Interannual multitemporal applications of Landsat to forest ecosystem monitoring and management

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Key Co-Is & Collaborators

- Chris Potter & Rama Nemani, NASA Ames
- Christine Blinn, Valquiria Quirino, Susmita Sen, Jess Walker, Tom Fox, Carl Zipper, & John Seiler, Virginia Tech
- Feng Gao & Jeff Masek, NASA Goddard
- Sam Goward, UMD
- Jason Moan, NC Division of Forestry
- Buck Kline, VA Department of Forestry
- Jim Ellenwood, USDA Forest Service

Overall Objective

- R&D in support of increased utilization of Landsat data for forest science and management, with particular focus on US Southeast, including forest industry

Key Themes

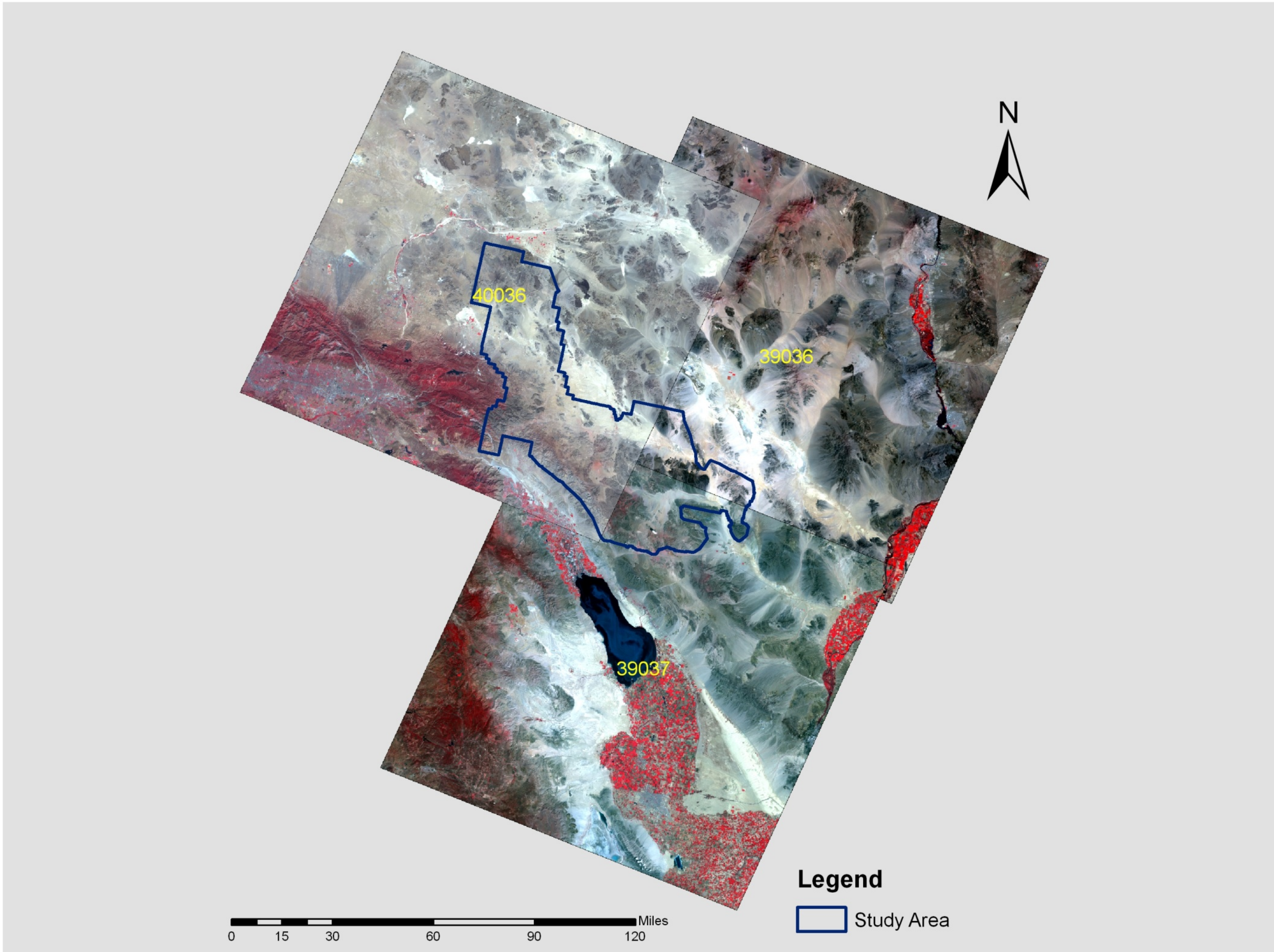
- Explicitly multitemporal
- Ties with rest of LDCM team
- Collaborators across agencies & organizations (coops, NGOs)
- Applied orientation

Update Summary

- IGSCR in support of USDA Forest Service FIA Phase I in areas of rapid change (mid-NLCD cycle, indiv. scenes or mid-decadal)
  - Imagine automation complete (Musy et al. 2006; ASPRS Leica paper award)
  - Shared memory parallelization complete and publicly available (Phillips et al. 2007, 2008)
  - Parlaying this success into NASA AISR proposal
- REDD pilot on 20,000 ha in SA
- DSM pilots in Mojave and WV underway

DSM Involvement (Blinn)

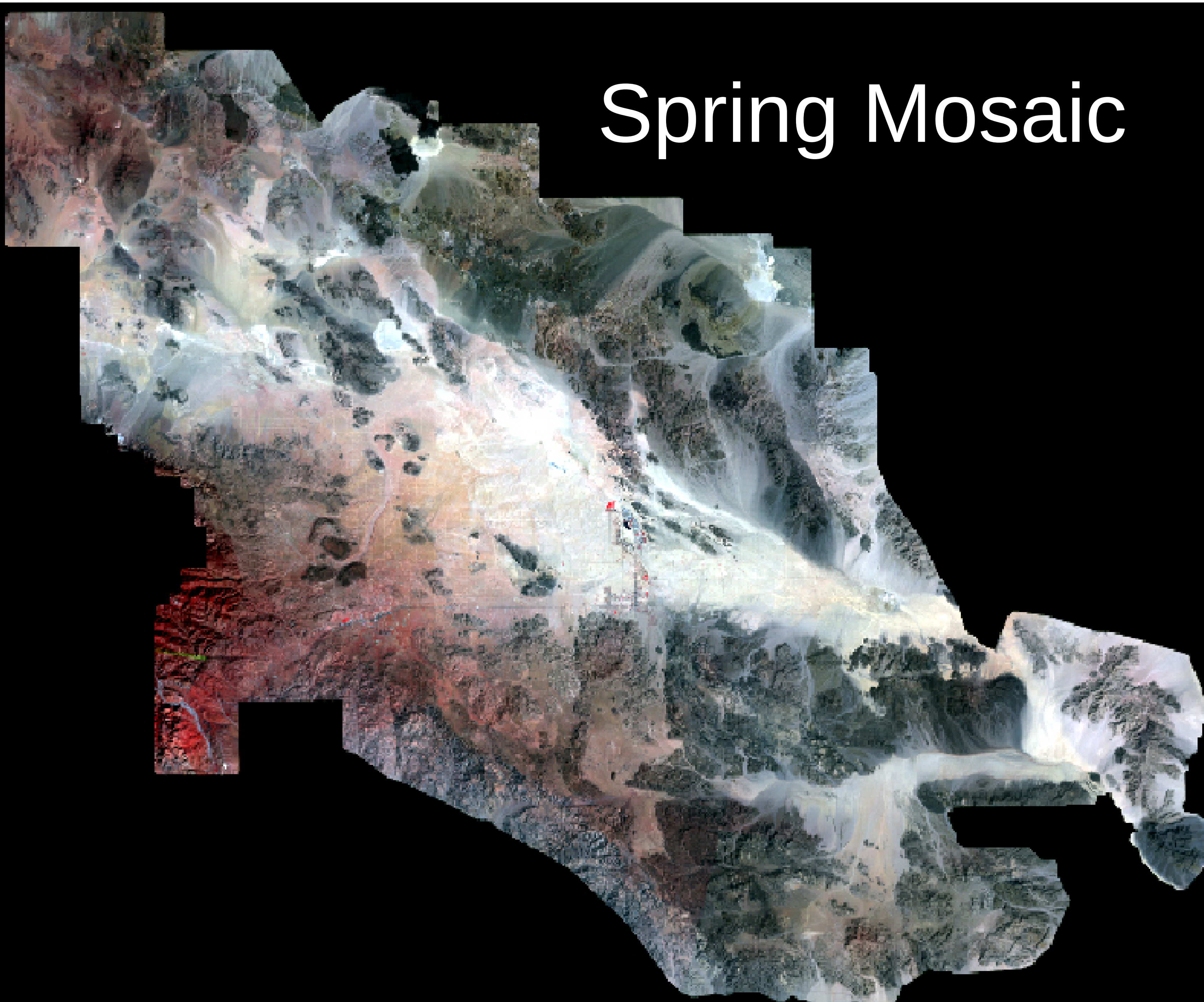
- Landsat & ASTER mosaics
- Band ratio development (TM, ASTER, other)
- Regression tree modeling
- Model design and development
- Spatial statistics
- Temperature modeling


N
40036
39036
39037
Legend
Study Area
0
15
30
60
90
120
Miles

Leaf-off Mosaic

Leaf-on Mosaic

Spring Mosaic



- Remote Sensing for Forest Carbon Management
  - Landsat downscaling prototyped using STARFM for three scenes; pine age class evaluation of algorithmic performance
  - Downscaled product being used for reducing variance in F_S models
  - Regionwide CO_2 efflux and LAI acquired at network of monospecific sites with alternative forest management strategies
  - Assessment of VI’s empirical relationship with LAI and stand growth within and across years
  - Interface with Ames LAI/fPAR team
  - CASA modeling with Landsat

