LiDAR & Hyperspectral Data Fusion Analysis from Simultaneous, Multi-Sensor Collection Project

2009 Civil Commercial Imagery Evaluation Workshop

Presented by:
Bill Emison, Merrick & Company

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Merrick & Company

- Corporate Headquarters: Aurora, Colorado
- Founded in 1955, incorporated in 1959
- Primary Services:
  - Architecture
  - Civil Engineering
  - Facilities Engineering
  - ***GeoSpatial Solutions***
  - Process Engineering

- 450 employees at 9 national & 2 int'l offices
- Annual revenue = $90M
- Ownership: Private (employee-owned)

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Project Objective

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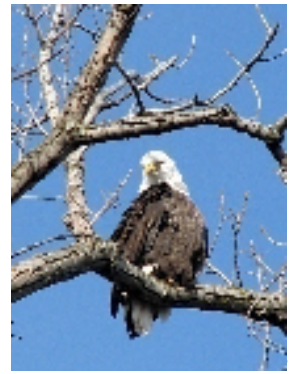
Project Objective

Identification of Bald Eagle Nesting Sites & Habitats

- Riparian habitat along the Missouri River
- Winter roosts / summer nesting grounds
- Nests found in mature old-growth trees, used for many years
- Large nest in a “super-canopy” tree, above surrounding trees
- Cottonwood trees (height >= 30 meters)
- Nests average 1.5 – 1.8 meters in diameter, 0.7 – 1.2 meters tall
- Nest: Eggs hatch after 35-day incubation, young leaves nest after 75 days
- ‘Sit and watch’ foraging behavior with proximity to water (~ ½-mile)
- Primary diet 60-90% fish, supplemented with waterfowl and small mammals
- Endangered Species Status
  - Pesticides like DDT
  - Loss of habitat and river bank erosion
  - Protected by Endangered Species Act (1973) & Bald Eagle Protection Act (1940)
  - 2007 Eagle Census: 11,000 pairs



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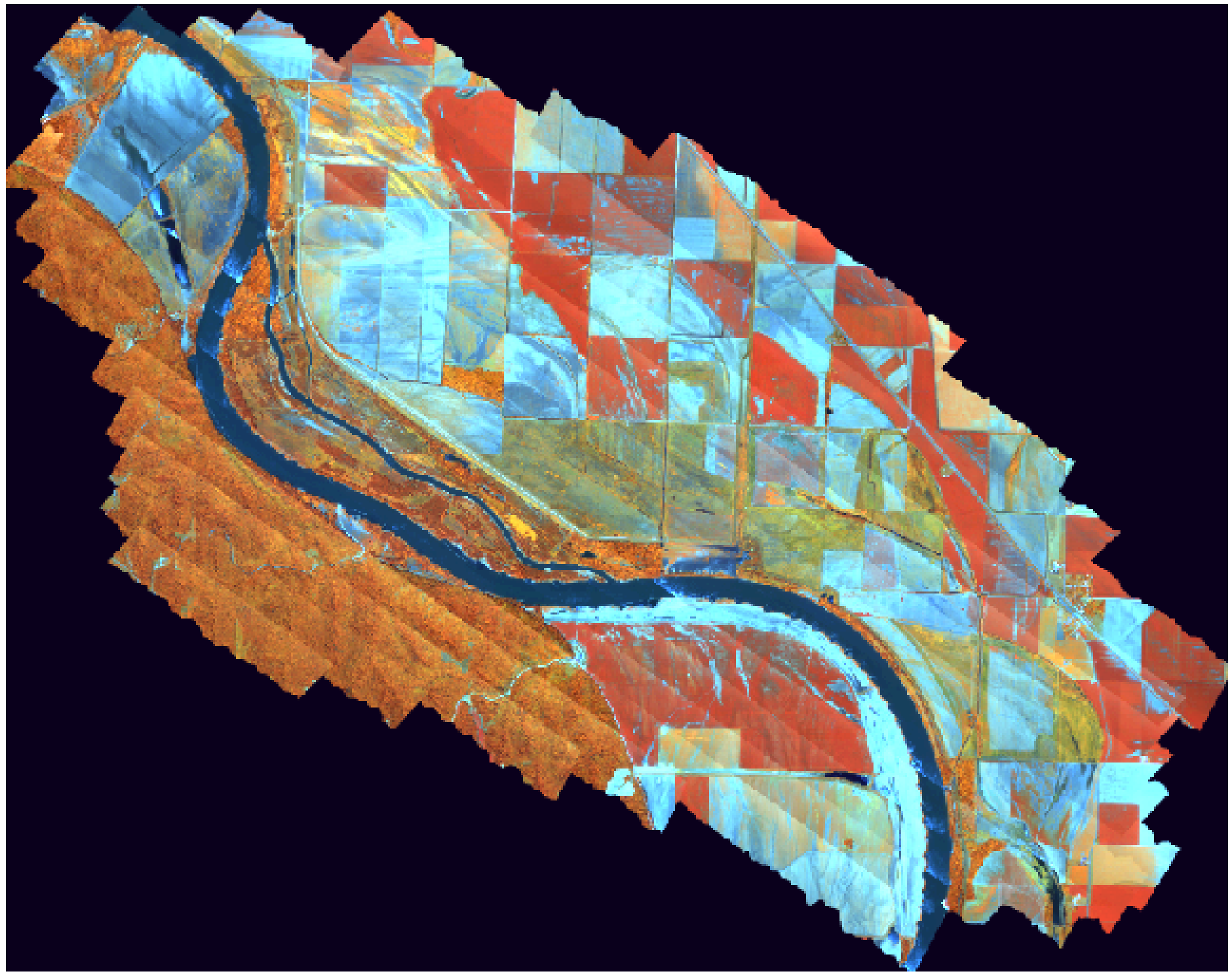
Hemmings Bend (Corning, Missouri)



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Data Acquisition

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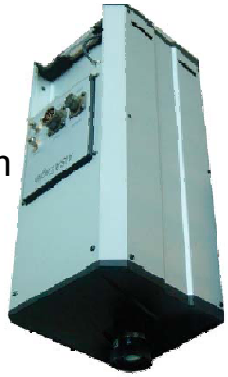
Airborne Sensors

Digital Camera
Merrick DACS-II™

- 7216 x 5472 pixel array; visible
- Field-of-View: 37° degrees
- Ground Resolution @ 2500 ft AGL: .07 m

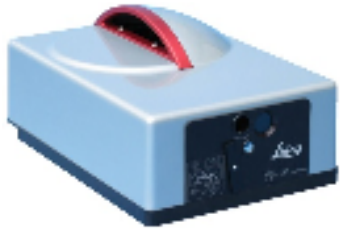
Hyperspectral Imager
AISA Eagle (VNIR)

- Spectral Range: 400 nm to 970 nm
- Field-of-View: 40° degrees
- Ground Resolution @ 2500 ft AGL: 0.6 m
- Includes algorithms to facilitate target detection and identification



Airborne Laser Scanner
Leica ALS50-II

- Ground Resolution @ 2500ft AGL: 1.31 m
- Scan Angle Range: 45° degrees
- Scan Rate: 5 – 160 scans/second
- Eye-safe operation above 200 meters AGL



