MAPPING CROP CHARACTERISTICS USING MULTITEMPORAL RADARSAT IMAGERY*

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ABSTRACT

Although research related to the use of remote sensing for crop mapping and monitoring has been conducted extensively in the past, the all weather capability of SAR and the steerable beams associated with RADARSAT mean that the availability of cloud free imagery during critical phenological stages has improved significantly. The Canada Centre for Remote Sensing is involved in a multi-year study to investigate the use of RADARSAT data for operational crop type mapping and crop condition assessment. Results to date indicate that a single RADARSAT acquisition during the crops' reproductive and seed development stages is better able to discriminate crop type when compared to a SPOT XS scene acquired during the same period. Multi-date RADARSAT and optical data provide very good crop type discrimination, although separating spring wheat is still difficult.

1.0 INTRODUCTION

The dynamic nature of vegetation growth and cropping patterns, together with the large geographic extent of the agricultural resource base, challenges our ability to gather information on cropping practices and to monitor crop growth over the growing season. In response to this challenge, visible-infrared satellite imagery has been providing useful information on agricultural targets for more than two decades. However, sensors operating in the microwave region - including Canada's RADARSAT - offer several advantages over optical sensors. For time critical applications, such as early estimation of crop yield, the ability of radar sensors to gather target information regardless of cloud cover is often of significant importance.

A large number of previous studies, using primarily ground-based scatterometers or airborne SAR systems, have demonstrated the ability of K-band (Bush and Ulaby, 1978), X-band (Hoogeboom, 1983), C-band (Brown *et al*., 1992) and L-band (Ulaby *et al*., 1980) radar to discriminate crop cover classes. Other research has reported the improvement in crop classification when both visible-infrared and active microwave data are used together (Rosenthal and Blanchard, 1984) and has demonstrated the advantages of multidate visible-infrared and SAR datasets (Brisco and Brown, 1995).

The flexibility associated with RADARSAT beam steering suggests that this sensor can provide the imagery required for crop mapping and monitoring, at a significantly improved revisit schedule. Within the Applications Development Section of the Canada Centre for Remote Sensing (CCRS), the agriculture group has been involved in a multi-year study which includes examining the information content of RADARSAT data for crop type and condition assessment, as well as determining the effects of time of day, environmental conditions and incidence angle on the operational use of RADARSAT data. In

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particular, this paper examines the separability of crop type based on single and multi-date RADARSAT acquisitions, as well as available visible-infrared imagery. Backscatter responses to crop type and growth stage are discussed in order to optimize RADARSAT acquisitions for crop characterization.

2.0 METHODOLOGY

The site used in this study is centered on the town of Carman (98^{o}00' W longitude, 49^{o}30' N latitude), located in southern Manitoba, Canada. The site covers an area of approximately 10 km (north-south) by 30 km (east-west). Both sandy and heavier clay soils are found across the site and this soil mix is reflected in the diversity of agricultural crops.

CCRS collected a total of 10 standard and fine mode descending RADARSAT images over the Carman area during the months of June, July, August and September 1997 (Table 1). Several optical images were also acquired including SPOT XS (August 6) and IRS-1C PAN (July 4). Meteorological records were used to assess target conditions at the time of image acquisition.

To characterize field conditions during the 1997 growing season, crop information was collected on July 18-19, 1997 for approximately 300 fields in the Carman area. For each field the information recorded included crop type, phenological stage, crop height and percent crop cover. A photo was also taken at each field to record crop and field conditions. The main crops identified in the study site included spring wheat, barley, oats, flax, canola, corn, beans, peas, potatoes and sunflower. Differential GPS ground coordinates were gathered at road intersections at approximately 1-mile intervals across the study site. Positional accuracies for the GPS model used are well within a RADARSAT pixel (approximately 3-5 metres in the XY direction, 95% of the time). These data were used in the geocoding of the RADARSAT imagery.

All RADARSAT data delivered for this project contained the most recent antenna pattern correction and payload parameter file which were applied during processing at the Canadian Data Processing Facility (CDPF). Consequently, the data quality and calibration accuracies of this dataset are consistent with those reported by Srivastava *et al*. (1997) (< 1dB relative within scene accuracy). Prior to image interpretation, the CDPF processor applied look up table was removed from all scenes, creating radar brightness (β^o) images. The RADARSAT data were then geocoded using the satellite ephemeris information and a second order cubic convolution resampling algorithm. Each image was then registered to a field boundary vector map. RMS resampling errors were within a pixel. Using the information from the crop survey sheets, masks were drawn over selected homogeneous fields and mean power values extracted for each field. Mean power and standard deviation values were used to calculate the transformed divergence statistic, a measure of crop separability. This statistic has proven to be highly correlated with crop classification accuracies (Haack and Jampoler, 1995).

