Comparing Single, Dual and Quad-Polarimetric Data at L-band for Classification Purposes in Eastern Amazon

Veraldo Liesenberg[1]; Richard Gloaguen[2,3]

[1] Universidade do Estado de Santa Catarina - UDESC
Centro de Ciências Agroveterinárias – CAV, Departamento de Engenharia Florestal
Av. Luiz de Camões, 2090 – 88520-000 - Lages - SC, Brasil
e-mail: veraldo.liesenberg@udesc.br

[2] TU Bergakademie Freiberg, Institute of Geology
B. von-Cotta-Str. 2 - 09599 – Freiberg - Germany
e-mail: gloaguen@geo.tu-freiberg.de

[3] Helmholtz Institute Freiberg of Resource Technology – HIF
Halsbrueckerstr. 34, 09599 - Freiberg - Germany
e-mail: r.gloaguen@hzdr.de

Abstract. Single, dual, and quad-polarization mode data at spaceborne L-band were evaluated for the classification of seven land use classes in an area with shifting cultivation practices located in the Eastern Amazon (Brazil). We evaluated Advanced Land-Observing Satellite (ALOS) Phased Array L-band Synthetic Aperture Radar (PALSAR) derived backscattering intensity, polarimetric features, interferometric coherence and texture parameters for classification purposes using support vector machines (SVM) and feature selection. Results showed that the forest classes were characterized by low temporal backscattering intensity variability, low coherence and high entropy. Quad polarization mode performed better than dual and single polarizations but overall accuracies remain low and were affected by precipitation events on the date and prior SAR date acquisition. Misclassifications were reduced by integrating Landsat data and an overall accuracy of 85% was attained. We show that in absence of Landsat data, polarimetric features extracted from quad-polarization L-band increase classification accuracies when compared to single and dual polarization alone. We argue that the joint analysis of SAR and their derived parameters with optical data performs even better and thus encourage the further development of joint techniques.

Key-words: land use, ALOS/PALSAR, successional forest stages, SVM, polarimetry.

1. Introduction

The ability to discriminate between successional stages has been investigated using multiple remotely sensed imagery (e.g. Rignot et al, 1997, Yanasse et al. 1997, Lu et al., 2003, Vieira et al., 2003, Kuplich 2006, Galvão et al., 2009, Liesenberg et al., 2010). The analyses were mainly limited either to optical images alone or their integration with microwave data considering a unique polarization configuration. The results from such investigations suggest that the discrimination of secondary forest is often difficult. This is due to the slight transition between the different successional stages, lacking abrupt boundaries between classes. The structure of secondary forest is mainly shaped by dominant species or a group of pioneer species that, under certain environmental conditions and their own dynamics, may reach maturity eventually. However, disturbance practices such as frequent cutting or burning events after abandonment makes the discrimination of secondary forest and the transition between classes even more difficult (Lu et al., 2003, Vieira et al., 2003). Therefore, the integration of multi-source data is of great interest (Lu et al., 2011, Zhang et al., 2012).

In this study, we evaluated the potential of different polarization modes from ALOS/PALSAR data for the discrimination of different land use classes.

2. Descrição da Área de Estudo

The 30 km by 60 km study area and its surroundings (Pará state, eastern Amazon) is shown in Figure 1. The area is relatively flat, ranging between 0-210 m above sea level. According to Köppen climate nomenclature, the climate of the study area is tropical with a very short dry season (AmW). The rainy season occurs between December and May and the historical average annual precipitation and temperature are 2240 mm and 26^{o}C respectively in the region of interest (RADAMBRASIL, 1975). A better description of the study area can be found in Liesenberg and Gloaguen (2013).

