Mapping Natural Habitat Communities Using High Resolution NAIP Imagery Coupled with Machine Learning Approaches: Hiawatha National Forest

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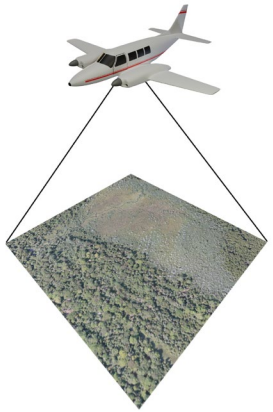

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Timeline of Projects

- **2017-2018**: Mapping Coastal Wetland on the Hiawatha National Forest Using Unmanned Aerial System (UAS) Imagery: Proof of Concept

- **2019-2021**: TNC-HNF Coastal Wetlands/Natural Habitat Communities Mapping

Both the projects were completed in the Fall of 2021

Lake of the Clouds, July, 2019. Source: Parth Bhatt

Introduction

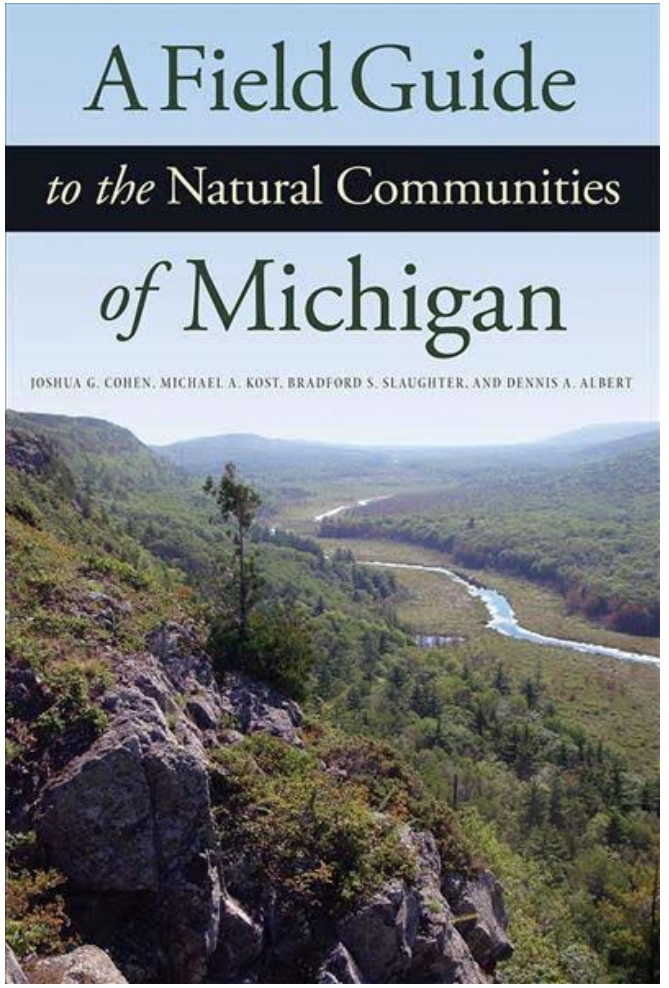
- Ecological classification schemes are critical for any classification, appropriate schemes can limit or enhance the end product's accuracy and utility
- Ecological habitats are divided in ecoregions, improves conservation and management by considering natural process and patterns of the communities
- Traditional approaches: field sampled regional vegetation classes, ecological units, land use/cover maps
- Fine scale mapping is critical to locate and map endangered habitats particularly with escalating global climate change impacts

Purpose

- Map coastal wetlands and adjacent areas for the U.S. Forest Service using the "**Natural Communities of Michigan: Classification and Description**". Published by the Michigan Natural Features Inventory (MNFI).

- Use this detailed information to divide a complex landscape into easily understood and describable components labeled as natural communities.

- Focus on diversity of native ecosystems unchanged by human activities Natural communities classification depends on data collected in the field, expert image interpretation skills and use of accepted classification schemes

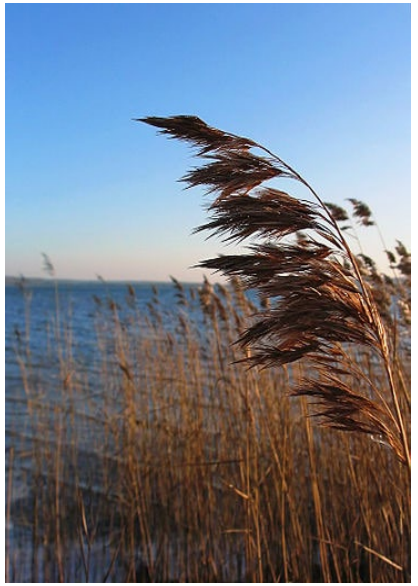


Cohen, Joshua G., Michael A. Kost, Bradford S. Slaughter, and Dennis A. Albert. *A field guide to the natural communities of Michigan*. Michigan State University Press, 2014.

Need For The Study

- Coastal wetlands and vegetation communities are under constant pressure from climate change, changes in land use/land cover, unsustainable agriculture practices, and the spread of invasive species
- Increasing need to delineate and map natural habitat communities health and vegetation changes (Husson et al., 2016), (Adam et al., 2009).

- Current Threats to Great Lakes Shoreline Natural Communities Include:
  - Invasion and expansion of non-native species such as phragmites (*Phragmites australis* subsp. *australis*)
  - Unauthorized off-road vehicle use
  - Potential hazmat contaminants such as fuel and chemical spills
  - Impaired hydrologic function due to poorly designed or degraded roads and ORV trails



Phragmites australis australis (Cav.) Trin. ex Steud. Common Name: Common reed. Source: GLANSIS

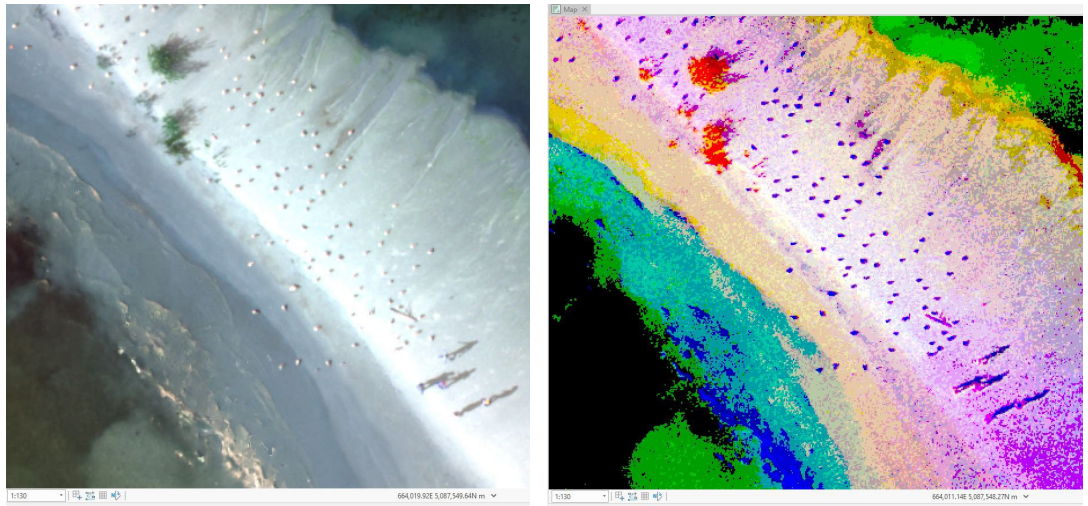
Key Questions

- What biogeophysical variables are critical to accurately classify complex Laurentian Mixed Forest natural habitat communities?

- Which machine learning-based algorithms (Random Forest, SVM) perform better for classifying complex natural habitat communities? How well do they perform compared to traditional classification approaches?

- How critical are high spatial resolution raster datasets to correctly classify complex wetlands and vegetation communities of Laurentian Mixed Forest (NAIP (60 cm) vs UAS (8 cm) imagery)?