3.0 RESULTS AND DISCUSSION

Transformed divergence statistics were generated for all RADARSAT and optical acquisitions. Results from only the best three RADARSAT dates, as well as the optical scenes, are presented in Tables 2 and 3. Crops were considered separable if the transformed divergence statistic was greater than 1.5. All acquisitions, except July 18 (S1) were at shallower incidence angles (>35^o) which maximizes interaction with the crop canopy. For the Standard Mode 1 scene, poor separability is observed for all crops except the large broadleaf crops such as corn and canola. This suggests that for all other crop types, contributions to total backscatter may be present from the soil surface when observed at this steep angle. Early in the growing season, the relatively low vegetative cover and significant soil contribution result in poor separation among most crops. The exception was canola (June 28) which was separable from barley and corn. Soon after emergence, the canola crop covers most of the soil surface, providing greater interaction of the microwaves with the crop. However, it is not until peak vegetative growth that separability among crops using a single date is notable. In this agricultural region, during late July to early August, crops have completed their vegetative growth period and are now in their reproductive and seed development stage. During this stage, canopy moisture content and canopy structures change dramatically. The enhanced separability of crops at this phenology stage was also reported by Brisco and Brown (1995) for a similar site in the Canadian Prairies.

When using several RADARSAT acquisitions during the late July to early August time period, almost all crops are separable based on their backscatter responses. Spring wheat, however, is the exception. Brisco and Brown (1995) also reported poor separability of grain crops and suggested that this was due to the very similar structure among the various grain classes. For the data presented here, it appears that the difficulty is also related to the large variability in backscatter responses associated with the spring wheat class. In referring to field notes and photographs, wheat crops across the site were in various stages of growth including vegetative growth, heading, lodging and senescing. These variations are primarily a result of slight differences in planting dates.

Later in the growing season, differences in backscatter among cereal crops are reduced as all grain crops senesce and are harvested. Separability of broadleaf crops declines and may be related to the saturation of the signal as the crop canopies are fully developed.

In examining the transformed divergence statistics from the SPOT and IRS-1C images, barley is the only grain crop which can be separated from all other crops. In early August, the barley crops are almost completely senesced, producing a significantly different visible-infrared signature. Other grain crops are slightly behind in their growth stage relative to barley. A significant amount of confusion exists among broadleaf crops. Only corn and canola are separable using SPOT’s near-infrared band. Although crop structure is changing during this reproductive stage, most crops still have significant chlorophyll content and remain green. The IRS-1C image, acquired earlier in the season, is able to resolve some of those classes confused in the SPOT image. However, corn is still confused and grain crops cannot be separated.

Table 4 provides an overview of the best RADARSAT-VIR dates for crop classification. Spring wheat continues to be difficult to separate from some classes. A single RADARSAT acquisition (either July 22 or August 8) provides significantly better discrimination than the August 6 SPOT or July 4 IRS-1C. The best three RADARSAT scenes occur in late July/early August time period (July 22, August 5 and August 8). This compares well with Brisco and Brown (1995) who found that the highest multi-date crop classification accuracy for C-HH, was associated with June 24, July 21 and August 10. Using these 3 dates, the authors were able to classify crops to a 72% overall accuracy.

4.0 CONCLUSIONS

As part of the Canada Centre for Remote Sensing’s project to evaluate the use of RADARSAT for crop type and crop condition mapping, this paper reported on the separability of crop type using single-date and multi-date RADARSAT and optical data. The best separabilities were observed when crops were in the process of seed development. A single RADARSAT image acquired during the period of crop reproduction is better able to differentiate crops relative to a SPOT XS scene acquired during the same period. Multi-date RADARSAT and optical data provide very good discrimination of crops, although separating spring wheat remains difficult. Results from this study support those previously published, although this study extends the application of SAR for crop mapping from airborne and ground-based platforms to RADARSAT. Within field crop information has also been gathered on a sample of fields and work will continue to establish the information content of RADARSAT and VIR sensors for crop condition assessment.

5.0 REFERENCES

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Table 1. 1997 RADARSAT Descending and Optical Data Acquisition Schedule Over Carman, Manitoba

Date	**Acquisition Mode**	**Incidence Angles**
June 28	Fine 2	39-42^o
July 4	IRS-1C PAN	
July 5	Fine 4	43-46^o
July 15	Standard 4	34-40^o
July 18	Standard 1	20-27^o
July 22	Fine 2	39-42^o
July 29	Fine 4	43-46^o
August 5	Fine 5	45-48^o
August 6	SPOT XS	
August 8	Standard 4	34-40^o
August 15	Fine 2	39-42^o
August 22	Fine 4	43-46^o