Decision Support for Forest Carbon Management: From Research to Operations

MODELS

ESE
- NASA-CASA

GYC
- PTAEDA 3.1
- FASTLOB

USDA Forest Service
- FORCARB

ESE MISSIONS
- Aqua
- Terra
- Landsat 7
- ASTER

Analysis Projects
- IGBP-GCTE
- IGBP-LUCC
- USDA-FS FIA
- USDA-FS FHM

Ancillary Data
- SPOT
- AVHRR NDVI
- Forest inventory data
- VEMAP climate data
- SRTM topographic data

Inputs

Information Products, Predictions, and Data from NASA ESE Missions:

- MODAGAGG
- MOD 12Q1
- MOD 13
- MOD 15A2
- ETM+ Level 1 WRS
- AST L1B and 07

Outputs

DECISION SUPPORT:

Current DSTs
- ***COLE (county-scale)***
- ***LobDST (stand-scale)***
  - ***Growth and yield***
  - ***Product output***
  - ***Financial evaluations***
- ***CQUEST (1 km pixels)***
  - ***Ecosystem carbon pools (g C/m²)***
  - ***Partitioned NPP (g C/m²/yr)***
  - ***NEP (g C/m2/yr)***

Linked DSTs and Common Prediction Framework (multiscale)
- ***Growth***
- ***Yield***
- ***Product output***
- ***Ecosystem carbon pools***
- ***Partitioned NPP***
- ***NEP***
- ***Total C sequestration***
- ***Forecasts and scenarios***

Outcomes

VALUE & BENEFITS

Improve the rate of C sequestration in managed forests

Decrease the cost of forest carbon monitoring and management

Potentially slow the rate of atmospheric CO_2 increase

Enhance forest soil quality

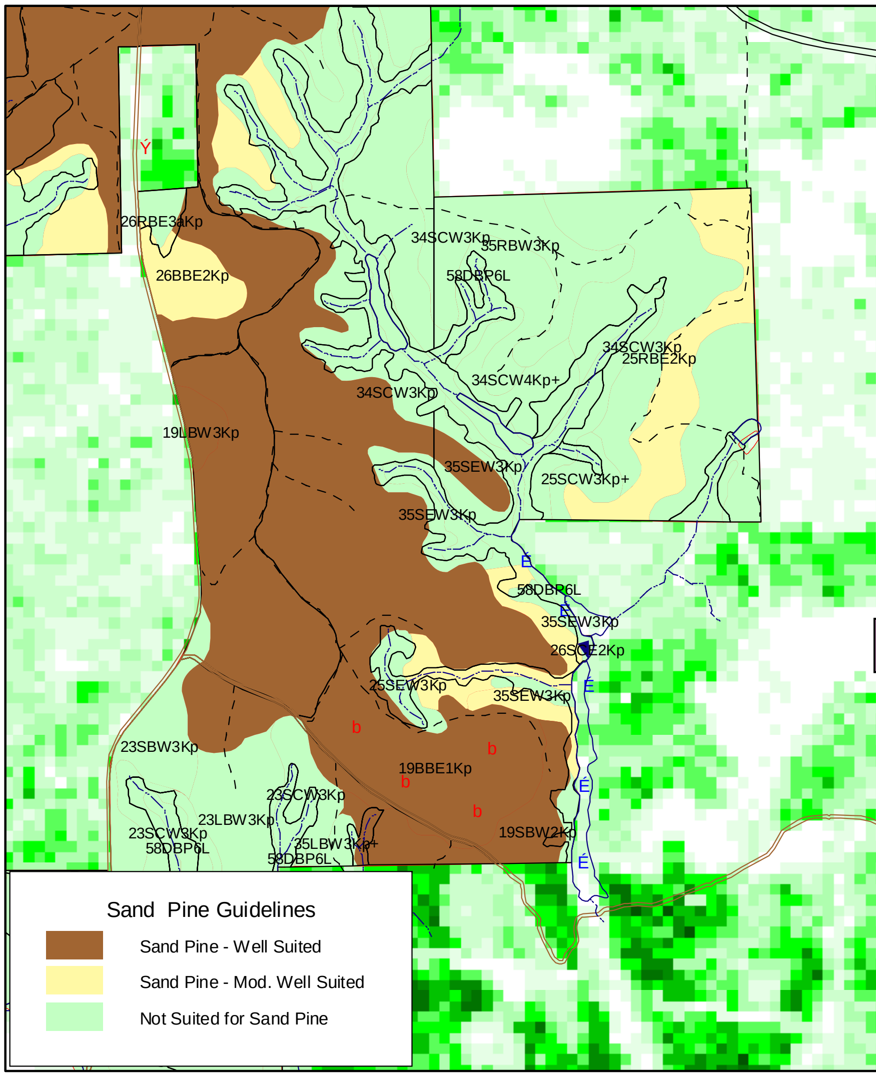
Impacts

LAI (Leaf Area Index):

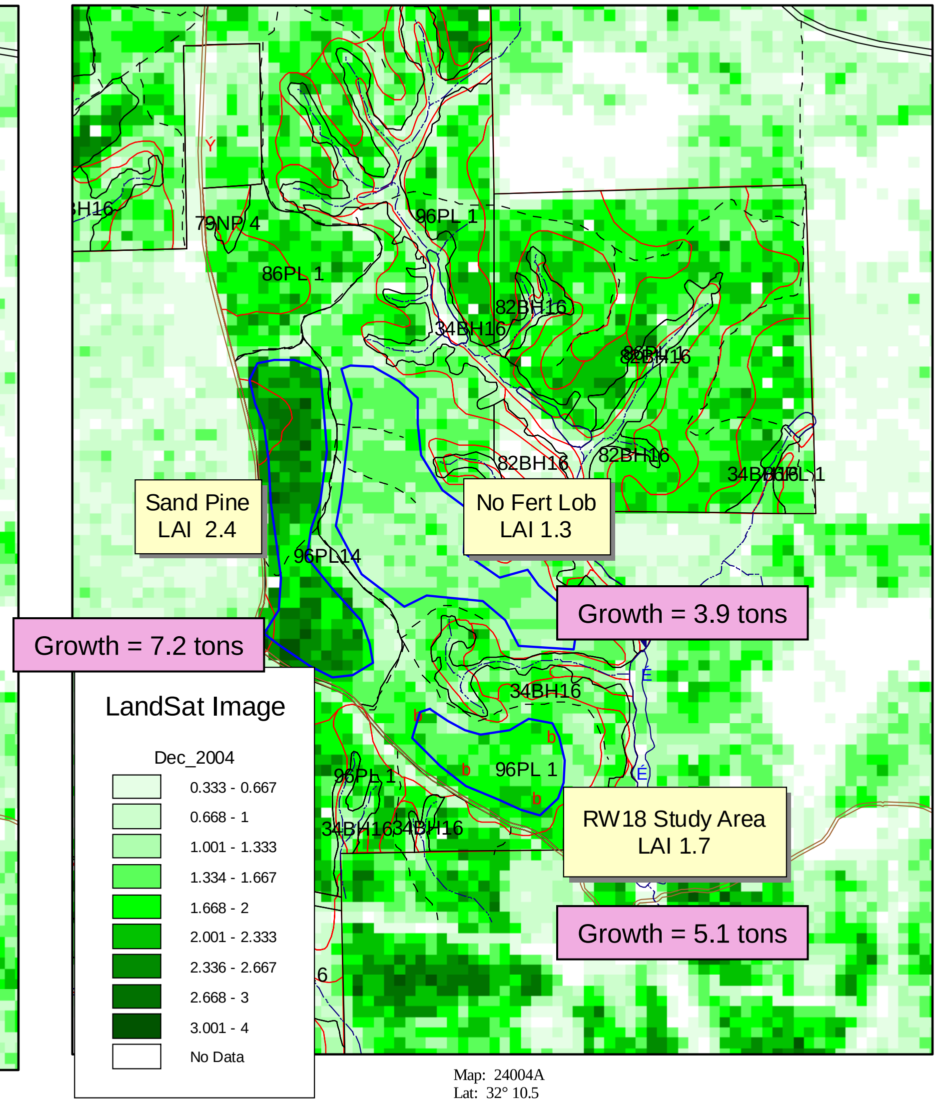
- stand stratification for inventory
- identification of poor-performing stands for early harvest
- identification of stands with high levels of competition

LAI plus GE (Growth Efficiency)

Provides ability to estimate stand-level response to silviculture: (fertilization, release, tillage)