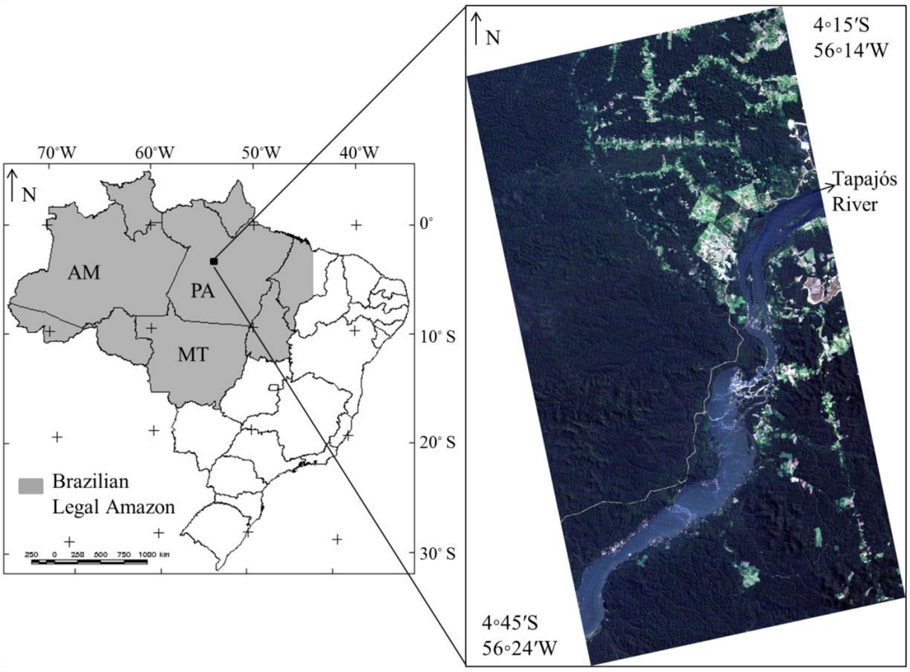

Figura 1. Localização da área de estudo na Amazônia Oriental (Estado do Pará, Brasil) com detalhe para a composição cor verdadeira (3R2G1B) do Landsat-5/TM acquirido em 28 de Junho de 2007.

3. Methodology

The SAR data were acquired on January 2, 2007 (in the middle of the rainy season) for the Fine Beam Single polarization (FBS, also single) mode, on March 13 and April 28, 2007 (at the end of the rainy season) for the polarimetric (PLR, also quad1 and quad2) mode, and on July 5 and August 20, 2007 (in the dry season) for the Fine Beam Dual polarization (FBD, also Dual 1 and 2) mode. The SAR data are further detailed in Table 2. There are five different science data modes in which PALSAR can operate (Rosenqvist et al., 2007). The other two remaining polarization modes (e.g. ScanSAR burst mode (WB1/2) and direct downlink (DSN)) were not considered due to coarse spatial resolution for WB1/2 and the unavailability of DSN for our test site.

All SAR data were acquired at the slant range single look complex (SLC) format (e.g. level 1.1). A co-registration between SLCs was performed taking the earliest acquisition as reference. In order to enhance radiometric resolution and to square the pixels in ground range geometry at similar spatial resolution (e.g. 30 m for Landsat), the amplitude images were multi-looked 36, 18 and 8 times for single, dual and quad-polarization respectively (Lee et al., 1994). A refined Lee filter was then applied to reduce speckle (Lee et al., 2009). In this procedure, the elements of the covariance matrix are filtered by averaging the covariance matrix of neighboring pixels using a moderate window size of 7 by 7 pixels (Lee et al., 1999).

The window size selection was based on the speckle suppression index (SSI) (Lee et al., 1994). In order to allow multiple dataset comparisons, a geocoding (orthorectification) based on a digital elevation model (DEM) from the Shuttle Radar Topographic Mission (SRTM, Rabus et al., 2003) was performed.

Table 1. Characteristics of the selected polarization modes from ALOS/PALSAR.

	Imaging or Polarization mode		
	PLR	**FBD**	**FBS**
Acquisition date	March 13 and April 28, 2007	July 5 and August 20, 2007	January 2, 2007
Baseline (m)	239.13	214.68	-
Polarization	HH/HV + VV/VH	HH/HV	HH
Orbit	Ascendent	Ascendent	Ascendent
Swath Width (km)	20-65	40-70	40-70
Look Angle (degrees)*	21.5	34.3	34.3
Resolution in Azimuth (m)**	27.6	27.7	27.7
Resolution in Range (m)**	22.8	29.7	29.7

Note: * Look angle of 21.5 and 34.4 degrees are equivalent in order to an incidence angle of ~ 25 and ~38 degrees, respectively. ** After multi-looking procedure of 8x1 (PLR), 9x2 (FBD) and 9x4 (FBS).

