Monitoring Changes in Cropping Practices Using Optical and Radar Imagery

Jiali Shang, Heather McNairn, Catherine Champagne

Agriculture and Agri-Food Canada, Research Branch, Ottawa, Ontario, Canada

Background

- Agriculture plans an important role in Canada's economy. Annual information on agricultural land use would permit more efficient and effective delivery of agricultural programs and policies supporting the economic and environmental sustainability of this sector.
- Since 2004, Agriculture and Agri-Food Canada (AAFC) has carried out a multi-year (2004-2007), multi-sensor (Landsat TM, SPOT, RADARSART-1, ASAR), and multi-site (five provinces: Ontario, Saskatchewan, Alberta, Manitoba, P.E.I.) research activity to develop a robust methodology to inventory crops across Canada's large and diverse agricultural landscapes. Results clearly demonstrated that multi-temporal satellite data can successfully classify crops for a variety of cropping systems across the country. Overall accuracies of at least 85% were achieved, and most major crops (corn, wheat, and soybean) were also classified to this level of accuracy.

Introduction

- EO-based geospatial information on crop type can supplement statistical surveys during non-census years. As well, spatially explicit information permits assessment of land use activities at user-specified units including, for example, watershed, political or eco-region boundaries. In addition to generating annual crop inventory maps, historical land-use information can be used to monitor changes in cropping practices. A four-year (2004-2007) study carried out by AAFC's Earth Observation Ottawa Branch Team (EO^{2}RBT) over a pilot site in Eastern Ontario demonstrated the significant advantage gained by the use of EO-derived spatial information (McNairn *et al*., 2007).
- In 2007, increased demand for bio-fuel crops and corn prices lead to an expected increase in corn acreage in areas of Southern Ontario and Quebec. To demonstrate how EO-derived crop survey information could be used to detect this change, historical crop inventory maps were analyzed to determine the magnitude of the corn-acreage increase.

Study Site

- The study site is centred around the town of Casselman, about 50 km east of Ottawa, Ontario, Canada. This site consists primarily of corn, soybean, cereal, and forage production.

Figure 1. Five pilot sites have been selected to assess crop inventory methods using EO-data. The current study focuses on the Eastern Ontario Site.

Data Collection

- EO data were acquired from optical sensors (Landsat-5 and SPOT-4) as well as two SAR sensors (RADARSAT-1 and Envisat-ASAR) throughout the growing season to capture the key signatures of the growth cycle.

Table 1. EO Data Acquired over Four Growing Seasons (2004 – 2007), Eastern Ontario (number of scenes)

	2004	2005	2006	2007
Landsat TM	3	3	3	3
SPOT	3	2	3	4
ASAR (VV/VH)	4	6	5	3
RADARSAT-1 (HH)	4	12	10	5

- Ground data acquired include crop type and crop growth stage. Fields were visited 3 times in mid June, late July, and late August.

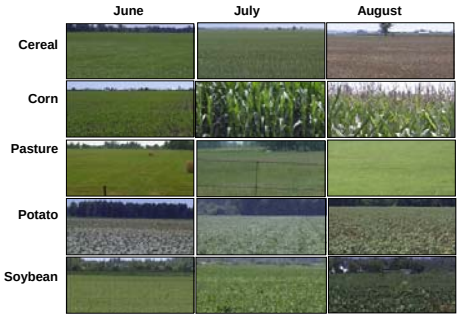

Figure 2. Phenology of major crops over Eastern Ontario.

Data Processing and Analysis

- Optical data were atmospherically corrected to retrieve at-surface reflectance.
- Radar data were absolutely calibrated by the data provider. Speckles were filtered using 2 passes of 3x3 Gamma filter.
- Supervised classification was performed on combinations of optical and radar data using a decision tree classifier.