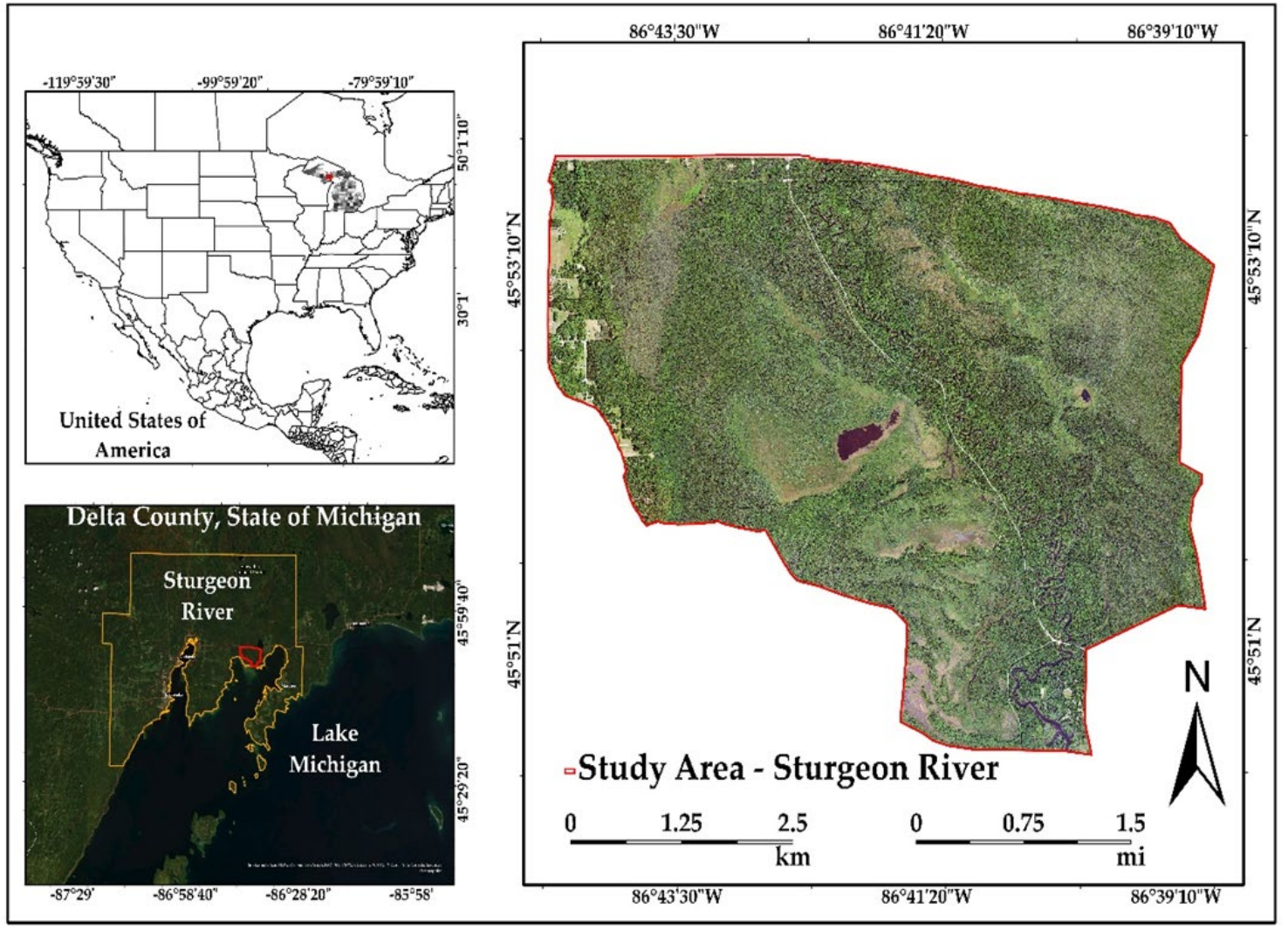
Aerial view of Pointe aux Chenes Bay. July, 2019. Google Earth Pro.



Counting seagulls and people on the beach over Pointe aux Chenes Bay. High-resolution UX5-AG, Micasense Imagery August, 2019.

Study area

- Sturgeon River Delta – Wester half of HNF
- 3,151 ha (7,7861 ac)
- Ecologically diverse natural habitat communities, pristine wetlands with complex hydrology



Source: Bhatt et. al., 2022

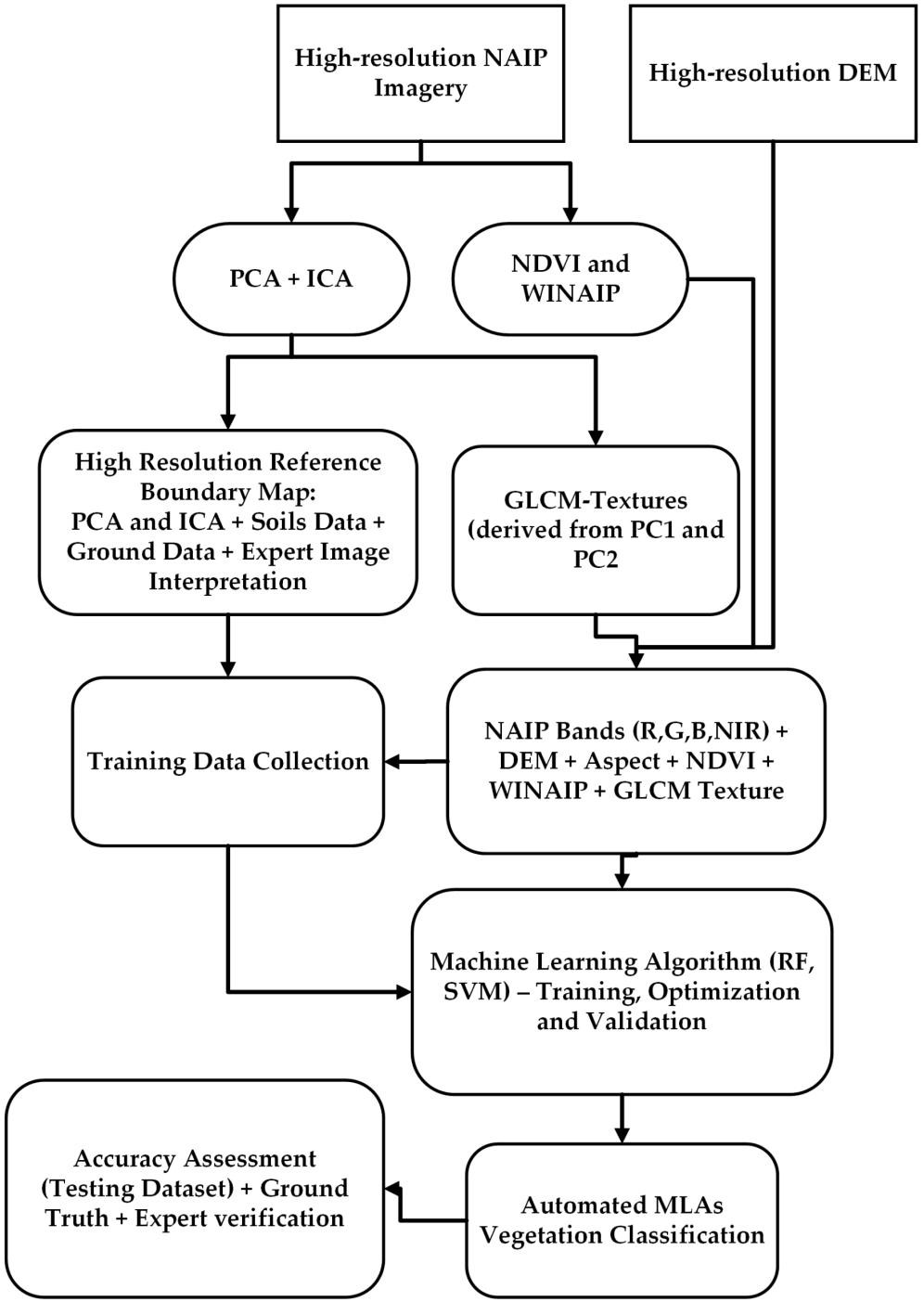
Datasets and Methods

- **NAIP** (National Agriculture Imagery Program) – July to August 2018
  - NAIP – Leaf on imagery, consists 4 bands (R,G,B, NIR) – 0.60 cm spatial resolution
  - Projects are contracted each year based on funding and FSA imagery acquisition cycle (2-3 years) (USDA, 2020)
- **DEM** – 1m LiDAR
- **Software**
  - R Studio
  - ERDAS IMAGINE 2020
  - ArcPro 2.6
  - ENVI 5.6

