DEFORESTATION DETECTION IN BRAZILIAN AMAZON REGION IN A NEAR REAL TIME USING TERRA MODIS DAILY DATA

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Abstract – This paper presents a methodology for detecting deforestation activities in a near real time using Terra MODIS daily data. This work is part of the operational PRODES Project of INPE (Brazil) that estimates the annual deforestation in Brazilian Amazon. The detection of deforested areas by MODIS daily data is a useful information for enforcement of forest protection laws. The proposed methodology, named "DETER" Project, will follow the dynamics of deforestation activities while the PRODES Digital project is evaluating the total area deforested during the study year using higher spatial resolution data. For the development of this methodology, it was used a temporal series of MODIS MOD09 product (surface reflectance) from June to October over an area covered by one Landsat ETM+ scene located in Mato Grosso State, Brazilian Amazon region. The obtained results were compared to the corresponding Landsat ETM+ images acquired in the same dates of MODIS images. The small deforestation areas (lower than 15 ha) are detected with less accuracy by MODIS. As the areas deforested increases, the MODIS results come near to the ETM+ results. The results showed that MODIS sensor daily data can be used for an operational deforestation detection in the Brazilian Amazon.

INTRODUCTION

The utility of satellite data to study global change and monitor land use and land cover has been established. Steady progress in satellite technology and remote sensing methodology continue to improve the accuracy and application of satellite data for understanding the Earth´s dynamic cycles and the influence of human activities in these systems. In this context, the Moderate Resolution Imaging Spectroradiometer (MODIS), onboard the first NASA (National Aeronautics and Space Administration) Earth Observing System (EOS) satellite, Terra, was launched in December 1999. The MODIS sensor characteristics are useful for these applications due to the spatial, spectral and temporal characteristics that makes possible to improve the studies on the earth sciences with a better accuracy and more rapid frequency.

The MODIS surface reflectance products MOD 09, is a seven-band product centered at 648 nm, 858 nm, 470 nm, 555 nm, 1240 nm, 1640 nm, and 2130 nm, respectively (Justice et al., 2002). The product is an estimate of the surface spectral reflectance for each band, as it would have been measured at ground level if there were no atmospheric scattering or absorption, due to the MODIS algorithm for atmospheric correction. This product also has the geolocation included on the dataset. Townshend and Justice (1988) deduced that spatial resolution finer than 1km is required for mapping land cover changes due to human actions, concluding that a resolution finer than 1 km is able to detect these disturbances. The MOD09 product used in this work has 250 m of spatial resolution (red and near infrared -NIR bands have already the 250 m of spatial resolution, while the other bands, (blue, green, and MIR) have 500 m resampled to 250 m of spatial resolution).

Using a moderate or low spatial resolution sensor data, it introduces 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 (DeFries et al. 2000). Fraction images derived from different remote sensing data have been used for monitoring deforestation (Shimabukuro et al., 1998), land cover change (Carreiras et al., 2002), vegetation classification (DeFries et al., 2000) obtaining consistent results. Fraction images, derived from a linear spectral mixing model, constitute synthetic bands with endmember proportions information. The generation of these images is an alternative approach to reduce the dimensionality of image data providing a useful tool for digital interpretation (Aguiar et al., 1999). This capability has being used in the development of the PRODES operational project (INPE, 2002). The objective of this paper is to present a methodology for detecting deforestation activities in a near real time using Terra MODIS daily data. It is based on the PRODES Digital methodology (Shimabukuro et al., 1998) and will the National Institute carry out part of the annual deforestation monitoring for Space Research (INPE).

STUDY AREA

Due to the abiotic variables (climate, terrain relief, precipitation pattern and length of the dry season), the state of Mato Grosso has a natural model of complex biodiversity, resulting on different vegetation type classes. Furthermore, Mato Grosso located in the “arc of deforestation” area at the southern extent of the Brazilian Legal Amazon, is the state that had the highest deforestation rate in the year 2002 (INPE, 2002). The main drivers of new deforestation activities are the increase of agriculture projects, principally soybean cultivation, and industrial logging that often do not respect the protection laws. Even though the methodological approach proposed in this paper is envisioned to apply to the entire Amazon Basin, a critical Landsat ETM+ scene (Path 227/Row 68), in terms of deforestation and burned activities, was selected in this region (figure 1).

