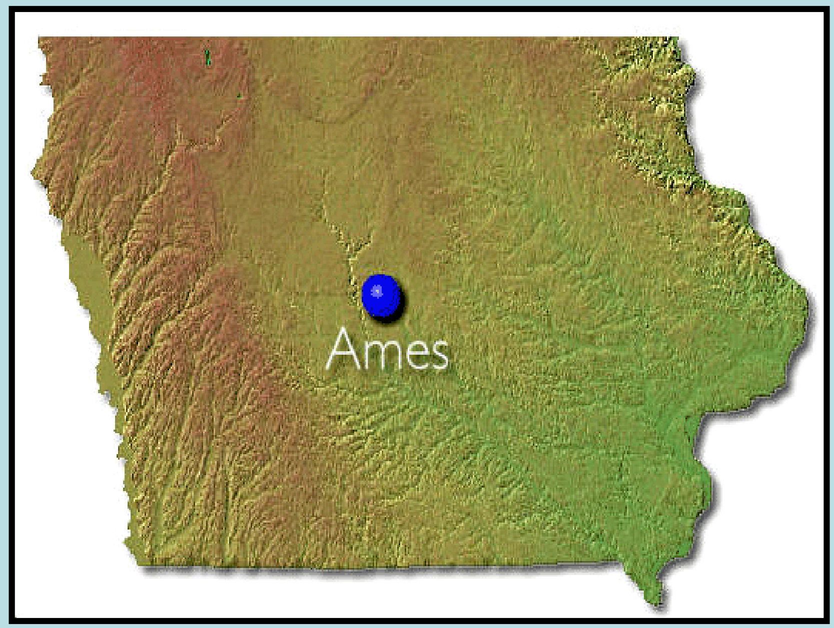
Plant water stress:

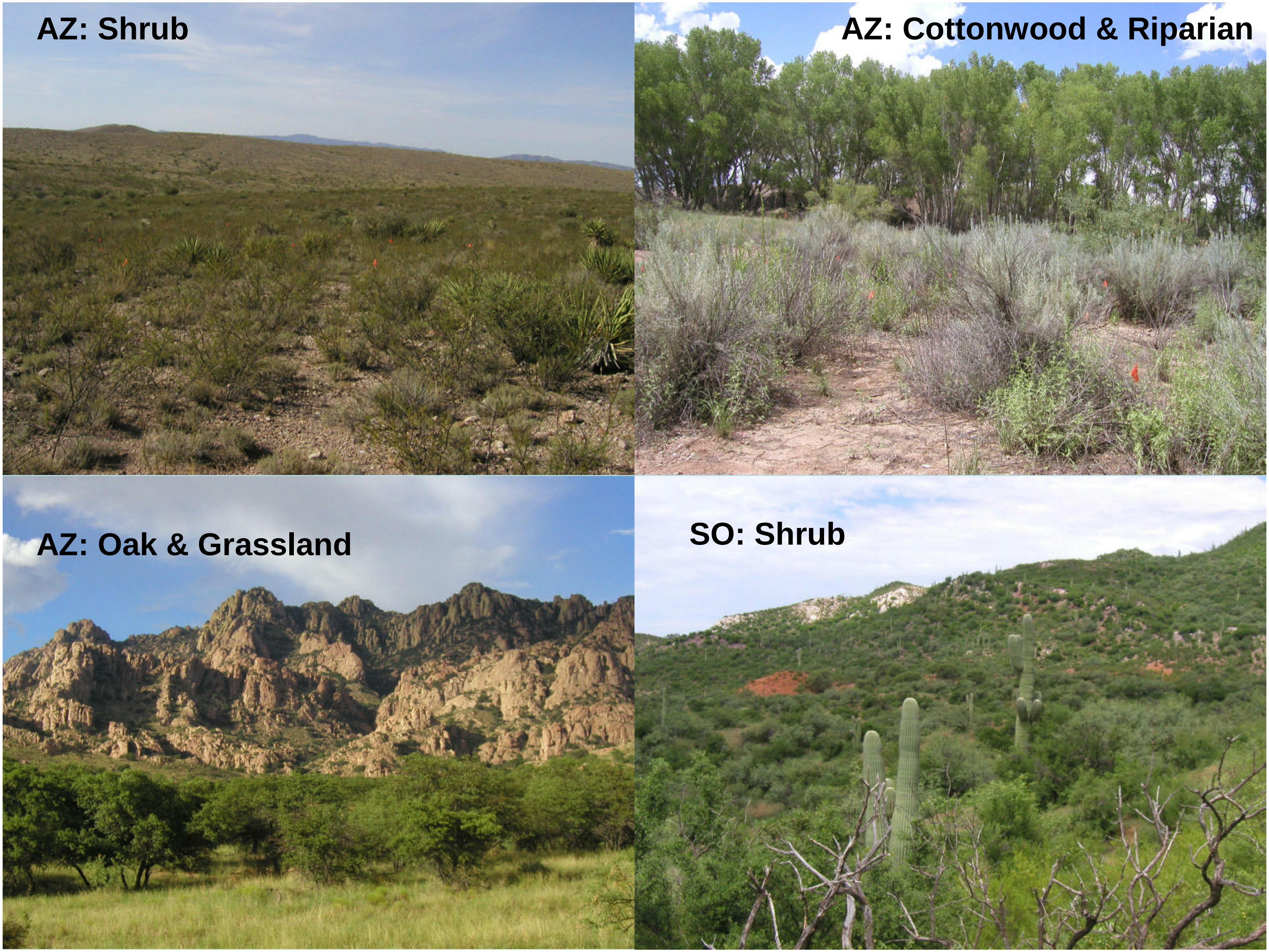
- Leaves wilting, leaf rolling or loss of leaves and leads to reduced growth
- Relative Water Content (RWC, %) falls below 75-85%
- Need estimates of leaf EWT and leaf EWT at full turgor
- Problem is canopy water content also depends on leaf area index
- NDVI and NDII are highly correlated, first principal component is LAI, is second principal component leaf EWT?

