The Contribution of ALOS PALSAR Multi-polarization and Polarimetric Data to Crop Classification

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Summary of originally proposed research

Mapping and monitoring changes in the distribution of cropland provide information that aids sustainable approaches to agriculture and supports early warning of threats to global and regional food security. This project tested the capability of PALSAR multipolarization and polarimetric data for crop classification. L-band results were compared with those achieved with a C-band SAR data set (ASAR and RADARSAT-1), an integrated C- and L-band data set, and a multitemporal optical data set. Using all L-band linear polarizations, corn, soybeans, cereals, and hay-pasture were classified to an overall accuracy of 70%. A more temporally rich C-band data set provided an accuracy of 80%. Larger biomass crops were well classified using the PALSAR data. C-band data were needed to accurately classify low biomass crops. With a multifrequency data set, an overall accuracy of 88.7% was reached, and many individual crops were classified to accuracies better than 90%. These results were competitive with the overall accuracy achieved using three Landsat images (88.0%). L-band parameters derived from three decomposition approaches (Cloude–Pottier, Freeman–Durden, and Krogager) produced superior crop classification accuracies relative to those achieved using the linear polarizations. Using the Krogager decomposition parameters from all three PALSAR acquisitions, an overall accuracy of 77.2% was achieved. These results emphasize the value of polarimetric, as well as multifrequency SAR, data for crop classification. With such a diverse capability, a SAR-only approach to crop classification becomes increasingly viable.

Keywords: PALSAR, RADARSAT, ASAR, crop classification, multifrequency

1. MULTI-FREQUENCY AND POLARIMETRIC SAR FOR CROP INFORMATION

Timely crop information is required to monitor, forecast and respond to emerging agricultural risk. This information also supports the targeting and assessment of national agricultural policies and programs which are designed to promote the economic and environmental sustainability of this sector. In response to this need Agriculture and Agri-Food Canada (AAFC) has on-going research activities to develop the methods needed to derive crop information from both optical and synthetic aperture radar (SAR) satellite data. The conclusion of a 4-year research project demonstrated that multi-temporal optical data, fused with C-Band multi-polarization SAR data, can produce consistent and reliable crop classifications [1]. The Canadian federal government is also investing in programs which target increased exploitation of biomass from crops for use in bioproducts and biofuels. Monitoring Canada's capacity for biofuel production, and the impact of shifting agricultural practices in response to this policy, is of critical importance.

The research objectives associated with the agricultural applications development portion of this ALOS project included:

1) to determine whether the integration of L-Band multi-polarization data, with C-Band SAR and optical satellite data, can improve overall and individual crop classification accuracies; and
2) to determine whether L- and C-Band polarimetric variables can assist in crop discrimination; and

ALOS-related field campaigns were run for two consecutive growing seasons, 2006 and 2007. The AAFC study site is located within the city of Ottawa, Canada (45°17'N / 75°46'W) where the Canadian Food Inspection Agency (CFIA) has provided access to its experimental fields. A total of 18 fields were accessible during each field campaign, coincident with each ALOS PALSAR acquisition. The average field size within the CFIA site was 24.6 ha. The pixel spacing of the ALOS PALSAR data in polarimetric mode is in the order of 10m, therefore an average of 2460 pixels per field were available. The smallest field offers 870 samples and the largest one 4170 samples. The crop mix within these intensive fields included corn, hay/forage, alfalfa, soybean, wheat and oats.

In 2006, near-coincident ALOS PALSAR and RADARSAT-1 acquisitions were planned (Table 1). In addition, a series of Envisat ASAR dual-polarization data were acquired, along with available cloud-free Landsat TM imagery. PALSAR data were acquired in polarimetric mode (incidence angle of 21.5^{o}), RADARSAT-1 in Standard Mode 1 (angles of approximately 20-27^{o}) and ASAR data in Alternating Polarization Modes 1-4 (angles of approximately 15 to 36^{o}). In 2007, only the May PALSAR image was fully polarimetric; the remainder being Fine Mode acquisitions (HH and HV polarizations and 41.5^{o} incidence angle). RADARSAT-1 images could not be acquired as temporally coincident as in 2006. RADARSAT-1 images were primarily Standard Mode 3 (incidence angles of approximately 30-37^{o}). No ASAR data were programmed. However, a limited number of cloud-free ALOS AVNIR-2 and TM images were purchased.

Five priority fields were selected from the 18 CFIA fields. An average of 3 sampling sites per field were selected based on field representativeness and accessibility, soil maps and other geospatial information such as NDVI products derived from Landsat TM imagery. At each of these three sites within the five priority fields, crop biomass samples were collected, weighed and dried to provide data on both wet and dry biomass as well as plant water content. The crop density, crop height and phenology were also recorded during the biomass collection. SPAD measurements were taken during the PALSAR field campaigns when green crop biomass was present. These SPAD measurements were collected for all the CFIA fields. Surface soil moisture measurements were taken at samples sites within all CFIA fields using ThetaProbe (0-6 cm) and Mini Trase (0-15 cm) instruments.

Table 1. Satellite Data Collected

	2006	**2007**
ALOS PALSAR	May 20 PLR July 5 PLR Aug 20 PLR Oct 5 PLR	May 23 PLR July 1 FBD Aug 16 FBD Oct 1 FBD
ALOS AVNIR-2		May 5 Nov 11
Envisat ASAR	May 27 IS3 June 9 IS1 July 1 IS3 July 14 IS1 Aug5 IS3 Sept 18 IS4	
RADARSAT-1	May 18 S1 July 5 S1 Aug 22 S1	June 23 S3 July 17 S3 Aug 10 S3 Aug 24 S1 Sep 3 S3
Landsat TM	June 5 July 7 Aug 8	June 24 July 26 Aug 27

In addition to the CFIA intensive site, qualitative information on crop type, growth stage and condition were collected on more than 200 fields surrounding the CFIA site, for both 2006 and 2007. These observations were used for training and testing of the crop classification algorithm. AAFC uses a Decision-Tree classification approach along with post-classification object-oriented filtering [1].

