Boreal Wetland Mapping: An Overview of DUC's Methods, Results and R&D

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Ducks Unlimited Canada
NATIONAL BOREAL PROGRAM

Presentation Outline

PART 1 | DUC National Boreal Program
PART 2 | Thematic Wetland Data Model
PART 3 | Reference Data Collection Methods
PART 4 | Earth Observation Data Inputs
PART 5 | Wetland Mapping Approach
PART 6 | On-Going R&D

About Us

Field Crew

1 wetland ecologists, 3 remote sensing analyst, a grey jay, and a helicopter. We have conducted over ~30 field campaigned, collected over 10K field sites, and mapped 146 million hectares!

100%

Boreal Team

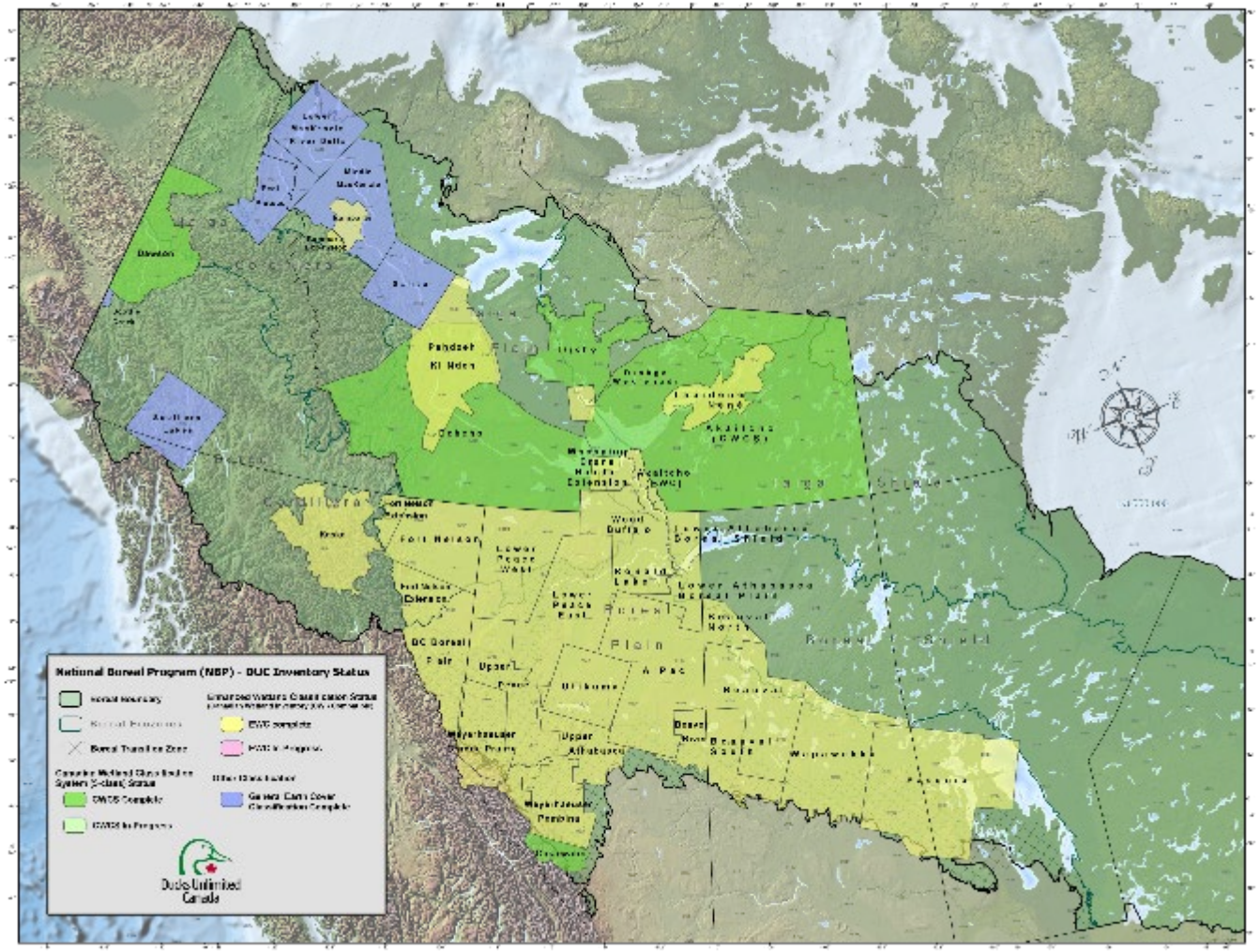
DUC National Boreal Program

Why do we need detailed and accurate wetland inventories?