Map: 24004A
Lat: 32° 10.5
Long: 84° 37.9
1:12118



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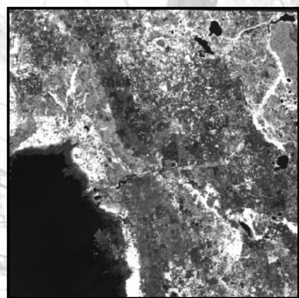
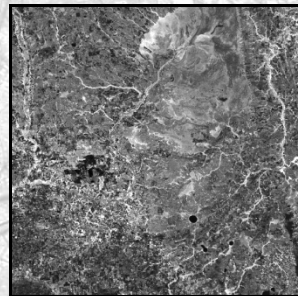
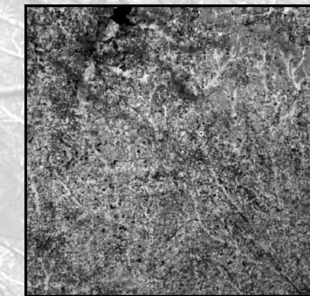
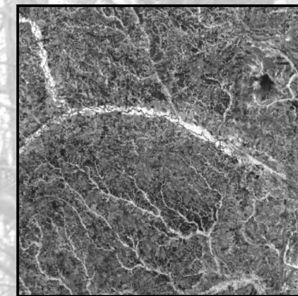
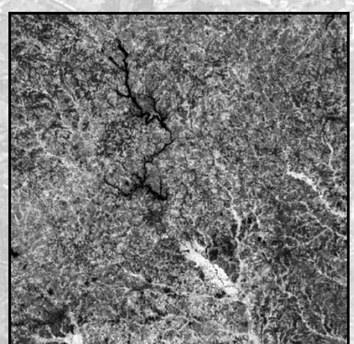
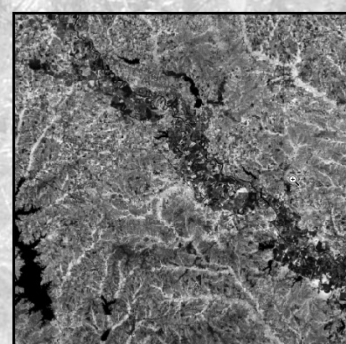
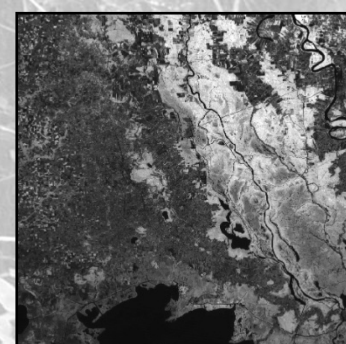
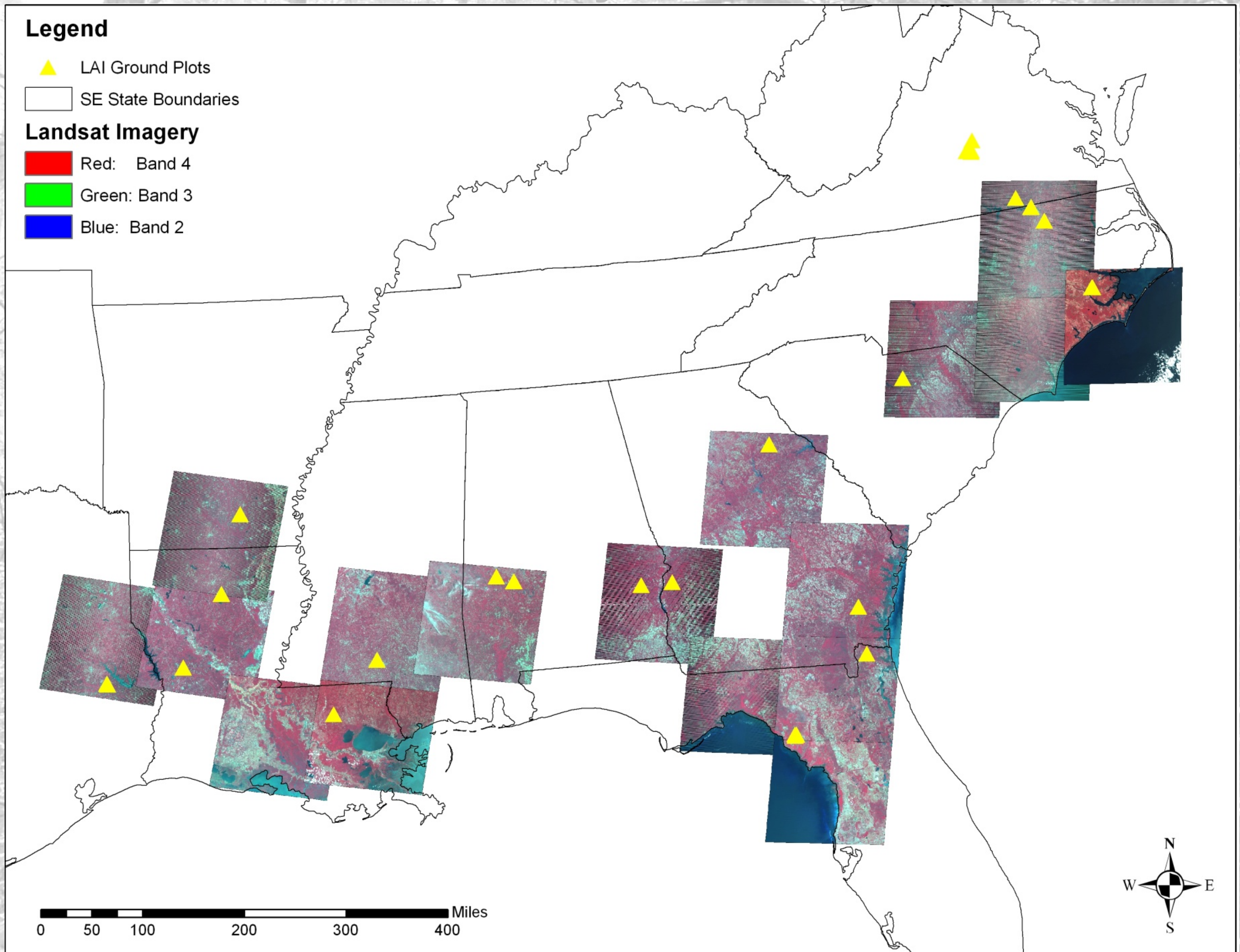





A Regionwide Evaluation of Vegetation Indices for the Prediction of Leaf Area Index in the Southeast

