Commercial Applications of Remote Sensing for Environmental Monitoring and Natural Resource Management

Yonsei University
Joon Heo, Ph.D.

2016.2.25

Forest One, Inc

2000.10 ~ 2005.2

http://www.forbes.com/forbes/2009/0907/technology-software-satellites-sky-high-tips-for-crop-traders.html device, the content plays.

Microsoft's PlayReady DRM standard also allows for the domain concept and has been licensed by companies like Nokia. Shamoon notes pointedly that Microsoft has yet to implement PlayReady on its Zune multimedia device or say when it will. He goes on to contend that Marlin is a more efficient software system than its DRM brethren. It employs a lightweight digital engine for license evaluation that does not need to be changed even as new usage rules evolve. That means Marlin doesn't add much to the cost of the DVD player, PC or whatever is playing the movie or song.

Wendy Seltzer, a fellow at Harvard Law's Berkman Center for Internet & Society, feels that all DRM protection schemes ultimately fall short—as will Marlin. "A maze with lots of gates looks more open than a maze with just one path through it," she says. "But in both cases, once you run in you're confined within the predefined path."

For Marlin to make good on its promise of interoperability, the devices all need to be running Marlin code and work according to the rules set forth by Marlin's governing standards body. The same is true of standards like PlayReady. Seltzer says such power consolidation puts an unnerving amount of control in the hands of a single company.

"It's the risk that the members of that consortium will have the incentive to veto things that don't match their business plan," she says. "Once you've given that control, there's no way for you to guarantee that it won't be used anticompetitively."

Shamoon says surrendering some control to patent holders is a risk with almost any technology standard. He argues that there will always be companies like Intertrust that own underlying intellectual property and that a one-stop licensing shop is better than a jumble of licensing pools.

Internet services and mobile devices seem likely to continue to converge. Instead of trying to stop copying, Marlin could be a way to encourage sharing—while helping content developers get paid. **F**

AGRICULTURE

High-tech crop forecasters Shailu Verma and Nicholas Kouchoukos.

MATTHEW GILSON FOR FORBES

Crop Prophets

Lanworth employs satellite imagery and nifty software to predict agricultural yields. By Christopher Steiner

THE 1983 MOVIE *Trading Places* features Dan Aykroyd and Eddie Murphy as commodities traders who get their hands on the U.S. Department of Agriculture's harvest report before its release. Predictable mischief ensues.

In real life it's not so easy to snatch unreleased government data. But a small Chicago firm, Lanworth, is doing the next best thing, which is to re-create it from the outside. By combining satellite images, analytical software and boots-on-the-ground reports, Lanworth is beginning to displace the USDA as the authority in predicting planted acreage and crop yields. "I think of us as the Intel processor of agriculture," boasts Lanworth President Shailu Verma.

Lanworth's data can be critical to its clients, some of whom pay $250,000 a year to get it. Verma says the nine-year-old company will haul in $5 million this year and is "very" profitable, but he won't say by how much. Most of Lanworth's 180 clients, including hedge funds and breakfast cereal makers, use its data to guide trading and hedging of corn and soy futures.

Verma, 41, dreamed up Lanworth (the name is meant to resonate with "land" and "value") with Clark Love, a classmate at Northwestern's business school, as an Ebay-like auction site for commodities, with a Web-accessible platform to buy and sell corn, soy and other staples. The two imagined including a crop-forecasting tool to provide as much clarity as possible. Only the forecasting idea made it out of the classroom. The duo landed $1 million in angel funding before they graduated with M.B.A.s in 2000.

Lanworth's software analyzes wide swaths of North American satellite photos accessed for free from NASA's Landsat satellite system, originally created in 1972 to keep watch on Soviet agriculture. The photos, updated daily, cover patches of land 1,400 miles wide; only six encompass the North American croplands Lanworth watches. One pixel on the photographs represents a square with sides 270 yards long. Lanworth assigns to each pixel that's a known patch of farmland several values, including date of germination, potential yield and probability that the crop is corn or soy. The software makes estimates on acres planted and projected yields by analyzing the soil color, how green the crop is and the rate at which the color changes.

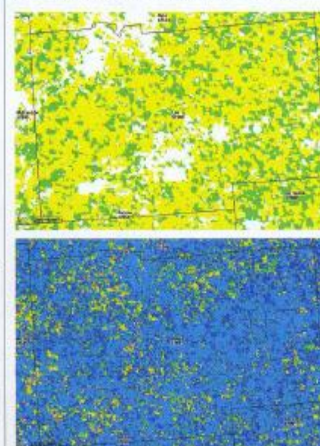
Aiding Lanworth's quest is a trove of historic satellite data and crop totals going back 30 years. Knowing what a field looked like, day by day, during a year when it produced 180 bushels per acre or 20% less than that, gives the software a reference point. Then Lanworth knits in observations made at ground level by four pairs of people who travel the back roads of America taking notes on how far along crops are or how wet or dry the fields might be. Lanworth dispatches the couples to places where data are thin or where weather conditions have proved especially adversarial—such as floods in Wyoming or a late-season frost in California. Data gleaned here helps the software engineers understand what, exactly, the satellite images are showing, especially when flooding makes certain fields hard to read from satellite images. Ground crews determine if seeds are germinating and how damaged the crops might be.

Lanworth raised $1.2 million from angel investors before it was acquired in 2007 for an undisclosed sum by Weyervelt, a timberland manager in Tuscaloosa, Ala. Cofounder Love sold his stake at that point and moved on. Verma is focused on making Lanworth as ubiquitous in farm and forest commodities as Dow Jones is in equity markets.

Commodity futures trade on what parties assume the year-end tally for certain crops will be. The USDA issues several reports during the growing season that attempt to gauge where the market will end up; it works largely off data taken from farmers who participate in the agency's phone, mail and Internet surveys. It's a time-consuming process that leaves room for gaps and mistakes in the data. Lanworth says that its early-season predictions the last three years have proved more accurate than the government's when compared with final crop tallies.

A year ago Lanworth predicted a 2008 U.S. corn yield of 12.2 billion bushels, while the USDA said it would be closer to 11.7 billion bushels—a large difference in the farm commodities world. As winter approached, the USDA figures yo-yoed, but Lanworth kept its original prediction. The final tally: 12.1 billion.

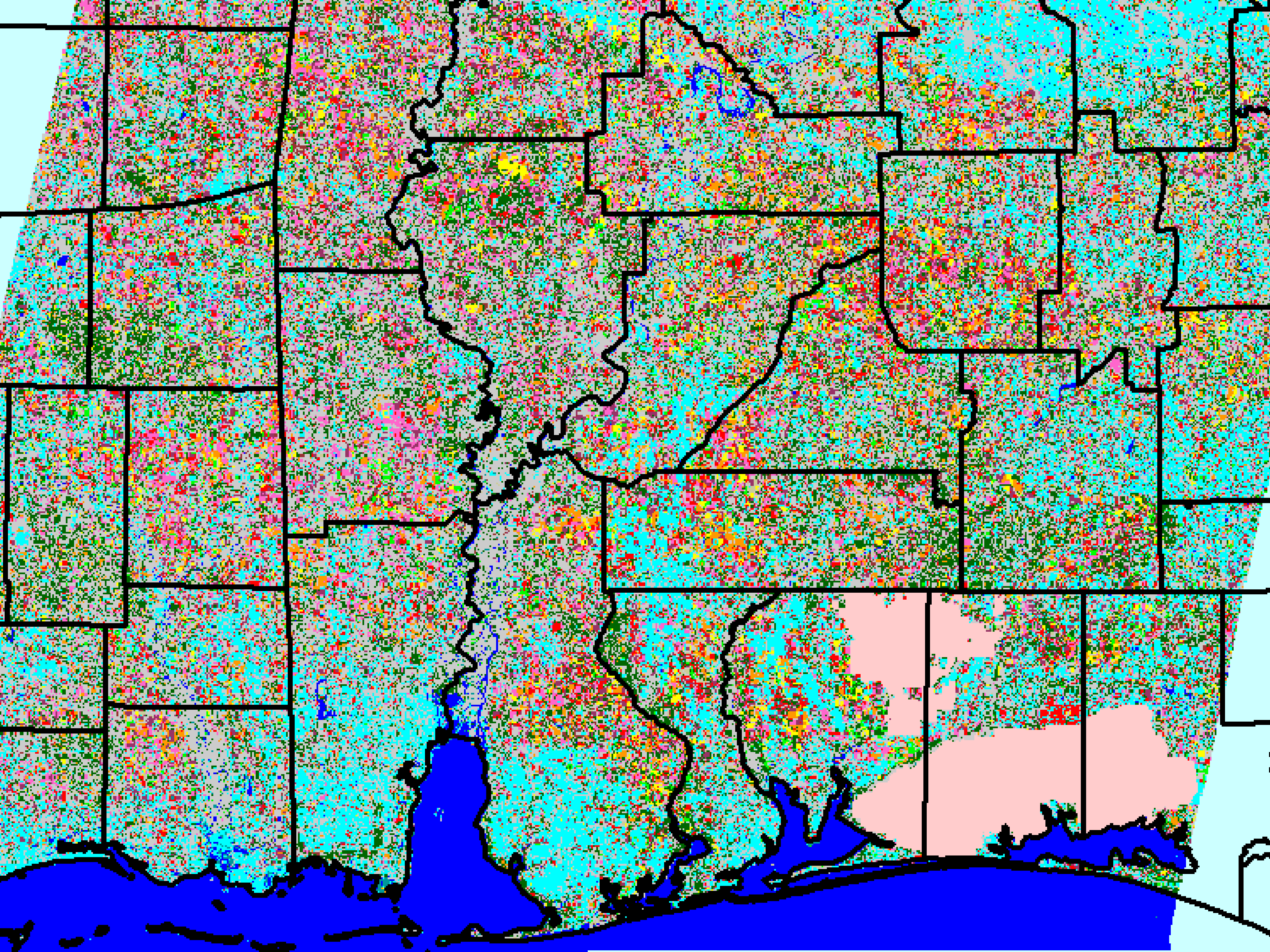
"Crops are one of the few commodities where you don't have a known supply until the end of the year. That's what makes this kind of information so important and valuable," says P. Joe Harroun, a consultant at commodities broker Advance Trading in Bloomington, Ill. "Companies as big as Cargill have been trying to get an edge on the standard sets of data for annual crop yields, but none of these proprietary systems has proved as accurate as Lanworth's." That includes efforts by several other companies to use satellite images to predict crop data, such as Informa Economics, a U.K. firm.



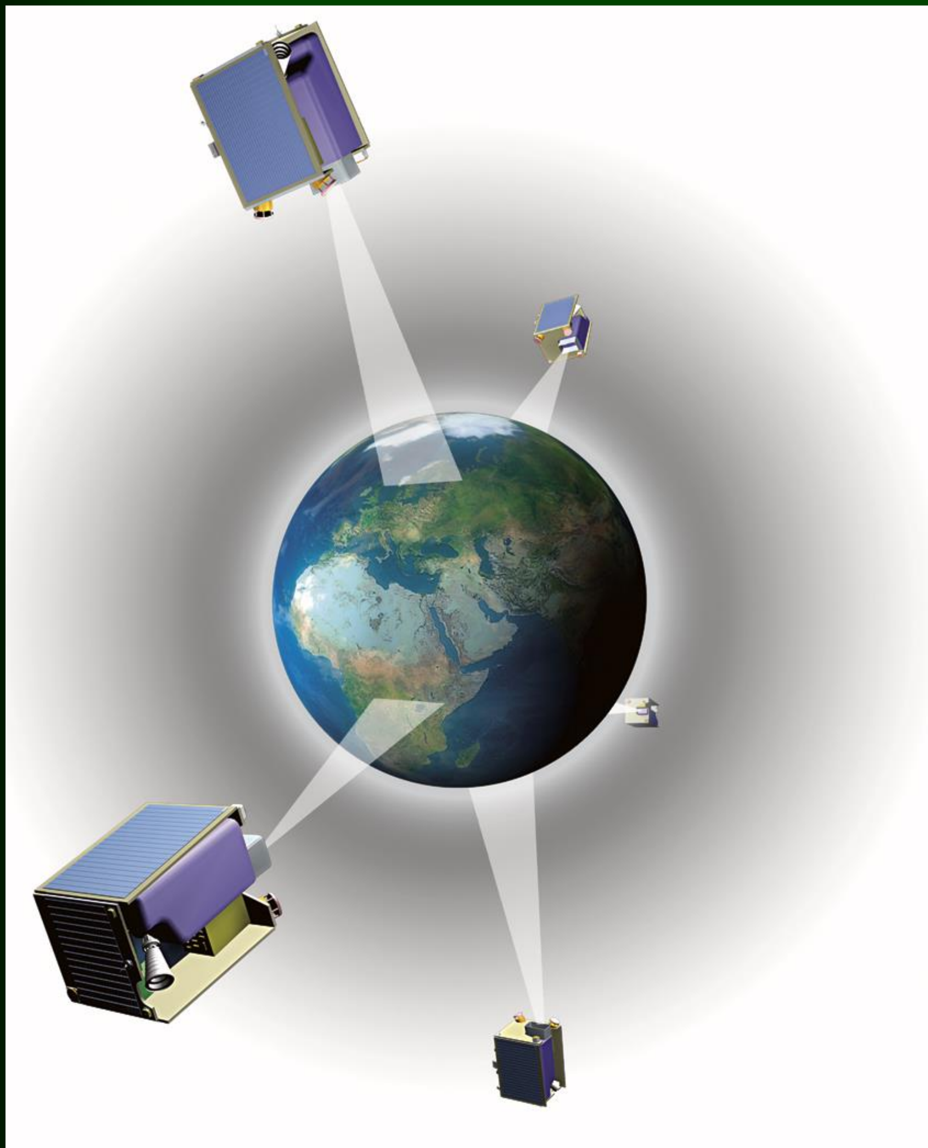
SATELLITES, ANTHROPOLOGY AND MATH. Lanworth's software delineates crops by acre and type; corn is yellow and soybeans, green *(top)*. Satellite imagery updated daily helps pinpoint signs of crop stress, which affects yields. Yellow, orange and red areas show stress; shades of blue indicate healthy crops.

Verma, a mechanical engineer from Kolkata who worked at General Motors and McKinsey before founding Lanworth, assembled a colorful crowd to inventory corn and soy crops before they bloom. Nicholas Kouchoukos, head of resource intelligence, was an anthropology professor at the University of Chicago before he joined Lanworth in 2005. Other employees sport Ph.D.s in computational science, ecology and anthropology.

Lanworth has begun expanding its analysis to croplands in South America, India and the former Soviet Union. Lanworth, always looking for new ways to gather real-time data, is figuring out how to pay crop dusters to snap photos from their planes. One more source of data could make its forecasts even more accurate. **F**



Recent Launch of Imaging Satellites



GeoEye (2008, Sept. 6)

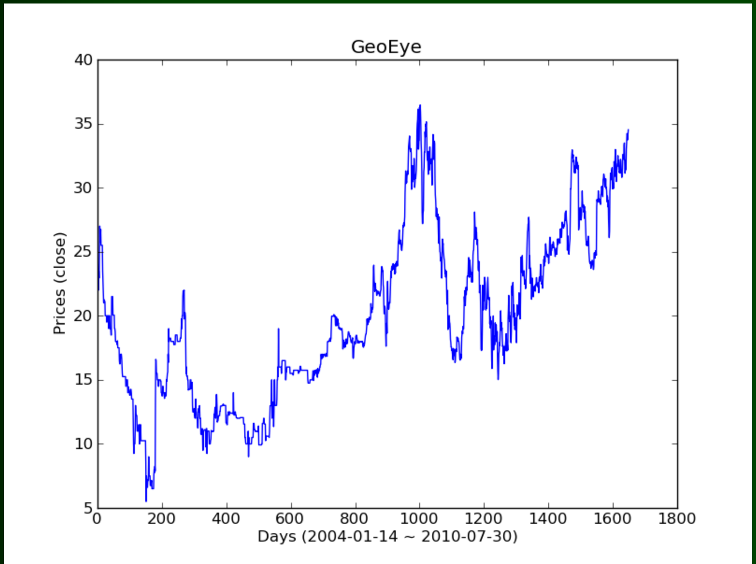
They are smaller than a dish washer

Final preparation

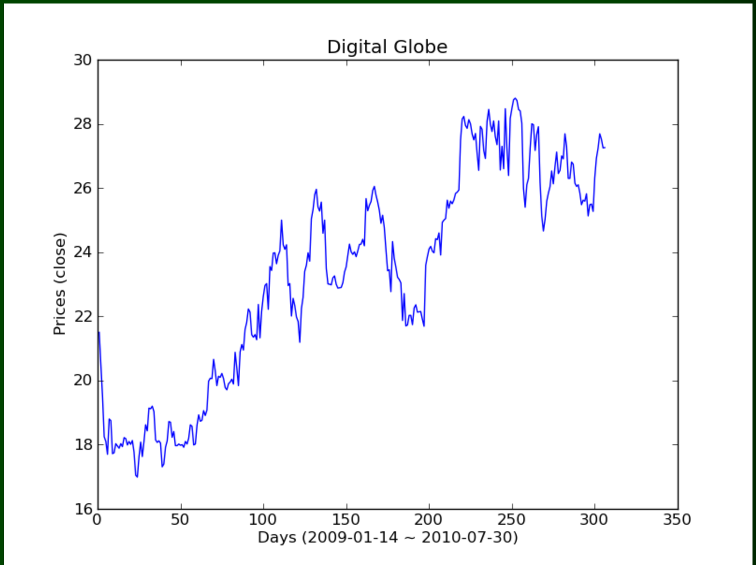
Launch

August 29, 2008

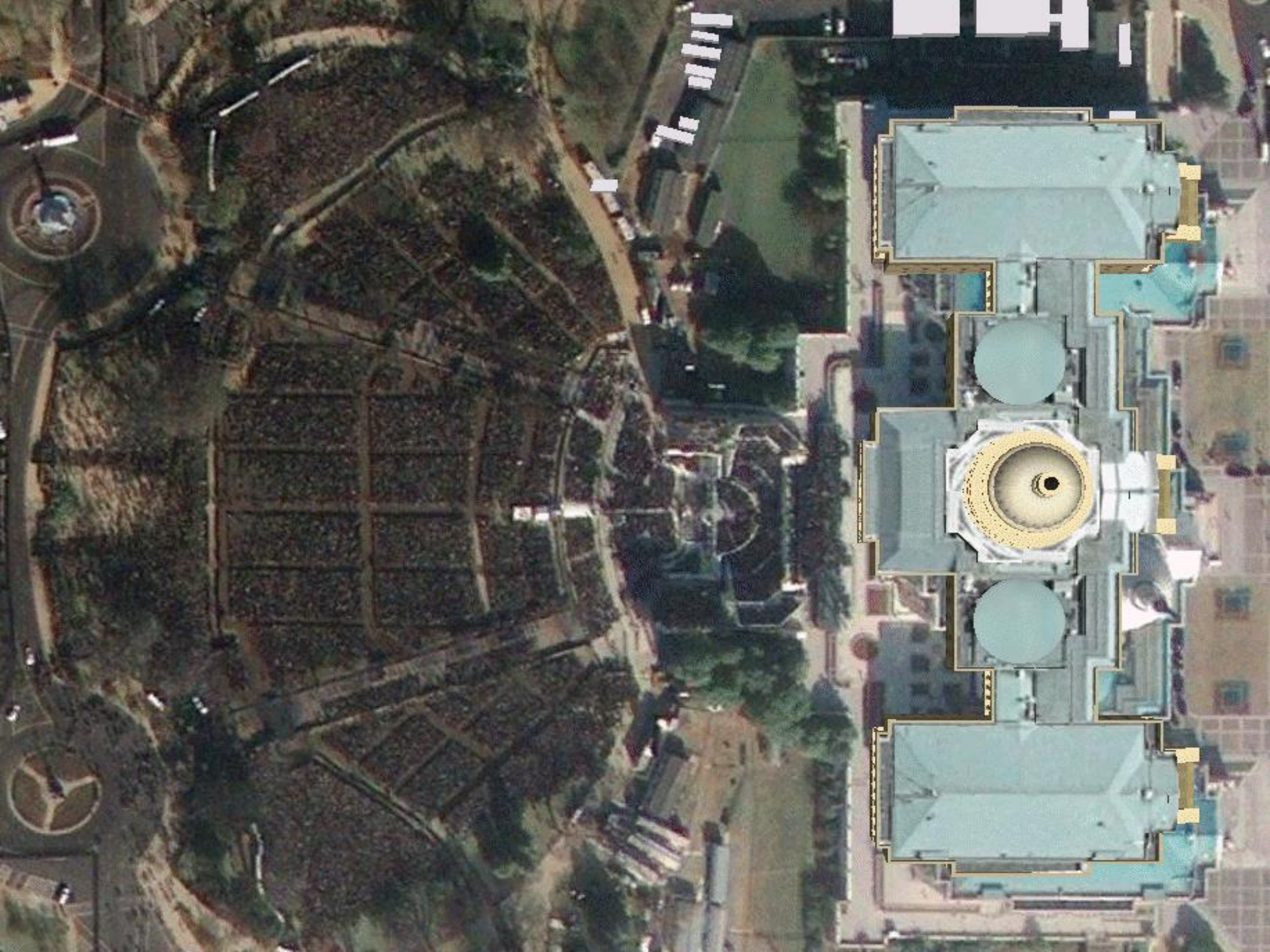
Commercial Satellite Image Providers



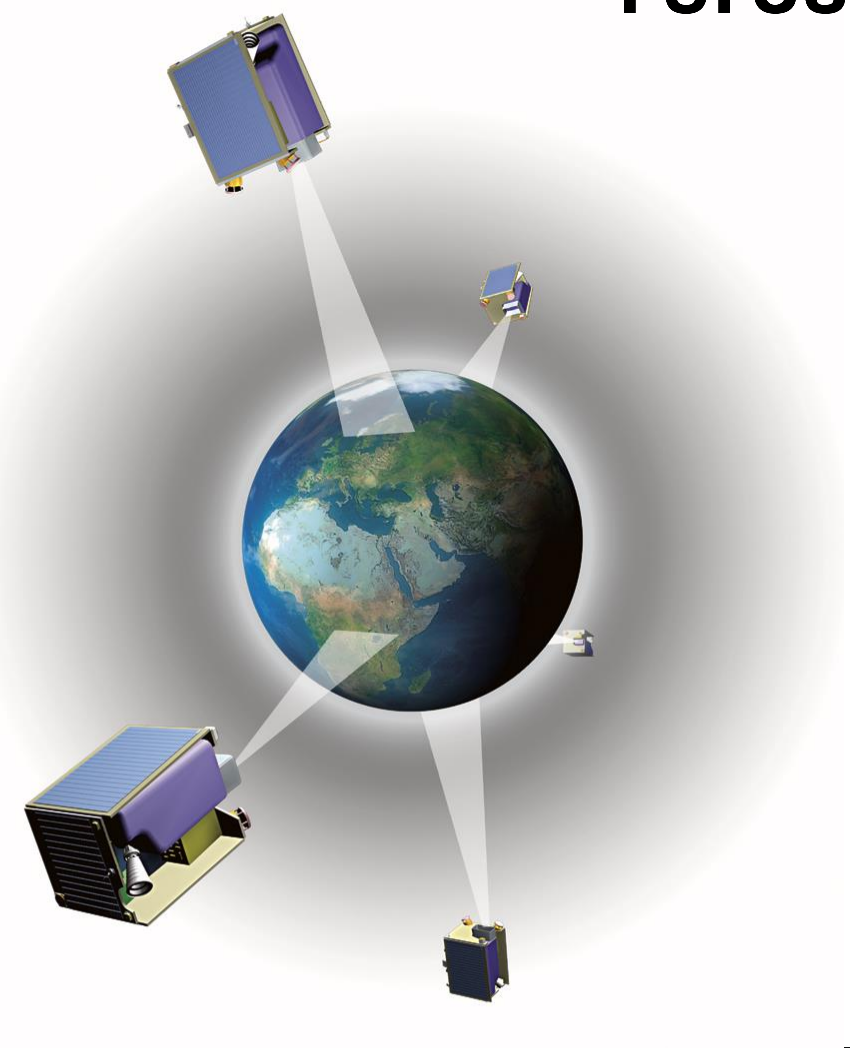
시가총액: 814.8 M



시가총액: 1.4 B



Forestry Applications

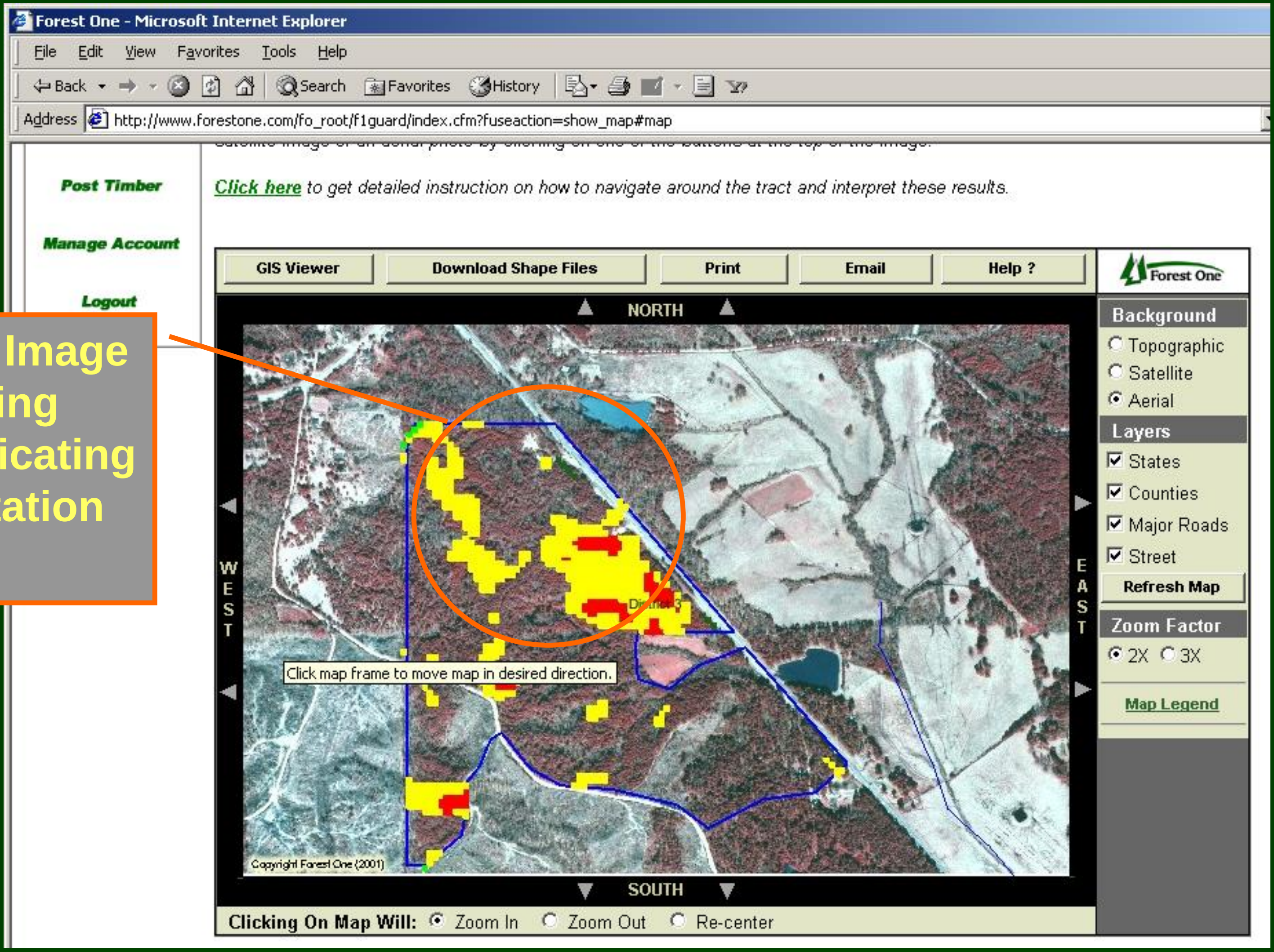


Forestry Applications

- F1.Guard: Web-based Monitoring System
- F1.Cruise: Web-based Timber Procurement Tool
- Leaf Area Index Estimation
- Due Diligence of Timberland Sales
- Timber Age Map™
- Historical Orthophotos for Timber Appraisal
- Eucalyptus Plantation in China
- Damage Assessments
- Target Marketing for Chemical Industry
- Data Entry
- Loggers' Route Optimization
- Invasive Species Mapping
- Forest Risk Analysis and Mapping (SPB, Wild Fire)
- UAV applications

F1.Guard: Web-based GIS

- Web-based land monitoring system:



Satellite Image Processing Data indicating Deforestation

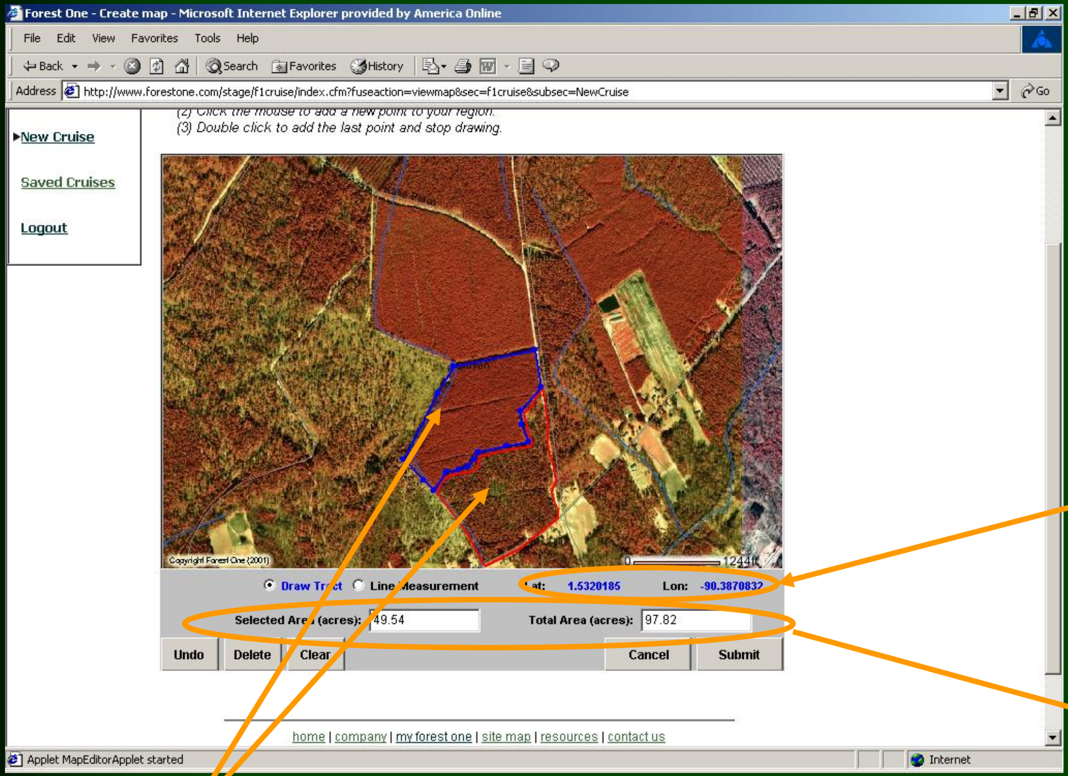
F1.Cruise: Web-based GIS

Data for forestry
- Aerial Imagery
- Satellite Imagery
- Soils Data
- Much more.....

