MONITORING GRASSLANDS WITH RADARSAT 2 QUAD-POL IMAGERY

Joseph R. Buckley

Royal Military College of Canada
Department of Physics
PO BOX 17000, Stn. Forces,
Kingston, ON, CANADA, K7K 7B4

*Anne M. Smith**

Agriculture and Agri-Food Canada
Remote Sensing Applications
P.O. Box 3000,
Lethbridge, AB, CANADA, T1J 4B1

1. INTRODUCTION

Native grasslands historically covered about 350 Mha of North America. Today, despite their ecological and economic importance, only 1-2% of the native grasslands remain, due to expansion of intensively cultivated agriculture and urban development. The status of the remaining grasslands is not only of economic importance as forage for the cattle industry but is important in maintaining plant and animal diversity and acting as sink for carbon sequestration. We have been exploring the utility of quad-pol synthetic aperture radar as a monitoring tool for this region, in a project focused on rangeland management issues of health, fragmentation and spread of invasive weed species, with secondary goals of crop identification and delineation. The project acquired almost 200 Radarsat 2 images, as well as airborne lidar and hyperspectral data, and significant amounts of ground truth information. Here we report on our initial findings from the Radarsat 2 imagery.

2. BACKGROUND

The ability of polarimetric radar to respond to the morphology of vegetation independently from its response to soil moisture makes it potentially a much more useful tool for ground cover monitoring than single polarization radar, in whose imagery both moisture and morphology are mixed, and consequently cannot be separately assessed. Pioneering work by Ulaby and Dobson [1] showed how polarimetric ratios could be used to differentiate types of vegetated and non-vegetated surfaces. Freeman and Durden [2] proposed a model-based decomposition of polarimetric radar imagery to assess the contributions of surface, volume and double-bounce scatterers to the full polarimetric response of a region. Cloude and Pottier [3] proposed a purely statistical approach to understanding the relative importance of different scattering mechanisms in an image. These approaches to polarimetric decomposition have been used by many authors to examine the small number of airborne and experimental spaceborne fully polarimetric images available.

With the launch of Radarsat 2 in December 2007, and the consequent availability of C Band quad pol (HH, HV, VH, VV) imagery, these decomposition tools may now be used operationally in projects requiring wide area coverage, or time series of imagery. The project discussed here is one such project. One significant drawback of Radarsat 2 for ground cover studies is its short wavelength. The 5.5 cm radiation is too short to penetrate thick foliage, and the backscatter signal saturates at relatively low biomass[4]. Rangeland vegetation is relatively sparse and short in height, and therefore saturation should not be a problem, so C Band polarimetry could be an ideal tool for vegetation studies in these regions.

*This work was sponsored by the Government Research Initiatives Programme of the Canadian Space Agency

3. EXPERIMENTAL DESIGN

Radarsat 2 provided the principal data set for this project. Fine mode, quad-pol images were collected over three areas of southern Alberta (Fig.1). A set of 21 different images was defined to cover these areas at both steep and shallow incidence angles, and on both ascending and descending passes, to assess the effects of incidence angle and surface moisture (dew) on our ability to meet the program goals. Acquisition of this image set was requested for every 24 day repeat period of the satellite from 1 April to 31 October, 2009. In all, 192 images were acquired.

Airborne hyperspectral and lidar data were acquired over one of the prime experimental sites in July, and site visits, where ground cover conditions were assessed visually, photographed and located with GPS, were conducted throughout the acquisition campaign.