Results and Discussion

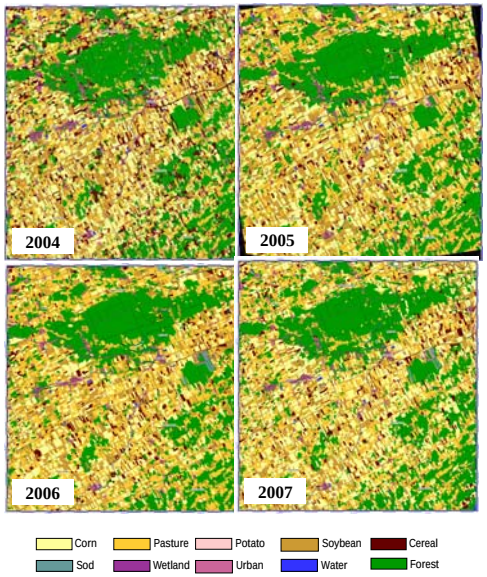

Figure 3. Land-use maps derived from multi-temporal optical and radar data integration over Eastern Ontario from 2004 to 2007..

Based on multi-year study over multiple sites, it has been consistently found that:

- Multi-temporal optical data are ideal for crop classification.
- Radar can support crop classification. The integration of a single radar image and a single optical image provide an alternative when multi-temporal cloud-free optical images are not available. However the timing of data acquisition is critical.
- For both optical and radar, single-date classifications using data acquired later in the growing season provided best overall classification accuracy.

Area Adjustment in Monitoring Land-Use Change

- Adjusting the area estimates based on the crop classification accuracy accounts for annual differences in the map accuracies, leading to more reliable area estimates. This can be achieved by multiplying the original crop acreage by the user-probability matrix (McMahon, 2007).

User's Accuracies from Confusion Matrix

	Pasture-Forage	Soybean	Corn	Cereals	Potato
Pasture-Forage	**0.990**	0.000	0.008	0.003	0.000
Soybean	0.000	**0.936**	0.054	0.009	0.000
Corn	0.007	0.039	**0.950**	0.004	0.000
Cereals	0.000	0.000	0.000	**1.000**	0.000
Potato	0.000	0.000	0.000	0.103	**0.897**

Area Estimates Before Adjustment (pixels):

Pasture-Forage	Soybean	Corn	Cereals	Potato
259470	274869	**351740**	128842	3579

Calculate Area Correctly Classified as Corn and Area & Area of Other Crops Misclassified that should be Corn (pixels):

Pasture-Forage	Soybean	Corn	Cereals	Potato
1726	10772	**334017**	555	0

→ **Sum: 347070**

351470 x 0.950

Figure 4. Example of area adjustment using probability matrix

Table 4. Corn Acreage over Four Growing Seasons (2004 – 2007), for a 5-county area in Eastern Ontario (acres)

	2004	2005	2006	2007	3 year Avg	% increase over Avg	% increase over 2006
Before Adjustment	78225	65479	61629	91568	68444	**33.8**	**48.6**
After Adjustment	77186	64296	61505	85823	67662	**26.8**	**39.5**

- Results indicate that for an area covering five municipalities, corn acreage over a three year period from 2004 to 2006 remained relatively constant, but showed an increase of 27% in 2007 over the average acreage of the previous three years. This adjusted number is consistent with regional estimates reported by Statistics Canada through direct survey

Conclusions

- EO data can be used successfully in crop inventory mapping; EO-based geospatial information on crop type can supplement statistical surveys during non-census years.
- When calculating change in crop acreage, area adjustment should be exercised in order to achieve a more realistic estimates.

References

- McMahon, G. (2007). Consequences of land-cover misclassification in models of impervious surface. PE&RS, Vol., 73, No. 12, pp. 1343-1353.
- McNairn, H., Champagne, C., Shang, J. (2007). The value of SAR multi-polarization data in delivering annual crop inventories, Proceedings of the IGARSS 2007, Barcelona, Spain, CD-ROM.

Acknowledgements

- Funding for this research was provided by the Canadian Space Agency under GRIP (Government Related Initiative Project).