LAND USE/LAND COVER MAPPING IN BRAZILIAN AMAZON USING NEURAL NETWORK WITH ASTER/TERRA DATA

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ABSTRACT:

The objective of this study is to show the applicability of the genetic synthesis of the unsupervised artificial neural network ART2 (Adaptive Resonance Theory) in the classification of ASTER image for land use/land cover mapping. The area under study is located in northern Mato Grosso State, Brazil, and is characterized by a strong human occupation process, which caused intensive changes at the landscape, by deforestation, selective logging and agriculture. Field data were acquired in May/June 2003. The use of ASTER data allowed an improvement of the analysis of the occupation process in tropical forest areas. ASTER images have adequate spatial and spectral resolution and are an alternative to the remaining remote sensing data available. The data had a correction of the cross-talk problem, after realized a resampling from SWIR bands (spatial resolution 30 to 15 m), a atmospheric correction and rectification of ASTER images from both data sets 2002 e 2003. The input parameters for the neural network ART2 were optimized by genetic algorithm and the neural network was evaluated by a comparison of classification results with field data. The evaluation of accuracy was done using Kappa statistics. The results of the classification were of satisfactory quality. ASTER bands 2 (630-690 nm), 3 (760-860 nm) and 4 (1600-1700 nm) allowed an increased differentiation of classes, while bands 8 (2295-2365 nm) and 6 (2185-2225 nm) were complementary for the identification of classes. The main land use changes that occurred between 2002 and 2003 were related to deforestation, since many areas of tropical forest were replaced by agriculture and pastures.

1. INTRODUCTION

The National Institute for Space Research – INPE/Brazil, has done several research and application studies with remote sensing data in the forestry area. Among the most important studies one can mention the project "Monitoring of the Brazilian Amazonian Forest by Satellite" (PRODES), an estimation of the extent and rate of deforestation using TM Landsat 5 images. More recently, due to the degradation of the TM-Landsat 5 signal and the non-availability of TM-Landsat 7 data, other sensors have been used to get subsidies needed by the Brazilian Government to control and monitor the Amazon environment.

The sensor system TERRA/ASTER has a great potential to follow on these environmental studies, due to its spatial, spectral and radiometric resolution characteristics. It is also a complementary source of data and information derived from other sensors which are now operational (NOAA/AVHRR, AQUA/MODIS, SPOT-5/HRV, RADARSAT, IRS and more recently CBERS-2/CCD), as a subsidy to studies which involve different evaluations in regional and local scales. Until now there are no works using ASTER sensor data for studies on forest formations, types of vegetation cover and land use in the Amazon, which justifies the interest of this study.

Apart the innovation of the product-sensor in this study, there is also a preoccupation on the evaluation of a new form of digital image processing. There is an interest for the use of Artificial Neural Networks applied to the reconnaissance of patterns. Within this perspective, Lee et al. (1990) report that neural networks seem perform image classification better than the traditional statistical techniques, since they don't require explicitly that data that will be classified requires a parametric distribution. There are several models of artificial neural networks which were developed for the most different applications, such as: perception by layers, self-organizing, by learning, and backpropagation, etc.

Within this context, the general objective of this study is to use a genetic synthesis of the unsupervised neural network ART2 (Adaptative Resonance Theory) to map land use/land cover of a section from northern Mato Grosso State, using images from Terra/ASTER, at the visible, near (VNIR) and middle (SWIR) infrared bands. Furthermore a temporal analysis of ASTER sensor data was done in this region for the years 2002 and 2003 in order to investigate land use/land cover changes.

The specific objectives are: (1) to analyze ASTER VNIR and SWIR bands for the spectral discrimination of land use/land cover classes; (2) to evaluate the performance of initially given parameters for the genetic optimization of the neural network ART2 for the reconnaissance of patterns of ASTER data; (3) to

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analyze the performance of the neural network ART2 in the thematic classification as related to data of field work, using Kappa statistics procedures; (4) to perform a temporal analysis with data of the years 2002 and 2003, aiming to investigate the dynamics of occupation from the physical space, evaluating the changes at the thematic classes identified by the neural network ART2 for both years.

