

A circular inset image showing a satellite in orbit above Earth's atmosphere, with solar panels extended.

Toward NL-wide wetland inventory system using satellite-based methods

Presented by:

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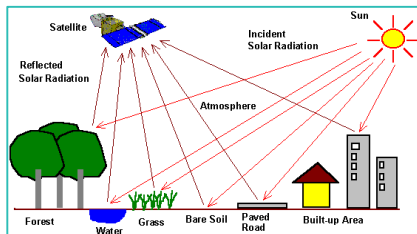
wood.



Remote Sensing

- Remote sensing is defined as the measurement of object properties on the earth's surface using data acquired from aircrafts and satellites
- Remote sensing satellites for wetland classification:

Optical



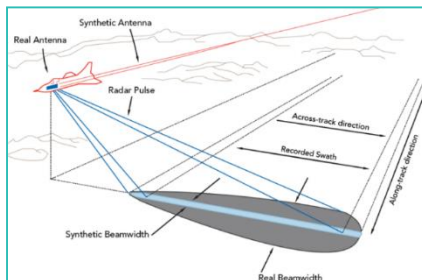
UAV



Hyperspectral



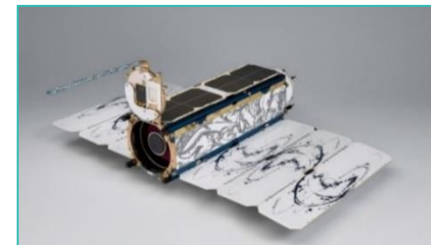
SAR



LiDAR



SmallSats



Wetland Service

- Flood control
- Erosion control
- Water purification
- Shoreline protection
- Soil and water conservation
- Carbon storage
- Recreation and tourist activities



Kidneys of environment

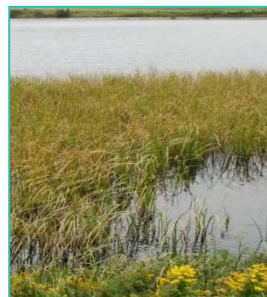
Bog



Fen



Marsh



Swamp



Shallow Water



Wetland Classification Methods

- Traditional (e.g., field work)
 - Expensive
 - Time-consuming
 - Not practical for large areas
 - No practical for wetland change detection and monitoring
 - Accessibility issues
 - **Necessary for remote sensing methods**
- Remote Sensing
 - Cost effective
 - Real-time data
 - Large coverage
 - Repetitive observation
 - No limitation regarding the accessibility

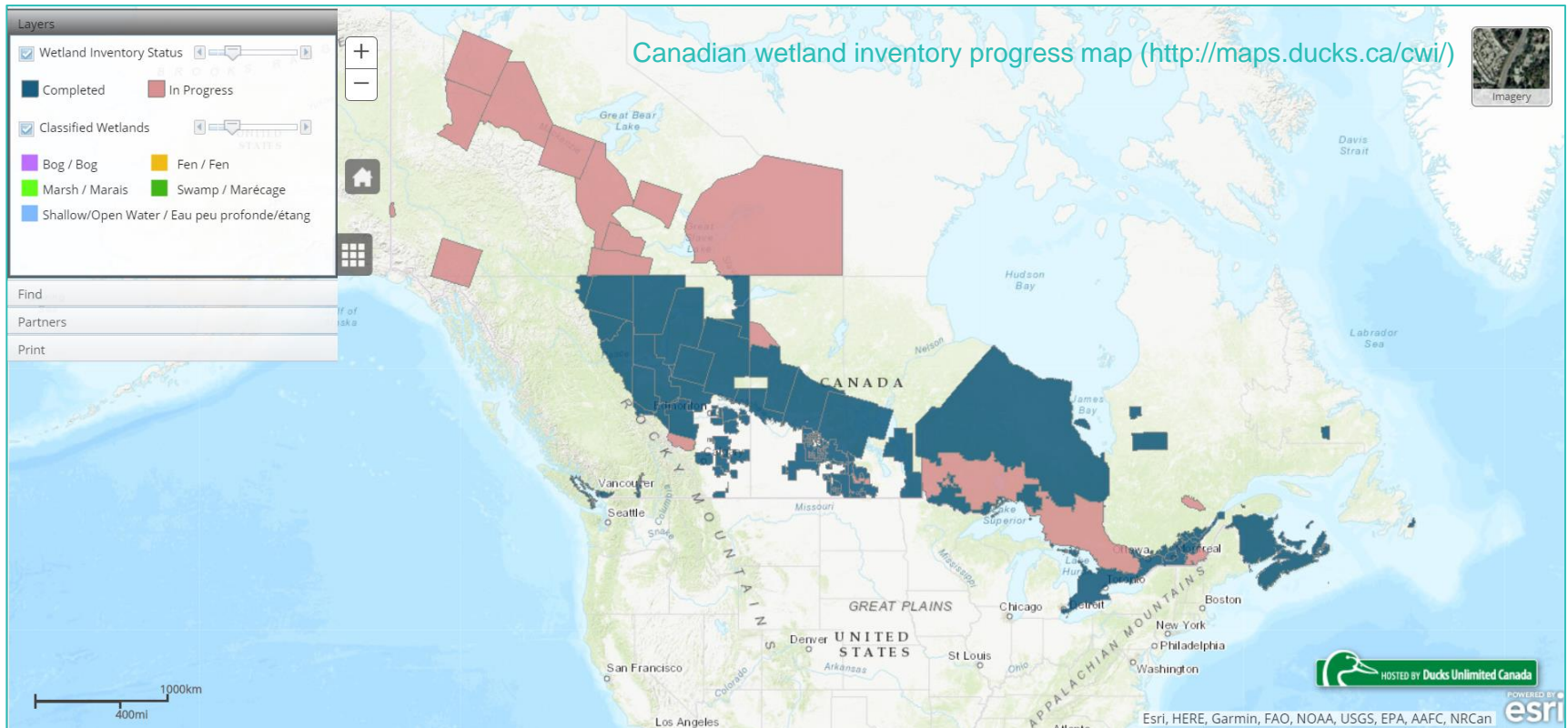


Wetland Classification in NL

- Importance
 - ~18% of NL is covered by wetlands (**It's more!!!!**)
 - Over the last decades, industrialization, urbanization, and agricultural activities have posed a serious threat to wetlands in the province
- Steps
 - Before Sept 2015
 - Before Dec 2018
 - Now
 - Future