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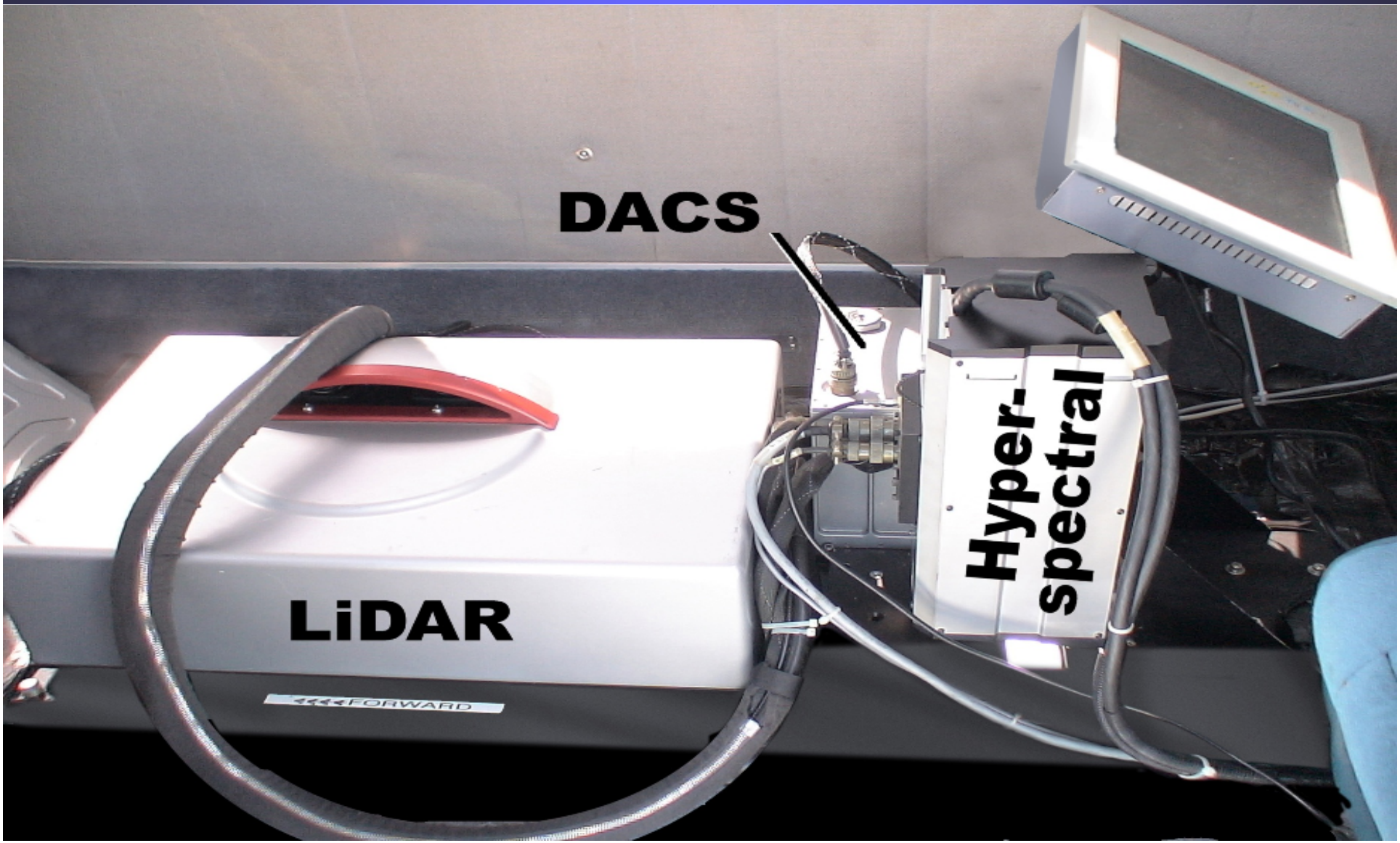
Sensor Configuration



Benefits of Simultaneous Collection

- Simultaneous data capture provides critical time coherency and efficiency
- Co-registered datasets require less post-processing work to achieve ‘best fit’
- Sensor integration with common Inertial System (IMU) eliminates disparities associated with multiple aircraft including:
  - Dynamic environmental conditions (ex. weather!)
  - Multiple calibrations (and associated inaccuracies)

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Data Processing & Analysis

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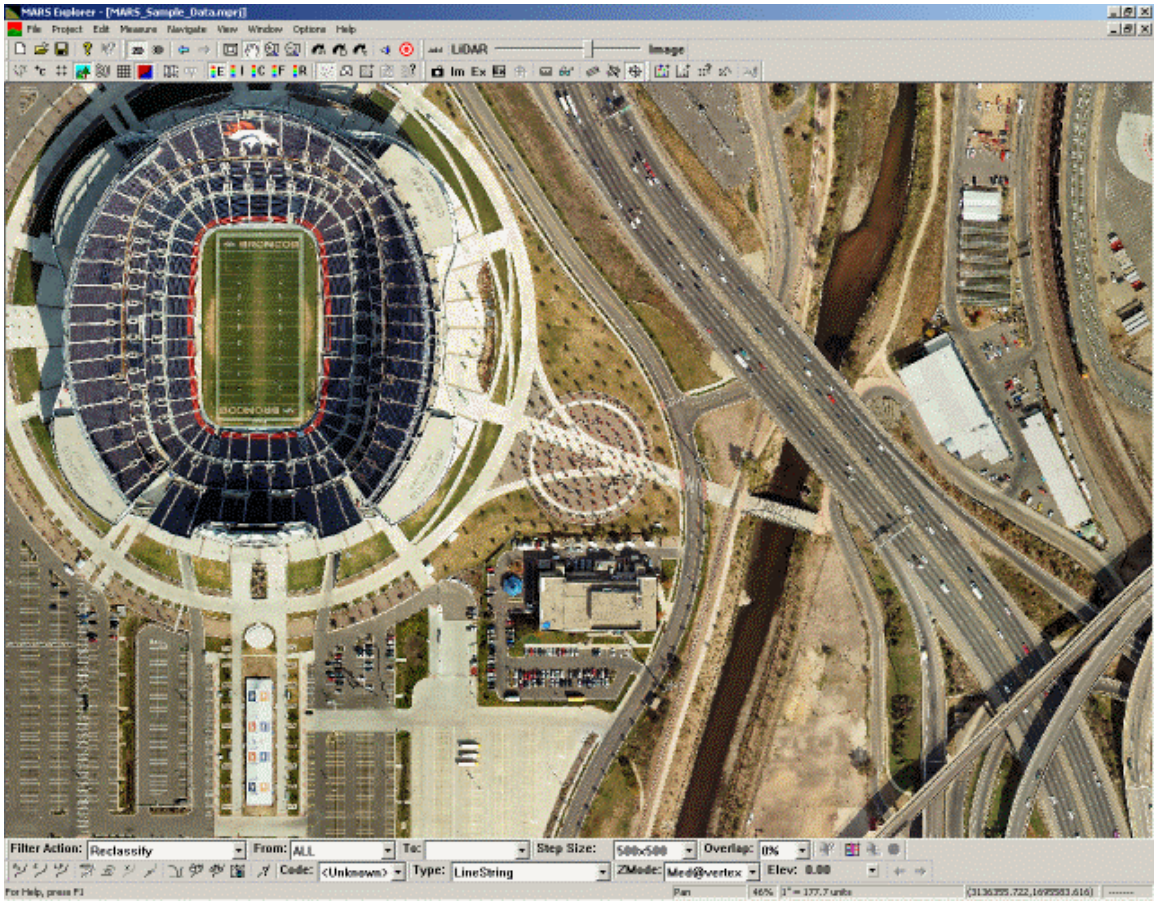
LiDAR Data Visualization

- Point cloud (raw data)
- TIN
- 2D (orthographic)
- 3D (perspective)
- Profile View



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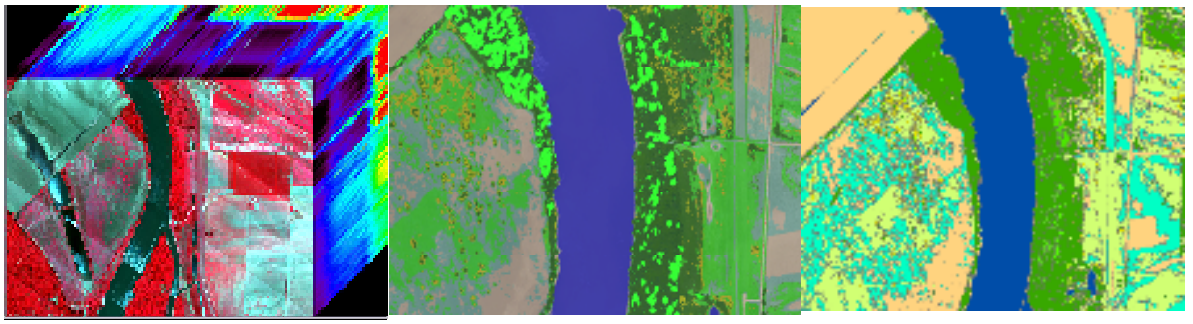
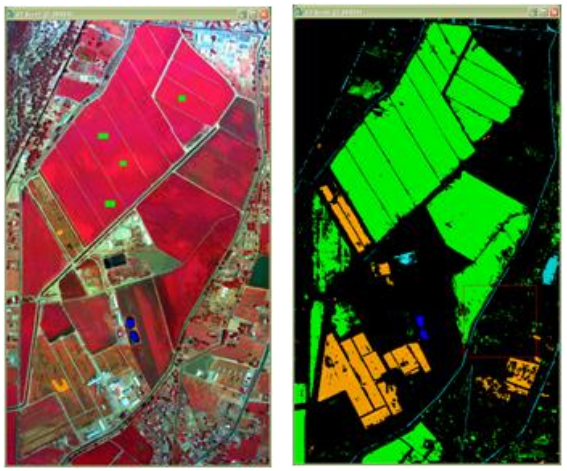
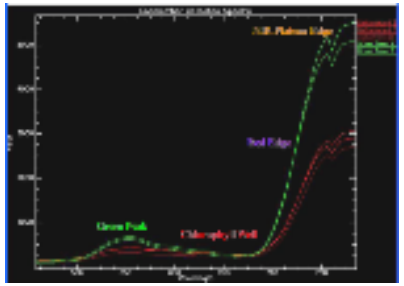
Hyperspectral Imaging (VNIR/SWIR)

