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VISUAL INTERPRETATION RESULTS OF MULTIPOLARIZATION C-SAR IMAGERY OF ALBERTA BOREAL FOREST

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ABSTRACT

This study presents preliminary results of a comprehensive program undertaken by the Canada Centre for Remote Sensing (CCRS) to achieve an understanding of the relationships between microwave backscatter and forest stand parameters. The area selected for study is near Whitecourt, Alberta, located about 200 km northwest of Edmonton. The boreal forest north of Whitecourt is characterized by a complex set of ecosystems and cover types ranging from recent burn regrowth to mature and over-mature softwood stands.

On June 27 and 28, 1988 the CCRS C-band SAR collected like (VV) and cross (HV) polarization data over six sites representing the major ecosystem groups within the Whitecourt study site. The SAR data were processed to image form in real time onboard the aircraft with a 6 m nominal resolution. Image interpretation was carried out using prints and transparencies of contrast stretched data produced on a commercial image recorder.

Interpretation results show significant differences between the information content of like (VV) and cross (HV) polarization images. Several forest types could be clearly differentiated and results indicate that backscatter intensities appeared to relate to tree species and total biomass.

KEY WORDS: SAR, forestry, forest types, Alberta

1. INTRODUCTION

Interest in SAR for monitoring global vegetation change is steadily increasing as spaceborne SAR platforms are being developed (RADARSAT, ERS-1). Worldwide deforestation and the health and nature of existing forest is of great concern. To date, an understanding of the relationship between SAR backscatter and forest parameters, which is a prerequisite to any forest monitoring program, is relatively limited. This is especially true in the case of Canadian literature dealing with airborne SAR. Published C-band SAR studies include an investigation of conifer regeneration, mature forest types and wetland identification in Eastern Ontario (Leckie, 1984), texture analysis of SAR in a Gaspe Peninsula site (Landry et al., 1988) and a quantitative analysis of clearcut mapping accuracies in an Alberta boreal forest site (Ahern and Drieman, 1988).

This study presents preliminary results of the first phase of a comprehensive program undertaken by the Canada Centre for Remote Sensing (CCRS) to achieve a better understanding of the relationships between SAR backscatter and forest stand parameters, landforms, and related surficial drainage. The data acquired for this investigation was airborne C-band HV and VV polarization SAR.

2. STUDY SITE AND DATA ACQUISITION

The study site is located about 200 km northwest of Edmonton, north of the town of Whitecourt. This site is in the boreal forest zone, consisting of the Upper and Lower Boreal Cordilleran (UBC, LBC) and Boreal Mixedwood (BMW) ecoregions, as defined by Forestry Canada (Corns and Annas, 1986). Mature stands common in the northern portion of the study site (UBC and LBC ecoregions) consist of white and black spruce (Picea glauca, Picea mariana), balsam fir (Abies balsamea), and lodgepole pine (Pinus contorta), the latter often occurring as pure stands. Hardwood stands of balsam poplar (Populus balsamifera) and trembling aspen (Populus tremuloides) occur in the southeastern portion of the study site (BMW ecoregion), mixedwoods occur in the older regrowth areas, and early stage hardwood and softwood regeneration is found in recent burns.

Within this site six areas were selected for intensive study. Each area is about 100 km^2 and dominated by a different set of ecosystems. C-SAR data were acquired over each area on 27 and 28 June, 1988 with the CCRS C-band SAR (Livingstone et al., 1988) in VV and HV polarizations and with incidence angles of 45^0 to 70^0 at a sampling rate of 4.65 m (range) and 3.89 m (azimuth). The signal data were processed to 7 look, 6 m resolution image data in real time (including slant to ground range conversion) onboard the aircraft. Subsequent processing using a digital image analysis system included a correction for cross-track image intensity, to minimize the antenna pattern effects, and a specialized contrast stretch. This stretch was essentially a linear one which mapped the portions of the original data falling between plus and minus two standard deviations about the mean into 95% of the 0 to 255 grey scale, centred about the mean. The remaining tails of the data distribution were compressed into the top and bottom ends of the grey scale.

