

**Mapping Coastal Great Lakes Wetlands and
Adjacent Land use Through Hybrid Optical-Infrared
and Radar Image Classification Techniques**

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Coastal Great Lakes



- Largest freshwater surface system on Earth
- Coastal Great Lakes border 8 states and Ontario Canada
- Range from temperate to boreal ecoregion
- Wetlands range from protected embayment to riverine, dune and swale, etc



Coastal Great Lakes

Needs:

- To protect existing wetlands and assess health and condition for management and planning

Problems:

- Pollution, invasive species and other environmental issues affect the entire Great Lakes basin, and do not know political boundaries
- An international comprehensive map depicting coastal Great Lakes wetlands does not exist

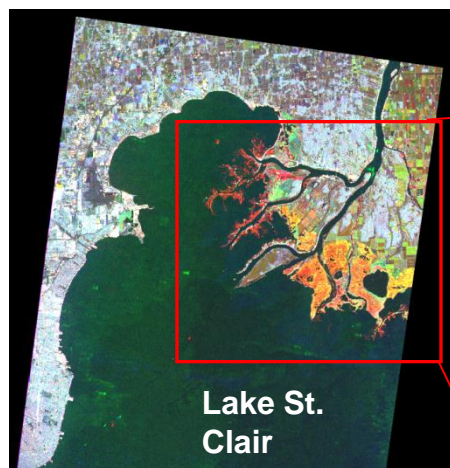
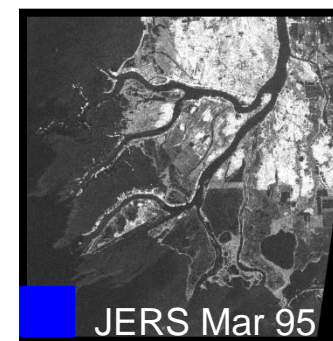
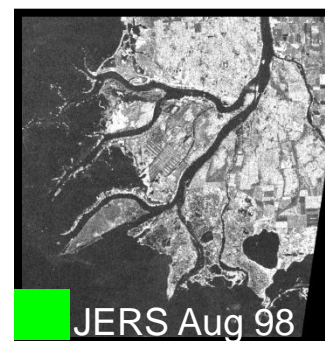
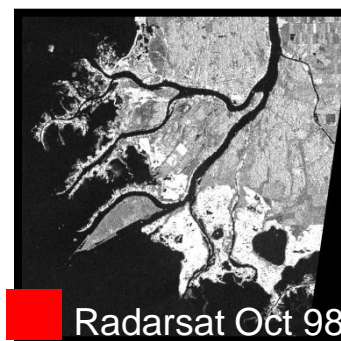
To comprehensively monitor and manage an ecosystem on the scale and complexity of the Great Lakes basin requires remote sensing integrated with field data and GIS



Great Lakes Coastal Wetland Mapping Project Overview

- **Project goal:** Develop repeatable mapping and monitoring techniques that allow for accurate delineation of Great Lakes coastal wetlands and adjacent land areas
- **Approach:**
 - Use techniques developed for landscape indicator protocol under the Great Lakes Coastal Wetlands Consortium Pilot Study (Bourgeau-Chavez *et al.* 2008)
 - Use fusion of moderate resolution (20-30 m) satellite remote sensing from optical and Synthetic Aperture RADAR (SAR) sensors
 - PALSAR L-band HH and HV polarization (20 m resolution)
 - Envisat C-band, HH and HV polarization (30 m resolution)
 - Landsat TM optical-IR (30 m) / thermal (120 m resampled to 30 m)

2004 Pilot Study: *Multi-SAR Sensor Composite*



Dickinson Island
Harsen's Island

Upland Forest

Cattail/*Scirpus* beds

Wet meadow-sedges

Phragmites dominant

Cattail dominant

22.7 km

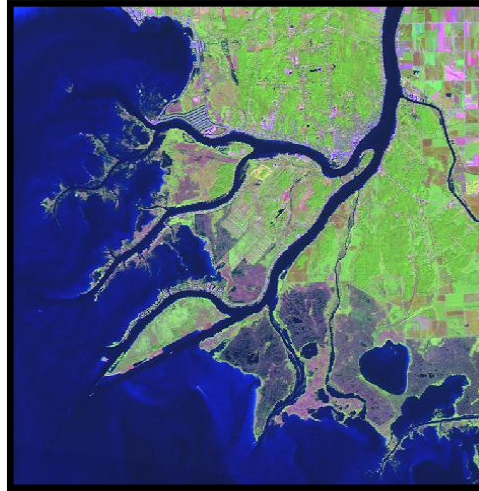
23.6 km

©CSA 1998 ©NASDA 1995-8 ©GD-AIS 2003

Multi-sensor L- and C-band radar composite depicts the biomass and flooding differences between the various emergent wetlands in this delta

Why Sensor Fusion?

Landsat ETM (Aug '01)
5,4,3 False Color
Composite



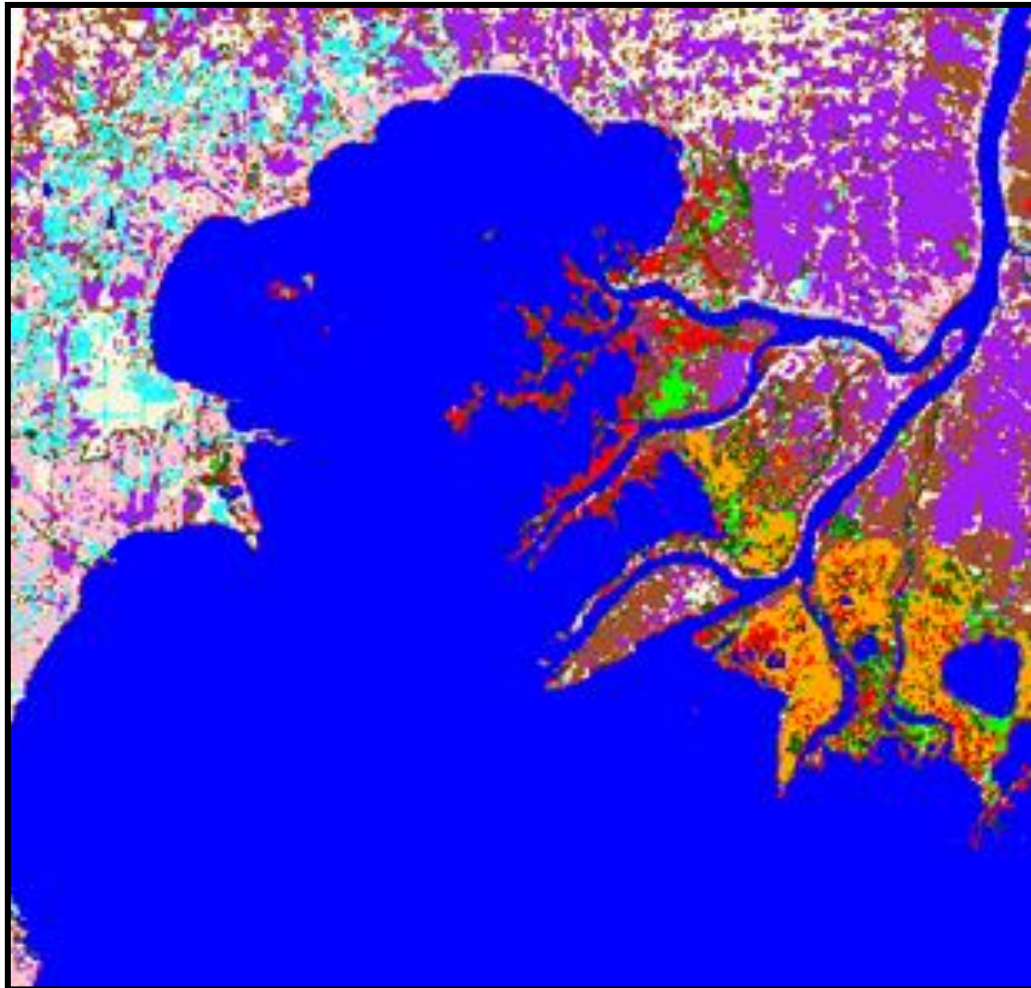
Radarsat (Oct'98),
JERS (Aug '98), JERS
(March '95) False
Color Composite



- **LANDSAT can be used to identify a broad spectrum of land cover types**
 - Radiant energy reflectance from vegetation varies depending on features at the cellular level (e.g. chlorophyll, leaf moisture), as well as variations in surface or background reflectance (e.g., soil type, water).
- **SAR can differentiate wetland types based on:**
 - Inundation/water level patterns
 - Vertical structure
 - Soil moisture
 - Biomass


GLCWC Pilot Study in 2004

Merged Landsat-SAR Land Cover Mapping



Landsat TM and Radar Combined

Classification

	Cattails
	Cropland
	Forage_LowHerbaceous
	Forest
	High Density Urban
	Low Density Urban
	Phragmites
	Scirpus
	Shrubland
	Unclassified
	Water
	Wetlands_other

Results 94% map accuracy when compared to NWI, 70% compared to IFMAP

Fusion reduced confusion

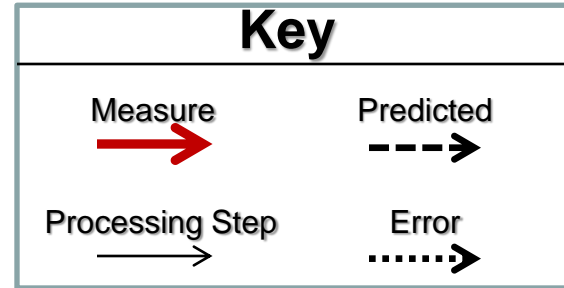
Increased number of wetland classes delineated including the invasive species *Phragmites*