Two Major Remote Sensing Campaigns

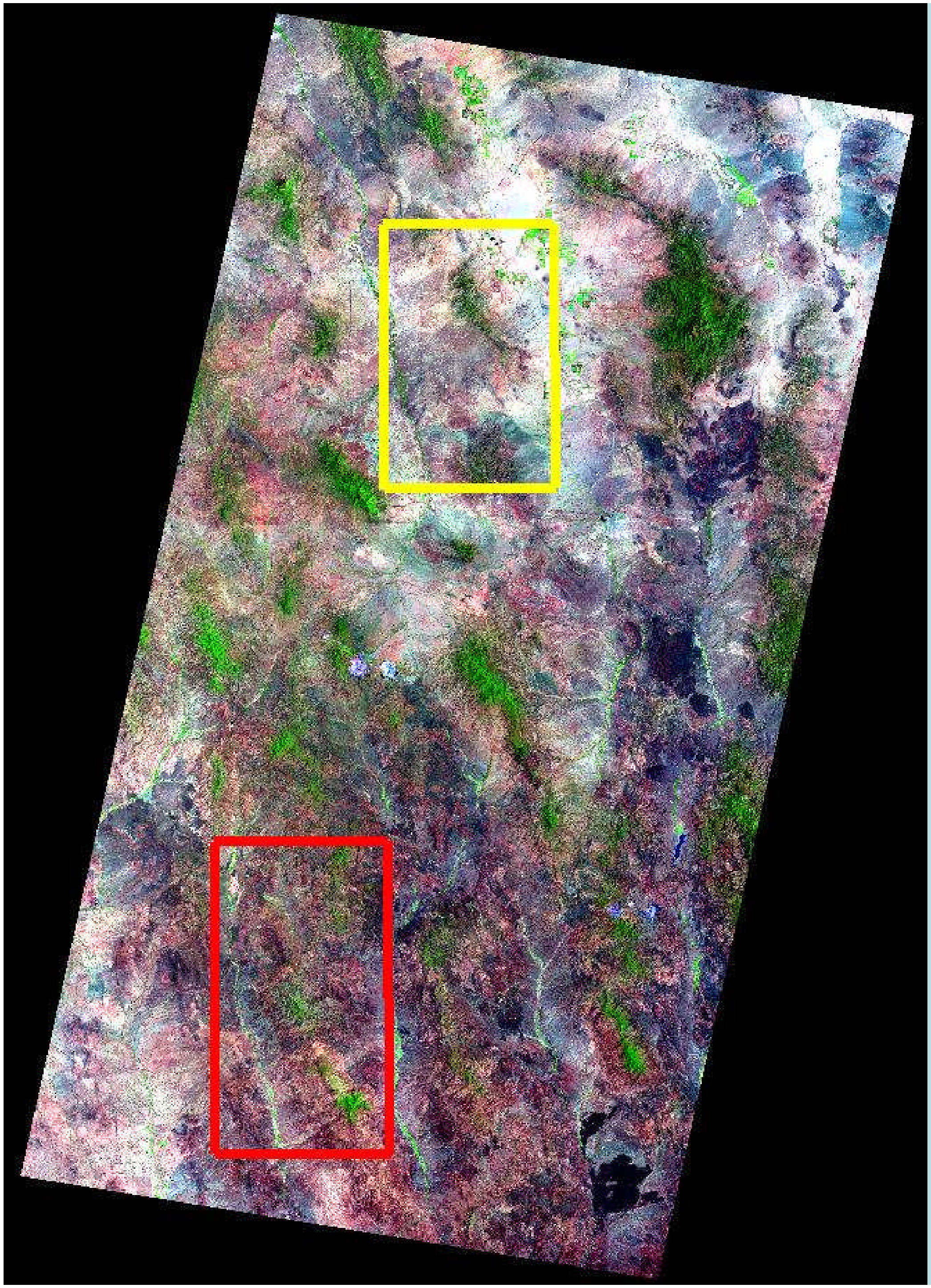


Soil Moisture Experiment 2005 and Polarimetry Land Experiment (SMEX05/POLEX)

