THE CONTRIBUTION OF CHRIS/PROBA DATA FOR TROPICAL PEAT SWAMP LANDSCAPE DISCRIMINATION PURPOSES

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ABSTRACT

This study examined the classification accuracy of a CHRIS (Compact High Resolution Imaging Spectrometer) image, acquired on May 18, 2004 (monsoon) in four view angles and 18 spectral bands for eight specific land use/cover categories from a single view angle (at nadir as a reference) and from a multiangular perspective. The test site is a typical peat swamp landscape site located in South Borneo (Central Kalimantan, Indonesia). Results showed that for a given angle the reflectance increase according to the successional stages and they presented also large reflectance values in near-infrared region with decreasing leaf area index (LAI). From the single (nadir) to the multiangular approach, classification accuracy increased from 77.1% to 90.4%. Kappa statistics increased from 0.74 to 0.89 and confirmed that the classification performances were statistically different at a 0.05% level of significance. Results showed that multiangular data can improve the differentiation between different Peatland landscape classes.

***Index Terms*—** CHRIS/PROBA, Peat Swamp Forest, Forest Succession, land cover, view angle effects.

1. INTRODUCTION

Natural tropical peat swamp forests are important because of its rich biodiversity and huge carbon pool [1]. However, peat swamp forests have been decreasing due to conversion of forests into managed land cover types, degraded ecosystems and large deforested areas that have been reverted to successional forest stages. These issues increase the interest in mapping such environments because they are recognized as an important source of carbon released in the atmosphere. In this study, the contribution of multispectral and multiangular Compact High Resolution Imaging Spectrometer (CHRIS) data collected over a Peat swamp landscape in Central Kalimantan (Indonesia) was evaluated as a function of viewing geometry (anisotropy). CHRIS is one sensor on board the European Space Agency Project for On Board Autonomy (PROBA) [2]. To demonstrate the Sun-view effects on the discrimination of a typical forest succession, an image collected under a very clear sky condition over the monsoon was also evaluated for classification purposes among typical peat swamp classes.

2. STUDY AREA

The location of the study area is a subset result of 7km x 12km close to Palangkaraya, the capital city in Central Kalimantan province (Indonesia), between Sebangau and Kahayan rivers and between -02°18'S/113°57'E and -02°21'S/114°05'E. The site shows a humid tropical climate (type Af in the Köppen system) with an annual rainfall of 3500mm and an annual mean air temperature of 25^{o}C. The area is very flat, with no undulations, the maximum altitude above sea level is 30m and the mean peat average thickness 4m. Eight major classes occur in the peat swamp environment of the study area: Peat Swamp Forest (PSF), Advanced Secondary Forest (ASF), Dense Regrowth (DRG), Sparse Regrowth (SRG), Wetland (WTL), Grassland (GSL), Burnt areas (BRT) and Shrubland (SHL) [3].

3. METHODOLOGY

CHRIS/PROBA data was acquired on May 18, 2004 in 18 bands (415-1050 nm) with a spatial resolution close to 20m at nadir and four different nominal view zenith angles (-36^{o}, +0^{o}, + 36^{o}, +55^{o}). Fig. 1 shows the geometry of the data acquisition. Striping effects were reduced using average response of adjacent columns and atmospheric correction was performed using the fast line-of-sight atmospheric analysis of spectral hypercubes (FLAASH) radiative transfer code that results in hemispherical directional reflectance factor (HDRF) values. The geometric correction was performed using the Ground Controls Points methodology. For each physiognomy, 440 pixels (40 pixels as training and 400 pixels as validation) were selected with approximately similar position at each camera image based on the combined analysis of available vegetation maps [3] and K-Means unsupervised classification results. Attention was given for neighbor pixels to avoid spatial correlation. The training dataset was normalized to the nadir response and

MODIS Level 2 Land Surface Products Leaf Area Index (LAI) and Vegetation Continuous Field were also considered in the analysis.