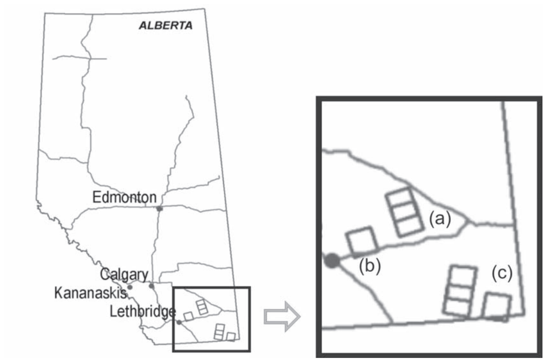

Fig. 1. Locations of Radarsat 2 imagery acquisitions: (a) Newell County, (b) Taber (c) OneFour

4. NATIVE GRASSLAND ANALYSIS

We focused first on the agricultural and range lands of Newell County (Fig.1(a)). All ascending mode imagery was filtered with a Lee Sigma filter [5] then subjected to a Freeman-Durden decomposition[6] to separate regions of broadleaf crops (potatoes, canola, corn), narrow leaf crops (wheat, barley) and grassland and to assess the relative biomass in each region. Results of these calculations yield imagery in which definition of regions of land cover is similar to that seen in traditional multispectral imagery (Fig. 2 for example). A supervised classification of the Radarsat-2 July 21 FQ-16 using Decision Tree methodology [7], [8], on the three Freeman parameters, gives classification accuracies almost as good as those resulting from application of the same procedure to Landsat imagery acquired at almost the same time. The classification using Radarsat 2 imagery is, of course, not influenced or occluded by weather or solar illumination conditions as the Landsat classificaiton would be.

The time series of FQ 16 imagery shows very different behaviour for broad leaf crops, narrow leaf crops and grassland. As shown in Fig. 3 (left), volume scattering increased significantly throughout the growing season for broad leaf crops, modestly for narrow leaf crops and not at all for grasslands. In contrast, the surface scattering (Fig. 3 (right))did not change significantly for any vegetation type throughout the season.

Examination of histograms of backscattered energy from the Freeman decomposition (Fig. 4 shows that most land cover regions are apparently K distributed, indicating homogeneity of scatterers in each region. Deviations from the shape of the ideal K distribution imply a heterogeneity of scatterers in a region. At present, these observations are speculative. Continuing work will focus on calculating how well the observed distributions actually match the expected K distributions.