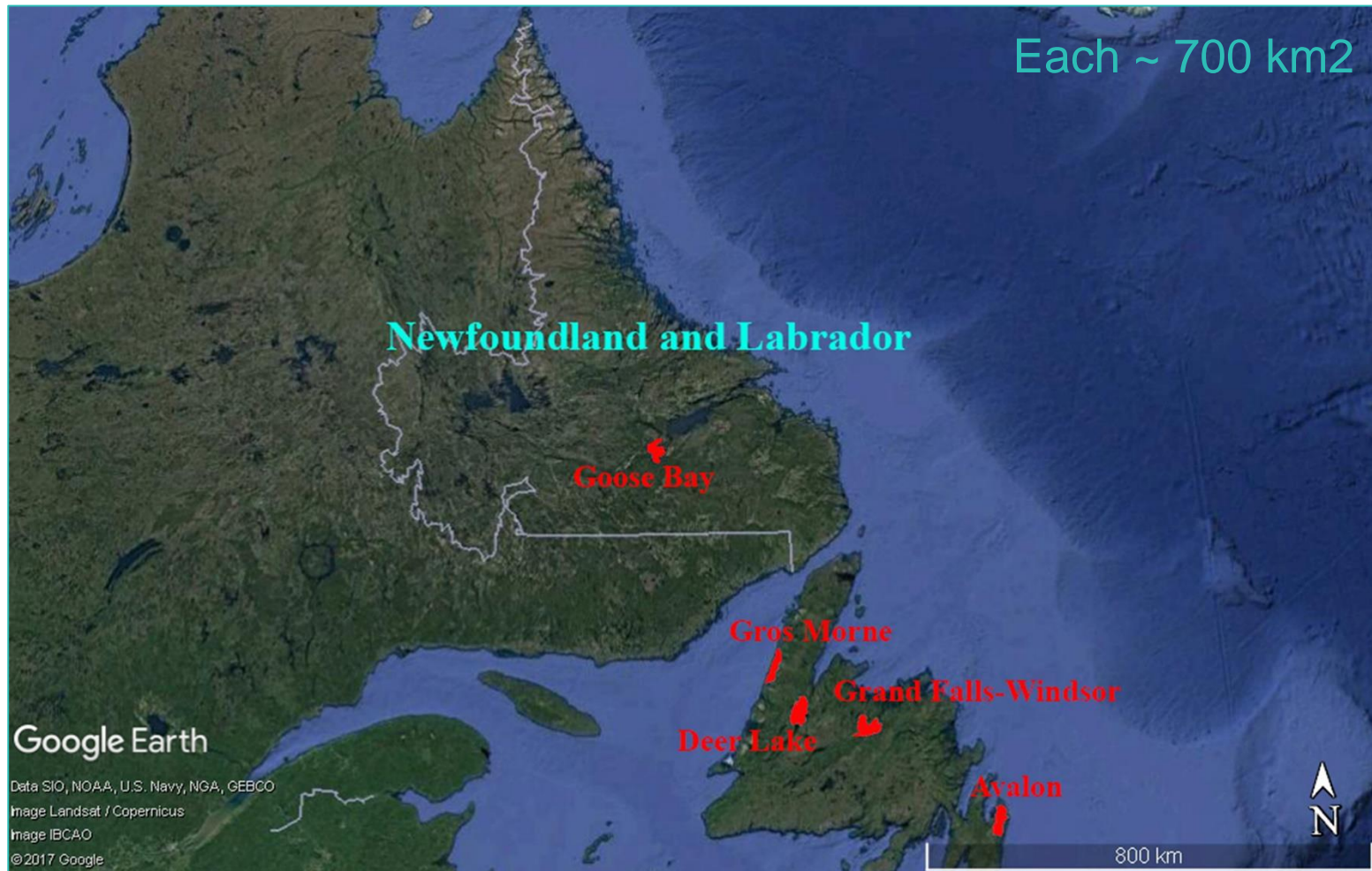
Wetland Classification in NL (2015)

- Only two small areas were classified
- Using basic methods
- Several field works



Wetland Classification in NL (2018)

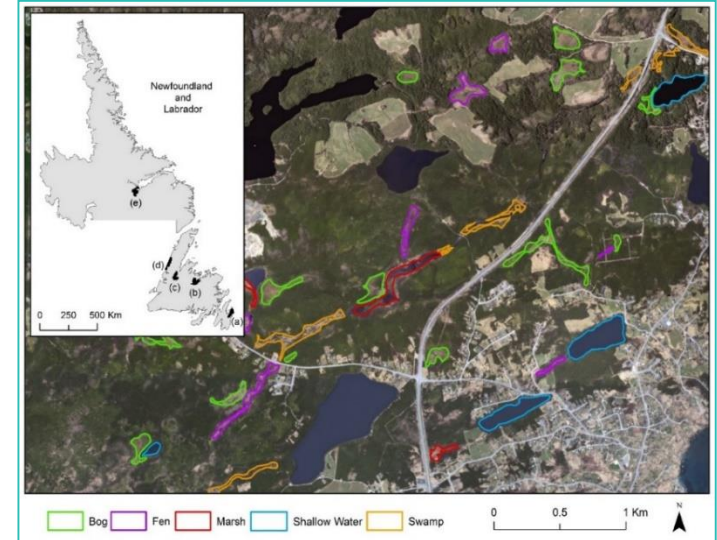
Study areas



Wetland Classification in NL (2018)

Field data

- Conducted in summer 2015, 2016, 2017
- Ancillary information, including GPS points, on-site photographs, field notes on dominant vegetation, and hydrology were collected at each wetland site
- The GPS points were inserted into ArcMap and, then, the boundary delineation was conducted using high resolution images
- Based on Canadian Wetland Classification System (CWCS)
- Five wetland classes: Bog, Fen, Marsh, Swamp, and Shallow Water
- Three non-wetland classes: Deep Water, Urban, and Upland Forest



The number of field samples (polygons) collected over five study areas.

Study area	Class	Number of polygons	Area (ha)
Avalon	Bog	83	269
	Fen	39	80
	Marsh	50	62
	Swamp	45	47
	Shallow Water	40	110
Grand Falls-Windsor	Bog	30	357
	Fen	61	194
	Marsh	45	102
	Swamp	30	47
	Shallow Water	21	52
Deer Lake	Bog	31	236
	Fen	54	121
	Marsh	24	19
	Swamp	40	56
	Shallow Water	23	68
Gros Morne	Bog	38	779
	Fen	31	98
	Marsh	31	50
	Swamp	42	48
	Shallow Water	27	64
Goose Bay	Bog	28	395
	Fen	29	139
	Marsh	21	78
	Swamp	23	35
	Shallow Water	11	19

Wetland Classification in NL (2018)

