Mapping and monitoring land cover in Acre State, Brazilian Amazônia, using multitemporal remote sensing data

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ABSTRACT

This paper presents the use of multitemporal remote sensing data for monitoring land cover changes in Acre State, Brazilian Amazônia. The 2000 Landsat ETM+, the 1990 Landsat TM, and 1980 Landsat MSS were used. The 2005 and 2007 MODIS images were also used to map deforestation occurred during the recent years and to map burned areas occurred in the 2005 dry year. The Landsat and MODIS images were converted to vegetation, soil, and shade fraction images. Then land cover maps were obtained by digital classification of these fraction images. The deforestation increased 7,114 km^2 from 1980 to 1990, 4,900 km^2 from 1990 to 2000, and 3,258 km^2 from 2000 to 2007. It also showed that about 2,815 km^2 of regrowth areas were observed in the 2000 ETM+ images. The analysis of MODIS images showed that 3,700 km^2 of deforested areas and 2,800 km^2 of forested areas were burned in Acre State in 2005. These information are critical for regional and global environmental studies and for efforts to control such burning and deforestation in the future.

Index Terms — Landsat data, land cover map, multitemporal analysis, digital classification, Amazonia region.

1. INTRODUCTION

Since 1988, INPE is monitoring annually the Amazon Forest using Landsat images. However it maps only the converted areas occurred in the forested areas. The deforested areas mapped since 1988 are not analyzed in the following years. Then the other land use areas are not estimated.

Significant part of these areas has been abandoned immediately after the cut or after few years of use for cattle raising [1]. Then these areas start the processing of natural succession of vegetation cover. The regrowth areas have higher photosynthetic, evapotranspiration, and respiration rates and higher capacity of carbon stock than agricultural areas as mentioned in [2]. Those factors show the important role of the secondary forest for the carbon balance and then the necessity to monitor these areas.

Using medium, moderate or low spatial resolution sensor data we have the so-called “mixture problem”, i.e., the pixel value is a mixture of reflectance from different targets within each pixel. Several techniques, such as modeling and empirical estimations, have been applied to depict subpixel heterogeneity in land cover from remotely sensed data [3]. Fraction images derived from different remote sensing data have provided consistent results for monitoring deforestation [4], land cover change [5], vegetation classification [3], and burned areas mapping [6]. Fraction images, derived from a linear spectral mixing model, constitute synthetic bands with information on end-member proportions. The generation of these images is an alternative approach to reduce the dimensionality of image data and enhancing specific information for digital interpretation [7].

The objective of this paper is to use multitemporal remote sensing data for mapping and monitoring land cover changes in Acre State located in the western Brazilian Amazônia.

2. STUDY AREA

Acre State, located in the western region of Brazilian Amazonia (Figure 1), served as the site for this study. According to IBGE vegetation maps, the study area is primarily covered by moist tropical forest ("Floresta Ombrófila Aberta") that has been partially deforested during the last decades. The climate in Acre is classified as Am in the Koppen system. Average monthly temperatures range from 24 to 27 degrees Celsius. Yearly rain is about 2,100 mm, with a dry season on June to August. In 2005, this study area suffered a drought that provoked a large number of fires, including fires that penetrated into standing forests [8].

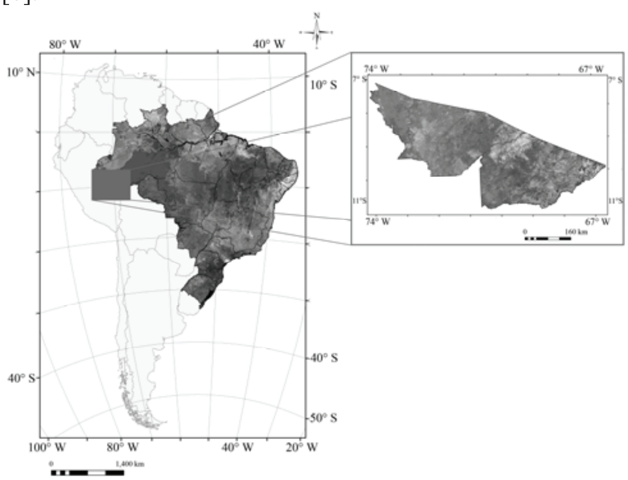

Figure 1: Location of the Study area: Acre State.