2. AREA UNDER STUDY

2.1 Localization

The area under study is located partially at the municipalities of Sinop, Cláudia and Itaúba, at northern Mato Grosso State, Central-West Brazil, between geographical coordinates S 10°48'55"- S 12°00'46" and W 54°54'03" - W 55°46'53" (Figure 1). This area is situated along a section of highway BR-163 Cuiabá-Santarém, encompassing an area of 382,000 ha.
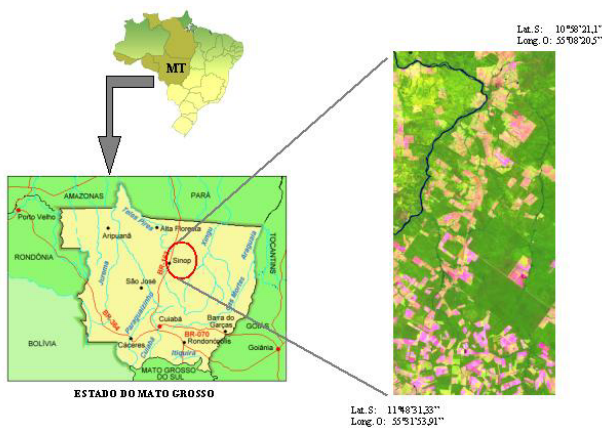

Figure 1. Location of the study area, in a mosaic of two images ASTER (bands 4, 3 and 2).

3. DATA AND METHODS

3.1 ASTER images

Spectral data obtained by the ASTER sensor system were used in this study (Table 1). The images referring to year 2002 were acquired at NASA and EROS Data Center (USA), and those of 2003 at ERSDAC (Earth Remote Sensing Data Analysis Center), Japan, under Agreement Nr. H140250. All scenes were of type 1B, which are delivered to users with radiometric and geometric calibrations. The images from 2002 were used complementarily, aiming to investigate the dynamics of land use/land cover in the area under study.

YEAR	ID IMAGE
2002	pg-PR1B0000-2002050402_019_001
	pg-PR1B0000-2002050402_181_001
2003	pg-PR1B0000-2003090902_005_001
	pg-PR1B0000-2003090902_167_001

Table 1. ASTER images used.

3.2 Methodology

Initially a pre-processing of data is done through correction of the cross-talk problem, of resampling from SWIR bands (spatial resolution: 30 to 15 m), of image registration, of atmospheric correction and rectification of ASTER images from both data

sets 2002 and 2003. Afterwards the automatic image classification is done using a non-supervised ART2 algorithm considering Artificial Neural Network (ANN), followed by a post-classification to minimize the presence of isolated pixels. Finally the evaluation of accuracy is done, using Kappa statistics, related to ground truth, with maps on land use/land cover are generated for both data sets considered.

4. RESULTS

The cross-talk problem (Iwasaki et al., 2001) was solved using a "cross talk correction" program developed by ERSDAC (2001). Afterwards resampling of SWIR bands from 30 to 15 m was done, in order to integrate with VNIR.

For the registration of the ASTER images, 20 control points were identified, using a first grade polynomial and resampling of pixels by the nearest neighbor algorithm. During the evaluation of the exactness of registration using as reference the image from 2003, a RMS error of 0,27 was obtained. This result is considered as reasonable, because for a spatial resolution of 15 m of ASTER images, the internal error of points used for mapping (4 m) is less than half a pixels' spatial resolution of the images. As for the 2002 image, the RMS error of 0.05 was considered excellent.

In order to obtain reflectance values on the surface, an atmospheric correction was done using the ACORN 4.0 program, based on the radiation transference model MODTRAN 4, which transforms radiance values of ASTER images for surface reflectance values. Data of water vapor were obtained from MODIS sensor data, located at the same Terra satellite corresponding to the same dates of obtainment from these ASTER images (MODIS, 2003).

To get uniform ASTER data for 2002 and 2003, the method of pseudo-invariant targets present in the image were used (Hill & Sturn, 1991). This procedure is used to eliminate those differences caused by factors which affect the image acquisition. The digital values obtained from these pseudo-invariant targets (clear and dark) at both dates, were adjusted by a linear regression to digital values of the reference image corrected, for clear and dark targets (Mendoza, 2004).