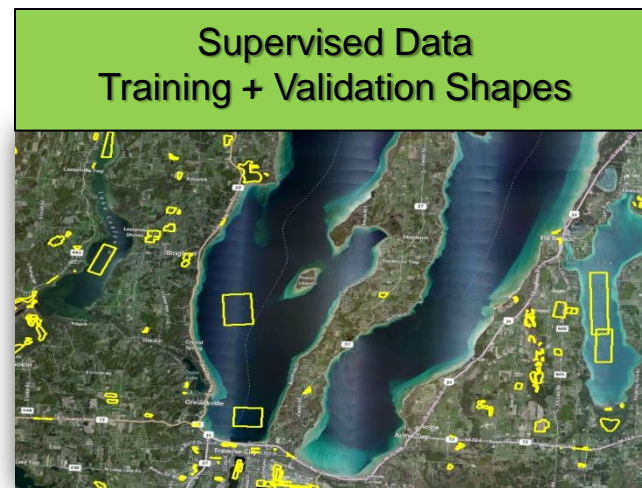
Great Lakes Coastal Wetland Mapping Project Overview

- **Development of Methods:**
 - **Wetland Field data collection** - Project builds from field data and PALSAR database created in 2010-11 to map invasive species *Phragmites australis*
 - **Air photo interpretation** (training and validation)
 - **Remote sensing**
 - Evaluated various methods for mapping wetlands using new technologies to compare to GLCWC pilot study methods (separate TM and SAR classifications - merged)
- **Preliminary Results:** Coastal maps of Lakes Huron and parts of Lake Michigan
- **Continued work:** Field data collection plan, work on woody wetlands

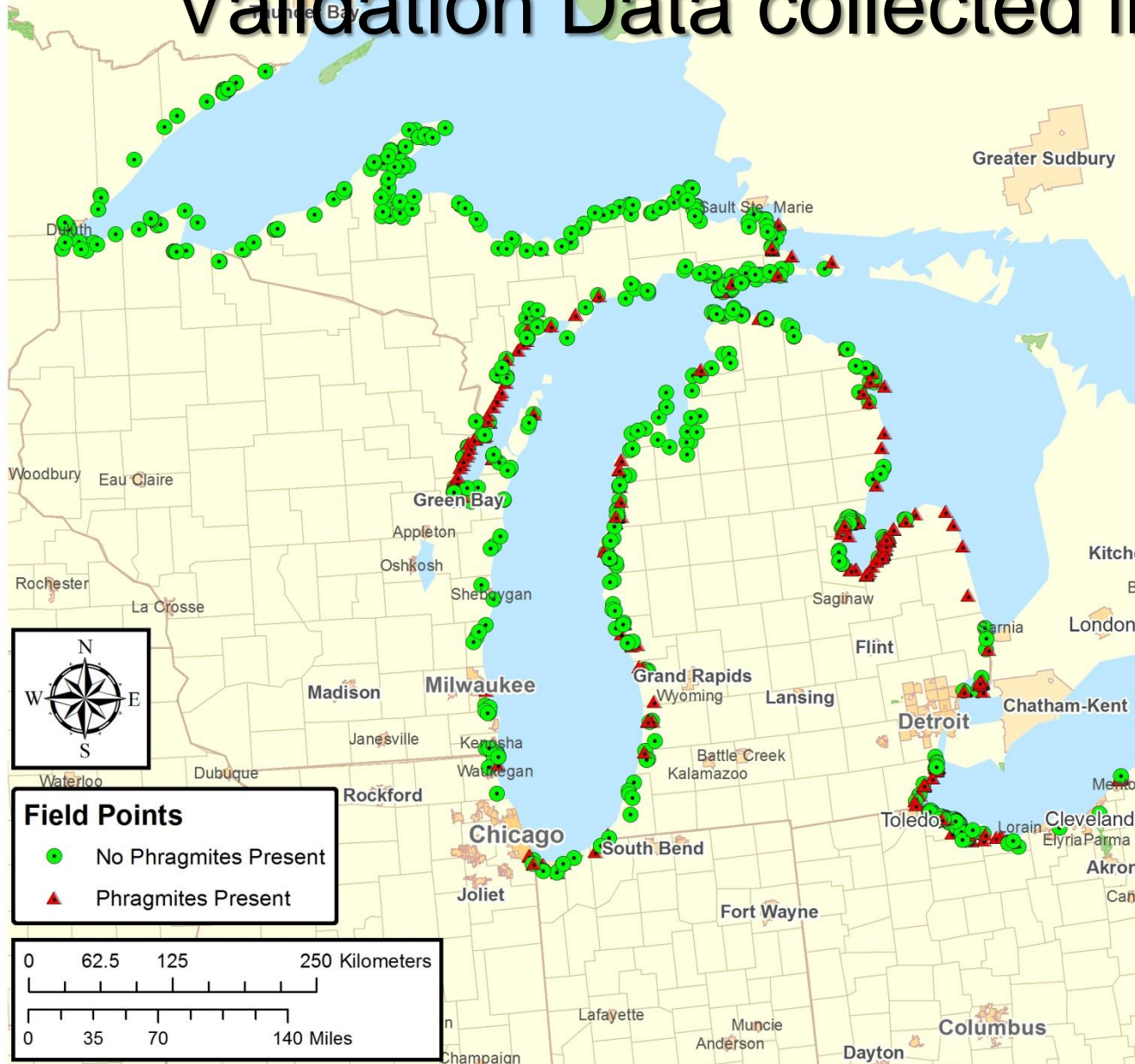
Field Data Integration and Air Photo Interpretation



USGS.gov
2012



Wetland Field Training and Validation Data collected in 2010-11



- 1145 unique field site visits.

- 782 validation, 363 training

- Phragmites* observed at 30% of sites.

- Only NWI "Palustrine Emergent" polygons used to generate random points for validation sites

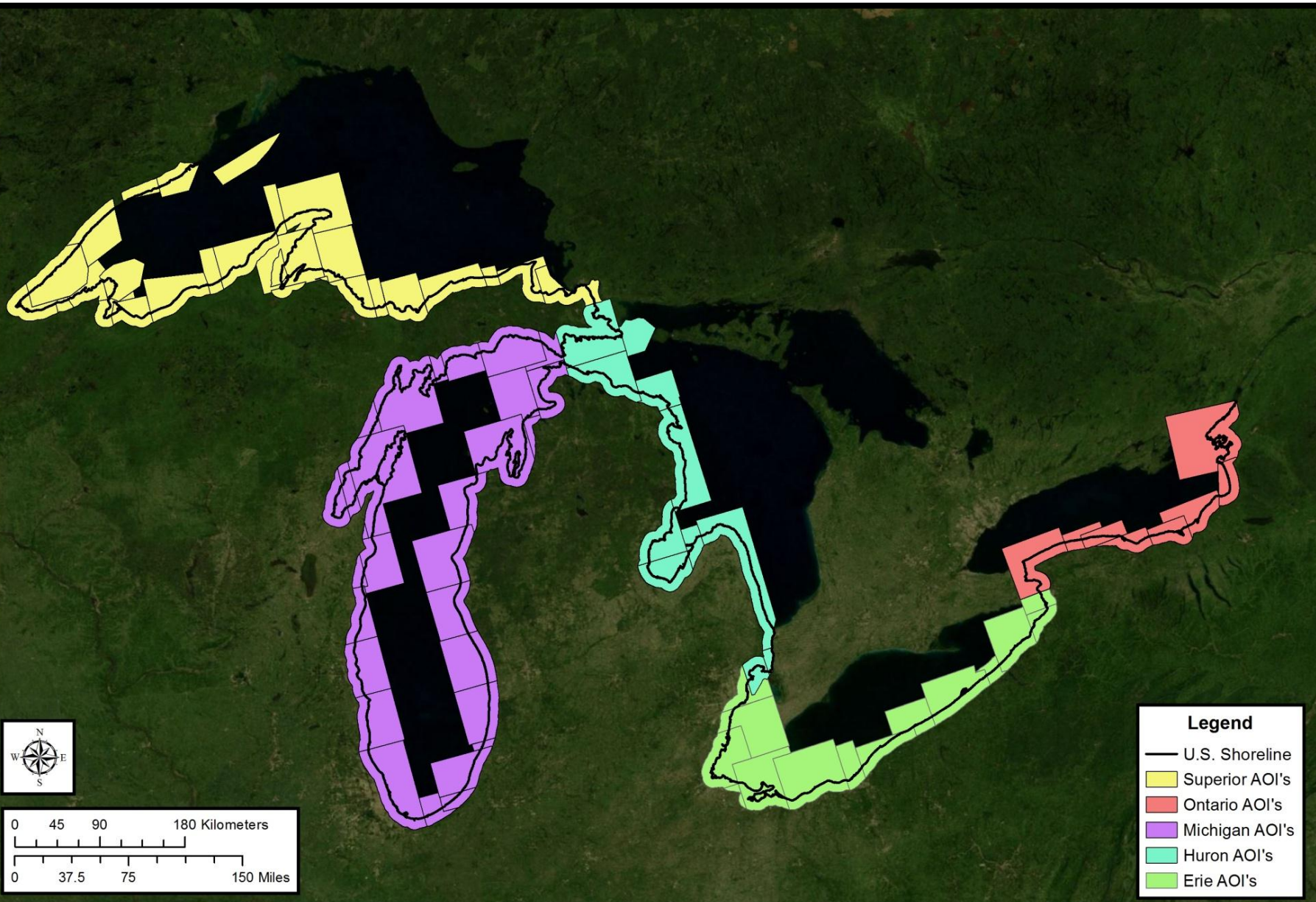
- Need to target other wetland types (Forest & Shrubby) for additional field validation data

- Need to target Canada coastal areas, Michigan Natural Features Inventory (MSU) funded to collect new field data