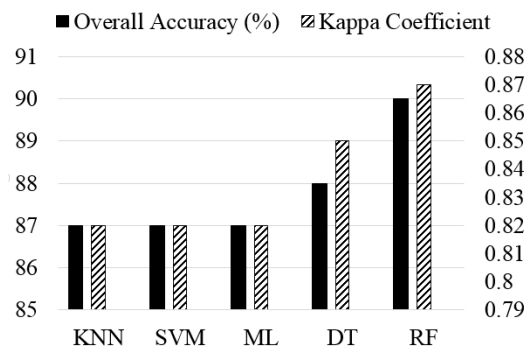
Satellite data

- Optical
 - RapidEye
 - **Landsat-8 (free)**
 - **Sentinel-2 (free)**
 - **ASTER (free)**
- SAR
 - RADARSAT-2
 - **ALOS-1 (free)**
 - ALOS-2
 - **Sentinel-1 (free)**
 - TerraSAR-X
- Aerial
 - Canadian Digital Elevation Model (CDEM)

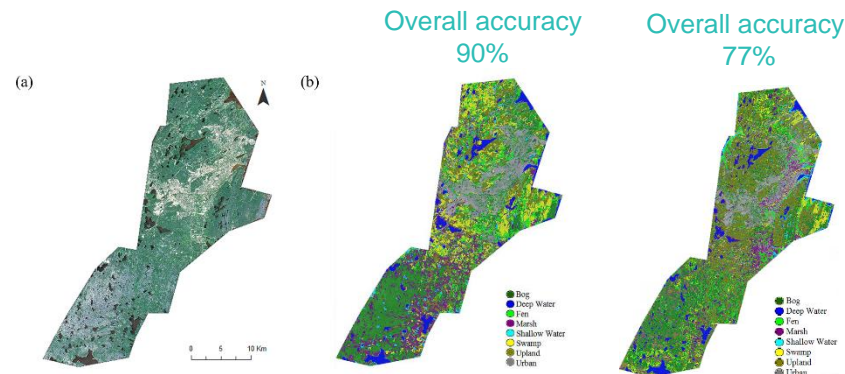
Wetland Classification in NL (2018)

Preliminary analyses

Comparison between classification algorithms



Pixel-based vs. object-based method

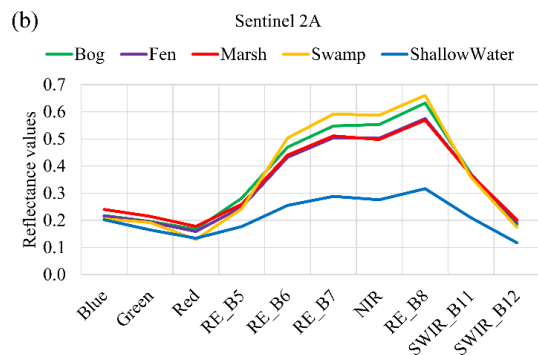


Evaluation of confusion matrix

Confusion matrix in terms of the number of pixels for the classification using the Random Forest algorithm with the User Accuracy, Producer Accuracy, errors of Commission and error of Omission (in %).

Reference Data												
Classified Data		B	F	M	SW	S	Up	DW	Ur	Total	C	UA
	B	20279	4241	1476	0	590	0	0	83	26669	24	76
	F	1672	7368	841	0	987	0	0	0	10868	32	68
	M	541	70	3941	92	0	1295	0	0	5939	34	66
	SW	0	0	0	1445	0	0	60	0	1505	4	96
	S	78	740	859	0	3470	2316	0	32	7495	54	46
	Up	0	682	0	0	178	24304	0	0	25164	3	97
	DW	0	0	0	0	0	0	69312	0	69312	0	100
	Ur	0	0	0	0	0	0	0	19340	19340	0	100
	Total	22570	13101	7117	1537	5225	27915	69372	19455	166292		
O	10	44	45	6	34	13	0	1			OA = 91	
PA	90	56	66	94	66	87	100	99			K = 0.87	
OA: Overall Accuracy			B: Bog				S: Swamp			C: Commission		
K: Kappa Coefficient			F: Fen				Up: Upland			O: Omission		
PA: Producer Accuracy			M: Marsh				DW: Deep Water					
UA: User Accuracy			SW: Shallow Water				Ur: Urban					

Visual analysis (spectral signature)