If we know where wetlands are, we can protect them

Species monitoring, carbon storage, wetland policy, land use planning, IPCA

Ts'udé Niljné Tueyata, Edéhzhíe, Thaidene Nëné, Salve Taltson, Dene k'éh kusān



Thematic Data Model

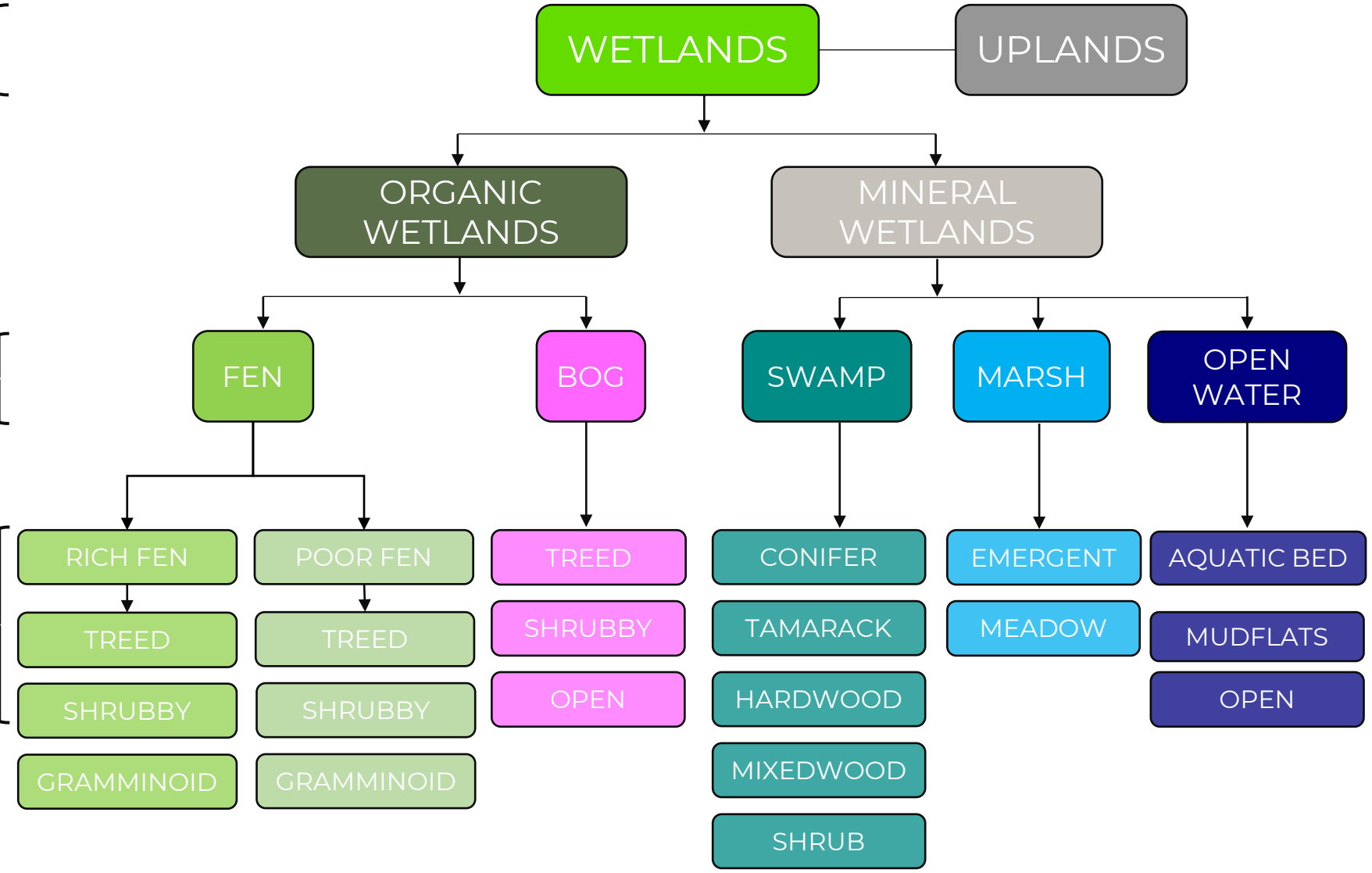
LEVEL 1 — Target Accuracy: **90%**

LEVEL 2 — Target Accuracy: **80%**

Canadian Wetland Classification System

LEVEL 3 — Target Accuracy: **70%**

Enhanced Wetland Classification



Reference Data Collection

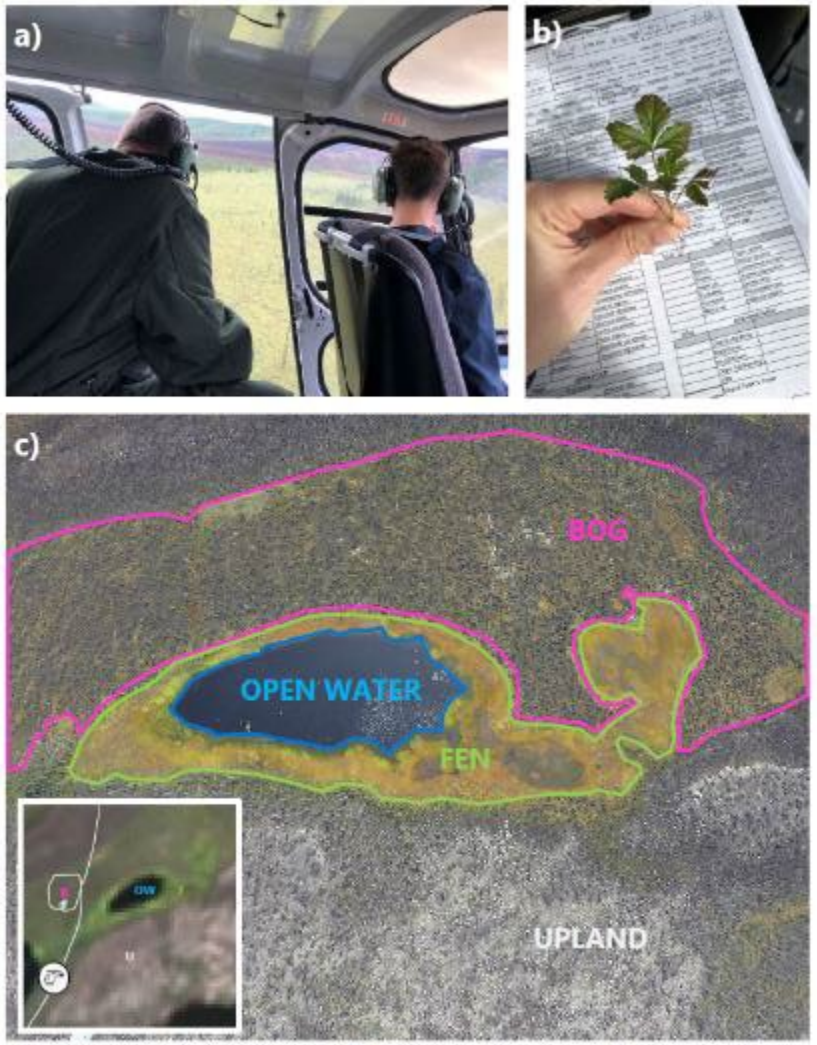


Figure 4: a) Navigator (right) and vegetation caller (left) surveying a field site, b) example of the data sheet used to record site information, and c) visual depiction of how sites are visited and assessed.