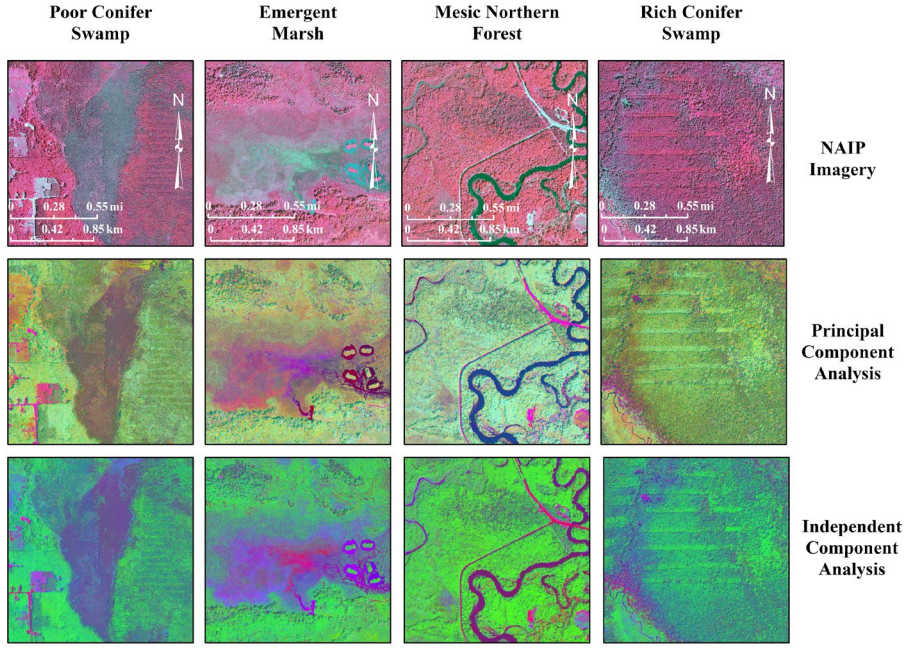
NAIP vs UAS Imagery comparison over Sturgeon River Delta, showing different vegetation community types.

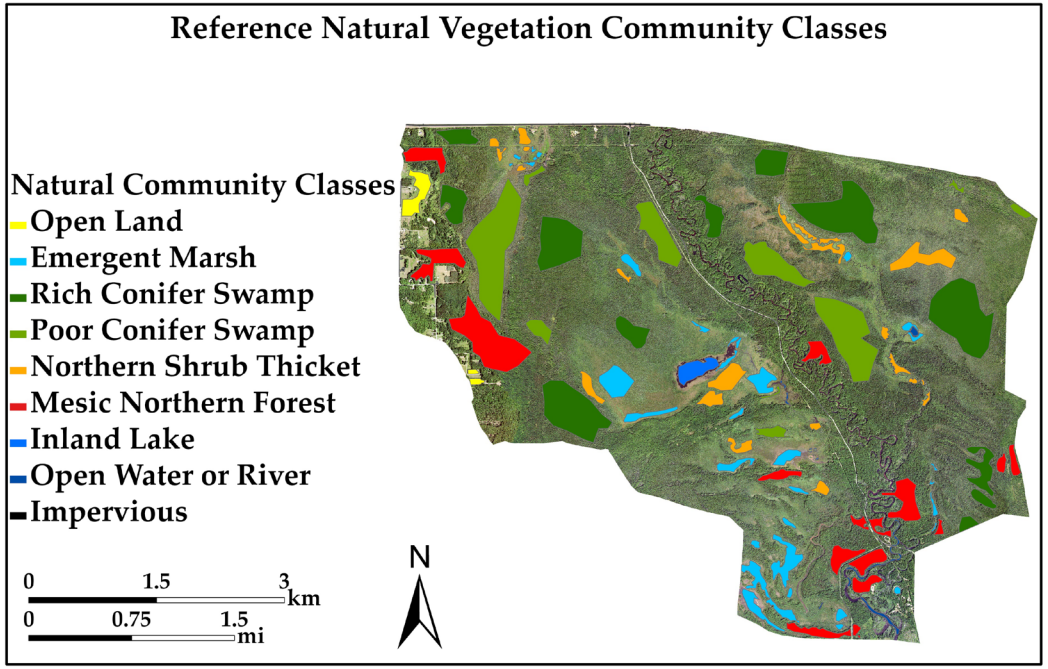
Methods

Workflow for the natural habitat classification.