Field Measurements Collected in ½ acre plots

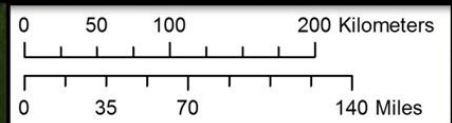
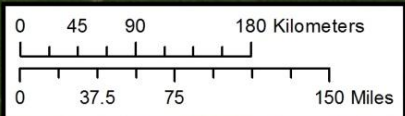


- GPS locations
 - Center of ½ acre plots
- Photos with GPS tag – 4 cardinal directions (over 3000 photos in archive)
- Dominant covertype-
Vegetative composition
- Wetland Ecosystem type
- Average Veg. height (3)
- Density of *Phrag* and *Typha* only
- *Phragmites* presence
- Recent changes/
herbicide/burn treatments



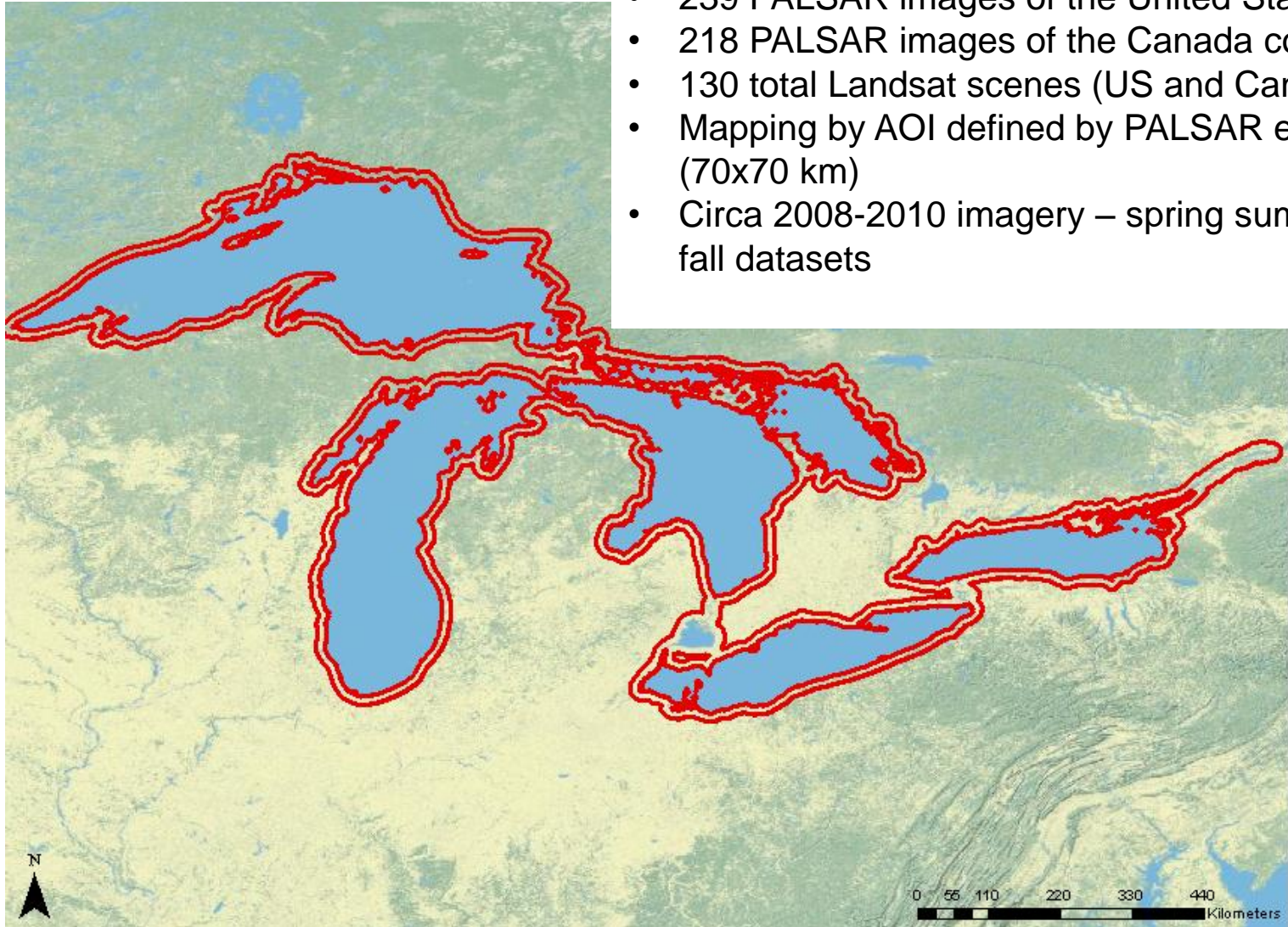
Legend

- U.S. Shoreline
- Superior AOI's
- Ontario AOI's
- Michigan AOI's
- Huron AOI's
- Erie AOI's



Mapping Area 10 km buffer on Coastal zone

- 239 PALSAR images of the United States
- 218 PALSAR images of the Canada coast
- 130 total Landsat scenes (US and Canada)
- Mapping by AOI defined by PALSAR extent (70x70 km)
- Circa 2008-2010 imagery – spring summer fall datasets



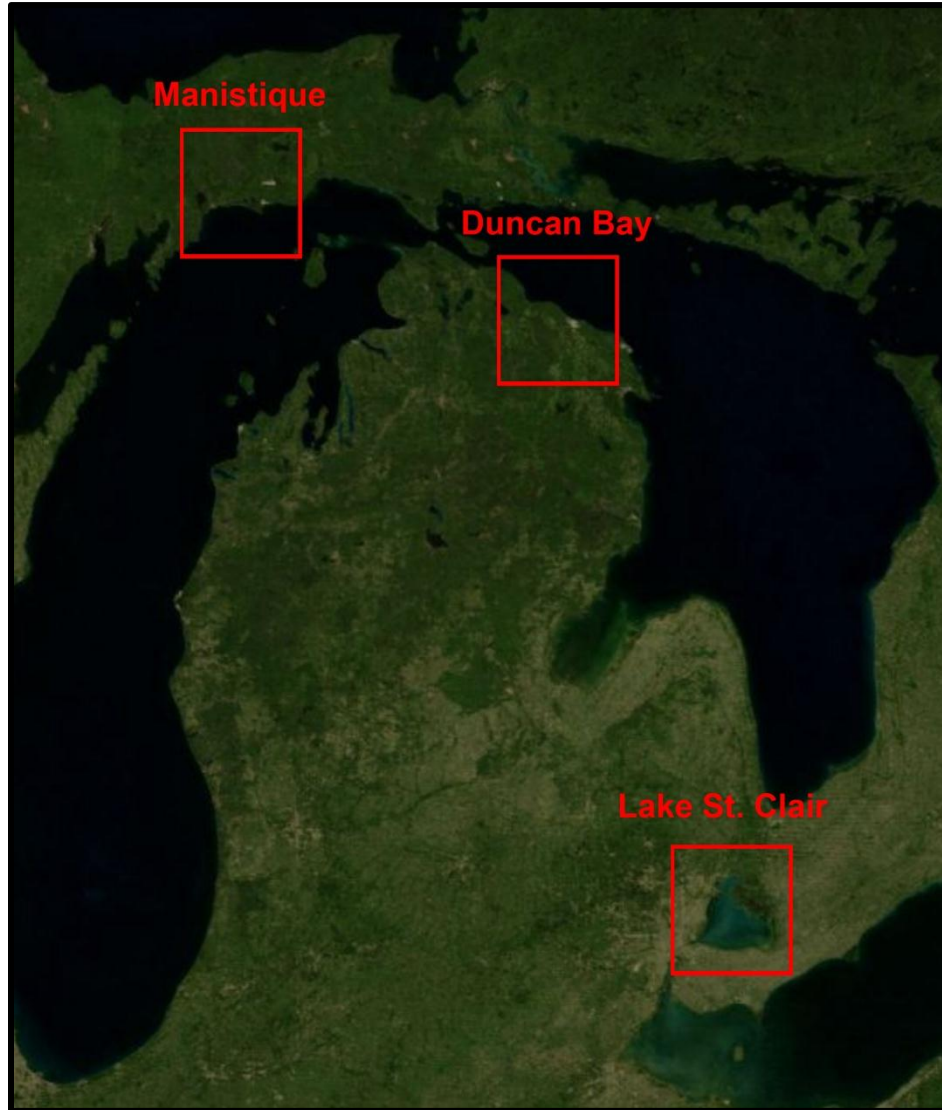
Classification Parameters

Legend	
	Urban
	Agriculture
	Forest
	Water
	Wetland
	Barren
	Aquatic Bed
	Phragmites
	Typha
	Scirpus
	Scrub/Shrub
	Wetland Scrub/Shrub
	Forested Wetland
	Urban Grass
	Urban Roads

- Anderson level one classification across entire Great Lakes Basin
 - Focus on wetland identification
- Wetland Classification
 - NWI Classes
 - Where applicable *Phragmites* and *Typha*

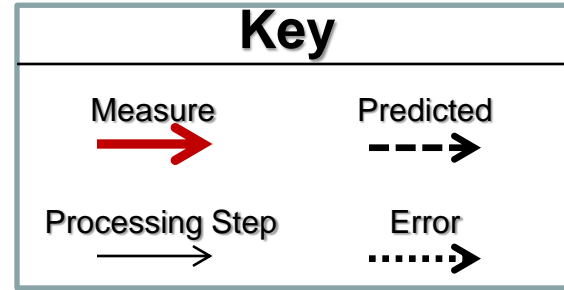


Development of Methodology – Pilot Study Areas



- **Methods Tested**
 - Original GLCWC Pilot study methods (separate Landsat and SAR classifications)
 - Thresholding multiple bands/band combinations
 - Random Forests classification
- **Landsat Processing**
 - TOA vs. Ledaps atmospheric correction tested