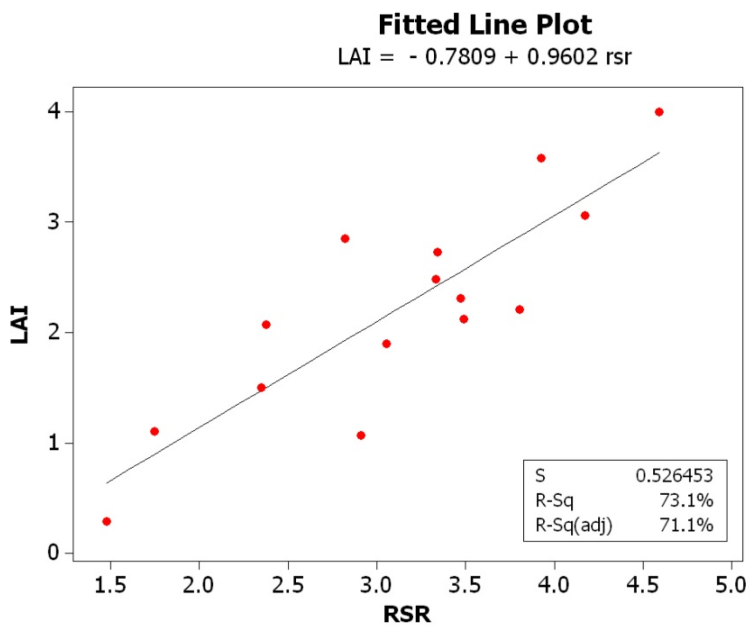





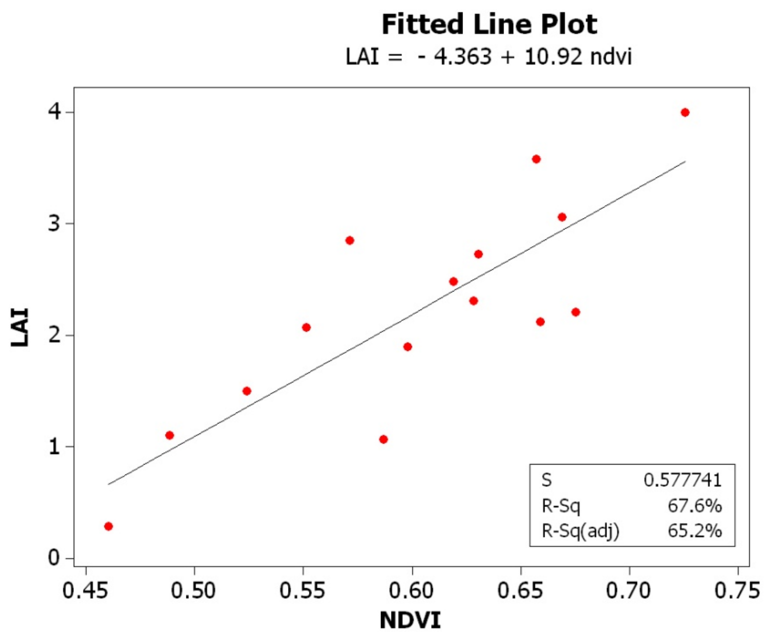
Study Area

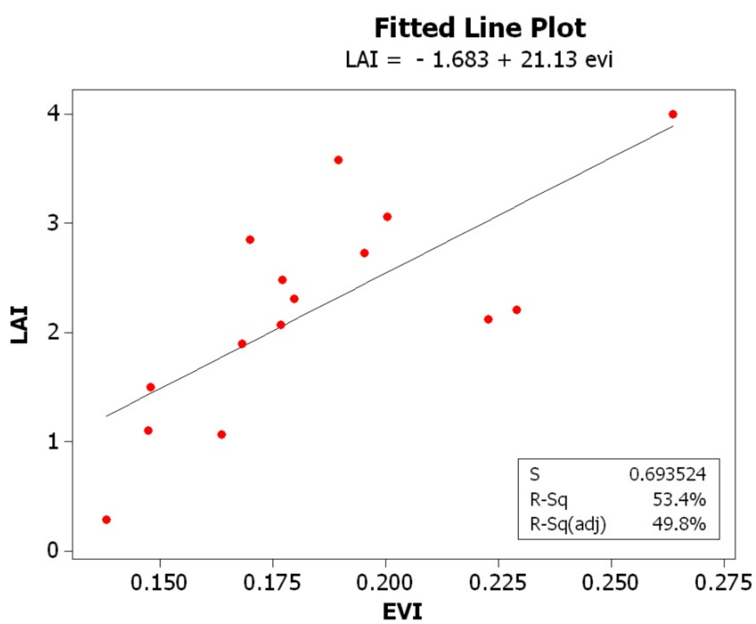


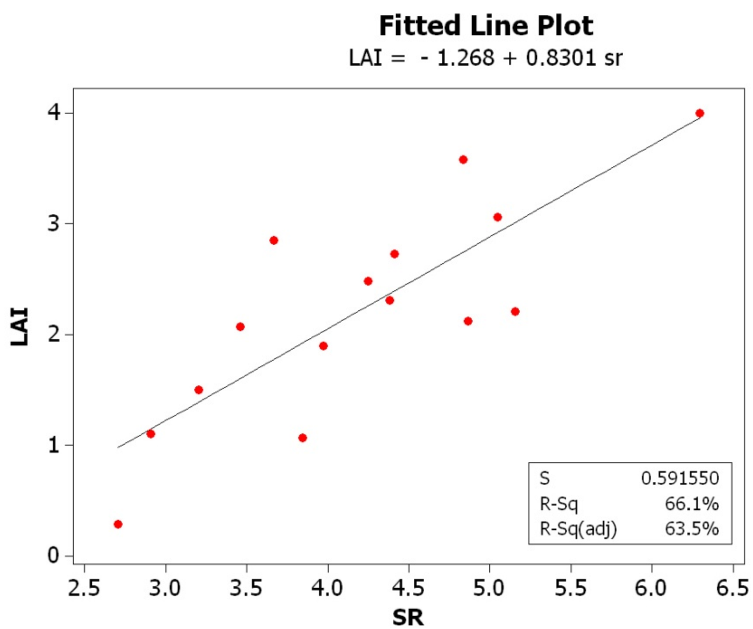
17 path/row combinations

LAI and VI Relationships

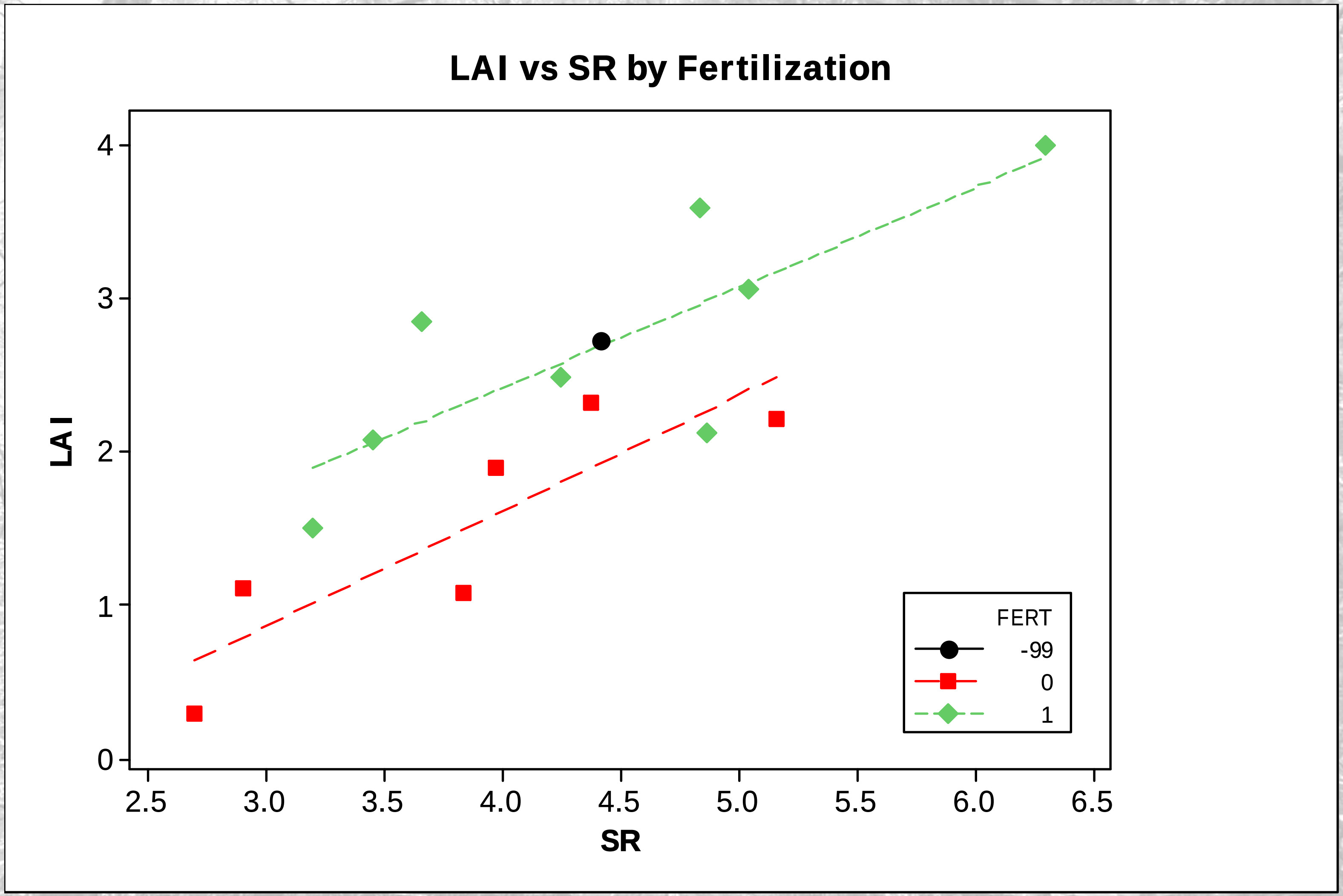








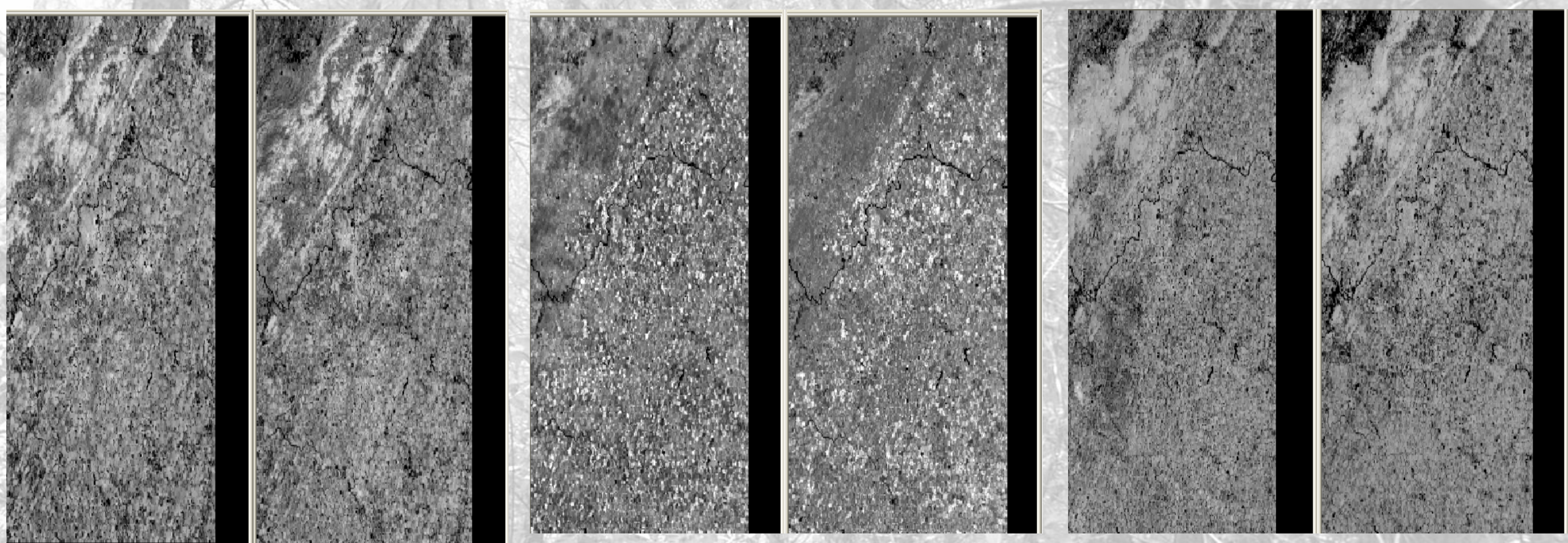
Fertilization Effect on LAI and VI Relationship



15 plots from 8 stands in three L5 images acquired either April 11 or May 2, 2006

STARFM NDVI Downscaling (Quirino, Gao)

(a) (b) (c)



