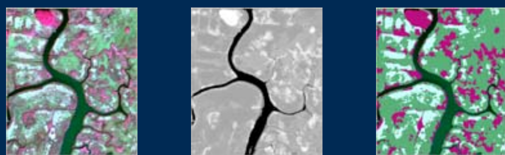
Invasive Species Mapping in Coastal Connecticut

A Fusion of High-Resolution Lidar and Multispectral Imagery



Chris Robinson, IM Systems Group at the NOAA Coastal Services Center
Jamie Carter, IM Systems Group at the NOAA Pacific Services Center

GeoTREE Center, Iowa State Lidar Workshop
August 8, 2007

Outline

NOAA Coastal Services Center

Mission
Linking people, information, and technology in the coastal zone

Constituents
Local, state, and regional programs that impact coastal communities and the environment

Role
Bringing new skills, data, and information to our constituency

Result
Decision makers have the tools they need

Strategic Focus Areas
- Coastal and Ocean Planning
- Coastal Hazards
- Coastal Conservation and Habitat Restoration Planning

The Coastal Change Analysis Program (C-CAP)

- **National coastal land cover and change mapping program**
- **Baseline 1996 and 2001, updates in progress**
- **Focus on intertidal areas, wetlands, and adjacent upland**
- **Consistent, accurate products**
- **Standardized data and methods**
- **Performance-based contracts with private industry partners**
- **Focus on applications**
  - i.e., customers

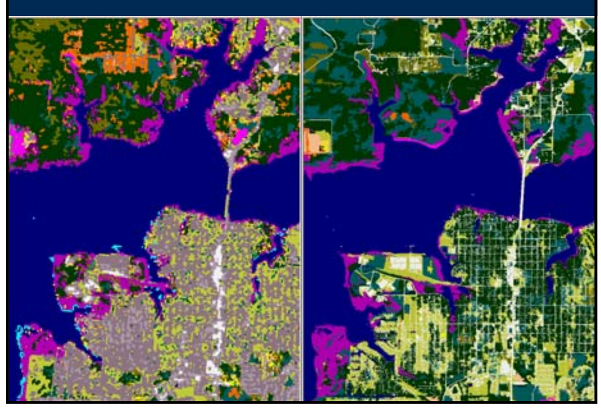
"Designed to help improve understanding of linkages between land change and the environment"

High Resolution Land Cover

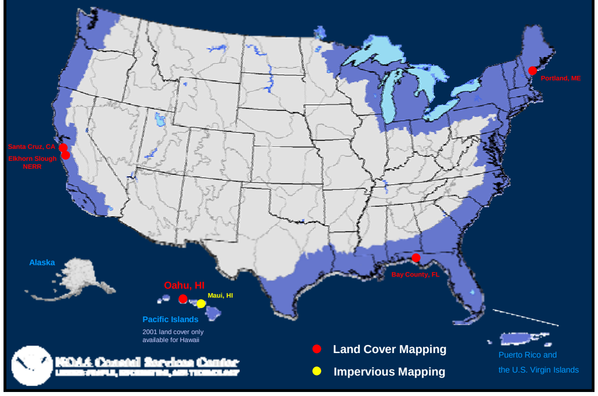
- **Customer demand / need . . .**
  and
- **Increasingly available, high-res imagery and supporting data**
  provide
- **New opportunities to**
  - Introduce new data streams
  - Introduce new approaches
  - Increase focus on coastal issues

"Our goal is to provide consistent, accurate, nationally relevant data at a spatial scale more appropriate for support of increasingly detailed, site-specific, management decisions".