3. ANALYSIS AND RESULTS

Image analysis was carried out using prints and transparencies of the stretched data produced on a digital image recorder. These data were not calibrated, but the assumption was made that radiometric stability was maintained between scenes, allowing SAR backscatter from specific forest types and forest disturbances to be compared within each scene and between scenes. Verification data included Alberta Phase-3 forest inventory maps as well as cruise data collected for several specific stands per area in the summer of 1988. This paper reports on the analysis of the imagery of Areas 1 and 3 through 6 while the analysis of Area 2 SAR imagery was carried out independently and reported separately (Kneppeck and Ahern, in these proceedings). The results of visual analysis of the VV and HV polarization SAR image sets are detailed below for each study area.

1) Area 1: This study area consists of mature pine (110 years old) and spruce stands (110 to 190 years old), small clearcuts and regenerating burns. Spruce is the dominant cover and surrounds pure pine stands in several locations. On the VV polarization image (Figure 1A) the spruce forest has a consistently medium backscatter level while the pine stands have a darker tone. This contrast between pine and spruce stands allows for clear delineation of pine stands and the only differentiation between softwood species in the Whitecourt test site. Areas of softwood regeneration (18 years old) have very dark tones. Confusion occurs between these regenerating burns and clearcuts, both having low returns, and between treed wetlands and mature spruce stands. The HV polarization image (Figure 1B) appears similar to the VV image with the following exceptions. The pine and spruce stands both have a high return, although the latter is slightly brighter than the former. The result is that pine is only marginally distinguishable from spruce. Detail within clearcuts in terms of cutline and block road visibility is much greater than on the VV image, as well as seismic lines being more clearly defined within the forest. Drainage patterns within the forest are clearly evident on both images due to topographic effects and bright returns from alder in the stream beds. The predominantly ground moraine landform is readily identifiable on both SAR images, although more clearly on the HV image due to the lack of contrast between forest types. The existence of topographic discontinuities allow landform units to be mapped.

2) Area 3: This area is dominated by immature spruce and pine stands dating to 1920. Mature stands of spruce (100 years) border the younger stands. On the VV polarization image (Figure 2A) the younger lodgepole pine and black spruce stands appear darker than the older black spruce stands. Areas of pure pine also appear darker than those with a mixture of pine and spruce. The lower backscatter levels from the 1920 stands appear to be in response to lower biomass and the lodgepole pine component of the species mix. Variations in backscatter intensity from the forest cover are almost non-existent within the HV polarization image (Figure 2B), therefore topography, drainage patterns and forest disturbances on the predominantly ground moraine landscape dominate the image. A topographic discontinuity is also clearly visible (Figure 2). More seismic lines are visible on the HV image than on the VV image and are more clearly defined.

3) Area 4: Logging operations are active in this area of mature spruce and pine stands. Open and treed wetlands (organic terrain) and pure lodgepole pine stands appear a dark grey on the VV polarization image (Figure 3). Mature mixedwood stands (aspen and pine) on predominantly ground moraine appear medium grey as do the mixed softwood stands (spruce and pine). The lowest radar return is from the most recent clearcuts, while older clearcuts have a slightly higher return as a result of grassland and softwood regeneration. The clearcut block roads are visible within most of the clearcuts as very dark, curvilinear features. When differentiating between softwoods, mixedwoods and hardwoods texture becomes an important element of SAR backscatter. The structural characteristics of hardwood crowns appear to result in a rough texture while softwood canopies appear much smoother. Although mixedwoods have backscatter intensities similar to mixed softwoods, the introduction of a hardwood component results in a rougher texture. Surface drainage and glacial meltwater channels are evident on the SAR image. There is also evidence of slumping on slopes, reflected by parallel ridges of vegetation.

An HV polarization image was not available for Area 4 due to a technical problem with data recording.

4) Area 5: Area 5 covers a young mixedwood forest regenerating from a 1950 logging operation. On the VV polarization image (Figure 4A) treed wetlands (organic terrain) are clearly defined by their dark tone and smooth texture, in contrast to the high return and coarse texture of the mixedwoods on ground moraine. Softwood stands, unlike those in Area 4, have a darker tone than the mixedwoods. Ground moraine topography and drainage patterns are clearly evident. The information content of the HV polarization (Figure 4B) is similar to the VV image, although the former provides more contrast between forest types. Seismic lines have a better definition in the HV image as well.