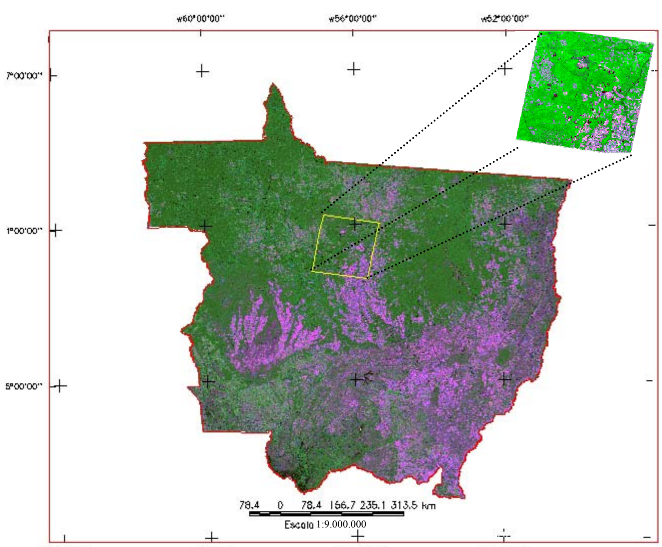

Figure 1: MODIS mosaic image (R-MIR, G-NIR, B-Red) for Mato Grosso State, showing the location of the study area.

REMOTE SENSING DATA ANALYSIS

In this study, all June to October temporal scenes (8 dates) of Landsat ETM+ from path/row 227/68 were used. The Landsat ETM+ data were registered and radiometricaly rectified (Hall et al., 1991), as a database for multitemporal land cover change analysis (Lillesand & Kiefer, 1994). The MODIS images were acquired on the same dates of the ETM+ scenes, and we also used the Landsat ETM+ image of PRODES project (INPE, 2002) for validation purpose. The PRODES database corresponding to this study area includes a thematic map with the following classes: forest, non-forest, old deforestation, and the year 2002 deforestation polygons.

The database was built in the GIS software package SPRING (Câmara et al., 1996). Initially, the PRODES information for the year 2001 was used to generate a mask for all deforestation areas that occurred up to October of that year, non forest areas (savanna), and water bodies, so that the corresponding Landsat scene shows only forest areas. Then all the deforestation that were observed on the temporal time series occurred after October 2001 (TM acquisition date).

The first Landsat ETM+ scene used was acquired on June 15, 2002 and numerous polygons of deforestation where detected in this image. To enhance the difference between forest and non-forest areas, the linear spectral mixing model was applied to both (ETM+ and MODIS) datasets and the soil fraction images were used to identify new forest clearings. This model estimates the proportion of each component within the pixels by minimizing the sum of squares of the errors. The proportion values must be nonnegative, and they also must add to one (Shimabukuro and Smith, 1991). For MODIS, it was used 5 spectral bands corresponding to the visible (blue, green, and red), near infrared (NIR), and middle infrared (MIR) of the electromagnetic spectrum; and for ETM+ it was used all bands except the thermal band (band 6). The model was run using 3 endmembers: vegetation, soil, and shade, for both sensor data. The image endmember approach was used to select the pure component, i.e., these endmembers were selected directly from the image scenes. Considering that the MODIS dataset is atmospherically corrected and ETM+ were radiometrically rectified, it was used one set of endmembers signatures for MODIS and another for ETM+ multitemporal images.

The resulting fraction images highlight specific information about the terrain targets. For example, vegetation fraction image, like as all vegetation indices, shows the vegetation cover condition; the shade fraction image highlights the water bodies and vegetation cover structure (Shimabukuro & Smith, 1991); and soil fraction image shows the contrast between forest and clear cut areas and then is the primary source of information for this study. The PRODES data for 2002 were adjusted on the ETM+ scene of October 2002, and a brief image edition was made. The next step was the edition of the deforestation polygons on the September image. This process was made for all ETM+ scenes, and the result were a precise temporal increase of the deforestation polygons area. For the MODIS images, a modified methodology was applied. Due to its moderate spatial resolution, interpretation and subjective errors should occur. To minimize these errors, the soil fraction images were segmented and the edition process was based on these limits.