To evaluate the discrimination between land use/land cover classes, an analysis of the spectral behavior given by the reflectance values and the wavelengths in the spectral range of 500-2500 nm was performed, which includes 9 bands of ASTER. At Figure 2 a graph of the average reflectance of typical samples of thematic classes defined in the area under study is presented for the scene from June 27th 2002.
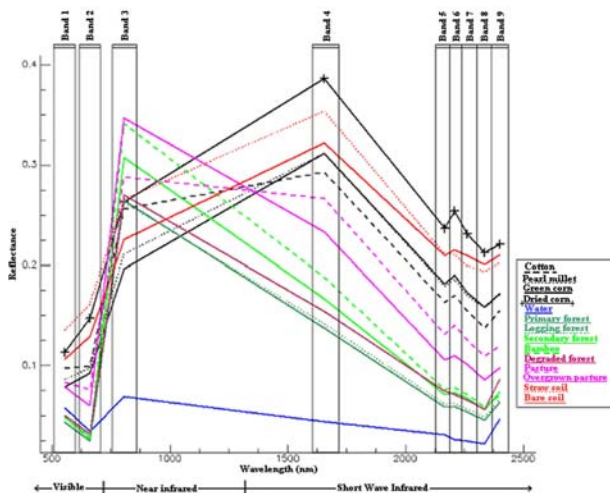
Figure 2. Spectral signature for the targets corresponding to the defined thematic classes.

At Figure 2 one observes that, in a general sense, the classes Primary Forest, Logged Forest, Degraded Forest, Bamboo formations, Secondary Forest, Pasture and Overgrown Pasture present a typical spectral behavior of vegetation, i.e. a low reflectance at bands 1 and 2, corresponding to the visible spectrum (VIS), high reflectance at band 3 (near infrared), and again a low reflectance at bands 4 to 9, corresponding to middle infrared, specially due to presence of water inside the leaves. The classes Overgrown Pasture and Pasture have a slight increase of reflectance in the SWIR, as related to classes Primary Forest, Bamboo and Secondary Forest, due to a lower water content in the leaves. This similar high reflectance in the SWIR occurs at Bare Soil and Straw covered soil.

Classes referring to cultures, such as Cotton (*Gossypium hirsutum*), Pearl millet (*Pennisetum glaucum*), "green" and "dried" corn (*Zea mays*), have a variable spectral behavior depending on its' maturation state. As for the class Water, the increase of its' reflectance, especially in the near infrared (band 3), is caused by suspended materials and by the low depth of it, because the scene was captured during the dry season. At the former figure one can observe that the best discrimination between the different targets found in the field is possible with band 4 (1600-1700 nm), i.e. at the middle infrared.

On the other hand, there is an increase of reflectance at band 9 for all classes, which is not a typical behavior of the targets, because there should be a lower or similar reflectance at all other SWIR bands. This behavior can be explained by the cross-talk phenomenon.

The digital image classification was done using the unsupervised artificial neural network ART2, inserted in the program Genetic Synthesis of Artificial Neural Networks (SGRNA) prepared by Silva (2003). As entries into the neural network, different band combinations were selected: [2,3,4] [2,3,4,5], [2,3,4,6], [2,3,4,7], [2,3,4,8], [2,3,4,9], [1,2,3], [1,3,8], [3,4,6] and finally all bands [1,2,3,4,5,6,7,8,9]. To start the classification process using three or more bands as entries into the network, the initial parameters of the artificial neural network were used, for the combination of classified bands. Besides that, the neural network was trained to recognize patterns in the image, taking into account the amount of nine thematic classes defined in the field, namely: Crops, Primary Forest/ recently logged Forest, Degraded Forest, Secondary

Forest/Bamboo, Bare Soil, Straw covered Soil, "Clean" Pasture, "Overgrown" Pasture, Water.

The Kappa statistics was used to evaluate the accuracy of classification generated, which allowed the generation of error matrices to compare images classified by the ART2 algorithm mentioned and ground truth data. Based on these error matrices, at Table 2 the different values of global exactness and the resulting Kappa coefficients are presented for the best band combinations [2,3,4] and [2,3,4,8] from images of both dates.

Bands combinations	Global accuracy (%)	Kappa
[2,3,4] image 2003	68.7260	0.6429
[2,3,4,8] image 2002	69.2790	0.6455

Table 2 – Global accuracy and Kappa coefficients for classifications from the image 2002 and 2003.