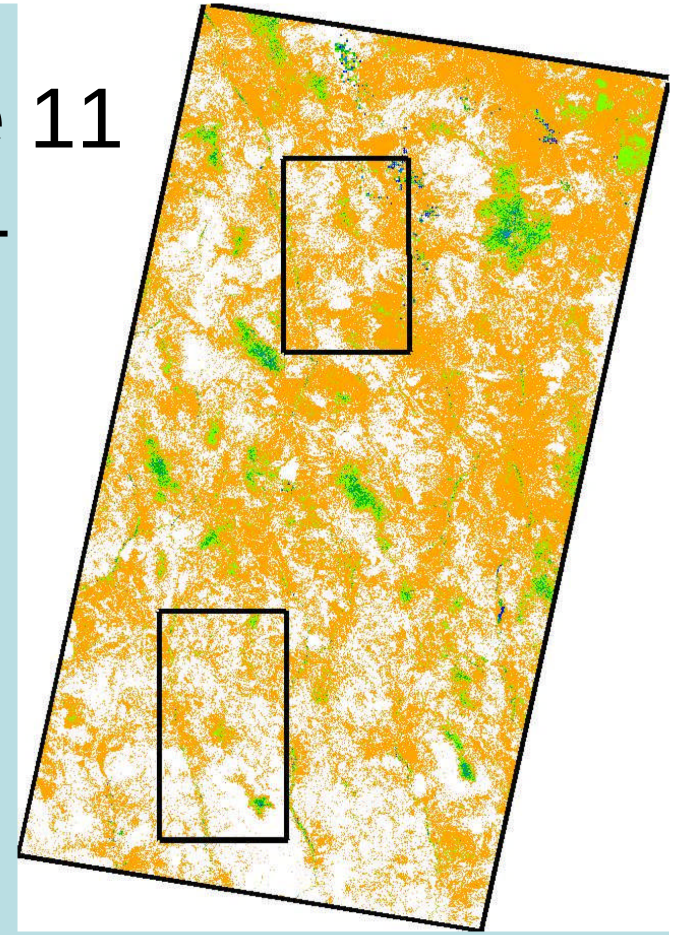


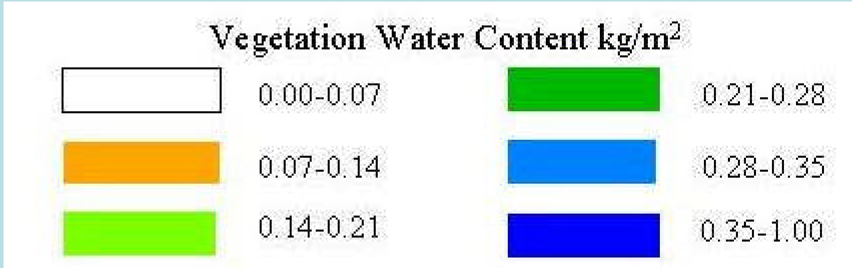

AZ: Shrub
AZ: Cottonwood & Riparian
AZ: Oak & Grassland
SO: Shrub

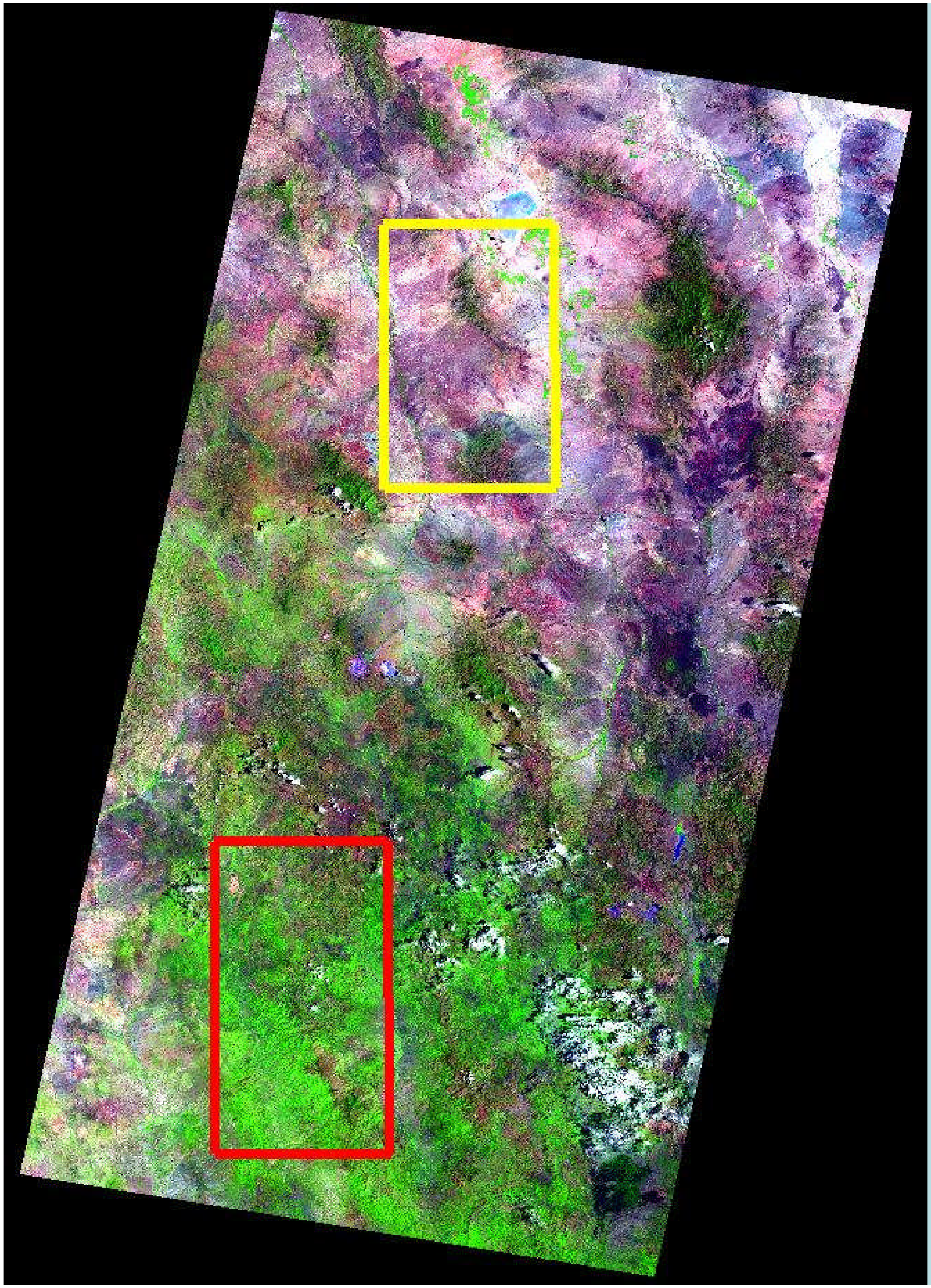

2.5"
2.5"
Kendell
#5



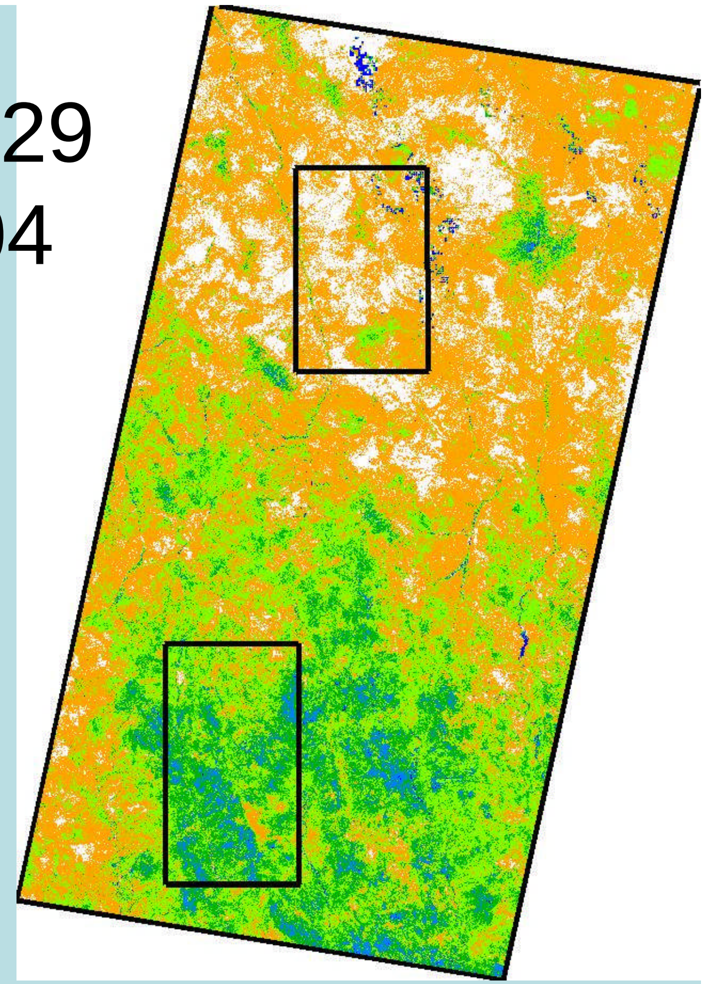
June 11
2004

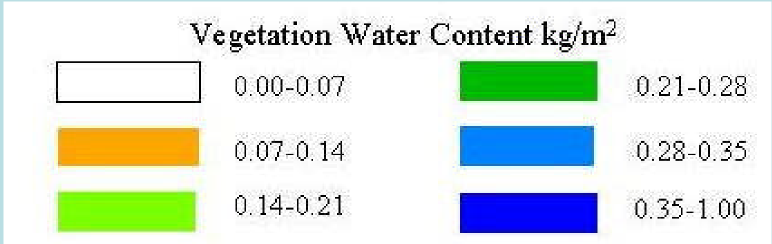