30 meter C-CAP | 2.5 meter C-CAP



High-Resolution C-CAP Mapping



Topographic Change Mapping

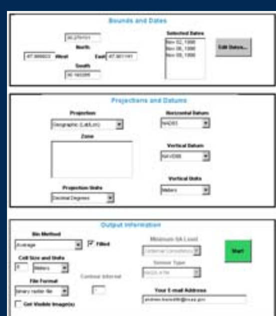
Activities

- Acquire high-resolution topographic data for the coastal U.S.
- Contract lidar acquisitions with specifications designed to suit multiple needs, including FEMA floodplain applications
- Acquire Interferometric Synthetic Aperture Radar (IfSAR) for state and local government use
- Update nearshore and coastal topo/bathy surfaces for enhanced flood and storm-surge modeling

Topographic Change Mapping

Data distribution

- Lidar Data Retrieval Tool (LDART)
- Stored as point data
- Several data output types
  - Points
  - Gridded
  - Contours
- Selectable projection and datum



CLEAR

- University of Connecticut – Center for Land Use Education and Research (CLEAR)
- Sandy Prisloe, geospatial extension specialist
- Provides information, education, and assistance to land use decision makers, in support of balancing growth and natural resource protection
- September 2004, NOAA Coastal Services Center funded the acquisition of 0.5-meter resolution color airborne imagery for Connecticut's coastal communities
- October 2004, high resolution Lidar data was collected through CSC funding

Invasive Vegetation

Phragmites

- Typically found along marshes, riverbanks, and disturbed areas such as roadsides
- Shades out and competes with native vegetation
- Connecticut Department of Environmental Protection, The Nature Conservancy, and others have undergone extreme and costly eradication efforts
- No monitoring plan in place
- Invasion by alien plants one of biggest causes of habitat loss in coastal states
- Important issue for many CSC constituents

Wetland Vegetation

Categories mapped

- *Phragmites australis* (invasive)
- *Typha angustifolia*
- *Spartina patens* dominated pans (these areas contain other species such as *Solidago sempervirens and Panicum virgatum*)

High Resolution Imagery

Associated issues:

- More pixels = more storage space required
- More computing resources required
- Increased detail creates issues such as shadowing
- More spectral classes required per information class
- Limited spectral resolution of high spatial resolution sensors

Why Use Lidar Data?

Incorporating ancillary data into classification process

- Common practice among remote sensing analysts
- Can improve accuracy and quality of resulting classification
- Must be cautious of data being used

High-resolution topographic data

- Increase dimensionality of data set to be classified
- Use height information to differentiate spectrally similar features
- Intensity layer may contain useful data

Project Objectives

- Investigate the impact of adding lidar data to an imagery based classification process
- Compare and contrast the use of lidar for mapping wetlands with digital aerial imagery (ADS40)
- Assess utility of advanced image processing software packages for high-resolution mapping
- Develop standardized methodology for species-level mapping in coastal wetlands (targeting *Phragmites*)

Study Site

Ragged Rock tidal marsh near Old Saybrook, Connecticut

- **Tidal marsh located along the Connecticut River**
- **Covers approximately 202 hectares**

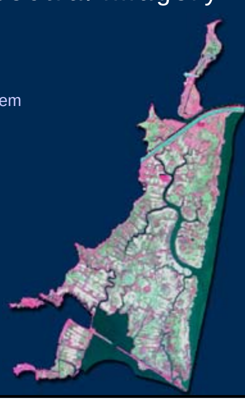
Data – Multispectral imagery

Color infrared orthoimagery

- Leica ADS40 Digital Camera System
- Acquired on September 20, 2004
- Leaf on conditions

Camera specs

- 0.5-meter spatial resolution
- 16-bit radiometric resolution
- Linear array digital camera



Data – High-Resolution Topography

Lidar

- Leica ALS50
- Acquired on October 8, 2004

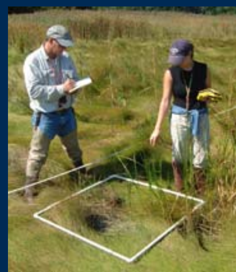
Collection specs

- 2 returns (First and Ground)
- 1 meter average ground sample distance
- Vertical Accuracy: RMSE – 5.7 centimeters
- Horizontal Accuracy: 50 centimeters

Data – Reference

Field data

- Collected in the southwest section of study site by researchers at the University of New Haven and University of Connecticut
- Location, dominant species and photos



Dr. Nels Barret and Cary Chadwick collecting plot data along a transect in the Ragged Rock tidal marsh study area