The first step consisted in the selection of homogeneous areas representative of the land cover classes. This step was performed using unsupervised classification results and visual interpretation over the Landsat images taking into account the PRODES' maps. An additional field inspection of potential sites representative of the selected land covers was also carried out. The classes were therefore identified and characterized in terms of their structure and representative in the study area.

A cloud-free Landsat image acquired on June 28, 2007 was taken as a reference and additional information for the SAR dataset classification. Support vector machines (SVM, Smola and Schölkopf, 2004, Mountrakis, 2011) were used for classification purposes with different datasets organized into seven groups (e.g. G1 to G7) and five sub-groups (e.g. "A" to "E") whose details are given in Liesenberg and Gloaguen (2013).

3. Results and Discussions

Figure 2 illustrates the classification accuracy results from SVM for different groups od data inputs. For a reference perspective (e.g. at Landsat; Group 1), classification accuracy values yielded an overall accuracy of 70% and tend to overcome all individual SAR datasets (e.g. G2 to G5) at the 5% significance level. However, there were still some poorly discriminated classes as observed for riparian and initial secondary forest that required a multi-sensor approach to improve classification. The overall classification accuracy generally increases from backscattering (G2), with the complementary addition of polarimetric features (G3) to interferometric coherence (G4) and texture parameters (G5).

Overall classification accuracy for quad1 reached 56% (G2A) using backscattering alone. In general, the poorly discriminated classes with backscattering or Landsat data alone becomes correctly classified (Table 2a) with the addition of SAR-derived parameters. It improved to 65% by adding polarimetric features (G3A), then to 66% (G4A) with coherence and then finally to 69% (G5A) including texture (Table 2b). However, both interferometric coherence and texture, which are assumed to provide additional information on the spatial characterization and classification improvement (Drezet and Quegan, 2007, Longepe et al., 2011, Laurin et al., 2013), showed only minor effects on the classification accuracy performance. In general, the magnitude of classification accuracy corresponds well with previous experiments conducted by Kuplich et al. (2000), Erasmi and Twele (2009) and Avtar et al. (2012) in tropical environments.

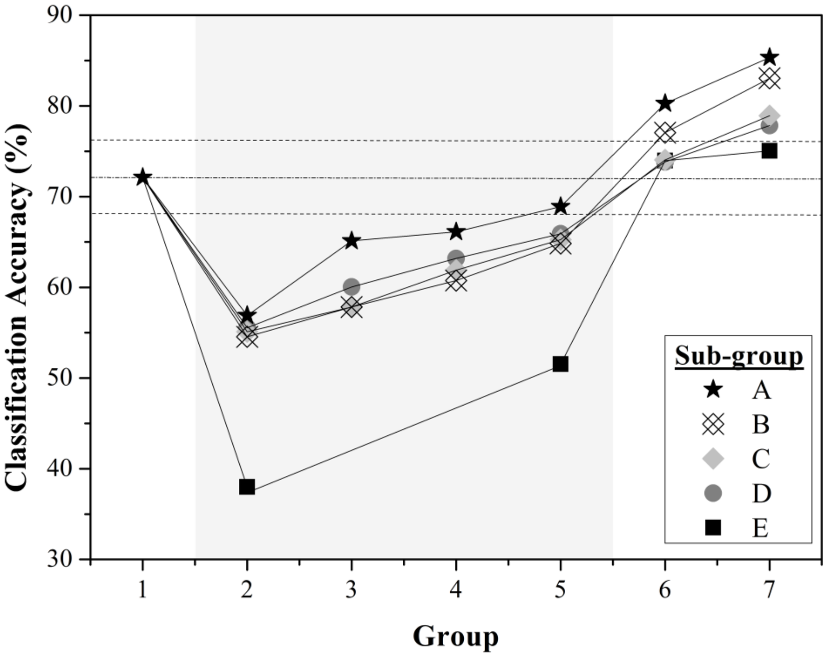

Figura 2. Overall classification accuracy for the selected groups and sub-groups. Results were based on the validation dataset. The shadowed area refers to groups in which SAR backscattering (i.e. G2) and their derived parameters (i.e. G3 to G5) were used. The dotted lines show both Landsat data accuracy (i.e. G1) and its Z-test threshold at a 95% confidence level (Z≥1.96). Refer to Table 4 for the group's description.