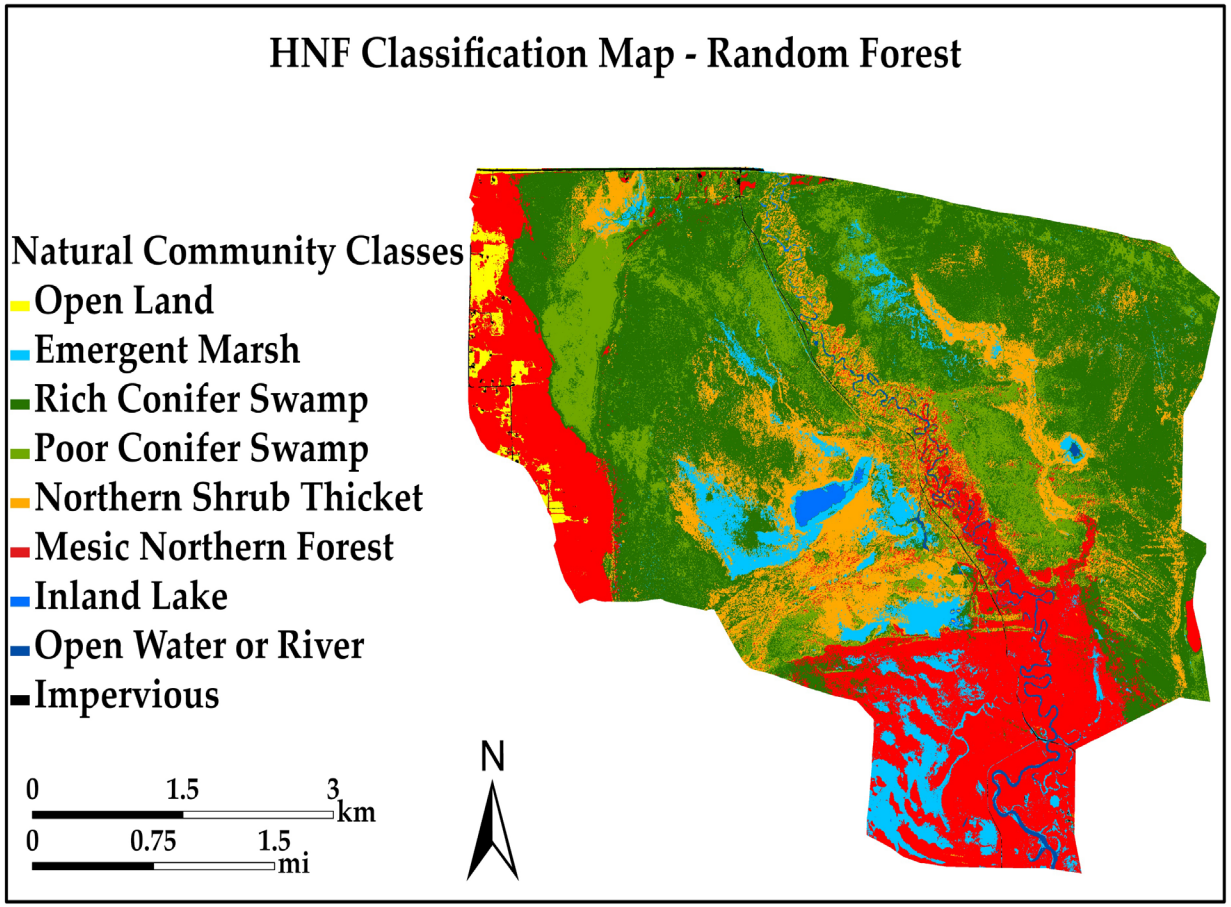


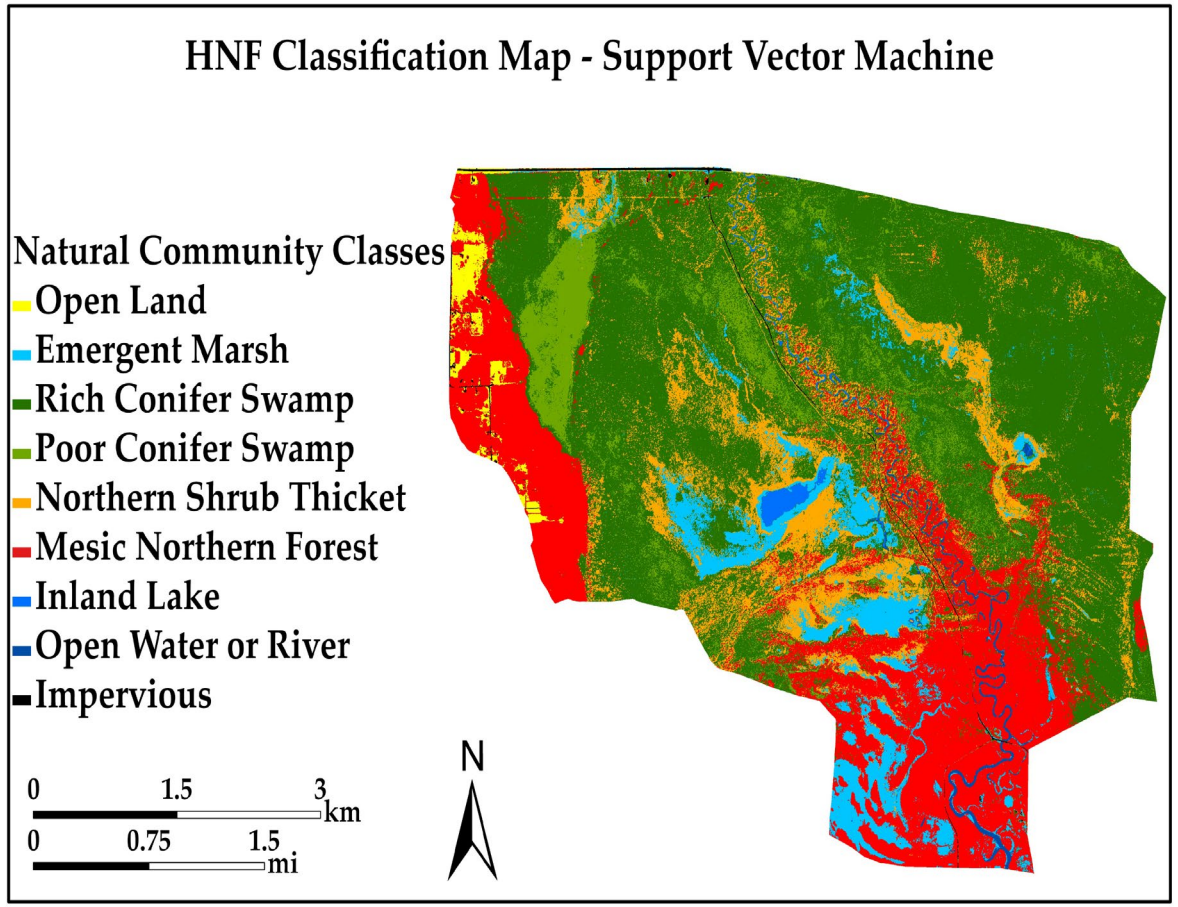
- DEM data pre-process
- Image enhancement using PCA and ICA
- Use of site knowledge and ground data to draw accurate natural communities class boundaries
- Training data - Use class boundaries to generate random points by class
- Generate Vegetation Indices NAIP Imagery (NDVI, NAIP-WI)
  - Highlighted different wetland and vegetation classes
  - Standing water bodies (rivers, lakes, ponds)
- Generate GLCM-Texture layers using PCA1 and PCA2 components (Contrast, Entropy, Standard Deviation)
  - It uses a 2nd order metrics to analyze relationship
  - Looks at spatial structure of forested wetland vegetation and forest classes along with water and Impervious surfaces
- Machine Learning algorithms – Random Forest and Support Vector Machine
- Training data accuracy and validation
- Download and pre-process NAIP Imagery by watershed boundaries