Methodology

Training Data
- Sampling Strategy
- Photo Interpretation

Data Preparation
- Stratification
- Spectral Derivatives
- Topographic Derivatives
- Image Segmentation

Image Classification
- Nearest Neighbor
- Feature Extraction

Accuracy Assessment
- Error Matrix

Methodology – Training Data

Training Data
- Critical to accuracy of classification map
- Representative of classes

Sampling Strategy
- Stratified random sample
- Performed on ISODATA cluster file
- 3 x 3 window to avoid feature edges

Photo Interpretation
- Created in ArcGIS
- Used field data as reference for training
- Analysts reviewed each other's points
- Points were sent to partners for review

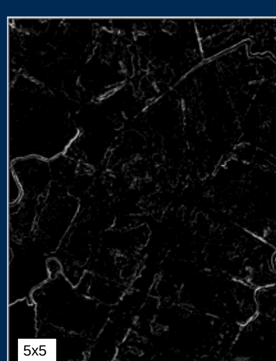
Methodology – Data Preparation

Masking/Stratification
- Increase image homogeneity
- Eliminate confusion with uplands
- Reduce processing time required
- Used boundary provided by CLEAR
- Other data sets available

Methodology – Data Preparation

Spectral Derivatives
- Additional channels for classifier
- Highlight variations in vegetation amount and condition
- Normalized Difference Vegetation Index (NDVI)

Texture Derivatives
- Differences in texture of vegetation



Methodology – Data Preparation

Topographic Derivatives
- Highlight elevation differences among vegetation classes
- Difference between first surface and ground return
- Lidar Intensity

Methodology – Data Preparation

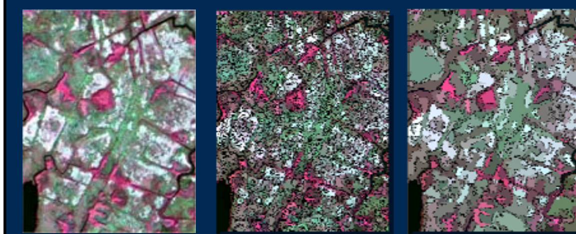
Image Segmentation (eCognition)

- Mitigates speckling
- Simplifies image from pixels to objects
- Classification is applied to image objects
- Region-growing algorithm starts with one pixel and then increases until user-defined homogeneity criteria (scale) is met
- Weights can be applied to different layers or left out for segmentation
- Additional information generated for each object (spectral, shape, texture)
- Segmentations were based on lidar and ADS40 data

Methodology – Data Preparation

Image Segmentation (eCognition)

- Homogeneity criteria (scale factor) determines object size



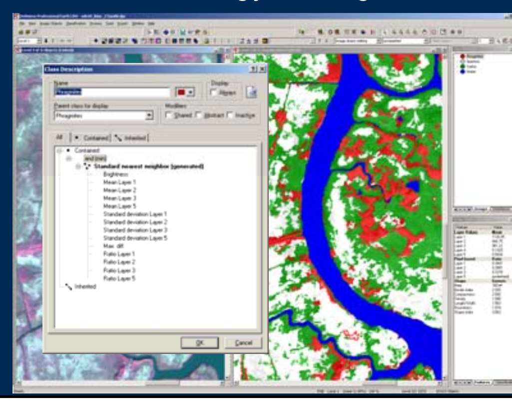
Pixel Scale 50 Scale 200

Methodology – Image Classification

Standard Nearest Neighbor Classifier

- Applied in Definiens eCognition
- Compares training data (samples) to user-defined feature space in n-dimensions
- Membership functions are automatically generated for image objects
- Image objects classified as nearest class in feature space
- Different combinations of lidar and image-based object features
- Various scale factors