5) Area 6: This area is dominated by large hardwood stands, mixedwoods and black spruce wetlands. Both the VV and the HV polarization images are similar, except that the VV image has a lot of blurring due to turbulence encountered by the aircraft. As a result, the HV image is more easily and reliably interpreted (Figure 5).

Hardwoods have the highest levels of radar return on the HV image. The predominantly black spruce wetlands (organic terrain) are a dark grey tone, while mixedwoods (on ground moraine) have a medium grey tone, contrasting to both the hardwoods and treed wetlands. Some confusion is encountered between younger hardwood stands in wet areas and treed wetlands. An interesting hydrological observation in this area is the differentiation between flooded land along the numerous creeks and beaver dams and the streams and ponds themselves. The streams and ponds show up as black areas while the surrounding flooded land appears very dark grey.

Image texture is also aiding in the discrimination between softwood, mixedwood and hardwood stands. Backscatter from the softwood stands has a smooth texture, while mixedwoods appear more rough and the pure hardwoods are noticeably rougher than any other vegetation cover. The backscatter from the latter also gives the appearance of a hummocky canopy surface; a reflection of the underlying terrain emphasized by radar shadows.

5. CONCLUSIONS

A number of conclusions can be drawn from the visual analysis of SAR imagery:

1) VV polarization data is often, but not always, significantly more effective for discriminating between a variety of forest

types than HV polarization data, which is consistently better suited for delineating seismic lines, roads and other forest disturbances.

2) Differences in backscatter from forest cover appeared to be related to tree species and total biomass, although exceptions do occur. In general, for both C-VV and C-HV images, hardwoods produced the highest backscatter intensities, spruce species produced the next highest intensities, and immature softwoods and immature mixedwoods had a medium backscatter level. Lower returns were produced by, in decreasing order, pine and bogs, and regenerating softwoods. Texture aided in the discrimination of hardwoods from softwoods, both in pure stands and mixedwood stands.

3) Confusion between forest types was a significant problem both within individual SAR scenes and between scenes. On C-VV and C-HV images, only mature hardwoods, mixed softwoods and softwood regeneration could be distinguished from each other and other forest types with little or no confusion.

4) Some very promising results in terms of softwood species differentiation and biomass estimation were found. These include the clear difference of tone between lodgepole pine stands and spruce stands on the VV image of Area 1, and separability of immature softwood stands from mature softwood stands on the VV image of Area 3.

5) Topography, major landscape units and drainage patterns can be discriminated and mapped. This can be of use in discriminating physiographic regions/districts or ecoregions/ecodistricts at smaller scales (1:500 000 to 12:100 000).

The challenge for future work will be to determine what aspects of the tree structure, species composition, and other forest parameters are causing the observed variations in radar backscatter. Efforts will also be made to improve upon the forest type separability with SAR by acquiring multitemporal data.