3. MATERIAL AND METHODS

The GeoCover orthorectified Landsat Enhanced Thematic Mapper Plus (ETM+) mosaic image centered on 2000, with pixel size of 14.25 m resampled to 100 m, the GeoCover orthorectified Landsat Thematic Mapper (TM) mosaic image centered on 1990, with pixel size of 28.5 m resampled to 100 m, and Landsat Multispectral Scanner (MSS) image centered on 1980, with pixel size of 80 m were used in this study. These remote sensing data were used for analyzing the land use and land cover changes during the 20 years (1980–2000) time period. In addition, 2005 and 2007 MODIS images, with 250 m of spatial resolution, were used to map deforestation occurred during the recent years and also to map burned areas occurred in the 2005 dry year in the study site. The Landsat-TM and -MSS and Terra-MODIS images were converted to vegetation, soil, and shade fraction images thus enhancing characteristics of land cover, expressed as different mixtures of these few number of terrain components. Fraction images, derived from a linear spectral mixing model [9], constitute synthetic bands with information on end-member proportions. The generation of these images is an alternative approach to reduce the dimensionality of image data and enhancing specific information for digital interpretation. Then land cover maps were obtained by digital classification of these fraction images, following a procedure based on image segmentation, unsupervised classification, and post-classification edition [4]. The linear spectral mixing model [9] has been used to analyze the mixture of signatures of vegetation, soil, and shade in each pixel for several remote sensor images. The unmixing methods available in several software packages estimate the proportion of each component inside the pixel by minimizing the sum of squares of the errors. The soil fraction image highlights mainly non-vegetated areas (clear cuts, bare soil, etc.); the vegetation fraction image shows the vegetation cover condition similar to the well known normalized difference vegetation index (NDVI); and the shade fraction image enhances water bodies, vegetation cover structure, and burned areas. The image segmentation approach used in this study was based on a region growing technique. Two threshold parameters have to be set by the analyst to define segments (regions) that will be used in the subsequent classification procedure: (a) similarity threshold (the Euclidean distance between the mean digital number of two regions, under which they will be grouped together); and (b) an area threshold (minimum area to be considered as a region, set by the number of pixels). Segmented images were classified using ISOSEG, a region classifier algorithm based on clustering techniques. This unsupervised algorithm uses the covariance matrix and the mean of the regions to estimate the centers of the classes. The analyst defines an acceptance threshold, the maximum allowed Mahalanobis distance that a mean digital number may be from the center of a class, to be considered as belonging to that class. After the classification process, some classes may be regrouped to express more faithfully terrain features. The map editing phase consists of a visual inspection directly on the computer monitor, correcting the commission and omission errors in classified areas.

These resulting products allowed to estimate the interchanges in the land cover classes over the considered period (such as classes of regrowth areas, burned forest, and burned grassland areas), as well as the increment of deforested areas from one period to another.

4. RESULTS AND DISCUSSION

The multitemporal analysis of Landsat datasets corresponding to 1980 (MSS), 1990 (TM) and 2000 (ETM+) showed that the deforestation areas increased 7,114 km^2 from 1980 to 1990, 4,900 km^2 from 1990 to 2000, and 3,258 km^2 from 2000 to 2007 time periods. It also showed that about 2,815 km^2 of regrowth areas were observed in the 2000 ETM+ images (Figure 2). The analysis of MODIS images showed that 6,500 km^2 of land surface were burned in Acre State in 2005. Of this, 3,700 km^2 corresponded to the previously deforested areas and 2,800 km^2 corresponded to the forested areas [6] (Figure 3). The derived information about deforestation, regrowth and burned areas are critical for regional and global environmental studies and for efforts to control such burning and deforestation in the future.