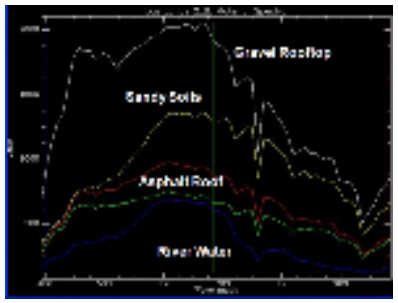
Applications

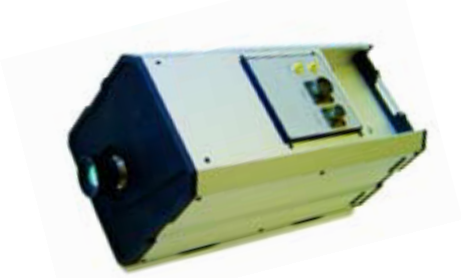
- Vegetation Mapping
  - Precision Agriculture
  - Invasive Species
  - Forestry
  - Wetlands Delineation
- Land Use/Land Cover Mapping
- Material Composition Analysis
- Impervious Surface Mapping
- VNIR/SWIR range: 0.4 – 2.5 microns

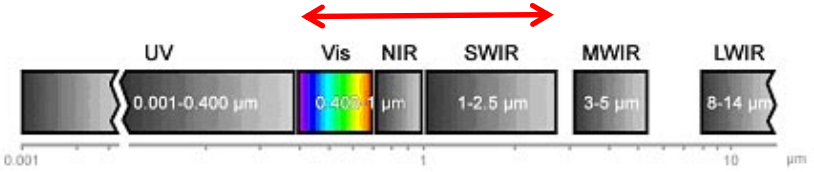












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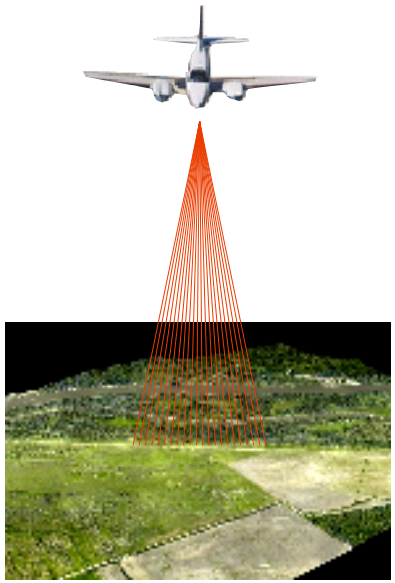
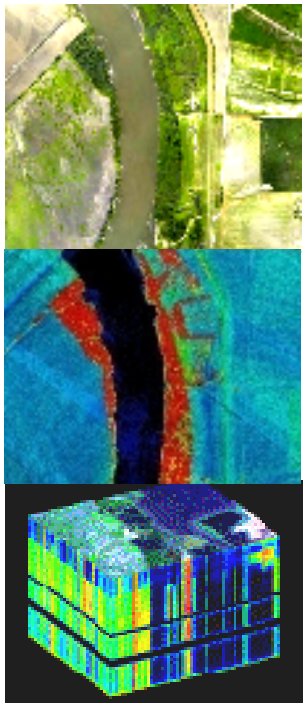
Missouri River Project Area
DACS-II Digital Orthophotography

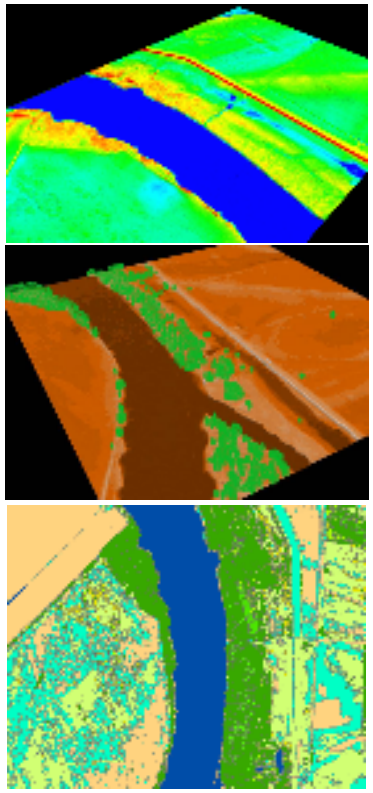
Multi-Sensor Feature Extraction



Acquisition
LiDAR
Digital Ortho
Hyperspectral
AGPS
IMU



Data Fusion
Digital Ortho
LiDAR
Hyperspectral



Data Extraction & Classification
Bare Earth Surface
Vegetation Canopy
Land Cover Classes

Eagle Habitat Database

LAS Bare Earth Surface
ECW Digital Orthophotos
ENVI Spectral Classes
Shape Files
- Cottonwood Trees
- Other Trees
- Low-High Density Grasses
- Brush-Shrubs
- Croplands (Ag-Veg)
- Bare Soils
- Man-made Structures
- Water Features

Processing Software
- ITTVIS ENVI v4.4
- MARS® Explorer v5.0
- ESRI ArcMap v9.2

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Data Fusion

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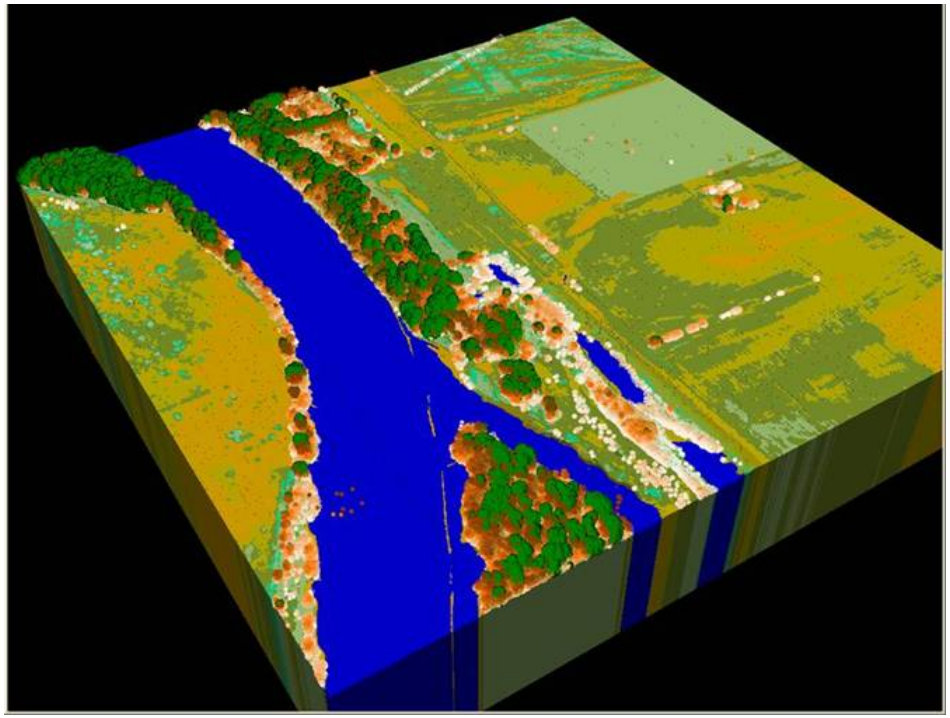
Analysis: Data Fusion Approach

- **Feature Extraction of Digital Orthophotography**
  - High resolution image-based ground truth methodology
  - ENVI Regions of Interest (ROI): Cottonwood Trees, Other Trees, Land Cover Classes
- **Feature Extraction of LiDAR Data (MARS® Explorer)**
  - Bare-earth extraction
  - Vegetation canopy points classes (low, medium, high height classes)
- **Feature Extraction of AISA Hyperspectral Data (ENVI)**
  - Vegetation Canopy Spectral Classes
    - Cottonwood Trees, Other Trees
  - Land Cover Spectral Classes
    - Vegetation, Bare Soils
    - Water
    - Man-made Structures