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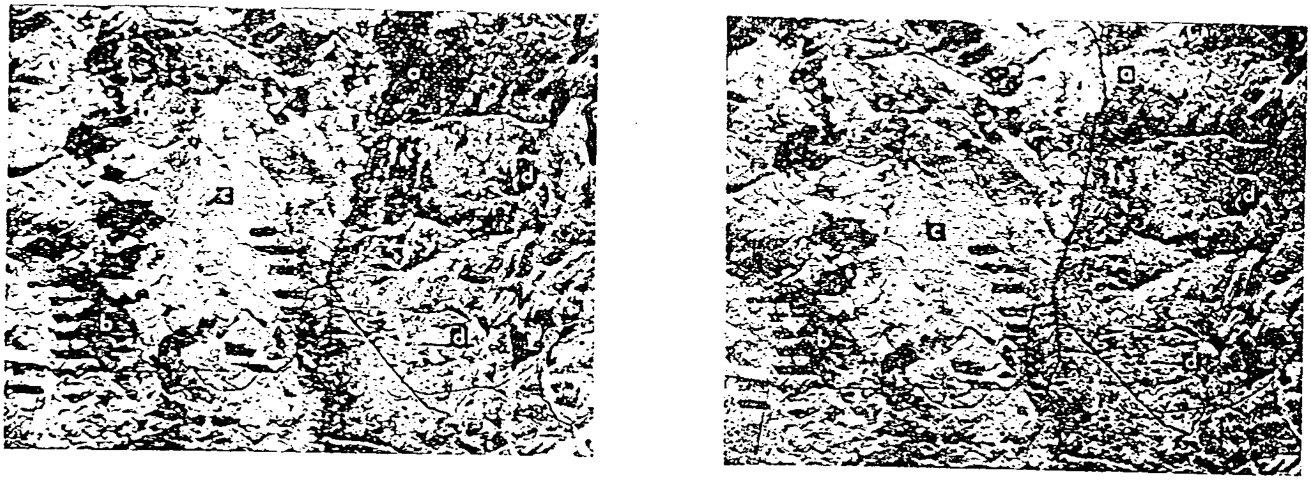

Figure 1. A) Area 1, C-VV SAR image

B) Area 1, C-HV SAR image

a) lodgepole pine stands, b) regenerating burn, c) drainage patterns, d) topographic discontinuity.

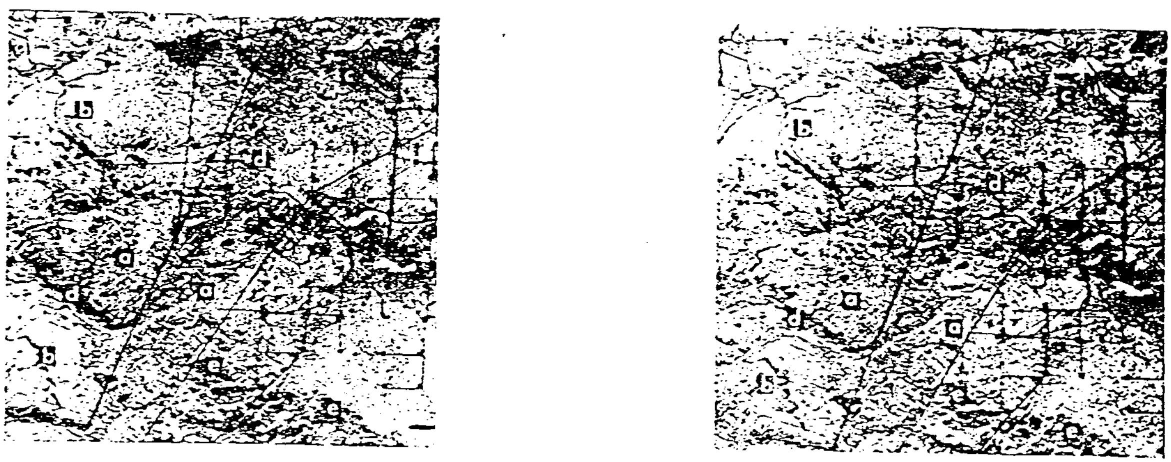

Figure 2. A) Area 3, C-VV SAR image

B) Area 3, C-HV SAR image

a) young lodgepole pine and spruce stands, b) mature spruce stands, c) lodgepole pine stands, d) drainage patterns, e) topographic discontinuity.