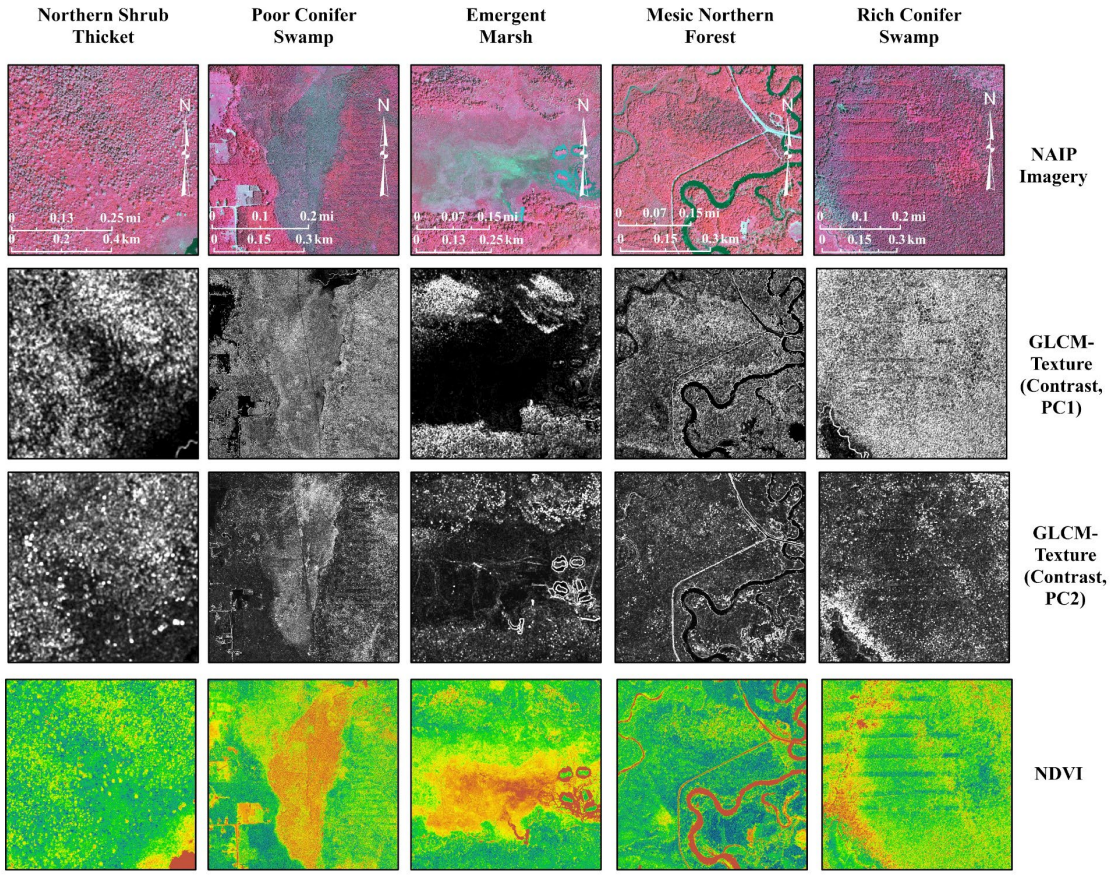
Results

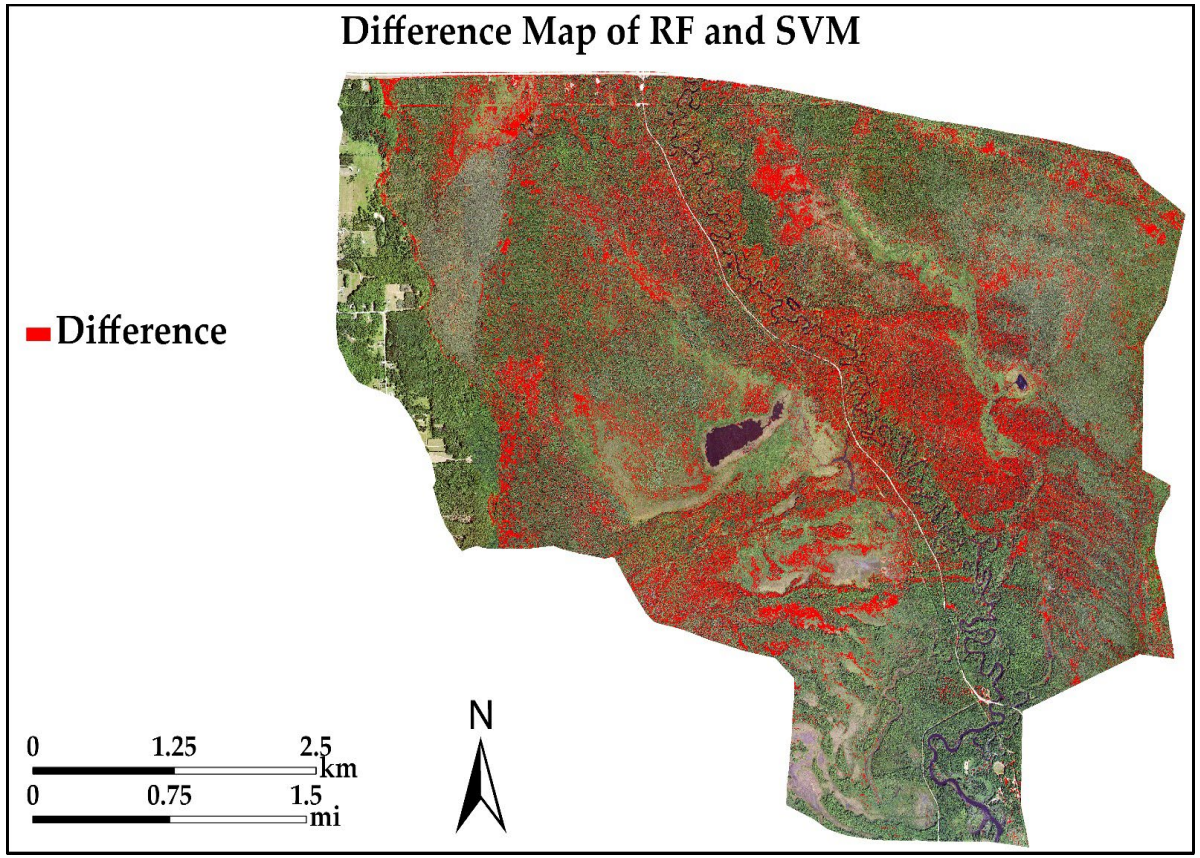




OA of **79.45%** and k of **0.75** with RF and OA of **75%** and k of **0.70** with SVM