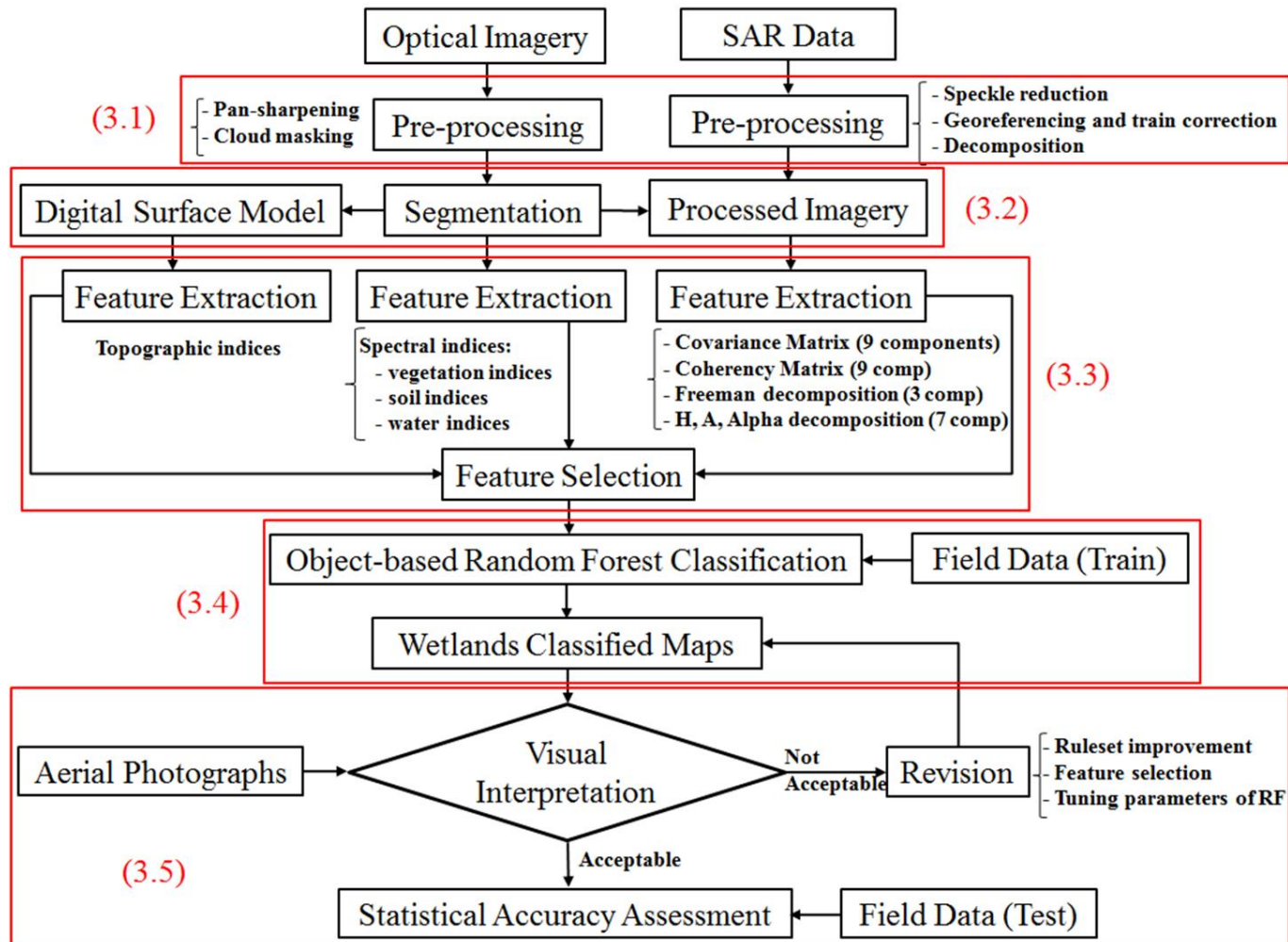


Evaluation of multi-temporal satellite data

Accuracy	June	August	November	Combination of multi-date images
OA (%)	86	88	81	88
APA (%)	60	64	56	68
AUA (%)	57	60	53	63

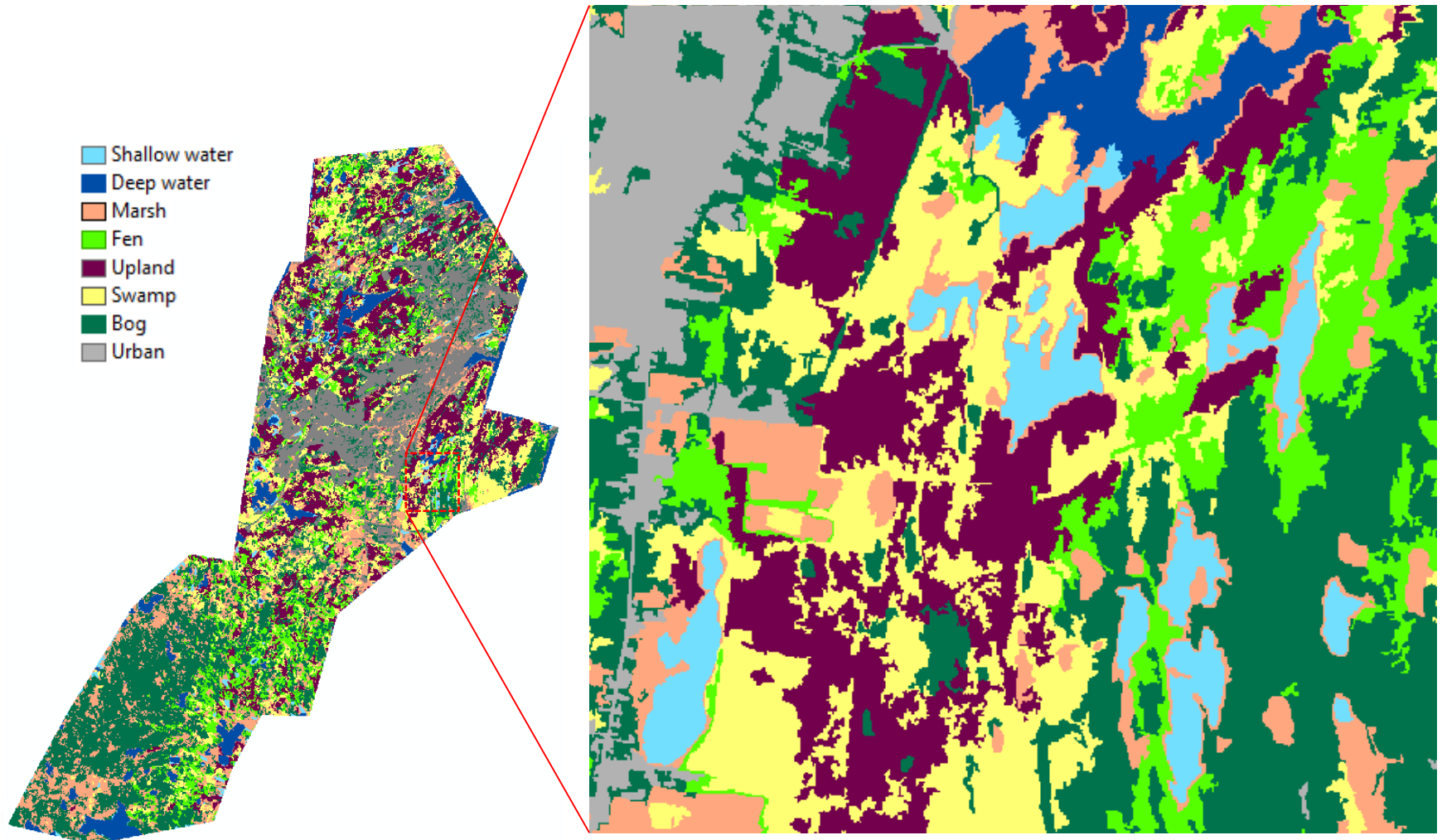
Wetland Classification in NL (2018)