Analysis: Data Fusion Approach

- **Data Fusion of Hyperspectral Cottonwood pixels and co-located LiDAR canopy classes**
  - Cottonwood Spectral classes
  - Fusion of Cottonwood spectral attributes with LiDAR canopy point classes
  - Cottonwood super-canopy LiDAR points (> 30 meters in height)



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Project Results

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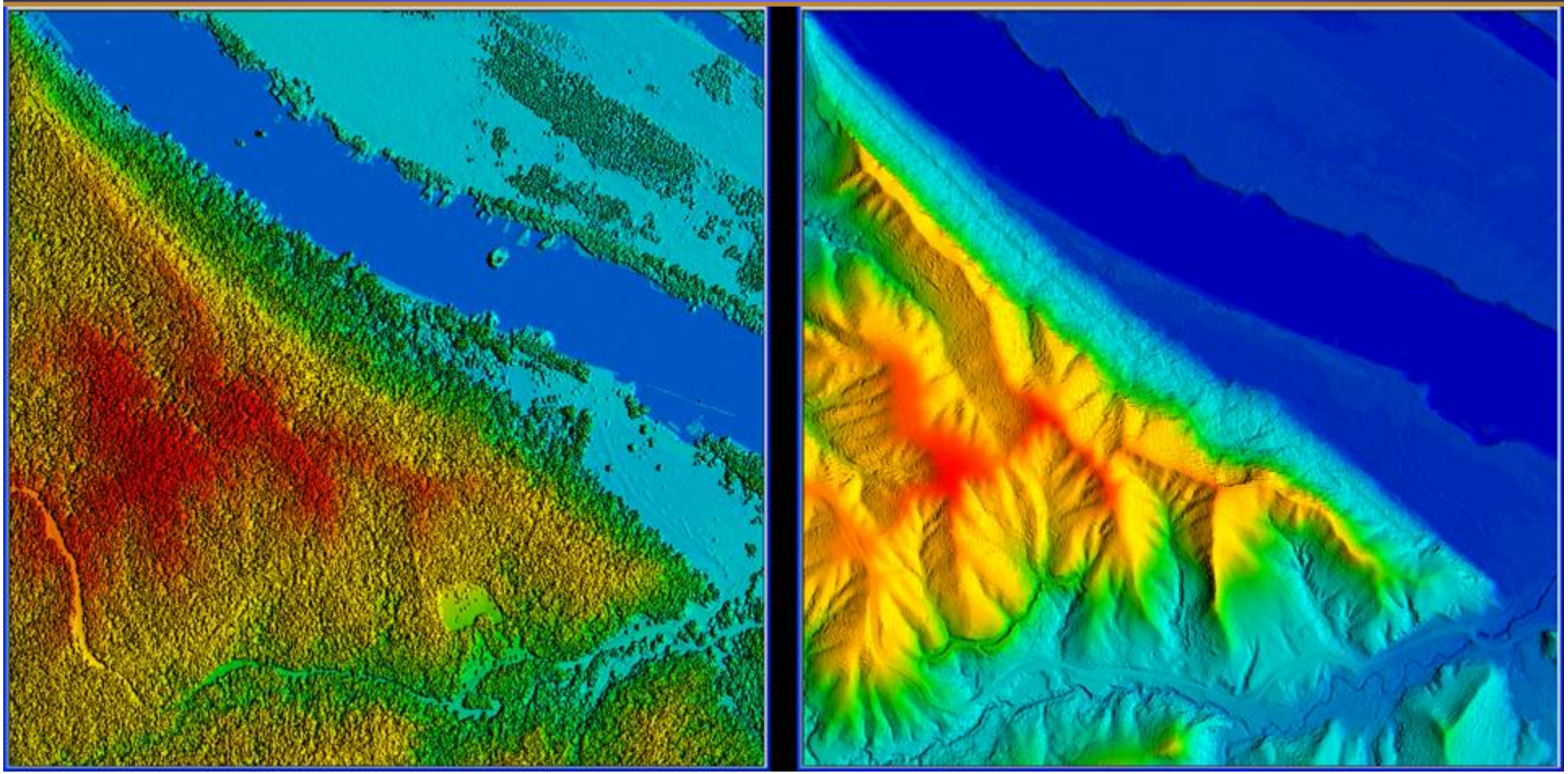
Reflectance LiDAR vs. Filtered Bare Earth Surface



Raw LiDAR with Vegetation Cover

LiDAR Bare Earth Surface

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DACS-II™ Digital Orthophotography

Cottonwood Training Samples

Other Trees Training Samples

Image Ground-Truthing Based on Tree Morphology

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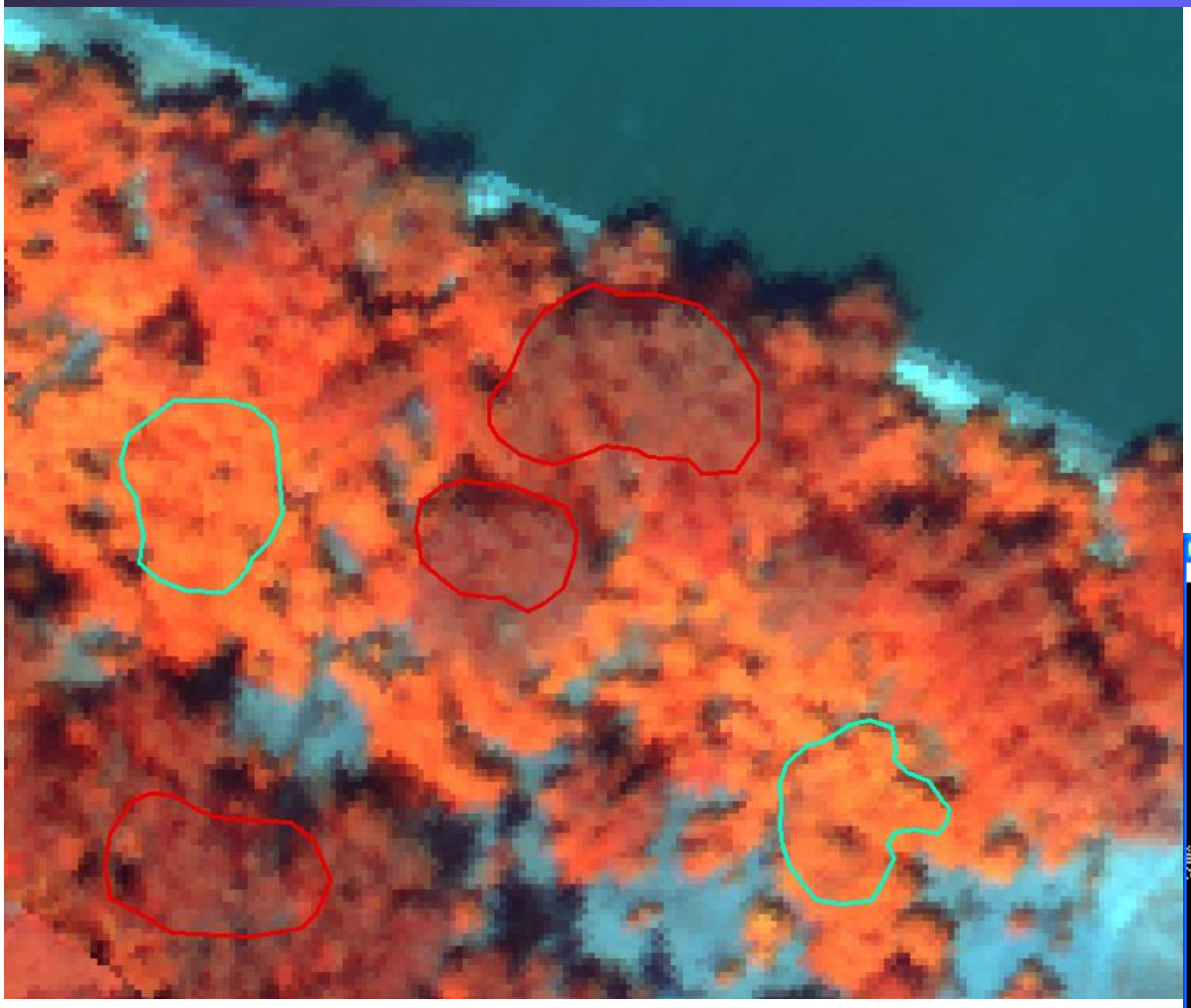
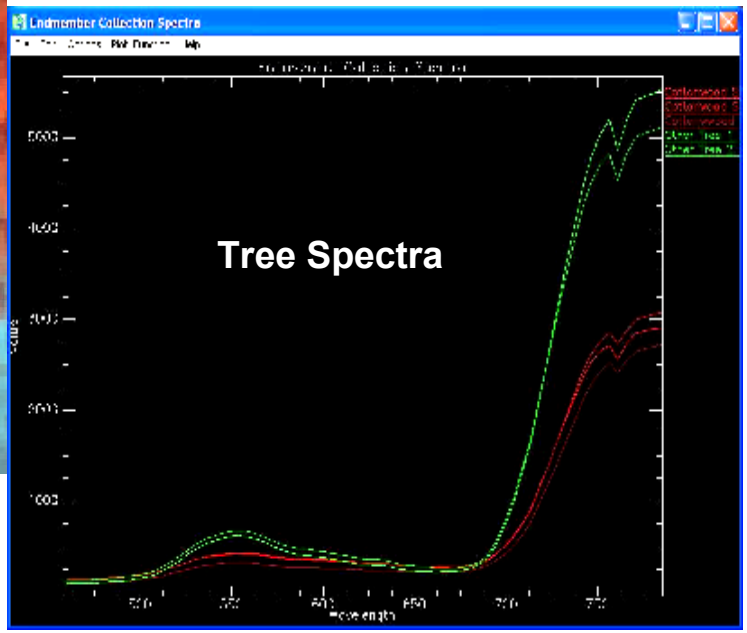
AISA Hyperspectral Imagery



