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Land Cover Classification in Amazon using Alos Palsar Full Polarimetric Data

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Abstract. The ALOS PALSAR sensor can provide full polarimetric SAR data (HH, HV and VV) but the full polarimetric mode is only available experimentally. Here, several supervised classifiers have been studied to determine how much the use of full polarized (HH, VV and HV, no phase information) PALSAR data information can improve, or not, the overall classification accuracy in comparison with the standard products, which, for PALSAR instrument, is the HH (like JERS-1) or the dual polarization product HH-HV. The study area, Tapajós National Forest at the south of Santarém City, in the Brazilian Amazon, Pará State, has being object of intensive scientific observation for more than 15 years. Several types of supervised classifiers are tested for having, as much as possible, an assessment rather independent of the classifier type. Initial results indicate that, no phase considered, the dual polarization product HH-HV is the better channels combination for mapping the set of tropical classes composed by the primary forest, secondary forest, bare soil, agriculture and degraded forest. Also, it was observed that one year regeneration areas are not discriminated in any PALSAR combination, which indicates the utility of maintaining the complementary use of optical images when possible, because, in the optical combination, the 'one year regeneration' class still shows different from secondary forest. Region based classification, particularly one developed to take in account as much as possible the radar statistical behavior, generally presented better performance.

Palavras-chave: Alos PALSAR, polarimetry, radar land cover, Tapajós, SAR.

1. Introduction

The importance of Microwave Remote Sensing for tropical forest monitoring is well known. The new generation of orbital SAR plataforms is capable of delivering several types of polarimetric products, but the full polarimetric mode is of restricted use because of operational limitations. This investigation is focused on how the use of full polarimetric PALSAR data information can improve, or not, the overall classification accuracy in comparison with the standard products. Particular attention is given to the discrimination capability of perceiving land cover alterations of great importance on tropical environment monitoring, like recent deforestation, degraded forest and regeneration, as a function of the channels set used. Several types of supervised classifiers are tested for having, as much as possible, an assessment rather independent of the classifier type. The classification results improvements are statistically tested for significance.

The study area, Tapajós National Forest at the south of Santarém City, in the Brazilian Amazon, Pará State, has being object of intensive scientific observation for more than 15 years.

2. Materials And Methods

2.1. Materials

The Tapajós National Forest (FLONA), Figure 1, is located at the south of Santarém City, in the Brazilian Amazon, Pará State. A polarimetric (PLR) scene (level 1.5), from October 21, 2006, was obtained via the User Remote Sensing Access (URSA) from the Alaska Satellite Facility (ASF). Field work was conducted to collect ground data on October 2005, during a L

Band airborne mission executed with the Brazilian SIVAM R99 sensor system. The mission was planned for acquiring scenes used for the simulation of the proposed German-Brazilian L-band orbital system MAPSAR. Field data was updated to reflect one year difference by visual interpretation of very clear Landsat scenes acquired on August,21, 2006 and other local eye witness reports.