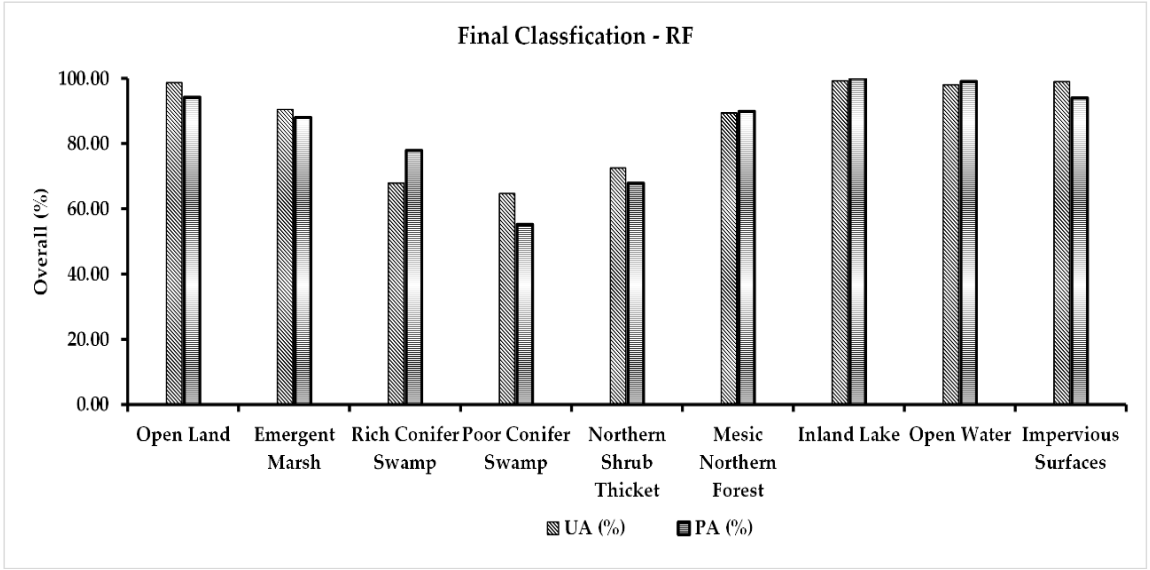
Difference Between the Two Classifiers

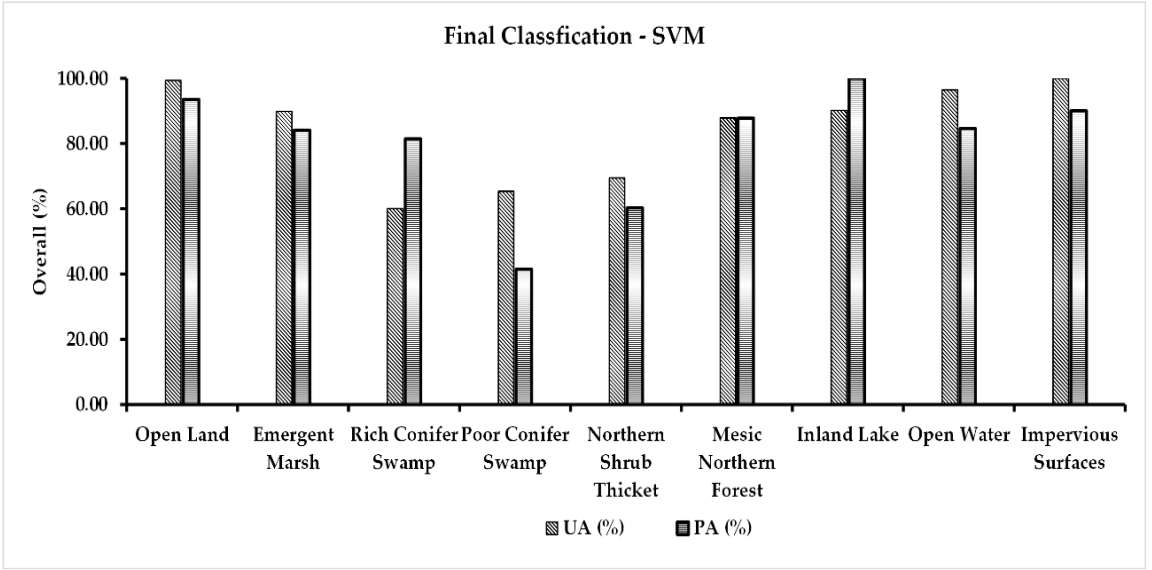




Source: Bhatt et. al., 2022

User's and Producer's Accuracy

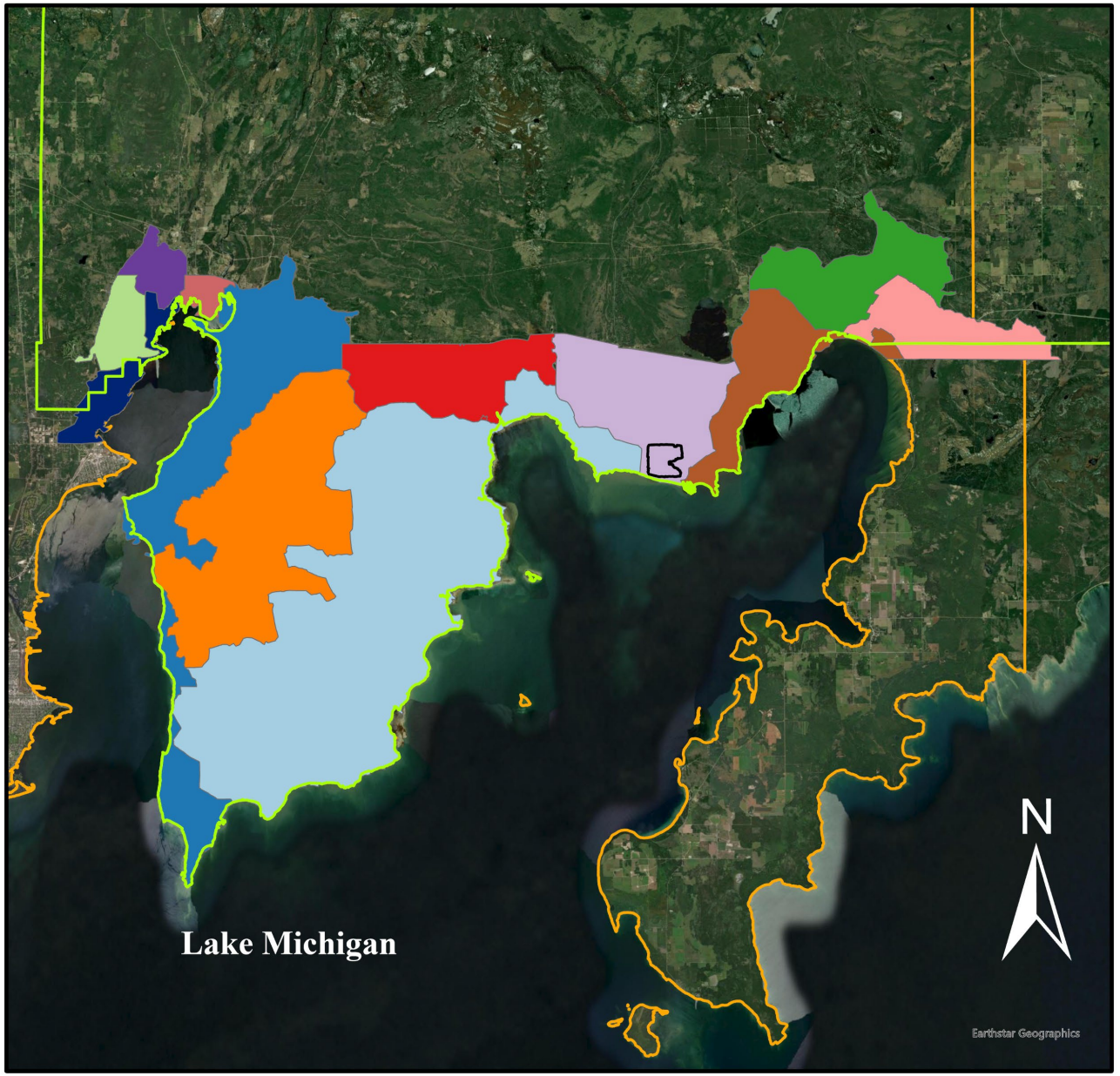




- Major confusion was observed between Rich Conifer Swamp, Poor Conifer Swamp and Northern Shrub Thicket
- Close spectral similarities, poor spectral resolution of NAIP
- **UA – 64 to 99%, PA – 55 to 100%** with **Random Forest**
- UA – 60 to 99%, PA – 41 to 100% with Support Vector Machine

Source: Bhatt et. al., 2022

12 Watersheds Area - 457 km^2



Hiawatha National Forest West Unit Watershed Boundaries

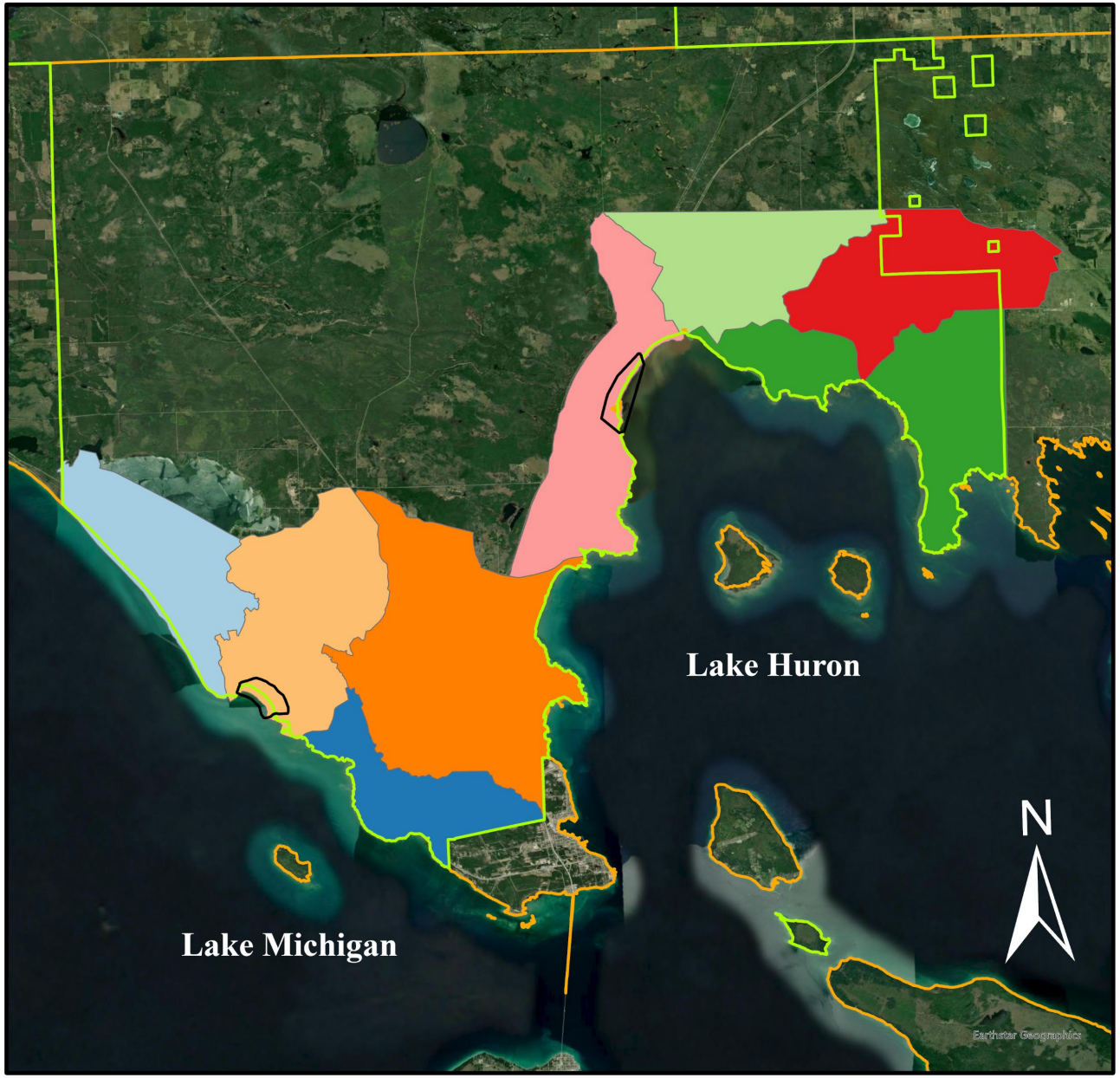
- Delta County
- HNF Forest Boundary
- Sturgeon River Delta Watershed Name
- Big River
- Black George Creek
- Days River
- Fishdam River
- Little Fishdam River
- Ogontz River
- Portage Creek
- Squaw Creek
- Sturgeon River
- Tacoosh River
- Town of Rapid River
- Valentine Creek

0 3 6 12 18 km

0 2 4 8 12 mi

Author: Parth Bhatt
Coordinate System: NAD 1983 UTM Zone 16N
Data Source: Michigan GIS Open Data, USFS, ESRI World Imagery

8 Watersheds
Area - 342 km^2



Hiawatha National Forest East Unit Watershed Boundaries

- Mackinac County
- Pointe aux Chenes Bay
- Carp River Mouth
- HNF Forest Boundary

Watershed Name

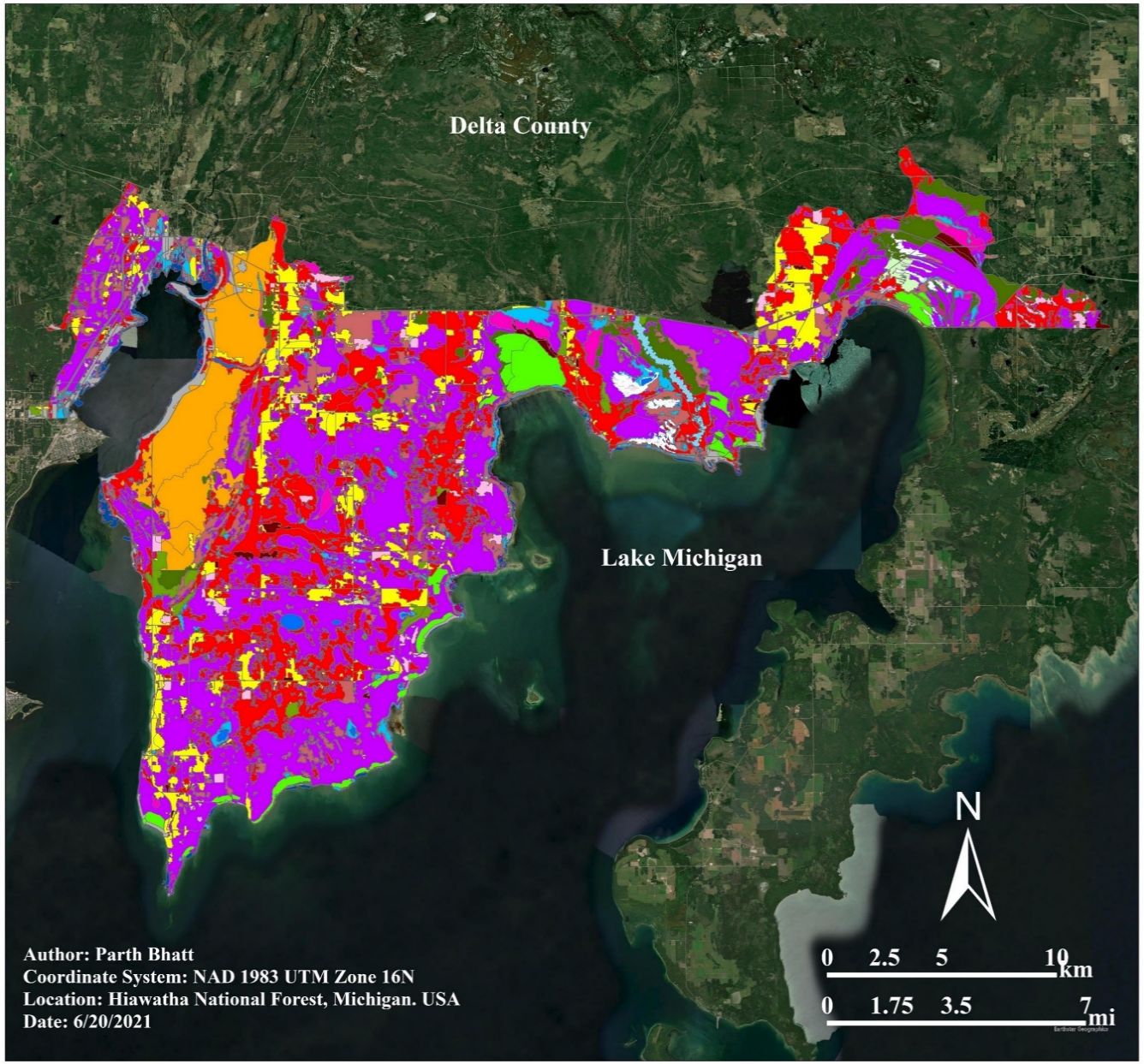
- Bervoort River
- Cut River
- Garden Hill Creek
- Law Creek
- Martineau Creek
- Nunns Creek
- Point Aux Chenes River
- Rabbit Back Creek