Vegetation Water Content kg/m2
0.00-0.07
0.07-0.14
0.14-0.21
0.21-0.28
0.28-0.35
0.35-1.00



July 29
2004





Vegetation Water Content kg/m²
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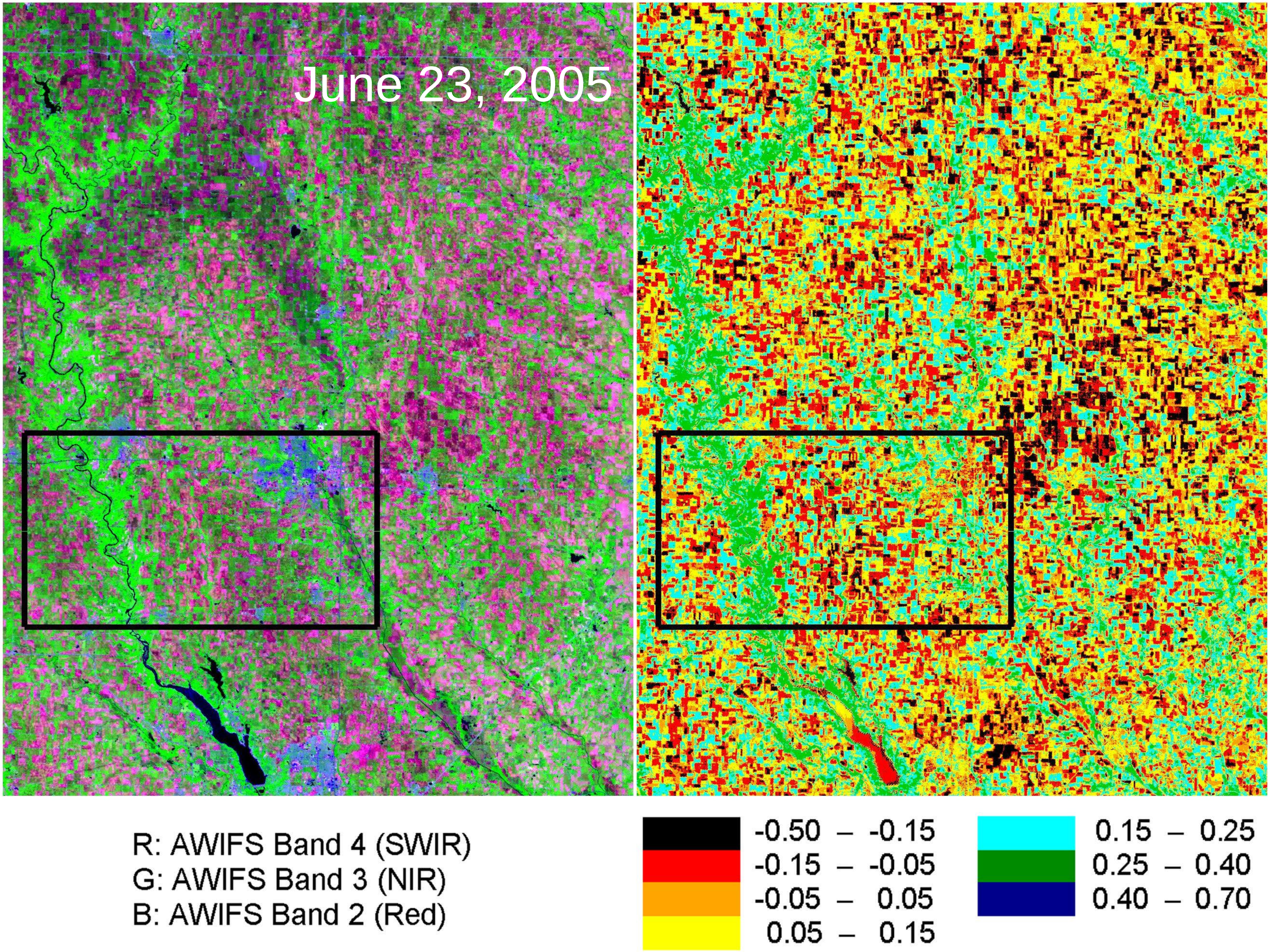
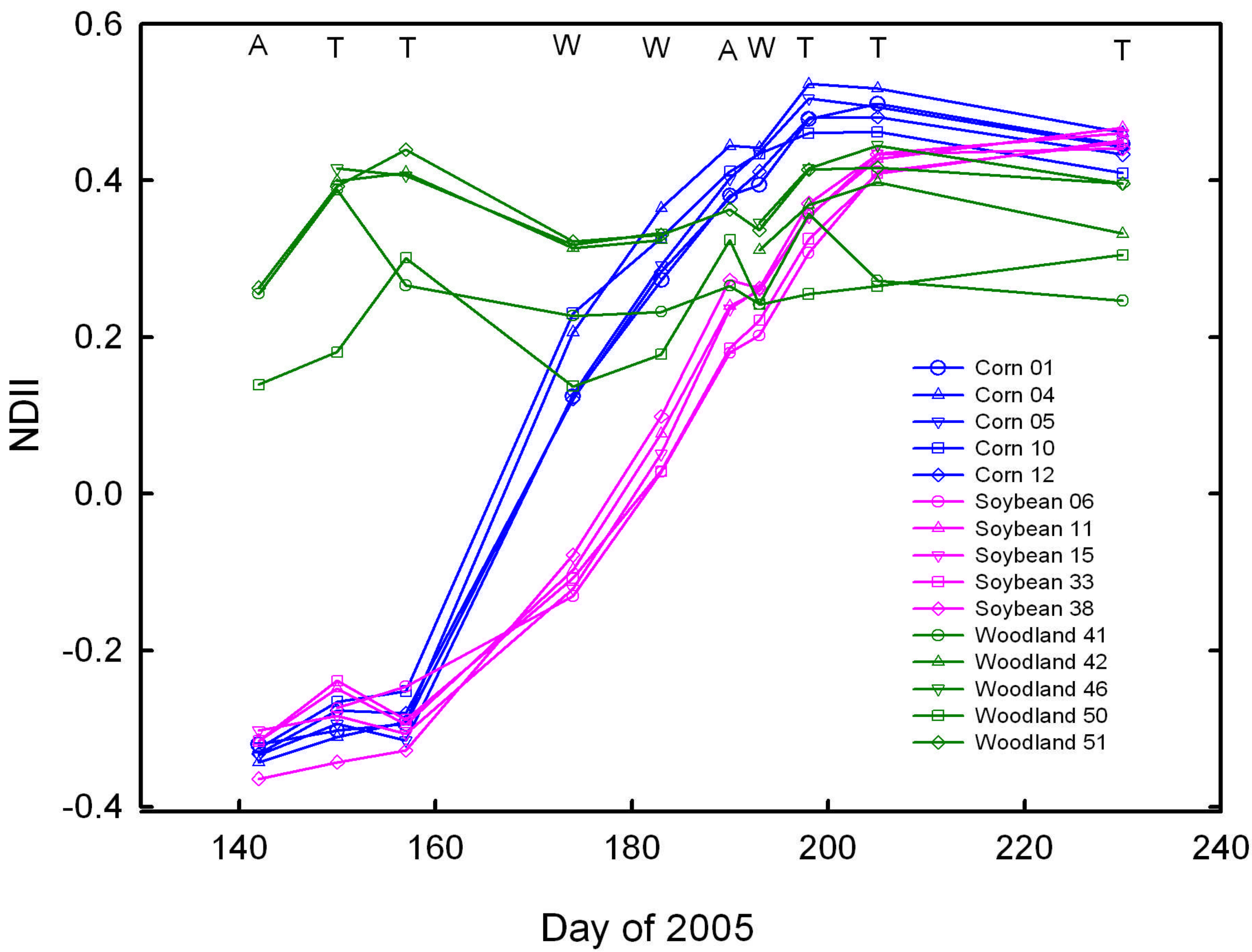
0.21-0.28
0.28-0.35
0.35-1.00