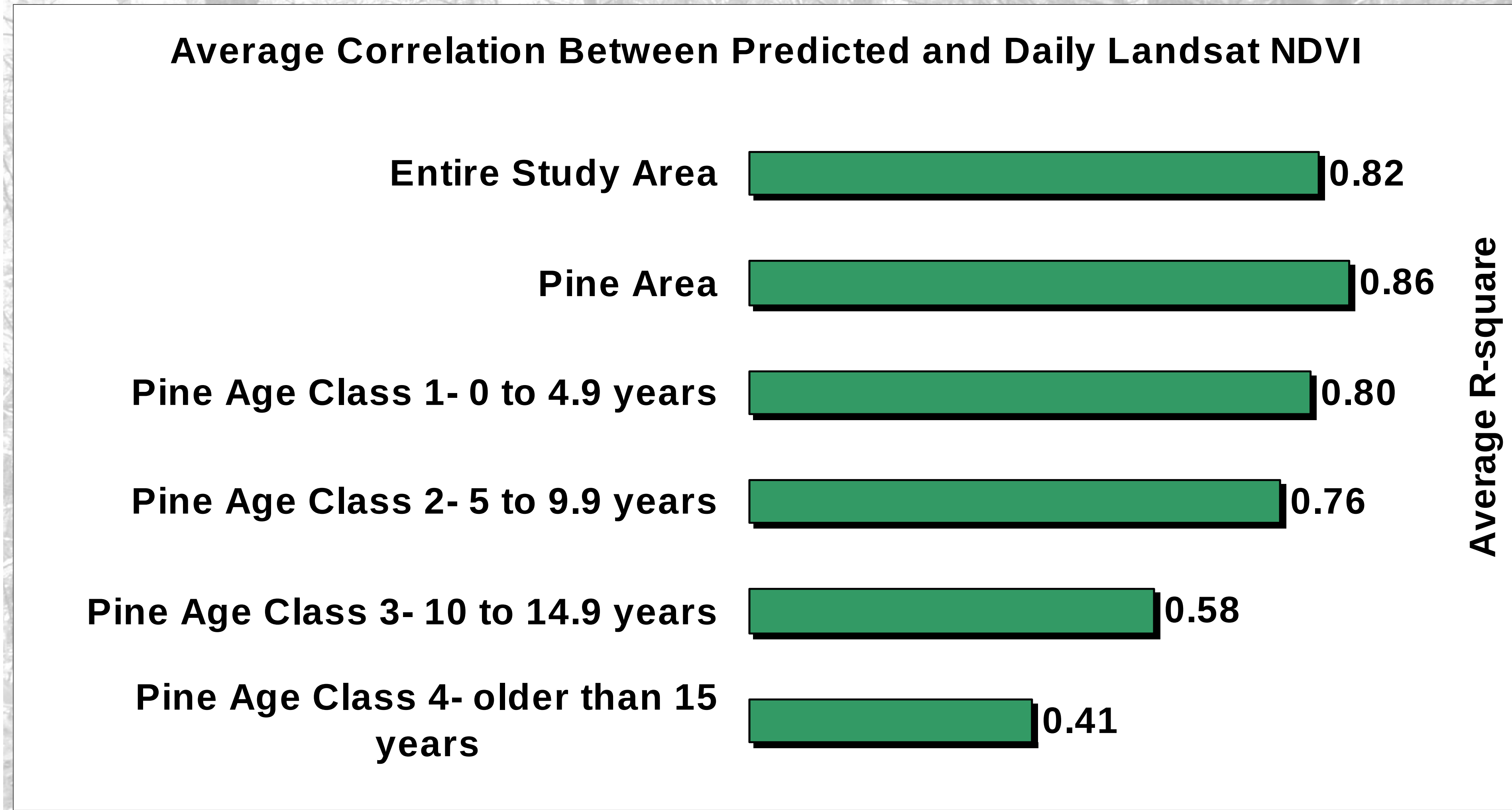
Predicted Landsat Composites (left images) and Landat Images Used for Their Validation (right images): (a) Sample 1, (b) Sample 2, (c) Sample 3.

STARFM for Pines

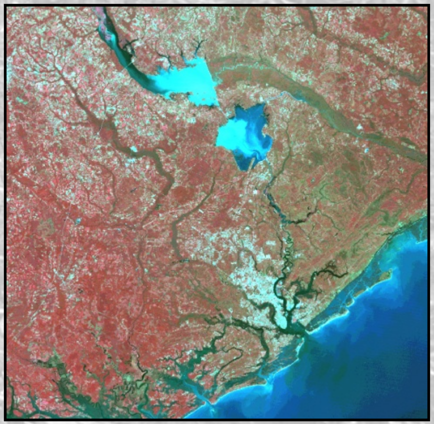
Part of the Image Included	Sample 1	Sample 2	Sample 3	Mean
Entire Image	10.8	2.7	4.4	**6.0**
Pine Area	3.4	2.1	0.1	**1.9**
Pines between 0 and 5 years	4.5	-0.4	1.1	**1.7**
Pines between 5 and 10 years	3.2	2.2	-0.2	**1.7**
Pines between 10 and 15 years	3.4	2.7	-0.1	**2.0**
Pines older than 15 years	2.4	2.6	0.1	**1.7**

Part of the Image Included	Sample 1	Sample 2	Sample 3	Mean
Entire Image	65.8	52.5	79.2	**65.8**
Pine Area	46.4	49.3	56.1	**50.6**
Pines between 0 and 5 years	60.5	48.8	85.4	**64.9**
Pines between 5 and 10 years	67.4	72.8	77.1	**72.4**
Pines between 10 and 15 years	113.0	132.4	119.0	**121.5**
Pines older than 15 years	150.4	184.2	172.0	**168.9**

Results Good Enough to Move Toward F_S Lag Analysis



Retrospective Analysis of Growth and Yield (Blinn, Goward, Masek)



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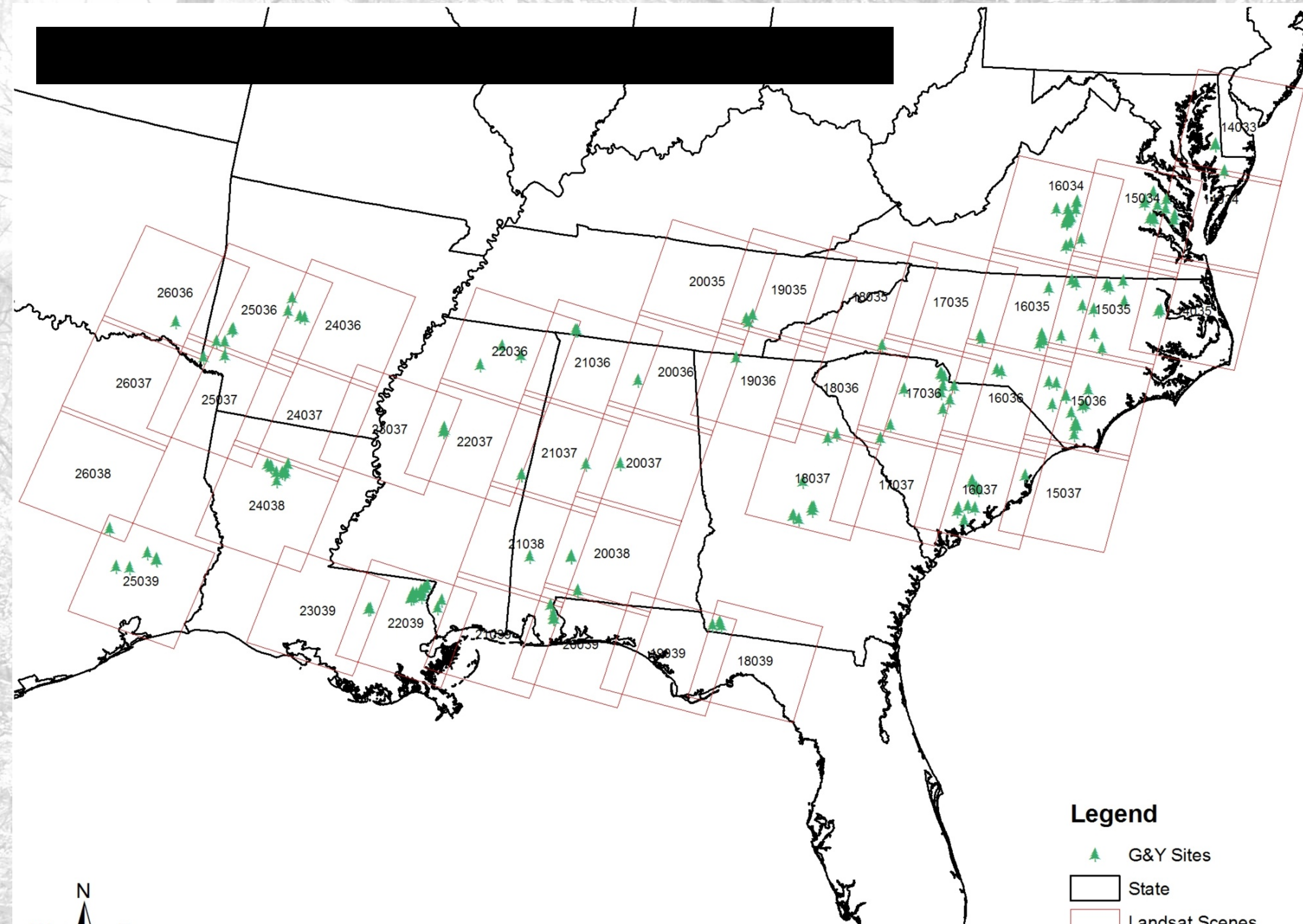
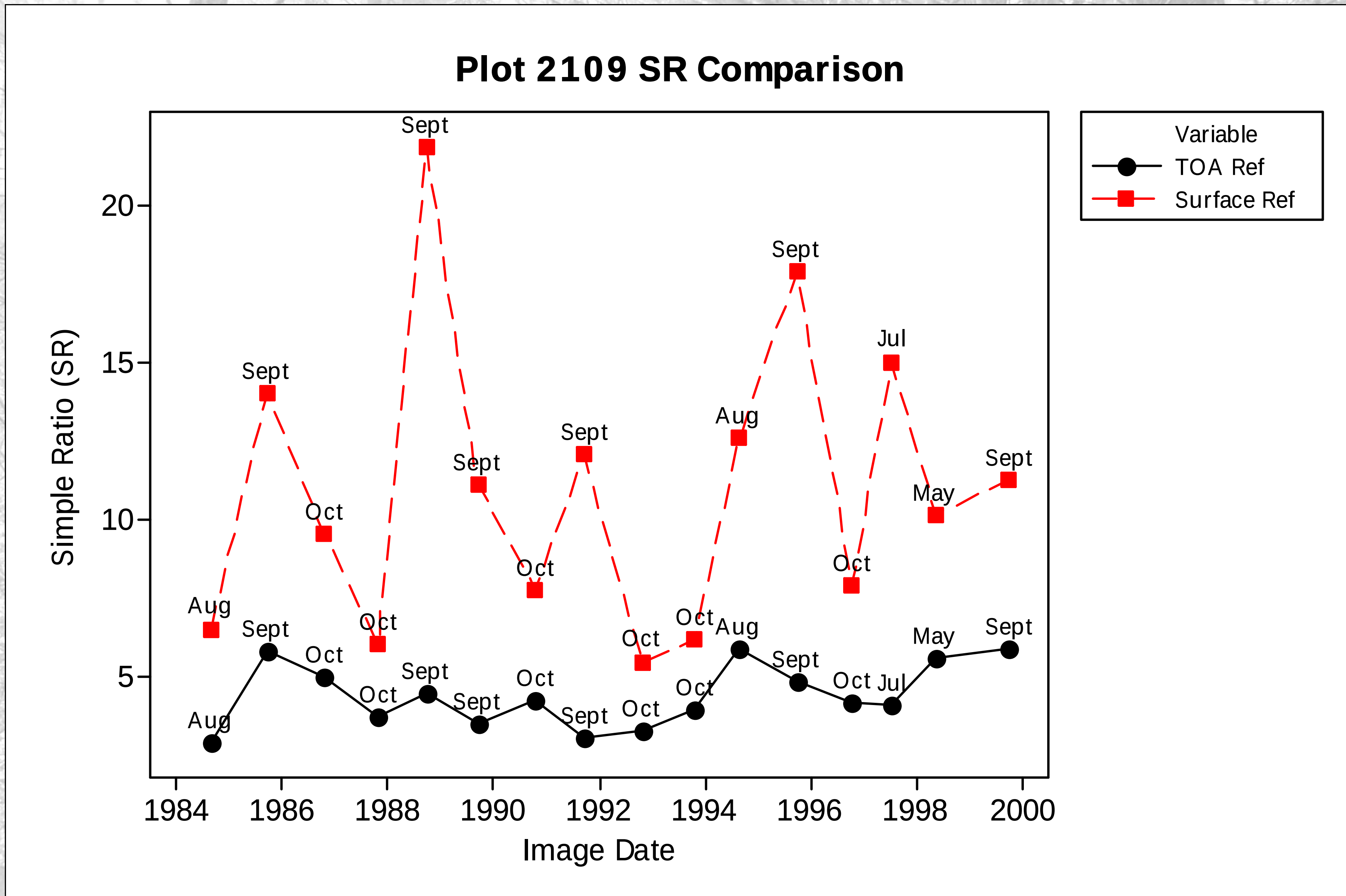