Helicopter surveys

- Wetland surveys are collected via helicopter.
- Field crews hover over pre-selected sites / polygons and survey their characteristics.
- Minimum polygon size: 1 ha.
- Information collected:
  - Vegetation species types
  - Vegetation species coverage (%)
  - Vegetation species heights (m)
  - Wetland / Upland class
  - Site photographs

Vegetation Species	Coverage (%)	Height (m)
Species A Sedge	40	< 1
Species B Litter	45	< 1
Species C Buckbean	5	< 1
Species D Peat moss	5	< 1
Species E Marsh cinquefoil	5	< 1

Field Site Example: Fen

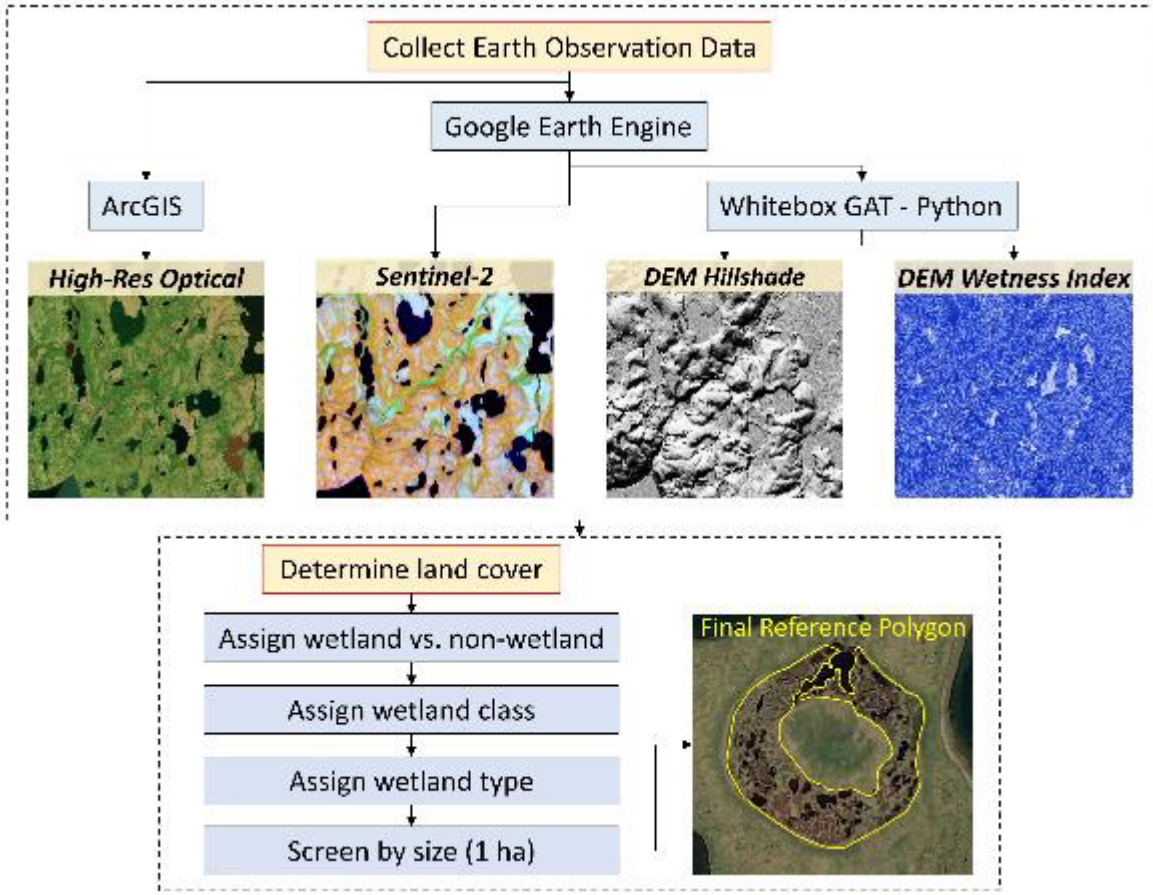
Vegetation Species	Coverage (%)	Height (m)
Species A Willow	45	2
Species B Brown moss	15	< 1
Species C Bearberry	15	< 1
Species D Brown moss	15	< 1
Species E Other	10	< 1

Field Site Example: Swamp

Reference Data Collection

Photo-Interpretation

- Cost-effective, desktop-based approach used to supplement field data.
- Methods require various Earth Observation datasets.