Cottonwood Training Samples

Other Trees Training Samples



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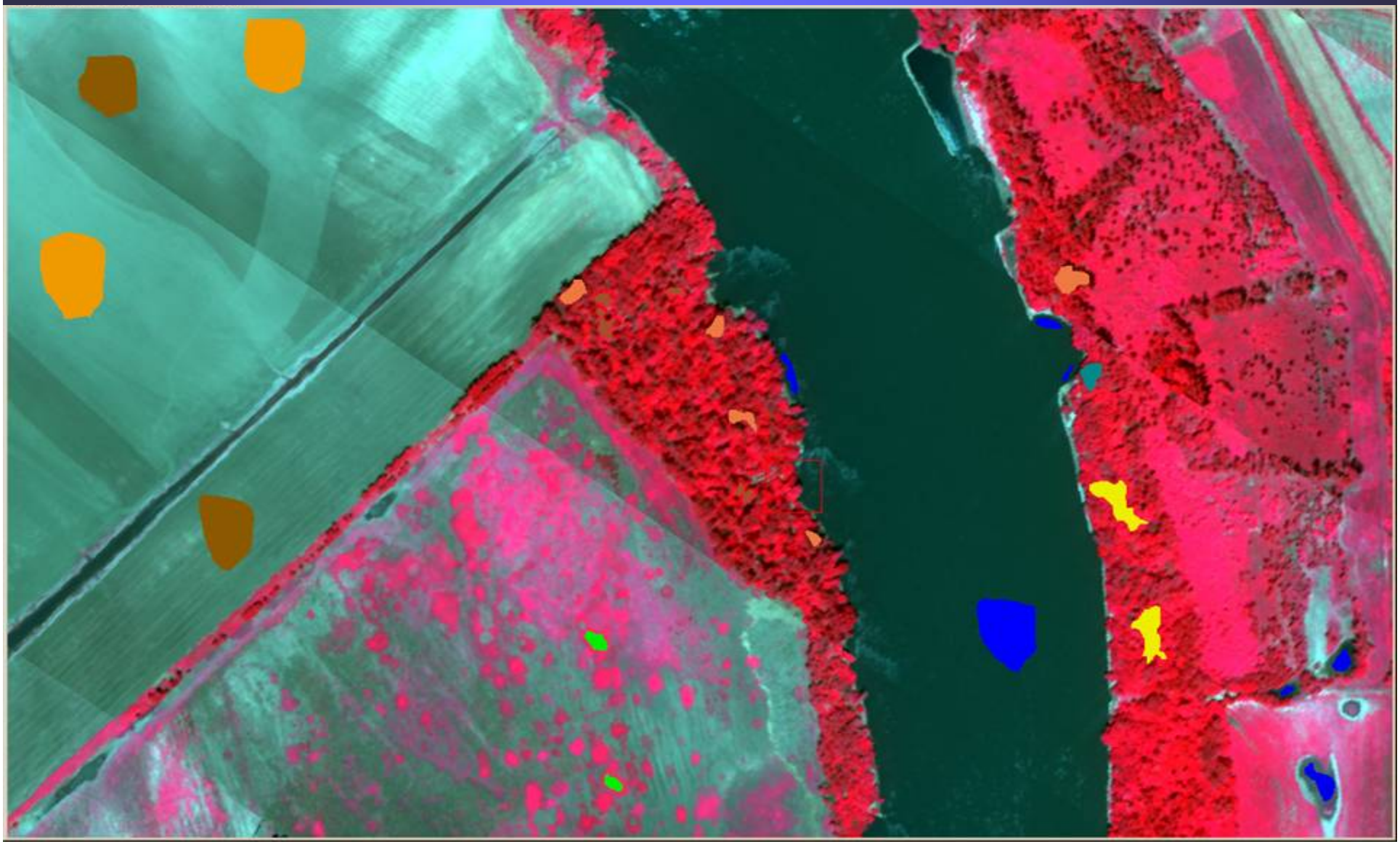
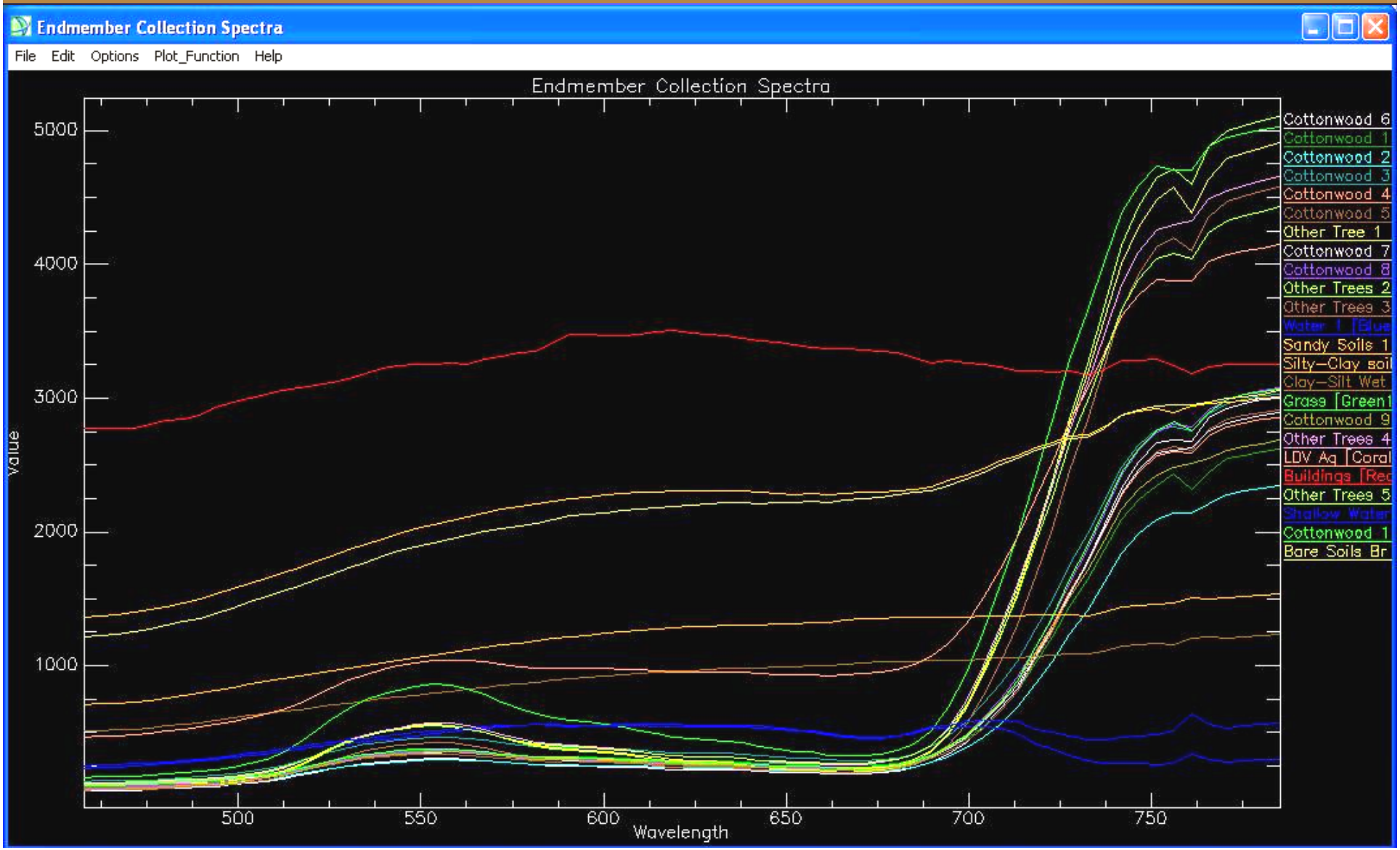
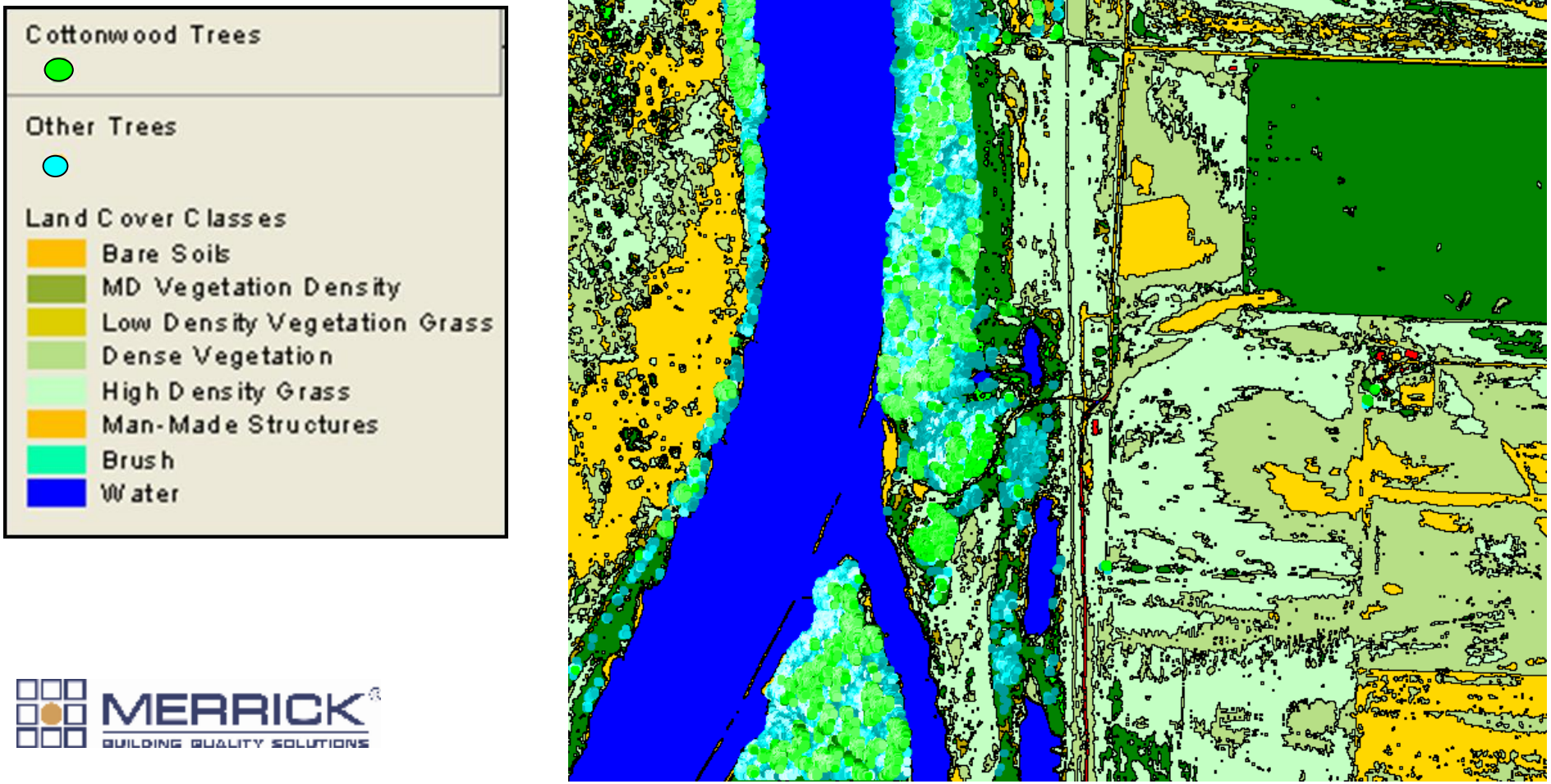
Land Cover Spectral Training Samples