Landsat Scenes with Growth & Yield Sites

44 Landsat Scenes contain at least one G&Y Site

Retrospective Analysis cont...

- Available Imagery:
  - 5 Landsat scene stacks were provided by the University of Maryland (UMD) courtesy of Sam Goward & Chengquan Huang
  - Each scene stack contained a time series of at least 12 images from 1984 through 2005 (at least 1 image every other year)
  - Scene stacks were already:
    - coregistered (aligned with each other)
    - converted to surface reflectance



13 years old in 1984

Summary

- Conversion of Landsat data to surface reflectance resulted in more scene to scene variation then TOA reflectance.

- Thus far, it appears that the stands used to develop the LPG&Y Coop’s growth and yield models had relatively low leaf areas.

    - Caveat: The Flores LAI equation was not validated for use with earlier Landsat TM scenes.

- Updated growth and yield models may be needed to accurately predict the outcomes of current silvicultural regimes.

Update Summary III (Moan, Ellenwood)

- Forest Health
  - Southern Pine Beetle hazard rating pilot (Landsat + NC Statewide Lidar)
  - Slight improvement in Landsat-based host BA models (Cubist) when statewide lidar-derived DEM used
  - Also integrating forest age into hazard rating using DI for age classes deemed susceptible to SPB from CART/Cubist models

Update Summary IV

- OSM Abandoned Minelands Reforestation Pilot (Sen, Zipper, Masek)
  - Focus on WV and western VA
  - Detection of previously mined areas (first phase)
  - Assessment of reclamation quality
  - Using explicit trajectory-based approach


3
2
1
10
9
8
7
N
0
0.125
0.25
0.5
Kilometers

Multitemporal approach-Rationale

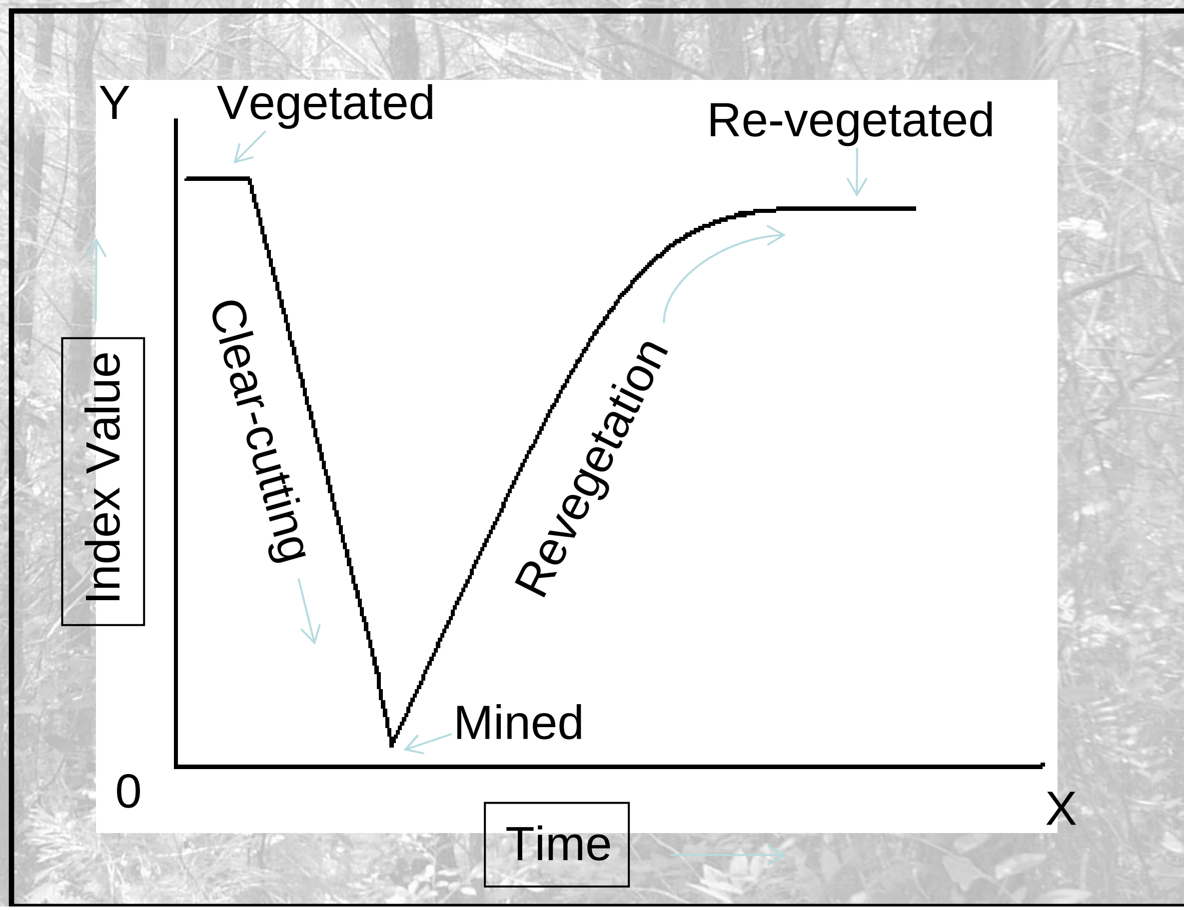
•Disturbance like mining has distinctive temporal progressions of spectral values