Open water

Swamp

Marsh

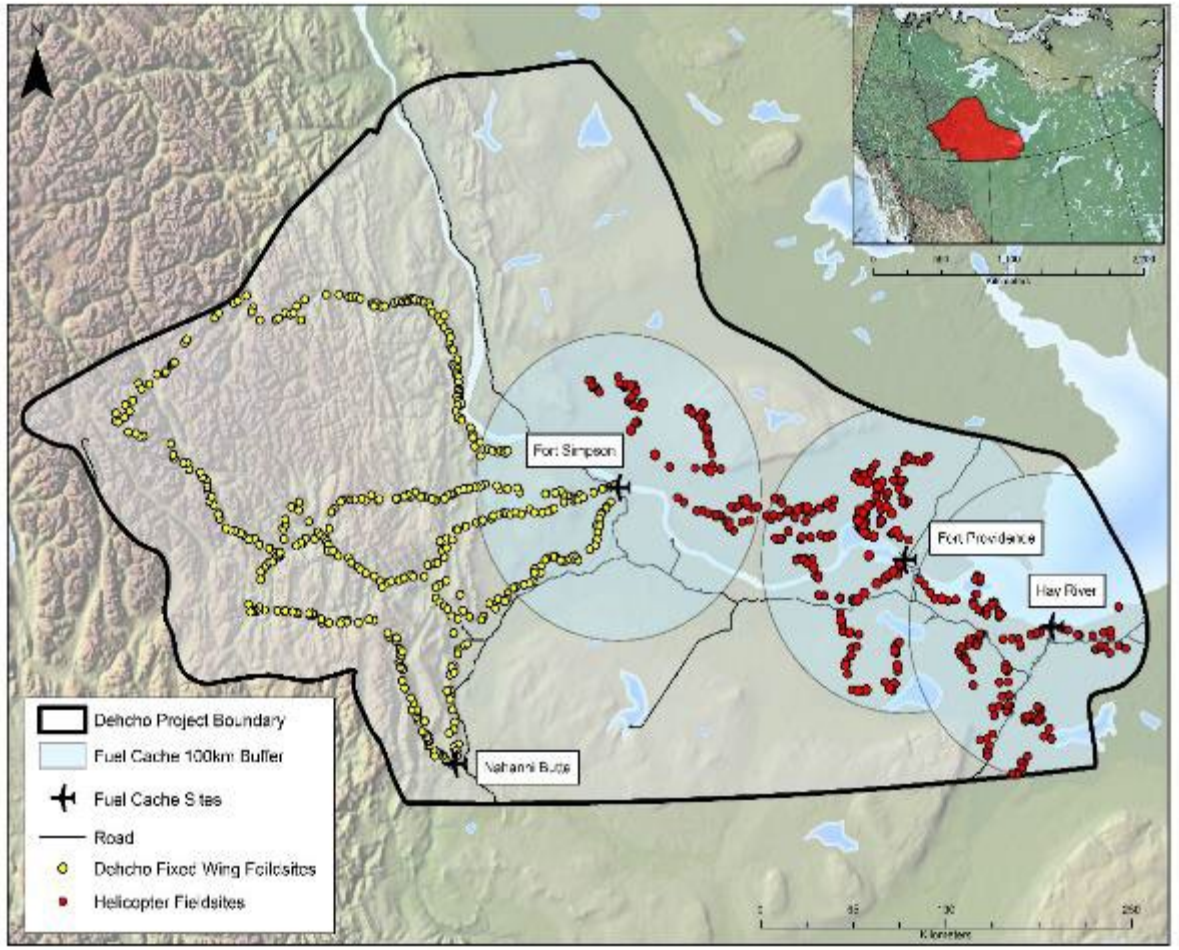
Bog

Fen

Boreal Inventory and Reference Data

Data Availability

- DUC has mapped over 200 million acres of boreal landscapes to various details.
- Each project contains field and/or photo-interpreted reference sites.

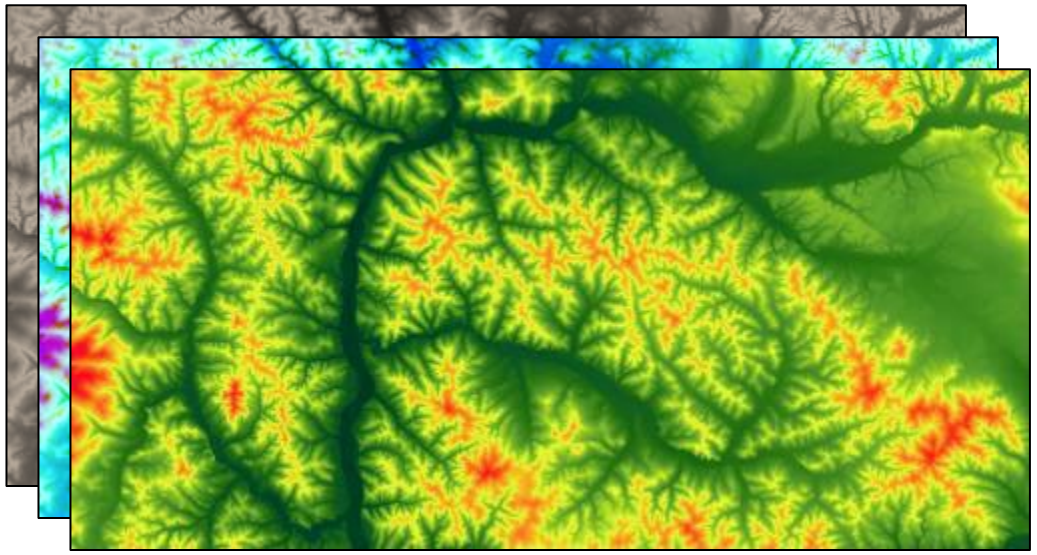


Earth Observation Data

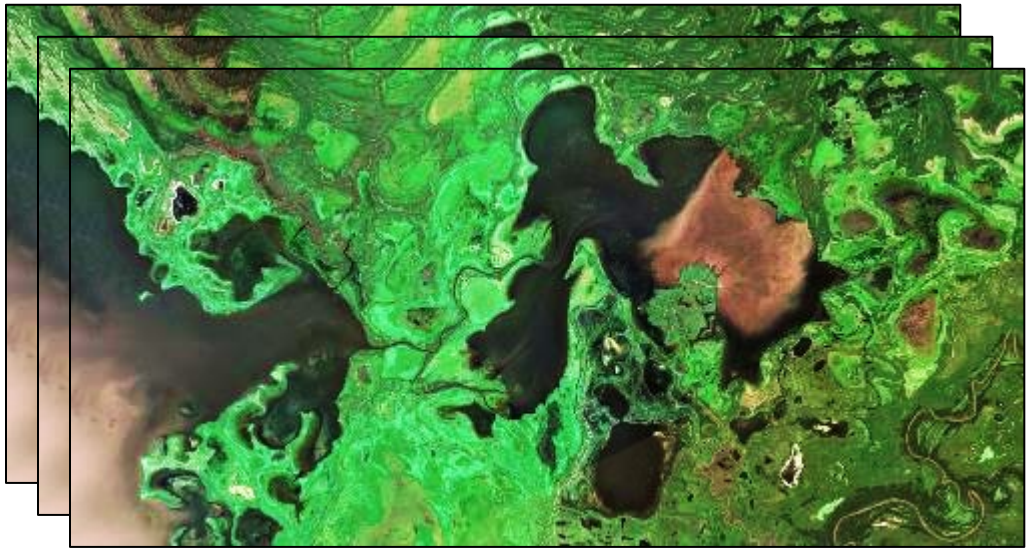
EO Datasets

- Through the fusion of **optical**, **SAR**, and **topographic** data, DUC's wetland inventories are produced using best practices and scientific methods.