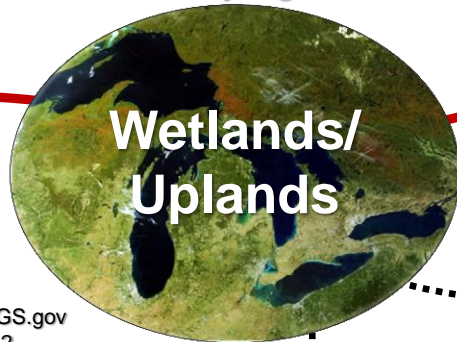
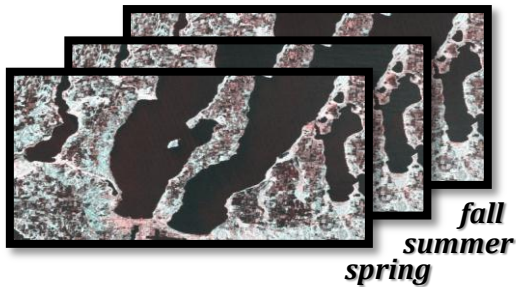
Random Forests Schematic Overview



*Landsat TOA data:
Traverse City, MI*



PALSAR HH/HV data



USGS.gov
2012

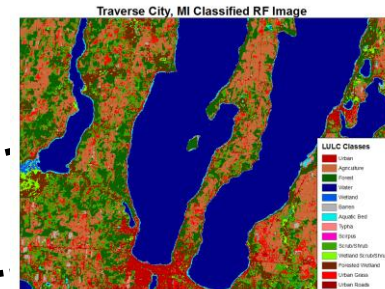
TM/PALSAR
Stack of 31
bands

Supervised
Data
80% training/
20%
validation

Field
Data

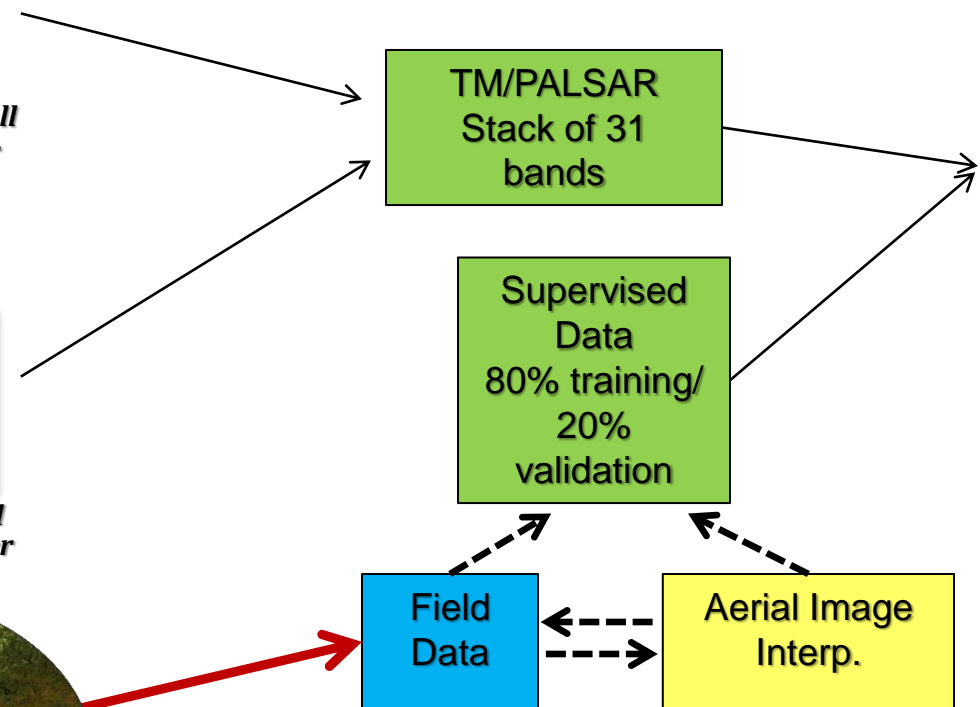
Aerial Image
Interp.