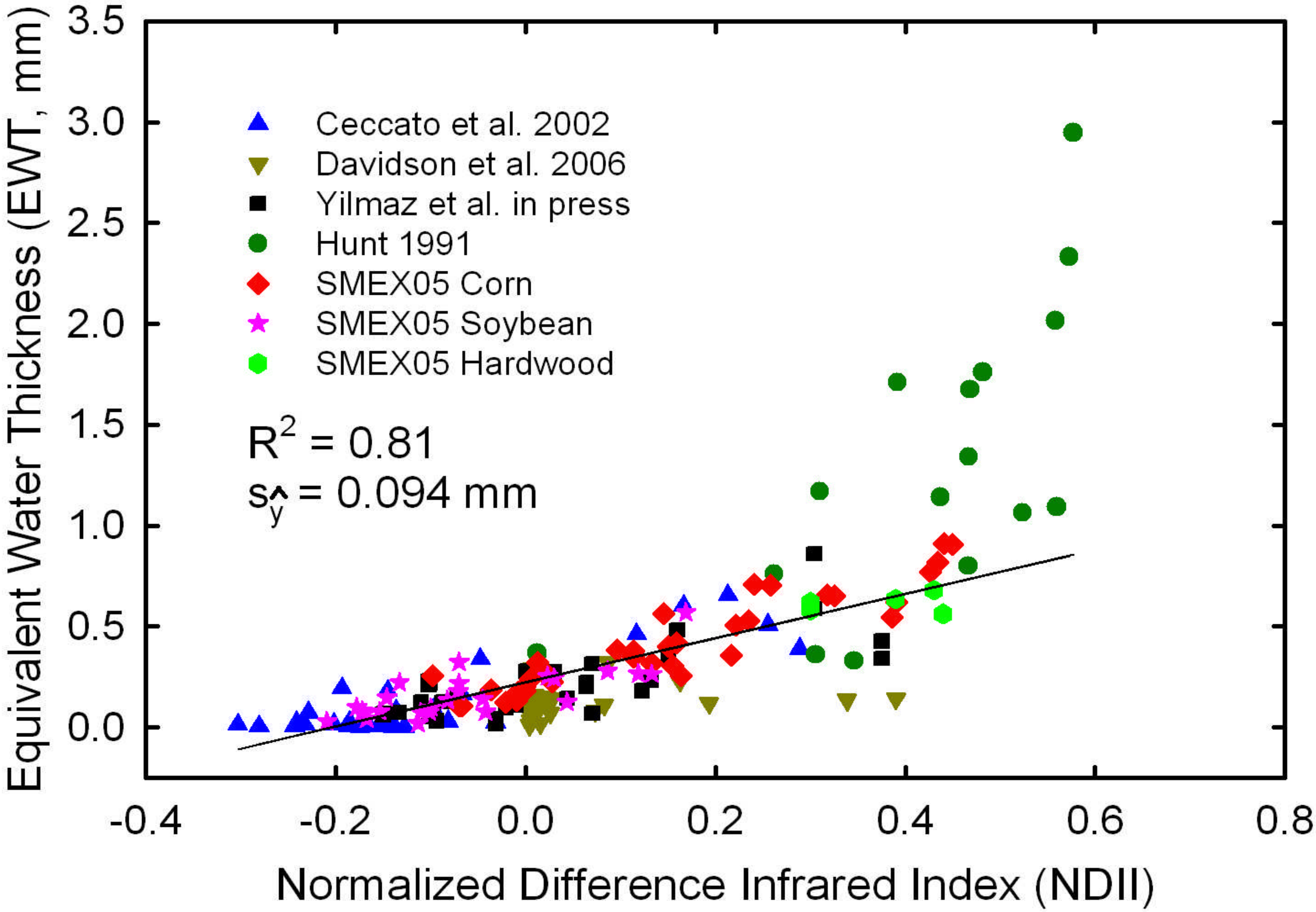


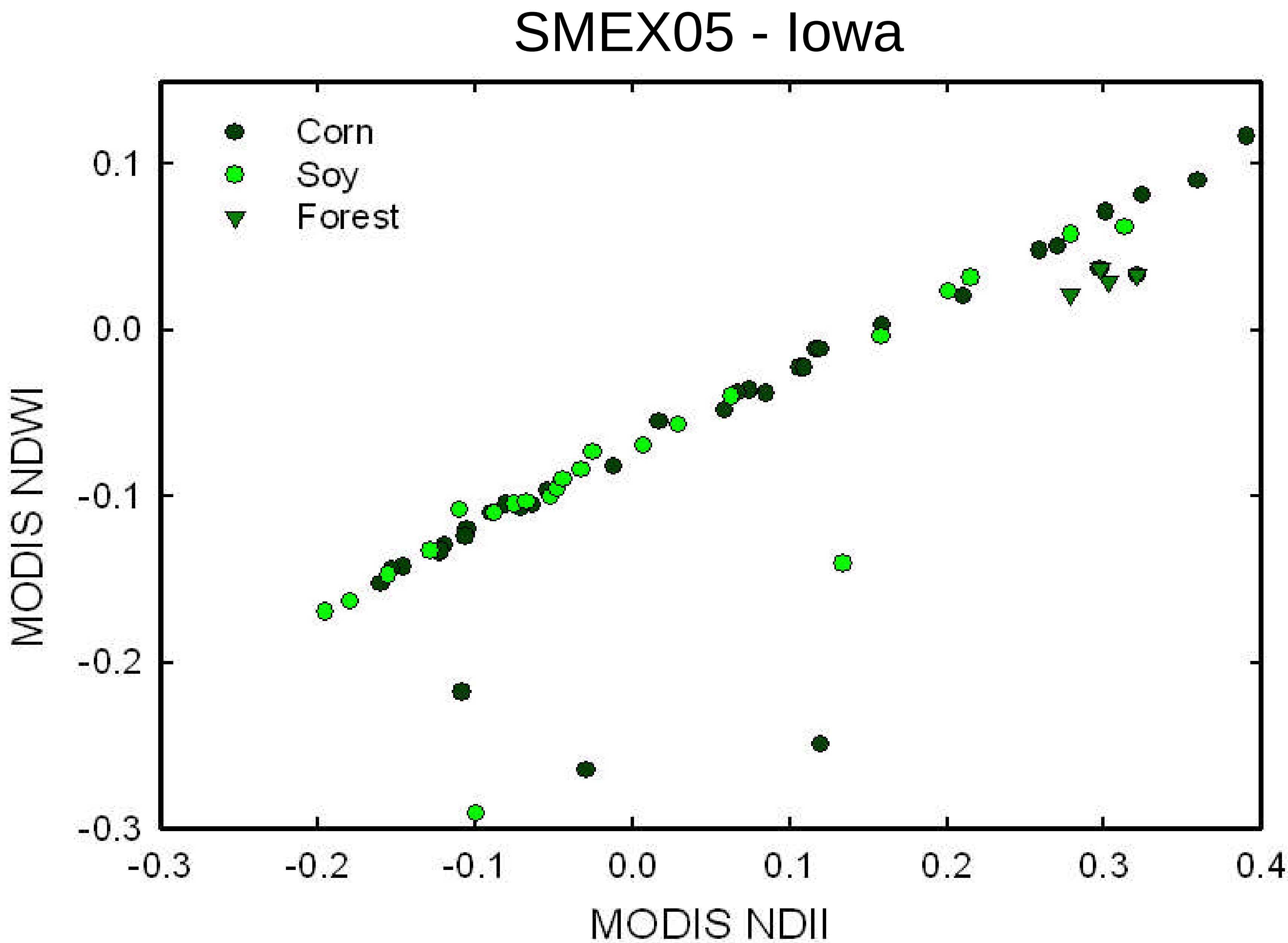

June 23, 2005
R: AWIFS Band 4 (SWIR)
G: AWIFS Band 3 (NIR)
B: AWIFS Band 2 (Red)
-0.50 – -0.15
-0.15 – -0.05
-0.05 – 0.05
0.05 – 0.15
0.15 – 0.25
0.25 – 0.40
0.40 – 0.70



0.6
0.4
0.2
0.0
-0.2
-0.4
NDII
140
160
180
200
220
240
Day of 2005
A
T
T
W
W
A
W
T
T
T
Corn 01
Corn 04
Corn 05
Corn 10
Corn 12
Soybean 06
Soybean 11
Soybean 15
Soybean 33
Soybean 38
Woodland 41
Woodland 42
Woodland 46
Woodland 50
Woodland 51