Web-based GIS Client
- Easy to use
- Forestry specific
- Very low Ownership Cost
- Image processing analysis

Direct Impact on the bottom line -
- Calculate accurate acres
- Print maps/analysis anywhere and reduce time in decisions.
- Store and manage harvest plans

F1.Cruise (cont.)



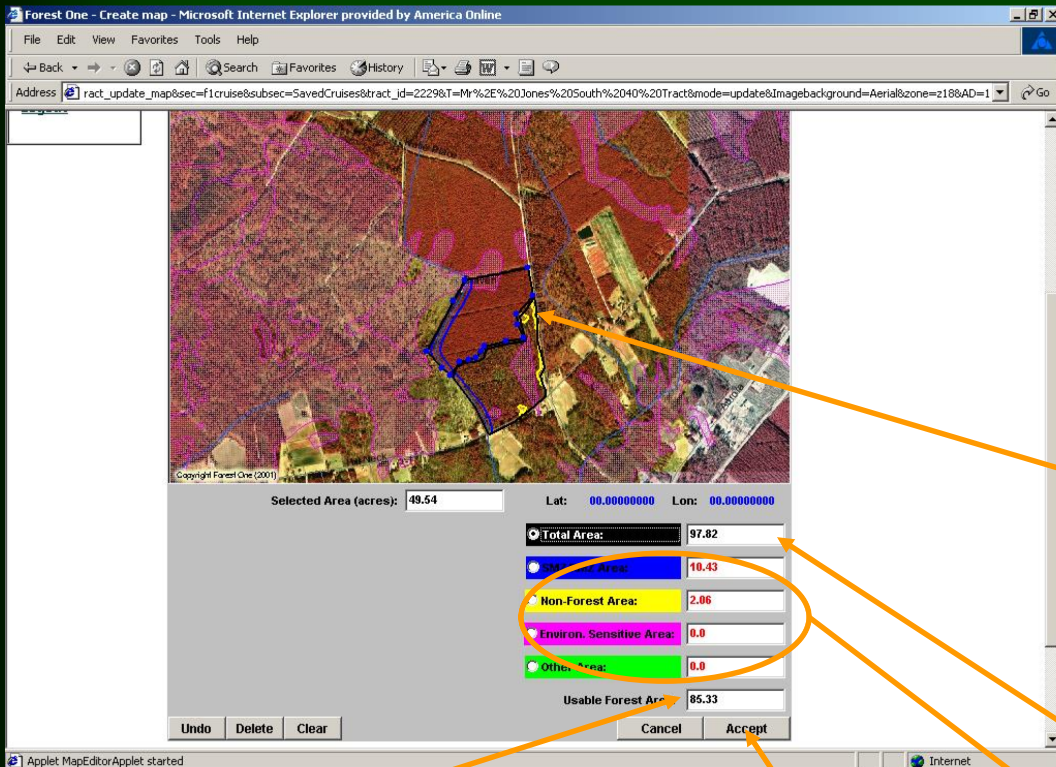
Performing analysis in F1.Cruise is very simple – unlike other GIS tools like ArcView. The interface shown to the left is easy to learn and can be mastered in just a few minutes.

The latitude and longitude are shown as you move your mouse around on the screen.

As you draw tracts, the current acreage is updated automatically. You can draw as many tracts as you need. There are two tracts shown here.

You draw polygons around tracts clicking on the aerial image. <u>To complete the polygon simply double click</u>. In the example here, there are 2 separate tracts drawn – one is in blue and other is in red. If you need to make adjustments to the tract <u>simply select a line or vertex in the polygon and move it to the desired location.</u>

Usable Forest Analysis



The goal of the Usable Forest Analysis is to help you derive the acres that are actually going to produce wood fiber by subtracting areas that are not forested or not harvestable (such as an SMZ acres).

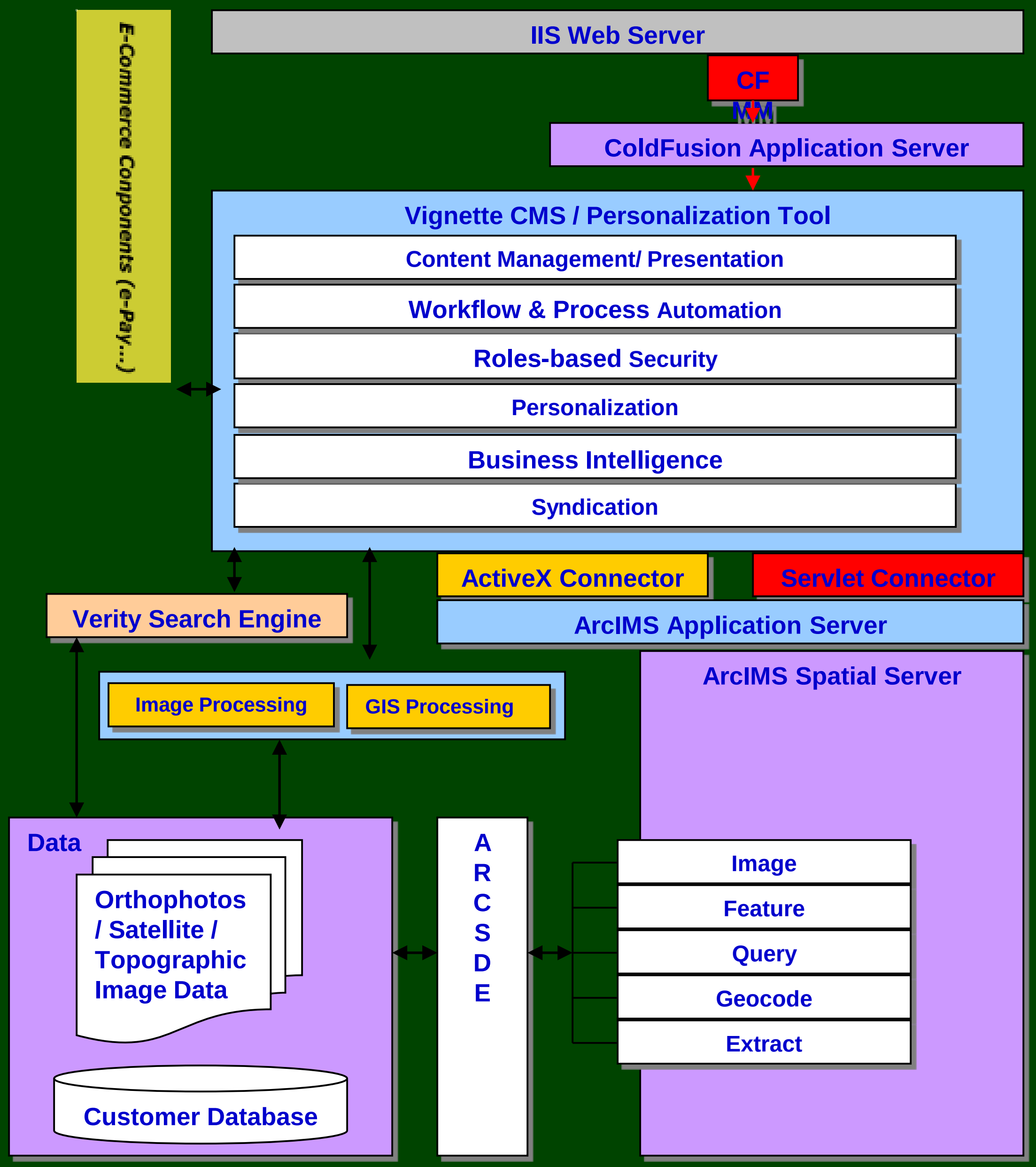
The system automatically generates and outlines SMZs, wetlands, and non-forested areas for you. You may then reshape each of the areas to get the usable forest acres just right.

Total acres are shown here.

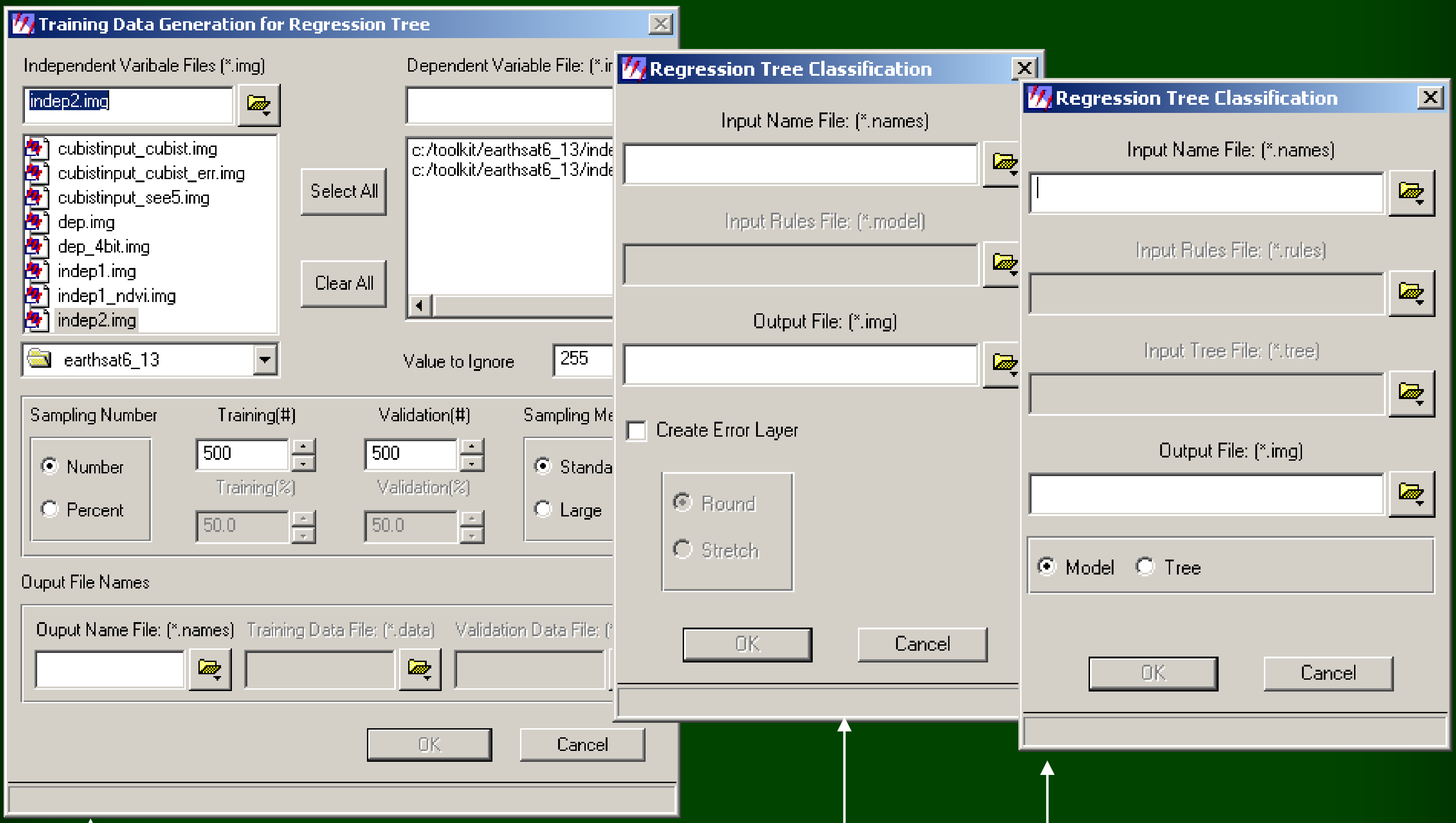
Unusable acres to be subtracted are color coded and shown here.

Subtracting the Unusable Acres from the Total acres gives you the number of usable acres within the tract. Combining this very accurate acreage estimate with your cruise plots should provide for a very accurate cruise. Clicking the "Accept" button will save all of your data and edits.

Confidential Architecture Design of F1.Gurad/Cruise



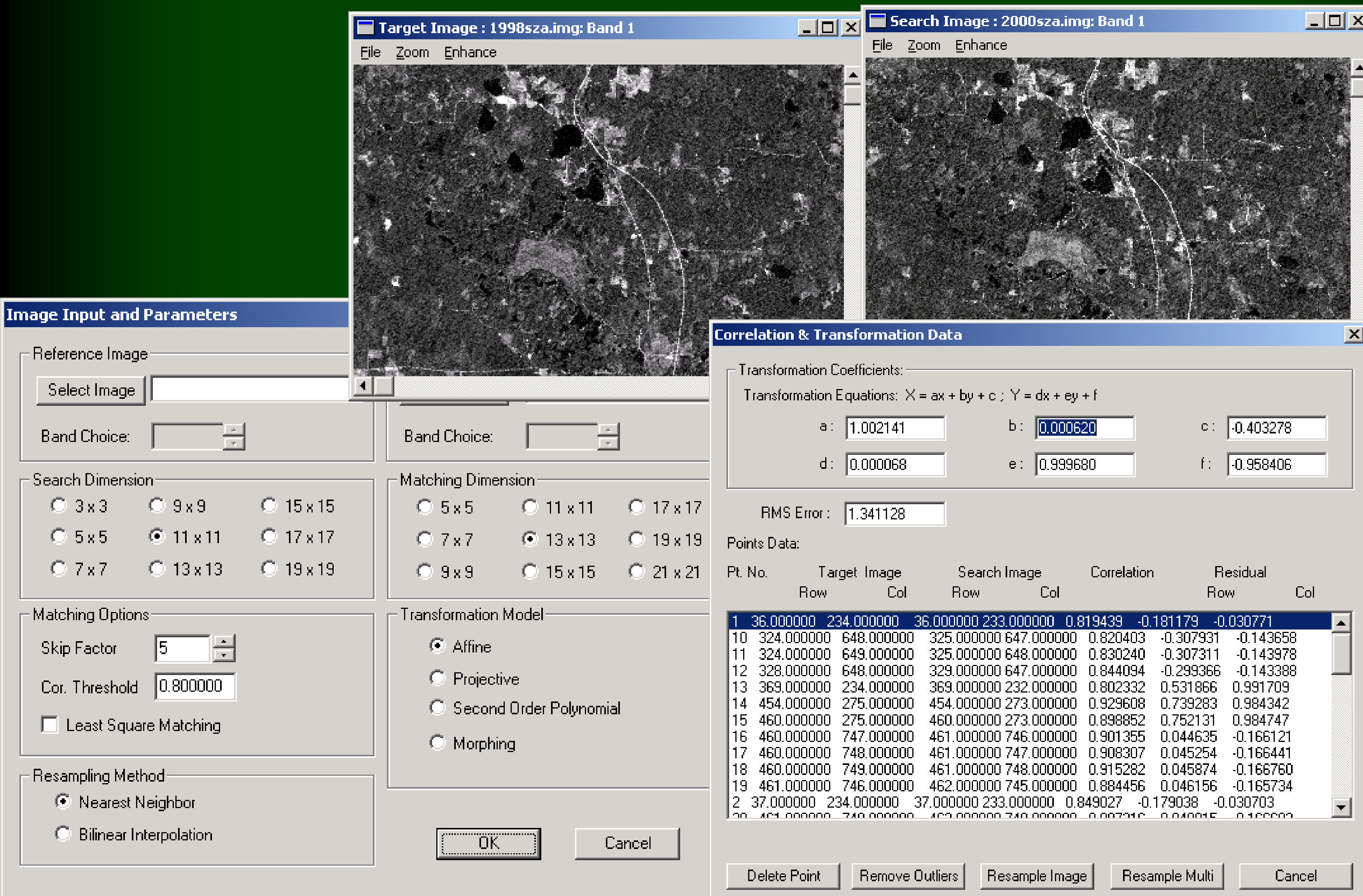
Regression Tree for Remote Sensing



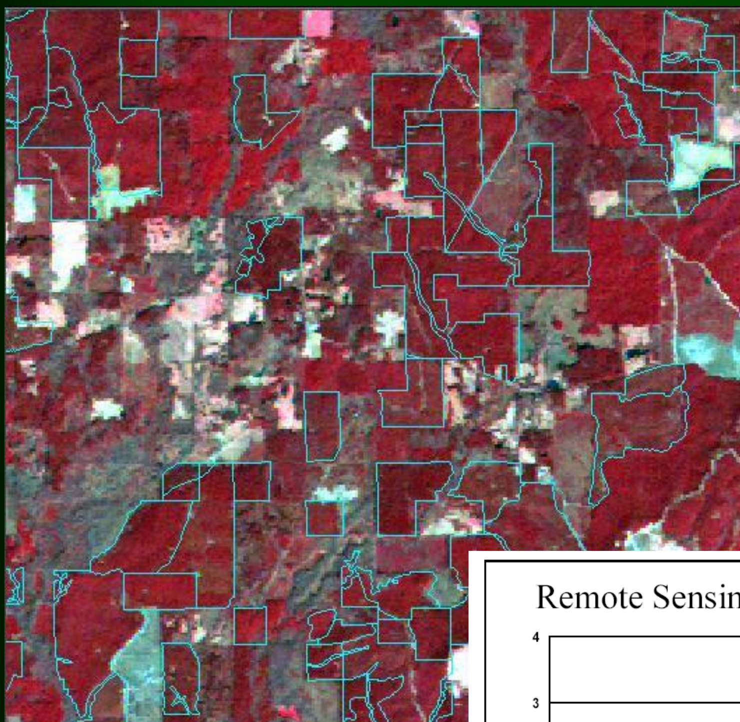
Training Data Sampling

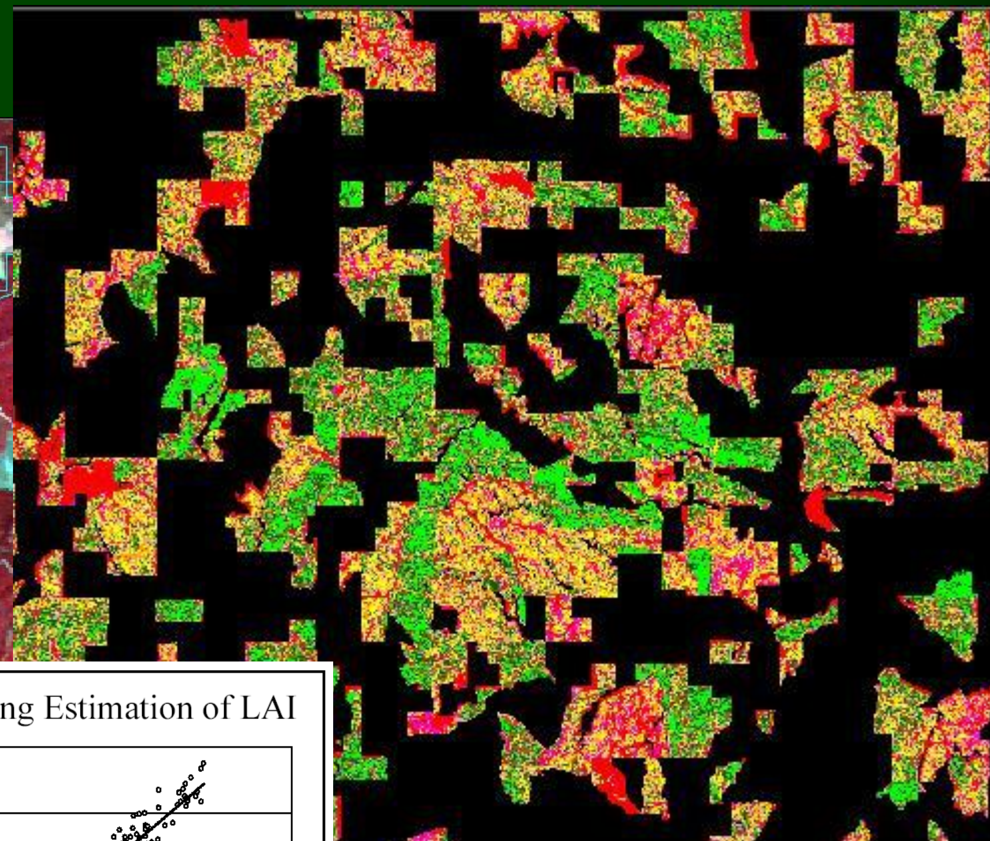
Regression/Classification

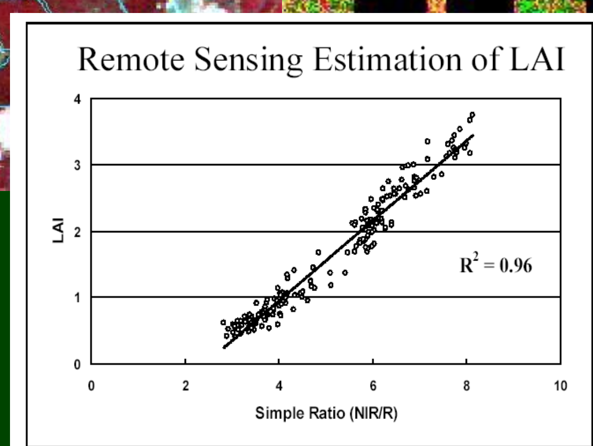
Co-registration for SLC-off image manipulation



