

## ASSESSMENT AND EVALUATION OF THE IMPACT OF USING POLSAR IMAGERIES WITH DIFFERENT INCIDENT ANGLES IN FOREST CLASSIFICATION

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### ABSTRACT:

Forests are a dominant biome of the earth and have an important impact on its economic and environmental well-being. Forestry applications of radar remote sensing are addressed in the context of both forest management and ecosystem understanding, modelling and monitoring. Nowadays, radar remote sensing is being used for a lot of applications in various fields. Due to the applications of polarimetric radar in recent decades, many researchers have tended to this field. One of the main advantages of SAR images is that these images are independent over the time (day and night) and weather condition. The polarimetric SAR (POLSAR) images compared with other remote sensing images are more informative. Classification of radar images is a way by which we can separate different types of forest species. In addition to the main characteristics of the target, the backscatter from a SAR image is widely dependant on various radar system parameters. One of these system parameters is the incident angle of the radar system. In this paper, the impact of using PolSAR images with different incidence angles for the classification of forest areas is investigated. Two polSAR images with different incident angles taken by RADARSAT-2 in fine quad polarized mode (FQ4 and FQ18) have been used in this study. The study area is located in the Petawawa Research Forest (PRF) near Chalk River, Ontario, Canada. The methodology of this paper contains three steps: 1) preprocessing, 2) wishart classification and 3) evaluating & analyzing the results. The preprocessing steps consist of the speckle noise filtering, covariance matrix extraction and georeferencing. In the second step, each incidence angle image was classified by using the supervised Wishart classification. The Wishart classification method has the capability of having multiple images at the same time. Thus, in the next experiment the classification was performed using both incidence angle images. Finally, the obtained results from each class and the classification results in each of three cases were evaluated and analyzed.

The results showed that Wishart classification provides an overall accuracy of %67.17 using the lower incidence angle PolSAR image and %65.38 for the higher incidence angle POLSAR image. Also, the overall accuracy of the simultaneous classification by using the extracted covariance matrix from both images is 72.63%. Those results showed a better performance of the image with lower incident angle compared to that of an image with higher incident angle for forest classification. It is also shown that combining extracted covariance matrix from the FQ4 image with extracted covariance matrix from the FQ18 image can significantly improve the classification accuracy (overall accuracy).

### 1. INTRODUCTION

Radar Polarimetry is an approach which offers a lot of choices in order to analysis and understanding of the forest characteristics (Lang, Townsend et al. 2008). The radar's system multi-polarization (quad-pol.) is used to record the full polarization information, which in turn, is used to calculate the scattering matrix.

The surface scattering depends strongly on the incident angle i.e. the majority of back scattering occurs in low incident angles and increasing the incident angle leads to a decrease in back scattering (Scheuchl, Hajnsek et al.). On the other hand, this dependence upon the incident angle lowers down when the surface roughness increases. It is also worthy to mention that dependence upon incident angle increases for mediums with high dielectric constant (Henderson and Lewis 1998).

The forest's canopy almost is considered as a volume scatterer. This assumption results in less back scattering in low incident angles (Svendsen, Skriver et al. 1998). This dependence, even minor, introduces some problems in satellite and airborne imaging applications. In various incident angles, because of polarization, canopy and ground's back scattering power,

different back scattered fields from tree's elements impinge on radar (Carandall 1969; Chauhan, Lang et al. 1991).

According to the diverse applications of forests, to better resource management, it is necessary to gather information related to trees like type, age, biomass, and etc. Various approaches have been incorporated to attain this information from the original image.

Radar images classification is an approach which it is possible to determine the tree's types. By taking into account that images with different incident angles provide us a lot of information about forests characteristics which this information are distinct, in this paper the classification of PolSAR images of a forestry with different incident angles is discussed.