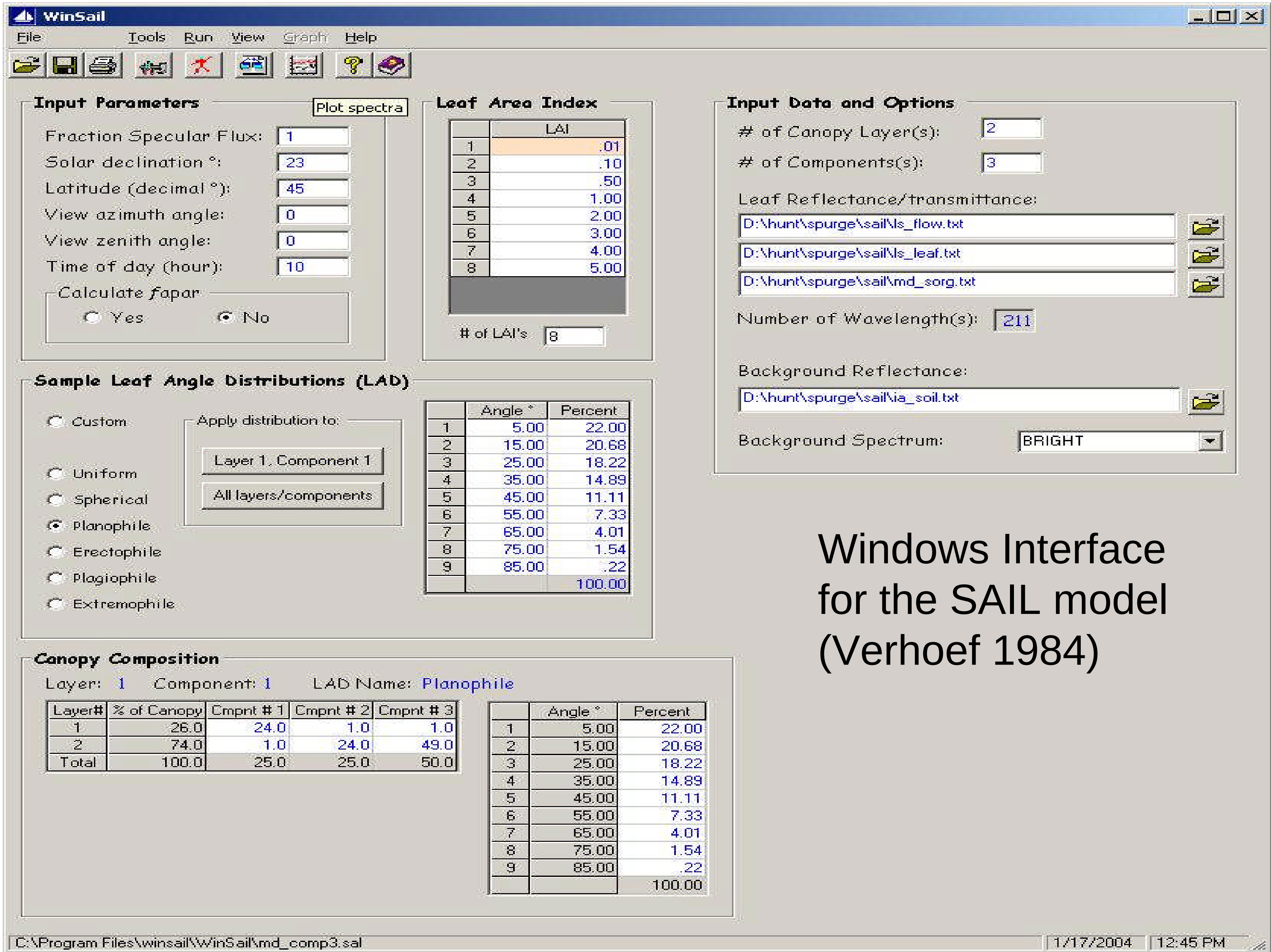
Canopy Water Content – All studies



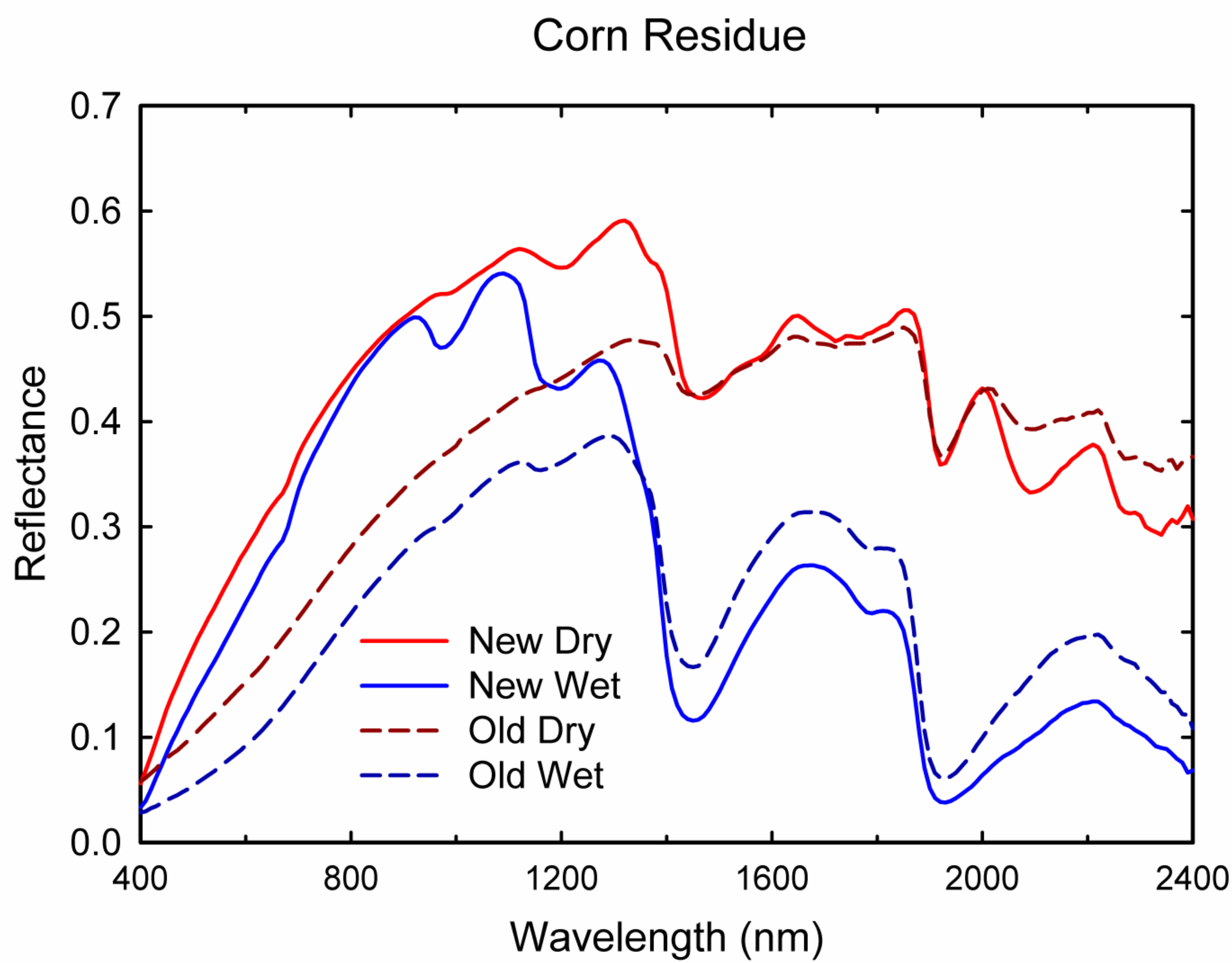


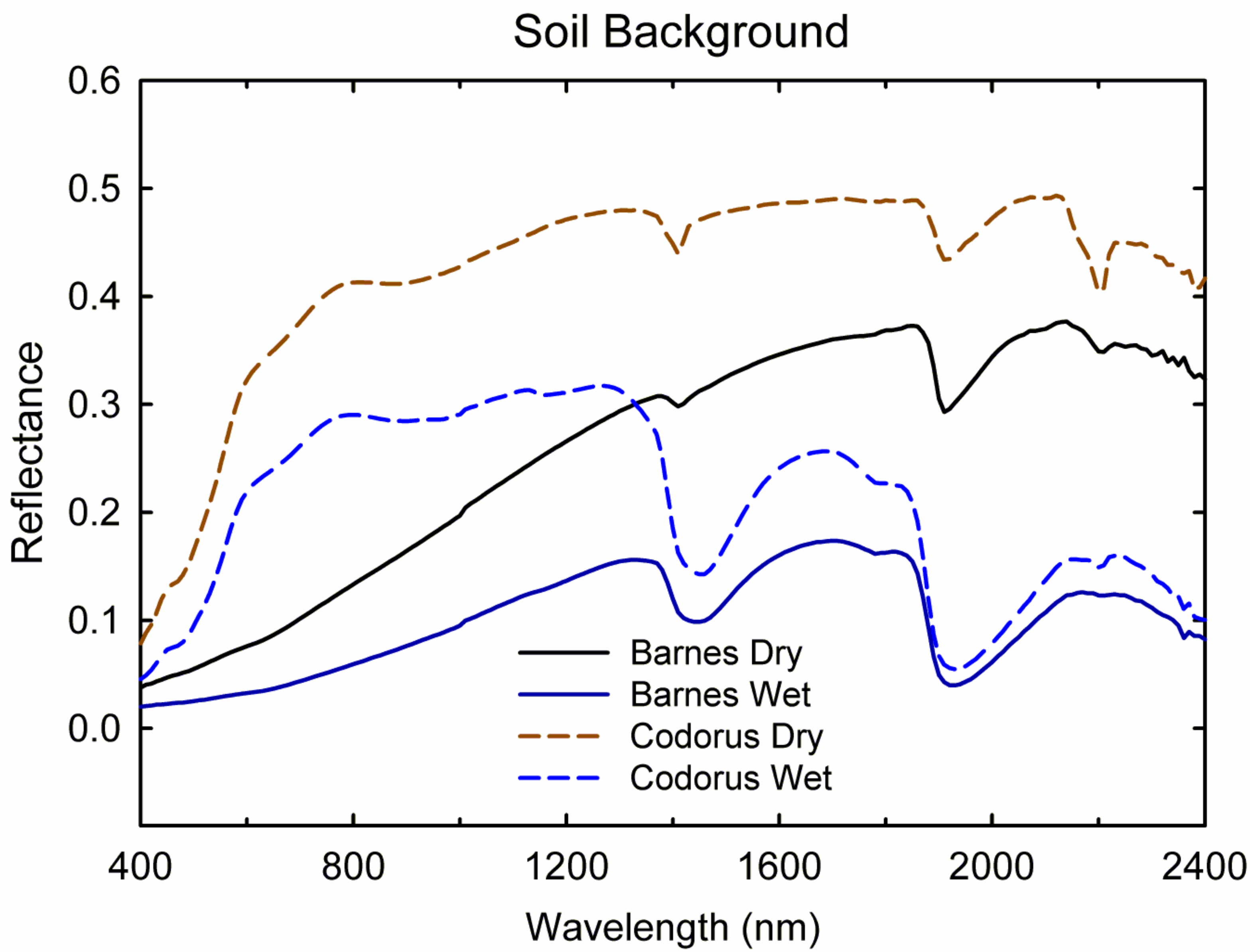
SMEX05 - Iowa
Corn
Soy
Forest
0.1
0.0
-0.1
-0.2
-0.3
MODIS NDWI
-0.3
-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
MODIS NDII


Statistical relationships between NDII and
canopy water content need basis for scaling
up leaf to canopy reflectances