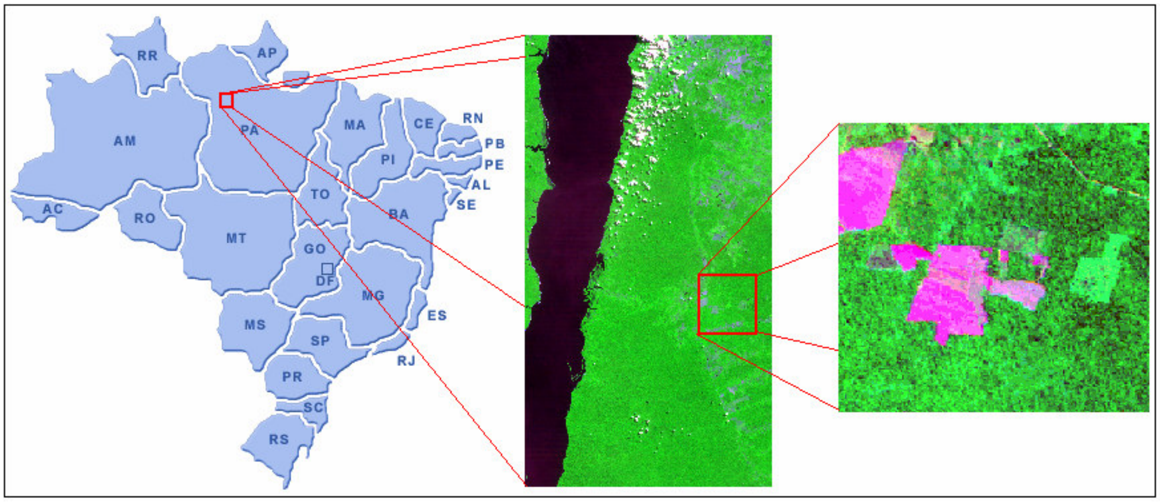

Figure 1. Study area.

2.1. Methods

The following classifiers have been used in the investigation: the standard maximum likelihood (ML) classifier with equal a prioris, for the 3 channel case, and a special case of the ML classifier for the two polarimetric channels case. The Support Vector Machine classifier (SVM) with Radial Basis Functions Kernel, was selected as the deterministic pixel based approach. Finally two versions of supervised region classifiers were also tested.

For all cases, the standard Gamma speckle filtering method was applied to the radar data in the intensity (power) format (5x5 window) for comparing the results with/without filtering. Also, for all possibilities of two-channel combination cases, the ML classifier considering the SAR data distribution as a special case of the Wishart Distribution, as developed by Lee e Grunes (1994), was employed to favor the best modeling construction for pixel based statistical classification.

Region based classification is executed in two phases: firstly, homogenous regions by some criteria are identified into the imagery. Secondly these regions are classified as a whole to one of the known (training) classes.

Two different segmentation strategies has been applied: SegSar (acronym: SS) (Sousa Jr, 2005 e Scofield et al., 2007) which is a specialized radar hierarchical segmentation strategy, where “region growing” is used in the highest compression level and the “split and merge” technique is used in the intermediate levels. Also a border refinement algorithm is applied to each level, before the “split and merge” procedure application, to enhance the region frontier resolution. A standard segmentation methodology available in SPRING system (Camara et al., 1996) (acronym: SP) was also tested. After the segmentation phase, the Bhattacharyya Distance (BD) (Richards, 1993) which is a measure of statistical distance between Probability Density Distributions (PDF) is used, as an association criterion between the region with unknown label and one of the training classes. BD is given by Equation 1 considering Gaussian hypotheses.

$$BD(m_i,m_j)=\frac{1}{8}(m_i-m_j)^t\left\{\frac{\sum_i+\sum_j}{2}\right\}^{-1}(m_i-m_j)+\ +\frac{1}{2}\ln\left\{\frac{\left|\sum_i+\sum_j\right|}{2\left|\sum_i\right|^{1/2}+\left|\sum_j\right|^{1/2}}\right\}^{-1} \tag{1}$$

BD is measured between the statistics of the region i, and the statistics of each class j, where j= 1,…#of_classes. The region i is associated with the class with the lowest BD. Region *i* and classes *j* are assumed to be normally distributed with means and covariances of m_i and m_j , $\sum_i$, $\sum_j$ respectively.

3. Results and Discussions

Figure 2a presents classes and locations used as training samples in this study. Figure 2b presents a Landsat color composition of an 2 month earlier acquisition. The one year regeneration marked of Figure 2b did not show up in the PALSAR composition. In the other hand, however, degraded area by fire (marked deep blue) is clearly visible in PALSAR composition while it is not in the Landsat image composition.