0 2.5 5 10 15 km

0 1.75 3.5 7 10.5 mi

Author: Parth Bhatt
Coordinate System: NAD 1983 UTM Zone 16N
Data Source: Michigan GIS Open Data, USFS, ESRI World Imagery

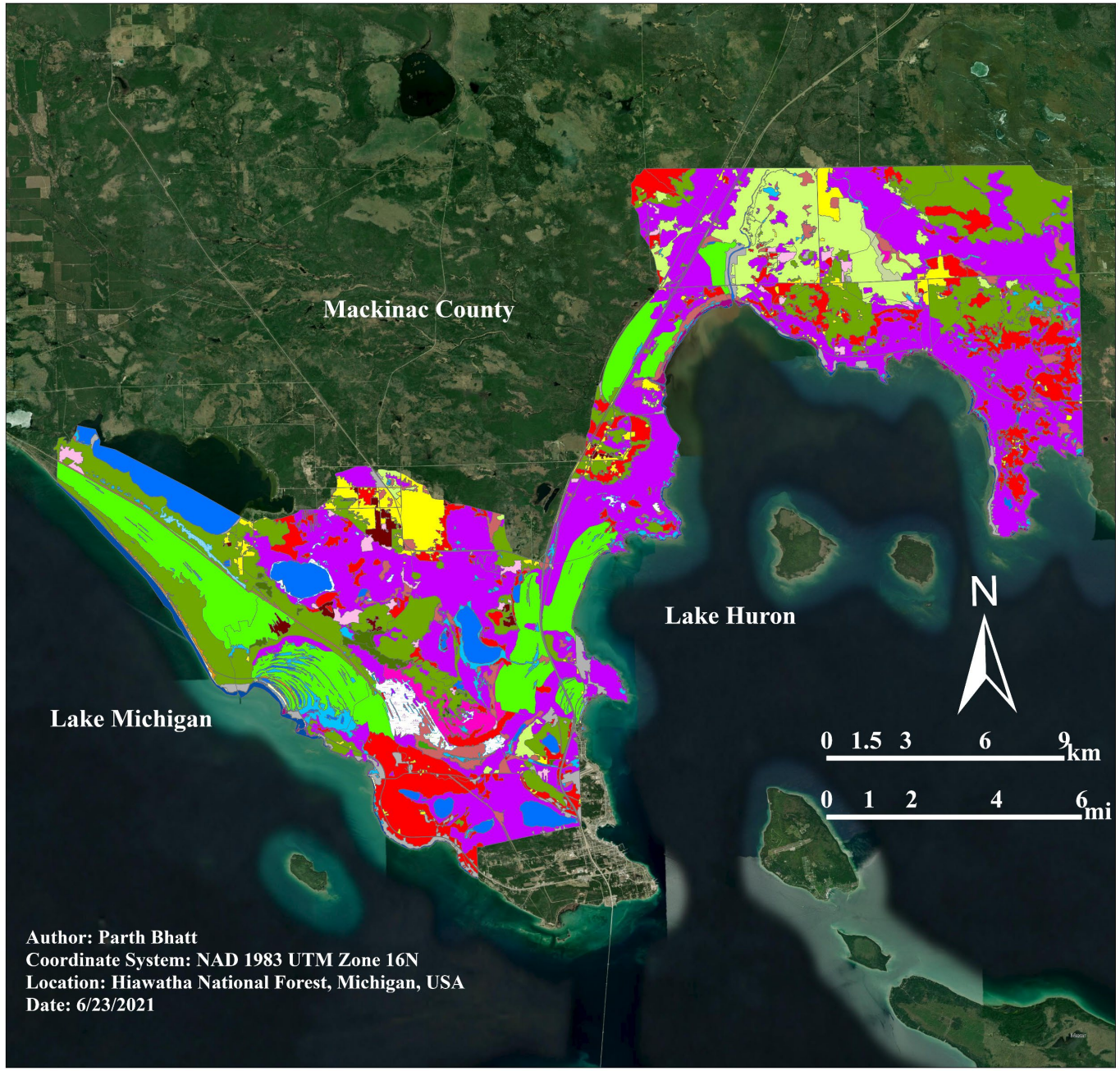
West unit: Overall accuracies (OAs) - **77 to 92%**, with kappa (k) between **0.72 to 0.90%** for 31 classes



Hiawatha National Forest West Unit MNFI Classification Map

Habitat_Classification
- Logged
- Bog
- Boreal Forest
- Developed & Impervious Surfaces
- Dry-Mesic Northern Forest
- Emergent Marsh
- Emergent Marsh, Potential Northern Fen
- Emergent Marsh, Potential Poor Fen
- Floodplain Forest
- Great Lakes Marsh
- Hardwood-Conifer Swamp
- Inland Lake or River
- Interdunal Wetlands
- Lake Michigan
- Limestone Bedrock Glade
- Logged
- Major Roads ROW
- Mesic Northern Forest
- Northern Fen
- Northern Shrub Thicket
- Northern Wet Meadow
- Open Land
- Pine Barrens
- Poor Conifer Swamp
- Poor Fen
- Railroad ROW
- Rich Conifer Swamp
- Rich Tamarack Swamp
- Sand & Gravel Beach
- Upland Pine Plantation
- Wooded Dune & Swale Complex

East unit - OAs between **71 to 93%,** with k between **0.62 to 0.91%** with 31 classes



Hiawatha National Forest East Unit MNFI Classification Map

Habitat Classification

- Aspen-Poorly Drained
- Bog
- Developed & Impervious Surfaces
- Dry-Mesic Northern Forest
- Emergent Marsh
- Emergent Marsh, Potential Northern Fen
- Floodplain Forest
- Great Lakes Marsh
- Hardwood-Conifer Swamp
- Inland Lake
- Inland Lake or River
- Interdunal Wetlands
- Lake Huron
- Lake Michigan
- Logged
- Major Roads ROW
- Mesic Northern Forest
- Northern Fen
- Northern Hardwood Swamp
- Northern Shrub Thicket
- Open Dunes
- Open Land
- Open Water
- Patterned Fen
- Poor Conifer Swamp
- Poor Fen
- Rich Conifer Swamp
- Rich Tamarack Swamp
- Sand & Gravel Beach
- Upland Pine Plantation
- Wooded Dune & Swale Complex