Spectral Curve for Land Cover Classes



Final Land Cover Classification



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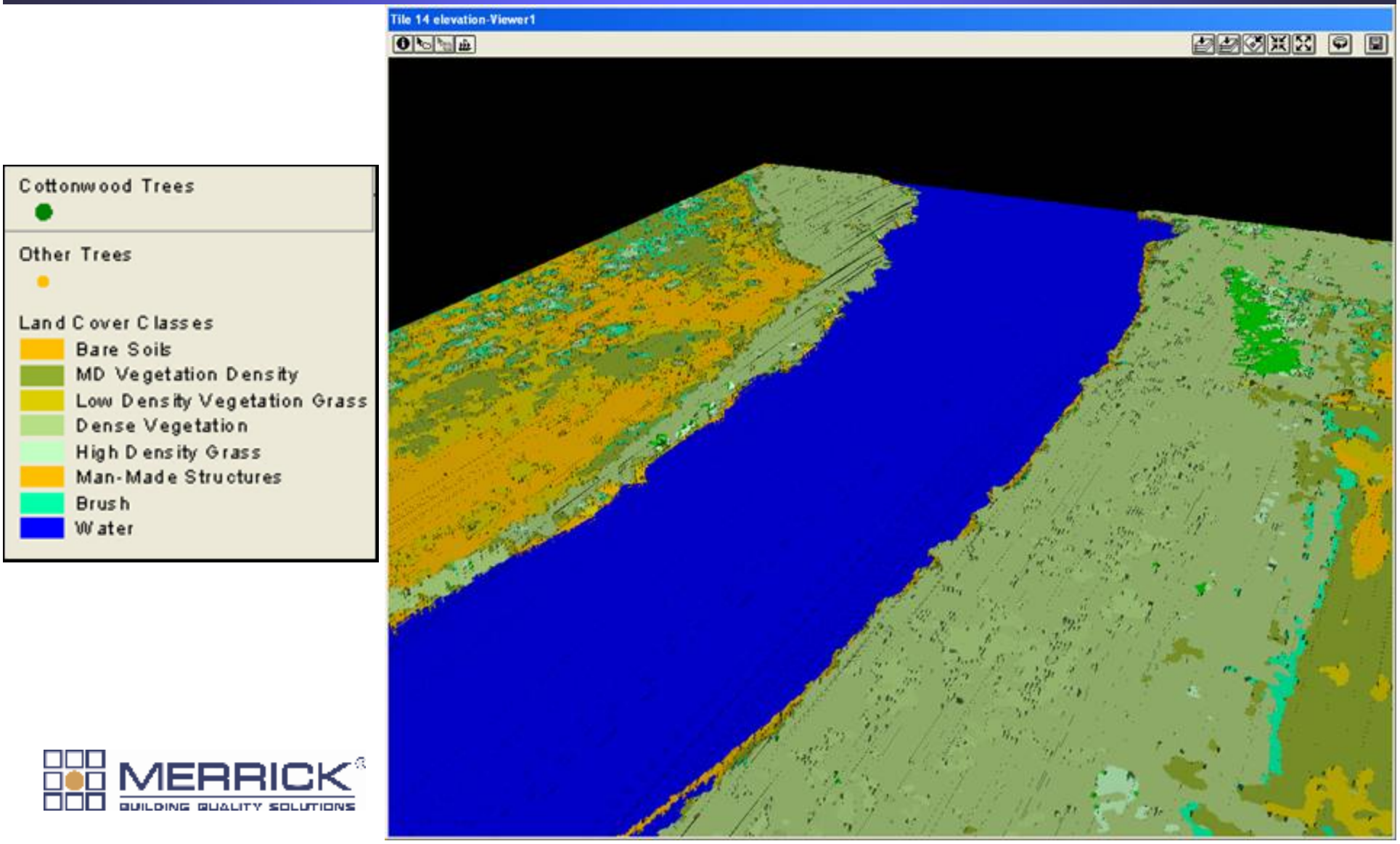
3-D View of Hyperspectral Classification