**Random
Forests**

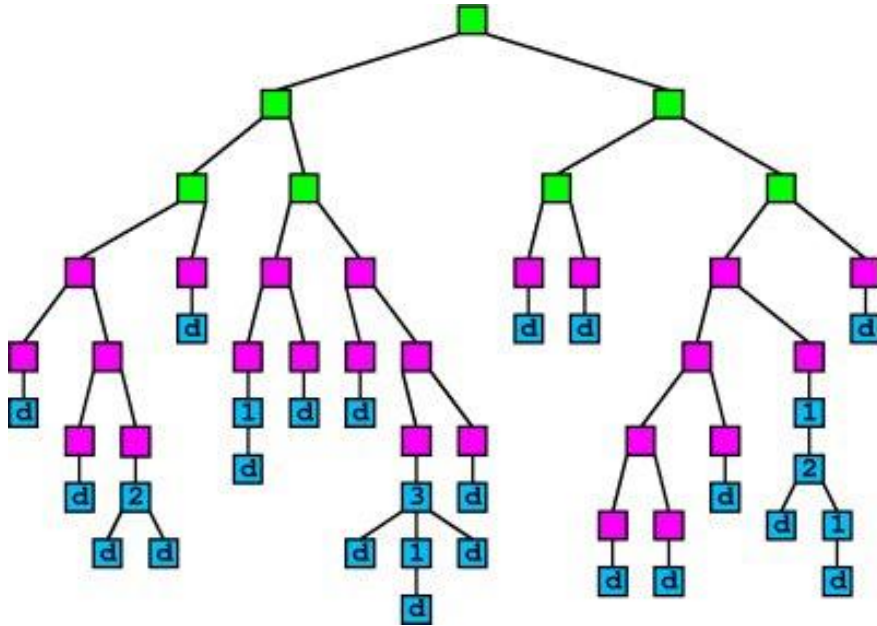


Precision

Accuracy

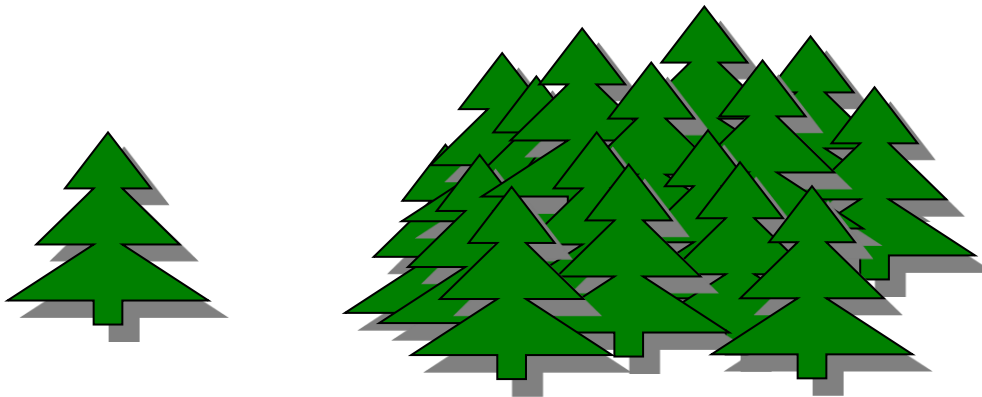


Random Forests – 500 Decision Trees

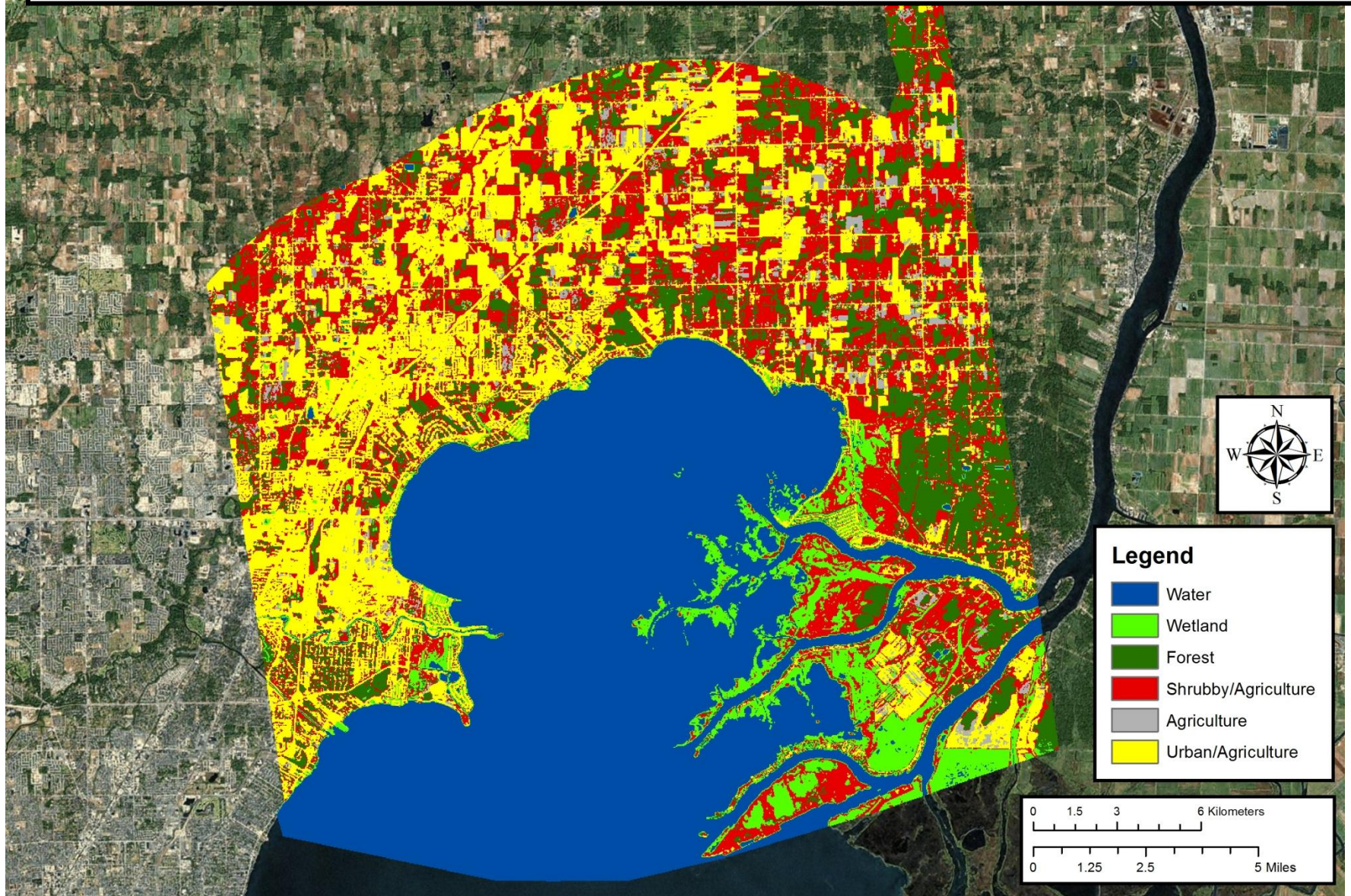


- Advantages:
 - Speed
 - Accuracy
 - Range of application

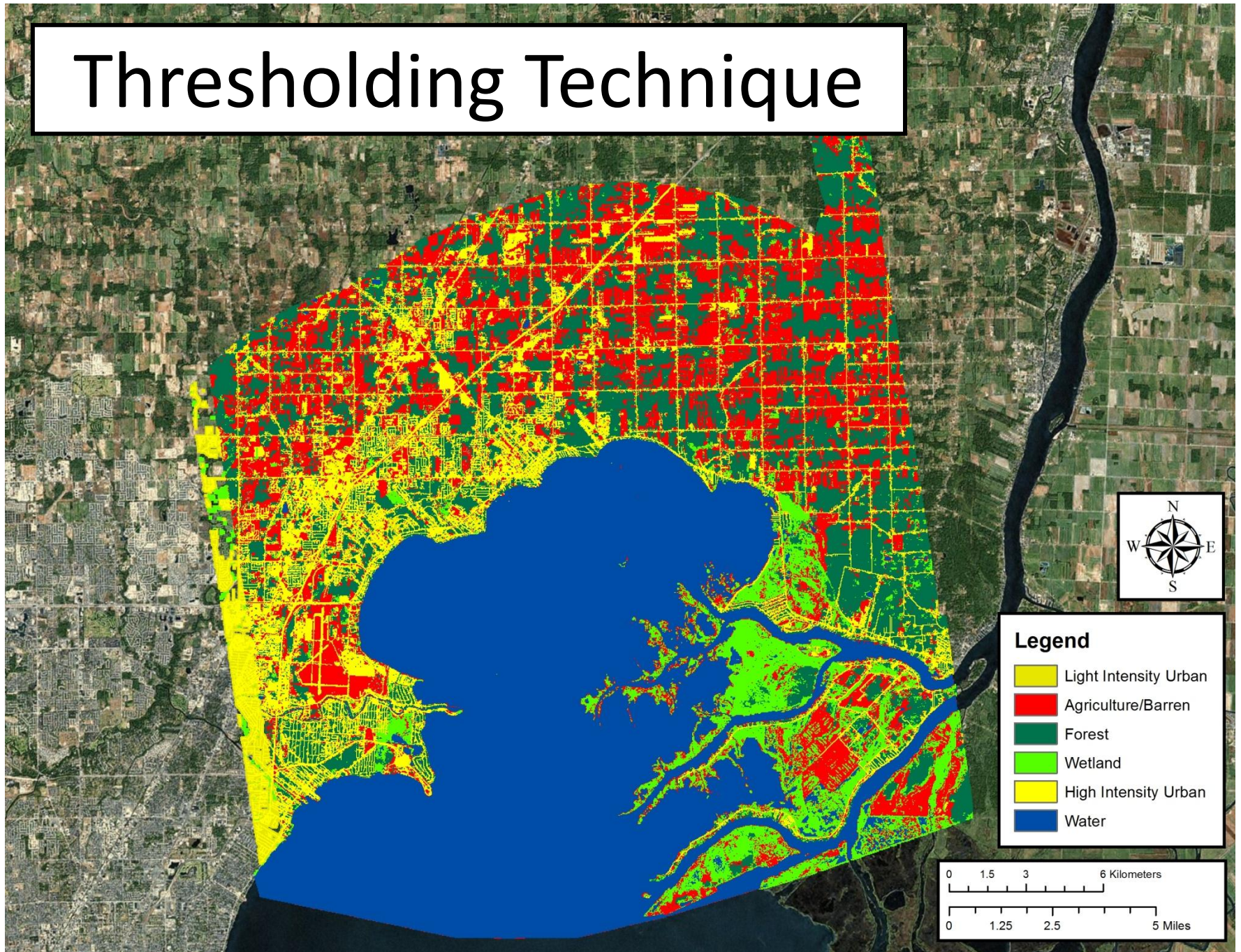
- Disadvantages
 - Heavily dependent on training data
 - Difficult to alter once classified