The Figure 3 and 4 presents the results of thematic classification with the highest Kappa value for the band combinations [2,3,4,8] of year 2002 and [2,3,4] of 2003.
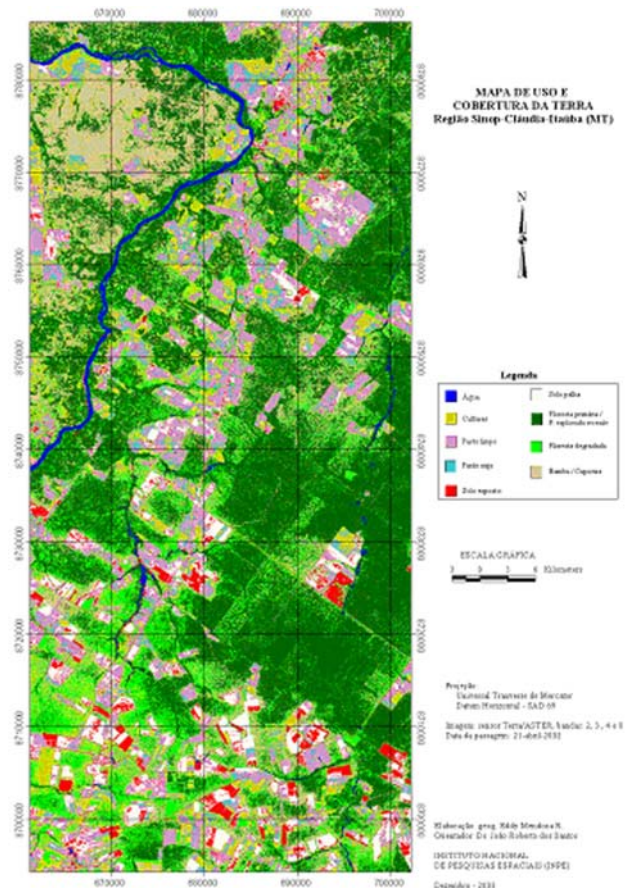

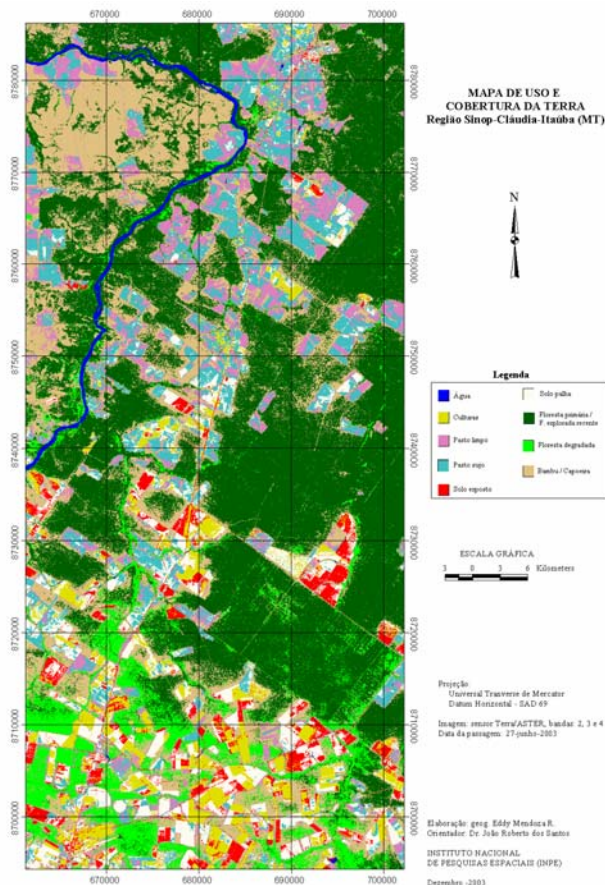Figure 3. Land use/land cover thematic map of 2002 obtained from ASTER/Terra image.

Figure 4. Land use/land cover thematic map of 2003 obtained from ASTER/Terra image.

5. CONCLUSIONS

As for the analysis of spectral values, the spectral and spatial resolution of ASTER images allowed a detailed discrimination of land use/land cover classes, even considering the large thematic complexity of the area under study (spectral superposition and regenerative process).

Besides bands 2 (630-690 nm), 3 (760-860 nm) and 4 (1600-1700 nm) which demonstrated its' utility for land use / land cover classification, we recommend the inclusion of bands 6 (2185-2225 nm) and 8 (2295-2365 nm), in order to complement the classification process.

The architecture of the neural network ART2 inserted in the environment SGRNA, presents characteristics (such as simplicity and easiness to enter and manipulate data) of an adequate ASTER image classifier. Besides that, the classification performance obtained by the neural network, as related to the ground truth, can be considered as satisfactory, taking into account the investigated thematic classes. The vigilance parameter is an important variable in the classification process done by neural network ART2, because it helps to control the number of patterns to be classified and that this number is not too large (e.g. for the case of values very close to 1). The training values, test and the population data vary according to the size of the area and of computational resources available, because for larger values there is an increased demand of computer capacity.

This new procedure of ASTER image analysis shows efficiency, indicating that ASTER products are of significant importance for the inventory and thematic monitoring of the Brazilian Amazon.

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