LAND USE AND LAND COVER MAPPING USING FRACTION IMAGES DERIVED FROM ANNUAL VIIRS-NPP DATASET

Yosio Edemir Shimabukuro, Egidio Arai, Andeise Cerqueira Dutra, Valdete Duarte

Instituto Nacional de Pesquisas Espaciais (INPE) Av. dos Astronautas, 1758, CEP: 12.227-010 – São José dos Campos – SP, Brazil
{yosio.shimabukuro, egidio.arai, andeise.dutra, valdete.duarte}@inpe.br

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ABSTRACT

This article presents a method to map the extent of annual land-use and land-cover (LULC) in Mato Grosso State, located in the Brazilian Legal Amazon. The proposed method applies the Linear Spectral Mixing Model (LSMM) to VIIRS NPP dataset to derive monthly vegetation, soil and shade fraction images for regional analysis. We used 500 m monthly image mosaics for VIIRS in 2015 year. These fraction images have the advantage to reduce the volume of data to be analyzed highlighting the target characteristics. Then we generated only one mosaic for each fraction images for VIIRS dataset computing de maximum value through the year, facilitating the classification of LULC classes. The proposed method allowed to classify three LULC classes: forest, cropland and non-forest (Savannah and pasture) areas. In addition, it allowed to map burned areas occurred during the study period. The results are very important for planning and management by the government and non-governmental organizations.

Index Terms— Remote Sensing, Image Processing, Deforestation, Forest Degradation, Burned Areas

1. INTRODUCTION

To implement environmental management policies depends on an accurate characterization and understanding of the land use and land cover. In particular, a representation of vegetation cover, including its dynamics, is essential for supporting the development, implementation and enforcement of policies involving the rational use of the land and the conservation of natural resources. Remote sensing techniques has been a useful tool for conducting the identification and characterization of land use and land cover (LULC) classes due to the synoptic view of large geographic regions and the lower associated costs, when compared to other information acquisition methods. Traditionally, less attention has been given to time and, in particular, to the high-frequency dynamics of several land cover types. The increasing availability of time series of satellite images and the potential contribution of these images to environmental management and conservation emphasize the need for the development of specific approaches to properly deal with the unique nature and volume of these data [1].

Time series analyses address the identification of types and patterns of changes in time and the incorporation of seasonality and phenological cycles of vegetation into analyses [2-3]. Many of these investigations have focused on local and regional scales, incorporating products derived from one or more remote sensors onboard satellites orbiting the Earth.

The primary objective of this work was to present a method to assess the extent of annual LULC in Mato Grosso Sate, Brazilian Legal Amazon using moderate image datasets from VIIRS NPP.

2. MATERIAL AND METHODS

2.1. Study Area

The study area corresponds to the Mato Grosso State, in Brazil (Figure 1), which is the third largest state in Brazil (over 900,000 km²) and located in the Midwest region. It comprises three biomes: Amazonia (54%), Cerrado (Savannah) (40%), and Pantanal (Wetlands) (6%) [4]. Due to variable climate, terrain relief, precipitation systems and length of the annual seasons, Mato Grosso State presents a complex biodiversity. Furthermore, the state is located partly in the “arc of deforestation” at the southern part of the Brazilian

Legal Amazon and presented one of the highest annual deforestation rates [5].

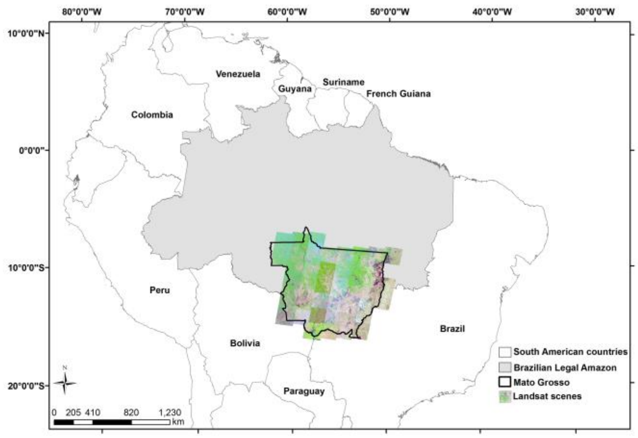

Figure 1. Location of the study area.