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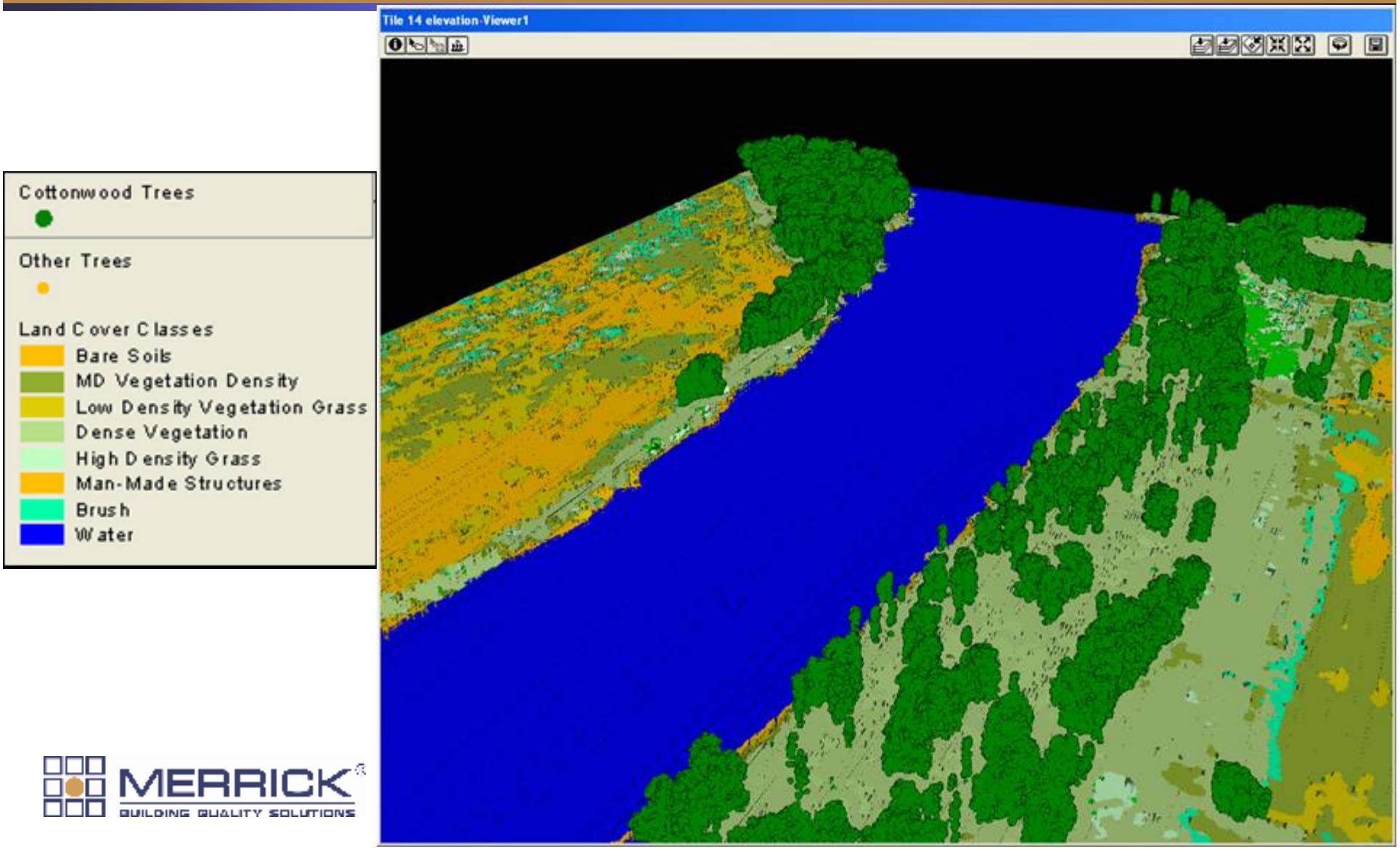
3-D View of Hyperspectral Classification



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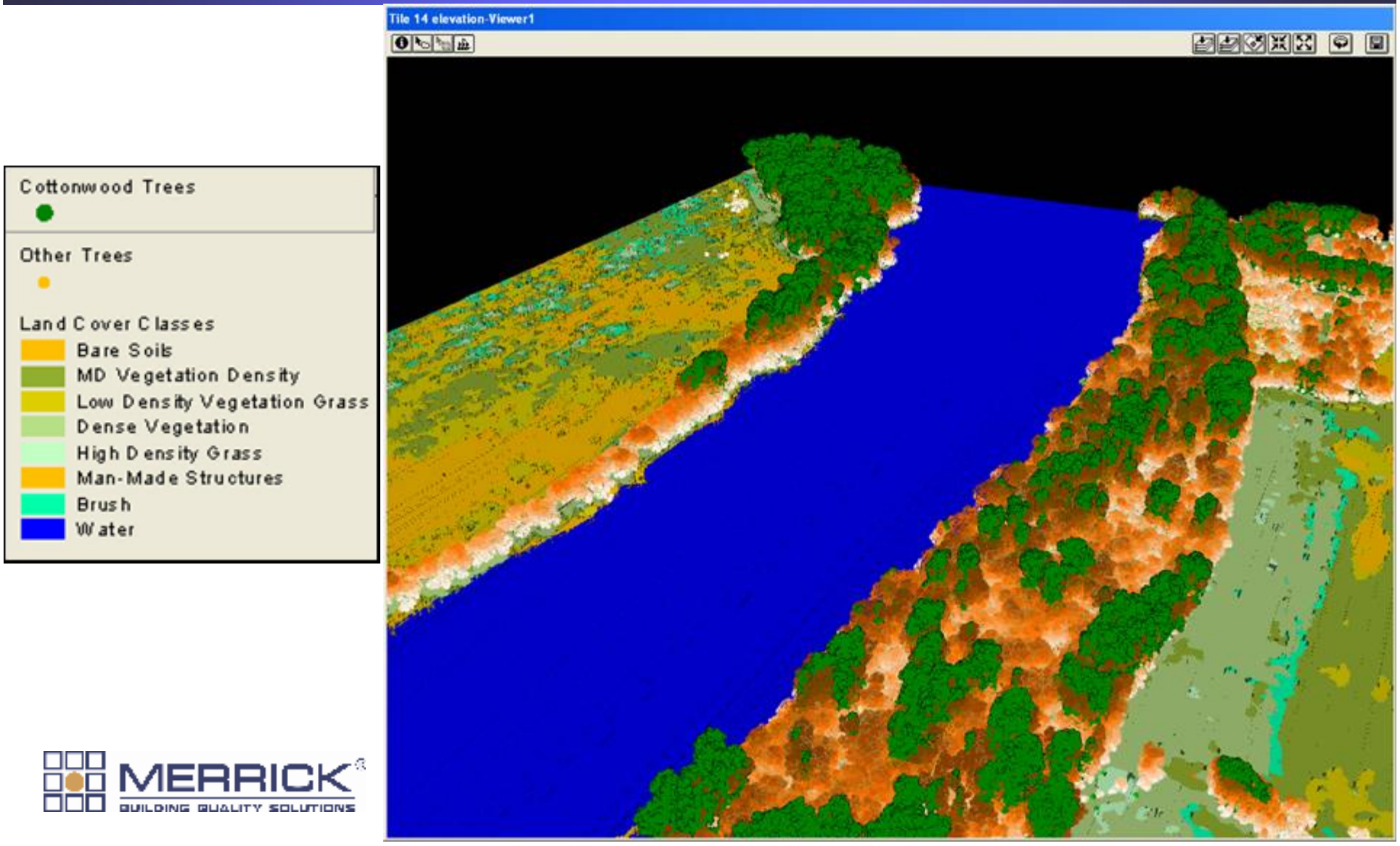
3-D View of Hyperspectral Classification