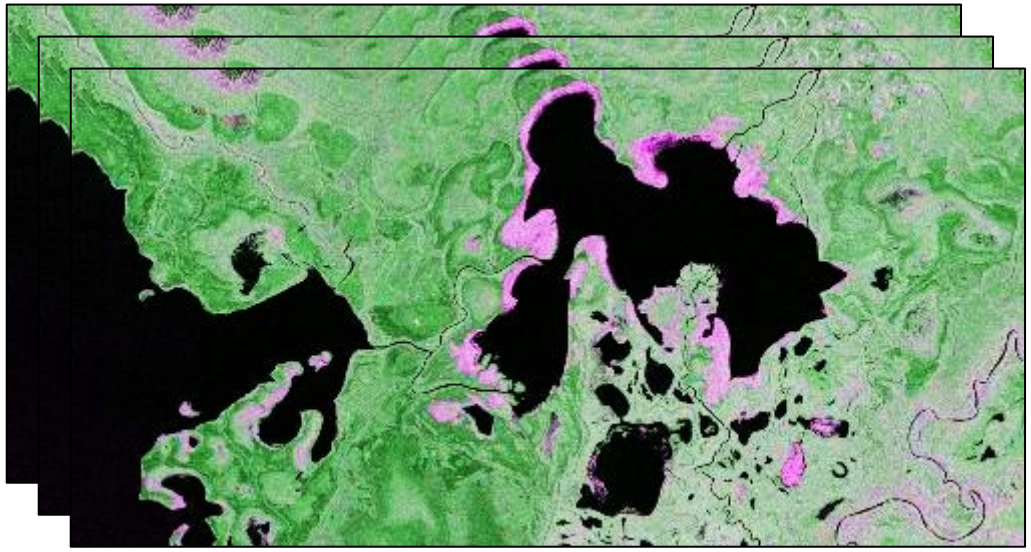
Elevation, Slope, Wetness



Multi-Seasonal Optical Composites



Multi-Seasonal SAR Composites



Earth Observation Data

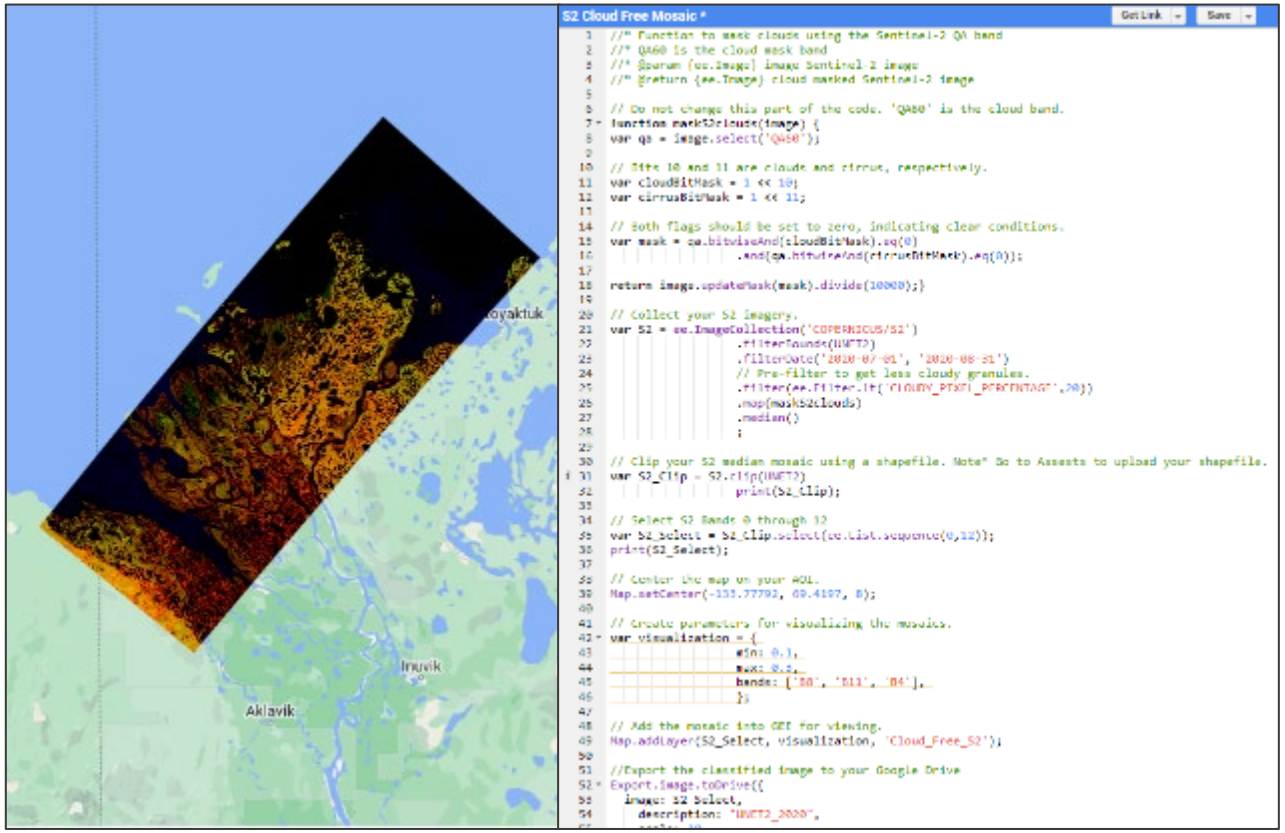
EO Datasets

- EO datasets acquired and preprocessed using Google Earth Engine cloud-computing.
- Processing scripts adjusted for each project/area.
- EO datasets: Sentinel-2, Sentinel-1, ALOS PALSAR, SRTM/ArcticDEM