Table 2. Error matrix for G1A/Landsat alone (A) and G7A/Backscattering plus polarimetric, interferometric coherence, texture and Landsat (B). Values are indicated in percentage values. Overall Accuracy was in order 72.1% and 85.5%, whereas Kappa index 0.67 and 0.83.

(A)

	RF	SS1	SS2	SS3	PF	WT	PT
RF	**50.5**	2	3.5	34.5	20.6	0	0
SS1	0	**83**	10.5	0	0	0	0.5
SS2	2.5	12	**74.5**	8.5	0	0	0
SS3	17	2.5	11	**28**	10.1	0	0
PF	30	0	0.5	29	**69.8**	0	0
WT	0	0	0	0	0	**100**	0
PT	0	0.5	0	0	0	0	**99.5**

(B)

	RF	SS1	SS2	SS3	PF	WT	PT
RF	**86**	0	0	4.5	0	0	0
SS1	0.5	**86**	9.5	0.5	0	0	0.5
SS2	0	10.5	**81**	6	0	0	0
SS3	8.5	2.5	9	**62.5**	17.6	0	0
PF	5	0	0.5	26.5	**82.9**	0	0
WT	0	0	0	0	0	**100**	0
PT	0	1	0	0	0	0	**99.5**

4. Final Remarks and Future Work

Complex areas with shifting cultivation practices can be classified with SAR backscattering and their polarimetric derived parameters. The addition of SAR-derived parameters with backscattering increases overall accuracy at the 5% significance level when compared with backscattering alone at different polarization modes. However, this classification accuracy did not overcome Landsat classification accuracy alone, but could be an alternative source of data for mapping purposes in regions affected by frequent cloud coverage.

Further research is needed in order to test the performance of other classification methods (e.g. neural networks, random forest, object-based classification) in terms of differentiating between vegetation-types in the Eastern Amazon. In the absence of optical imagery, there is much potential for the additional use of a multi-frequency approach, whose data unfortunately cannot be collected simultaneously by any available orbital SAR system.

In the near future, the new generation of full polarimetric SAR technologies could be helpful for long-term monitoring of secondary forest in order to quantify changes in carbon stocks and tropical rainforest dynamics. This technology will also permit the evaluation of forest regeneration responses to climate and land use changes as required by the upcoming REDD protocols.

Acknowledgements

CNPq (290043/2007-7) and FAPESP (13/05081-9) for the support.

References

Avtar, R., Takeuchi, W., Sawada, H., 2012. Full polarimetric PALSAR-based land cover monitoring in Cambodia for implementation of REDD policies. **International Journal of Digital Earth**, 6(3), 255-275.

Drezet, P.M.L., Quegan, S., 2007. Satellite-based radar mapping of British forest age and Net Ecosystem Exchange using ERS tandem coherence. **Forest Ecology and Management**, 238(1-3), 65-80.

Erasmi, S., Twele, A., 2009. Regional land cover mapping in the humid tropics using combined optical and SAR satellite data - a case study from Central Sulawesi, Indonesia. **International Journal of Remote Sensing**, 30(10), 2465-2478.

Galvão, L.S., Ponzoni, F.J., Liesenberg, V., Santos, J.R., 2009. Possibilities of discriminating tropical secondary succession in Amazônia using hyperspectral and multiangular CHRIS/PROBA data. **International Journal of Applied Earth Observation and Geoinformation**, 11(1), 8-14.

Kuplich, T.M., 2006. Classifying regenerating forest stages in Amazônia using remotely sensed images and a neural network. **Forest Ecology and Management**, 234(1-3), 1-9.

Kuplich, T.M., Freitas, C.C., Soares, J.V., 2000. The study of ERS-1 SAR and Landsat TM synergism for land use classification. **International Journal of Remote Sensing**, 21(10), 2101-2111.