General method



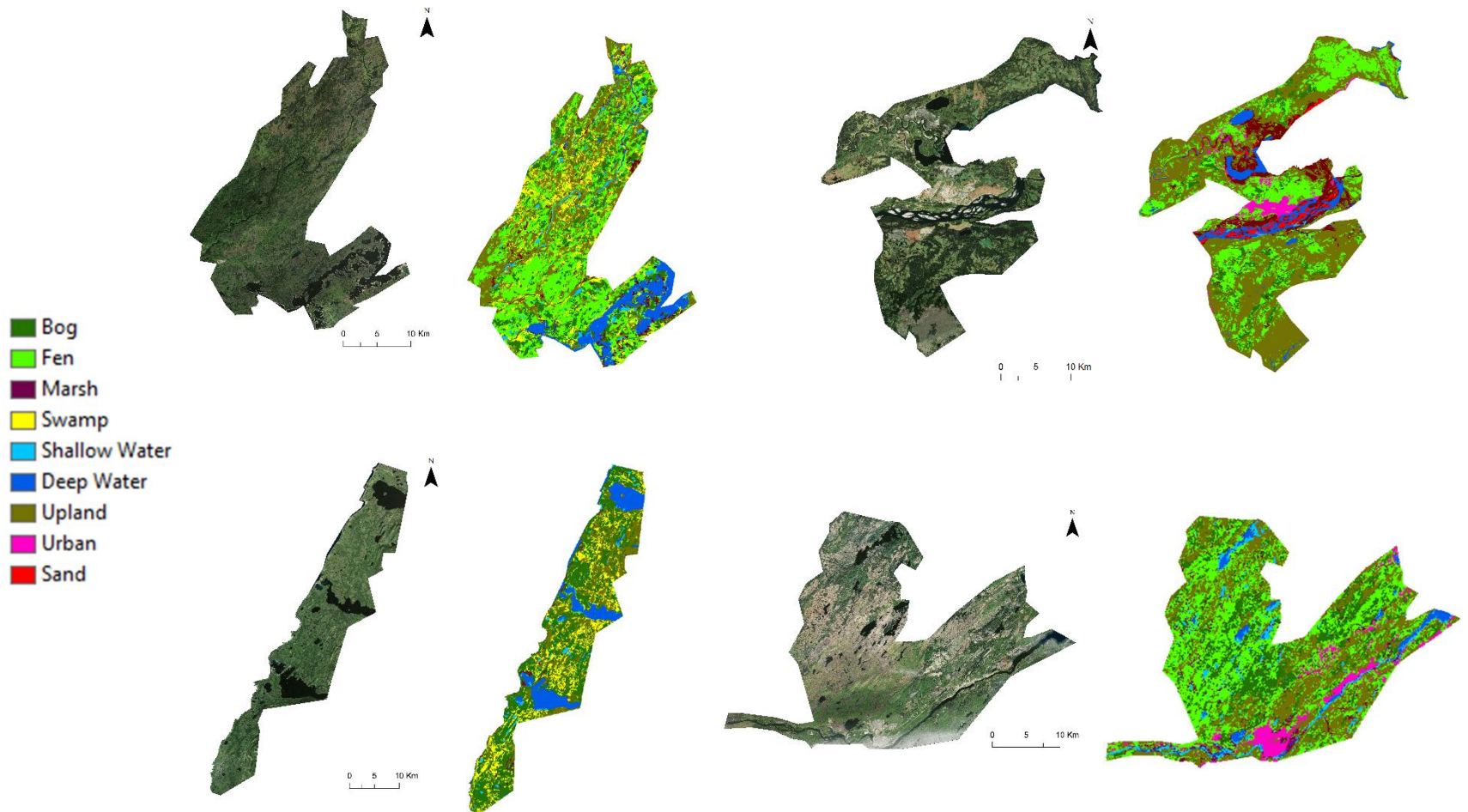
Wetland Classification in NL (2018)

Wetland classified maps



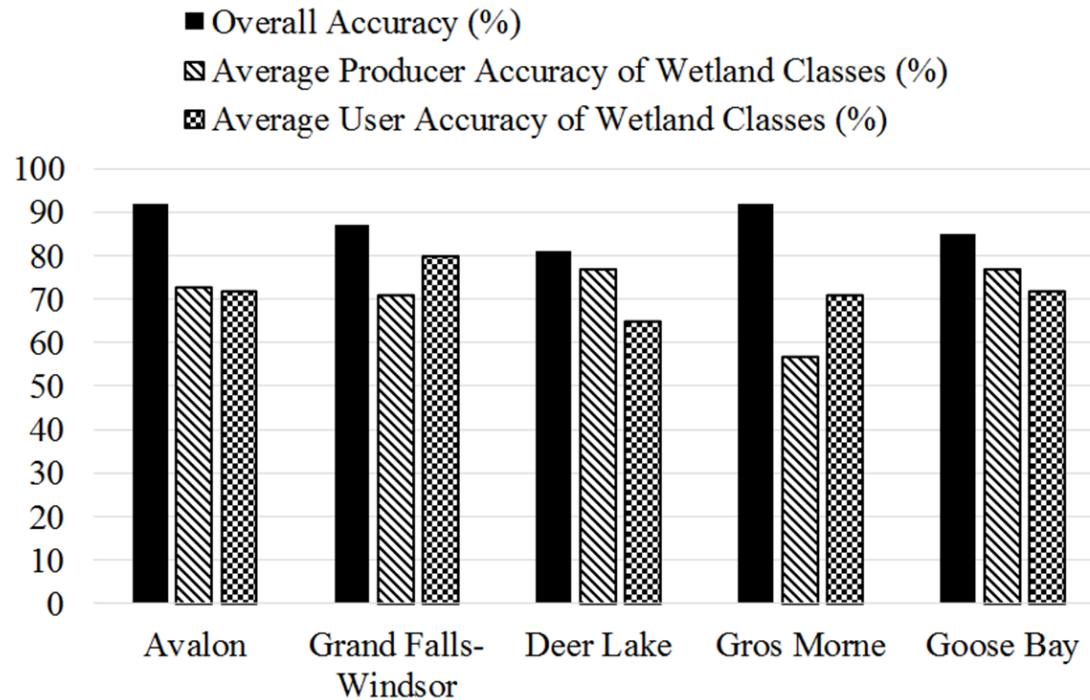
Wetland Classification in NL (2018)

Wetland classified maps



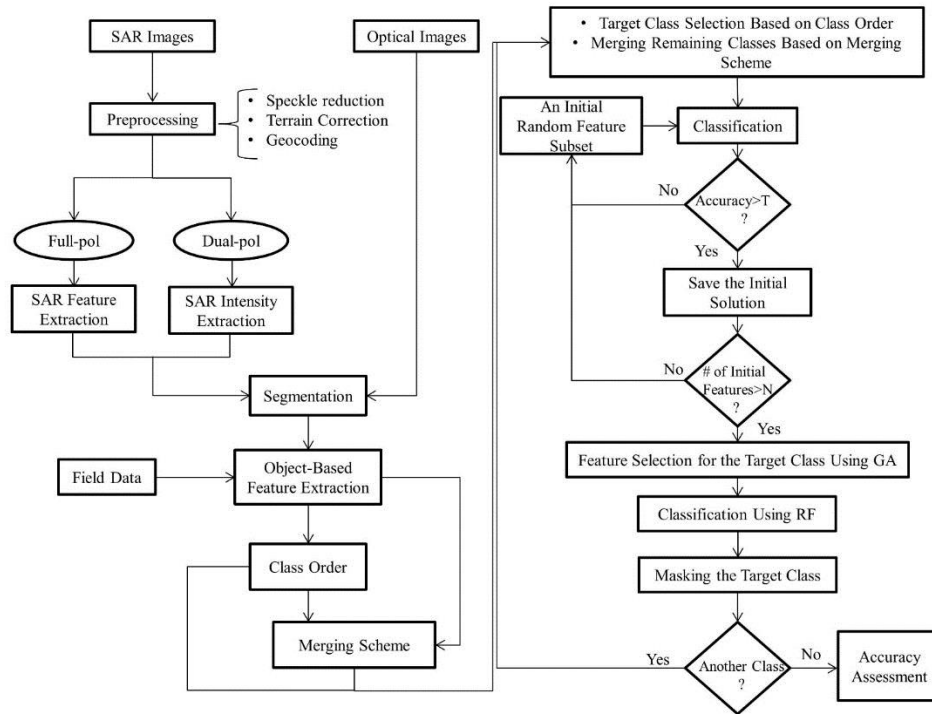
Wetland Classification in NL (2018)

