Develop an operational wetland mapping approach by integrating optical and radar remote sensing images

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Reducing Canada's vulnerability to climate change

Introduction

Satellite remote sensing is an efficient and practical approach that can map wetland distribution in a timely manner over a large region. Both optical and radar remote sensing techniques have been used in wetland research. Since optical sensors are unable to penetrate vegetation canopies, forest wetlands mapping using only spectral-based remote sensing techniques has proven to be problematic. Combining radar and optical remote sensing therefore represents a promising approach for wetland identification and mapping because radar can provide additional information under forest. However wetlands are of various types with great of variability in Canada and forest wetlands can be confused with other forest area. There is a need to find an operational way to accurately map the distribution of wetlands of Canada to support national programs including carbon budget for northern ecosystems in Canada, national wetland inventory (NWI), and extent of wetlands indicator within the National Round Table on the Environment Sustainable Development Indicator (ESDI) Initiative.

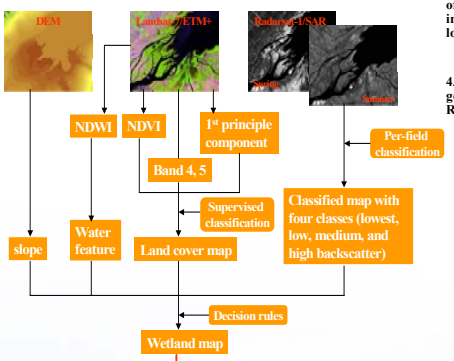
Objective

Our objective is to use optical and radar remote sensing images to develop an operational wetland mapping approach, which can deal with wetland complexity in Canada.

Approach

1. Usually wetlands will more likely occur on flat terrain surface and marsh and forest wetlands are often found adjacent to water features. The slope < 5%was used for potential wetlands. A slope image with 30-meter resolution was derived from 1:50,000 DEM data and a water feature image was generated by NDWI (Normalized Difference Water Index)derived from Landsat-7/ETM+.

2. Several studies have pointed out that optical sensor images are good for non-forest wetland mapping. In this study, TM4, TM5, first principal component of TM bands, and NDVI were selected as inputs to a decision tree classifier to delineate open wetlands and generate the land cover map.



3. Generally in the SAR image, water, roads and pasture produce lowest backscatter and present to be dark in SAR images because of their smooth surfaces; the forest is least affected by the ground cover effects and the backscattering coefficient has medium value, therefore the forest is the medium brightness that you see in SAR image; as to open wetlands (bogs and fens), their backscatters are low because of the effect of moisture contents, but it is difficult to distinguish with single-date SAR the difference between various types of open wetland; the high radar returns in the SAR image are from wetlands covered by tree such as marshes and swamps, caused by the double-bounce scattering between the water surface and vertical stems and leaves of the tree, in addition, the high radar returns may be from corner reflection or the side of the mountain or hill facing towards the radar. Unlike optical image, classification of SAR imagery based on individual pixel values does not generally give satisfactory results because of the effects of 'speckle' or noise within the data. A per-field method for SAR image classification was employed to classify the SAR images to three classes with low, medium and high backscatter.

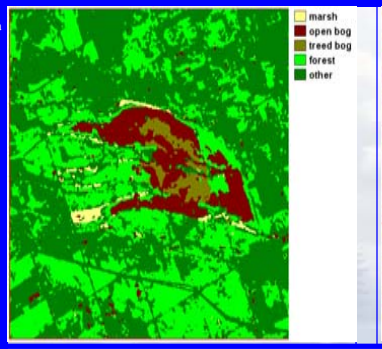
4. The decision rules within a GIS framework is designed to merge all results to get a final wetland map. Some rules for Landsat-7/ETM+ and spring/summer Radarsat-1/SAR are listed as following:

- *If pixel belongs to TM class marsh and spring SAR class high and slope < 0.05 and within water feature buffer zone, then the pixel is labeled as marsh;*
- *If pixel belongs to TM class water and summer class high and slope < 0.05, then the pixel is labeled as marsh;*
- *If pixel belongs to TM class forest and SAR class high and slope < 0.05, then the pixel is labeled as nontidal swamp;*
- *If pixel belongs to TM class forest and spring SAR class high and in water feature buffer zone, then the pixel is labeled as tidal swamp;*
- *If pixel belongs to TM class sparse forest and SAR class low and slope < 0.05, the pixels labeled as treed bog/fen;*
- *If pixel belongs to TM class open bog/fen and slope < 0.05 and summer SAR class low, then the pixel is labeled as open bog/fen;*
- *If pixel belongs to TM class herb/fallow field and slope < 0.05 and spring SAR class lowest and summer SAR class low, then the pixel is labeled as open bog/fen;*