Methodology – eCognition

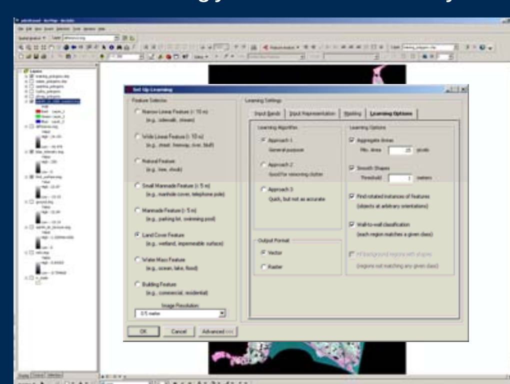


Methodology – Image Classification

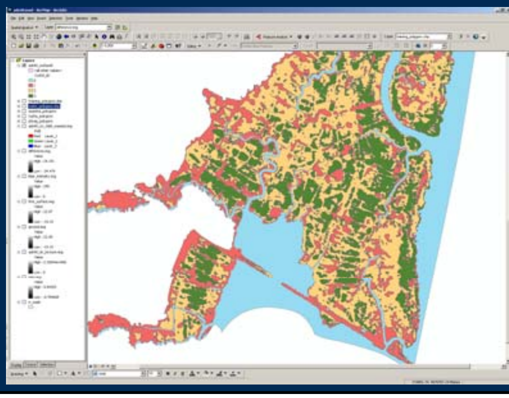
Feature Analyst (Visual Learning Systems)

- Extension for ArcGIS
- Uses artificial intelligence to perform automated feature extraction
- Intelligent software agent – Learner
- Relies on quality training data
- Same training sites that were used in eCognition
- Utilizes spatial context to extract target features
- Single or multi-feature extraction

Methodology – Feature Analyst



Methodology – Feature Analyst

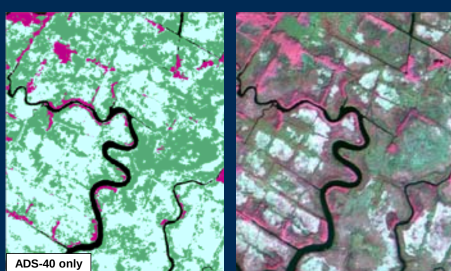


Methodology – Accuracy Assessment

- Important component of thematic mapping
- Quantitative assessment of classification accuracy
- Comparison of data sources and techniques
- Error Matrix – relationship between reference data and classification
- Provides class and overall accuracy
- Typically used to improve the map
- Performed using photo-interpreted data
- Points derived from regions **not** chosen for training sites

NOAA Coastal Services Center

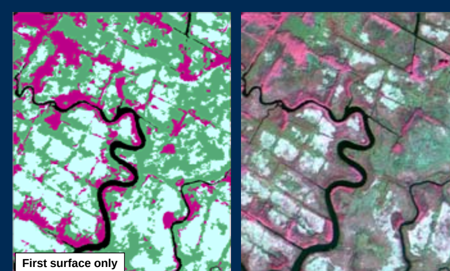
Results – eCognition



Phragmites
Typha
Spartina

	Phragmites	Typha	Spartina	Grand Total	Comission
Phragmites	71	11	2	84	85%
Typha	10	74	19	103	72%
Spartina	1	17	75	93	81%
Grand Total	82	102	96	280	
Omission	87%	73%	78%	Overall -	79%

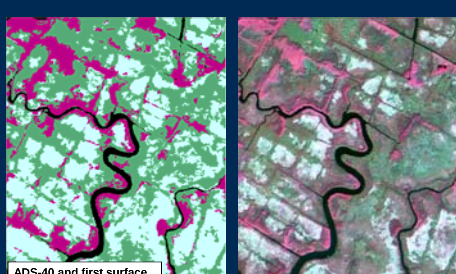
Results – eCognition



Phragmites
Typha
Spartina

	Phragmites	Typha	Spartina	Grand Total	Comission
Phragmites	74	10	0	84	88%
Typha	11	73	19	103	71%
Spartina	1	18	74	93	80%
Grand Total	86	101	93	280	
Omission	86%	72%	80%	Overall -	79%