Laurin, G.V., Liesenberg, V., Wilebore, B., Chen, Q., Guerriero, L., Del Frate, F., Bartolini, A., Coomes, D., Lindsell, J., Valentini. R., In press. Optical and SAR sensor synergies for forest and land cover mapping in a tropical site in West Africa. **International Journal of Applied Earth Observation and Geoinformation**, 21, 7-16.

Lee, J.S., Hoppel, K.W., Mango, S.A., Miller, A.R., 1994. Intensity and phase statistics of multilook polarimetric and interferometric SAR imagery. **IEEE Transactions on Geoscience and Remote Sensing**, 32(5), 1017-1028.

Lee, J.S., Grunes, M.R., De Grandi, G., 1999. Polarimetric SAR speckle filtering and its implication on classification. **IEEE Transactions on Geoscience and Remote Sensing**, 37(5), 290-301.

Lee, J.S., Wen, J.H., Ainsworth, T.L., Chen, K.S., Chen, A.J., 2009. Improved Sigma Filter for Speckle Filtering of SAR Imagery. **IEEE Transactions on Geoscience and Remote Sensing**, 47(1), 202-213.

Liesenberg, V., Boehm, H.D.V., Gloaguen, R., 2010. Spectral variability and discrimination assessment in a tropical peat swamp landscape using CHRIS/PROBA data. **GIScience & Remote Sensing**, 47(4), 541-564.

Liesenberg, V., Gloaguen, R., 2013. Evaluating SAR polarization modes at L-band for forest classification purposes in Eastern Amazon, Brazil. **International Journal of Applied Earth Observation and Geoinformation**, 21, 122-135.

Longepe, N., Rakwatin, P., Isoguchi, O., Shimada, M., Uryu, Y., Yulianto, K., 2011. Assessment of ALOS PALSAR 50 m Orthorectified FBD Data for Regional Land Cover Classification by Support Vector Machines. **IEEE Transactions on Geoscience and Remote Sensing**, 49(6), 2135-2150.

Lu, D., Li, G., Moran, E., Dutra, L., Batistella, M., 2011. A Comparison of Multisensor Integration Methods for Land Cover Classification in the Brazilian Amazon. **GIScience and Remote Sensing**, 48(3), 345-370.

Lu, D., Mausel, P., Brondízio, E., Moran, E., 2003. Classification of successional forest stages in the Brazilian Amazon basin. **Forest Ecology and Management**, 181(3), 301-312.

Mountrakis, G., Im, J., Ogole, C., 2011. Support vector machines in remote sensing: A review. **ISPRS Journal of Photogrammetry and Remote Sensing**, 66(3), 247-259.

Rabus, B., Eineder, M., Roth, A., Baler, R., 2003. The shuttle radar topography mission – a new class of digital elevation models acquired by spaceborne radar. **ISPRS Journal of Photogrammetry and Remote Sensing**, 57(4), 241-262.

RADAMBRASIL, 1975. **Levantamento de Recursos Naturais**: Tapajós. Departamento Nacional da Produçao Mineral, Rio de Janeiro. 358p.

Rignot, E., Salas, W.A., Skole, D.L., 1997. Mapping deforestation and secondary growth in Rondônia, Brazil, using imaging radar and Thematic Mapper data. **Remote Sensing of Environment**, 59(2), 167-179.

Smola, A.J., Schölkopf, B., 2004. A tutorial on support vector regression. **Statistics and Computing**, 14(3), 199-222.

Vieira, I.C.G., Almeida, A.S., Davidson, E.A., Stone, T.A., Carvalho, C.J.R., Guerrero, J.B., 2003. Classifying successional forests using Landsat spectral properties and ecological characteristics in eastern Amazônia. **Remote Sensing of Environment**, 87(4), 470-481.

Yanasse, C.C.F., Sant'Anna, S.J.S., Frery, A.C., Rennó, C.D., Soares, J.V., Luckman, A.J., 1997. Exploratory study of the relationship between tropical forest regeneration stages and SIR-C L and C data. **Remote Sensing of Environment**, 59(2), 180-190.

Zhang, H., Zhang, Y., Lin, H., 2012. A comparison study of impervious surfaces estimation using optical and SAR remote sensing images. **International Journal of Applied Earth Observation and Geoinformation**, 18, 148-156.