Google Earth Engine

tps://code.earthengine.google.com/

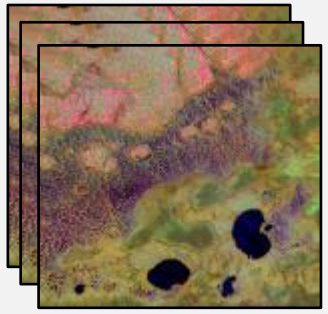
Google Earth Engine



Operational Mapping Workflow

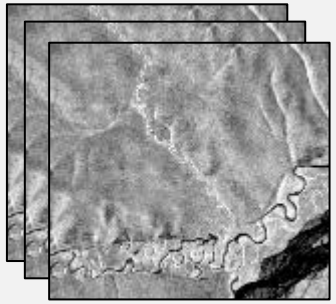
Seasonal Composites

Optical

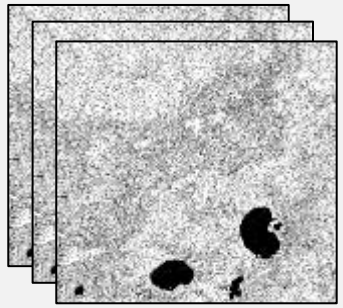


Sentinel-2

SAR

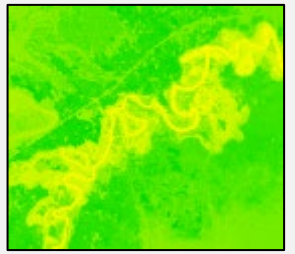


ALOS PALSAR



Sentinel-1

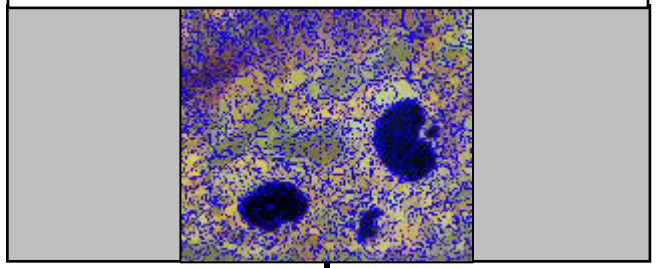
Topographic



ArcticDEM / SRTM

Photo-Interpretation

Object-Based Image Analysis



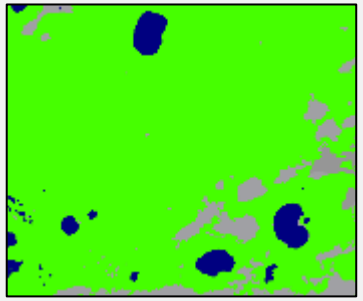
Calibration / Validation

Fieldwork

Machine Learning, Random Forest

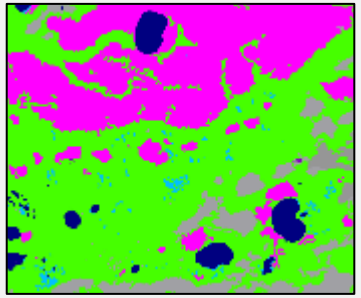
Wetland Mask

Wetland/Upland



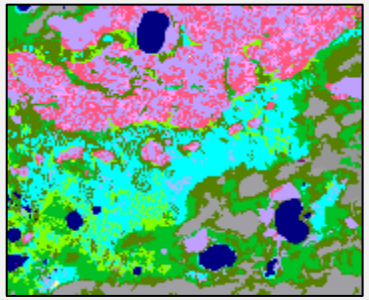
Major Wetland Class

5 Wetland Classes



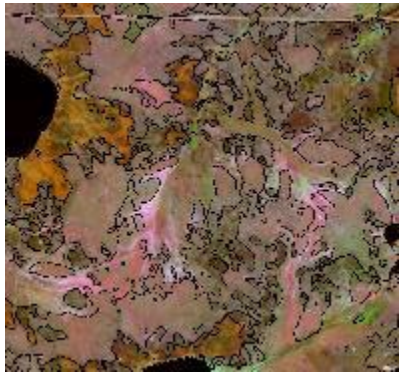