Results – eCognition



Phragmites
Typha
Spartina

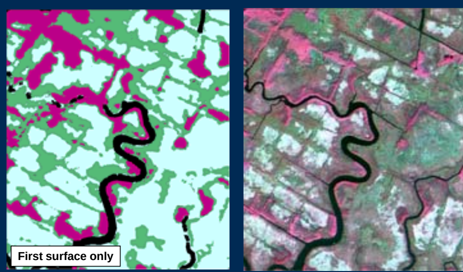
	Phragmites	Typha	Spartina	Grand Total	Comission
Phragmites	75	9	0	84	89%
Typha	10	79	14	103	77%
Spartina	1	13	79	93	85%
Grand Total	86	101	93	280	
Omission	87%	78%	85%	Overall -	83%

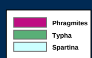
Results – Feature Analyst

Phragmites
Typha
Spartina

	Phragmites	Typha	Spartina	Grand Total	Comission
Phragmites	78	11	3	92	85%
Typha	6	85	23	114	75%
Spartina	0	7	67	74	91%
Grand Total	84	103	93	280	
Omission	93%	83%	72%	Overall -	82%

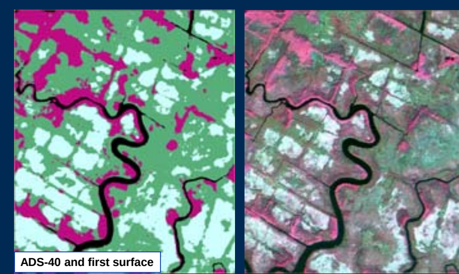
Results – Feature Analyst

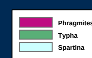




	Phragmites	Typha	Spartina	Grand Total	Comission
Phragmites	73	10	0	83	88%
Typha	9	64	2	75	85%
Spartina	2	29	92	122	75%
Grand Total	84	103	93	280	
Omission	87%	63%	98%	Overall -	82%

Results – Feature Analyst





	Phragmites	Typha	Spartina	Grand Total	Comission
Phragmites	81	9	1	91	89%
Typha	3	88	19	110	80%
Spartina	0	6	73	79	92%
Grand Total	84	103	93	280	
Omission	96%	85%	78%	Overall -	86%

Results

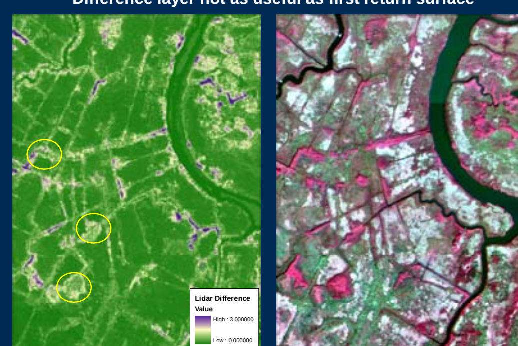
The addition of lidar information did increase the overall accuracy
- First return surface (approximately 5%)
- Difference (approximately 1%)

Increased producer's accuracy (omission error)
- First return surface (*Spartina* – 6%, *Phragmites* – 3%, and *Typha* – 1%)
- Difference (*Spartina* – 4% and *Phragmites* – 2%)

Increased user's accuracy (commision error)
- First return surface (*Spartina* – 2%, *Phragmites*, and *Typha* – 5%)
- Difference (*Typha* – 2% and *Spartina* – 2%)

Discussion

Difference layer not as useful as first return surface



Inability of lidar to penetrate dense wetland vegetation

Conclusions

- First return information proved to be more useful than difference
- Additional spectral indices such as NDVI did not help with the discrimination of wetland species
- Using ADS40 and lidar first surface, *Phragmites* was mapped with 89% user's accuracy
- Best results were achieved when ADS40 and Lidar were combined
- Lidar information by itself had accuracies similar to maps created with only ADS40
- Lidar intensity did not yield marked improvements in overall accuracy
- Results were consistent across software packages but Feature Analyst performed slightly better

Future Directions

- Connecticut researchers will continue to test different mapping techniques for wetland vegetation
- The Center will continue to investigate high-resolution data-fusion mapping techniques
- Lessons learned from this project will enhance topographic change mapping's data analysis and product development
- Lessons learned from this project will be applied to C-CAP's high-resolution land cover products

Questions?

Land Cover

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