### 2. METHODOLOGIES

#### 2.1 Study area and data

The study site selected is the Petawawa Research Forest (PRF) located near Chalk River, Ontario (45°57' N, 77°34' W). It is approximately 200 km west of Ottawa and 180 km East of North Bay, Ontario, Canada. Two Radarsat-2 scenes were used: 16<sup>th</sup> September 2008 (FQ4) and 19<sup>th</sup> September 2008 (FQ18). The imaging modes were fine quad and were both ascending

passes. An image subset was selected for testing the classification algorithms. Figure 1 shows the false color image of the area (R: HH, G: VV, B: HV), which covers a forest area of approximately  $22 \times 22 \text{ km}^2$ . In order to evaluate the classification algorithms, a variety of different forest classes were considered in this study. These forests are being divided into two general categories: hardwood and softwood trees. Classes that have been evaluated in this research are aspen (A), poplar (*Populus L.*) (Po), white pine (*Pinus strobus L.*) (Pw), black spruce (*Picea mariana (Mill) B.S.P*) (Sb), ground vegetation (GV), building (B) and water (W), that aspen and poplar trees are components of hard wood and white pine and black spruce trees are components of soft wood.

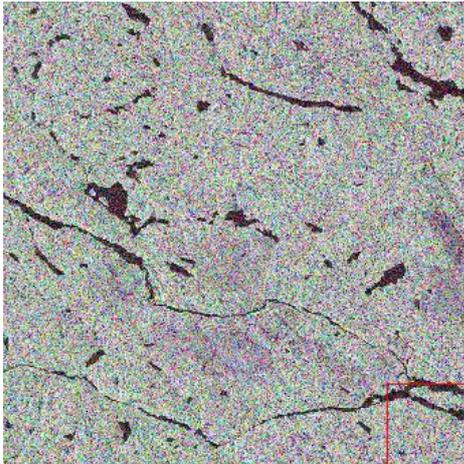


Figure 1 Radarsat-2 polarimetric SAR data of PRF, Ontario (2200 × 2200 pixels, R: HH, G: VV, B: HV)

Reference data was collected from forest inventory maps, aerial photographic interpretation, Landsat ETM+ images and field visits.

These referenced data are divided into two parts: training data and test data. Table 1 shows the number of the training data and test data for each class.

Table 1 training data and test data

Test Data	Training Data	Name
1344	1623	PO
1090	970	A
866	799	Sb
607	607	Pw
1984	1306	GV
1690	1976	B
1638	1457	W

## 2.2 Pre-processing

SAR data pre-processing includes three stages of filtering, features extraction, and image geo-referencing. These stages are described in the following sections.

### Filtering

Generally, SAR images are noisy in nature. Existence of speckle noise influences the information and features which are extracted from the image, significantly. Therefore, speckle noise reduction is one of the most important steps in using the PolSAR images.

To eliminate the noise effects in Polarimetry features, two scenarios are used. For incoherent parameters, at first the coherency matrix elements are speckle filtered. Then, the features are extracted from the coherency matrix. In the second scenario, for coherent parameters, features are extracted from unfiltered coherency matrix. In this paper, the BoxCar filter will be used.

### Feature Extraction

Another pre-processing step which applies to images is Polarimetry feature extraction. In this research, covariance matrix extracted from each image.

### Image Geo-Referencing

The next step in pre-processing is image geo-referencing. In order to geo-referencing the extracted features, the geo-referenced RadarSat-1 image have been used.

## 2.3 Wishart classifier

The most important advantage of using covariance matrix is that its elements have Wishart distribution. Thereby, the classification can be applied to multiple images in different frequency bands, different times or in different incident angles, concurrently.

The Wishart classifier proposed by Lee (Lee, Grunes et al. 1994) was adopted in this study. It has been shown that the polarimetric covariance matrix  $Z$  may be described by a complex multivariate Wishart distribution. Let  $C = E(Z / \omega m)$  be the mean covariance matrix for class  $\omega m$ , based on the maximum likelihood classifier and the complex Wishart distribution, the Wishart distance measure was derived as  $dm = \ln|Cm| + Tr(C_m^{-1} Z)$

The supervised classification rule becomes as follows: assign the pixel to class  $\omega i$   $i \in \{1, 2, \dots, k\}$ , if  $d(i)m \leq d(j)m \quad \forall \omega j \neq \omega i$

## 3. RESULTS

After carried out the steps that mentioned in the previous section, a series of results obtained for each of the scenarios are as follows:

In the case of Wishart classifier was applied on FQ18 image, the overall accuracy of 65.38%, respectively. Figure 2 shows the classification accuracy for each of the class.