Wetland Type

19 Wetland Classes

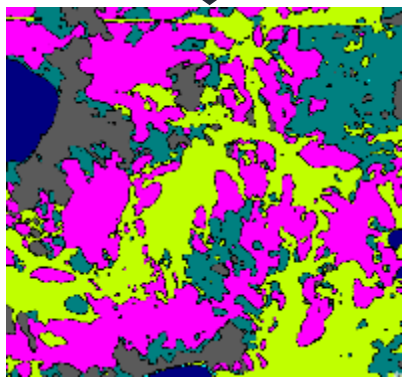


Classification Approach: Machine Learning

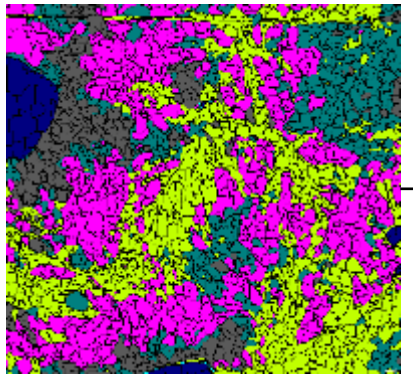
Imagery



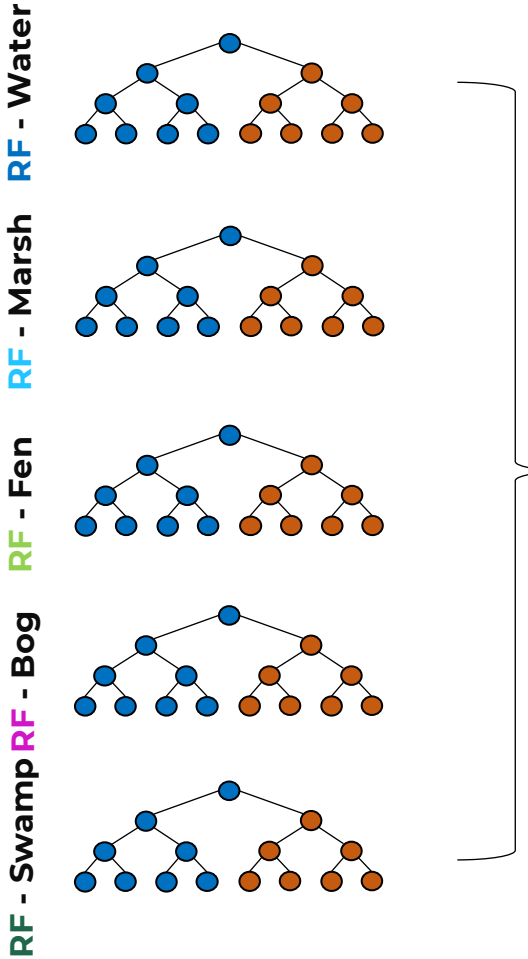
Wetland Class



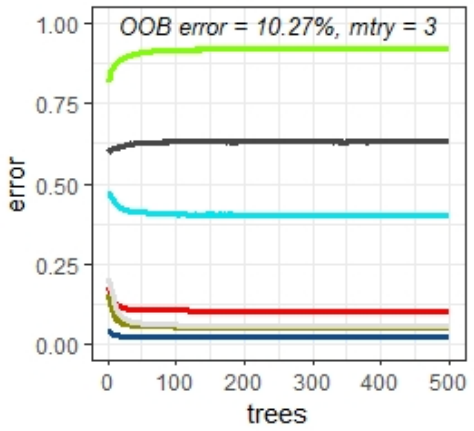
Objects



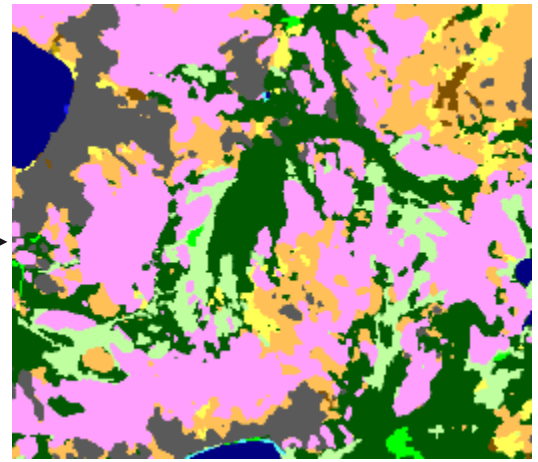
Random Forest (RF) Modelling



Hyperparameter Fine Tuning



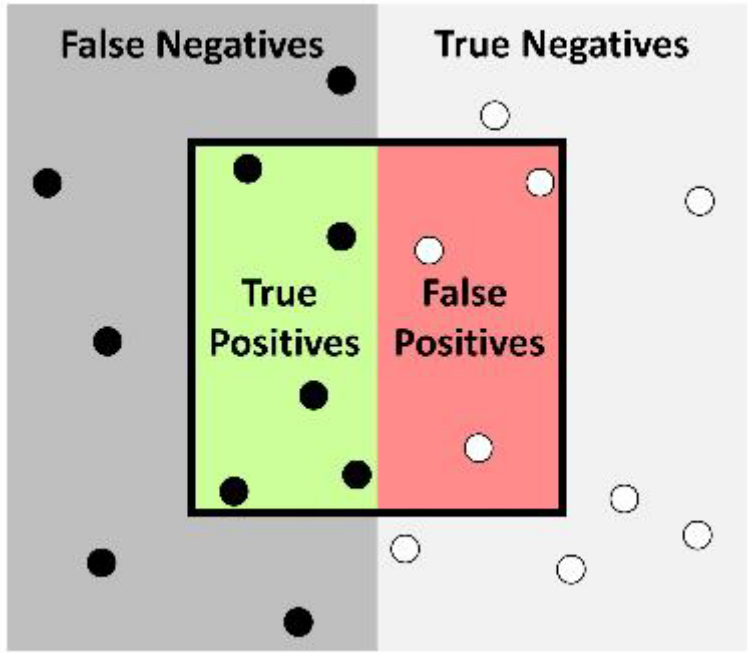
Wetland Type Map

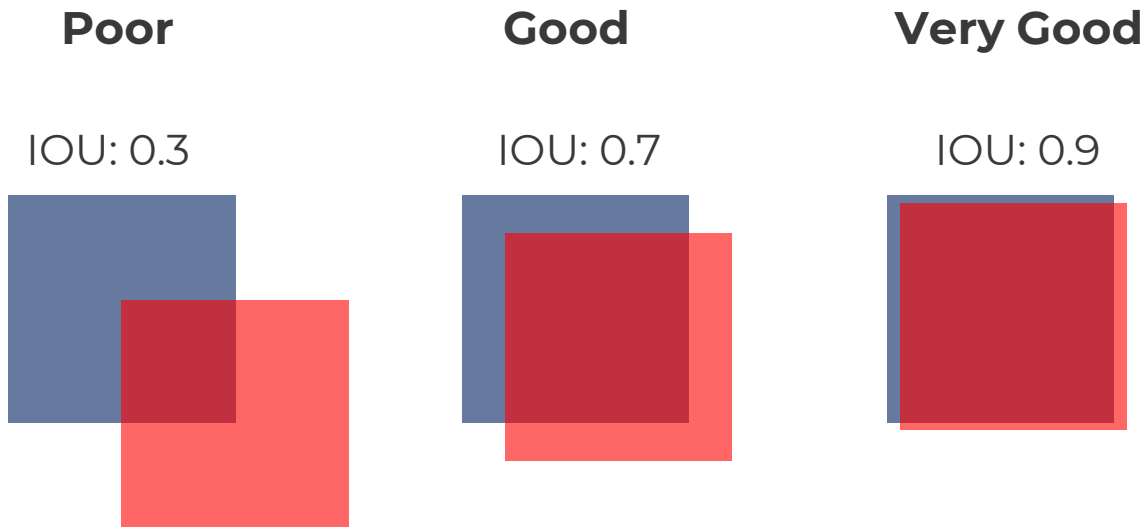


Accuracy Assessment

Accuracy Assessment

- Each DUC project is accompanied by an error matrix at each classification level: wet/up, class and type.
- Reported metrics: overall accuracy, user accuracy, and producer accuracy.
- Suggested metrics: F1-Scores and Intersection over Union (IOU)