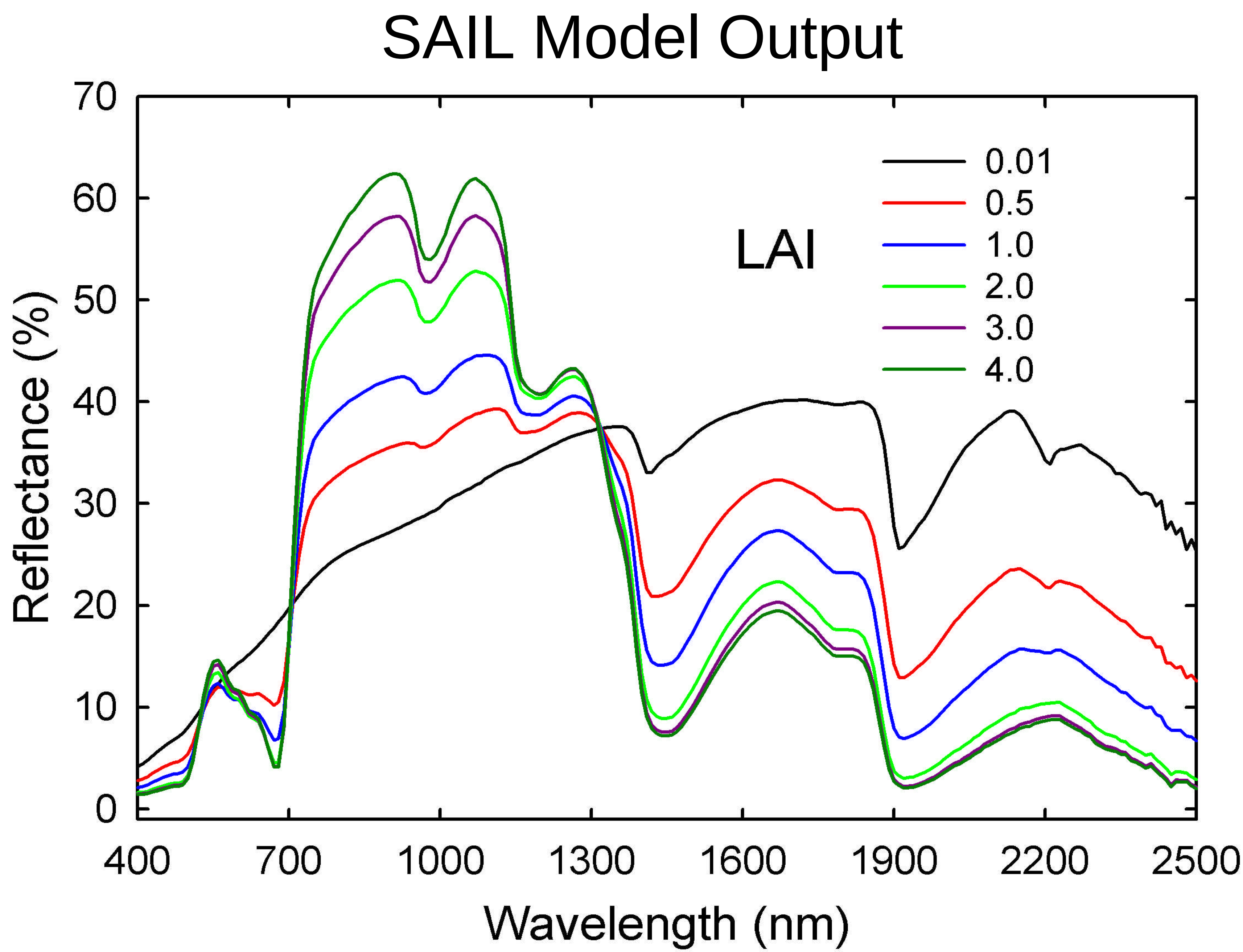


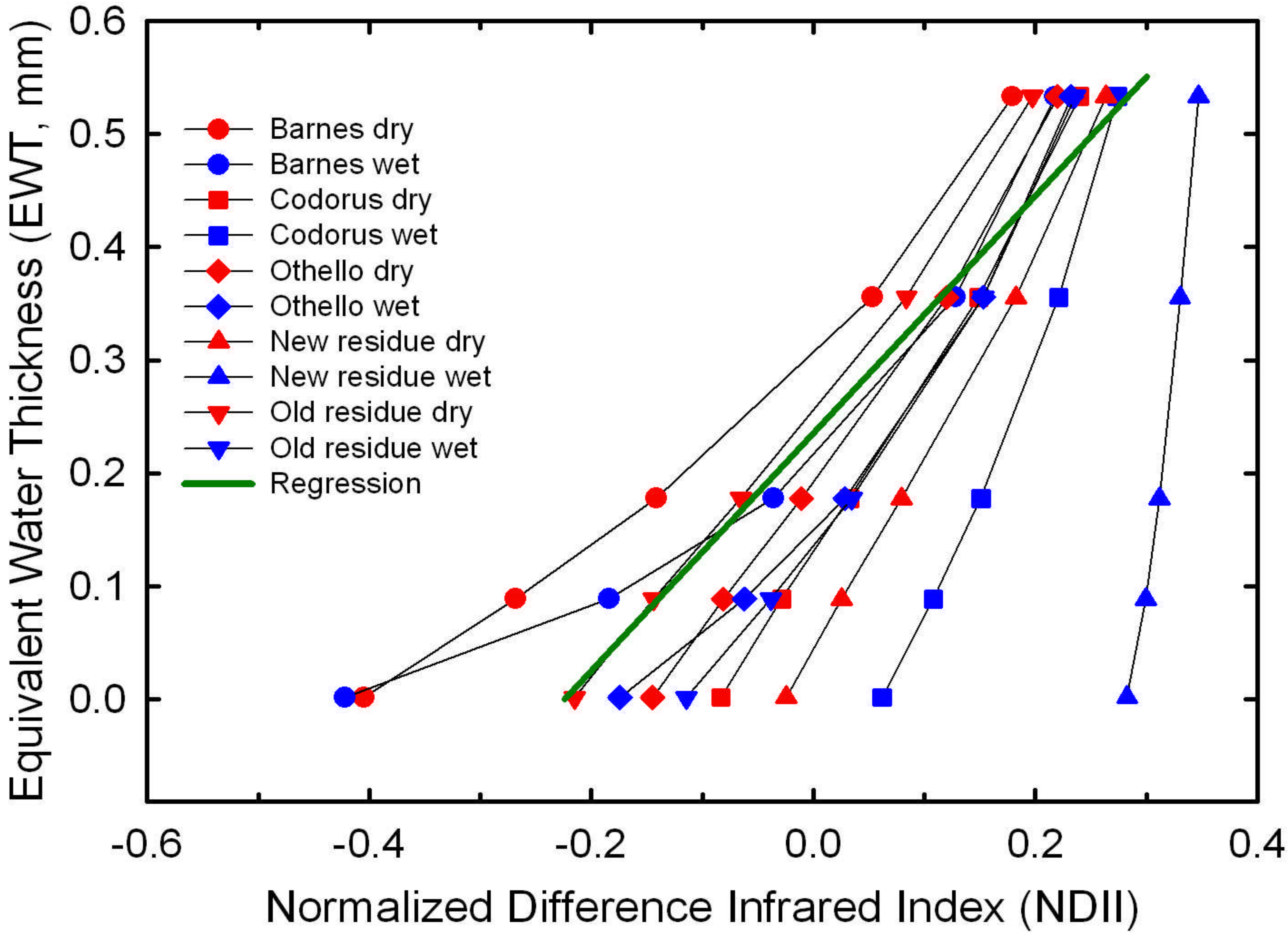
Windows Interface for the SAIL model (Verhoef 1984)


Corn Residue
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Reflectance
400
800
1200
1600
2000
2400
Wavelength (nm)
New Dry
New Wet
Old Dry
Old Wet



Soil Background
Reflectance
0.6
0.5
0.4
0.3
0.2
0.1
0.0
400
800
1200
1600
2000
2400
Wavelength (nm)
Barnes Dry
Barnes Wet
Codorus Dry
Codorus Wet


SAIL Model Output
Reflectance (%)
70
60
50
40
30
20
10
0
400
700
1000
1300
1600
1900
2200
2500
Wavelength (nm)
LAI
0.01
0.5
1.0
2.0
3.0
4.0

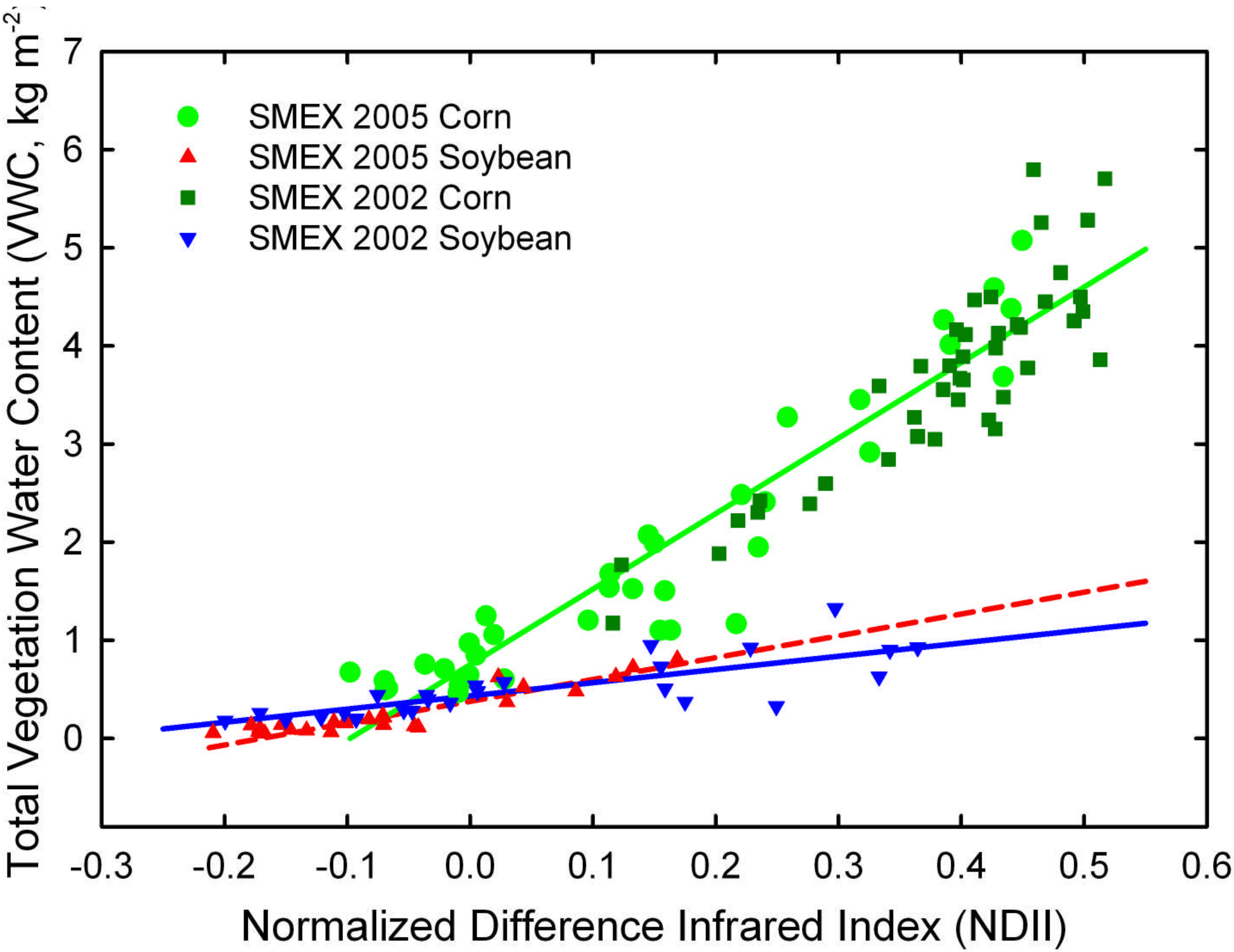


Equivalent Water Thickness (EWT, mm)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Barnes dry
Barnes wet
Codorus dry
Codorus wet
Othello dry
Othello wet
New residue dry
New residue wet
Old residue dry
Old residue wet
Regression
-0.6
-0.4
-0.2
0.0
0.2
0.4
Normalized Difference Infrared Index (NDII)