Post classification processing

Images were post-processed in ERDAS IMAGINE and ArcPro

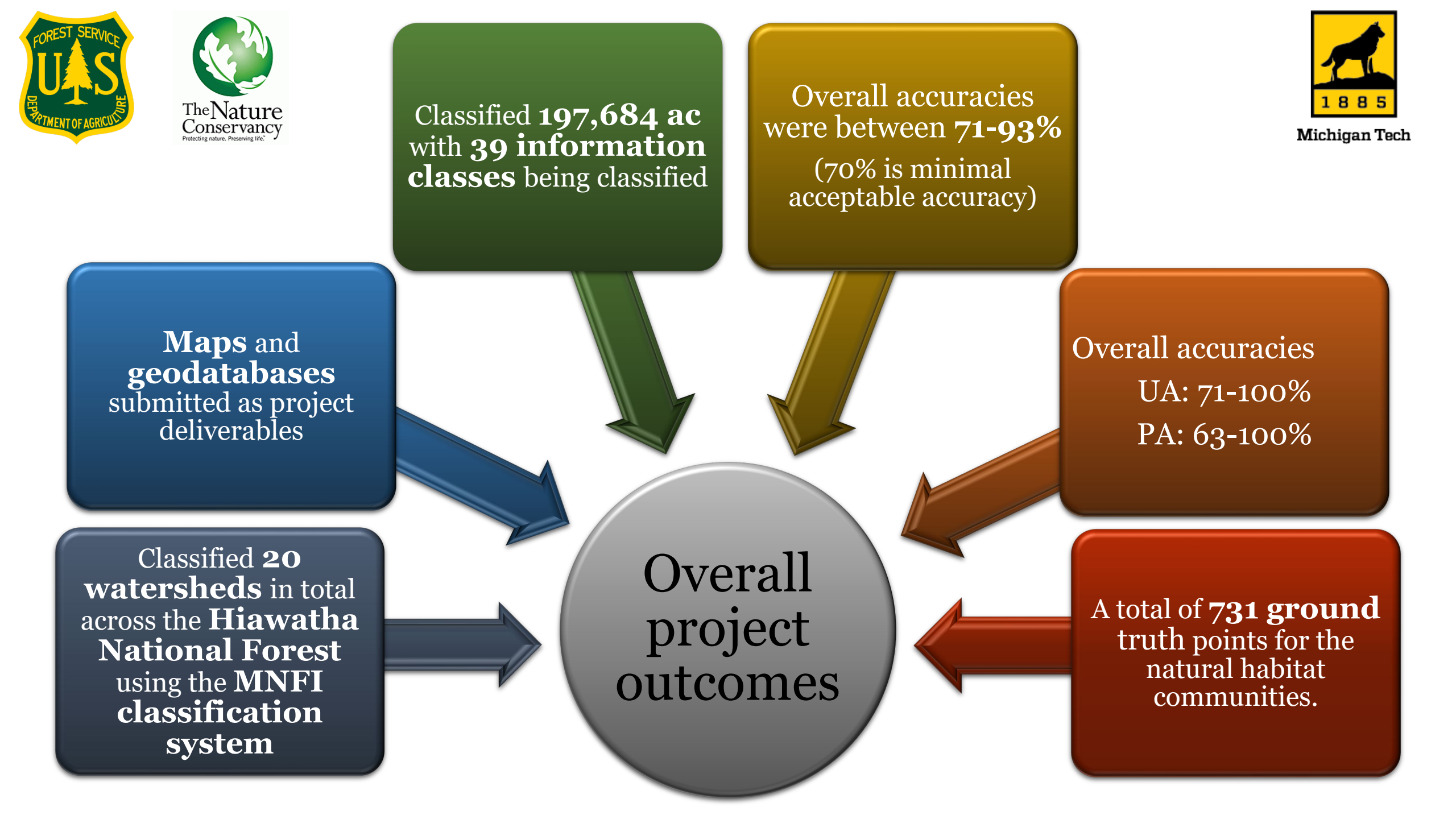
Smoothing the classified imagery twice in order to remove any salt and pepper effect present using “Majority” function and a 7×7 scanning window in the “Neighborhood” function

We eliminated any clumps less than 1 acres of size as per the HNF management instructions

The process was performed with an Intel (R) Xenon (R) 4114 CPU 2×2.2 GHz, using a 64-bit Microsoft Windows 10 operating system with 128 GB of RAM computer.

The total processing time (including downloading the data, training data collection, pre-processing, classification in R, and post-processing) took about ten months in total.

In total **800 sq. kms (197,536 ac) of the HNF** was classified including the West and the East unit.


Classified 197,684 ac with 39 information classes being classified
Overall accuracies were between 71-93%
(70% is minimal acceptable accuracy)
Maps and geodatabases submitted as project deliverables
Overall accuracies
UA: 71-100%
PA: 63-100%
Classified 20 watersheds in total across the Hiawatha National Forest using the MNFI classification system
Overall project outcomes
A total of 731 ground truth points for the natural habitat communities.

Conclusions

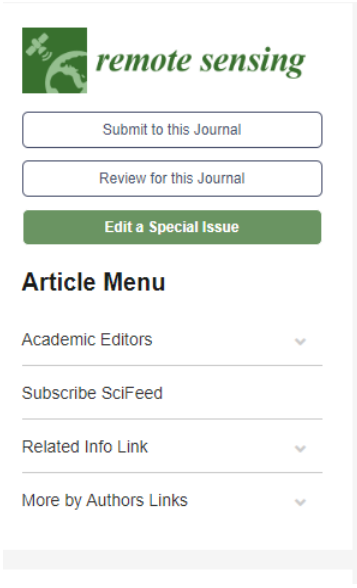
- Approach proves to be robust for classifying complex natural habitat communities
- Effective use of NAIP and UAV datasets
- Feature selection methods critical to evaluate variable importance and reducing data complexity
- Can save time and money and provide accurate classifications
- Maps are extremely useful to resource managers to manage forests in a timely and better way, monitor vegetation changes, enhance decision-making, map invasive species and phenological changes
- The choice of classifier is RF with machine-learning approaches
- Similar approach currently being applied to the Keweenaw County in MI, at present mapping 35,000 acres, goal is to map 185,000 acres in total

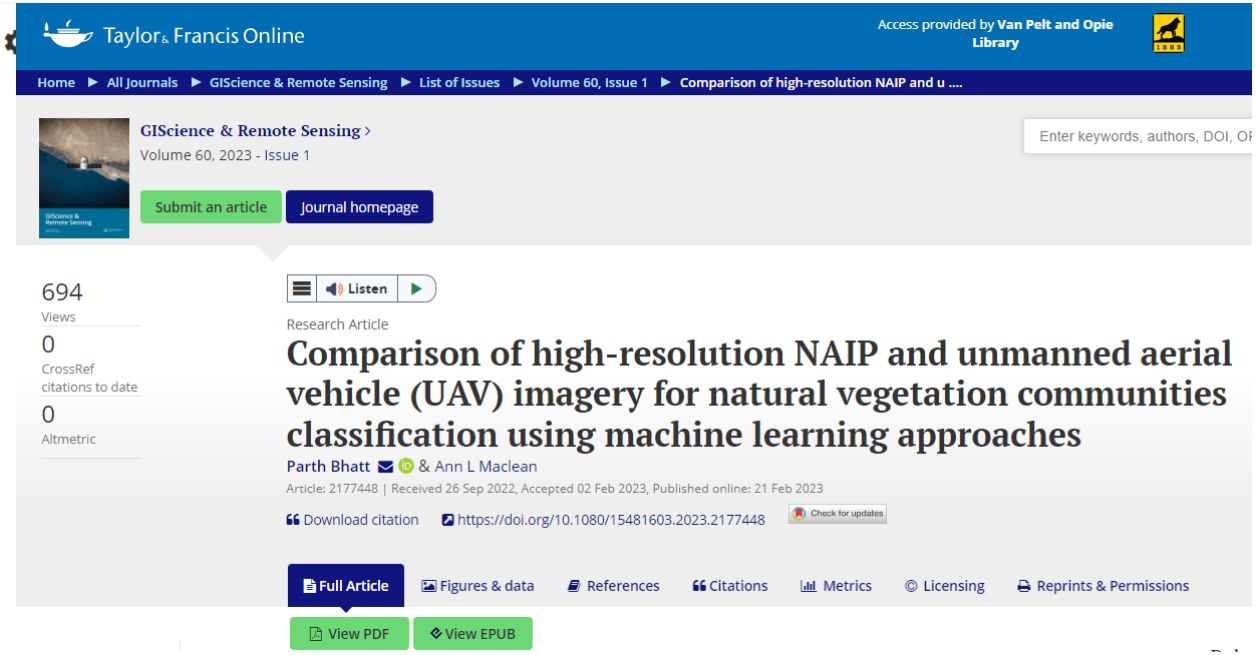
Source: ESRI, Maxar

Have a good one ☺

Image Source: Parth Bhatt

Published Works





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