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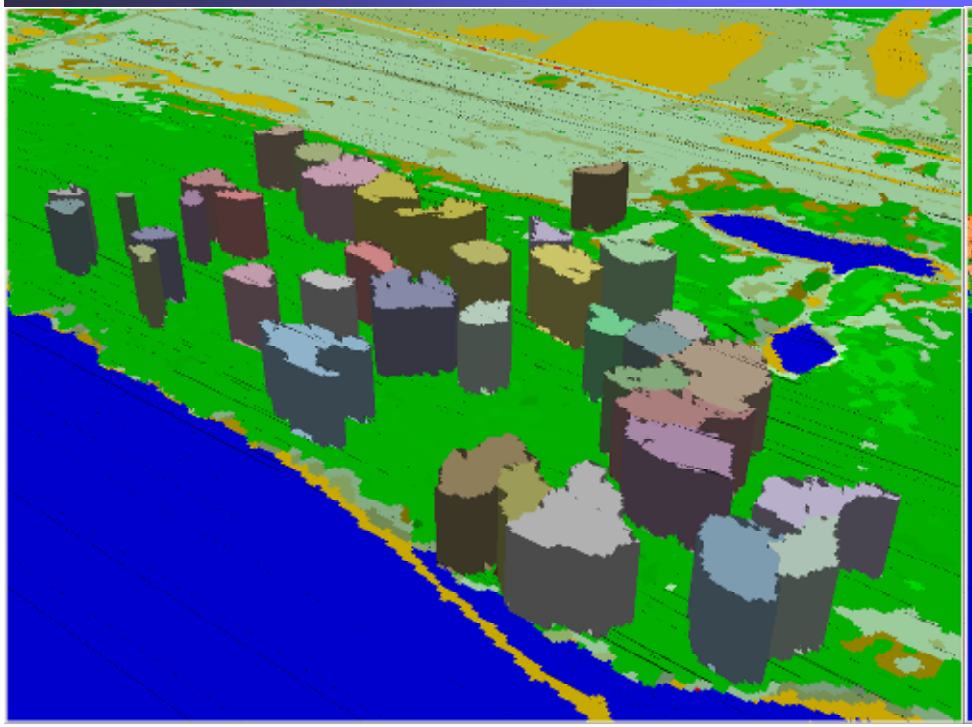
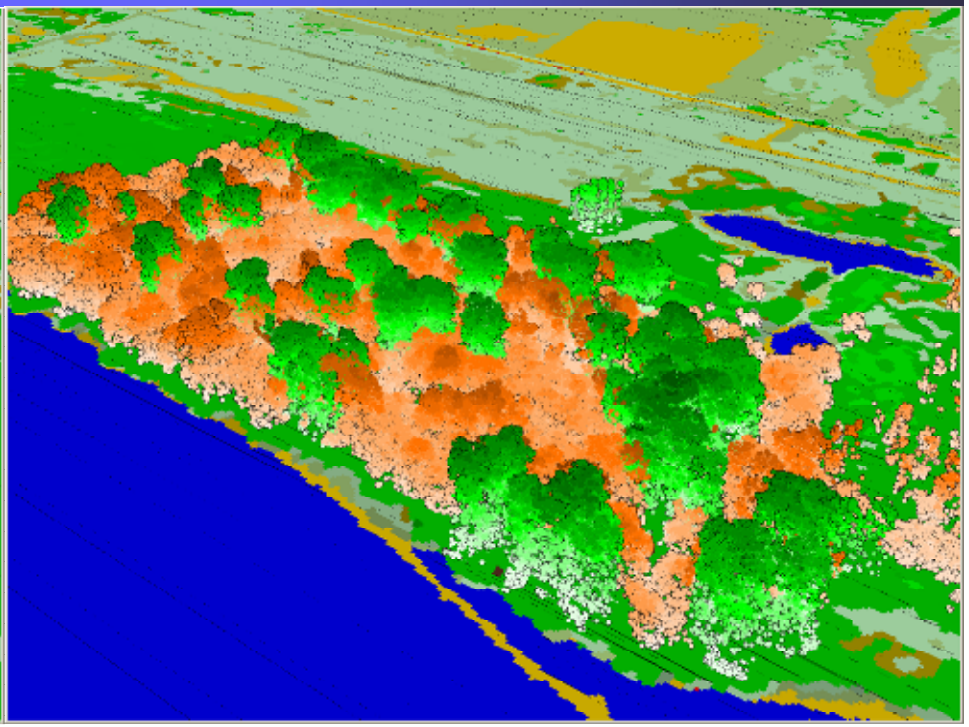
Super-Canopy Trees



Individual Cottonwood Tree polygons



Individual Cottonwood Tree Super-Canopies

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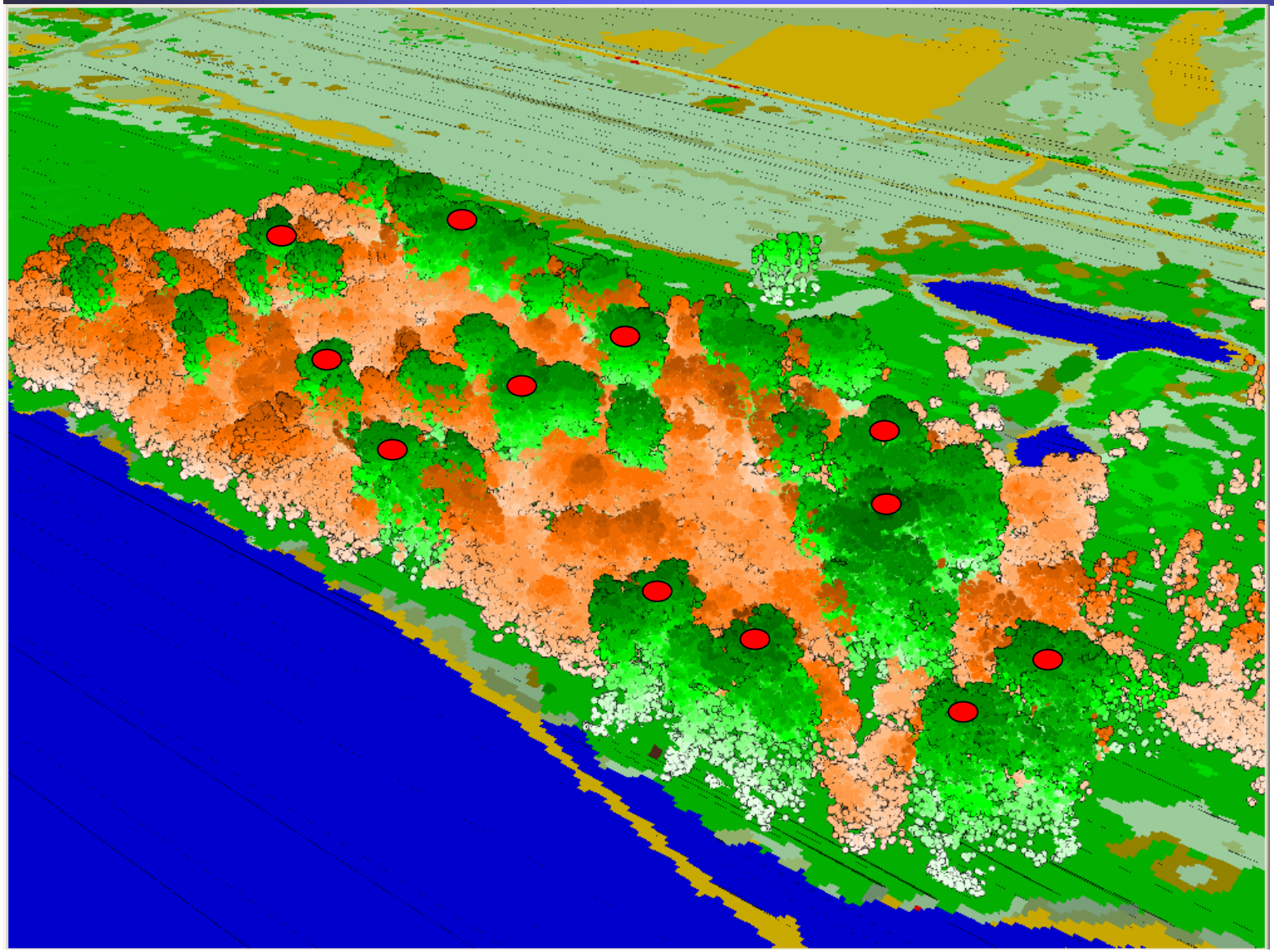
Super-Canopy Trees



Individual Cottonwood Tree Super-Canopy Locations

Height 15 - 35 meters

Potential Eagle Nesting Sites

Project Summary

- Data Fusion approach served as an effective means for mapping potential Bald Eagle habitats
  - Digital Orthophotography as “Image-based Ground Truth”
  - Hyperspectral for species identification of Cottonwood Trees
  - LiDAR for detailed canopy mapping, tree-height and crown-diameter estimation, super-canopy structure identification
  - Data Fusion techniques using MARS® software
- Valuable tool for assessing large areas and providing data for decision support and implementation of management practices for Bald Eagle habitats
- Client to determine cost-benefit of manual vs. digital remote sensing approaches

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