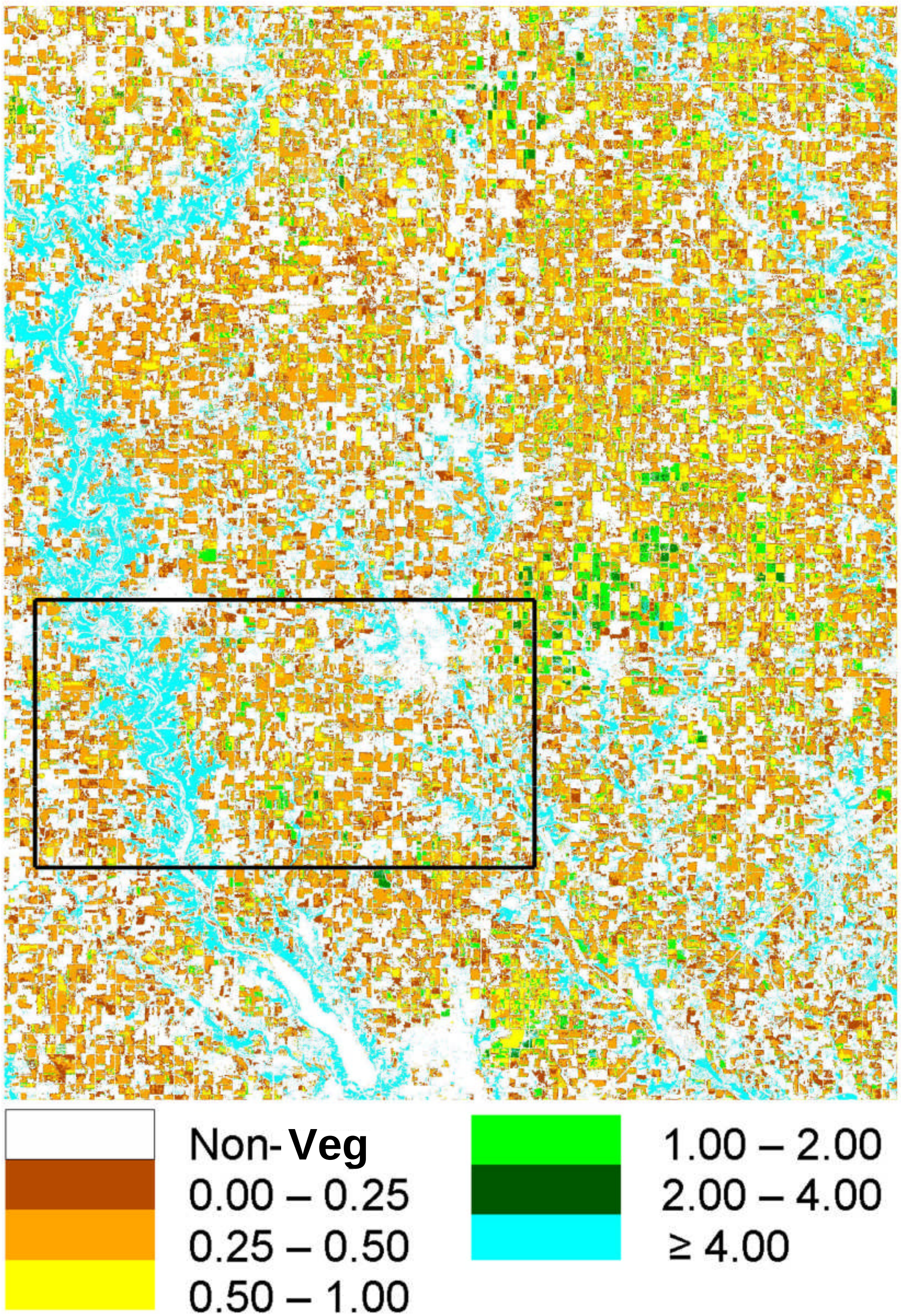
Allometric relationships may be used to relate Canopy Water Content to total Vegetation Water Content (VWC = stems + leaves)

Stem Water Volume = α (Leaf Water Volume)$^{\beta}$

Separate relationships by land cover class



SMEX 2005 Corn
SMEX 2005 Soybean
SMEX 2002 Corn
SMEX 2002 Soybean
Total Vegetation Water Content (VWC, kg m-2)
Normalized Difference Infrared Index (NDII)
-0.3
-0.2
-0.1
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0
1
2
3
4
5
6
7



SMEX05 – Iowa

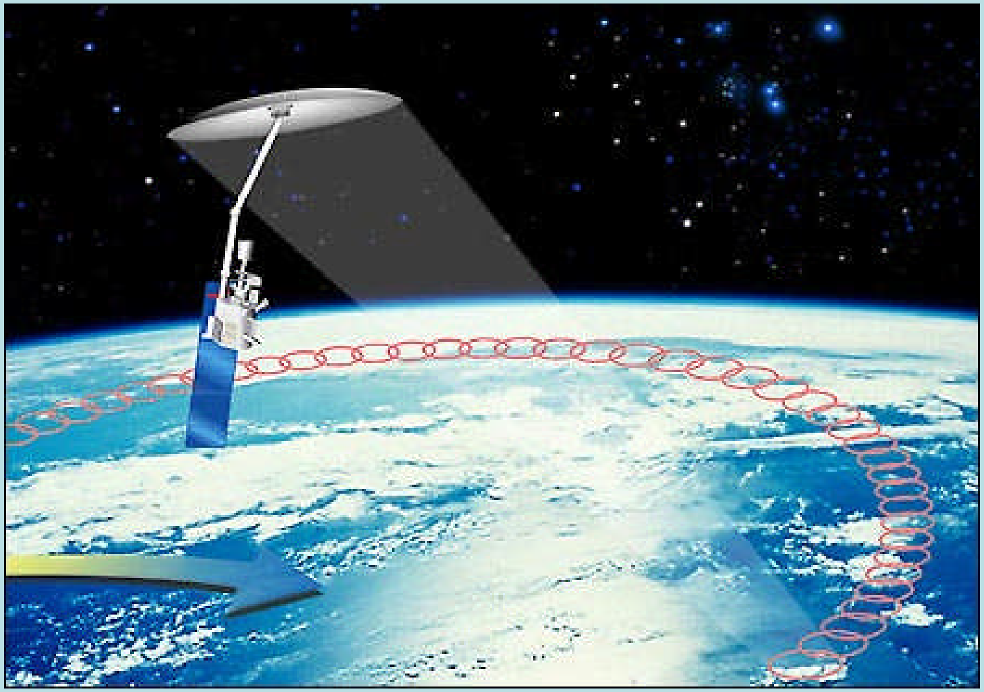
Total VWC as a function of NDII and land-cover class

Land cover from USDA – NASS

AWiFS: July 18, 2005

Useful for microwave remote sensing of soil moisture

Soil Moisture Active Passive (SMAP) Mission



This SMAP, not this SMAP

Conclusions

- NDII using AWiFS band 5 (SWIR:1.55-1.70 µm) or MODIS band 6 (SWIR: 1.63-1.65 µm) estimates canopy water content independent of land-cover class
- AWiFS and other sensors can use NDII to produce maps of vegetation water content for input into microwave soil moisture algorithms, but total vegetation water content requires an allometric relationship between CWC and VWC
- Estimation of plant water stress is problematic at this time because NDII is very highly correlated to leaf area index


Thank you very much