2. RESULTS

Analysis was focused on assessing the contribution of L-Band multi-polarization data to crop classification. The 2006 data permitted the assessment of C-Band versus L-Band data for crop classification. In this analysis, RADARSAT-1 and PALSAR data were acquired near-coincident in the growing season and at approximately the same incidence angle. Only classification results with L-HH and C-HH data were compared. This comparison demonstrated that L-Band provided slightly higher overall classification accuracies. However, although the longer wavelength L-Band data were better at classifying large biomass crops such as corn, C-Band provided better classifications for lower biomass crops such as hay-pasture. The sensitivity of frequency as a function of vegetation biomass is expected. This result reveals the value of integrating multi-frequency SAR data in order to achieve optimum classification accuracies. When results from individual linear L-Band polarizations were compared, the cross-polarization channel provided the highest accuracies, consistent with previously reported C-Band results.

The benefit of integrating multi-temporal PALSAR (HH, VV, VH) and RADARSAT-1 (HH) data were clear. Classification accuracies of 76.5% were achieved using this combination of data (3 dates of PALSAR and RADARSAT). SAR images acquired early in the growing season produced the poorest accuracies, while late season SAR images were key to a successful classification. A single Landsat TM image acquired late in the season provided acceptable classification accuracies (84.3%). Integration of multi-temporal L- and C-Band SAR significantly improved classification results over the use of a single early or mid season Landsat image (Figure 1). Improvements in accuracies over classifying a single late season optical image were not evident.

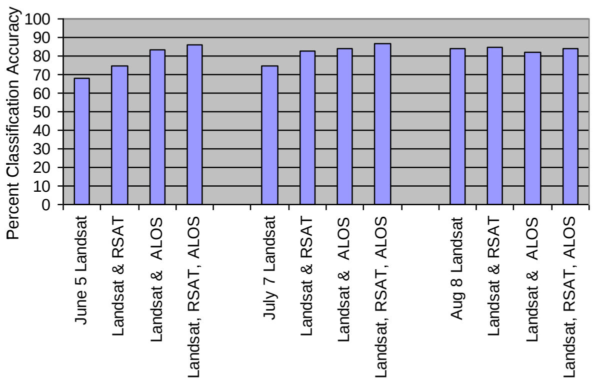

Figure 1.Comparison of Crop Classification Accuracies

Post-classification object-based filtering was applied. The best results were achieved using a mid-season Landsat TM image (July 7) along with all 3 PALSAR and RADARSAT-1 images (acquired late May, early July and late August). With this combination an overall crop classification accuracy of 91.7% was achieved (Figure 2).

With polarimetric data from sensors such as ALOS PALSAR, users are no longer restricted to exploiting backscatter recorded for linear polarizations for the purpose of land cover and land use classification. The parameters derived from three decomposition approaches (Cloude–Pottier, Freeman–Durden, and Krogager) were tested within the Decision-Tree classifier. Using parameters derived from all three dates of polarimetric PALSAR data, all three decomposition approaches produced superior crop classification accuracies relative to those achieved using the L-band linear polarizations. Using the Krogager decomposition parameters, an overall accuracy of 77.2% was achieved. Although all crops fall within the same class of scatterers, the differences in the relative contributions of scattering mechanisms among the crops and over the growing season were sufficient for discrimination.

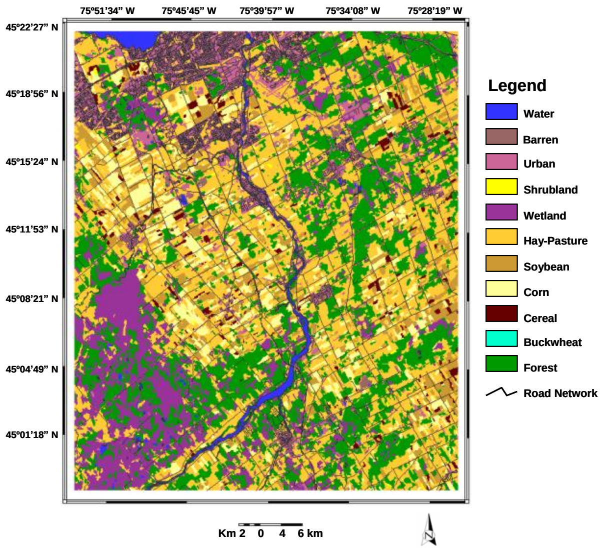

Figure 2.Crop Map Derived Using a Single Landsat TM (July 7) Image and Three Dates of ALOS PALSAR and RADARSAT-1 (overall accuracy is 91.7%).

[1] McNairn, H., Champagne, C., Shang, J., Holmstrom, D.A., and Reichert, G. (2009). "Integration of optical and Synthetic Aperture Radar (SAR) imagery for delivering operational annual crop inventories.", ISPRS Journal of Photogrammetry and Remote Sensing, 64(5), pp. 434-449.

McNairn, H., Shang, J., Jiao, X., and Champagne, C. 2009. The Contribution of ALOS PALSAR Multi-polarization and Polarimetric Data to Crop Classification, IEEE Geoscience and Remote Sensing, 47(12): 3981-3992.

Shang, J., McNairn, H., Champagne, C. and Jiao, X. 2008. Contribution of multi-frequency, multi-sensor, and multi-temporal radar data to operational annual crop mapping. International Geoscience and Remote Sensing Symposium, Boston (Massachusetts), 7-11 July 2008, 4 pp.

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