LAI Estimation for Fertilization







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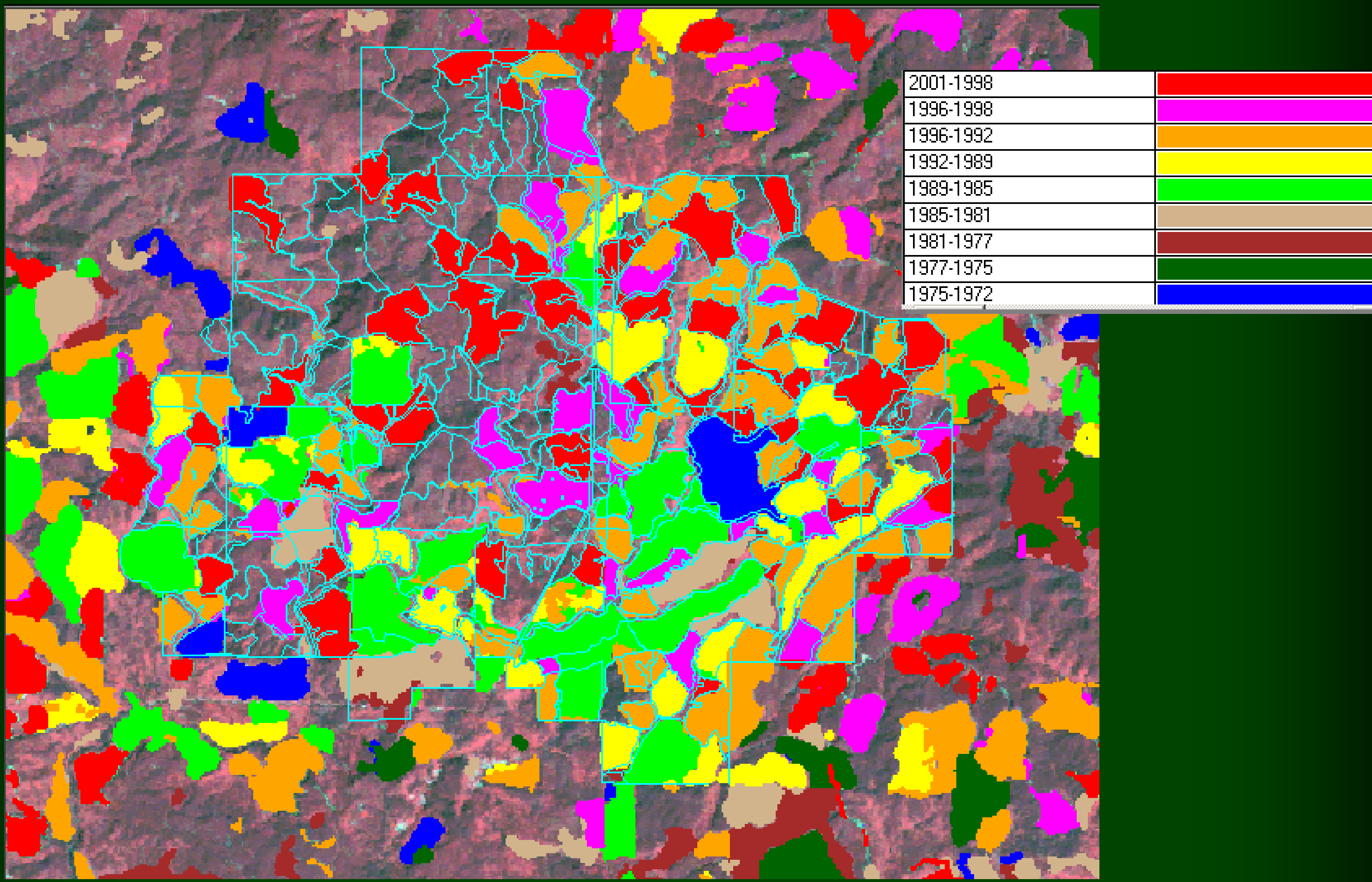
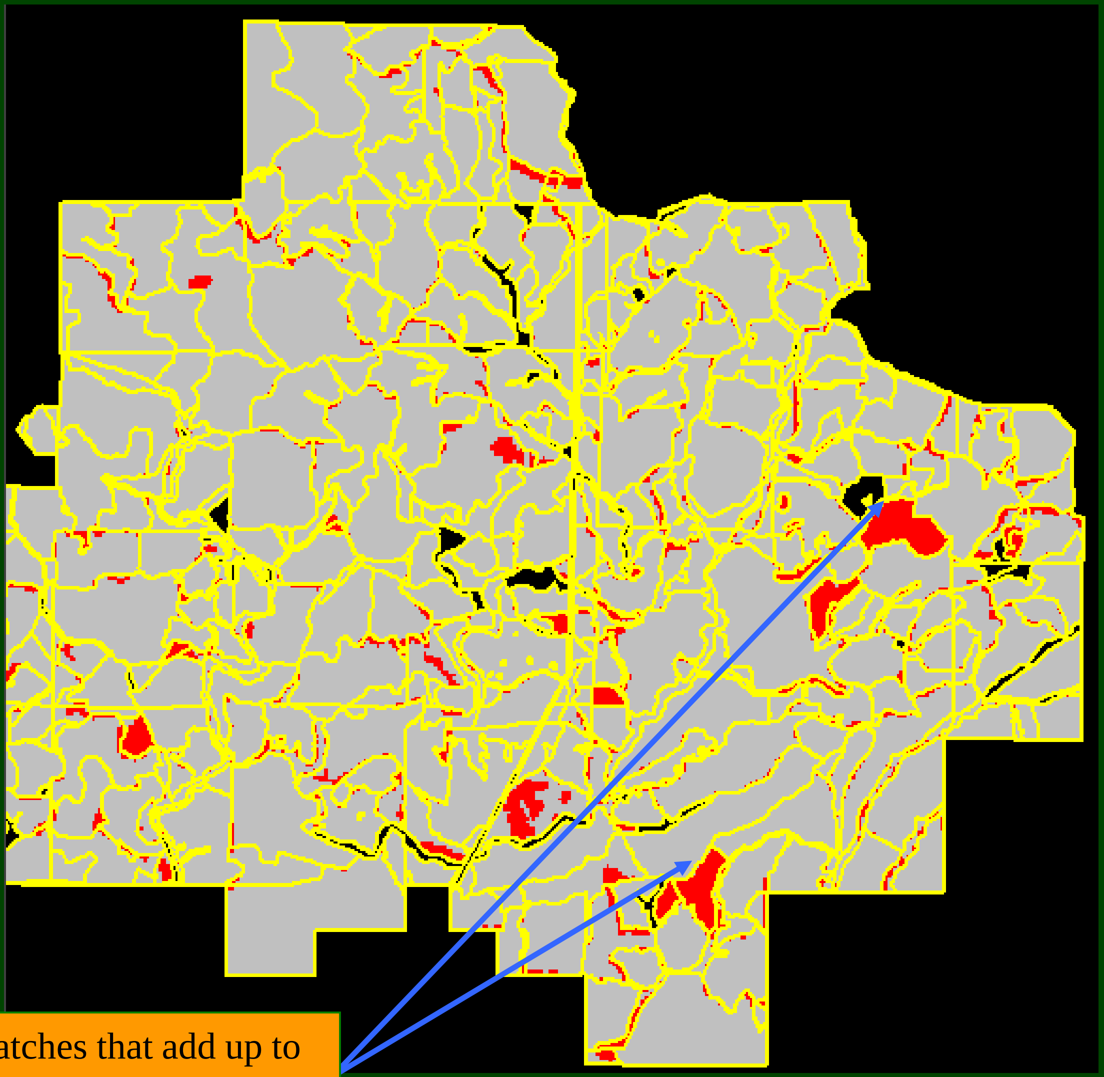
Timber Investment Management Organization (TIMO) in the U.S.

Company	Value (millions)	Acres
Plum Creek Timber	$3,500	7,800,000
Hancock Timber Resource Group	$2,700	3,085,000
The Campbell Group	$1,600	813,000
Forest Investment Associates	$1,500	980,000
UBS Timber Investments	$1,200	1,129,000
Wachovia Evergreen Timberland Trust	$1,200	900,000
Molpus Woodland Group	$877	692,000
Prudential Timber	$489	NA
Timbervest	$430	330,000
Forest Systems	$400	340,000
GMO Renewable Resources	$307	770,035
Forest Capital Partners	$190	250,000
The Forestland Group	NA	*1,100,000
Citigroup Global Investments	NA	NA
Total	*$14.4 billion*	*18,189,035*

Due Diligence of Timberland Inventory

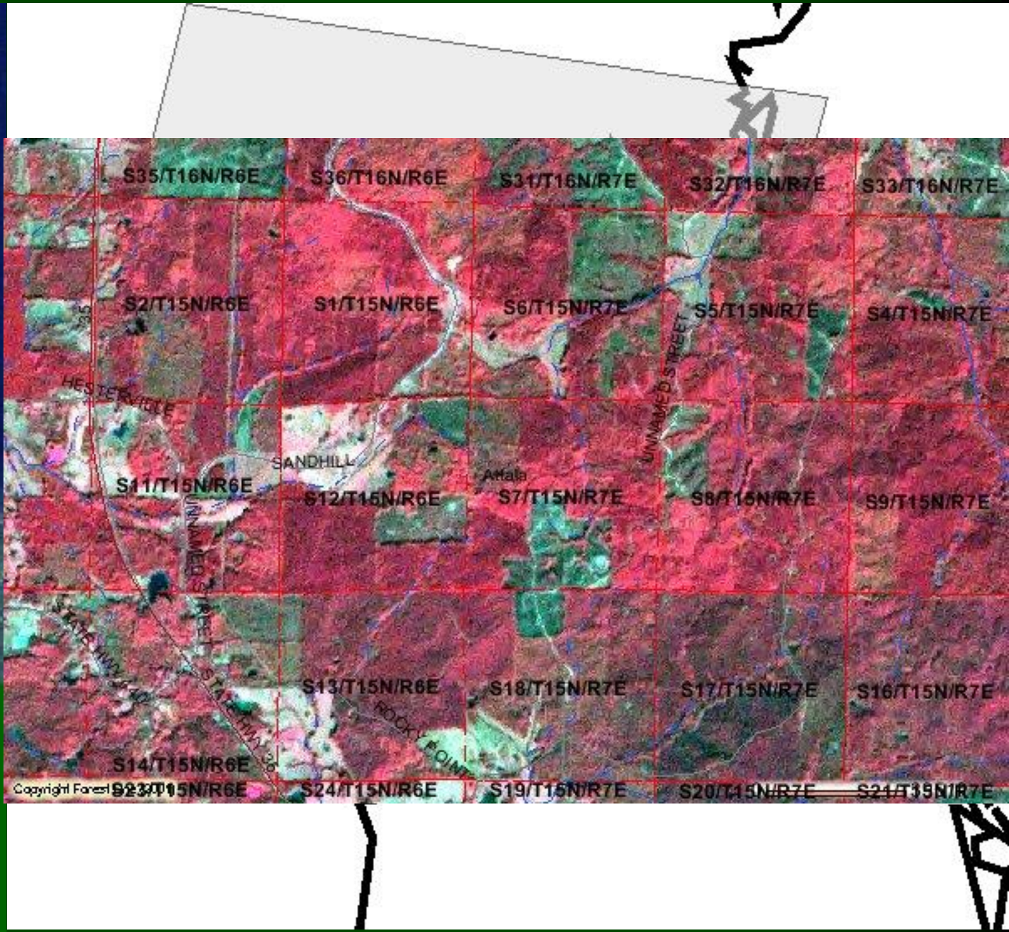


Due Diligence (cont.)



Significant mismatches that add up to significant dollars

Applications for Tax and Collateral Management



Washington IRS

Farm Credit of North Florida

Wood Basin Analysis – FIA Reports

United States Department of Agriculture

Forest Service

Southern Forest Experiment Station

New Orleans, Louisiana

Resource Bulletin SO-168

February 1992

Forest Statistics for Louisiana Parishes — 1991

John S. Vissage, Patrick E. Miller, and Andrew J. Hartsell

United States Department of Agriculture

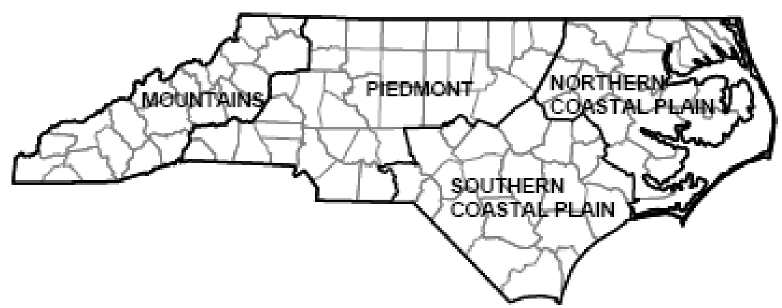
Forest Service

Southern Research Station

Resource Bulletin SRS-88

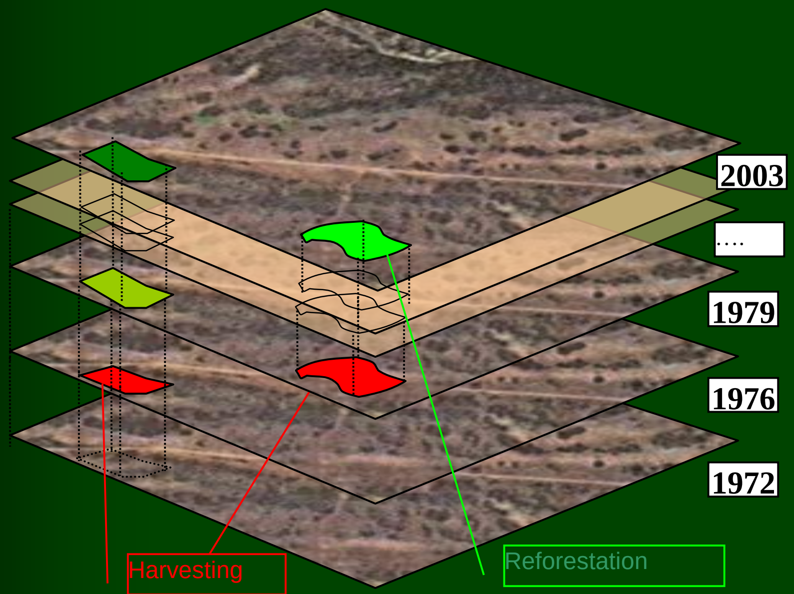
Forest Statistics for North Carolina, 2002

Mark J. Brown

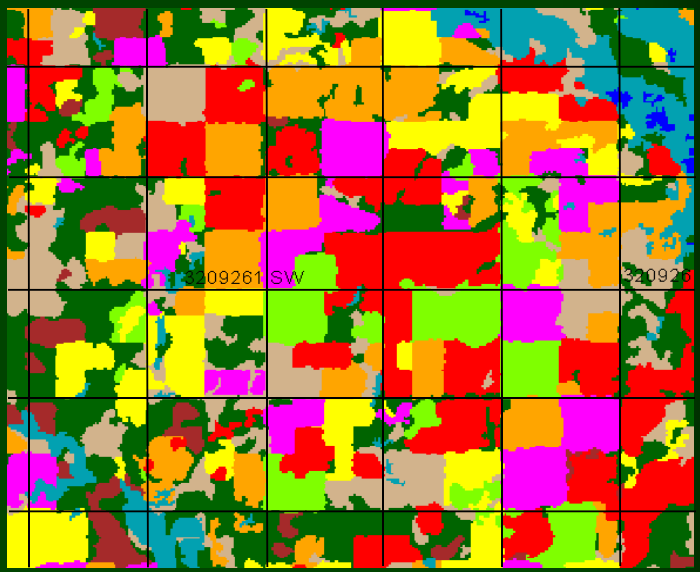


Timber Age Map™

- Change detection over an archive of historical images.

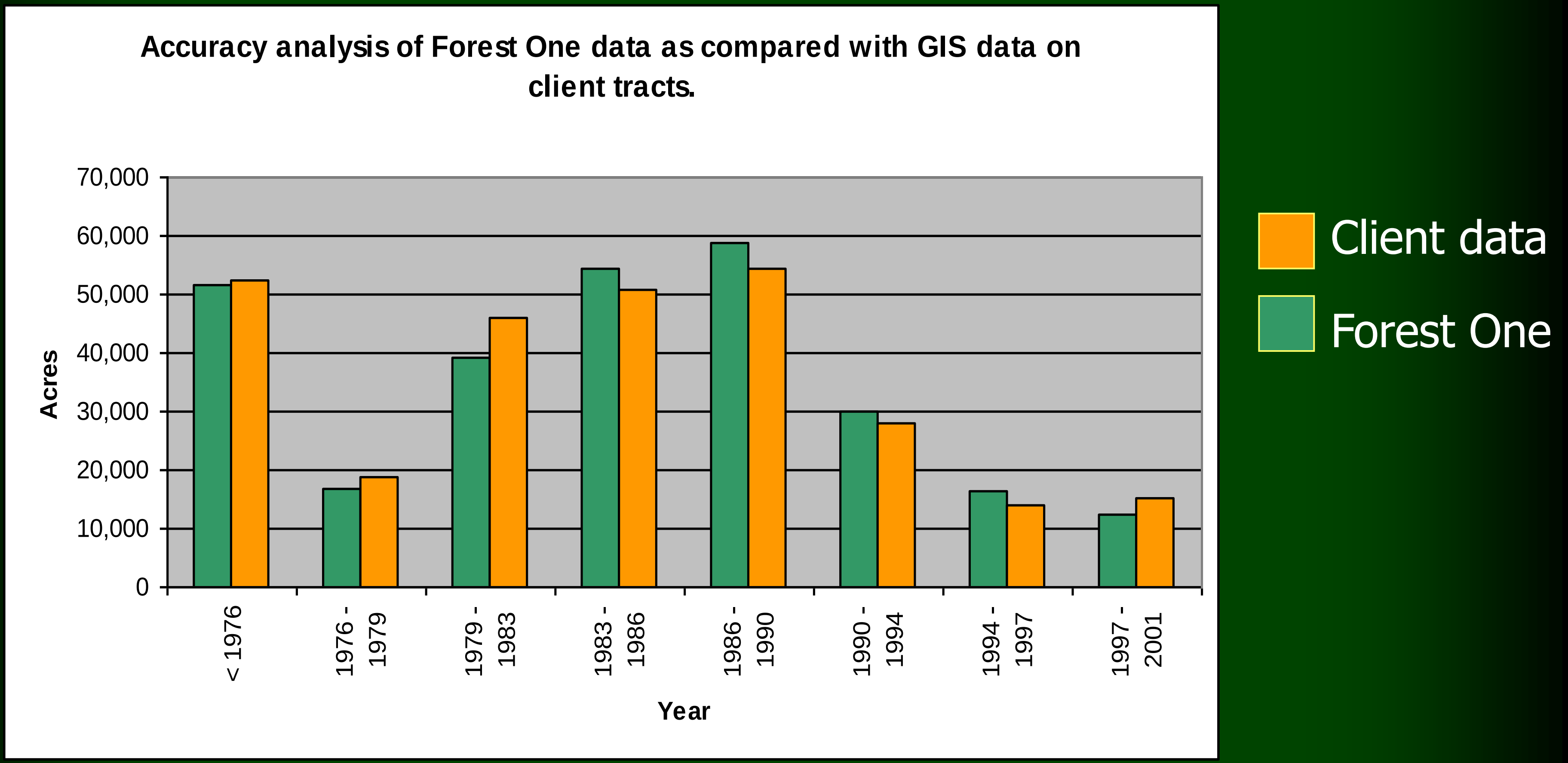


Historical satellite images over the past 30 years



Forest Age	Color
0-4 years old	
5-8 years old	
9-12 years old	
13-16 years old	
17-20 years old	
21-24 years old	

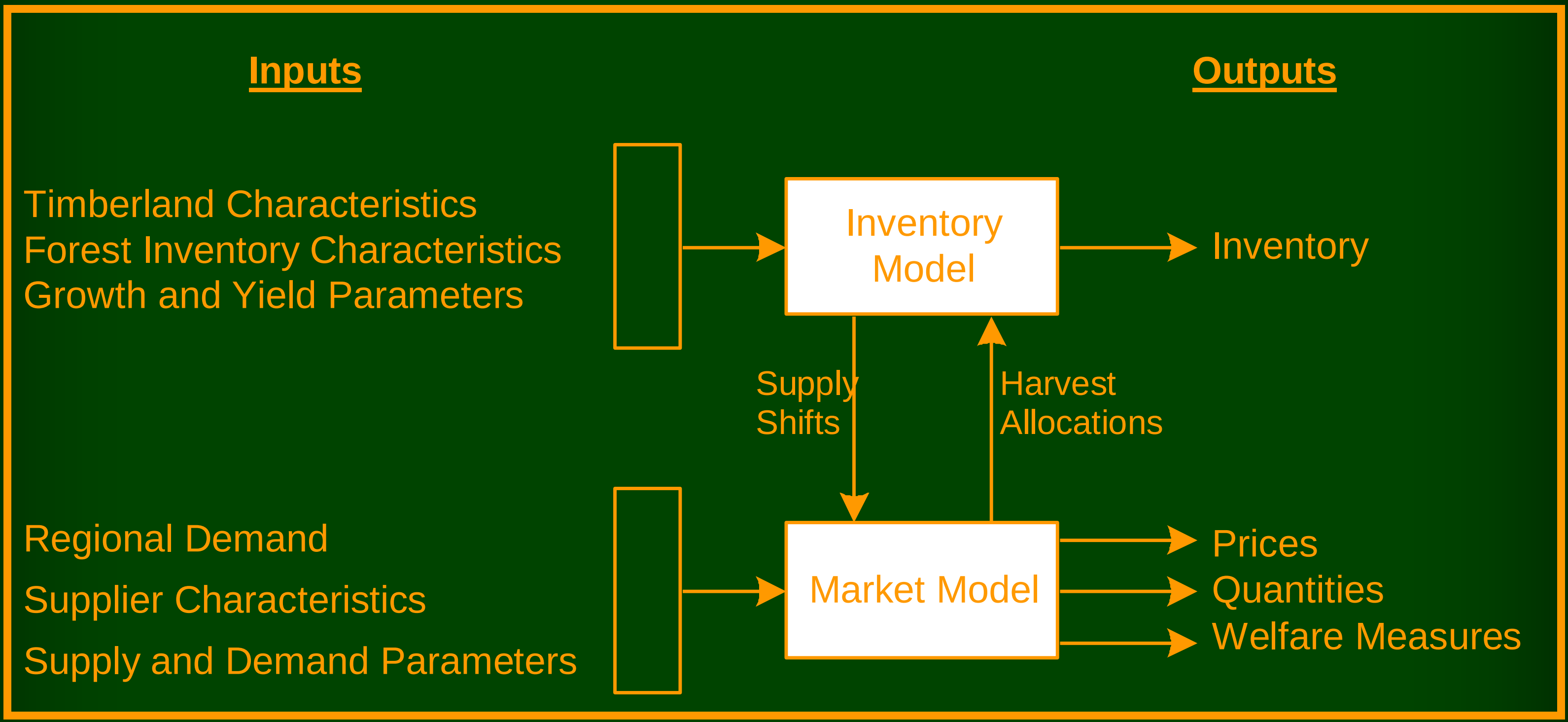
Accuracy Estimate of Timber-Age Map™



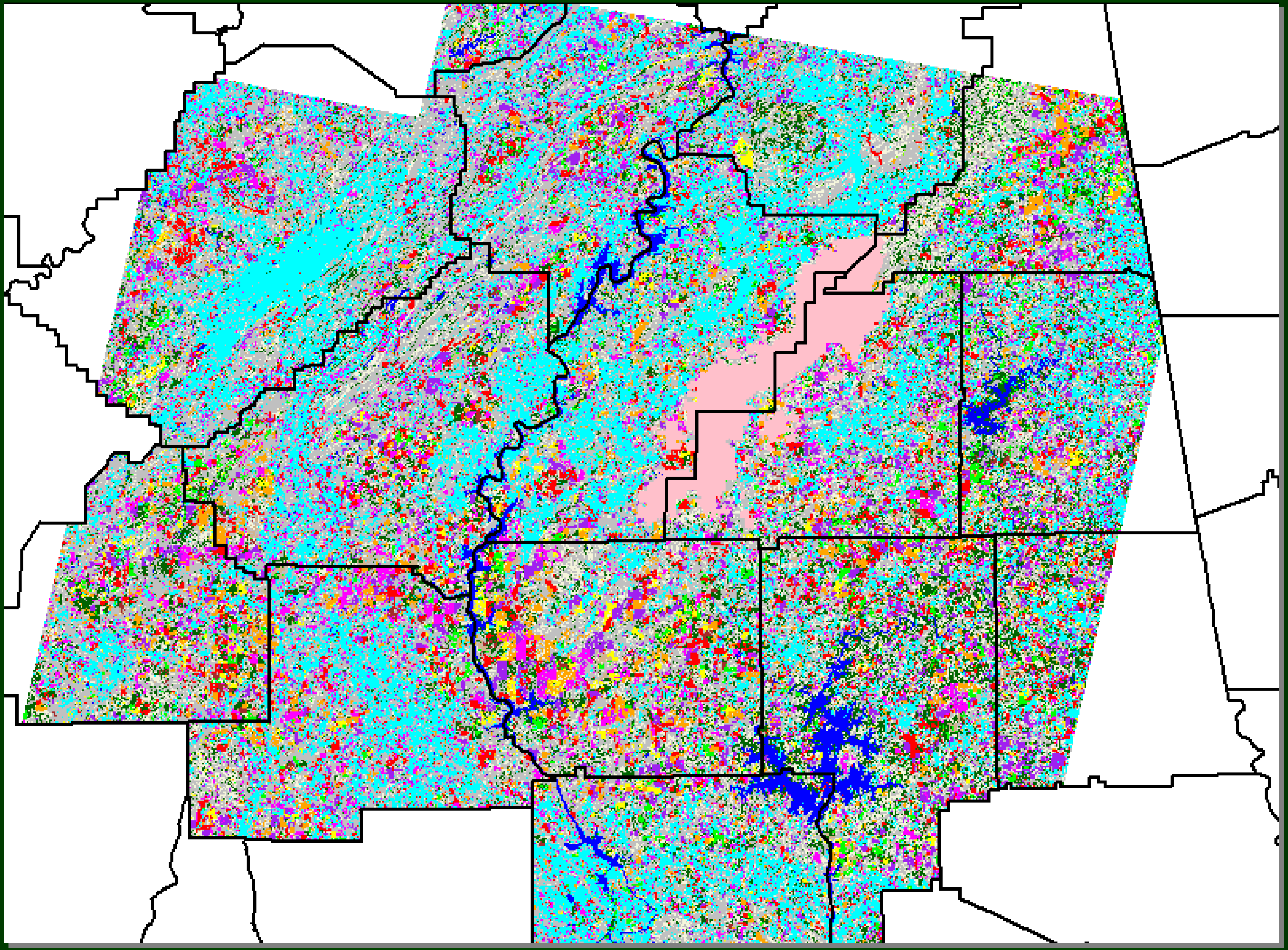
Overall accuracy of over 85%

• Components to Timber Supply Analysis

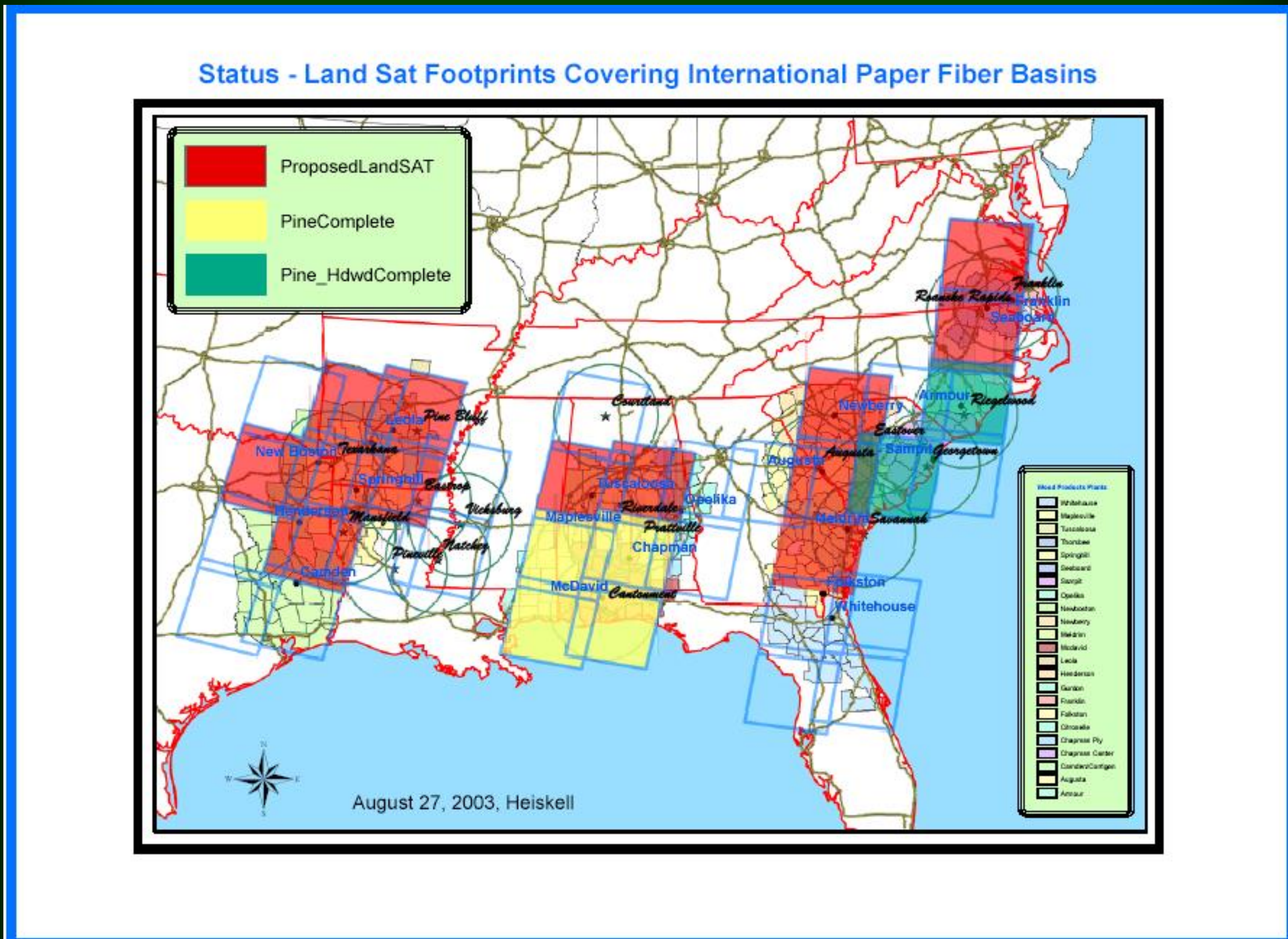
- Mapping forest age
- Mapping forest composition
- Estimating fiber volume
- Mapping increase or decrease in forest cover
- Mapping competitor mill locations
- Mapping transportation cost contours