Classification accuracies

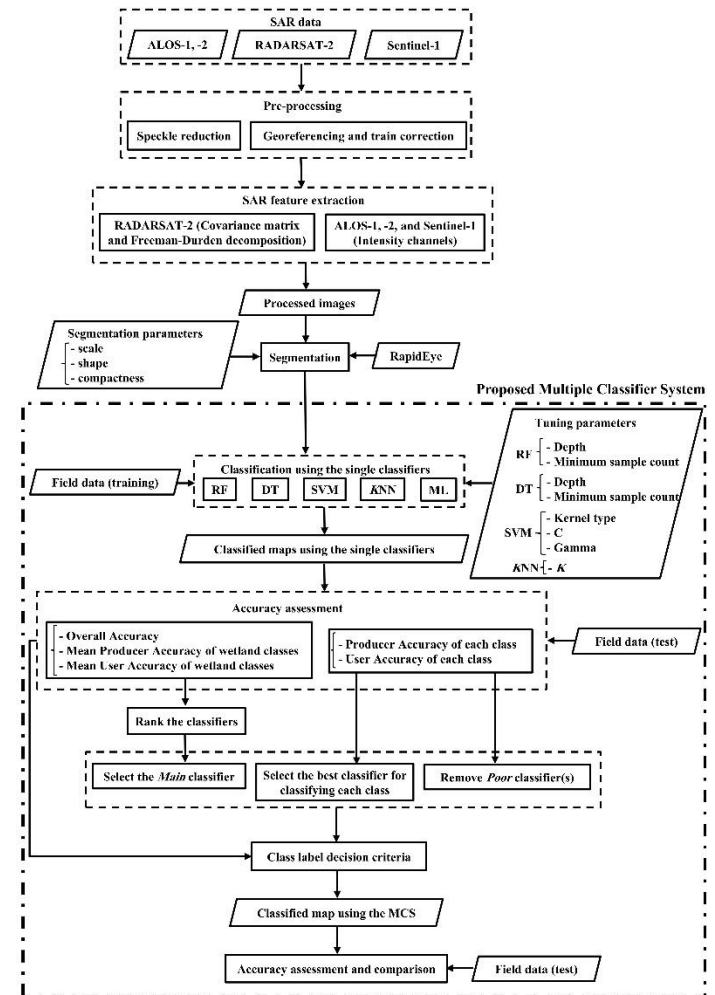


Wetland Classification in NL (2018)

Other analysis (Advanced classification algorithms to improve the accuracy)



Mahdavi et al., 2018



Amani et al., 2018

Selected Journal Publications

- Amani, M., Salehi, B., Mahdavi, S., Granger, J., & Brisco, B. (2017). "Wetland classification in Newfoundland and Labrador using multi-source SAR and optical data integration". *GIScience & Remote Sensing*, 54(6), 779-796.
- Amani, M., Salehi, B., Mahdavi, S., Granger, J. E., Brisco, B., & Hanson, A. (2017). "Wetland Classification Using Multi-Source and Multi-Temporal Optical Remote Sensing Data in Newfoundland and Labrador, Canada". *Canadian Journal of Remote Sensing*, 43(4), 360-373.
- Mahdavi, S., Salehi, B., Amani, M., Granger, J. E., Brisco, B., Huang, W., & Hanson, A. (2017). "Object-based classification of wetlands in Newfoundland and Labrador using multi-temporal PolSAR data". *Canadian Journal of Remote Sensing*, 43(5), 432-450.
- Mahdavi, S., Salehi, B., Granger, J., Amani, M., & Brisco, B. (2017). "Remote sensing for wetland classification: a comprehensive review". *GIScience & Remote Sensing*, 1-36.
- Amani, M., Salehi, B., Mahdavi, S., Brisco, B., & Shehata, M. (2018). "A Multiple Classifier System to improve mapping complex land covers: a case study of wetland classification using SAR data in Newfoundland, Canada". *International Journal of Remote Sensing*, 1-14.
- Amani, M., Salehi, B., Mahdavi, S., & Brisco, B. (2018). "Spectral analysis of wetlands using multi-source optical satellite imagery". *ISPRS Journal of Photogrammetry and Remote Sensing*, 144, 119-136.

Wetland Classification in NL (2019)

Limitation of the previous works

- Wetland maps from only 5 pilot sites (1% of the province in total)
- No wetland map from the entire province
- Did not evaluate the changes over years and did not estimate the amount of loss/gain in wetland areas
- Did not consider most of the non-wetland classes
- Conducted solely based on remote sensing

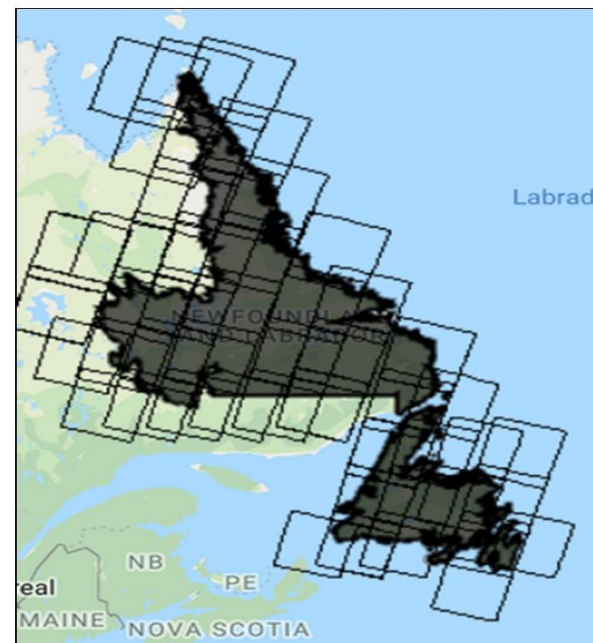
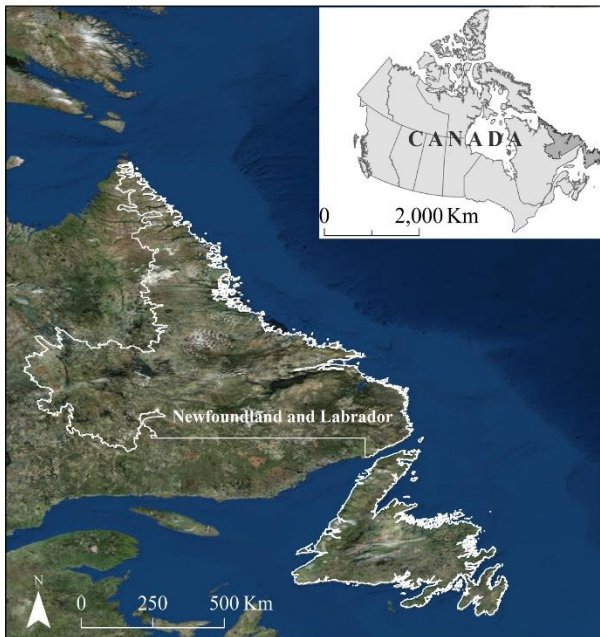
NL-wide wetland inventory (2019)