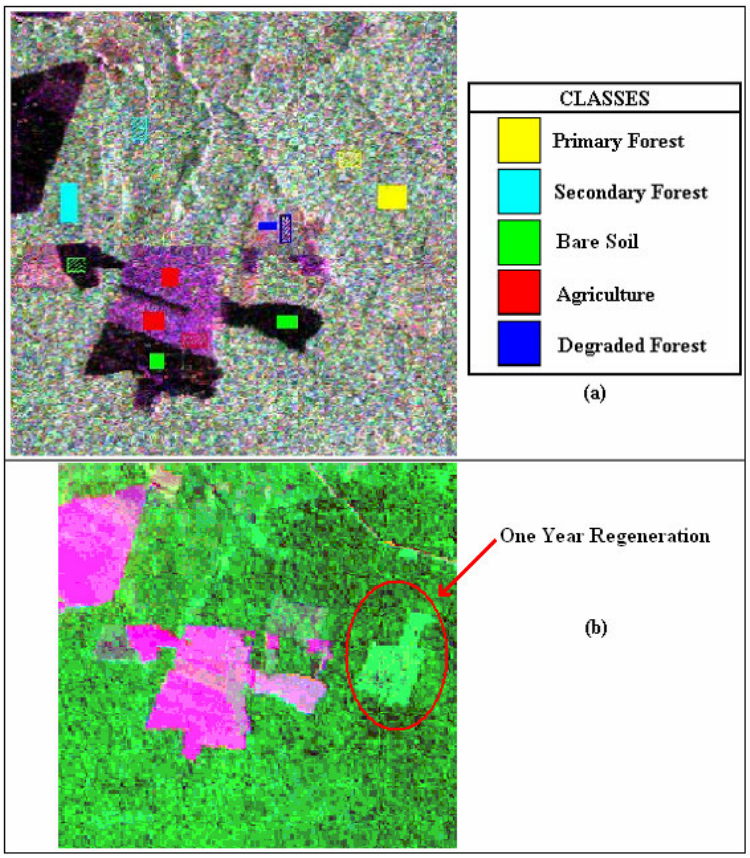

Figure 2. a) PLR image (2006, October 21), composition: HH-VH-VV on RGB and b) TM Landsat-5 composition:5-4-3on RGB (2006, August 21). Degraded areas are only distinctly visible in PALSAR while One Year Regeneration is only noticeable in TM composition.

Table 1 presents a summary of all classification accuracies calculated over training areas. Test areas are not presented here. The best result of all was obtained using the Region Classification approach with the SS segmentation phase. It is possible to observe that SS with no speckle reduction had better performance than with filtering in 2 cases, which maybe explained by the fact that SS is tailored to take in account radar statistics behavior more effectively. Region classification using a standard segmentation (SP) procedure has showed better performance with filtering than with no filtering which is normally expected. In general, however radar tailored segmentation presented better results than standard segmentation approach which was found statistically different at significance level of 95% in almost all cases. Also, in general, HH-HV channels lead to a better classification, including for degraded forest discrimination from regeneration and primary forest which have special importance in several ecological studies.

Figure 3 presents the results for the SVM classifier using the filtered channels. Figure 4 shows the results for the region classifier technique with SegSar (SS) phase. It is possible to observe that all combinations with the VV channel tend to present worse results.

5. Conclusions

Initial results indicate that, no phase considered, the dual polarizarition product HH-HV is the better combination for general mapping of the rain forest problem composed by the primary forest, secondary forest, bare soil, agriculture and degraded forest. One year regeneration areas are not observed in any PALSAR combination, which indicates the utility of maintaining the complementary use of optical images when possible. Region based classification, particularly one developed to take in account as much as possible the radar statistical behavior, seems to perform better. Much more studies are necessary to advance this research to take in account the polarimetric phase information, the scattering mechanisms, more suited classifiers including the contextual ones, more detailed assessment procedures, etc. Other previous radar studies on Tapajos are Santos et al. (2002); Freitas et al. (1999); e Dutra et al. (2007).

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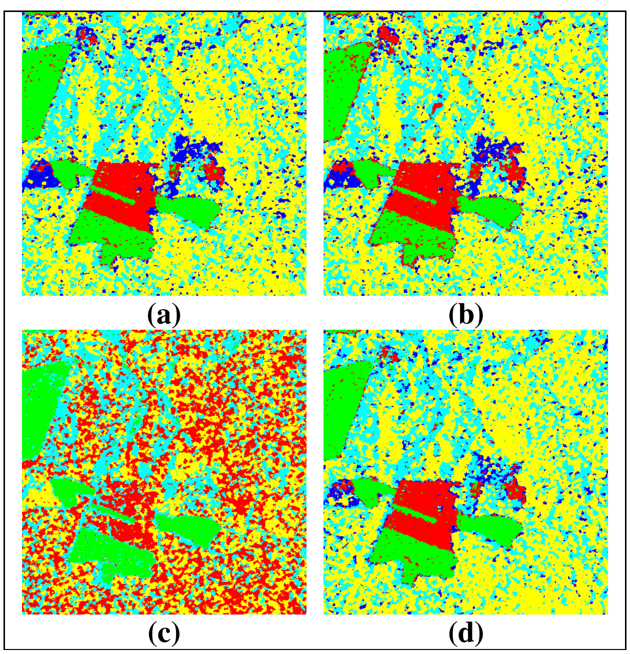

Figure 3. Classification results using SVM classifier and speckle reduced channels. a) 3 channels, b) HH-HV, c) VV-HV, d) HH-VV

Table 1. PALSAR land cover classification accuracy of (supervised).

