The discriminatory capability of polarimetric SAR data for land use classification*

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In this paper a SIR-C data is used to assess the discriminatory capability of full polarimetric data for several classes of land-use. It is analysed the contribution of each type of data (phase difference, intensity ratio, intensity pair and intensity-phase difference pair), using the Iterated Conditional Modes (ICM) classifier. It is shown that each class was better classified using a different type of polarimetric data. The result of the classification (measured by the confusion matrix and the Kappa coefficient of agreement) was considered very good, allowing the discrimination of nine land use classes, which includes different cultivation stages of some crops.

INTRODUCTION

Digital classification is one of the most extensively used tools in Remote Sensing applications. Several classical statistical classifiers are based on the assumption that the data are Gaussianly distributed. However, when radar data are used, this assumption is seldom verified, especially in the case of polarimetric radar images. Therefore, the development of new techniques and methods to classify digital radar images has been the focus of attention in several studies [2], [8], [10].

Usually, these new techniques and methods model the radar data by the multiplicative model [6]. Statistical models for multi-look polarimetric data are derived from the covariance matrix, which exhibit a complex Wishart distribution [4], [7].

In [9] it was developed the distributions of the univariate (phase difference and intensity ratio) and bivariate (intensity pair and intensity-phase difference pair) multi-look polarimetric data by assuming a constant backscatter. In this paper these distributions are used to classify a radar polarimetric data using the ICM classifier.

The objective of this paper is to quantitatively analyse the contribution of each type of data (phase difference, intensity ratio, intensity pair and intensity-phase difference pair) for the discrimination of several classes.

ICM CLASSIFIER

The ICM classifier incorporates the multiplicative and a contextual model for the observations (returned radar data) and classes, respectively. The Markovian model known as Potts-Straus is assumed to describe the classes. The ICM algorithm consists of the iterative improvements on a classification, using the information of a given observation and the classes of its neighboring. This improvement is obtained by maximizing the a posteriori distribution of the classes, which is given by:

$$L(\xi') = f_{\xi'}(z_s)\exp(\beta\#\{t \in \partial_s : \xi_t = \xi'\}),$$

where $f_{\xi'}(z_s)$ is the density associated to class ξ, which has radiometric value z_s on co-ordinate s, β is a real parameter that quantifies the influence of the neighbouring classes and it is estimated iteratively and ∂_s is the set of neighbouring co-ordinates around s. This expression can be reduced to the Maximum Likelihood (ML) classifier and to Mode Filter, when $\beta = 0$ and $\beta \to \infty$, respectively. For more details of the algorithm, the reader is referred to [1], [5] and [10].

DATA AND METHODOLOGY

The images selected for this work are those from the SIR-C/X-SAR mission acquired over Bebedouro region, Pernambuco State, Brazil, using full polarimetric L and C bands. This area corresponds to an irrigated region with

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several types of crops. The central co-ordinates of the study area is 09°07' S, 40°18' W. The main parameters of these images are presented in Table 1.

Table 1: SIR-C/X-SAR image main parameters.

Acquisition date	April 14^{th}, 1994
Size of the images	407x370 pixels
Frequency	L (1.254 GHz) and C(5.304 GHz)
Polarisation	HH, HV, VV and VH
Incidence angle	49.496°
Nominal number of looks	4.7854018
Pixel spacing	12.5m in range and azimuth

Fig. 1a and 1b present the colour compositions for L and C bands, respectively, of the data set under study. These figures also present the training and test samples.

The classes of interest are presented in Table 2, where their respective colour keys (the colours with which they will be represented in the classification) and sizes of training and test samples. There are two stages of corn (Corn1 up to 124 days, and Corn2 with 133 days of cultivation), and three stages of soybean (Soybean1 with 52 days, Soybean2 with 66 days and Soybean3 between 76 and 113 days of cultivation).

Table 2: Classes of interest, colour keys, training and test samples.

Classes	Colour	#Training Pixels	#Test Pixels
River	Blue	4949	3844
Caatinga	Green	5177	3585
Prepared Soil	Red	3221	2101
Soybean1	Gray	961	436
Soybean2	Magenta	914	550
Soybean3	Brown	1849	1086
Tillage	Cyan	934	530
Corn1	Yellow	3039	1645
Corn2	Purple	847	378

In [2] a detailed analysis of many ML/ICM classifications for each band (L and C) were performed, using phase difference, intensity ratio, intensity pair and intensity-phase difference pair data set and their corresponding distributions [9]. All combinations of polarisation for each band were analysed. Some of the results area also presented in [3]. It was noted that the information that these data set carry is very specific, and each class was better classified with a different data. By the analysis of all ICM classification and their corresponding confusion matrix it was found the polarimetric data that best discriminate each class. The result of this analysis is shown in Table 3.

Based on the results of the ICM classifications using the data presented in Table 3, a set of Boolean operations were performed in order to form a final classification. After this operations, several pixels were unclassified. To solve this problem, each unclassified pixel was assigned to the class with a higher number of pixels (mode) within a window of 5x5 pixels, considering all the data presented in Table 3.

The final classification is shown in Fig 1c. The confusion matrix is presented in Table 4, where the number inside the parenthesis represents the percentage of classified pixels. This matrix has an associated Kappa coefficient of agreement of 0.8235, with variance of 1.2124×10^{-5}.