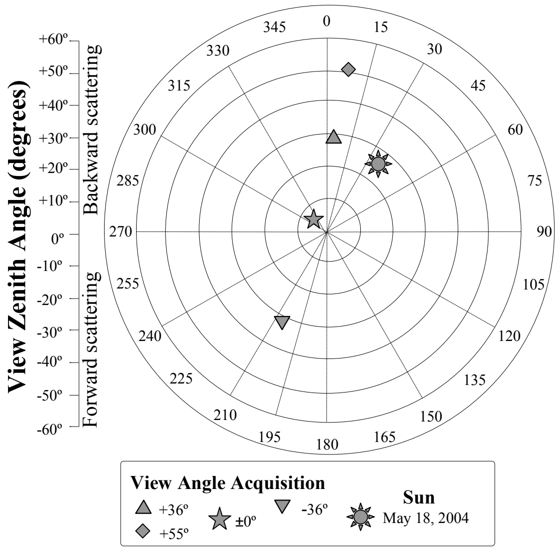

Fig. 1. Geometry of CHRIS/PROBA data acquisition.

Data analysis included the use of Principal Components Analysis (PCA) applied separately at each view angle (-36º, nadir, +36º, +55º) using the reflectance value of the 18 bands as input variables. This technique was applied in order to reduce data dimensionality at each dataset, enhance separability between the classes, and to provide input variables for Multiple Discriminant Analysis (MDA), respectively. PCA was also applied over all dataset (four view angles). Principal Components (PC) with eigenvalues greater than 1 were retained. The total set of retained PC scores was used as input candidate variables for MDA and the best variables were selected from stepwise procedure. Finally, classification accuracy results from MDA using the validation set of pixels were compared between both approaches (single one at each view angle and a multiangular one) and Kappa coefficients were calculated as a measure of classification accuracy using both McNemar and Z-test methods.

4. RESULTS AND DISCUSSION

4.1. Angular Sensitivity

CHRIS-derived surface reflectance anisotropy between the different peatland classes are shown in Fig. 2 for two extreme view angles (-36º and +36º). With exception to Wetland that showed a specular reflectance due to a water blade reflection at -36º (forward scattering), the reflectance increased for all the remaining classes in the 415-1050 nm range from the forward (Fig. 2a) to the backward (Fig. 2b) scattering direction due to the predominance of sunlit canopy components at +36º and +55º view angle.

To demonstrate the angular sensitivity of the Peatland classes under study, Fig. 3 shows the nadir-normalized red and near-infrared reflectance values. Except for Wetland (result not shown due to its large values) the strongest differences from the nadir were noticed in the backward scattering direction (positive view angles) with the predominance of illuminated vegetation components for the sensor. The red band (Fig. 3a) presented a more anisotropic behavior than the near-infrared band (Fig. 3b), as indicated by the wider range of normalized HDRF data in the backward direction [4].