Main challenge

- Processing of hundreds of satellite images

Area= ~ 405,000 km²

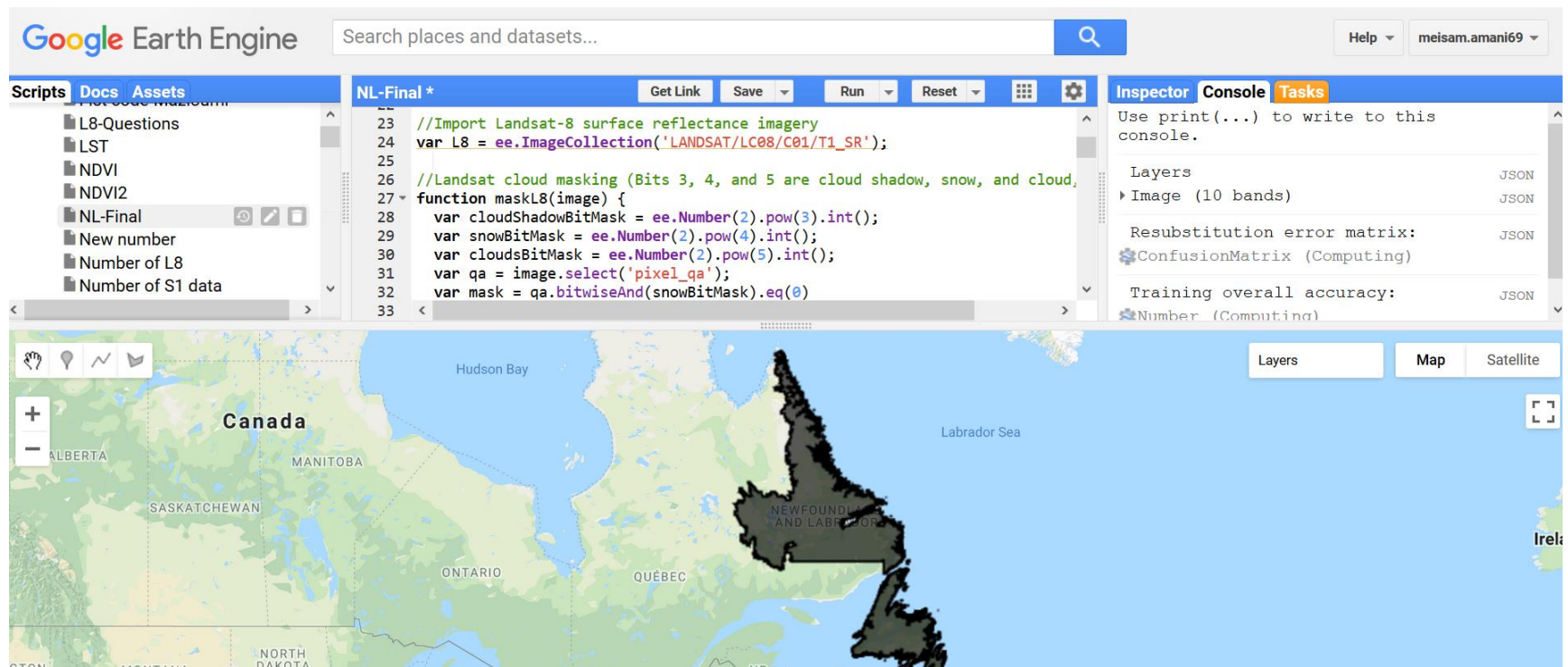
Satellite data= Only 1588 Landsat-8 images during 2018



NL-wide wetland classification (2019)

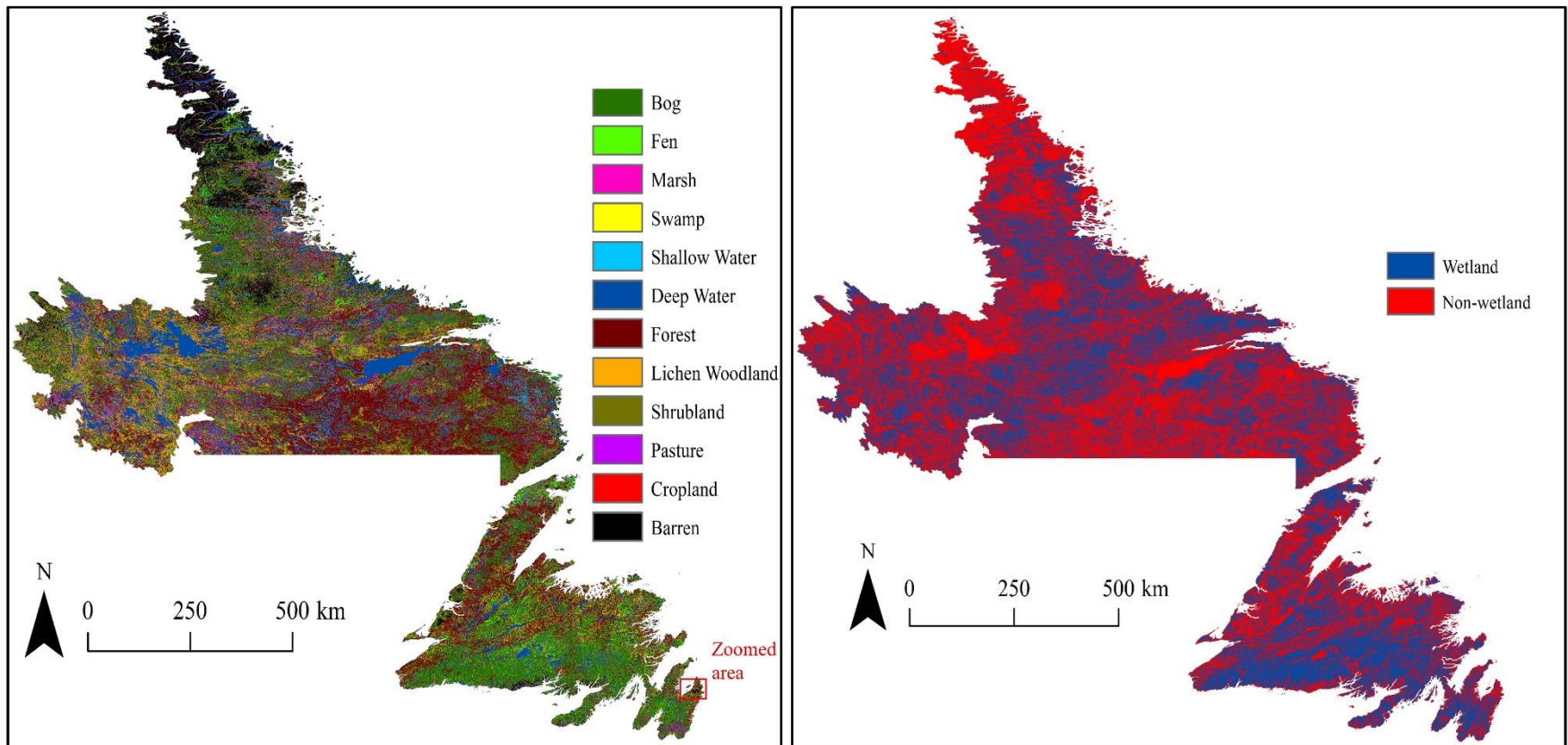
Solution

- Google Earth Engine (GEE)