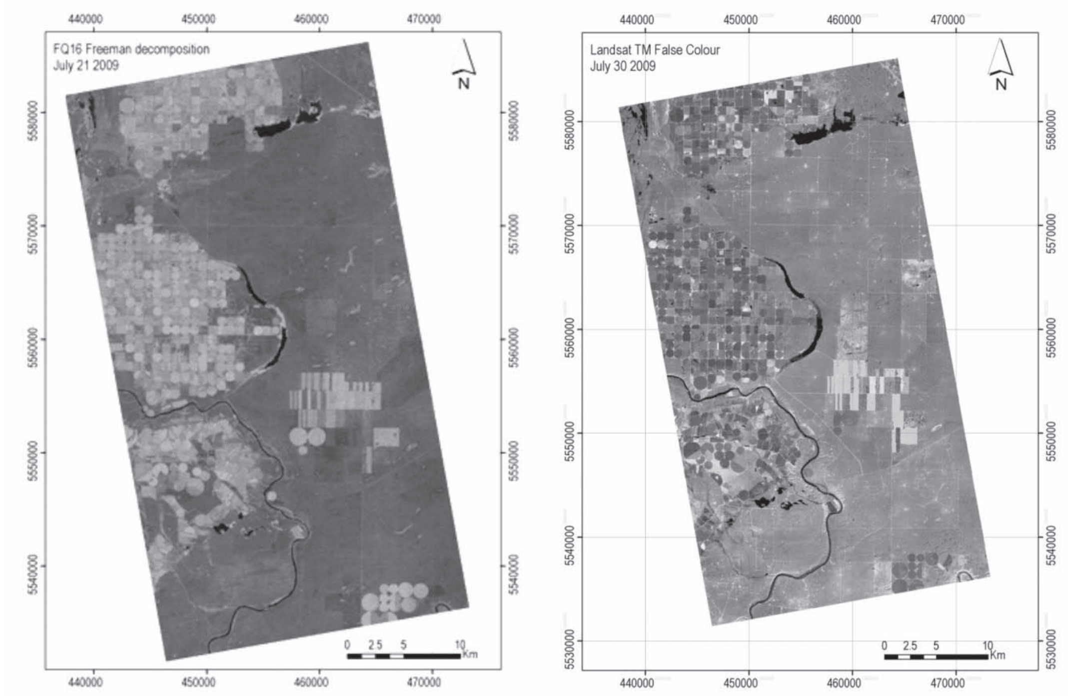

Fig. 2. (left) Radarsat 2 FQ16 July 21, 2009, Freeman decomposition, (right)Landsat 5 July 30, 2009 4,3,2 image.

5. INVASIVE WEED ANALYSIS

A second area of early analysis in this project is our attempt to identify and delineate patches of the invasive weed Leafy Spurge (*Euphorbia esula*). Detailed study of this problem is taking place in rangeland on the north bank of the Oldman River (Fig.1(b)), where detailed field surveys have mapped the boundaries of several Spurge patches, as well as patches of two other weed species: sagebrush (*Artemisia tridentata*) and buckbrush (*Symphoricarpos occidentalis*) mixed in with native grasses. Both Freeman and Cloude-Pottier decompositions were performed for the Radarsat 2 imagery over the area, and mean parameters were computed for selected regions defined as homogeneous by the filed observations. Bhattacharyya distances, based on the nine parameters of the full coherency matrix (six amplitudes and three inter-pol pase differences), were computed [9] between the three types of invasive weeds, native grassland, trees, water, oil and gas infrastructure (small buildings, pumpjacks and the like) and bare ground. All classes were separable with a Bayes error of no greater than 0.16, the least separability being between the three types of weed. The separability of these weeds from all other classes of vegetation was significantly higher. Work continues on this part of the project to translate these separability criteria into an operational classification system.

6. REFERENCES

[1] F. T. Ulaby and M. C. Dobson, *Handbook of Radar Scattering Statistics for Terrain*, Artech House, 1989.

[2] A. Freeman and S.L. Durden, “A Three-Component Scattering Model for Polarimetric SAR Data,” *IEEE Trans. Geoscience Rem. Sens.*, vol. 36, no. 3, pp. 963–973, 1998.

[3] Shane R. Cloude and Eric Pottier, “An entropy based classification scheme for land applications of polarimetric SARs,” *IEEE Trans. Geoscience Rem. Sens.*, vol. 35, no. 2, pp. 68–78, 1997.

[4] Jong-Sen Lee and Eric Pottier, *Polarimetric Radar Imaging: from Basics to Applications*, CRC, 2009.