Table 3: Data which best discriminate each class.

Classes	Data
River	Intensity Pair C-HVVV
Caatinga	Intensity Pair L-HVVV
Prepared Soil	Intensity Pair C-HVVV and Phase Difference C-HHVV
Soybean1	Intensity-Phase Difference Pair L-HHVV
Soybean2	Intensity Pair C-HHVV and Intensity Pair L-HVVV
Soybean3	Intensity Pair L-HHVV
Tillage	Intensity-Phase Difference Pair L-HHVV
Corn1	Intensity Pair L-HVVV and Intensity-Phase Difference Pair L-VVHH
Corn2	Intensity Pair L-HHVV

Comparing with the individual classifications, the use of this methodology allowed, in general, to decrease the misclassification among classes, in spite of the decrease of the number of pixels correctly classified. The three classes of Soybean presented the smallest overall accuracy (around to 56%), while the overall accuracy for the others classes were more than 71%. The greatest confusion was observed between Corn2 and Soybean2, which was close to 26%.

Although the Soybean3 class has had high overall accuracy (84%) with intensity ratio L-HHVV classification, this data was not selected to contribute for the final classification, because it has a high degree of confusion among classes.

CONCLUSIONS

The analysis of SIR-C images showed that each class was better classified using different type of data (phase difference, intensity ratio, intensity and intensity-phase difference pairs), highlighting the importance of having the full polarimetric data for land use classification. The classification methodology, which uses all these information, showed to be very efficient for the intent purpose. It was possible the discrimination of different stages of Corn and Soybean.

In general, the L band seems to carry more information than C band to discriminate the study classes, but the C band was useful to improve the classification of River, Prepared Soil and middle stage of Soybean.

The ICM classifier showed to be a good method for classifying the polarimetric radar data.

The obtained results were very encouraging for continuing the study of the potentiality of polarimetric data for land use classification.

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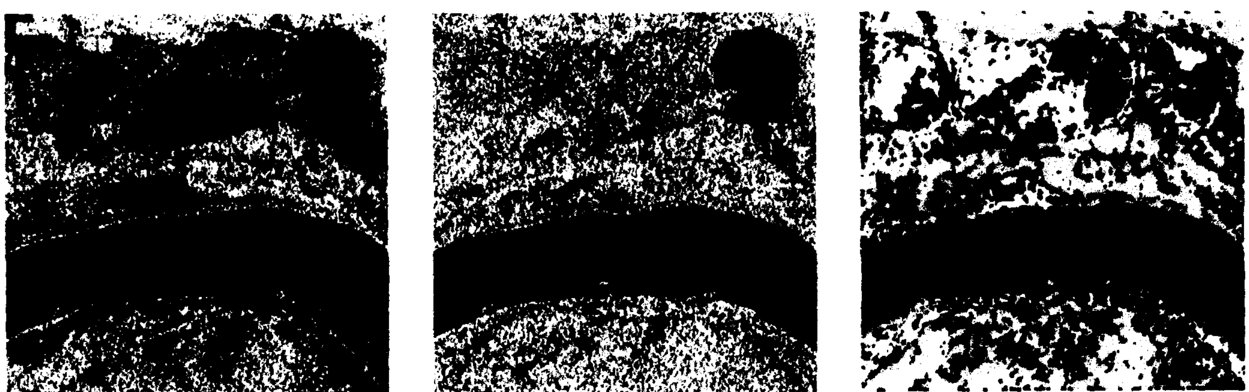

(a) (b) (c)

Fig. 1: Colour compositions of the original data R-HH, G-HV, B-VV, L band with training sets (a), C band with test sets (b) and final classification (c).

Table 4: Confusion matrix of the classification.

	River	Caatinga	Prepar. Soil	Soybean-1	Soybean-2	Soybean-3	Tillage	Corn-1	Corn-2
River	**3844 (100)**	0	0	0	0	0	0	0	0
Caatinga	0	**3160 (88.2)**	0	0	24 (0.7)	209 (5.8)	0	110 (3.1)	79 (2.2)
Prepar. Soil	0	0	**1682 (80.1)**	6 (0.3)	1 (0.1)	0	412 (19.6)	0	0
Soybean-1	0	1 (0.2)	12 (2.8)	**252 (57.8)**	22 (5.5)	0	75 (17.2)	1 (0.2)	73 (16.7)
Soybean-2	0	10 (1.8)	3 (0.5)	59 (10.7)	**299 (54.4)**	16 (2.9)	10 (1.8)	0	153 (27.8)
Soybean-3	0	187 (17.2)	0	22 (2.0)	206 (19.0)	**618 (56.9)**	39 (3.6)	1 (0.1)	13 (1.2)
Tillage	0	0	0	9 (1.7)	2 (0.4)	21 (4.0)	**473 (89.2)**	0	25 (4.7)
Corn-1	0	28 (1.7)	33 (2.0)	0	20 (1.2)	14 (0.9)	2 (0.1)	**1501 (91.3)**	47 (2.9)
Corn-2	0	0	0	0	90 (23.8)	15 (4.0)	5 (1.3)	0	**268 (70.9)**