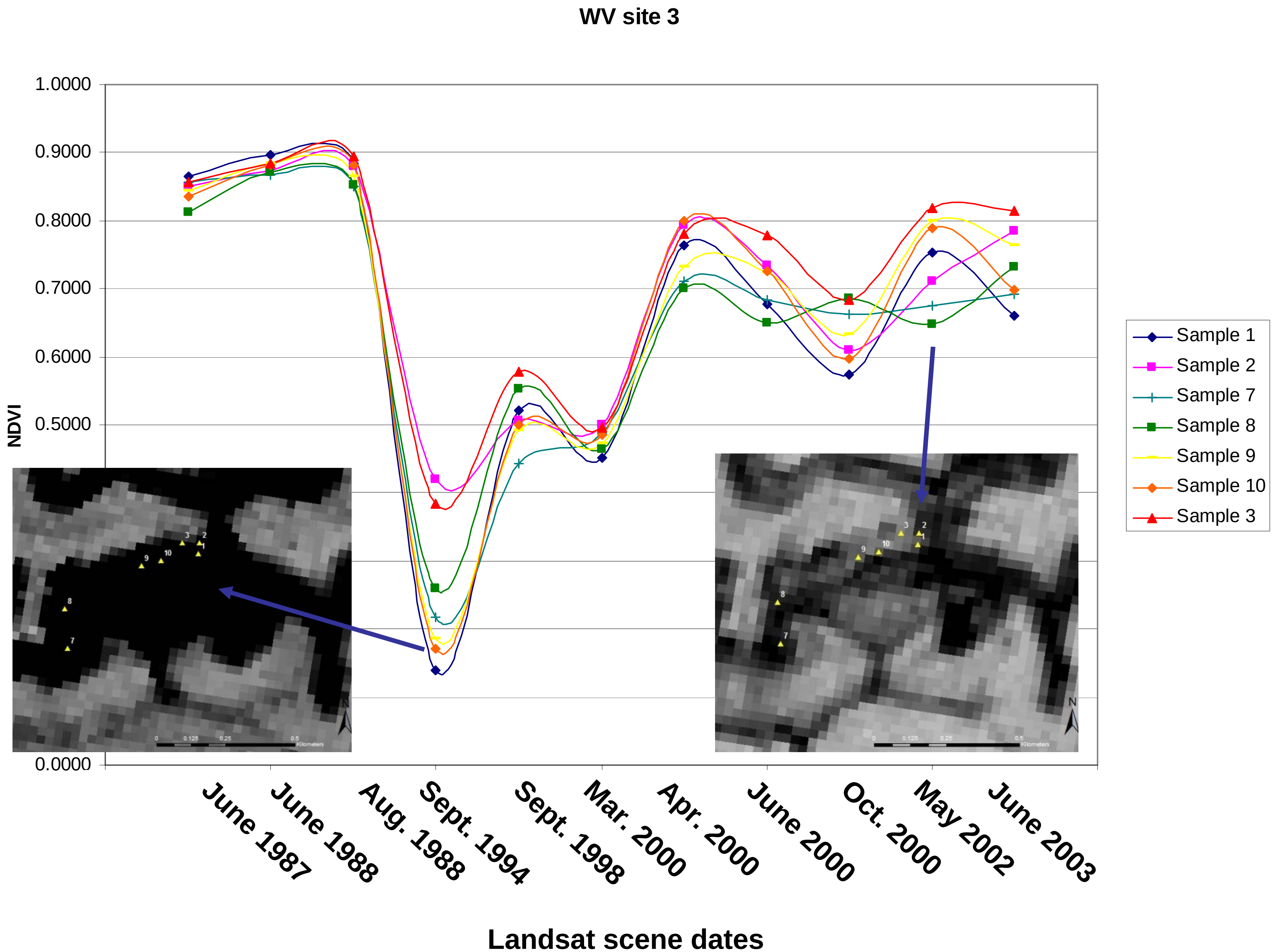
• Temporal trend of vegetation recovery termed as "spectral trajectory"

• Spectral trajectories function as a diagnostic of the change

•Multitemporal trends are more stable than individual image pixel change reading (Kennedy et al, 2007).

Fig.1 Ideal Spectral Trajectory of a reclaimed mined vegetation



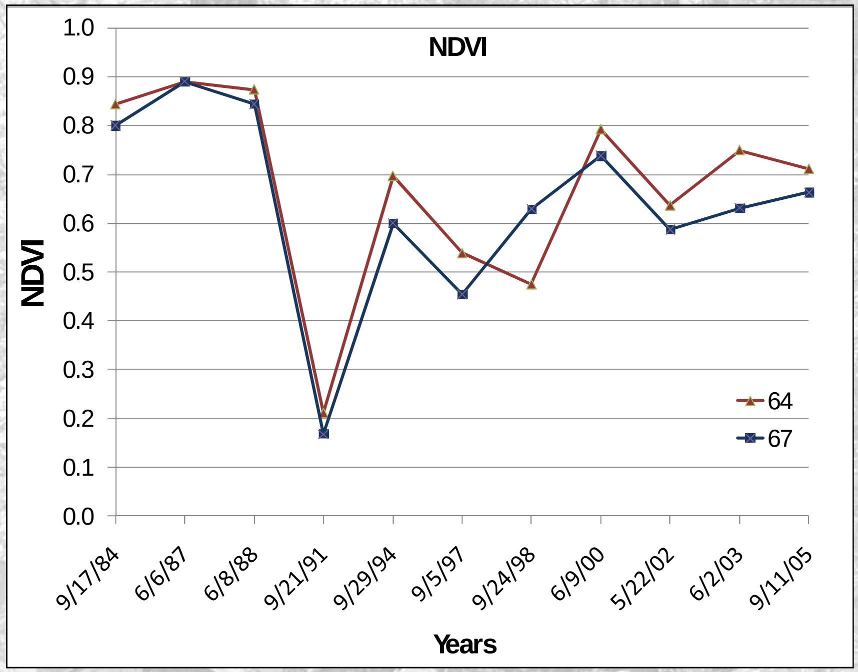


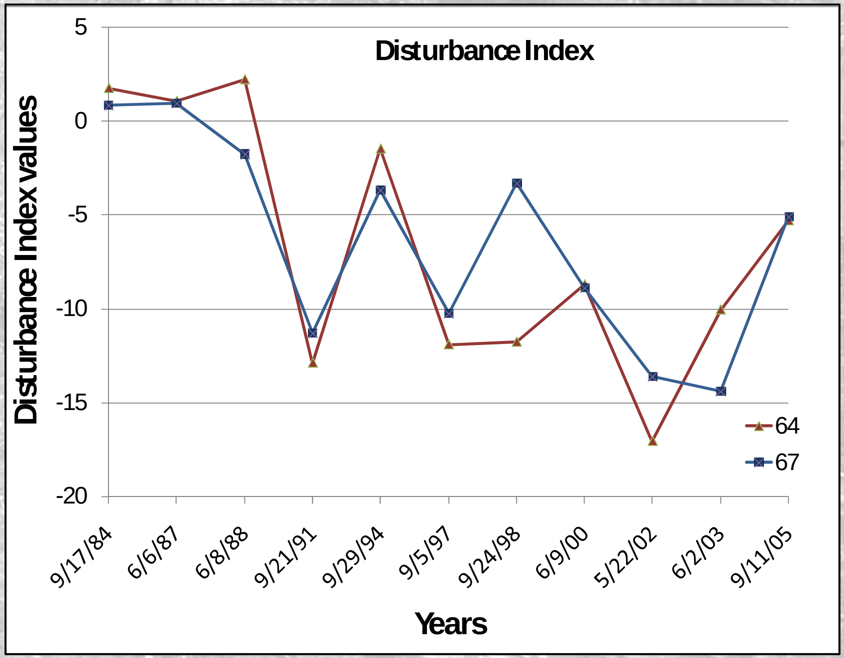
WV site 3
NDVI
1.0000
0.9000
0.8000
0.7000
0.6000
0.5000
0.0000
Sample 1
Sample 2
Sample 7
Sample 8
Sample 9
Sample 10
Sample 3
June 1987
June 1988
Aug. 1988
Sept. 1994
Sept. 1998
Mar. 2000
Apr. 2000
June 2000
Oct. 2000
May 2002
June 2003
Landsat scene dates

Search for the ideal index value:

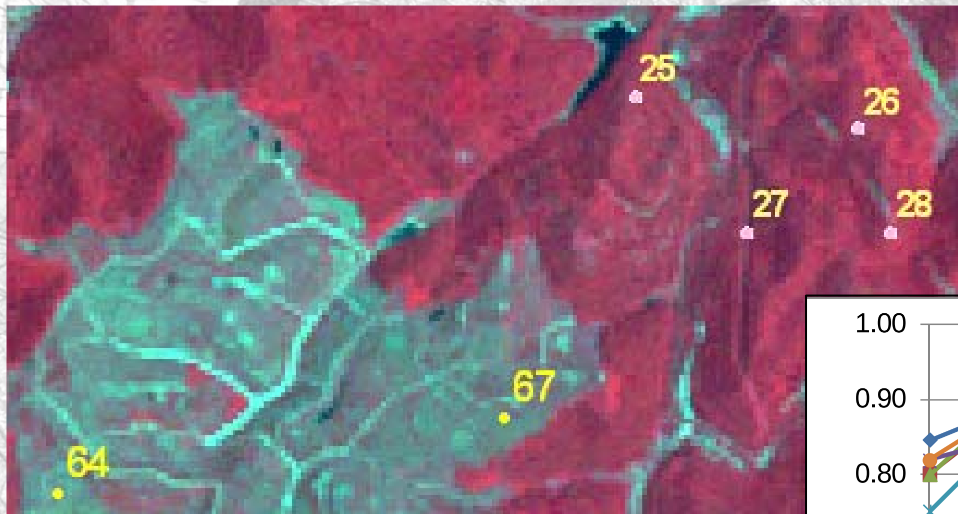
1988, points not mined

1991, points already mined



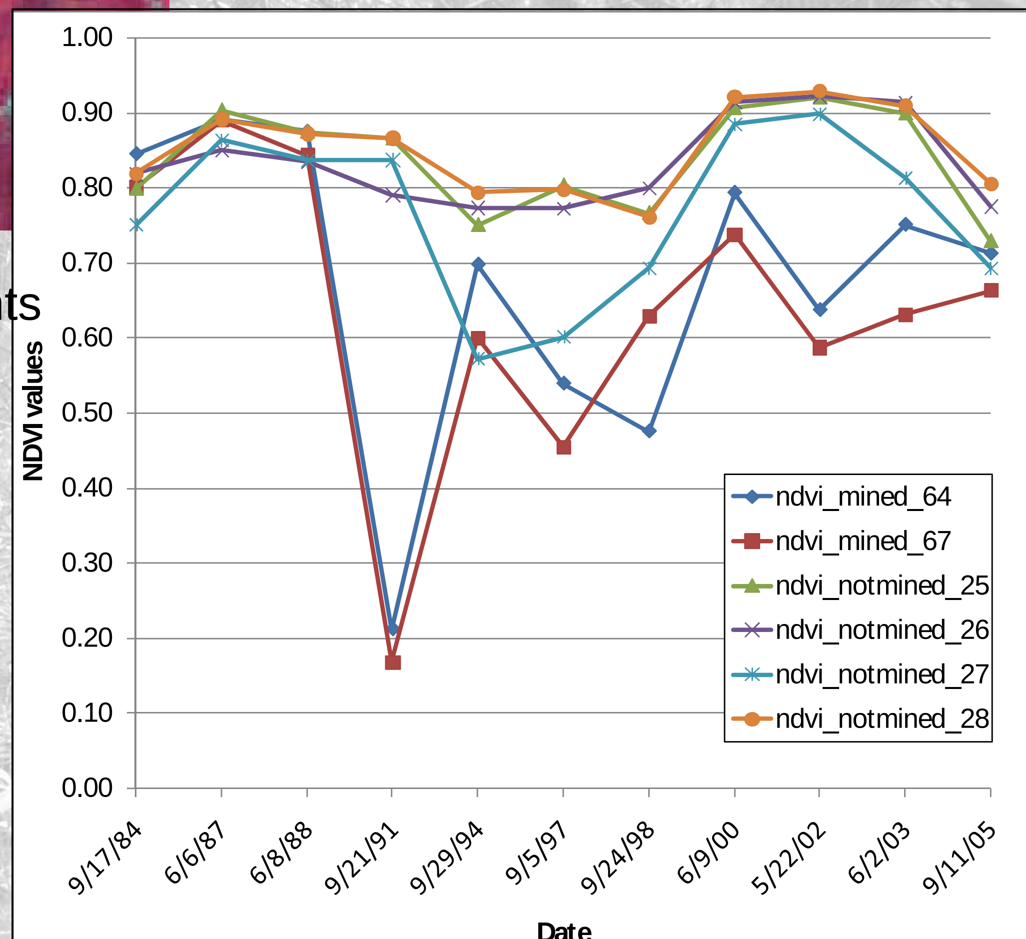


Comparison of NDVI of mined and surrounding un-mined points



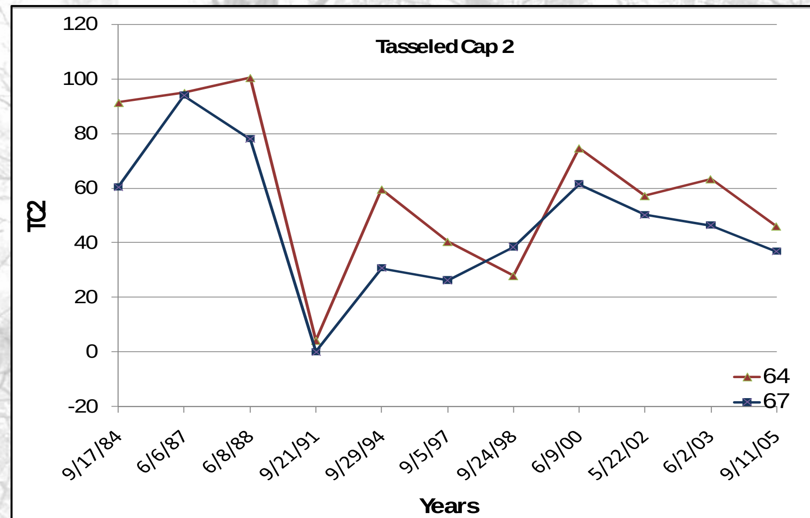
Location of the mined and un-mined points on the False color image of 1998

- Points 64 and 67 are mined points
- Points 25, 26, 27 and 28 are un-mined points.

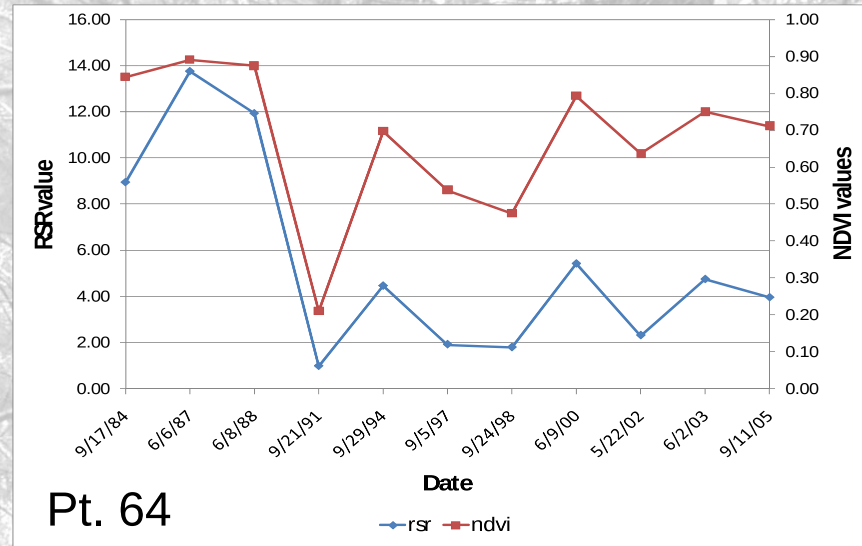


Comparison of NDVI values of mined and un-mined points

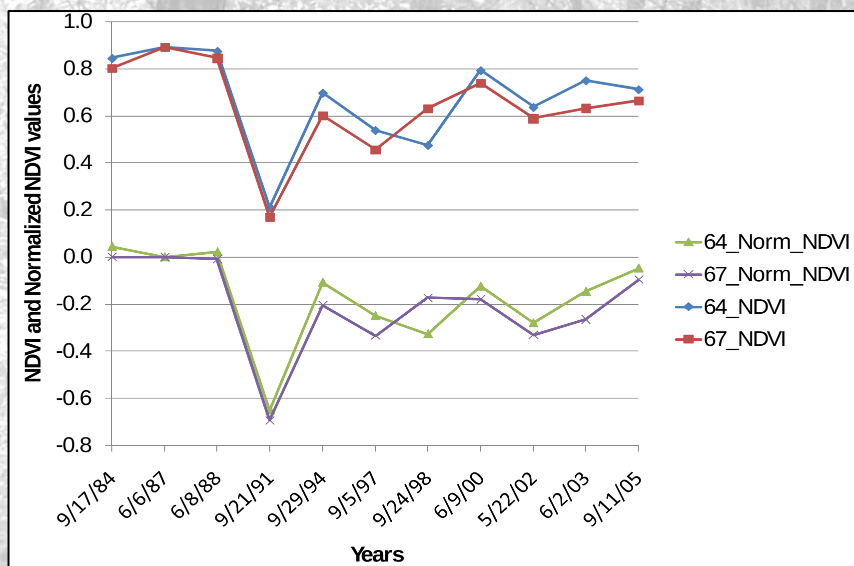
Some other promising indices:



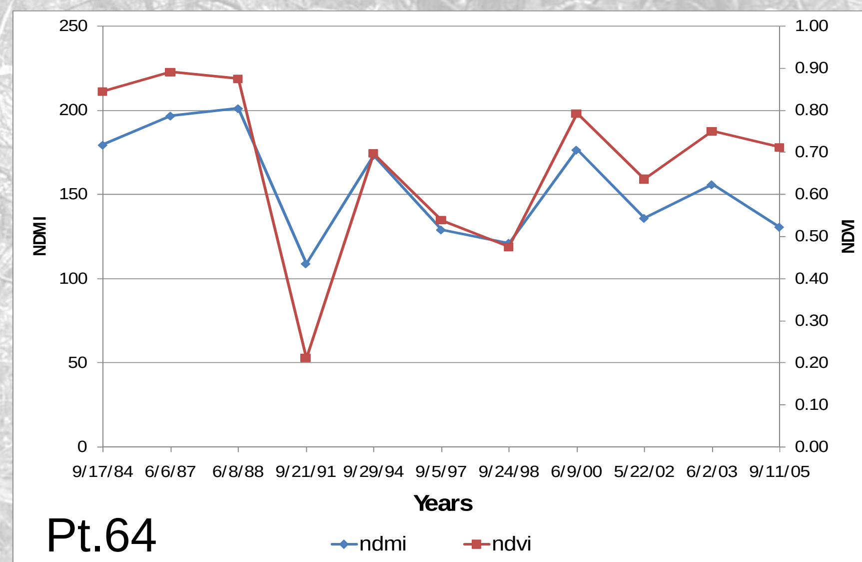
TC2 (Greenness) values for pts. 64 and 67



Reduced Simple Ratio (RSR) and NDVI values for pt.64



NDVI and normalized NDVI values for pts.64 and 67



NDMI and NDVI values for pt.64

Update Summary V

- MEASURES (**M**anagement-scale **E**cological **A**ssessment **U**sing **R**emote **S**ensing; Potter, Kline, Blinn, Saleh, Walker)
- Key features: web-delivery, RS (lidar, digital orthoimagery, Landsat), scale, validated numbers, real-time modeling
- Foundation, state, and Forest Service support
- Initially just C and water; biodiversity in development
- Linkage with BSI and NGO Ecosystem Services model clearinghouse (TNC)

Conclusions

Landsat-scale = management scale (almost perfect spatial resolution)

Seasonal and interannual time series now pro forma (function, process)

Importance of data set continuity
(Why not 8-day revisit akin to Resource21)

Synergism from working more as team

Multitemporal in situ data sets greatly increase value of Landsat data

Thanks!

The Center for
Environmental Applications
of Remote Sensing
at Virginia Tech