2.2. Dataset

The Visible Infrared Imaging Radiometer Suite (VIIRS) sensor is on board the Suomi National Polar-orbiting Partnership (Suomi-NPP) satellite that has been developed and administered by cooperation between NASA and NOAA. For this work, 500 m monthly images mosaics for the year 2015, with bands I1 (red, 600-680 nm), I2 (NIR, 846-885 nm) and I3 (MIR, 1580-1640 nm) were used.

2.3. Linear Spectral Mixing Model

For the purpose objective, we applied the Linear Spectral Mixing Model (LSMM) [6], which assumes that pixel values are linear combinations of reflectance from a number of components, called endmembers:

$$R_i = \sum_{j=i}^{n} f_i r_{i,j} + \varepsilon_i \qquad (1)$$

where:
Ri - represents the spectral reflectance in the ith spectral band; $r_{i,j}$ - is the spectral reflectance of the jth component in spectral band ith (endmember); fj - is the proportion of the jth component within the pixel; εi - is the residual for the ith spectral band.

Fraction images derived from LSMM can be used for mapping LULC changes due to the following characteristics: a) vegetation fraction images highlight the forest cover conditions similarly to vegetation indices such as the Normalized Difference Vegetation Index (NDVI) and the Enhanced Vegetation Index (EVI); b) shade fraction images highlight areas with low reflectance values such as water, shadow and burned areas; and c) soil fraction images highlight areas with high reflectance values such as bare soil. First, we applied LSMM for VIIRS images datasets generating the image fraction images for vegetation, soil, and shade endmembers for the year 2015. Following we built one image mosaic for each endmember composed by the maximum proportion values in the entire year.

In that manner, VIIRS maximum vegetation fraction mosaic was used to map the extent of agricultural areas; VIIRS maximum soil fraction mosaic was used to map the extent of forest and non-forest (Savannah and pasture) areas; and VIIRS maximum shade fraction mosaic was used to map the burned over forest and non-forest areas.

2.4. Unsupervised classification

The digital classification was performed using SPRING software [7]. Then LULC classes were classified following a procedure based on image segmentation and unsupervised classification [8].

Image segmentation is a technique to group the data, in which only contiguous regions and similar spectral characteristics can be joined. The image segmentation approach used in this study is 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: (1) similarity threshold (the Euclidean distance between the mean digital number of two regions, under which they will be grouped together); and (2) an area threshold (minimum area to be considered as a region, set by the number of pixels) [9]. Segmented images were classified using ISOSEG [9], a region classifier algorithm based on clustering techniques. After the classification process, some classes are assigned to the corresponding class of the predefined legend. This method was applied to the VIIRS sensor mosaics.

An agreement analysis based on a stratified sampling was employed using the approach proposed by [10], between the results and the datasets produced by the PROBA-V [11] and MODIS (MCD64) [12].

3. RESULTS AND DISCUSSION

Agricultural areas assessment

Figure 2 shows the classification of agricultural areas using 500 m VIIRS mosaic composed by the maximum vegetation fraction values during the year 2015. The result showed that agricultural areas occupied 63,206 km² of the Mato Grosso State. This area corresponds to the main annual crop planted in the December to March period (1st crop). We also mapped the crop planted in Abril to July (2nd crop) time period occupying 28,603 km².

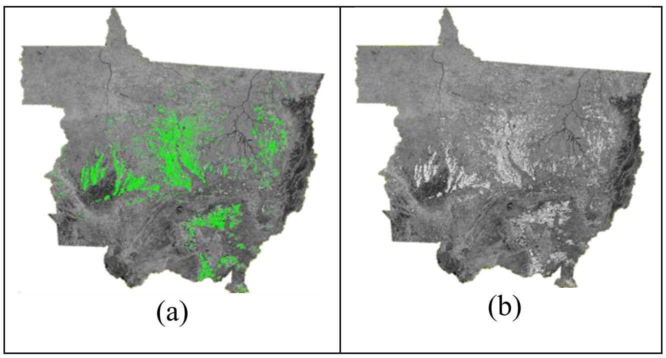

Figure 2. Classification of agricultural areas in 2015 (a) for the Mato Grosso State based on the maximum vegetation pixel fraction of VIIRS 500m mosaic (b).

Regarding the comparison with the PROBA-V datasets, the producer accuracies ranged from 94% to 89%, and the user accuracies ranged from 74% to 98%, in cropland and non-cropland, respectively. The estimated overall accuracy was 90%.

Forest and non-forest areas assessment

Figure 3 shows the classification of forest and non-forest areas using 500 m VIIRS mosaic composed by the highest soil fraction during the year 2015.