Examples of Timber Age Map™



Vision of Timber Age Map™

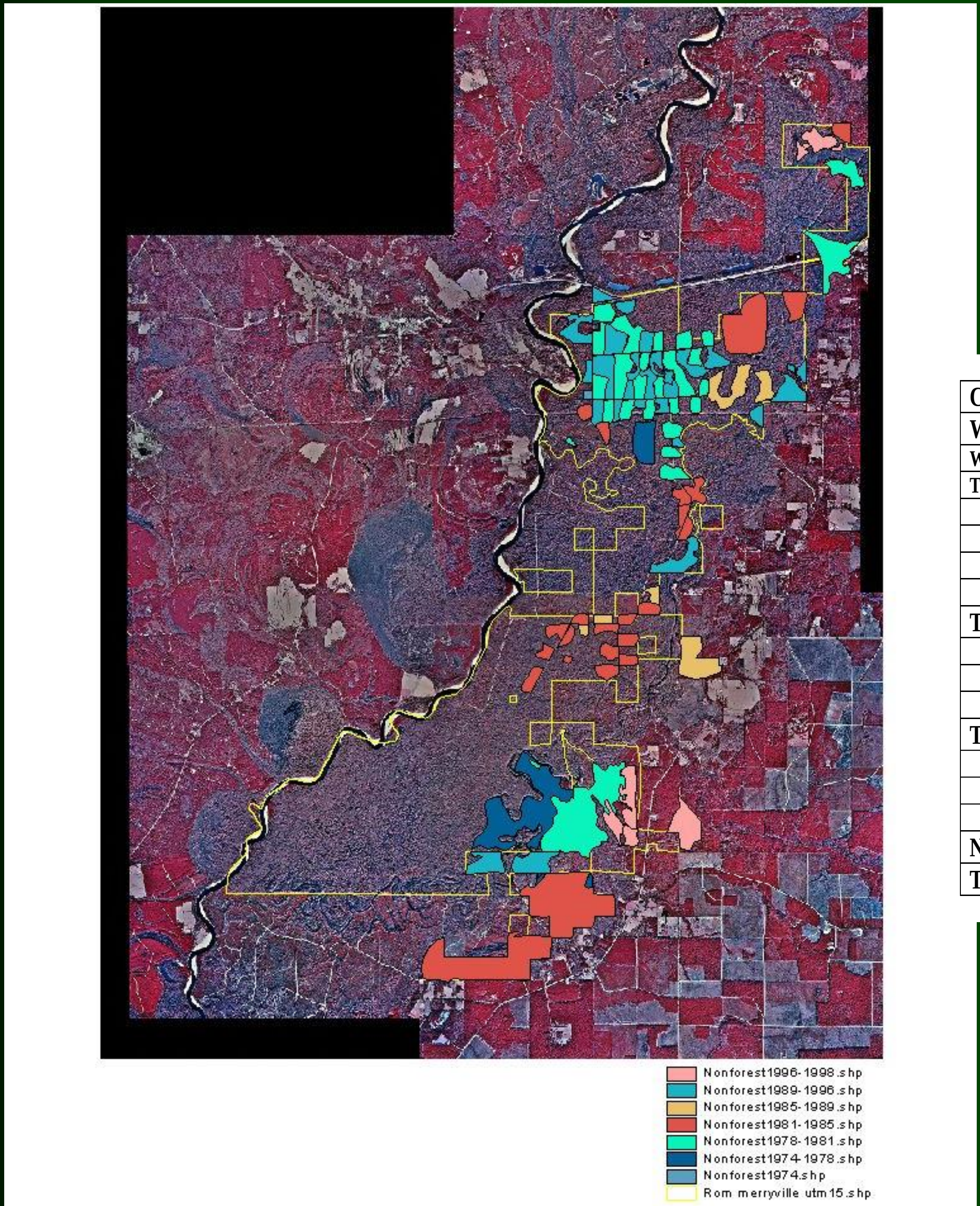


Historic Orthophotos for Inventory

1974

1996

Historic Orthophotos for Inventory



Class	Acreage	Sub Categorized Area
Water	246	
Wetland	52	
Total Softwood	1455	
Softwood (~5 years)		98
Softwood (5~15 years)		681
Softwood (15~25 years)		479
Softwood (+ 25 years)		198
Total Mixed	686	
Mixed (5~15 years)		108
Mixed (15~25 years)		267
Mixed (+ 25 years)		311
Total Harwood	8141	
Hardwood (5~15 years)		569
Hardwood (15~25 years)		667
Hardwood (+ 25 years)		6904
Nonforest	1074	
Total Acreage	11653	

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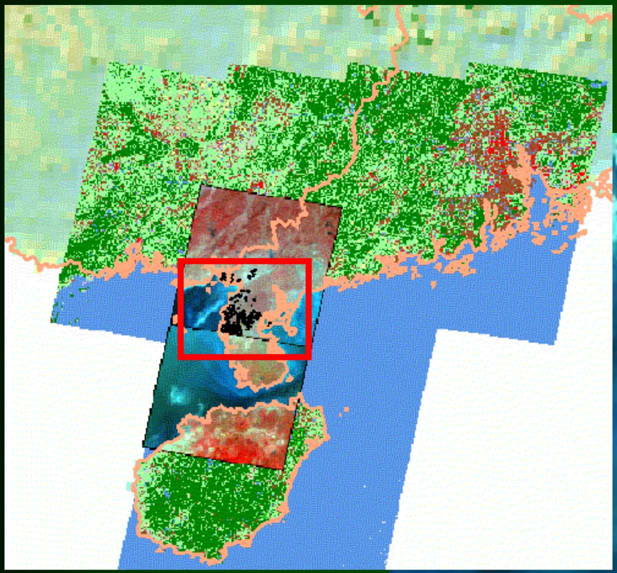
Eucalyptus Plantation in China



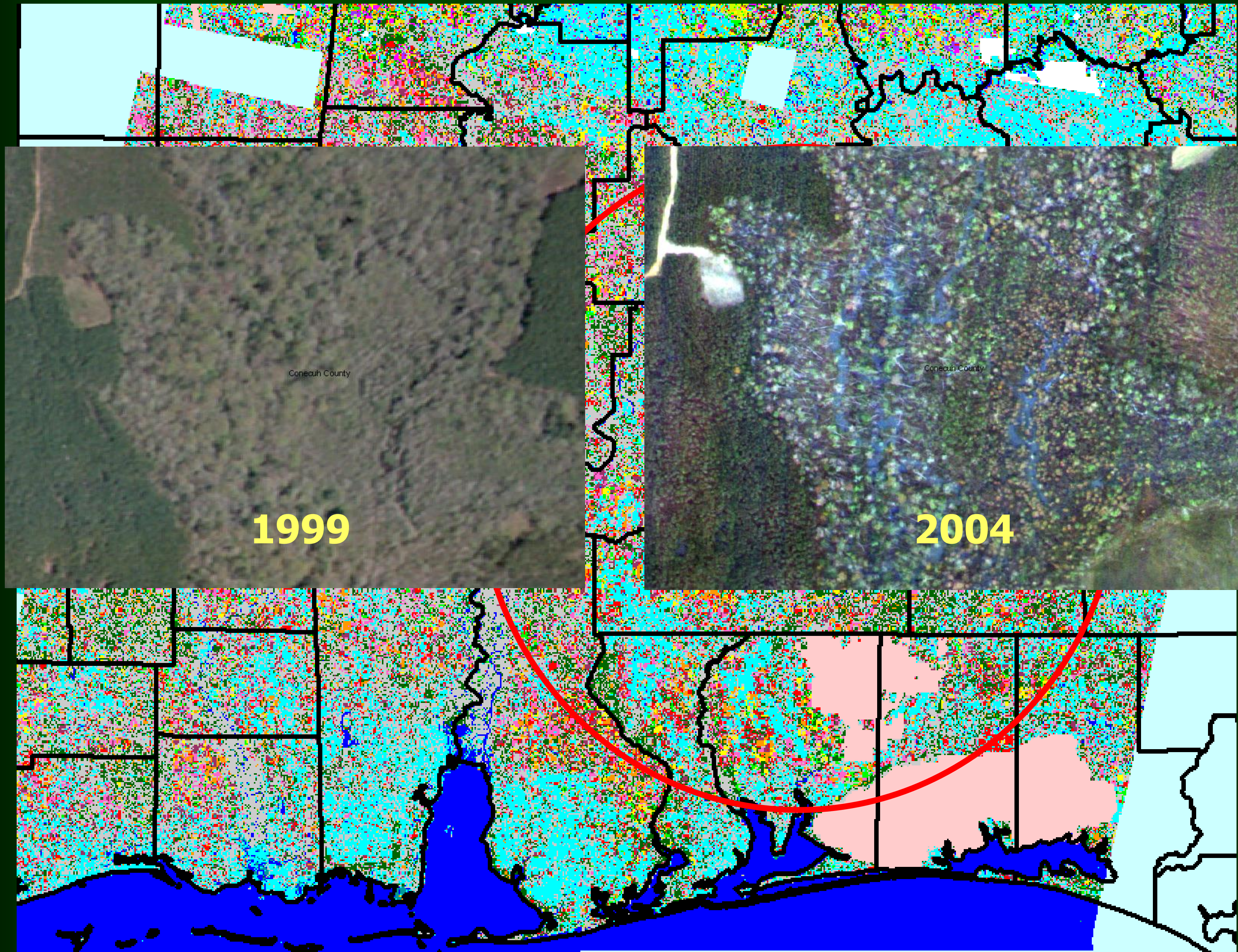

2002 4 15



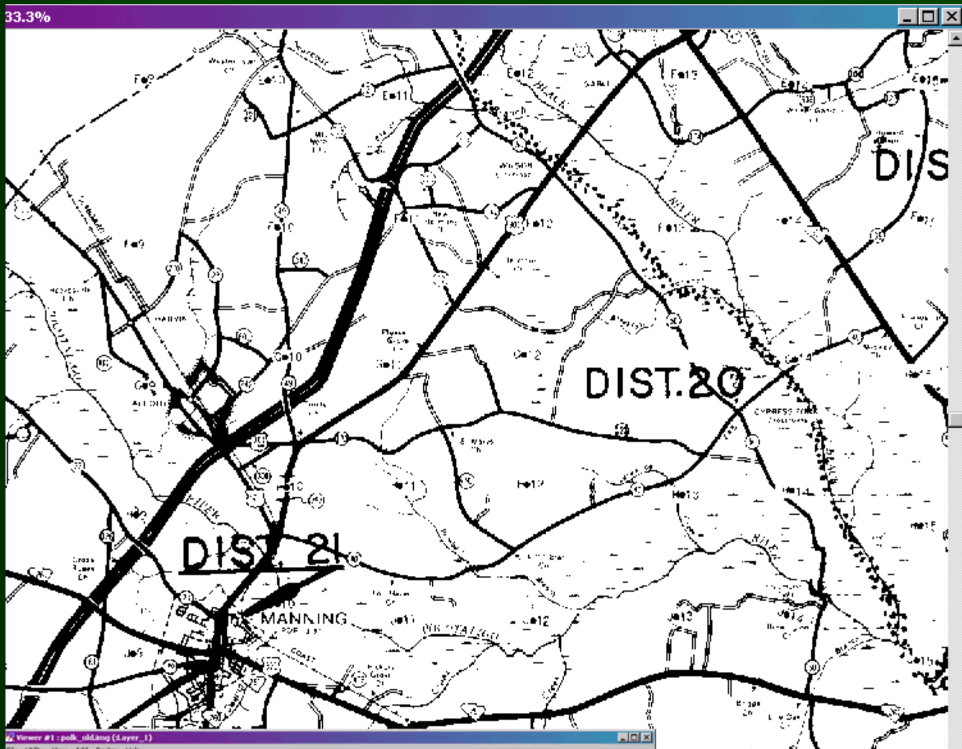
30 7 2004

Damage Assessment

Damage Assessment (Hurricane Ivan)

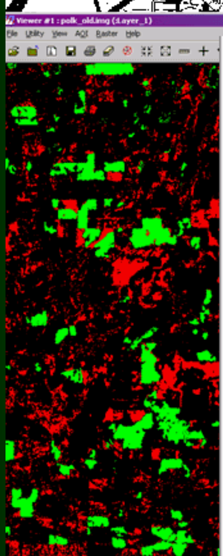


Target Marketing for Chemical Industry



3 way Join + Anywho.com

Tel # of potential clients

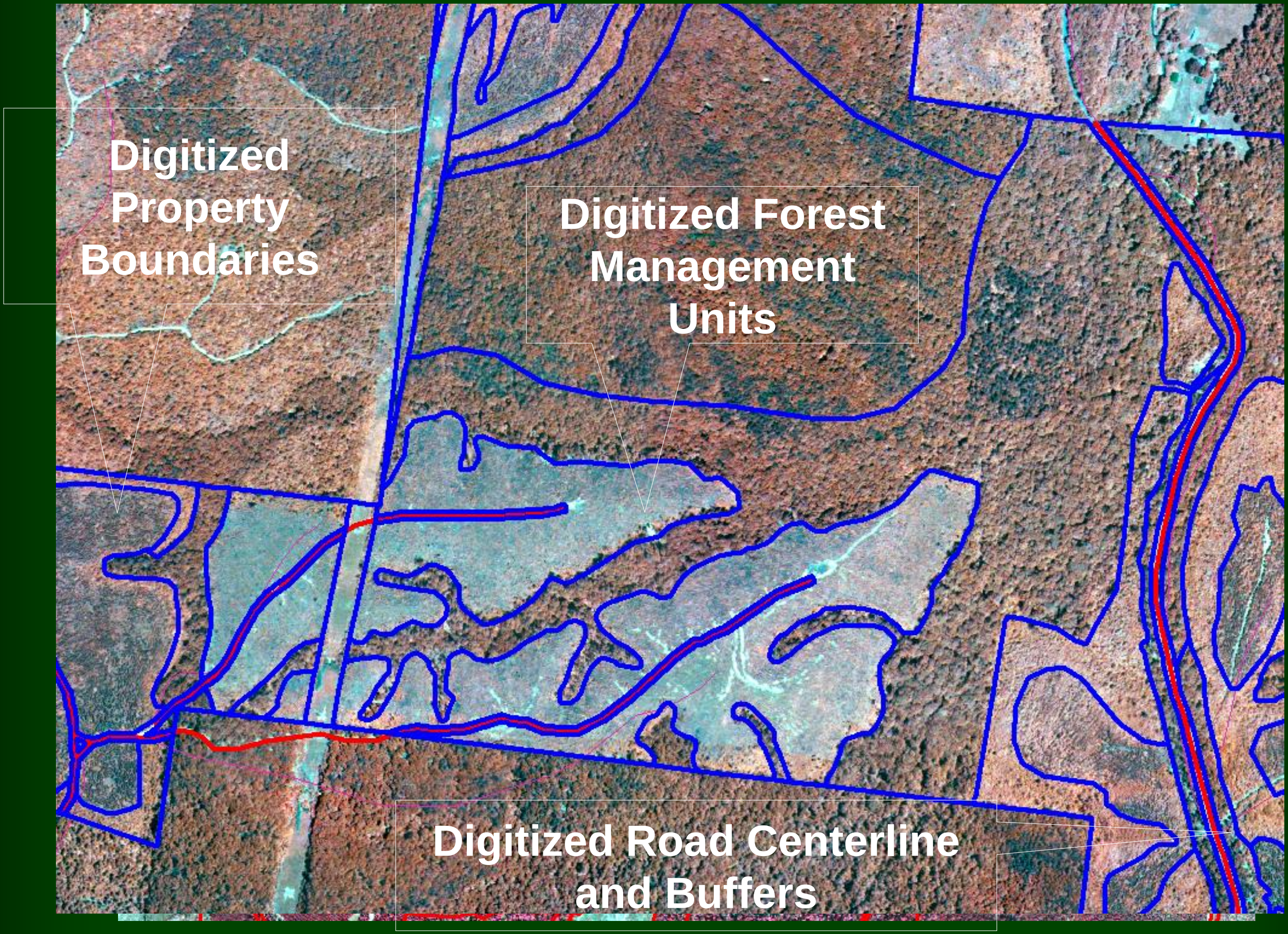


Standrd : Table

I	MAPN	BLOCKI	LOTN	MAPTIFF	COUNTYSTAT	OWNERNAME	OWNERADDRE	OWNERCITY	OWN
1	0298	26	3253	0298-00-.TIF	NC017	HEFLIN OTHELLA S L/E	11315 TWISTEI	BLADENBORO	NC
2	0278	20	9817	0278-00-.TIF	NC017	BRADSHAW JESSIE S	2967 GRIMSLE	BLADENBORO	NC
3	0288	98	7791	0288-00-.TIF	NC017	JOHNSON GARY L ETUX KIMBERLY	508 BURNEY R	BLADENBORO	NC
4	0287	39	4882	0287-00-.TIF	NC017	MCPHERSON WAYNE W & HELEN	13506 TWISTEI	BLADENBORO	NC
5	0287	38	5412	0287-00-.TIF	NC017	HYATT WILLIE RAY	PO BOX 784	CLARKTON	NC
6	0298	69	6408	0298-00-.TIF	NC017	BRITT LARRY JAMES L/E	10359 TWISTEI	BLADENBORO	NC
7	0287	28	8039	0287-00-.TIF	NC017	FALLS CHARLENE J THEODORE JOI	13758 TWISTEI	BLADENBORO	NC
8	0286	01	1174	0286-00-.TIF	NC017	JORDAN BETTY JO	1203 PAGE RD	CLARKTON	NC
9	0288	10	7850	0288-00-.TIF	NC017	BRYANT LIZZIE % J BRYANT JR	11 LELAND AV	SOUTH RIVER	NJ
1	0287	38	0750	0287-00-.TIF	NC017	HYATT BILL L ETUX CONNIE	P O BOX 113	CLARKTON	NC
1	0287	29	7125	0287-00-.TIF	NC017	WIGGINS CHARLES	2305 OLD ABBI	BLADENBORO	NC
1	0287	29	5088	0287-00-.TIF	NC017	WIGGINS CHARLES	2305 OLD ABBI	BLADENBORO	NC
1	0287	29	6097	0287-00-.TIF	NC017	WIGGINS CHARLES	2305 OLD ABBI	BLADENBORO	NC
1	0288	26	6312	0288-00-.TIF	NC017	TODD SHANE ET UX REGINA	85 OLD ABBOT	BLADENBORO	NC
1	0298	26	0361	0298-00-.TIF	NC017	COOK GIRLINE S	11278 TWISTEI	BLADENBORO	NC
1	0287	28	2433	0287-00-.TIF	NC017	THORNTON JILL GREGORY ANTHON	14105 TWISTEI	BLADENBORO	NC
1	0286	03	0383	0286-00-.TIF	NC017	CURRIE JAMES & AMELIA	16133 TWISTEI	BLADENBORO	NC
1	0277	91	0056	0277-00-.TIF	NC017	DARDEN GEORGE F JR	3330 PACIFIC A	VIRGINIA BEAC	VA
1	0287	38	2419	0287-00-.TIF	NC017	TATUM GLORIA DEAN ET VIRE DAVI	PO BOX 1214	BLADENBORO	NC
1	0277	39	0857	0277-00-.TIF	NC017	DOWLESS DEWEY	1836 OLD ABBI	BLADENBORO	NC

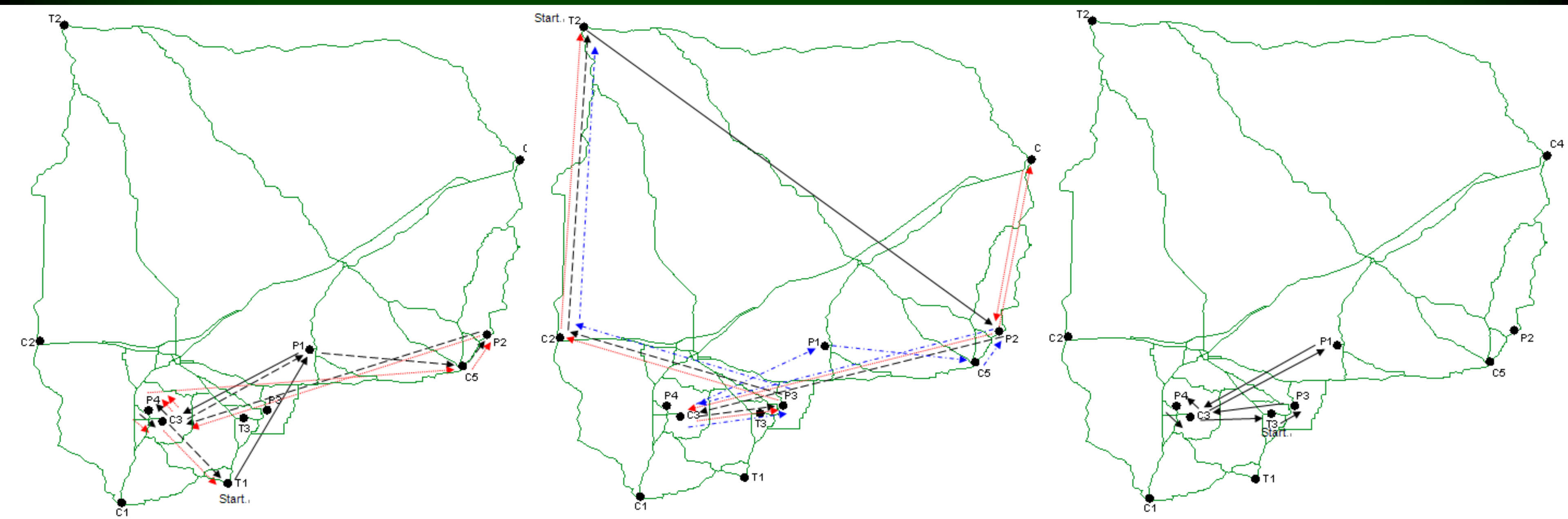
Record: 1 of 29544

Data Entry


Digitized Property Boundaries
Digitized Forest Management Units
Digitized Road Centerline and Buffers

Loggers' Route Optimization (MTSP)

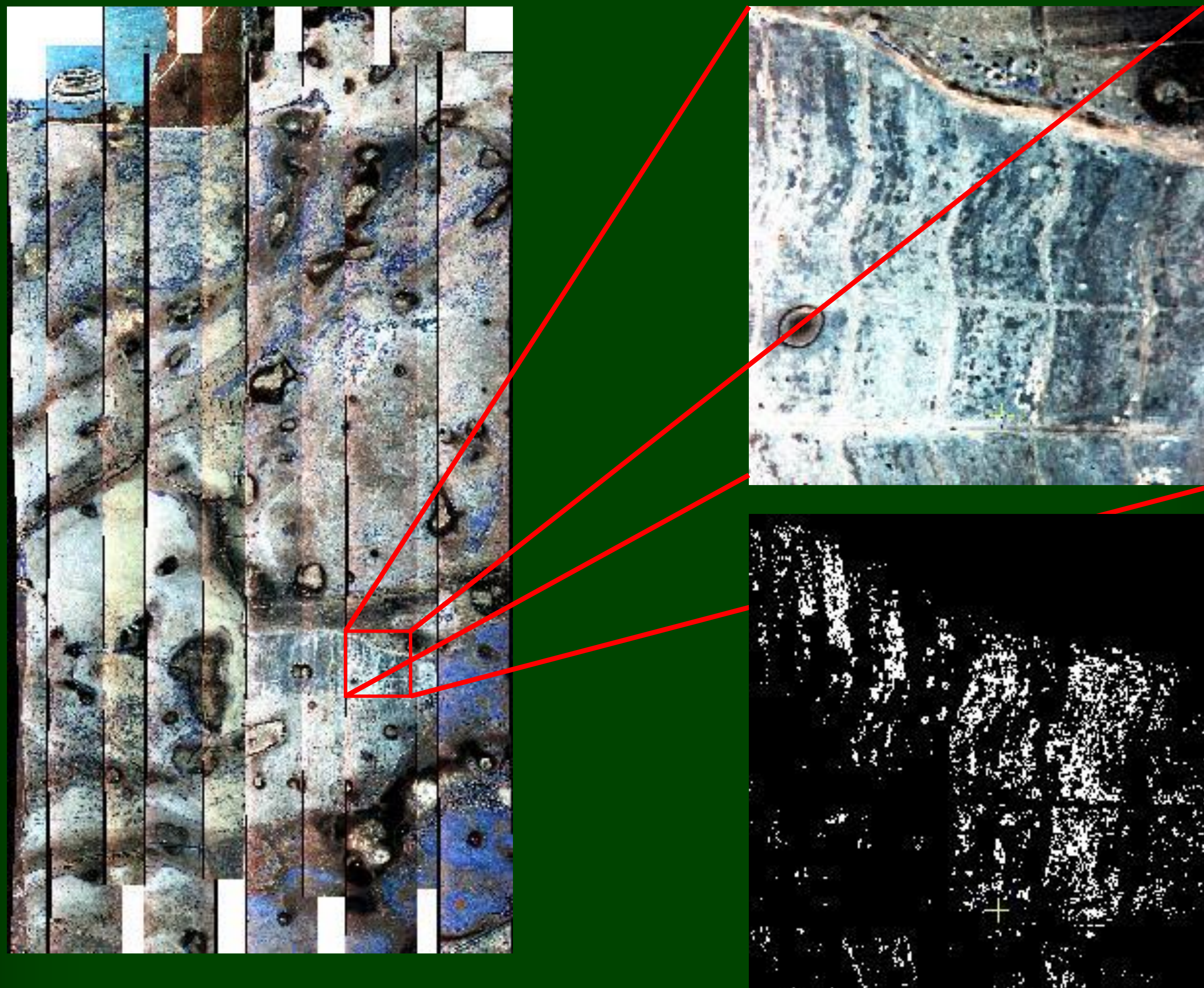
Destinations		Name	Coordinates	Product 1	Product 2
	D1	T&M Tie	N33 02.158' W94 11.356'	Hardwood Sawlogs	
	D2	IPCO New Boston Sawmill	N33 27.81' W94 23.41'	Pine Sawlogs	Small Pine Sawlogs
	D3	IPCO Texarkana Paper Mill	N33 15.52' W94 04.67'	Hardwood Pulpwood	Pine Pulpwood
	D4	IPCO Gurdon Plywood and Sawmill	N33 56.75' W93 08.01'	Pine Sawlogs	Small Pine Sawlogs
	D5	Quad Lumber Company	N33 23.86' W93 16.99'	Hardwood Sawlogs	
Tracts	T1	Weigh Station/Tinkes Logging	N33 27.27' W93 41.02'	15 loads/day Hardwood Pulpwood	3 loads/day Hardwood Sawlogs to Q
	T2	Two Mile Tract/Mudford Logging 1	N33 28.10' W93 13.18'	13 loads/day Pine Pulpwood	3 loads/day Small Pine Sawlogs to (
	T3	McKinny Bayou/Mudford Logging 2	N33 17.115' W93 48.15'	8 loads/day Pine Pulpwood	w loads/day Small Pine Sawlogs
	T4	Sulphur River/Hartline	N33 16.74' W94 07.05'	15 loads/day Hardwood Pulpwood	5 loads/day Hardwood Sawlogs
Loggers	L1	Hartline Farm and Timber	N33 05.216' W 93 54.178'	7 trucks	
	L2	Billy Tinkes Logging	N34 18.367' W94 20.307'	5 trucks	
	L3	Steven Mudford Logging	N33 16.132' W93 51.14'	8 trucks	



Cogongrass mapping with hyperspectral images analysis

- Nineteen bands hyperspectral *casi* image was acquired in Florida in Jan. 2004
- Ninety ground truthing points captured in Dec. 2003.
- A state-of-art mapping algorithm applied to strips of images
- Pinpointing result of cogongrass aggregation

Cogongrass in fall and winter



A composite of 10 image strips

A major aggregation of cogongrass

Southern Pine Beetle Risk Modeling (with Ron Billing)

Southern Pine Beet

Epidemic

Other Infes

Billings and Bryant (1983) have developed a method to hazard and risk rate large pine-forested areas (18,000 acre TFS grid blocks) for susceptibility to SPB. The initial grid block hazard map for east Texas, which covered 656 grid blocks (11,808,000 acres), was based on 1981-83 aerial photos and validated in east Texas using SPB detection records (Billings et al. 1985). Twenty circular photo plots, each representing a ca. 30 acre area, equally spaced in five rows and four columns, provide a 3% systematic sample of host conditions within each grid block.