RESULTS AND DISCUSSION

The generation of fraction images for MODIS daily data (MOD09) was complicated by the difficulty finding a reasonable endmember responses. The soil endmember always appears on the blue, red and green channel with overestimated values. This may be due to two potential sources of errors. First, it is possible that these channels have the atmospheric correction influencing the expected reflectance curve. The second explanation is due to the moderate spatial resolution of the data: the selected endmember pixels may have a percentage of mixture response of other components in the pixel.

The results obtained for the detection of the deforested areas and the comparison with the ETM+ images showed that the MODIS data has a tendency to subestimate the deforested areas compared with the ETM+ results. Our results also show that small deforestation areas (lower than 15 ha) are detected with less accuracy by MODIS. As the areas deforested increases, the MODIS results come near to the ETM+ results (Figure 2).

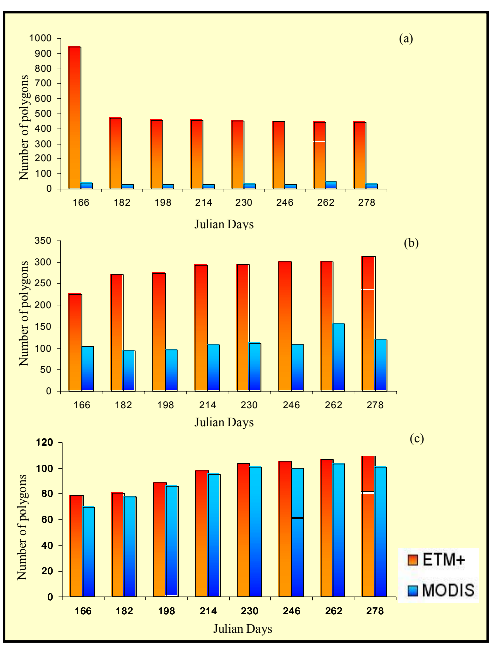

Figure 2: Number of polygons detected by ETM+ and MODIS data divided in three size classes: (a) polygons size less than 15 hectares; (b) polygons size between 15 and 50 hectares; and (c) polygons size between 50 and 100 hectares.

Our results showed that the number of polygons and area estimated by the MODIS data depend on the pattern (shape and spatial distribution) of the new clearings. For example: polygons with large areas close to other polygons can be considered just one deforestation.

In figure 3 we can observe the spatial distribution of the deforestation polygons detected by the MODIS data through the time series. The use of PRODES information to generate a mask is very important for avoiding classification errors over areas already deforested and non-forest (savanna) areas. We have to keep in mind that savanna and some old deforestation areas are spectrally similar to bare soil or clear-cut areas.

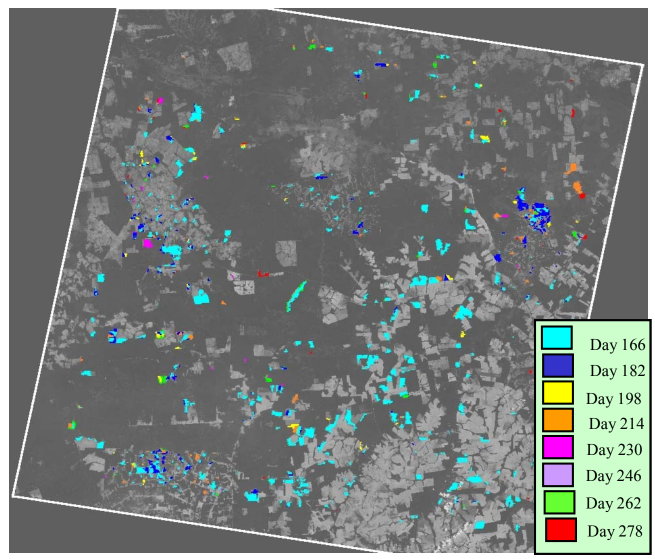

Figure 3: Deforestation polygons classified in the MODIS sequential dates.

CONCLUSION

The results showed that MODIS daily data is a useful source of information for monitoring the deforestation areas. The transformed fraction images, especially the soil fraction, showed to be very useful for enhancing the contrast between forest and clear cut areas and also reducing the dimensionality of multitemporal dataset to be analyzed for detecting and mapping deforested areas. This kind of information is essential for a detection of deforested areas in a near real time, which is very important for designing a deforestation alert (DETER) project, at INPE, for the entire Amazon region.

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