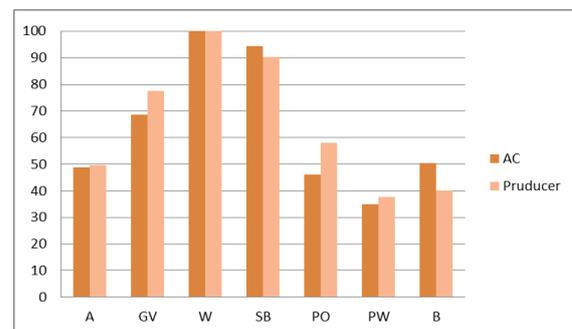


Figure 2 classification accuracy for FQ18 image

In the case of Wishart classifier was applied on FQ4 image, the overall accuracy of 67.17%. Figure 3 shows the classification accuracy for each of the class.

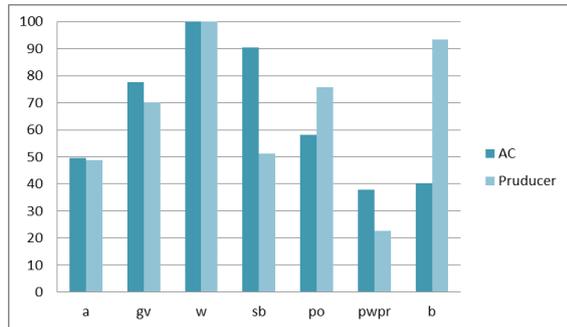


Figure 3 classification accuracy for FQ4 image

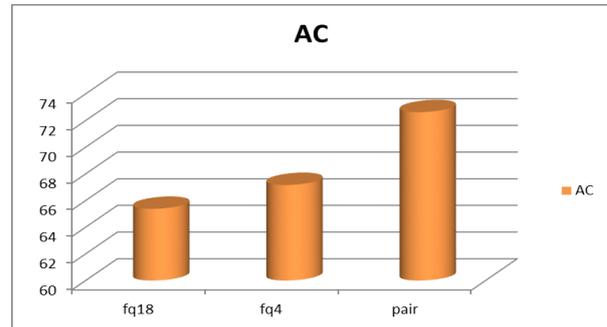


Figure 5 the overall classification accuracy in all three cases

Also, the overall accuracy of the simultaneous classification by using the extracted covariance matrix from both images is 72.63%. Figure 3 shows the classification accuracy for each of the class.

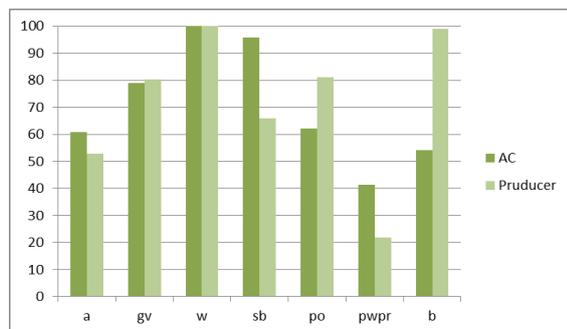


Figure 4 classification accuracy for both images

#### 4. CONCLUSION

According to the table 2, the results showed a better performance of the image with lower incident angle compared to that of an image with higher incident angle for forest classification.

Table 2 comparison the classification accuracy

	FQ18	FQ4	Pair
<b>A</b>	48.72	49.72	60.92
<b>Gv</b>	68.50	77.62	78.88
<b>W</b>	100	100	100
<b>Sb</b>	94.46	90.42	95.84
<b>Po</b>	45.98	58.04	62.05
<b>Pw</b>	35.09	37.73	41.35
<b>B</b>	50.30	40.24	54.08
<b>Overall accuracy</b>	65.38	67.17	72.63

It is also shown that combining extracted covariance matrix from the FQ4 image with extracted covariance matrix from the FQ18 image can significantly improve the classification accuracy (overall accuracy).

In Figure 5, the overall classification accuracy in all three cases is visually comparable, which can be easily found that, by using the images with different incident angles, the classification accuracy is improved

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