Each of the 20 circular plots per grid block is classified by host type as follows:

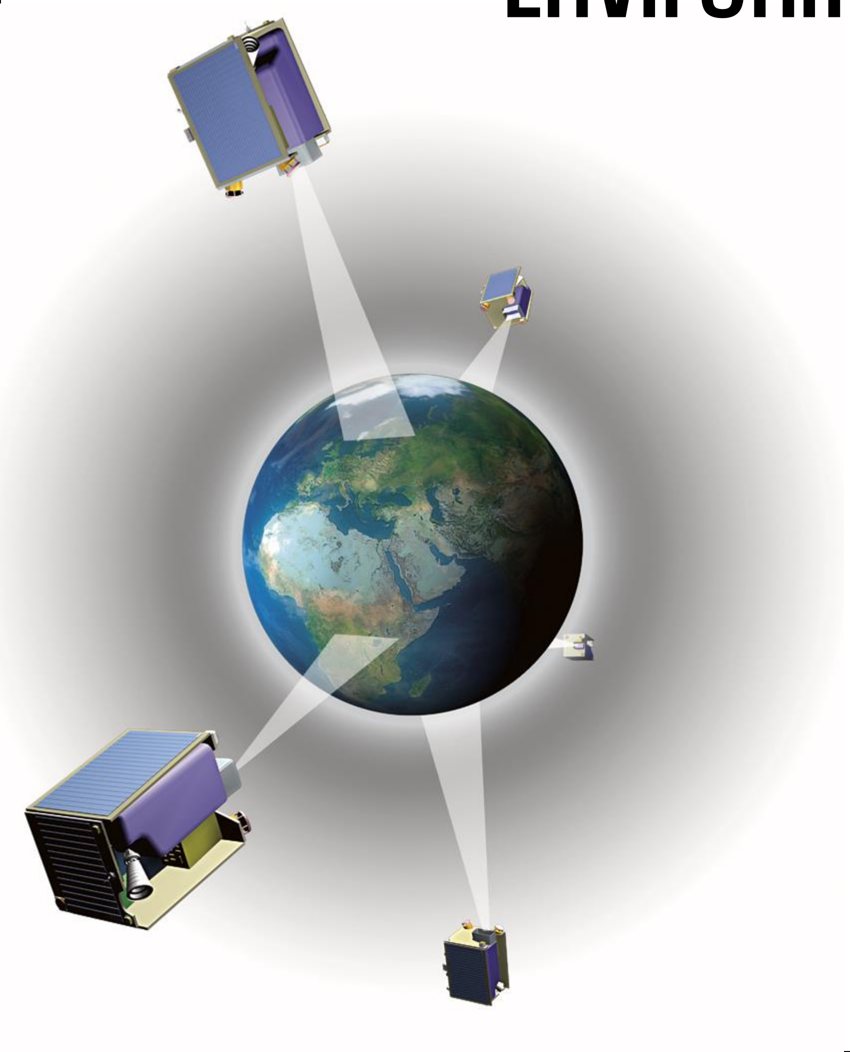
Host Type	Classification
Non-host	0
Young pine less than 15 years old	1
Pine host at least 15 years old	2

For each circular plot with pine host type, additional information is recorded for percent pine coverage, percent pine crown closure and landform, according to the following method of dichotomous classification:

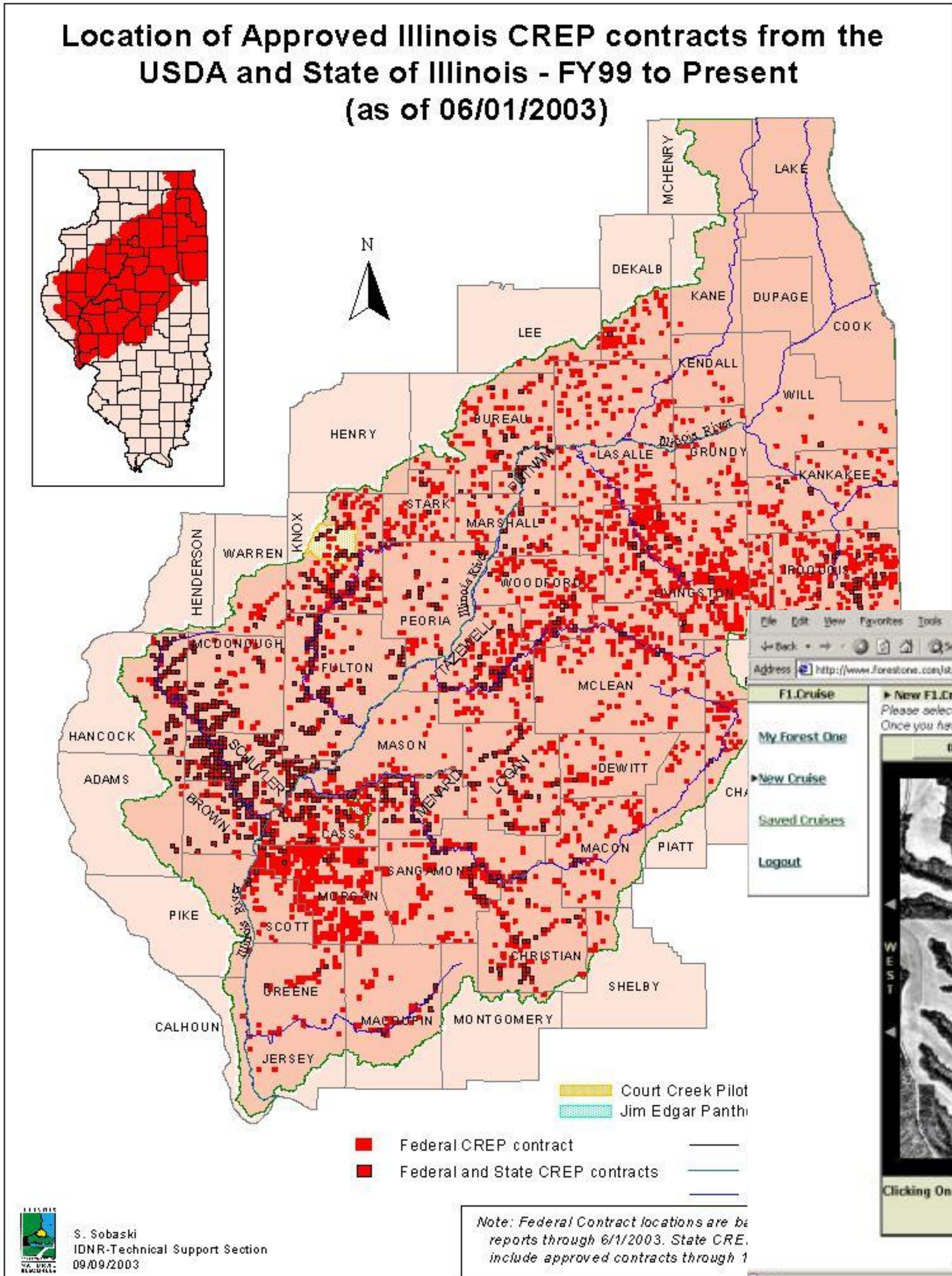
Site/stand factor	Value	Classification
Percent pine coverage	15-69%	1
	>69%	2
Percent pine crown closure	<80%	1
	>79%	2
Landform	Other terrain	1
	Bottomland	2

UAV Application

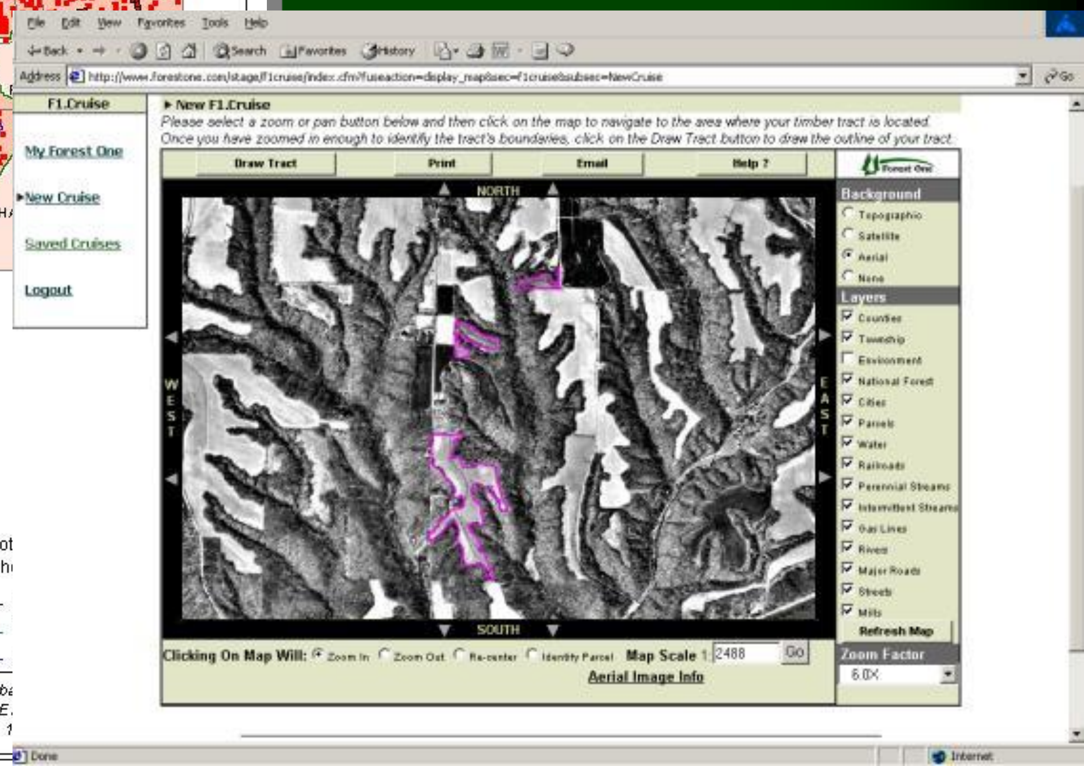
Environmental Applications



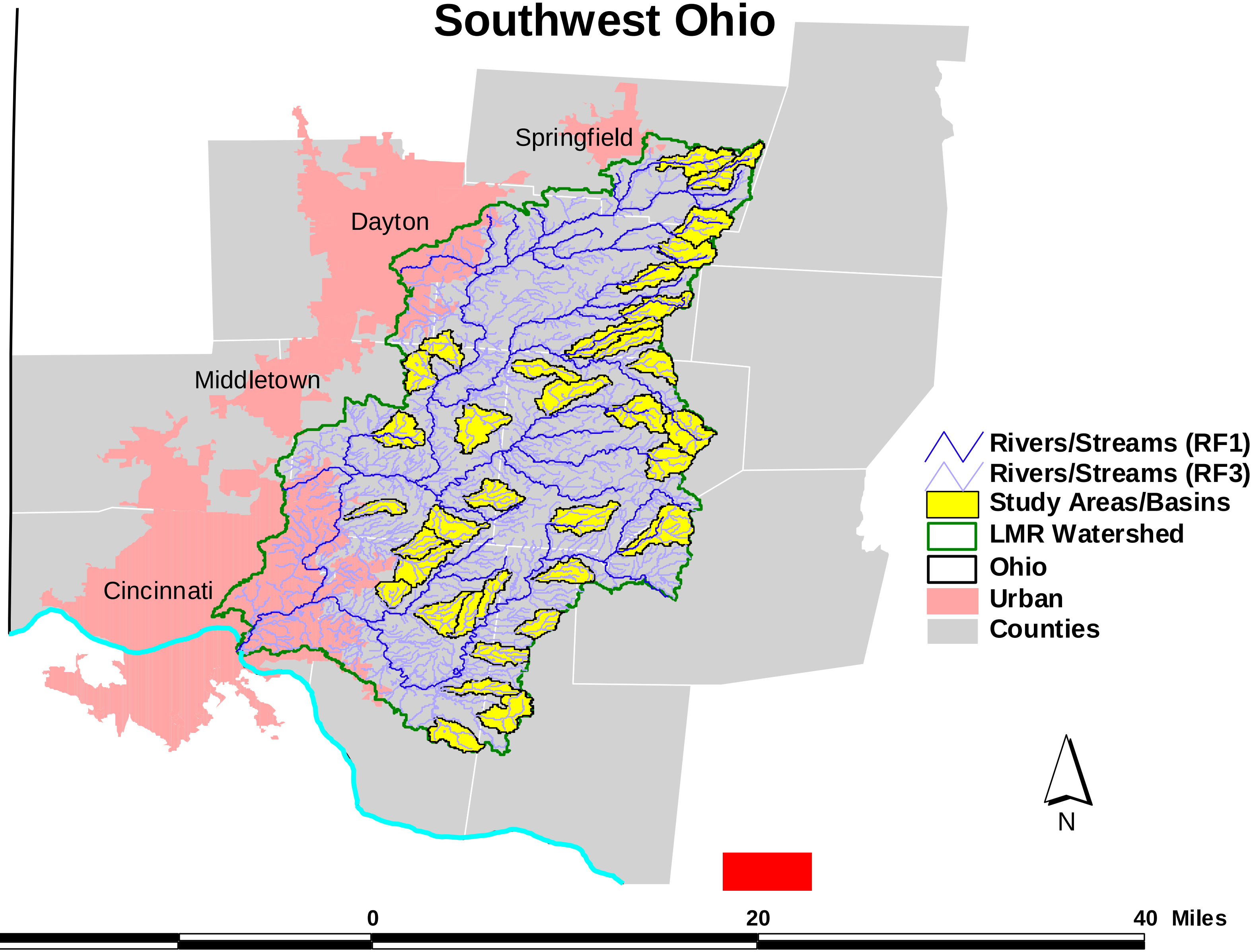
NASA Illinois Conservation Practice Monitoring (PS)



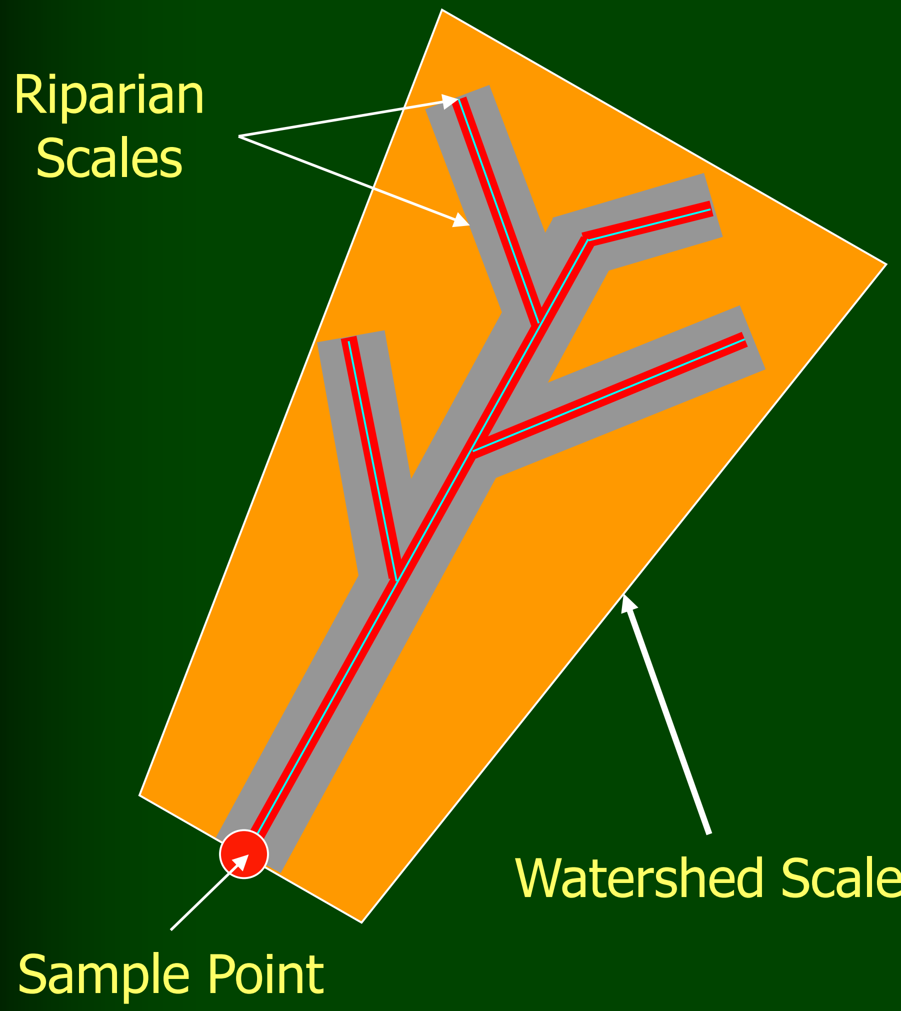
- 8,500+ contracts, in 18 counties
- 135,000+ acres of enrollments

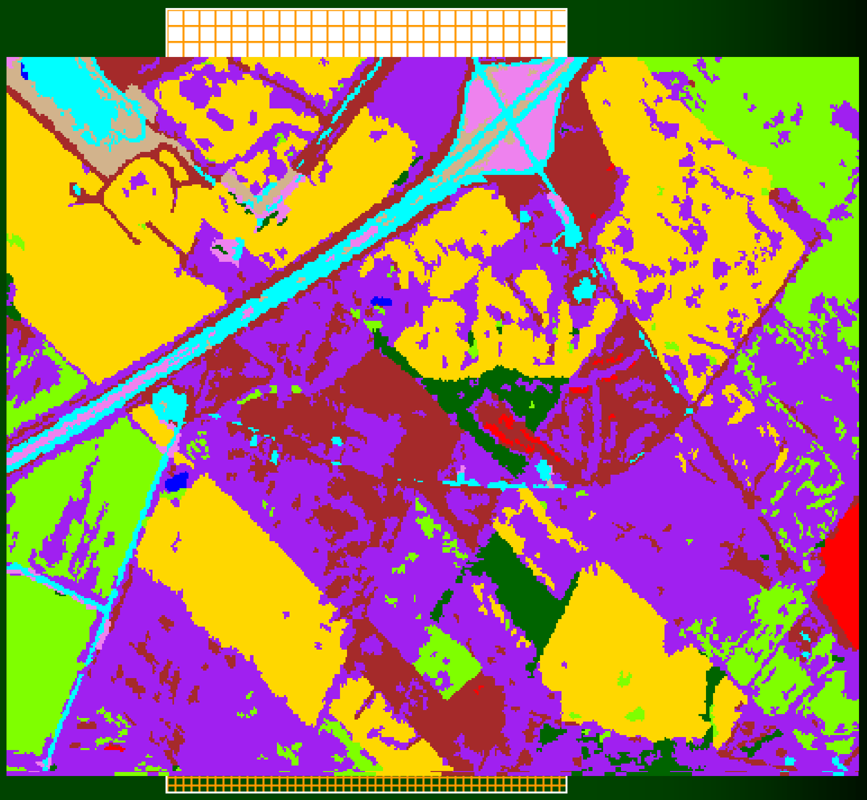


Little Miami River Watershed
Southwest Ohio



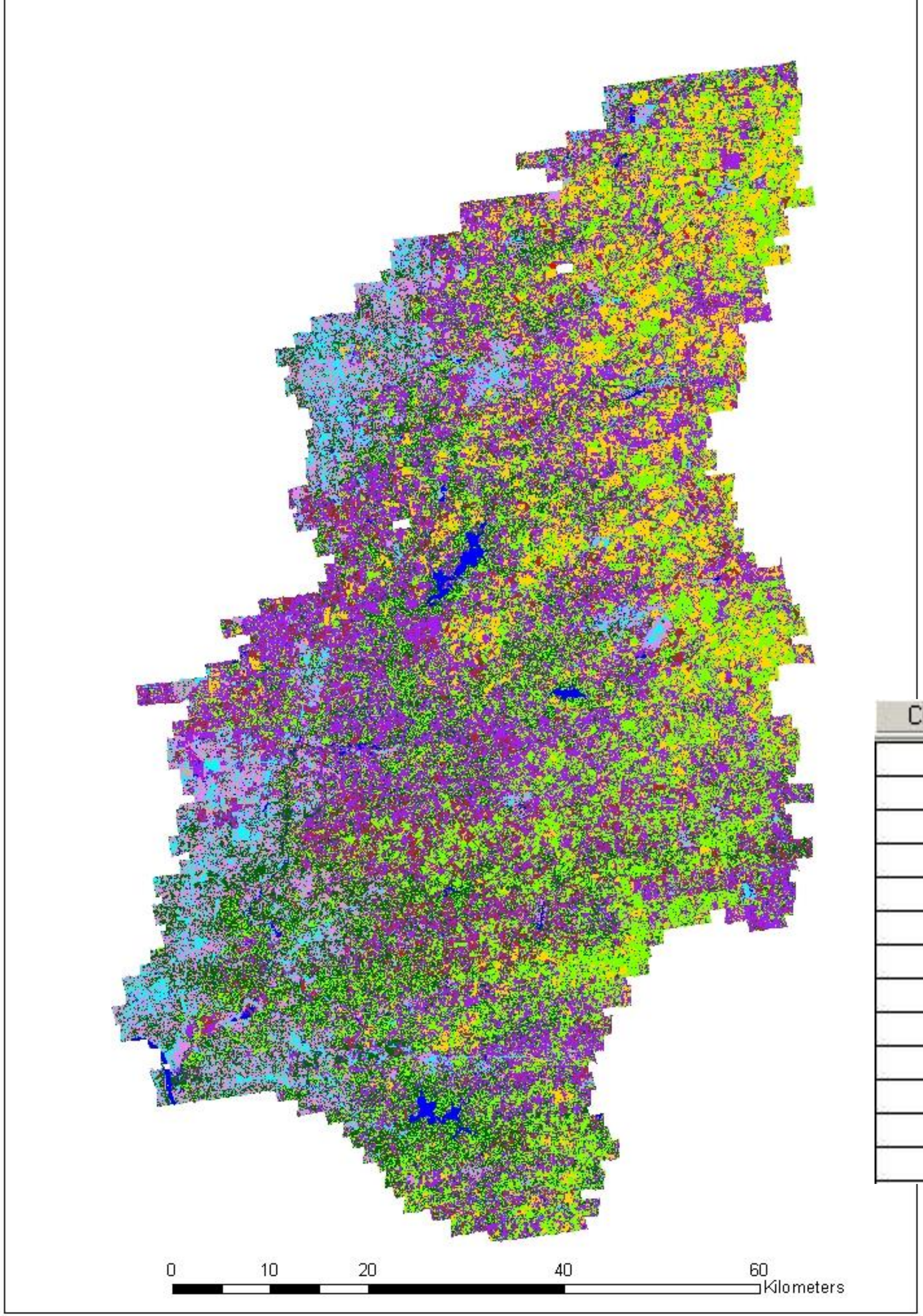
Considering Multiple Spatial Scales and Resolutions





EPA Non-point Pollution For Water Quality Modeling (PI)

- 4m Hyperspectral Image Processing
- 83 Flight Lines



Class Code	Class Name	Color
-99	Background	
1	Lentic	
2	Lotic	
3	Forest	
4	Corn	
5	Soybean	
6	Wheat	
7	Dry Herbaceous	
8	Grass	
9	Urban Barren	
10	Rural Barren	
11	Urban/Built	
99	Unclassified	

Water Quality and Related Applications

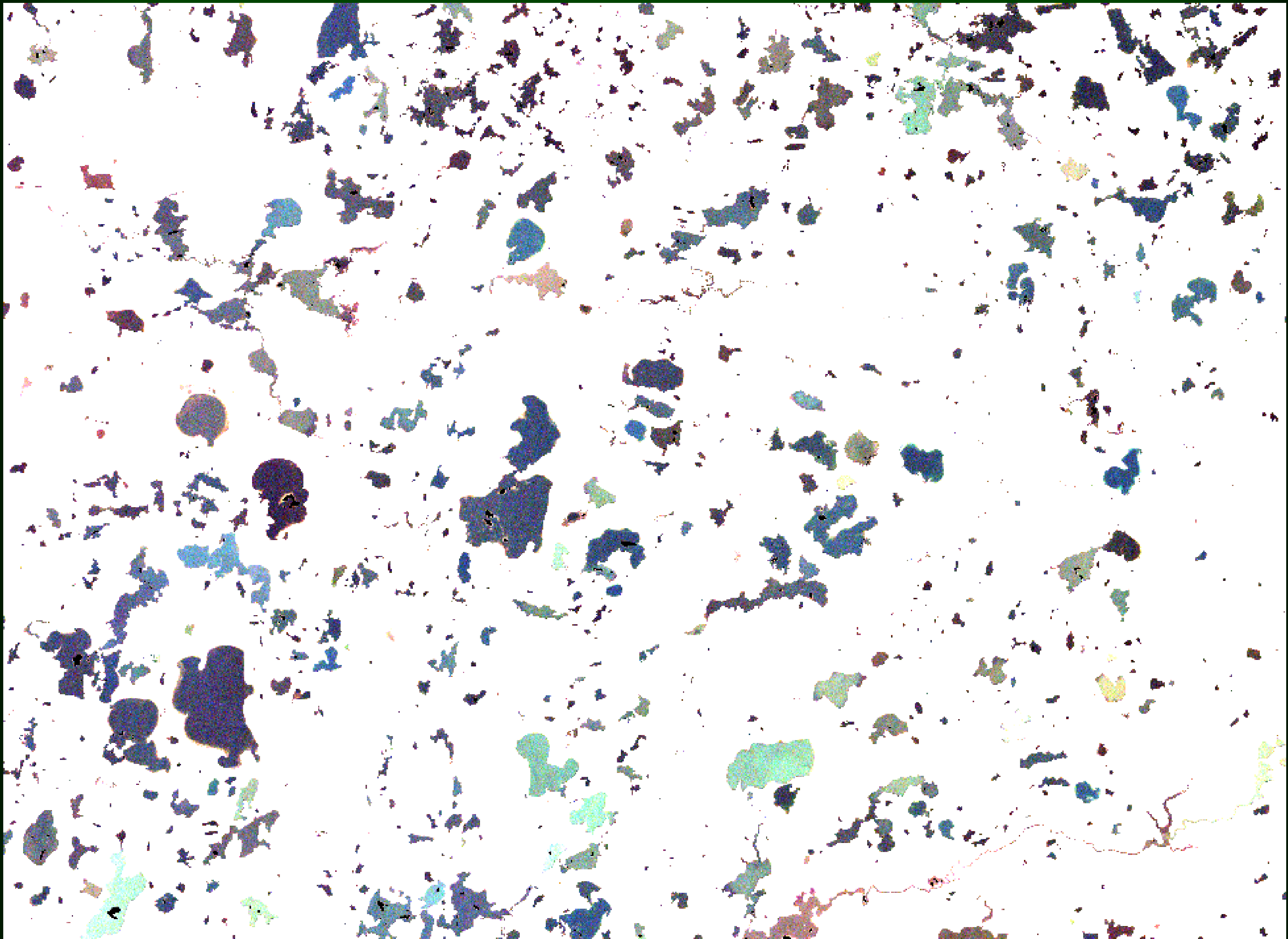
- Water Quality Index – Biophysical Parameter Estimation
  1. BOD – DO (Temperature)
  2. Suspended Solid (SS) – Turbidity (Clarity)
  3. Ph
  4. Total N and P
- Non-point pollution monitoring and management
  1. LU/LC Classification
  2. Riparian Zone Management

Base Maps from RapidEye Images

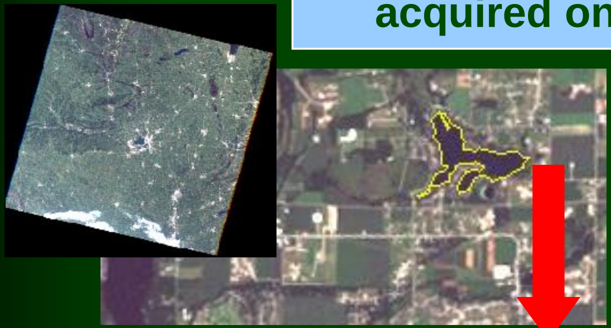
- High Resolution imagery comparable to 1:25,000 map scale.
- Accuracy better than 5 m with user supplied GCPs
- Very up to date imagery for map products
- Multi Channel data for additional analysis

Landsat-7 ETM+ Image of the Trout Lake Region (6 October 1999)

Lakes only (land masked out) - Bands 3, 2, 1 as R, G, B



Landsat-7 satellite image acquired on 7/27/99



Sensor Channel	Wavelength (µm)	Spectral Region	Mean Digital Number (DN)
1	0.45-0.52	Blue	62.97
2	0.53-0.61	Green	37.85
3	0.63-0.69	Red	25.23
4	0.75-0.90	Near-infrared	19.09
5	1.55-1.75	Mid-infrared	10.17
7	2.09-2.35	Mid-infrared	9.23

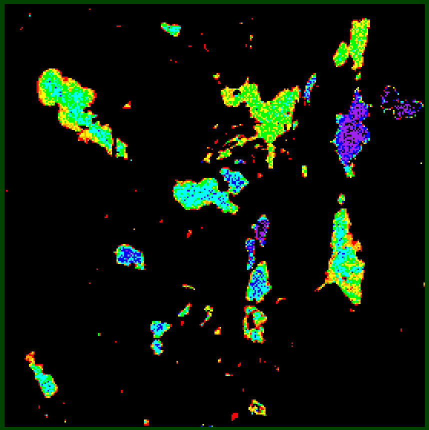
Water samples collected by Lake Monitoring Volunteers

WBIC	Lake Name	Date	SD(feet)
0852400	Lake Keesus	07/26/99	14
0854300	Ashippun L.	07/25/99	7
0816800	Whitewater L.	07/27/99	5
0741500	Pleasant L.	07/28/99	11

MODEL

Satellite-Assisted Lake Water Quality Monitoring

1. Find lakes in Landsat image.
2. Find corresponding water clarity data collected by Self-Help Lake Monitoring Volunteers.
3. Develop a model to correlate the secchi disk (SD) clarity measured by volunteers with the satellite-measured reflectance at different wavelengths.
4. Use the model and the satellite data to predict SD and trophic state index (TSI) for lakes where actual SD and TSI data are not available.