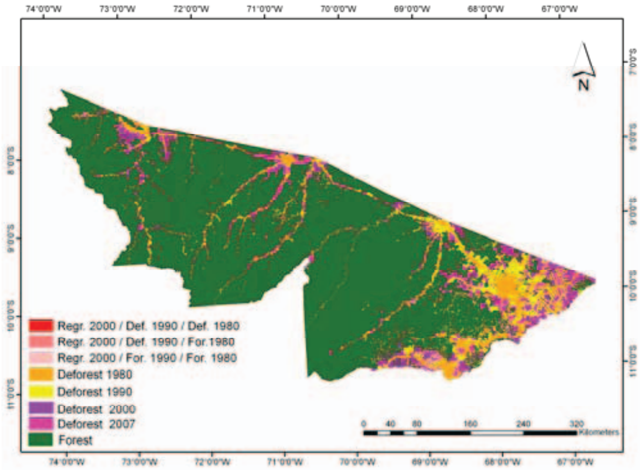

Figure 2: Classification of multisensor data of Acre State. “Regr.” means regrowth areas and “Def.” means deforested areas.

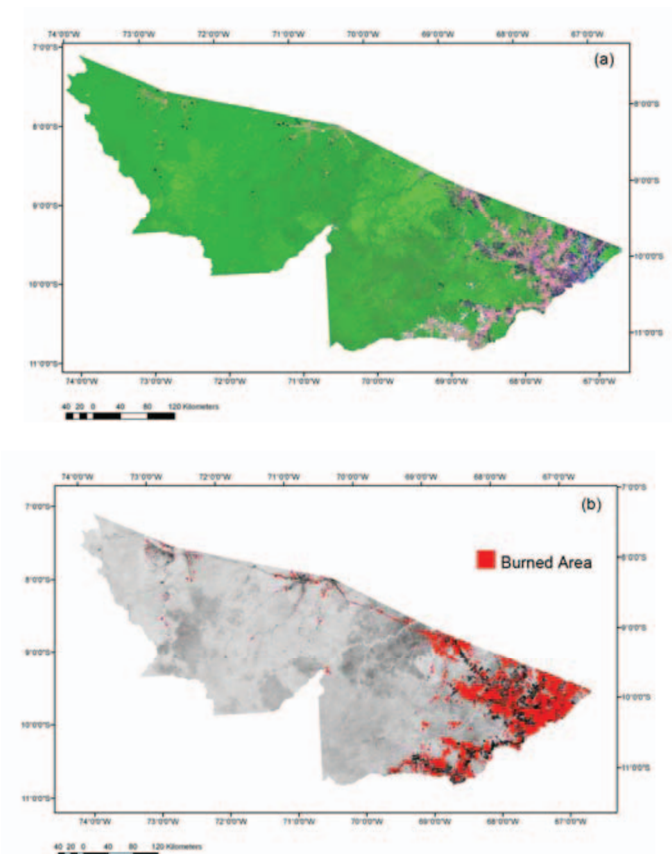

Figure 3: Classification of burned areas using 2005 MODIS data of Acre State: (a) MODIS color composite (band 6(R) band 2(G) band 1(B)); and (b) classification of burned areas.

5. CONCLUSIONS

The method described in this paper can be used to digitally classify land cover changes using multisensor images of Acre State. The results demonstrate that multisensor data are important sources of information for mapping and monitoring land cover changes and can be used at the regional level in Brazilian Amazonia. The next step of this research is to apply the proposed method for the entire Amazonia as part of DETER [10] (Detection of Deforested Areas in Real Time, http://www.obt.inpe.br/deter/) and PANAMAZONIA (http://www.dsr.inpe.br/panamazon.htm) operational projects developed at the Brazilian Institute for Space Research (INPE).

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