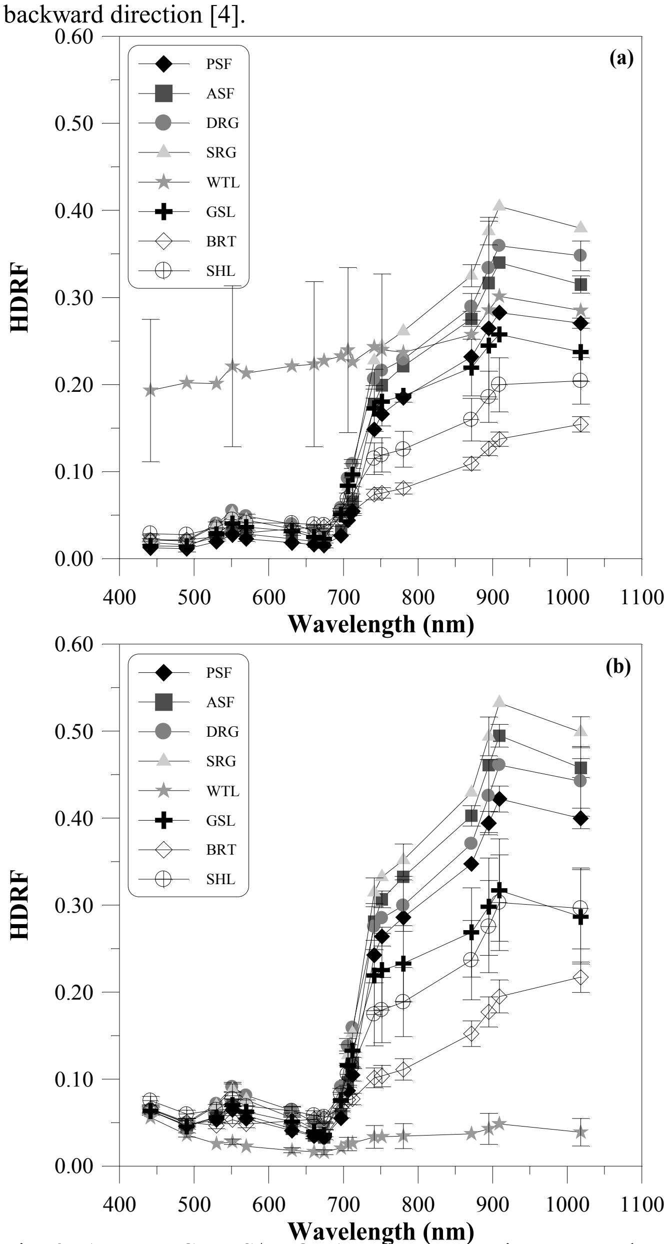

Fig. 2. Average CHRIS/PROBA reflectance anisotropy and standard deviation values of Peatland land cover classes in the (a) forward (-36º view angle) and (b) backward (+36º view angle) scattering directions.

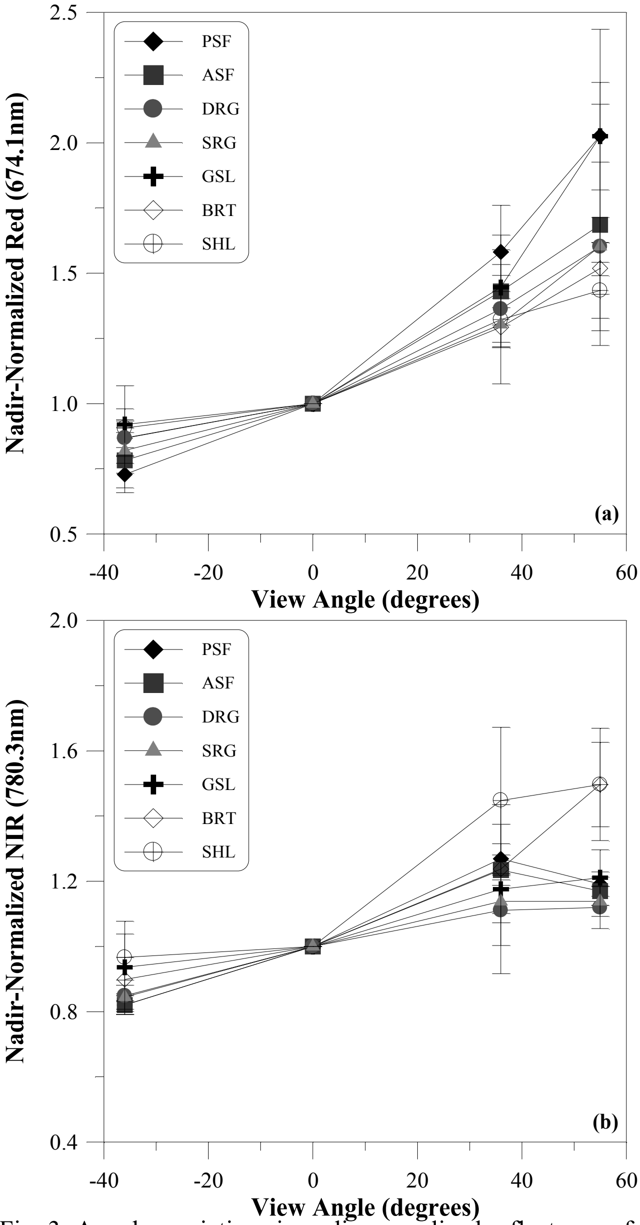

Fig. 3. Angular variations in nadir-normalized reflectance of different tropical peat swamp classes for selected (a) red (674.1nm) and (b) near-infrared (780.3nm) bands.