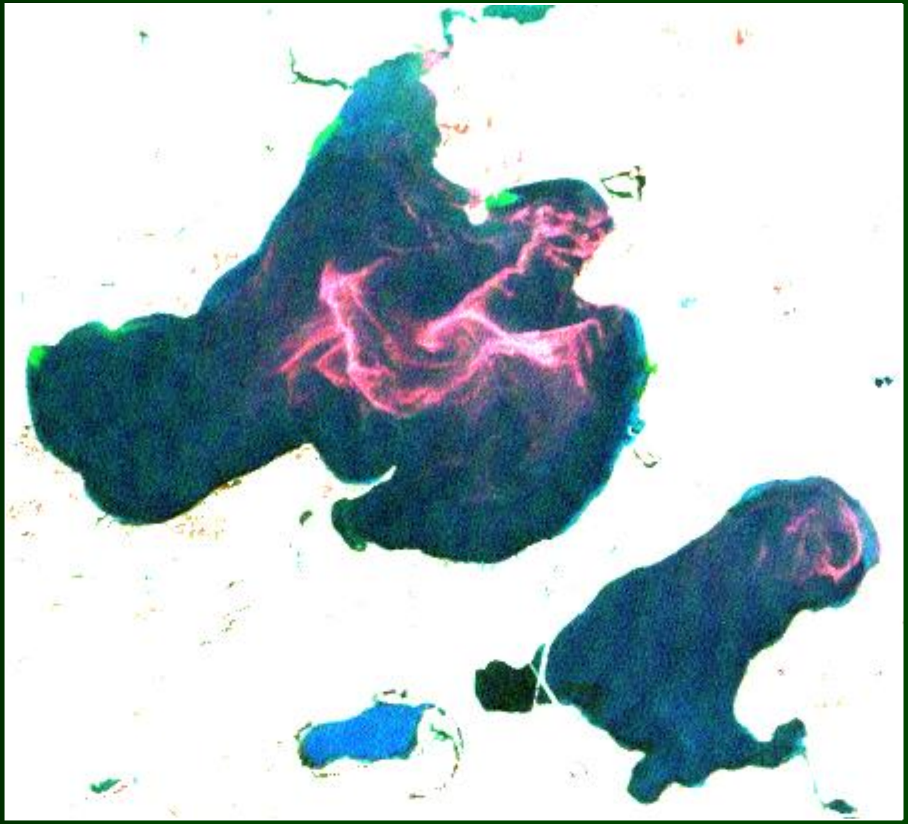


Legend

- TSI < 30
- 30 - 40
- 40 - 50
- 50 - 60
- 60 - 70
- 70 - 80
- > 80

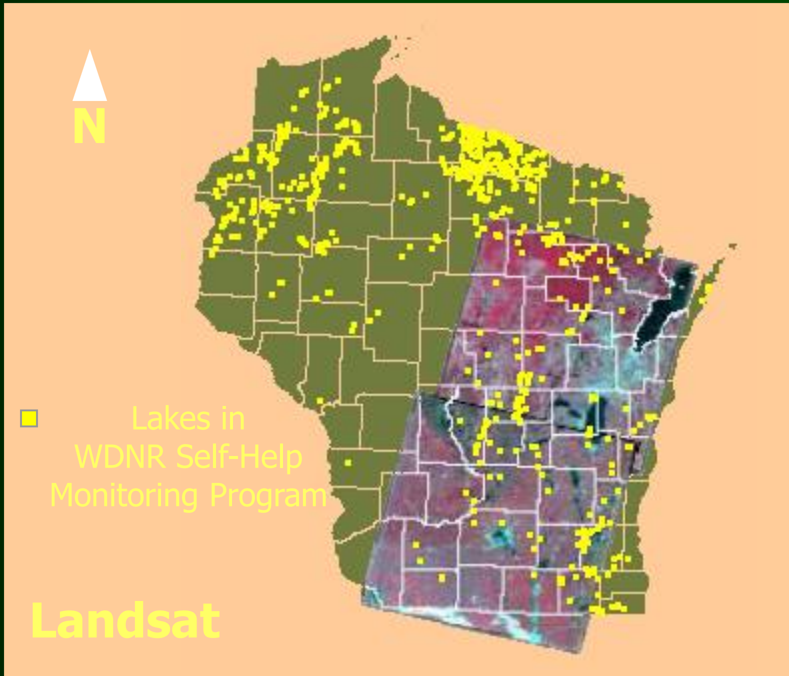
Model output: map of trophic state index (TSI) for all lakes

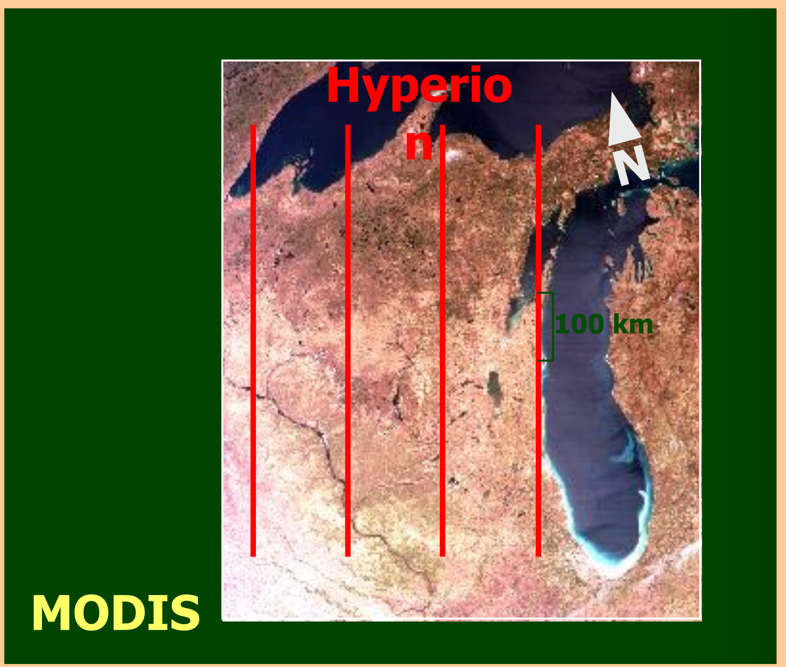
Monitoring algal blooms with satellite imagery

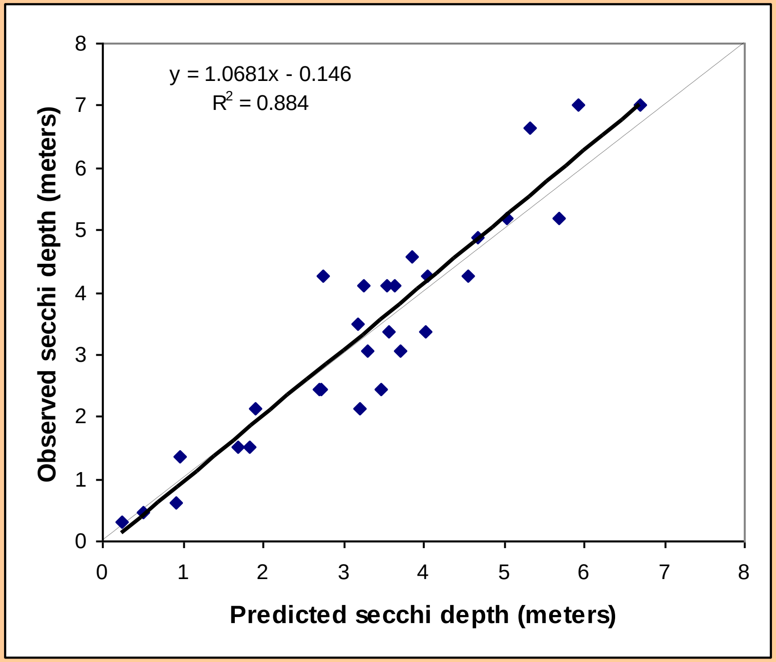


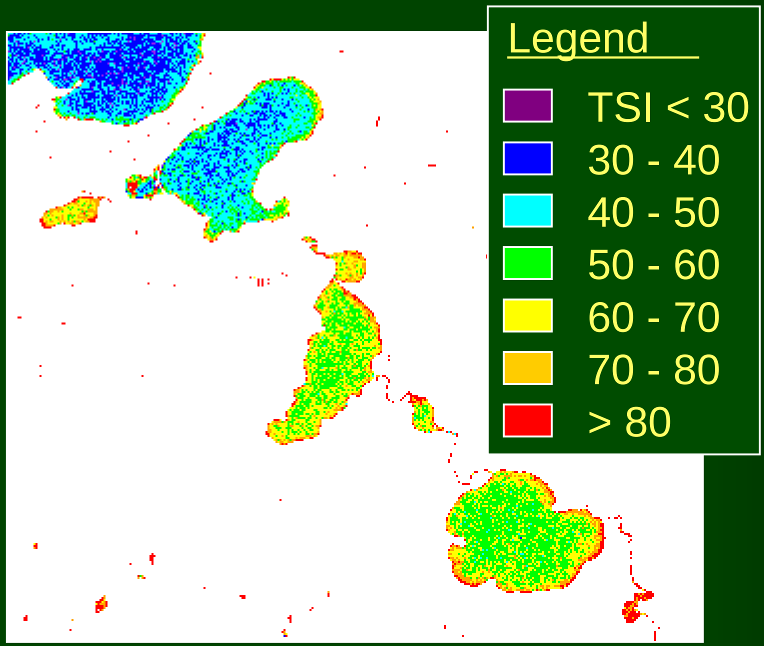
Algal blooms in Lake Mendota and Lake Monona: 31 October 1999

Landsat-7 bands 4, 3 ,2

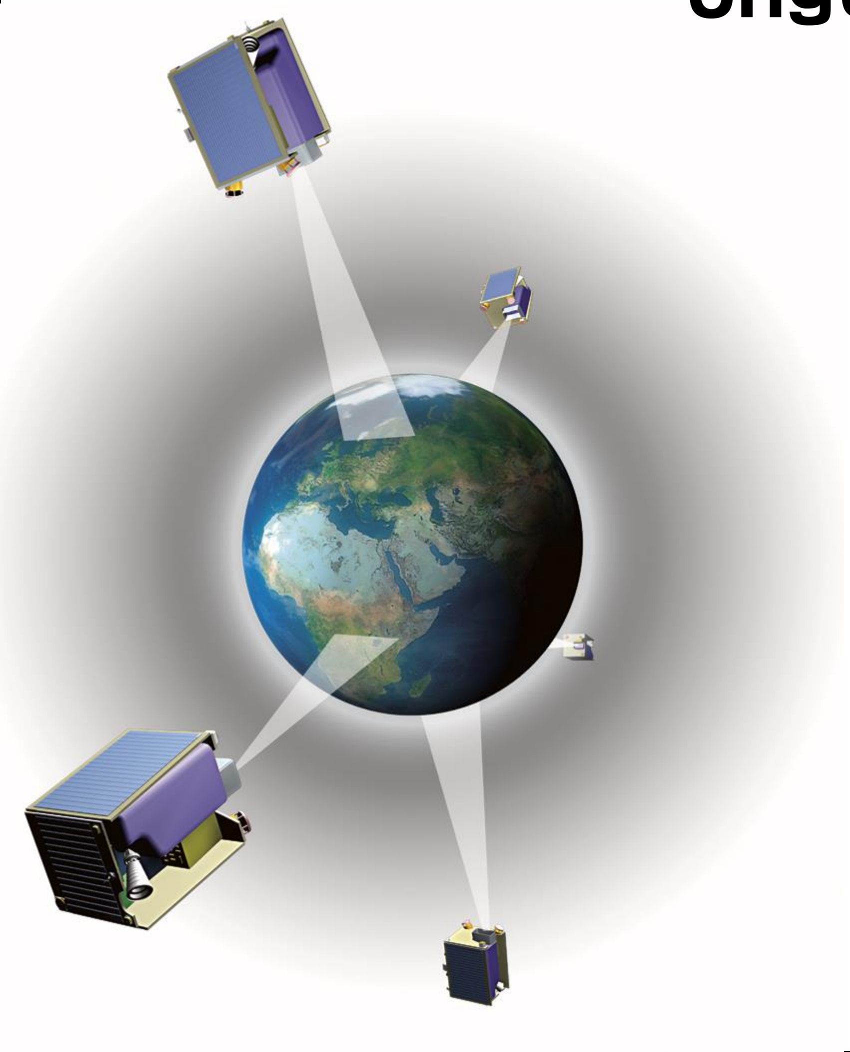

N
Lakes in
WDNR Self-Help
Monitoring Program
Landsat


Hyperio
n
N
100 km
MODIS

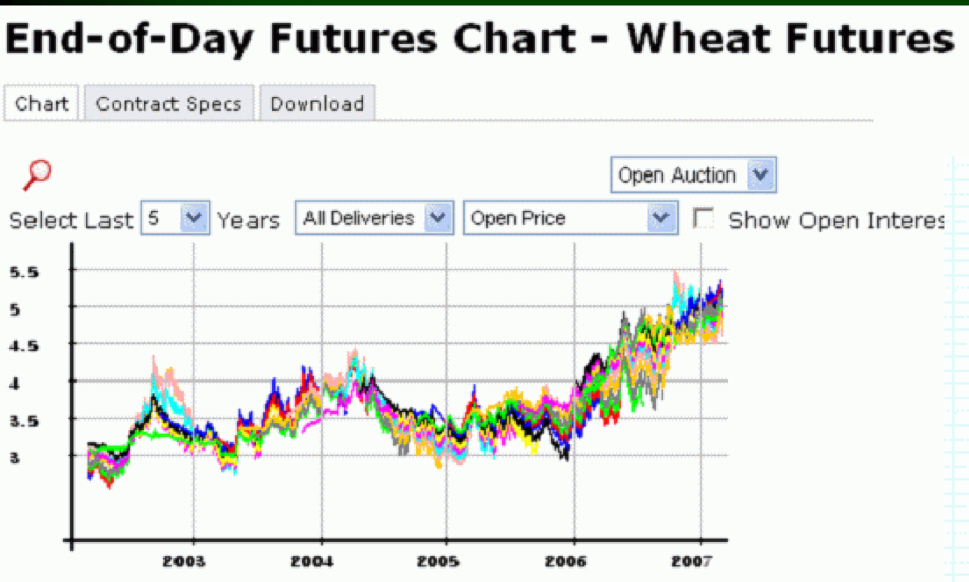

y = 1.0681x - 0.146
R^2 = 0.884
Observed secchi depth (meters)
Predicted secchi depth (meters)

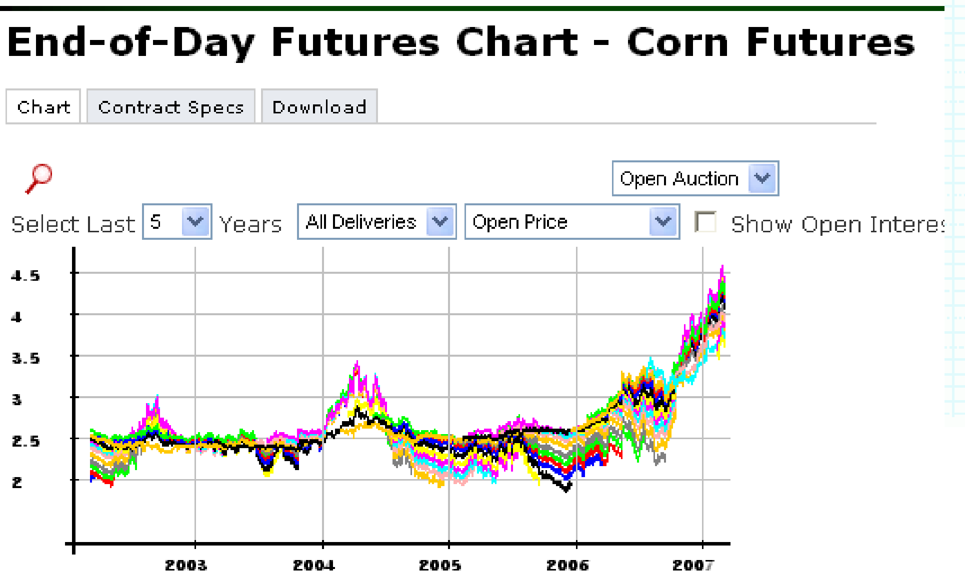

Legend
TSI < 30
30 - 40
40 - 50
50 - 60
60 - 70
70 - 80
> 80

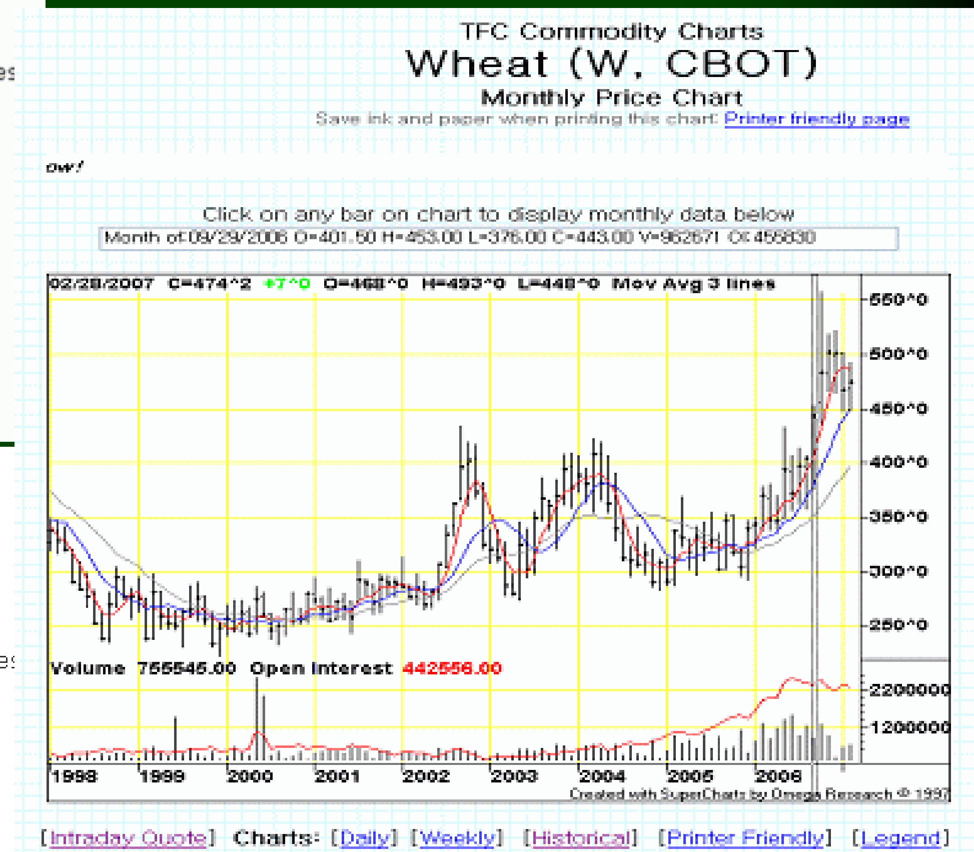
Ongoing Research Agenda



Agro Investment Market - CBOT







Volatility of Crop Price 2008-2009

LANWORTH
THE VALUE OF INSIGHT.

Current Analysis

This page contains data and maps that our team of agronomists, geographers, meteorologists and remote sensing analysts have constructed as relevant insight into our current analysis...
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Recent News

Spying for Profits: Agriculture -CNBC
August 19, 2010

Lanworth's Analysis of 2010 Forest Cover Confirms a Significant Decrease in the Rate of Forest Clearing in the U.S.
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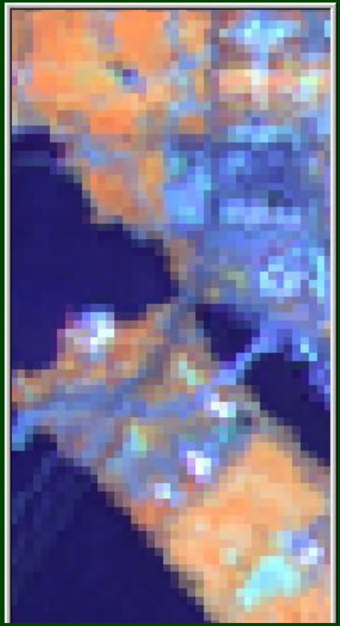
CMC ACORE National Grain and Feed Association

Step1: Concept

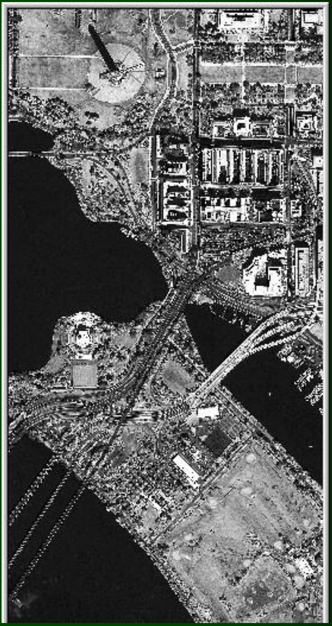
- **Crop Analysis and Forecasting**

- Using Satellites imagery (AVHHRR, Landsat,) and a variety of vegetation index such as NDVI (Normalized Difference Vegetation Index)
- NDVI is formed from satellite imagery by combining (adding, subtracting, multiplying, or dividing) various spectral band, and is somehow related to the productivity of crop field.
- A hierarchical approach would be possible to make a reasonable estimation of crop yield.