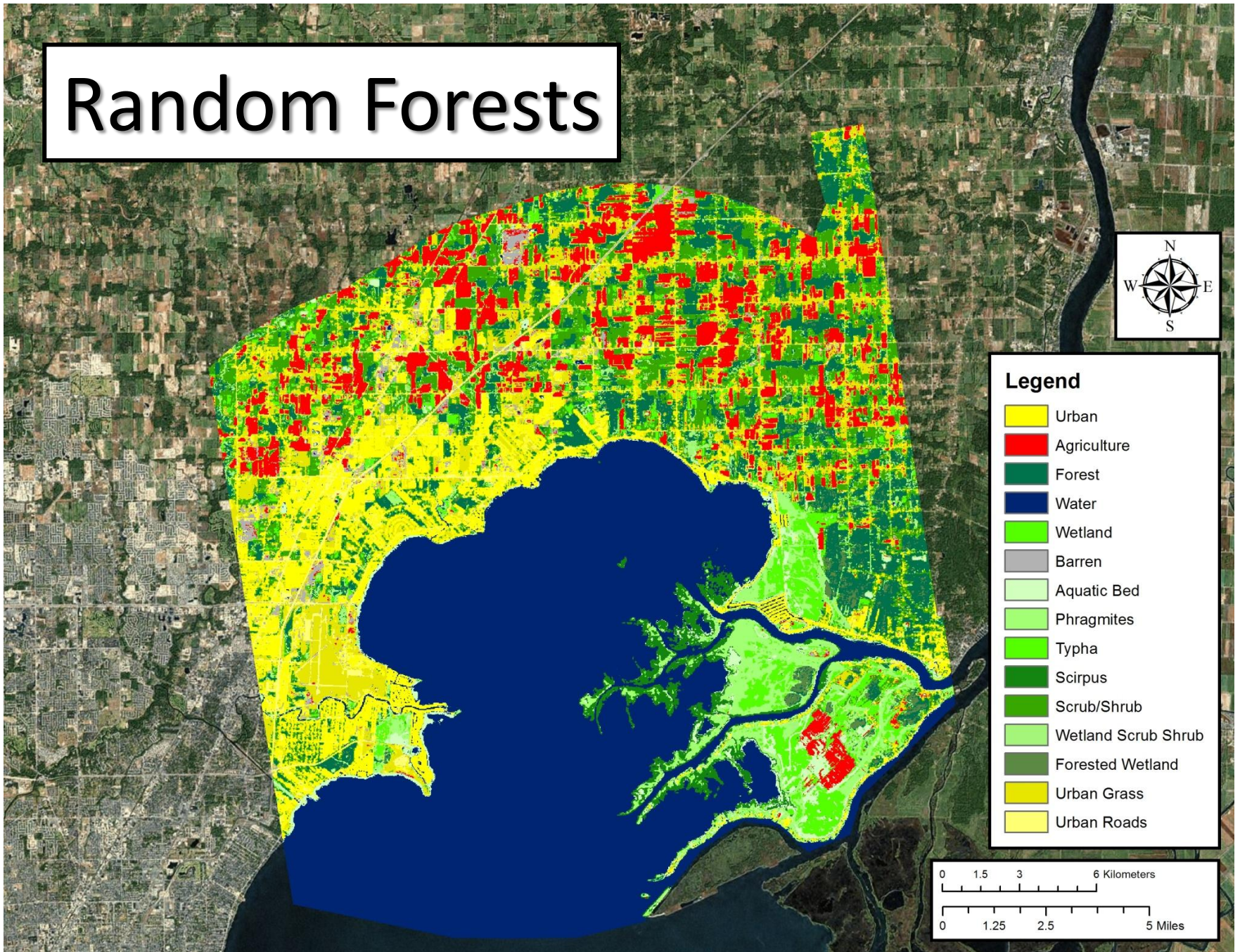
GLCWC PALSAR-Landsat Merge



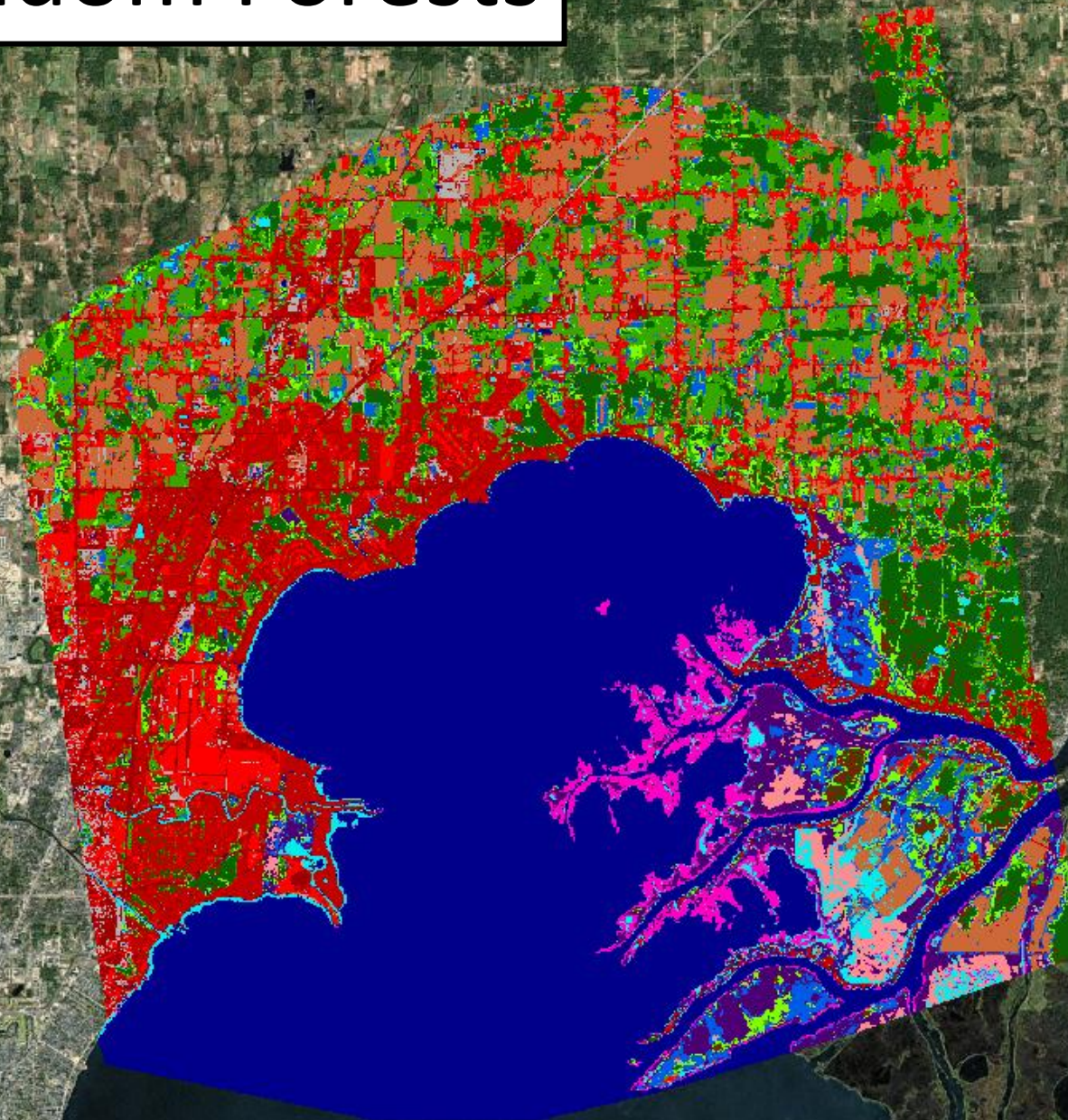
Thresholding Technique



Random Forests

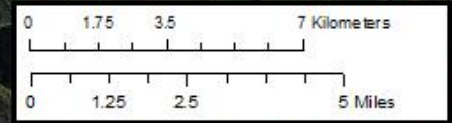


Random Forests



Legend

- Urban
- Agriculture
- Forest
- Water
- Wetland
- Barren
- Aquatic Bed
- Phragmites
- Typha
- Scirpus
- Scrub/Shrub
- Wetland Scrub/Shrub
- Forested Wetland
- Urban Grass
- Urban Roads



Preliminary

Confusion Matrix: St. Clair

Overall Accuracy = 91%

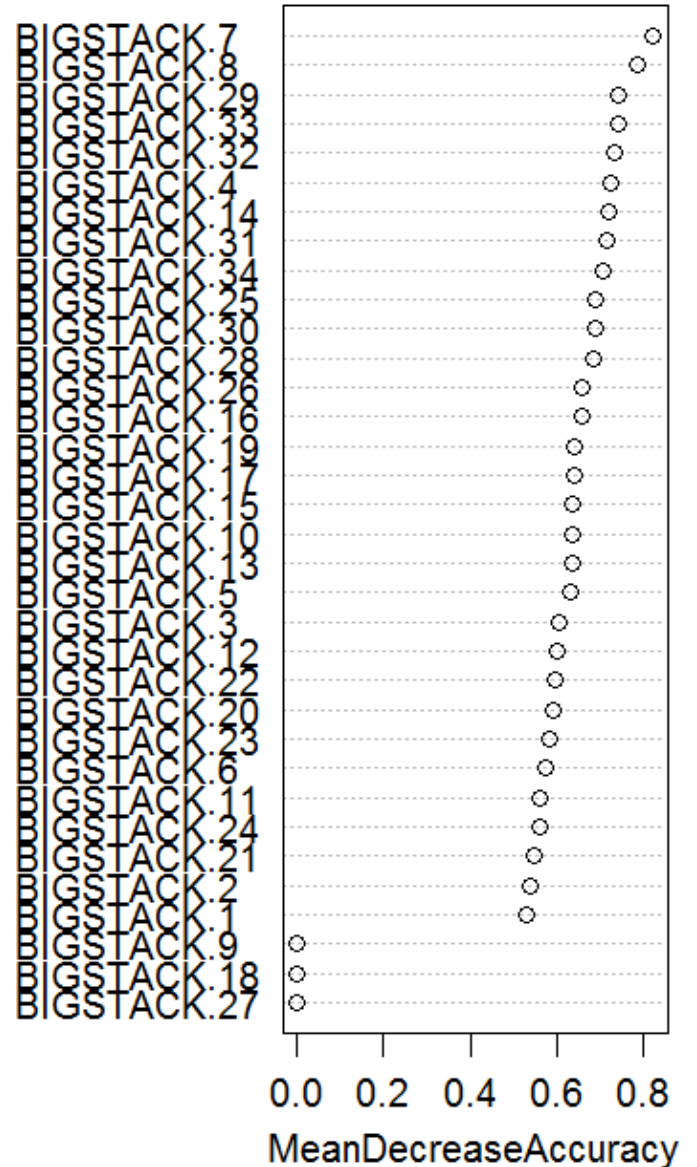
Kappa Coefficient = 0.89

Classified	Ground Truth Values														Sum	Comm- ission	User Acc.
	Urban	Ag	Forest	Water	Wet- land	Barren	Aqua Bed	Phrag	Typha	Scirpus	Shrub	Wet Scrub	Forest wet				
Urban	15901	27	10	35	0	203	2	11	0	0	32	15	0	16236	2.1%	98%	
Ag	202	18977	0	0	0	122	2	0	0	0	271	0	0	19574	3.1%	97%	
Forest	0	0	20878	0	0	0	0	0	0	0	125	39	616	21658	3.6%	96%	
Water	4	0	0	14570	0	0	25	0	1	3	0	0	0	14603	0.2%	100%	
Wetland	4	36	1	2	1411	0	15	108	73	0	165	132	0	1947	27.5%	72%	
Barren	551	279	0	10	0	651	9	0	0	0	0	1	0	1501	56.6%	43%	
Aqua_Bed	0	0	2	506	1	0	1386	17	192	2	0	2	0	2108	34.3%	66%	
Phrag	0	0	8	1	93	0	28	1354	34	0	8	86	0	1612	16.0%	84%	
Typha	1	0	0	0	31	0	7	1	4000	2	0	4	0	4046	1.1%	99%	
Scirpus	0	0	0	0	0	0	23	26	147	490	0	0	0	686	28.6%	71%	
Shrub	7	2	263	0	25	2	2	0	0	0	2867	370	0	3538	19.0%	81%	
Wet_Scrub	0	0	220	0	91	0	2	67	6	0	365	832	0	1583	47.4%	53%	
Forest_wet	0	0	2717	0	0	0	0	0	0	0	0	10	548	3275	83.3%	17%	
Sum	16670	19321	24099	15124	1652	2810	304	577	228	10164	4547	638	42319	92367			
Omission	5%	2%	13%	4%	15%	33%	8%	15%	10%	1%	25%	44%	53%				
Prod. Acc.	95%	98%	87%	96%	85%	67%	92%	85%	90%	99%	75%	56%	47%				