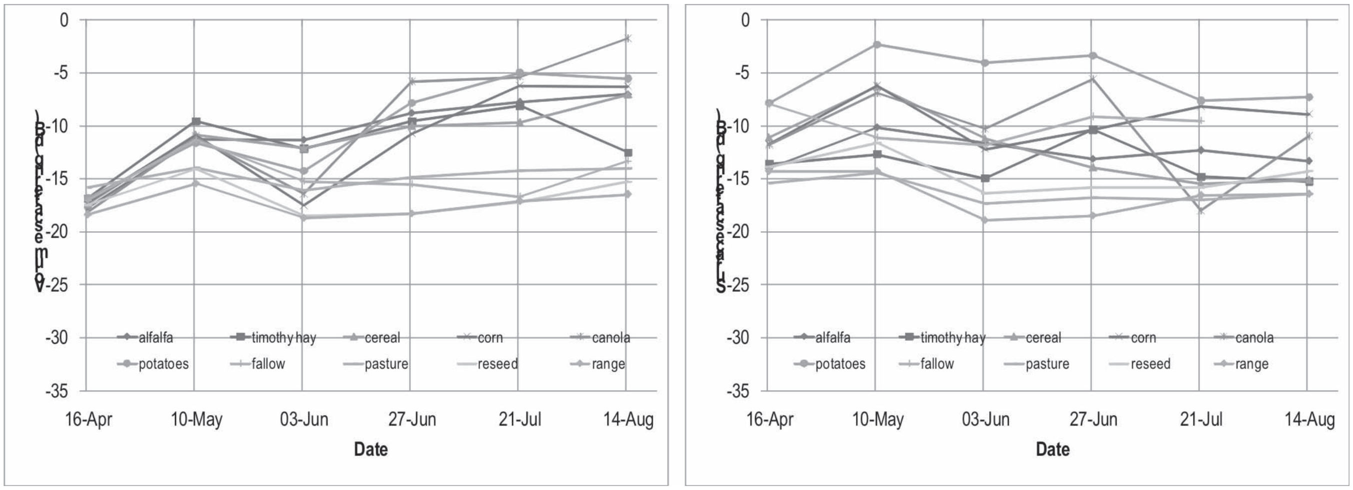

Fig. 3. (left) Time series of mean backscatter energy for ten land cover types. (left) Freeman Volume scattering. (right) Freeman surface scattering.

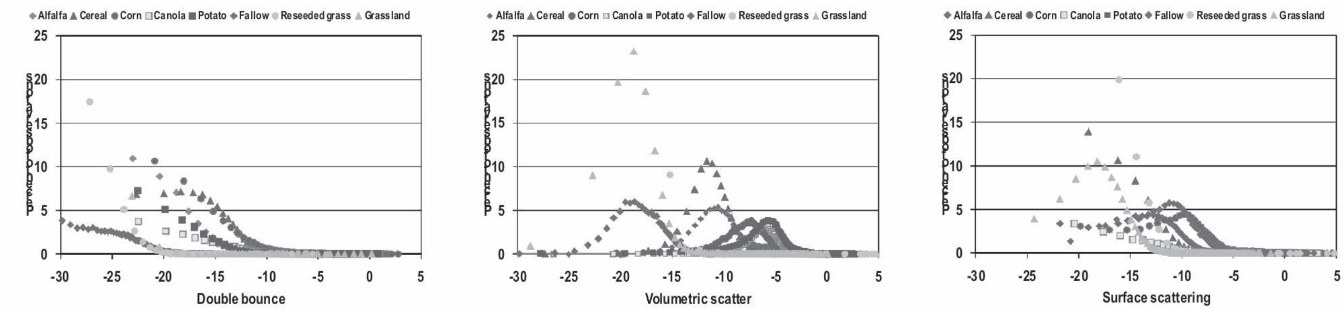

Fig. 4. Histograms of the Freeman backscattered energy in Double Bounce, Volume and Surface scattering types for seven different land cover types from a Radarsat 2 FQ3 image acquired 21 July over Newell County.

[5] European Space Agency, *PolsarPro*, Software Copyright 2005-09.

[6] A. Freeman, J. Villasenor, J.D. Klein, P. Hoogeboom, and J. Groot, "On the use of Multi-Frequency and Polarimetric Radar Backscatter Features for Classification of Agricultural Crops," *Int. J. Rem. Sens.*, vol. 15, no. 9, pp. 1799–1812, 2001.

[7] Marc Simard, Sasan S. Satchi, and Gianfranco De Grandi, "The use of decision tree and multiscale texture for classification of JERS-1 SAR data over tropical forest.," *GRS*, vol. 38, pp. 2310 – 2321, 2000.

[8] Heather McNairn, Catherine Champagne, Jiali Shang, Delamr Holmstrom, and Gordon Reichert, "Integration of optical and synethtic aperture radar (sar) imagery for delivering operational annual crop inventories.," *ISPRS J. Photogrammetry and Remote Sensing*, vol. 64, pp. 434–449, 2009.

[9] J. Morio, Ph. Réfrégier, F. Goudail, P. Dubois-Fernandez, and X. Dupuis, "Application of information theory measures to polarimetric and interferometric SAR images," in *Physics in Signal and Image Processing, 2007*, Mulhouse, France, 31 Jan – 2 Feb. 2007.