According to these authors [4], the directional effects are particularly stronger in spectral regions of high absorbance such as the red chlorophyll interval, and in this study they were noticed mainly for Peat swamp forest and Grassland. On the other hand, directional effects were less pronounced at extreme viewing in the near-infrared due to the predominance of multiple scattering processes that reduce the spectral contrast between shadowed and illuminated components [5]. Thus, the direction of maximum reflectance at backward scattering direction at near-infrared region was better defined for Peat Swamp forest and Advanced Secondary forest, classes with high LAI values.

4.2. Discrimination performance

PCA of the 18 CHRIS reflectance bands was responsible not only for reducing the data dimensionality, but they produce also an enhancement of the spectral separability between the vegetation types at each view angle. Based on the use of eigenvalues greater than 1, the first two components were retained at each view angle dataset and the cumulative variance (PC1 plus PC2) was at least 93% for each dataset.

PC1 at each view angle represented brightness and was good correlated with the mean reflectance in the 410-1050 nm. PC2 at nadir and positive view angle expressed contrasting contributions of the near infrared (negative loadings in the 760-1050 range) and visible (positive loadings for blue and red wavelengths) data and represented inversely variations in shape of the vegetation spectra. At negative view angle PC2 showed relation to the green vegetation spectra where loadings for near infrared were positive and negative for the visible with a peak in the green bands remembering a green vegetation spectrum.

Classification accuracy results from MDA with the first two PC scores as input variables at each view angle confirmed that the only +55^{o} view angle was statistically different at a 0.05% level of significance in comparison with nadir view angle. Kappa statistics ranged from 0.74 (at nadir view angle) to 0.81 (+55^{o} view angle). In general, there was a significant improvement from nadir to the backward scattering direction (+55^{o} view angle) for six of the eight classes under study.

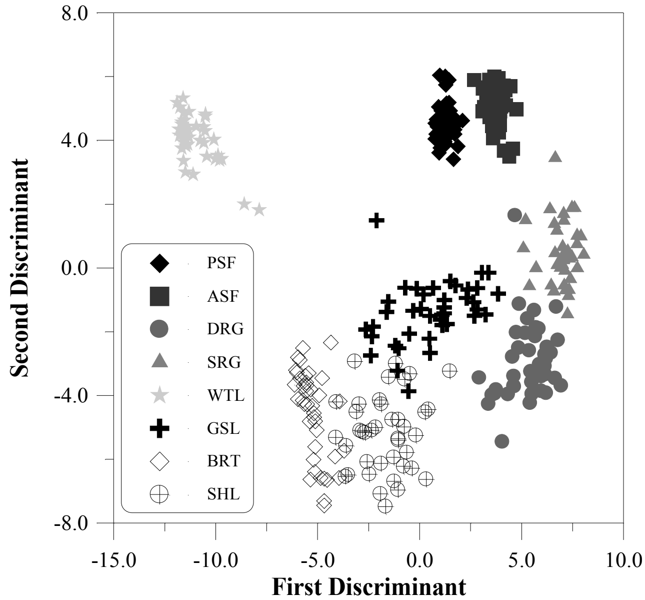

Fig. 4. Projection of different tropical peat swamp classes in the first and second discriminant component using the multiangular approach.

The use of the discriminant function to classify a separate set of pixel spectra showed an overall classification accuracy improvement from 77.1% (nadir) to 90.4% (multiangular approach). Kappa statistics ranged from 0.74 to 0.89. Results from both McNemar and Z-test confirmed that the multiangular approach produced statistically different classification values at a 0.05% level of significance to better differentiate the peatland classes than the single view angle approach (either nadir or +55^{o} view angle). Additionally, there was a significant improvement for five of the eight classes under study.

Fig. 4 shows the projection of the first two discriminant component scores for the multiangular approach. The most interesting result was the differentiation between primary forest and secondary forest using multiangular data that are reported as the most difficult to be mapped in the tropical rain forest environments [6], [7]. Fig. 5 shows the classification accuracy for a single view approach at nadir and +55 degrees and the multiangular approach. According to this figure, only the dense regrowth class was not well discriminated using a multiangular approach.