< NDVI image from AVHRR satellite >



Landsat 7 multispectral 30 m



IKONOS panchromatic 1 m

Step1: Concept

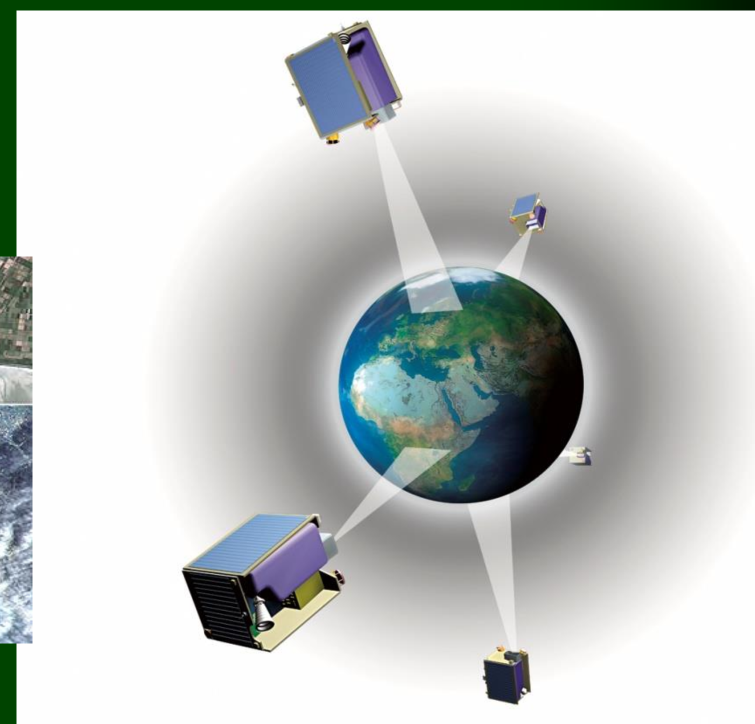
- **Difficulty in the past**

- Difficulty in obtaining cloud free imagery of interest at key times during the growing season.
- Vegetation vigor measurements seldom have strong correlations with crop yields.
- Different planting times in season and year-to-year are not accounted for in the correlation coefficients relating yield to measurements of crop vigor

- **Why now?**

Kompsat-2
1m resolution

RapidEye
5-satellite system



Step1: Methodology

NOAA TIROS-N
RapidEye

Meteorological Satellites
(e.g. METEOSAT, GOES)

Vegetation Data

Meteorological Data

CROPCAST Commodity Forecast System

Vegetation vigor analysis

Short/long term Weather forecast

Weather Data from Ground stations

Crop filed observations

Crop Growth Models
Soil moisture
Plant physiology
Evapotranspiration
Yield histories
Crop husbandry

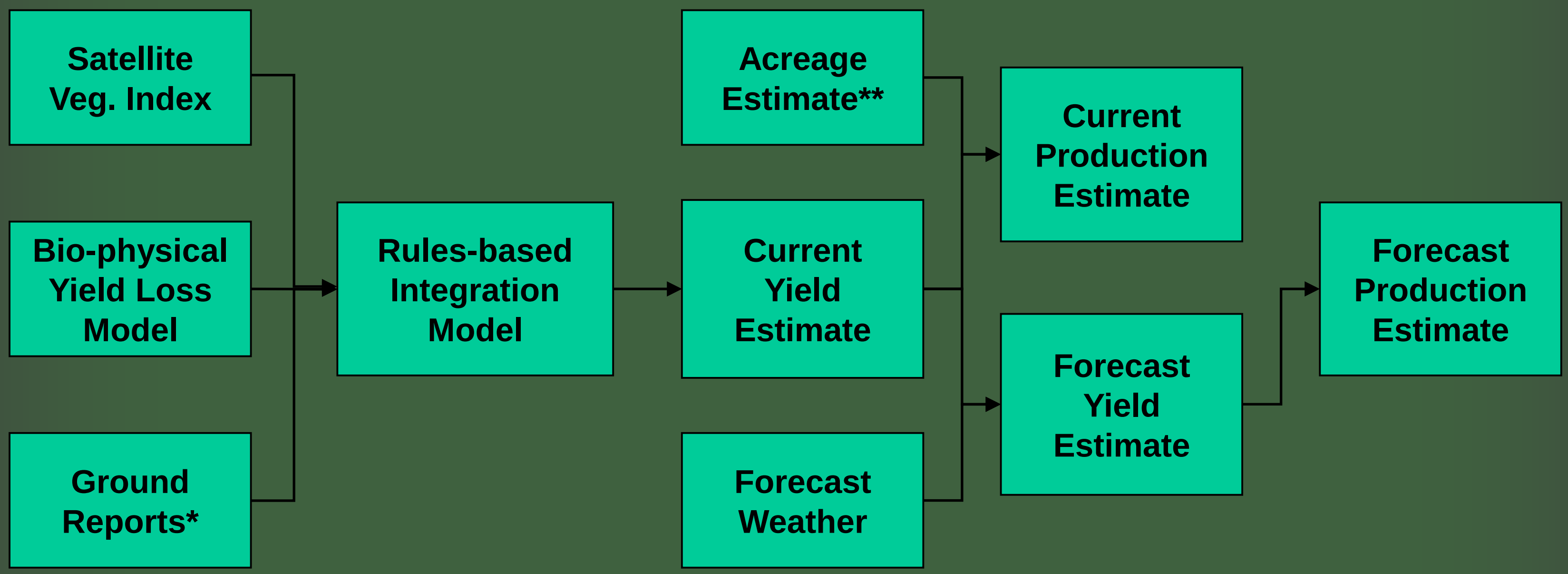
Crop types

Sowing dates

Crop hectarages

YIELD FORECAST

Step2: Methodology



*When available ** Based on official sources or our team's proprietary techniques

Step3: Application

- **Corn crop monitoring and yield prediction in China**

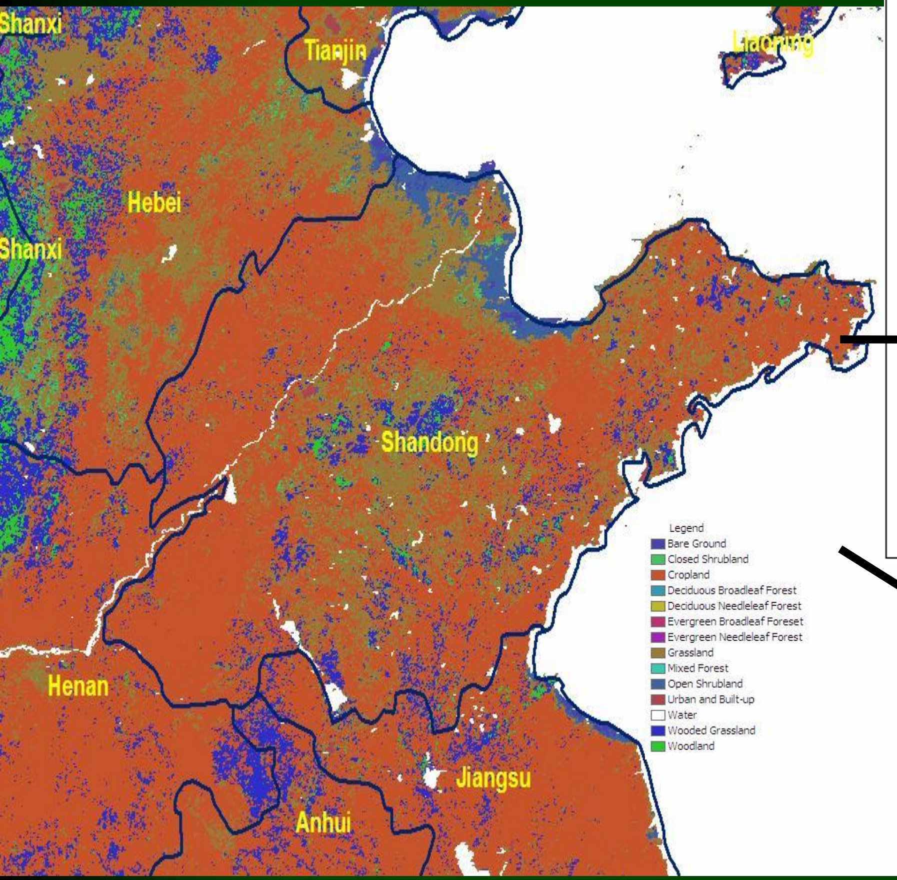
- Productivity of corn agriculture in core agricultural regions of China varies with temperature, rainfall, and other meteorological factors.
- Crop response to weather conditions can be modeled, but models are difficult to calibrate over large, remote regions.
- Coarse spatial resolution (250m-1km), high temporal resolution (1-2day) imagery supports comparison of present crop status to historical highs and lows
- Comparison at key points in crop cycle allows semi-quantitative yield prediction with significant lead times
- Moderate resolution (15-30m) satellite images allow the second order effects of agricultural expansion and contraction (urbanexpansion) to be integrated into regional assessments

- **Expansion and variability of Brazilian soybean production**

- Soybean cultivation in Brazil is expanding rapidly into grasslands, savannah, and forest.
- Resulting gains in productivity are uncertain due to uncertainty in cultivated area and yield variability.
- Moderate spatial resolution (15-30m) satellite images allow expansion to be monitored and quantified annually.
- Coarse spatial resolution (250m-1km), high temporal resolution (1-2day) satellite images allow yield variability to be characterized and explained.

Step3: Application

- **Corn Crop Analysis and Forecasting in China**



•**Shandong Province, China: Annual cropping patterns**

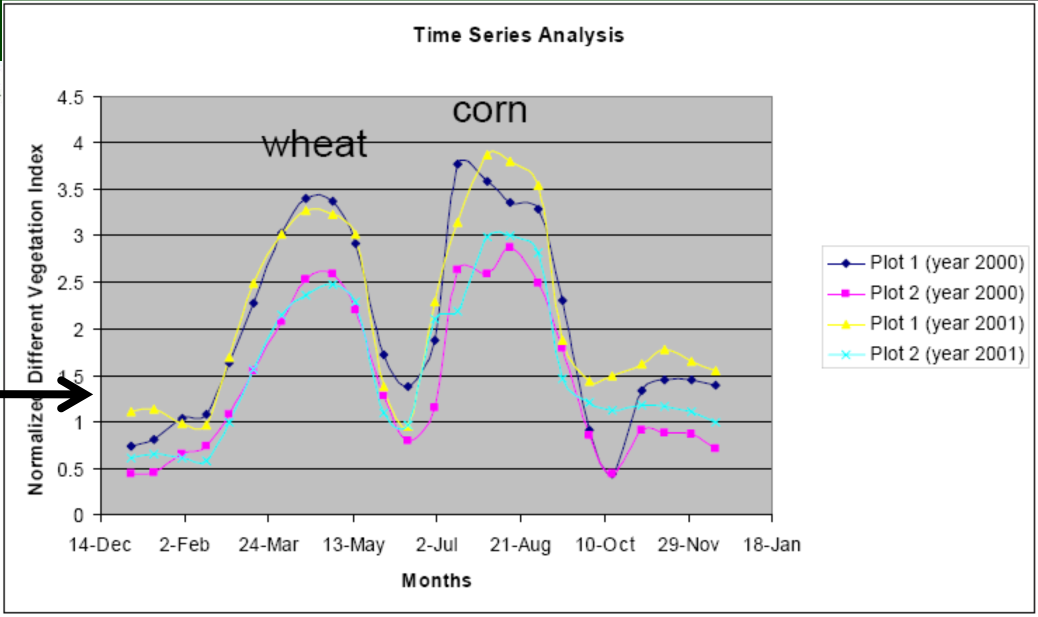
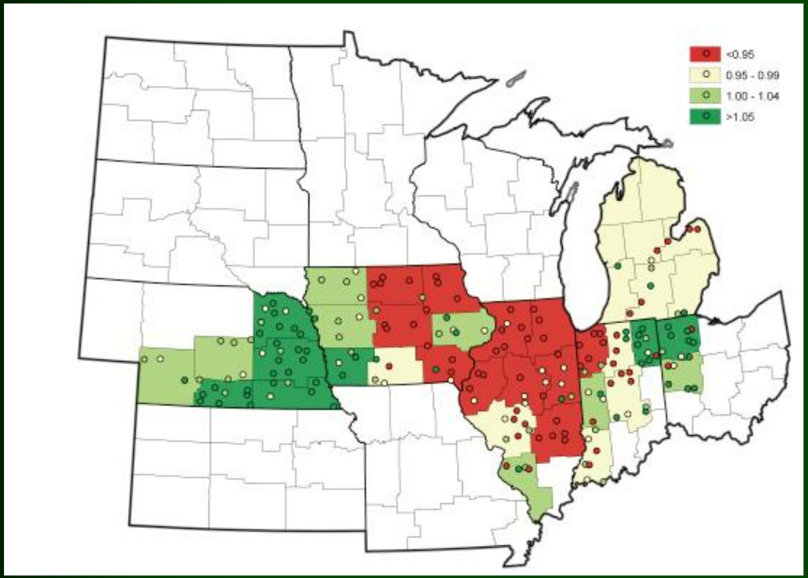


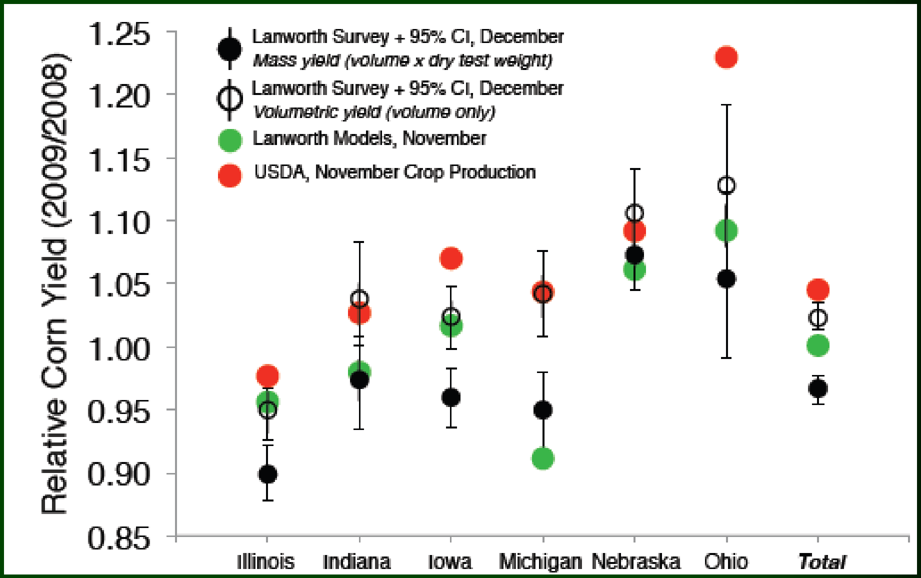
Table 1. The Operation Parameters of Winter Wheat – Summer Corn Rotation for EPIC Model in North China

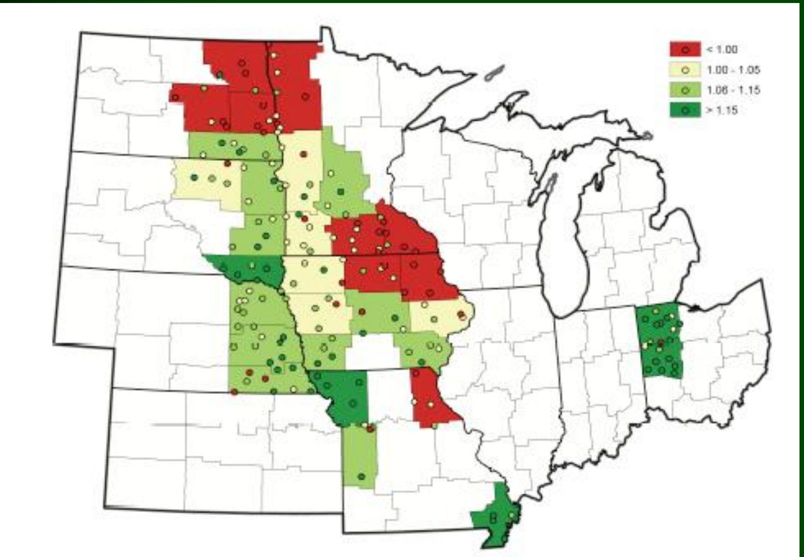
SUMMER CORN			WINTER WHEAT		
Date	Operation	Volume	Date	Operation	Volume
Jun. 20	Irrigation	40mm	Oct. 8	Irrigation	40mm
Jun. 20	Fertilizer	72kg/ha*	Oct. 8	Fertilizer	72kg/ha*
Jun. 23	Planting		Oct. 8	Fertilizer	55kg/ha**
Aug.10	Fertilizer	48kg/ha*	Oct.10	Planting	
Sep.28	Harvest		Apr.10	Irrigation	100mm
			Apr.20	Fertilizer	48kg/ha*
			May10	Irrigation	100mm
			Jun.18	Harvest	

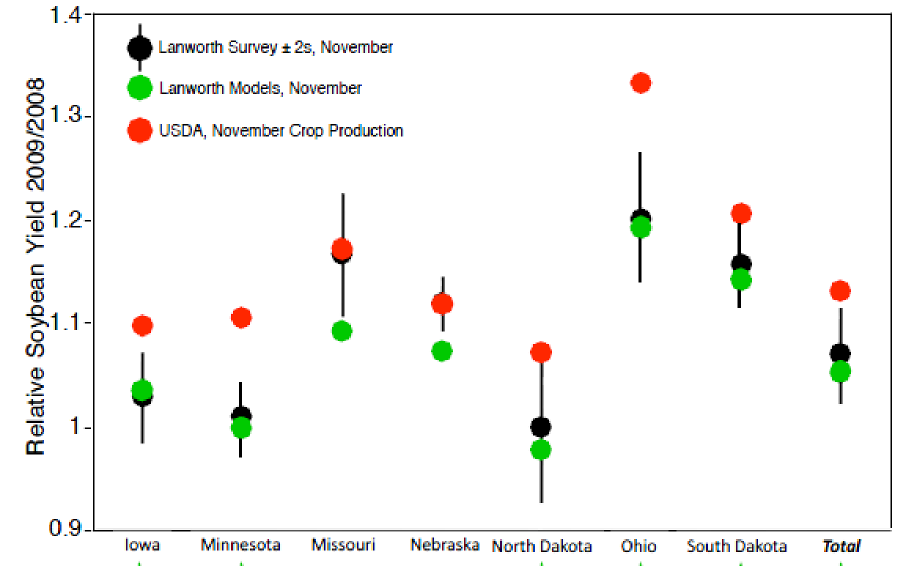
Note: "*" means the application amount of 100% nitrogen in chemical fertilizer.
"**" means the application amount of 100% phosphorus in chemical fertilizer.

Step3: Application



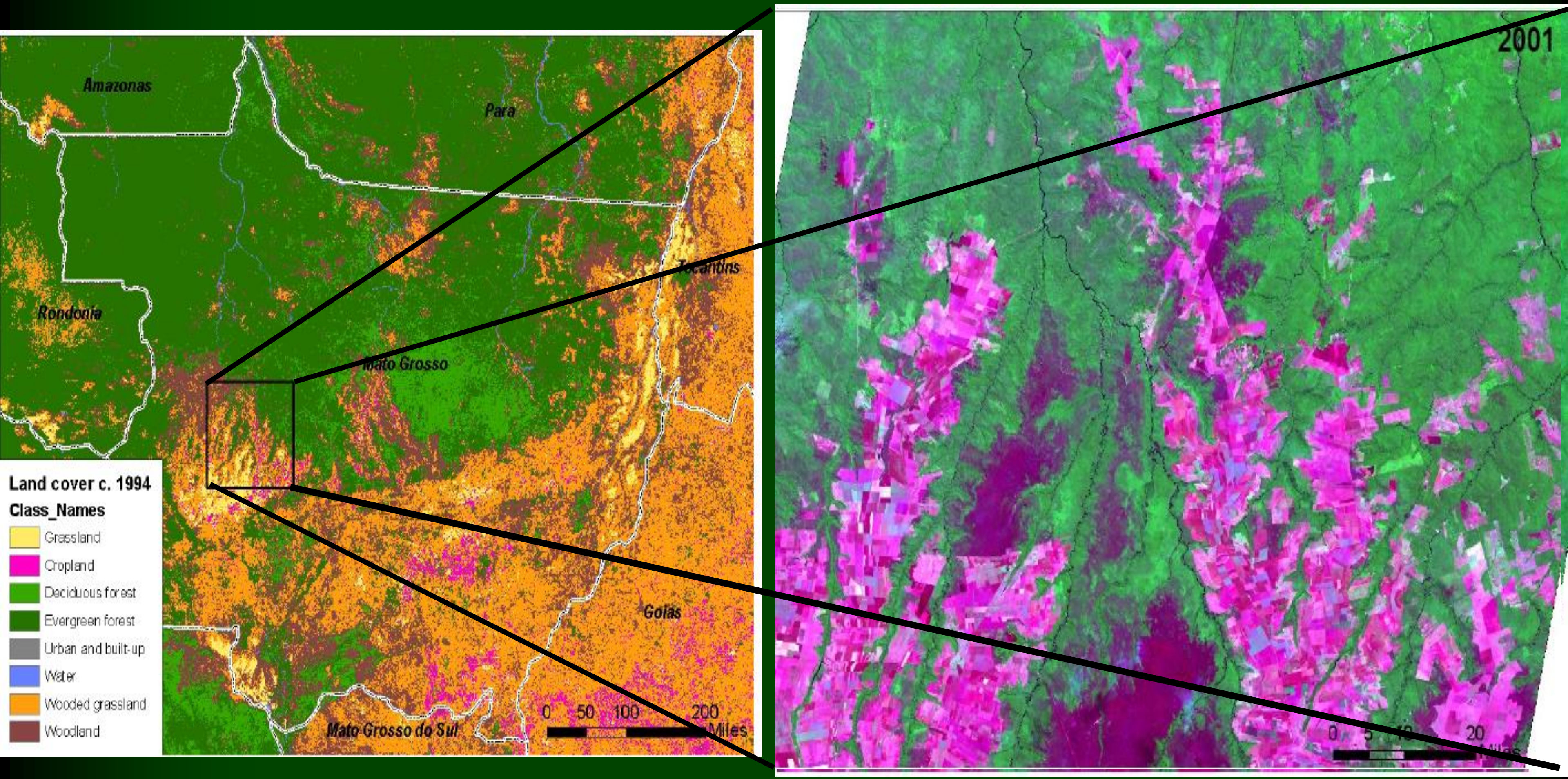




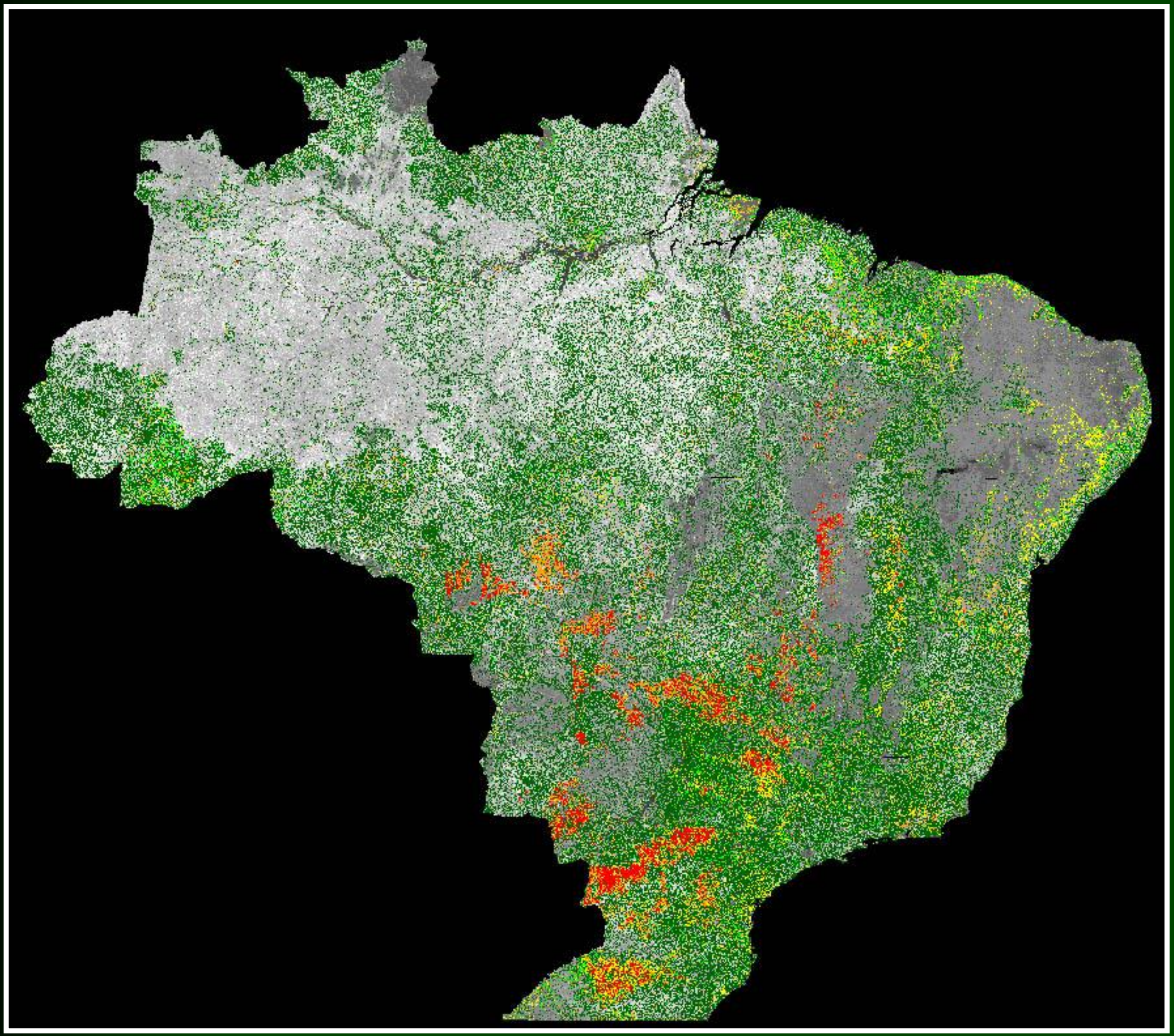


Step3: Application

- **Soybean Crop Analysis and Forecasting in Brazil**



Step4: Results



Soy Bean Acreage
Estimation
for Brazil

Soy Range (%)	Color
1.5 - 5	
5 - 10	
10 - 25	
25 - 50	
>50	

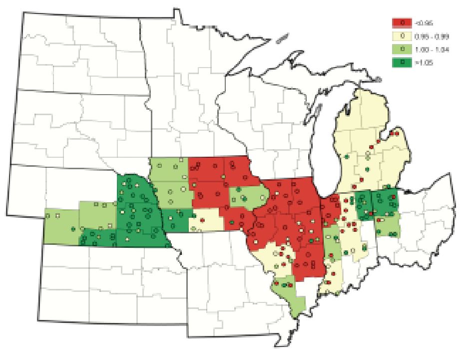
Step4: Results

US Spring Crop Production 2009
Corn yield survey: 18 December 2009

Corn Production: 12,318 million bushels
Soybean Production: 3,081 million bushels

Since early August, Lanworth's US corn yield estimates have been substantially lower than those of USDA and most private forecasters. At last report (10 November), Lanworth's 155.7 bushels/acre estimate stood 7.3 bushels/acre (4%) below USDA's 162.9 bushels/acre estimate. Although reported in nominally volumetric units (bushels/acre), USDA's yield estimates are standardized for test weight (lbs/bushel) and thus represent mass quantities (lbs/acre). To date, USDA has indicated that 2009 mass yield will be at a record due to record-high volumetric yield coupled with relatively normal test weight. Lanworth's simulation models, in contrast, predict lower mass yield due to resource limitations (time, light, water) during grain fill. If correct, Lanworth's models indicate that USDA's mass yield estimates are biased high and will be adjusted downward as test weights and volumetric yield are estimated directly on the basis of yield surveys or indirectly though stocks inventories.

To confirm modeled mass yields, Lanworth surveyed 188 elevator operators in six states (Illinois, Indiana, Iowa, Michigan, Nebraska, and Ohio) where Lanworth and USDA yield estimates differ most (Map 1). Lanworth asked operators to estimate local corn volumetric yield and test weight relative to 2008 (see *Methods*, below). The survey results show that dry corn test weights in the US Corn Belt have fallen by 5.5% from 2008. When applied to reported volumetric yield, the test weight data imply corn mass yield well below USDA's November estimate and slightly below Lanworth's most recent model estimates. Therefore, Lanworth continues to expect USDA to lower its 2009 corn yield and production estimates in its January *Crop Production Annual* report and/or in subsequent *Grain Stocks* reports.



Map 1: Reported relative corn mass yield (2009/2008) by elevator (n=188) and crop reporting district (n=32), 8-14 December 2009.

Contact: Nick Kouchoukos, (630) 250-1428, nkouchoukos@lanworth.com

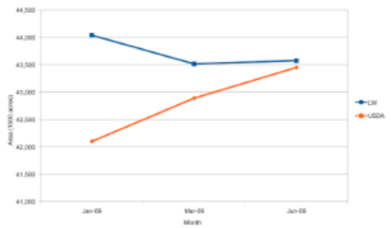
WINTER WHEAT

In January, Lanworth indicated that substantially more winter wheat had been planted than reported by USDA in its January Winter Wheat Seedings report.

In its March Prospective Plantings report and again in its June Acreage report, USDA revised its acreage estimates upward by unusually large amounts to converge with Lanworth's estimates. In the meantime, Lanworth made only comparatively small downward adjustments to its estimates.

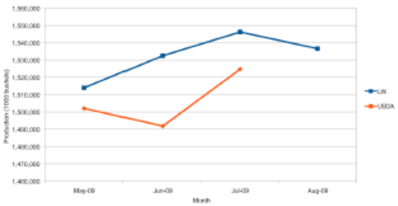
Lanworth has consistently recognized significantly higher winter wheat production than USDA. In July USDA revised its wheat production estimate upward, largely as a result of adjusting its seeded acreage estimate to align with Lanworth's.

WINTER WHEAT PLANTINGS



In subsequent reports, USDA revised its estimates upward by a virtually unprecedented 1.35 million acres to confirm Lanworth's position.