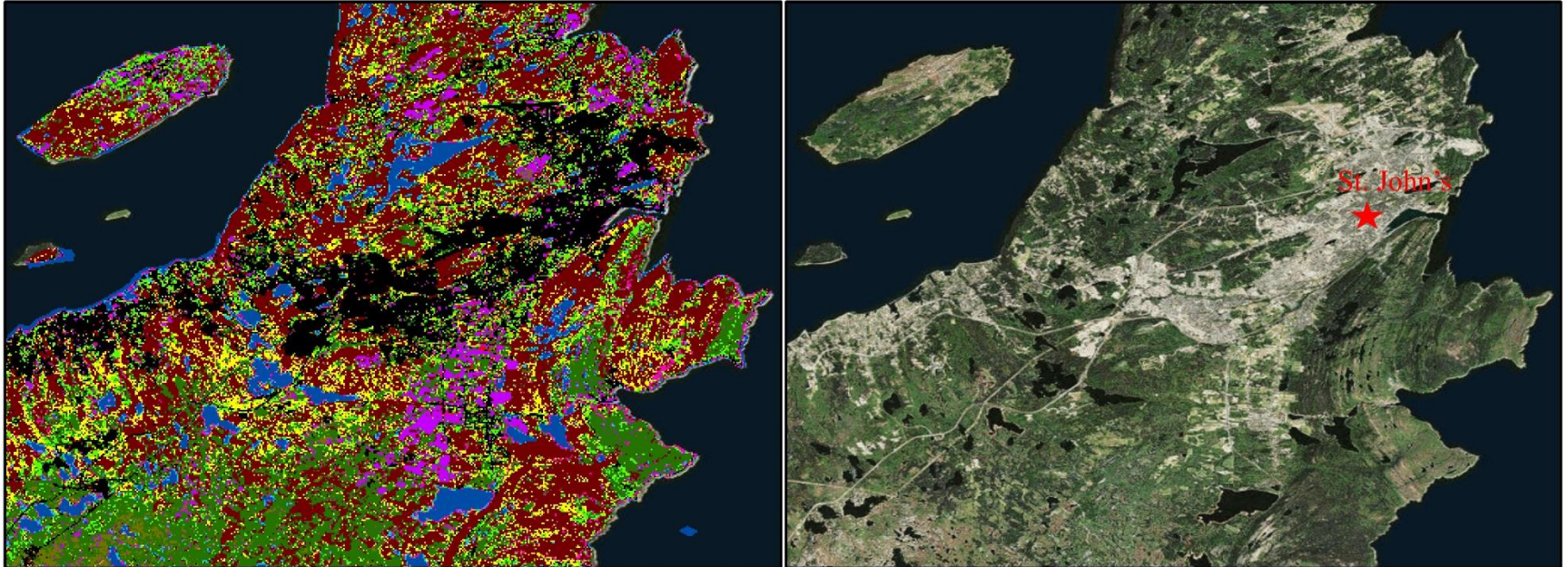
NL-wide wetland classification (2019)

Final map



NL-wide wetland classification (2019)

Zoomed image



NL-wide wetland classification (2019)

Wetlands area

The area of each class in the province of NL based on the classified map						
Class	Province of NL		Newfoundland		Labrador	
	Area (km ²)	% of NL	Area (km ²)	% of Newfoundland	Area (km ²)	% of Labrador
Wetland						
Bog	102,293	25.24	38,248	36.08	64,045	21.41
Fen	24,094	5.94	12,176	11.49	11,918	3.98
Marsh	33,429	8.25	4,143	3.91	29,286	9.79
Swamp	6,502	1.60	4,698	4.43	1,804	0.60
Shallow Water	18,116	4.46	3,113	2.94	15,003	5.01
Total	184,434	45.49	62,378	58.85	112,056	40.79
Non-wetland						
Deep Water	40,507	10.00	7,322	6.91	33,185	11.09
Forest	93,878	23.17	26,933	25.41	66,945	22.37
Lichen Woodland	26,434	6.53	1,227	1.16	25,207	8.42
Shrubland	15,717	3.88	2,553	2.41	13,164	4.40
Pasture	2,619	0.65	1,603	1.51	1,016	0.34
Cropland	180	0.04	157	0.15	23	0.01
Barren	41,443	10.24	3,828	3.61	37,615	12.57
Total	220,778	54.51	43,623	41.16	177,157	59.20

NL-wide wetland classification (2019)

Accuracy

The producer and user accuracies of wetland and non-wetland classes obtained from the province-wide wetland map. The overall accuracy and kappa coefficient for this classification were **78%** and 0.76, respectively.

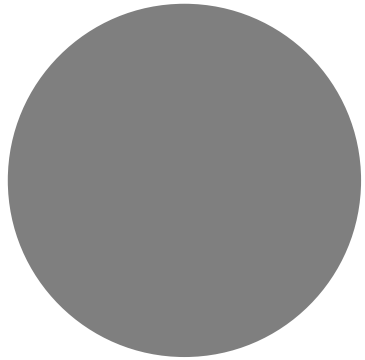
Class	Producer Accuracy (%)	User Accuracy (%)
Wetland		
Bog	71.7	79.0
Fen	60.3	73.5
Marsh	62.1	69.8
Swamp	79.8	63.9
Shallow Water	57.3	66.6
Average	66.2	70.6
Non-wetland		
Deep Water	97.9	96.2
Forest	82.8	88.1
Lichen Woodland	80.1	55.3
Shrubland	76.6	81.1
Pasture	82.4	68.6
Cropland	51.8	67.7
Barren	98.2	93.7
Average	81.4	78.7

Wetland Classification in NL (What is next...)

How to improve the accuracy of maps

- Include more field data
- Use advanced classification algorithms with more input features
- Produce wetland maps each year and evaluate the changes, gain, and loss in wetland areas over time
- Contribution in other fields: relate the results to the other variables (carbon storage, ducks migration, etc.)

Support / Collaboration



Thanks

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