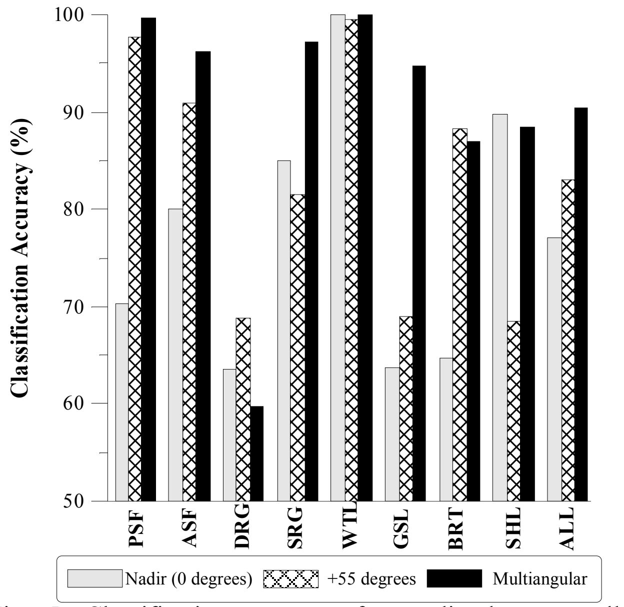

Fig. 5. Classification accuracy for: nadir; best overall classification accuracy results for a single view approach at +55◦ view angle; and multiangular approach.

5. CONCLUSION

In relation to nadir view angle, the strongest anisotropy was observed in the backward scattering direction in which great amounts of sunlit canopy components were viewed by the sensor and in the visible bands. In the backward scattering direction Primary Forest and Grassland were more anisotropic than the remaining classes, especially for the red band. The two more spectrally similar classes were Dense and Sparse regrowth which were better differentiated at +55^{o} view angle using PCA and MDA. In comparison with the single view angle approach (nadir), the multiangular approach produced an overall discrimination improvement. MDA-derived overall classification accuracy was statistically significant using a separate set of pixels and it increased from 77.1% to 90.4% (Kappa statistics from 0.74 to 0.89). Further research to achieve better results may be carried out with additional use of shortwave infrared (SWIR) data.

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6. REFERENCES

[1] S.E. Page, F. Siegert, J.O. Rieley, H.-D.V. Boehm, A. Jaya, S. Limin, “The amount of carbon released from peat and forest fires in Indonesia during 1997,” *Nature*, vol.420, no.6911, pp.61-65, 2002.

[2] M.J. Diner, J.J Settle, M.A. Cutter, D.R. Lobb, F. Teston, “The PROBA/CHRIS mission: A low-cost smallsat for hyperspectral multiangle observations of the Earth surface and atmosphere,” IEEE Transactions on Geoscience and Remote Sensing, vol.42, no.7, pp.1512-1520, 2004.

[3] Boehm, H.-D.V., S. Ramirez, D. Bustillo, *Environmental Management Study of the Tangkilling Distric along River Rungan in Central Kalimantan, using Remote Sensing and GIS*, Open Science Meeting in Yogyakarta, Indonesia, 2005.

[4] St. Sandmeier, Ch. Müller, B. Hosgood, G. Andreoli, “Physical mechanisms in hyperspectral BRDF data of grass and watercress,” *Remote Sensing of Environment*, vol.66, no.2, pp.222–233, 1998.

[5] St. Sandmeier, D.W. Deering, “Structure analysis and classification of Boreal forests using airborne hyperspectral BRDF data from ASAS,” *Remote Sensing of Environment*, vol.69, no.3, pp.281-295, 1999.

[6] D. Lu, P. Mausel, E. Brondízio, E. Moran, “Classification of successional forest stages in the Brazilian Amazon basin,” *Forest Ecology and Management*, vol.181, no.3, pp.301-312, 2003.

[7] R.M. Lucas, M. Honzák, I.D. Amaral, P.J. Curran, G.M. Foody, “Forest regeneration on abandoned clearances in central Amazonia,” *International Journal of Remote Sensing*, vol.23, no.5, pp.965-988, 2002.