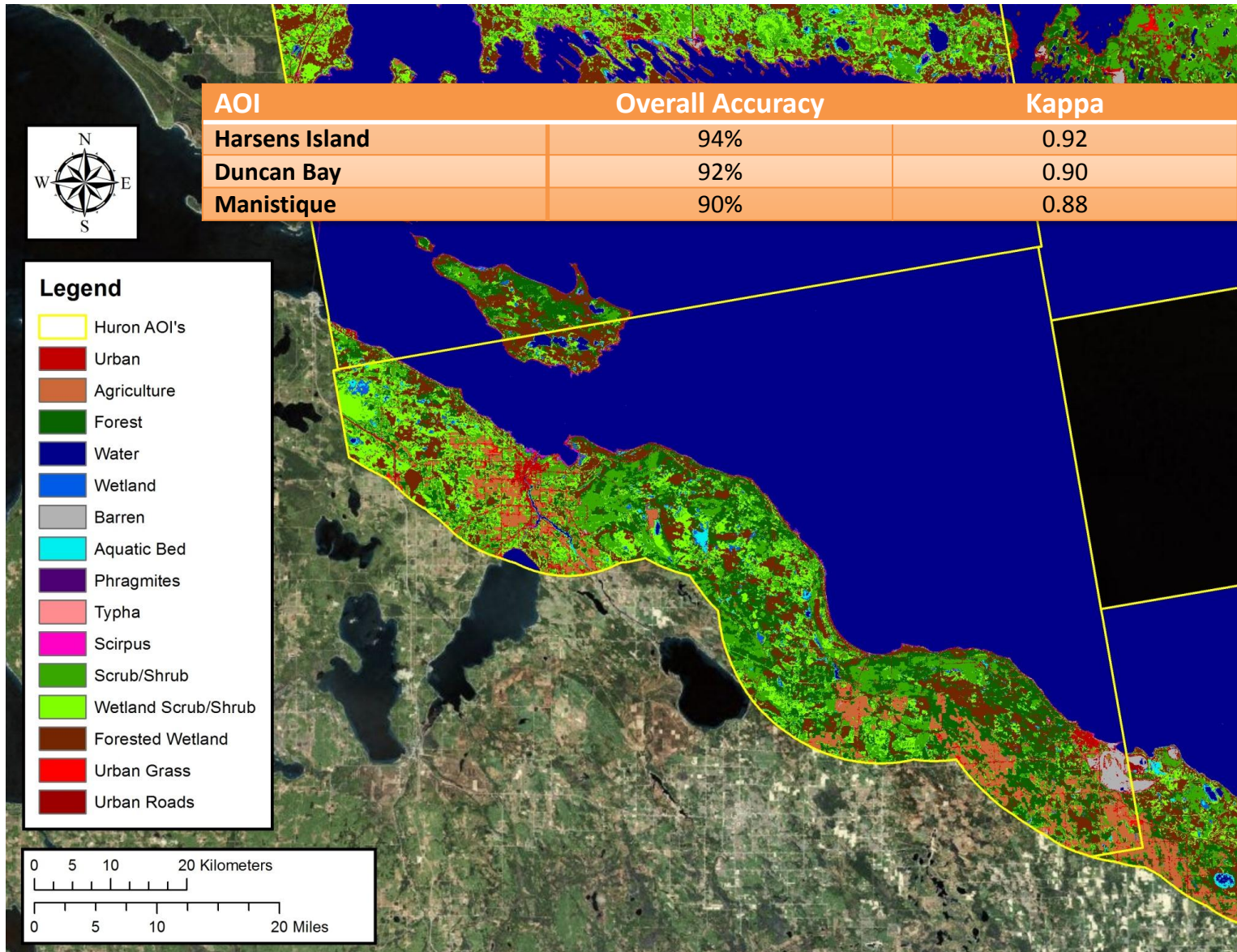
Bands for Random Forest -> BIGSTACK

- 1 Layer (Band 1 TOA ref (0.485) Spring:Landsat 5.dat)
- 2 Layer (Band 2 TOA ref (0.560) Spring:Landsat 5.dat)
- 3 Layer (Band 3 TOA ref (0.660) Spring:Landsat 5.dat)
- 4 Layer (Band 4 TOA ref (0.830) Spring:Landsat 5.dat)
- 5 Layer (Band 5 TOA ref (1.650) Spring:Landsat 5.dat)
- 6 Layer (Band 7 TOA ref (2.220) Spring:Landsat 5.dat)
- 7 Layer (NDVI Spring:Landsat 5.dat)
- 8 Layer (Band 6 (11.45) TOA temp (C) Spring:Landsat 5.dat)
- 9 Layer (YYJJ YY-year JJJ -Julian day Spring:Landsat 5.dat)
- 10 Layer (Band 1 TOA ref (0.485) Summer:Landsat 5.dat)
- 11 Layer (Band 2 TOA ref (0.560) Summer:Landsat 5.dat)
- 12 Layer (Band 3 TOA ref (0.660) Summer:Landsat 5.dat)
- 13 Layer (Band 4 TOA ref (0.830) Summer:Landsat 5.dat)
- 14 Layer (Band 5 TOA ref (1.650) Summer:Landsat 5.dat)
- 15 Layer (Band 7 TOA ref (2.220) Summer:Landsat 5.dat)
- 16 Layer (NDVI Band 6 (11.45) Summer:Landsat 5.dat)
- 17 Layer (TOA temp (C) Summer:Landsat 5.dat)
- 18 Layer (YYJJ YY-year JJJ -Julian day Summer:Landsat 5.dat)
- 19 Layer (Band 1 TOA ref (0.485) Fall:Landsat 5.dat)
- 20 Layer (Band 2 TOA ref (0.560) Fall:Landsat 5.dat)
- 21 Layer (Band 3 TOA ref (0.660) Fall:Landsat 5.dat)
- 22 Layer (Band 4 TOA ref (0.830) Fall:Landsat 5.dat)
- 23 Layer (Band 5 TOA ref (1.650) Fall:Landsat 5.dat)
- 24 Layer (Band 7 TOA ref (2.220) Fall:Landsat 5.dat)
- 25 Layer (NDVI Fall:Landsat 5.dat)
- 26 Layer (Band 6 (11.45) TOA temp (C) Fall:Landsat 5.dat)
- 27 Layer (YYJJ YY-year JJJ -Julian day Fall:Landsat 5.dat)