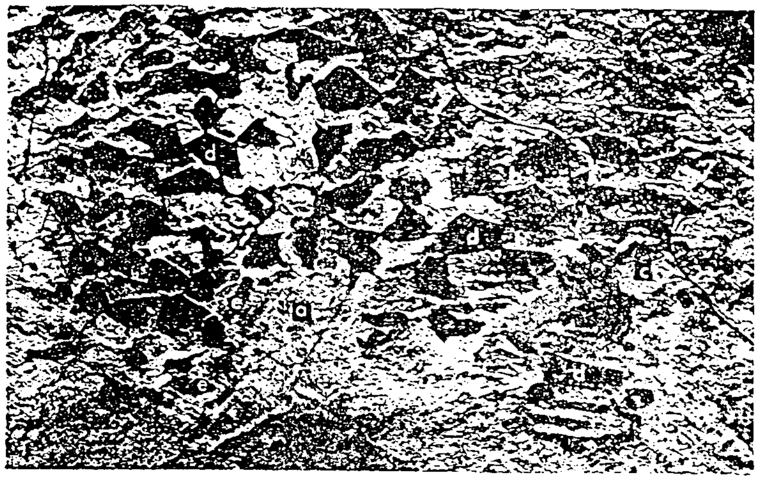

Figure 3. Area 4, C-VV SAR image

a) spruce stands, b) lodgepole pine stands, c) mixedwoods, d) clearcuts, e) slumping on forested slopes.

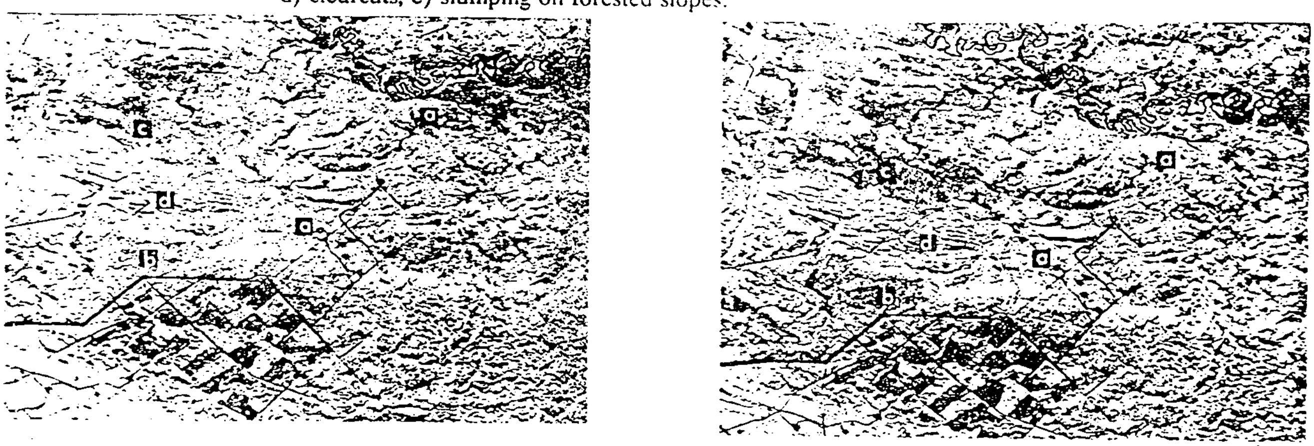

Figure 4. A) Area 5, C-VV SAR image B) Area 5, C-HV SAR image

a) mixedwood, b) softwood, c) treed wetlands, d) dominant topography

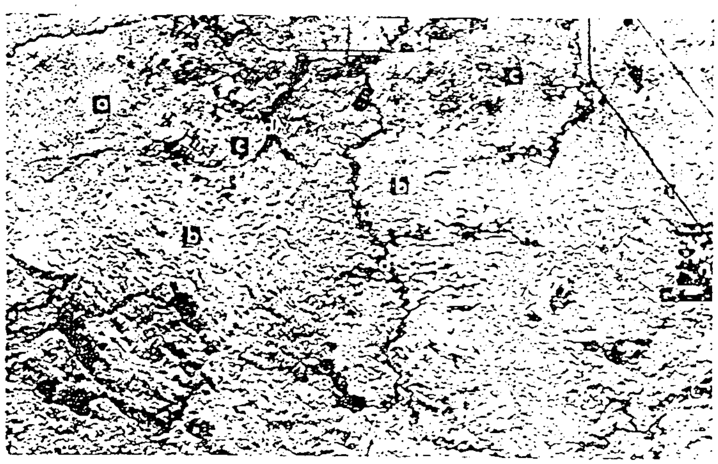

Figure 5. Area 6, C-HV SAR image

a) mixedwoods, b) hardwoods, c) black spruce wetlands, d) flooded land

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