The non-forest areas includes the Cerrado and deforested areas occupied by agricultural and pastures. The result showed the remained forest areas occupied (341,236 km²) of the Mato Grosso State in 2015, compared to the 308,744 km² obtained by PRODES [5]. Forestlands have a low soil proportion, due the canopy cover, and also low standard deviation for all fractions throughout the year because of the weak seasonality compared with savannas physiognomies [13]. This characterization allows identified easier by using the LSMM approach based on optical data.

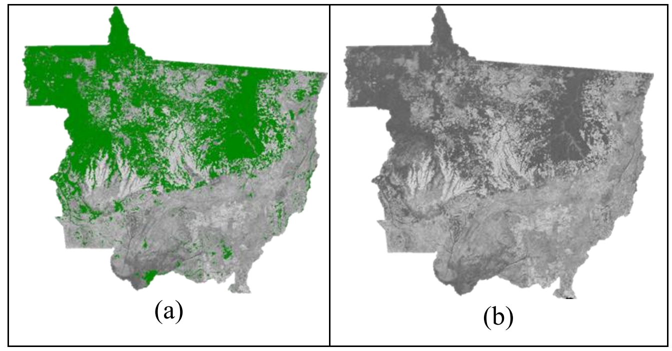

Figure 3. Classification of forest and non-forest areas in 2015 (a) for the Mato Grosso State based on the maximum soil pixel fraction of VIIRS 500m mosaic (b).

Burned areas assessment

Figure 4 shows the classification of burned areas using 500m VIIRS mosaic composed by the highest shade fraction during the year 2015. The result showed that burning activities affected 24,033 km² of the Mato Grosso State. Most of the burned areas occurred in the non-forest occupied by Cerrado and pasture classes. The degraded forest by fire corresponded to 3,393 km².

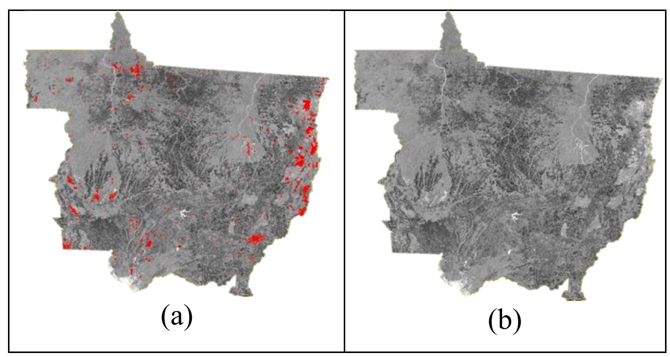

Figure 4. Classification of burned areas in 2015 (a) for the Mato Grosso State based on the highest shade pixel fraction of VIIRS 500m mosaic (b).

Comparing the results obtained with MODIS (MCD64), the producer accuracies ranged from 50% to 87%, and the user accuracies ranged from 28% to 94%, in burned and non-burned areas, respectively. The estimated overall accuracy was 83%. Our result is underestimated compared with MODIS MCD64 product in terms of total area, but include non-burned areas classified as burned areas. This can be explained by the difference in methodology, image type and image dates of the sensors. While MCD64 uses daily images, we used monthly image composites that showed to be appropriated for agricultural and forest and non-forest areas mapping. For burned assessment it was not appropriate since the mosaic mask some burned areas due to the criteria used to compose the mosaic. Therefore, for burned areas assessment is recommended the use of daily images for VIIRS dataset especially for the Cerrado biome.

4. CONCLUSION

The VIIRS mosaic composed of the maximum vegetation fraction value highlighted the areas that were occupied by agricultural areas during the 2015 year for the study area. In addition, the VIIRS mosaic composed of the highest shade pixels highlighted the areas that were burned during the 2015 year for the study area. The VIIRS mosaic composed of the highest soil pixels highlighted the difference between forest and non-forest areas during the 2015 year for the study area. The burning activities affected mostly the non-forest areas covered by the Cerrado biome and pasture classes. The different agreement between the accuracy results could be explained by the small burned scars identified, different sensors and acquisition date.

The burned forest areas are known as forest degraded by fire that is important for REDD+ program and needs more studies. The VIIRS dataset with moderate spatial resolution showed to be appropriated for mapping Land Use and Land Cover areas and can be potentially used operationally for global and regional analysis. These results are very important for the government and non-governmental organizations for planning, for management and for monitoring the tropical environment.

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