Band Importance

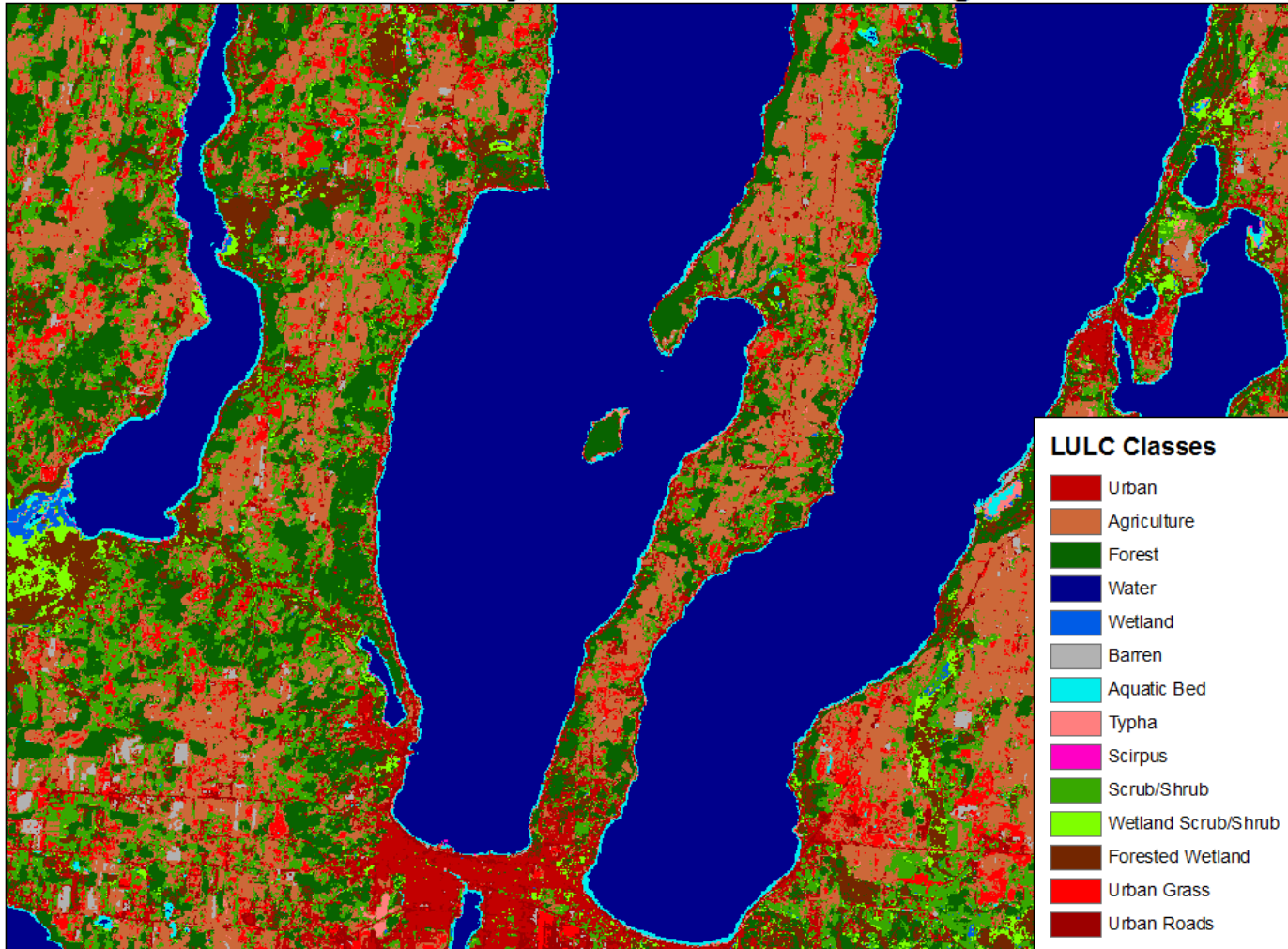


Duncan Bay Preliminary Results



LULC Map

Traverse City, MI Classified RF Image



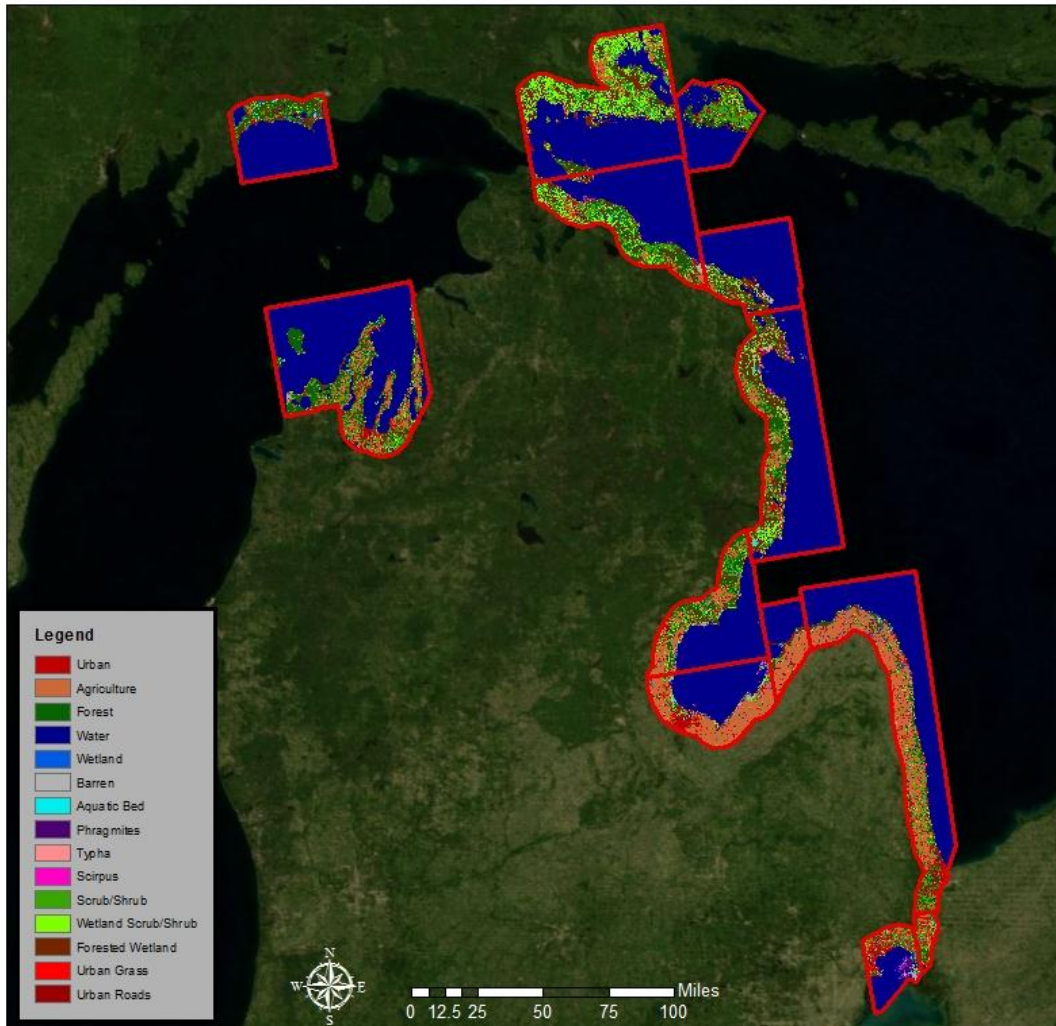
Accuracy:

Confusion Matrix of Traverse City

Overall Accuracy = 97%
Kappa Coefficient = 0.95

Classified	Ground Truth Values															Sum	Comm- ission	User Acc.
	Urban	Ag	Forest	Water	Wetland	Barren	Aquatic Bed	Typha	Scirpus	Shrub	Wet shrub	Wet forest	Urban grass	Urban road				
Urban	686	10	0	0	0	26	0	0	0	11	6	0	0	114	853	20%	80%	
Ag	27	14940	17	0	0	7	2	8	1	33	0	0	150	40	15225	2%	98%	
Forest	1	1	51590	0	0	0	0	0	0	18	0	59	8	13	51690	0%	100%	
Water	0	0	0	96353	0	0	1	0	0	0	0	0	0	0	96354	0%	100%	
Wetland	0	0	0	0	957	0	3	6	0	6	11	0	0	0	983	3%	97%	
Barren	0	200	0	25	0	1713	0	0	0	0	14	0	0	2	1954	12%	88%	
Aqua_Bed	0	0	0	42	2	2	594	10	3	0	0	0	0	0	653	9%	91%	
typha	0	30	0	0	831	0	63	192	4	0	7	0	0	16	1143	83%	17%	
Scirpus	0	0	0	0	0	0	0	2	50	0	0	0	0	0	52	4%	96%	
Shrub	24	573	56	0	0	4	3	4	0	3391	4	0	15	40	4114	18%	82%	
Wet shrub	0	0	134	0	8	0	31	10	0	317	1116	31	0	13	1660	33%	67%	
Wet forest	0	0	1150	0	0	0	1	0	0	0	48	961	0	2	2162	56%	44%	
Urban grass	0	289	0	0	0	0	0	0	0	0	0	0	283	51	623	55%	45%	
Urban road	7	0	0	0	0	16	0	0	0	0	0	0	0	1295	1318	2%	98%	
Sum	745	16043	52947	96420	1798	1768	698	232	58	3776	1206	1051	456	1586	178784			
Omission	8%	7%	3%	0%	47%	3%	15%	17%	14%	10%	7%	9%	38%	18%				
Prod. Acc.	92%	93%	97%	100%	53%	97%	85%	83%	86%	90%	93%	91%	62%	82%				

Preliminary Mapping Status



- Priority
 - Lake Huron
 - Lake Michigan
 - Lake Erie
 - Lake Ontario
 - Lake Superior
- Need more field data on Canadian side of Lake Huron

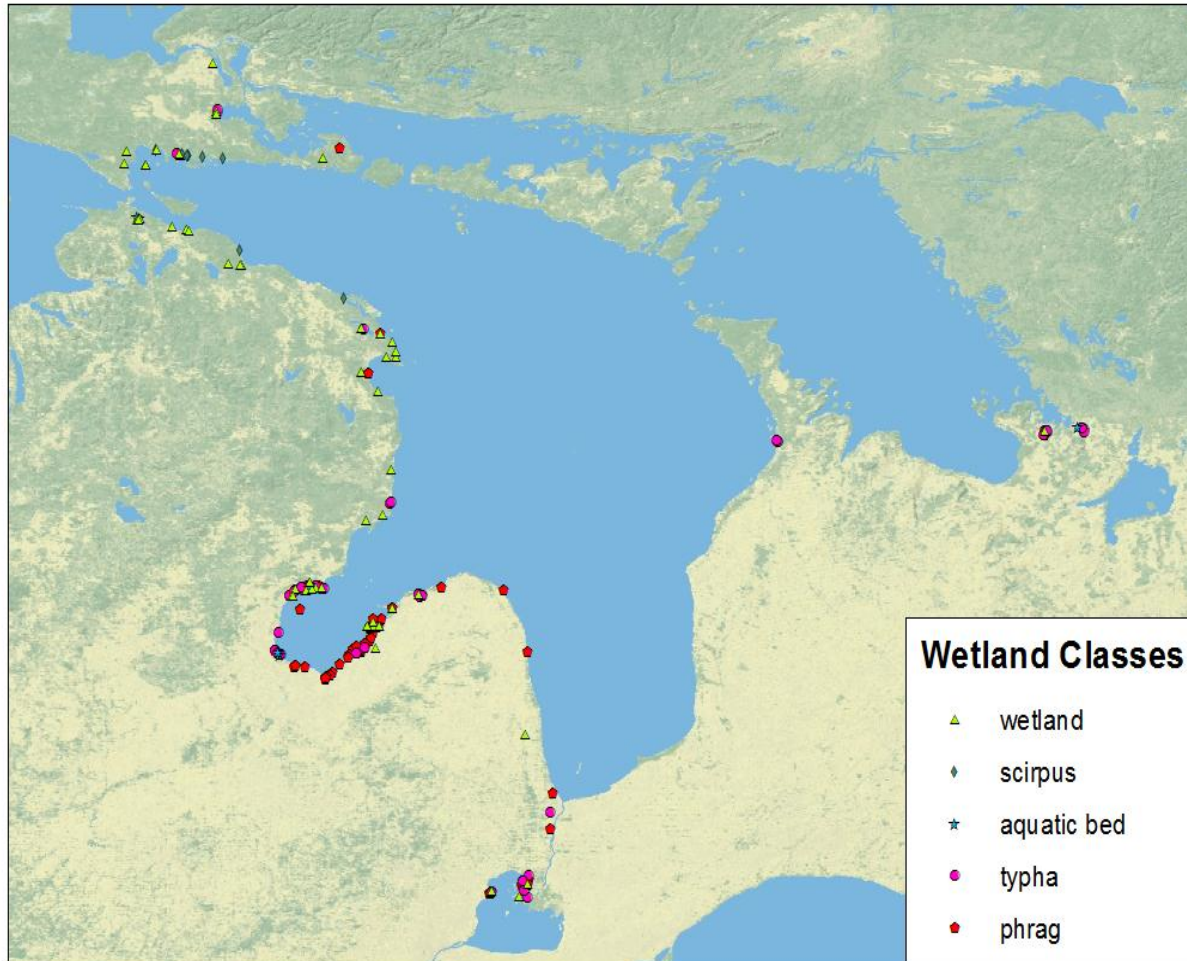


Summary & Continued Work

- Random Forests allows a semi-automated method that provides consistent results among various image interpreters
- Problem types: forested and shrubby wetlands
 - Developed methods to map forested wetlands with PALSAR, through thresholding
 - Collect field validation data/ training
 - Leaf off air photos to aid in delineation
- Field verify preliminary maps and adjust training data as necessary
- Continue work on Lakes Michigan and Huron

Current Distribution of Available Field Data for Lake Huron

2010-2011 Data Field Data Collect Coverage



Areas of Most Concern: Informed Site Selection

2012 Proposed Field Data Collect Coverage