Type	Channels	Filtering Y/N	Overall accuracy (%)	$\hat{\sigma}_k^2$ (10^{-5})	$\hat{k}$
ML	3	N	67.09	29.04	0.589
ML	HH-VV	N	49.48	32.10	0.369
ML	HH-HV	N	65.02	28.04	0,565
ML	VV-HV	N	61.12	30.80	0.631
ML	3	S	91.70	10.28	0.896
ML	HH-VV	S	56.30	29.83	0.4571
ML	HH-HV	S	93.35	8.40	0.9168
ML	VV-HV	S	82.64	19.40	0.783
SVM	3	N	62.09	29.79	0.5227
SVM	HH-VV	N	46.45	29.99	0.3264
SVM	HH-HV	N	63.81	28.31	0.5439
SVM	VV-HV	N	63.04	29.58	0.5346
SVM	3	S	86.79	15.60	0.8343
SVM	HH-VV	S	59.15	30.86	0.4856
SVM	HH-HV	S	89.20	13.07	0.8647
SVM	VV-HV	S	74.96	25.13	0.6856
SS-BD	3	N	96.54	4.5	0.9567
SS-BD	HH-VV	N	77.97	22.91	0.7247
SS-BD	HH-HV	N	96.71	4.29	0.9589
SS-BD	VV-HV	N	90.67	11.4	0.8830
SS-BD	3	S	91.88	9.99	0.8983
SS-BD	HH-VV	S	86.09	15.88	0.8263
SS-BD	HH-HV	S	96.54	4.51	0.9567
SS-BD	VV-HV	S	91.88	9.99	0.8983
SP-BD	3	N	88.51	13.73	0.8564
SP-BD	HH-VV	N	67.27	26.58	0.5925
SP-BD	HH-HV	N	96.45	4.62	0.9557
SP-BD	VV-HV	N	85.06	17.35	0.8130
SP-BD	3	S	91.70	10.22	0.8963
SP-BD	HH-VV	S	77.97	20.30	0.7261
SP-BD	HH-HV	S	94.99	6.41	0.9373
SP-BD	VV-HV	S	86.96	15.20	0.8368

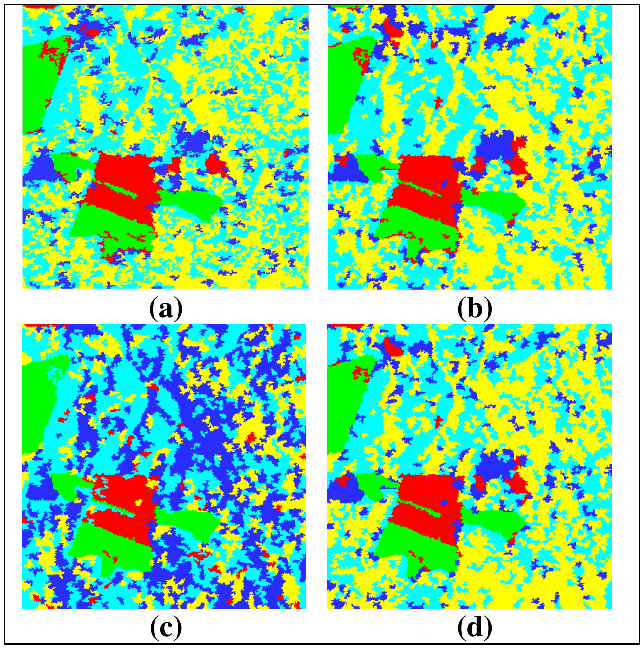

Figure 4. Classification results using Region Classifier with SegSar segmentation phase. (SS-BD): a) 3 channels, b) HH-HV; c) VV-HV, and (d) HH-VV

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