$$IOU = \frac{area\ of\ overlap}{area\ of\ union}$$

On-Going Research and Development

Cloud-Computing

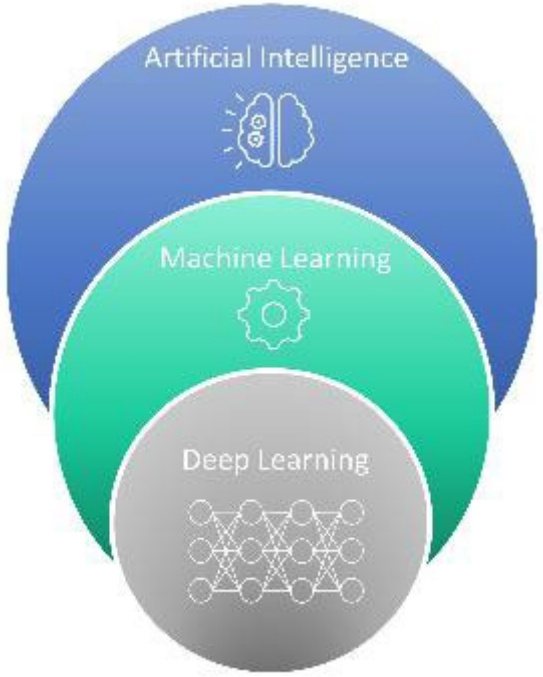
- Use of Google Earth Engine and machine learning to achieve baseline target accuracies all within a cloud-based environment.

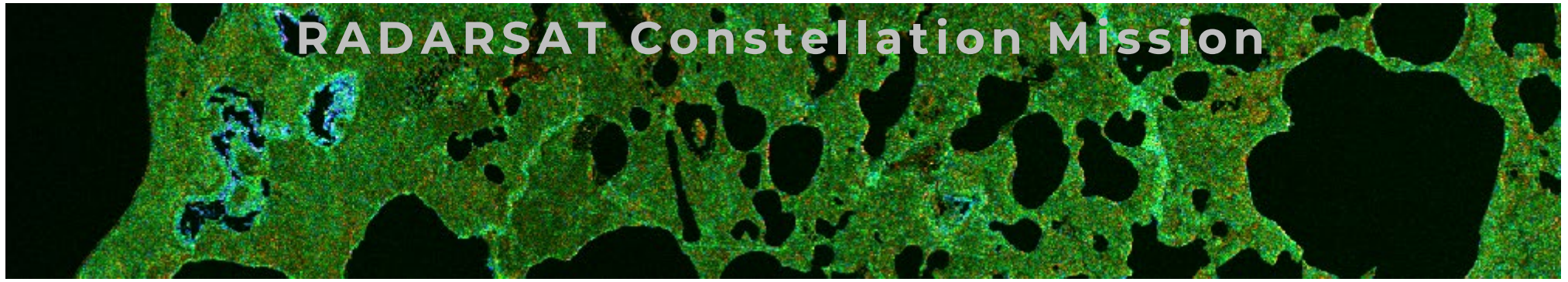
Deep Learning Methods

- Use of Convolutional Neural Networks (CNN) for highly-accurate wetland class mapping.
- Development of novel CNN architectures.

Novel SAR datasets

- Time-series Interferometric SAR (InSAR) coherence as a predictor variable for wetland classification.
- Compact polarimetric C-Band and L-Band SAR for wetland classification: RCM, NiSAR.





Relevant References

Merchant, M., et al. (2022)

- Applying Machine Learning and Time-Series Analysis on Sentinel-1A SAR/InSAR for Characterizing Arctic Tundra Hydro-Ecological Conditions. *Remote Sensing*, 14(5), 1123.
- Result: Established the ability of SAR **Coherence** products to map wet/dry conditions at high-latitudes.

Merchant, M., et al. (2020)

- Classifying Open Water Features Using Optical Satellite Imagery and an Object-Oriented Convolutional Neural Network, *Remote Sensing Letters*, 11(12), 1127-1136.
- Result: First DUC assessment of **CNN modelling** for boreal wetland features.

Merchant, M., et al. (2020)

- High Latitude Wetland Mapping Using Multi-Date and Multi-Sensor Earth Observation Data: A Case Study in the Northwest Territories, *Journal of Applied Remote Sensing*, 14(3), 034511.
- Result: Demonstrated the use of **multi-temporal EO data** for wetland mapping.

Merchant, M., et al. (2019)

- An Object-Based Assessment of Multi-Wavelength SAR, Optical Imagery and Topographical Datasets for Operational Wetland Mapping in Boreal Yukon, Canada, *Canadian Journal of Remote Sensing*, 45(3-4),
- Result: Established DUC's **multi-sensor machine learning** approach to wetland mapping.

Merchant, M., et al. (2017)

- Merchant, M., et al. (2017). Contributions of C-Band SAR Data and Polarimetric Decompositions to Subarctic Boreal Peatland Mapping. *IEEE JSTARS*, 10(4), 1467-1482.
- Result: Early assessment demonstrating **SAR capabilities** for peatland mapping.

Questions?

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