WINTER WHEAT PRODUCTION

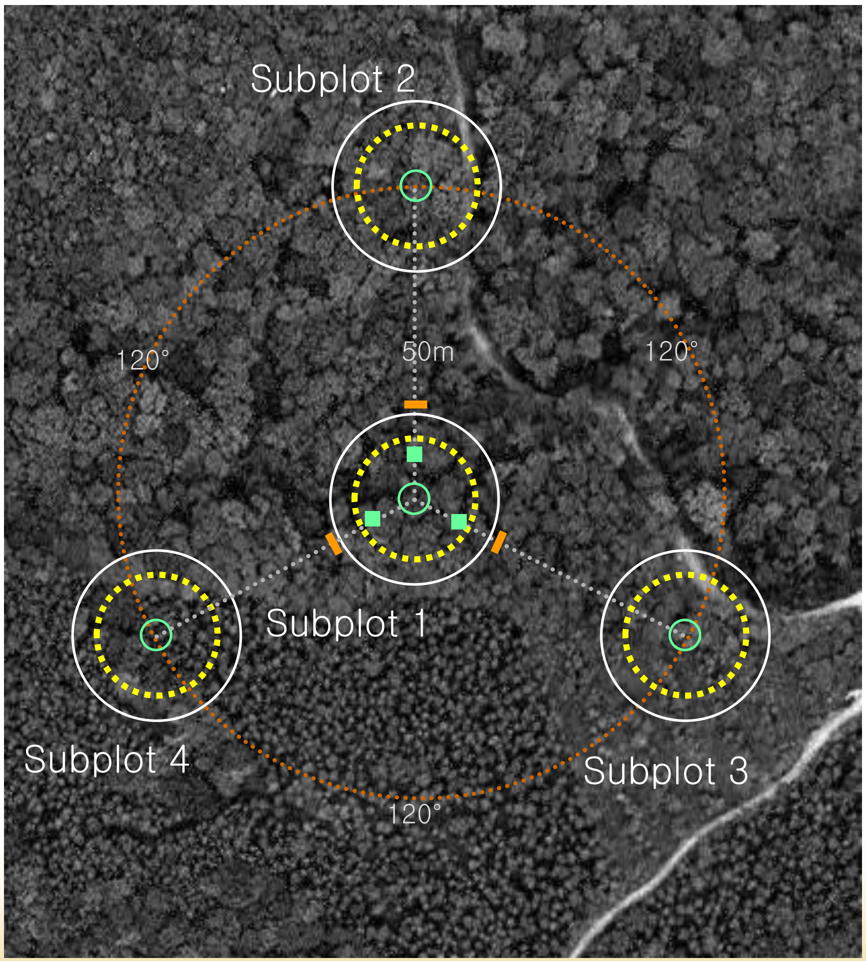


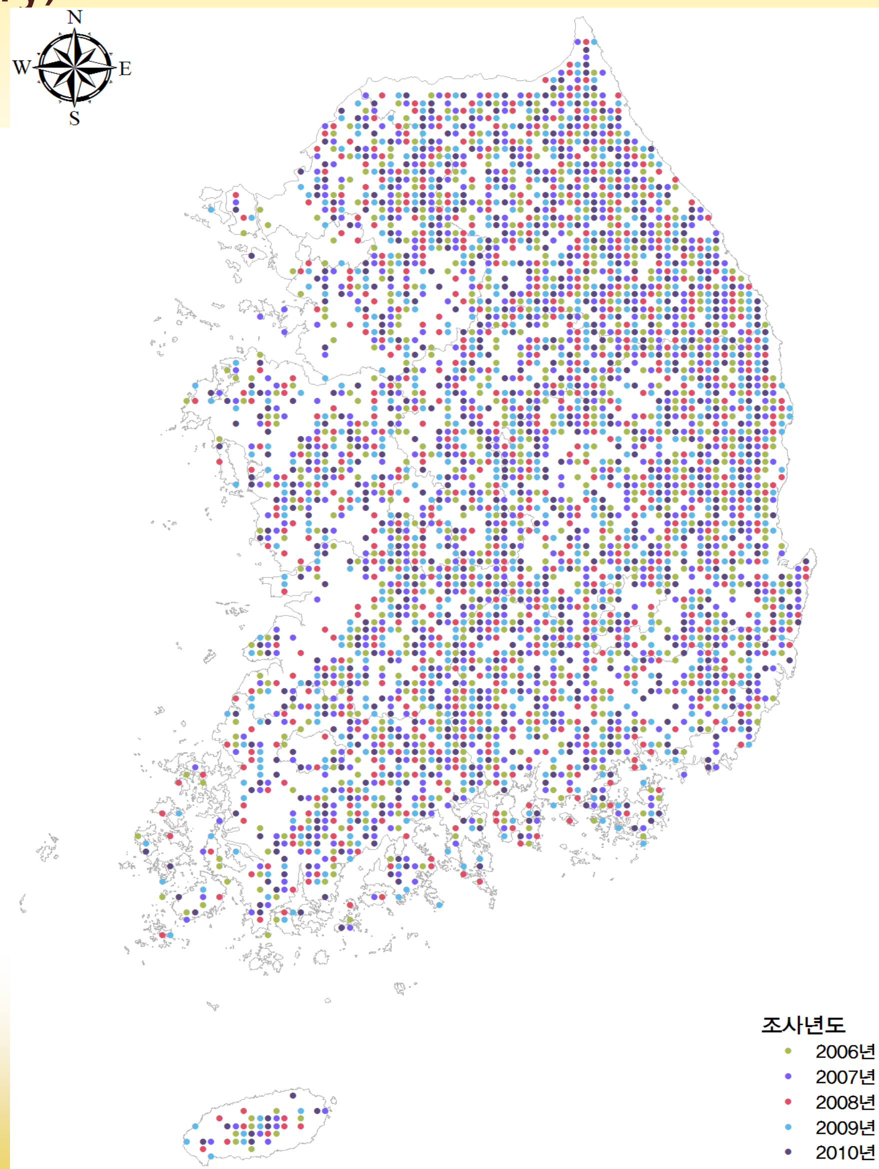
Lanworth's Winter Wheat Production reports have consistently indicated higher national production than USDA, especially in May and June. In July, USDA incorporated significant seed acreage revisions into its estimate, and its production estimate is now closely aligned with Lanworth's.

300 Park Boulevard, Suite 425 • Itasca, Illinois 60143
(630) 250-1299 • (630) 672-7500 Fax • lanworth.com

Above ground carbon and Biodiversity Mapping

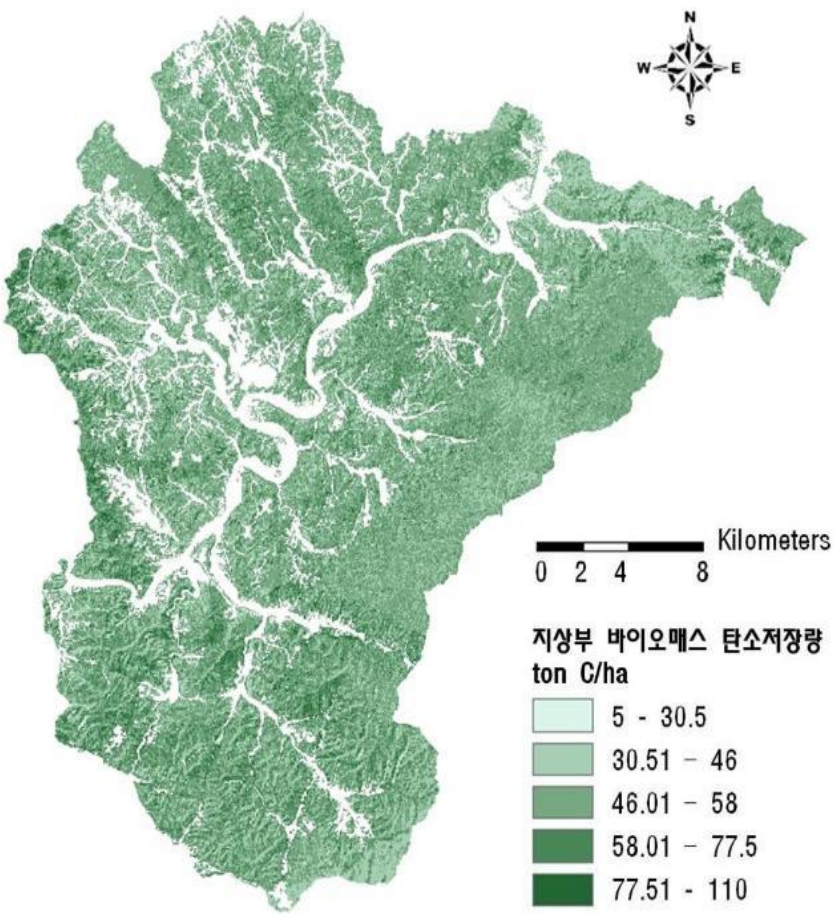
- ◆ 5th NFI (National Forest Inventory)
  - ◆ Ground Plot Configuration



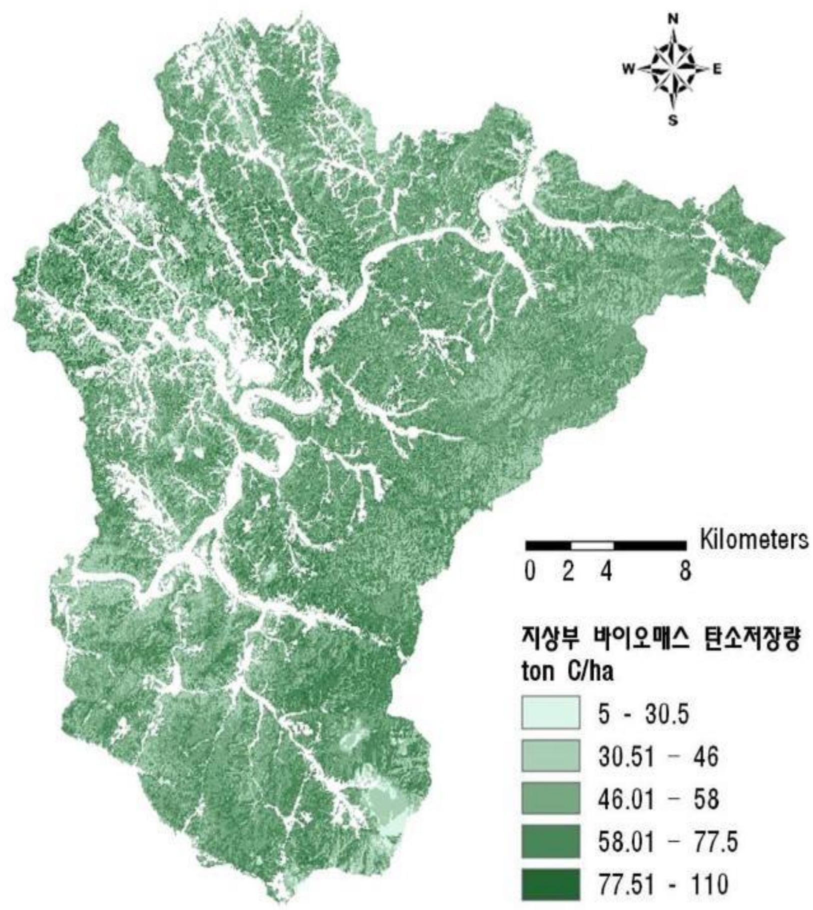


Ongoing Research Issues

Above Ground Carbon Estimation



2004/04/09

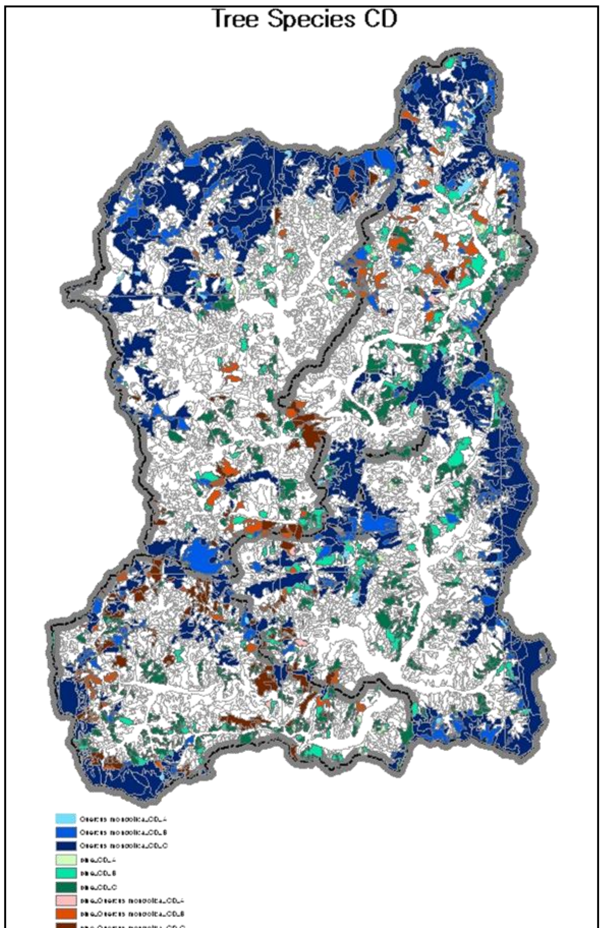


2004/08/31

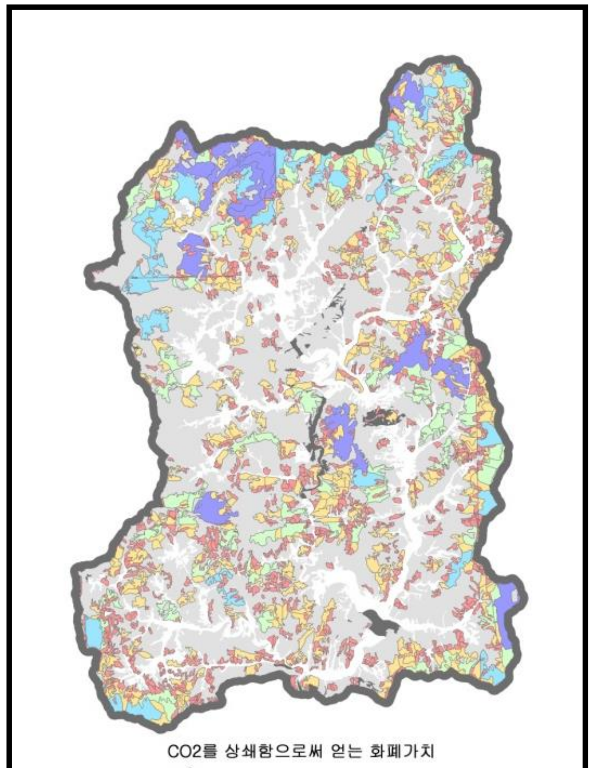
Ongoing Research Issues

Biodiversity Mapping and Valuation

Valuation of Timber Volume

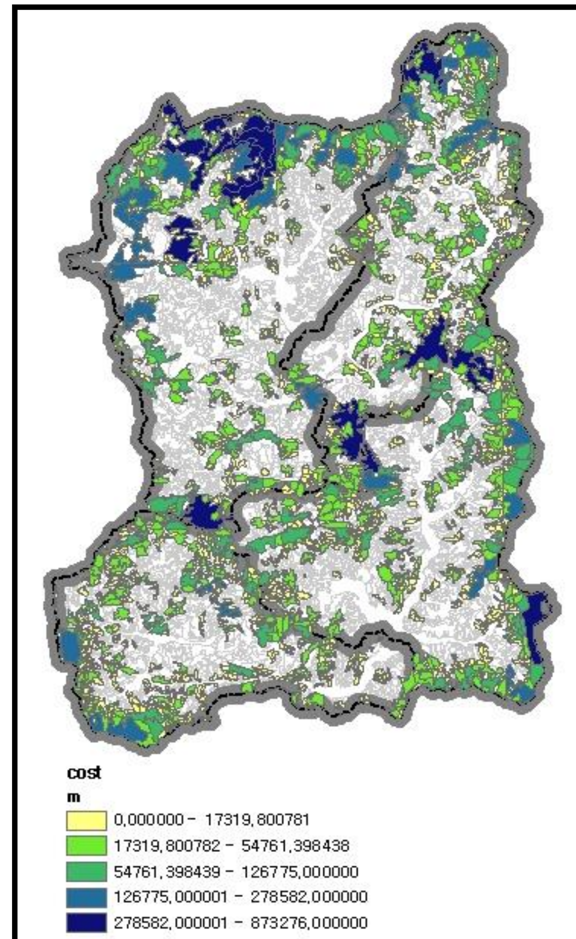


Valuation of Carbon Storage



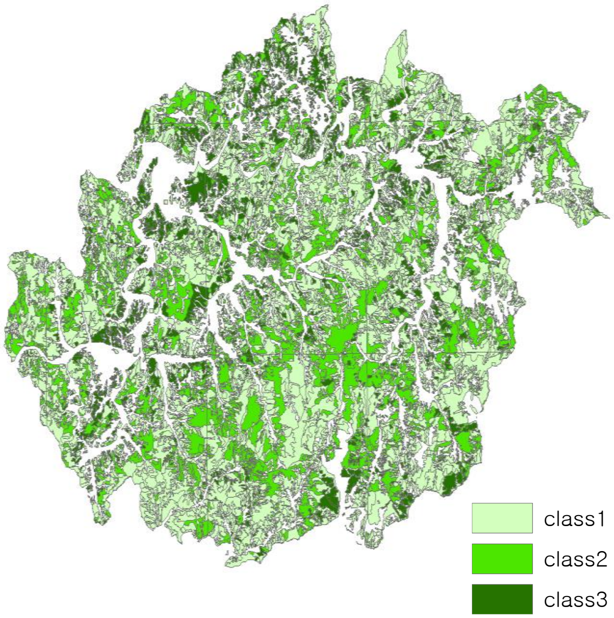
	Interest	Valuation
Carbon Storage of 170 Mil Ton	3%	350 Mil $
	5%	320 Mil $
	10%	250 Mil $

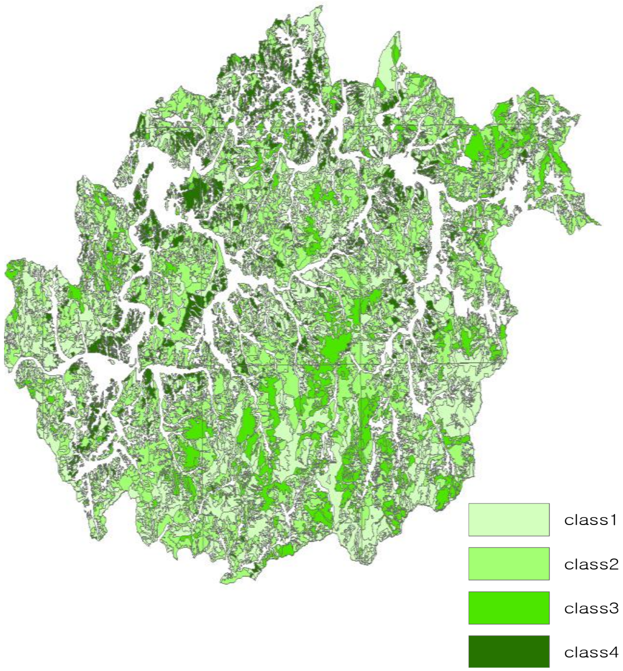
Valuation of CO_2 Reduction

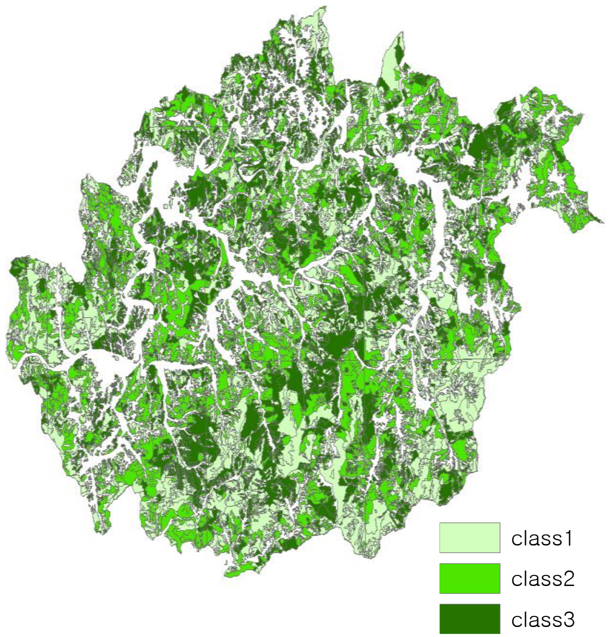


"Be spatially specific – because natural productivity of ecosystems and biodiversity vary across space"

◆ Biodiversity Mapping with National Forest Inventory (NFI)



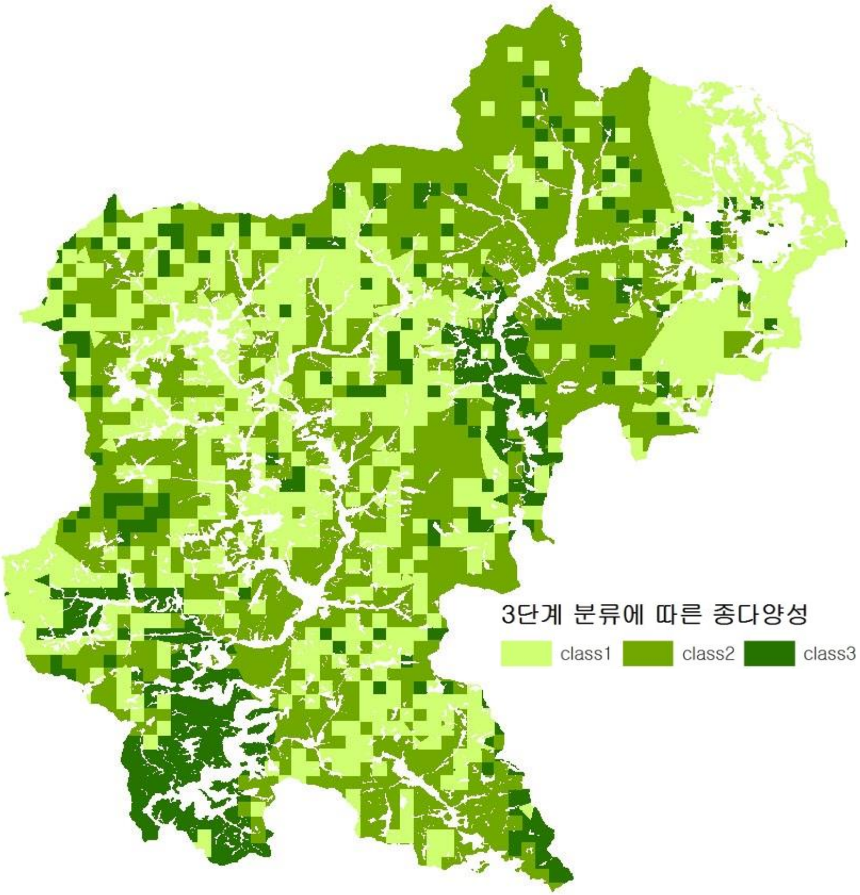




Class3(natural break) – 72.4%

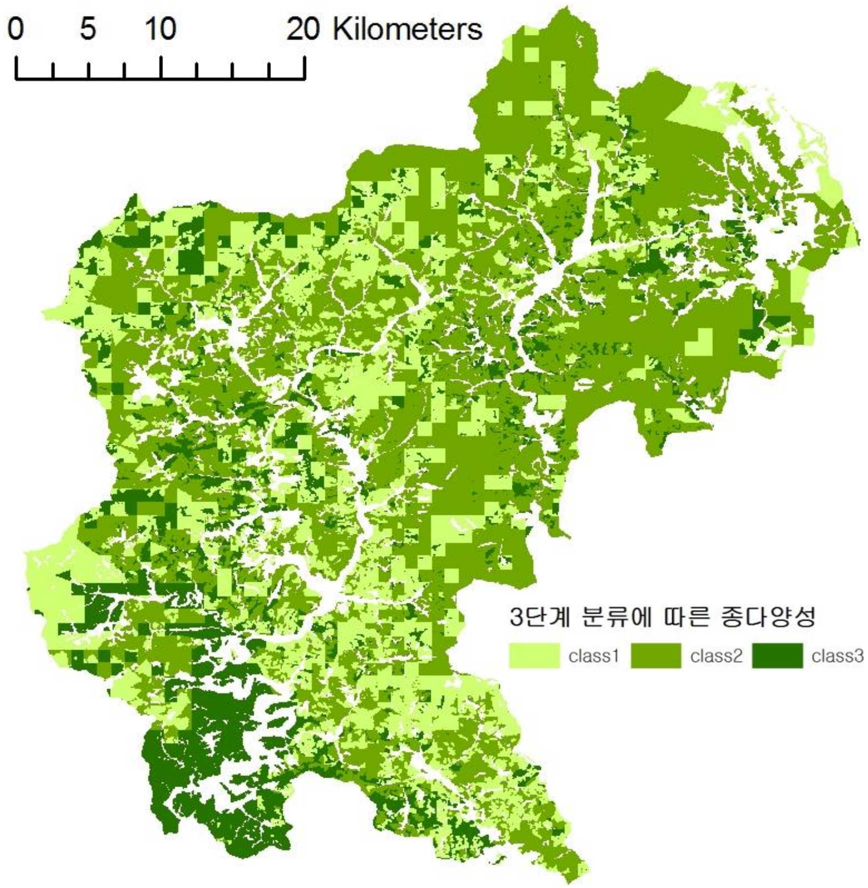
Class4 – 73.3%

Class3(threshold) – 77.1%



precision : 94.76% (k = 0.9143)

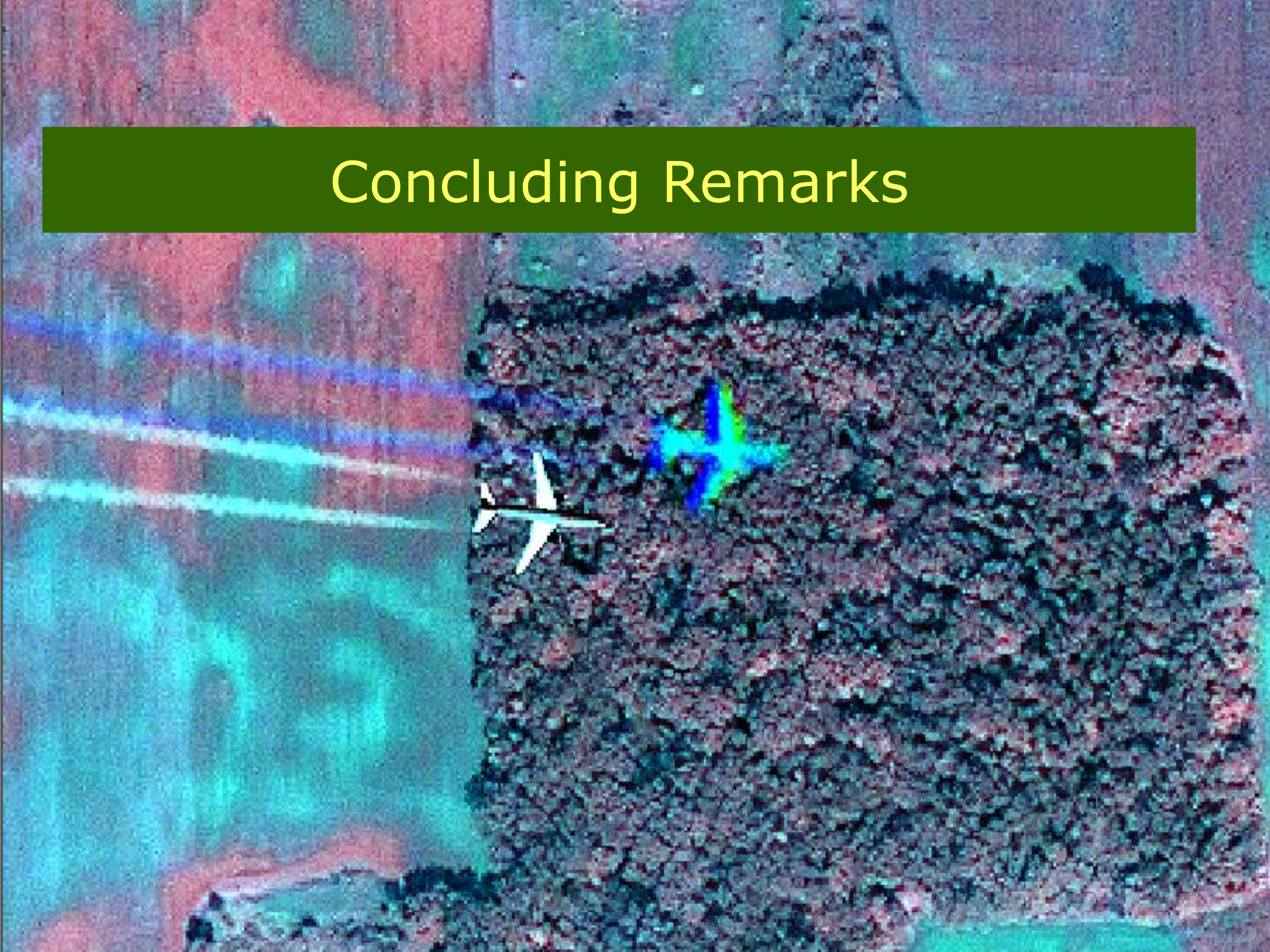
Under 10-fold cross validation



precision : 89.53% (k = 0.8284)

Under 10-fold cross validation

Concluding Remarks




Thank You