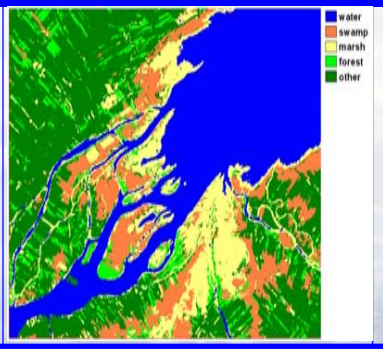
3 Testing sites

Three sites: Mer Bleue (a large peat bog located 10km east of the city of Ottawa in the Ottawa river valley), Lac St. Pierre (marsh and forest swamp are the main wetland types in this area), Goosebay, Newfoundland (black spruce, lichen forests, open bogs and open fens dominate the landscape) were used to test the approach. Right maps show the classified wetland maps for three sites.

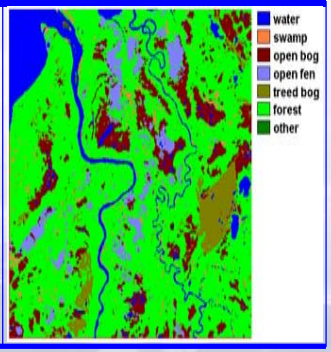
1. Mer Bleue, Ontario



2. Lac St. Pierre, Quebec



Goose Bay, Newfoundland



Wetland Classification System

Fen Bog Swamp

Image source: http://www.qc.ec.gc.ca/

1. Fens
   open fens: *no-treed, grassy fens*; treed fens: *fens with shrub cover and a low to high density of tree cover*;
2. Bogs
   open bogs: *non-treed bogs*; treed bogs: *Bogs with a low to high density of tree cover.*
3. Swamps:*forested wetlands with water table at or below the surface, they have deciduous or coniferous trees.*
4. Marsh: *have shallow, fluctuating surface water,and may contain emergent aquatic vegetation.*
5. Shallow water: *they are transitional between seasonally wet wetlands and permanent deeper Waters (lakes).*

Accuracy assessment

The Kappa coefficient is used to evaluate accuracy for wetlands classification. To evaluate the performance of this approach (denoted as method 1), we also classified wetlands by using Landsat-7/ETM+ only (denoted as method 2) and both Landsat-7/ETM+ and two seasons Radarsat-1/SAR (denoted as method 3) with a decision tree classifier. Three tables show the wetlands classification accuracy of three methods.

Table 1. Mer Bleue, Ontario

	Open bog	Treed bog (covered by low-middle dense tree)	Marsh
Method1	0.92	0.87	0.89
Method2	0.89	0.74	0.47
Method3	0.85	0.83	0.71

Table 2. Lac St. Pierre, Quebec

	Swamp (covered by low-middle dense tree)	Marsh
Method1	0.88	0.90
Method2	0.24	0.67
Method3	0.79	0.85

Table 3. Goose Bay, Newfoundland

	Open bog	Open fen
Method1	0.85	0.83
Method2	0.83	0.79
Method3	0.78	0.80

* Validation data for swamps and treed bogs is not available for this site.

Conclusions

The initial results are promising and show that the wetland classification got a significant improvement when the approach was used compared to when traditional methods used on Landsat-7/ETM+ or both Landsat-7/ETM+ and Radarsat-1/SAR. More specifically, the achievements include:

1. Swamps covered by low-middle dense forest was successfully detected;
2. The treed peatlands were delineated from sparse forest class;
3. Misclassification on open wetlands is reduced ;

However, the method has a problem to detect high dense forest covered wetlands because C-band Radarsat-1/SAR can not penetrate high dense forest. The ongoing work will incorporate L-band JERS-1/SAR image to the approach for mapping swamps covered by middle-high dense forest and more testing sites will be selected to improve the method.

Acknowledgements

The authors are very grateful to Josef Cihlar (NRCan), Mario Beauchemin (NRCan), Jennifer Sokol (NRCan), Nancy Hoffmann (Statistics Canada), Canada NWI technical group, and NASA/JPL wetland research group for their assistances.