

MONITORING TROPICAL FOREST FROM SPACE: THE PRODES DIGITAL PROJECT

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ABSTRACT:

This paper presents the results of a new methodological approach to identify and to estimate deforested areas. The work refers to the PRODES DIGITAL PROJECT, which develops an automatic procedure to analyze satellite data, using the techniques of Linear Spectral Mixture Model, Image Segmentation and Classification by regions, that are available on software SPRING (GEOREFERENCED INFORMATION PROCESSING SYSTEM), a state-of-the-art GIS and remote sensing image processing system with an object-oriented data model, which integrates raster and vector data representations in a single environment.

1. INTRODUCTION

PRODES (Monitoring the Brazilian Amazon Gross Deforestation) is the largest forest monitor project in the world, based on orbital remote sensing.

For many years, the NATIONAL INSTITUTE FOR SPACE RESEARCH (Ministry of Science and Technology) has been promoting the interpretation of images provided by the U.S. LANDSAT satellite to monitor the evolution of the extent and rate of gross deforestation in the Brazilian Amazon (Figure 1).

Due to the geometric problems faced during the development of the manual interpretation of multi-temporal TM images (image hardcopies with different scales, overlays digitizing/scanning, complexity of deforestation pattern), the availability of these deforestation maps in a digital format has been restricted to some areas.

Over the last years, an effort to find a methodology to overcome this problem has been successful (Mello et al., 2003 and Moreira et al., 2003).

The digital image analysis is an alternative to perform this task. However, the conventional digital classification using a pixel by pixel approach has shown to be feasible only for small (local) areas, where is possible to have a good quality control of the image classification.

For large areas, as the ones studied by PRODES, two factors had been restricting the digital analysis of TM images: lack of a reliable image classifier and the huge amount of disk space required to process several TM scenes.

With the increasing capacity of computers in terms of processing and storage, the development of a methodology to study large areas using digital techniques is now possible (Shimabukuro et al., 1998).

Data from PRODES DIGITAL PROJECT, properly georeferenced, form a database of multi-temporal layers with easy access and integrated with different information sources and or computer systems (www.obt.inpe.br/prodes).

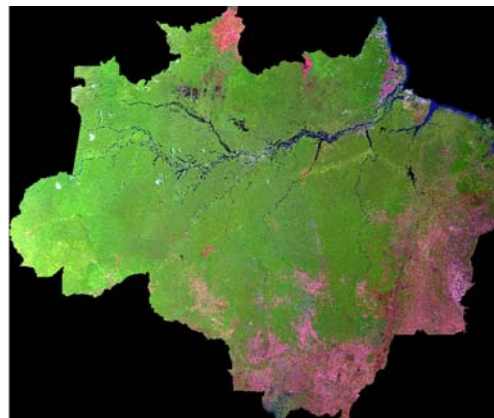


Figure 1 – Brazilian Amazon – WRS-TM/LANDSAT

2. A NEW METHODOLOGICAL APPROACH

2.1 Satellite Data and Image Processing System

Amazon Brazilian WRS-TM/LANDSAT images of bands 3, 4, and 5 were used. The Landsat TM data were resampled to a pixel size of 60 m by 60 m resulting on an image size of 3326 pixels by 3072 lines, in order to reduce computer processing time.

Digital Charts at 1: 100 000, edited IBGE and DSG, were used for georeferencing the satellite images.

The GIS software package SPRING (GEOREFERENCED INFORMATION PROCESSING SYSTEM) with basic functions of image processing (including 'segmentation' and 'per-field clustering classifier' – ISOSEG) was used (www.dpi.inpe.br/spring). Spring is a state-of-the-art GIS and remote sensing image processing system with an object-oriented

data model, which provides integration of raster and vector data representations in a single environment.

2.2 Image Processing Procedure

2.2.1 Shade and Soil fraction

There are several approaches to determine the fractional proportions of a multispectral image. The constrained least squares method was employed here using bands 3, 4, and 5 of the Landsat TM to generate the fraction images of vegetation, soil, and shade within the pixels. The mathematical description of the mixture model based on the constrained least squares method is detailed in Shimabukuro and Smith, (1991). The end members spectral signatures were collected directly from the Landsat TM images, using representative targets of green vegetation, soil, and shade. This was done interactively until it was verified that the component signatures were an adequate representation of the mixture components of the area analyzed, and therefore the constraint equations were strictly true.

2.2.2 Image segmentation

The procedure used for image segmentation was based on the 'region growing' algorithm where, a region is a set of homogeneous pixels connected according to their properties (Zucker, 1976). A detailed description of the segmentation procedure used can be found in Alves *et al.* (1996).

The segmentation algorithm was applied to the shade fraction image, and the proportion, the spatial and the contextual attributes of the segments (regions) were acquired for use in the classification procedure.

Two parameters have to be set by the analyst:

(1) *similarity*: the Euclidean distance between the mean digital numbers (here shade proportion) of two regions under which two regions are grouped together; and (2) *area*: minimum area to be considered as a region, defined in number of pixels.

2.2.3 Classification

An unsupervised classification based on a clustering algorithm was applied to the segmented shade fraction image. Clustering techniques are largely known (Duda and Hart, 1973). The algorithm used in this experiment, named ISOSEG (Bins *et al.*, 1993) uses the covariance matrix and mean vector of the regions to estimate the means of the classes. The analyst can define an acceptance threshold, which is the maximum Mahalanobis distance that means digital numbers (here shade proportion) of regions can be far from the centre of a class to be considered as belonging to that class.

First, the original TM bands 3, 4 and 5 were converted to vegetation, soil, and shade fraction images applying Linear Spectral Mixing Model. Next, the selected fraction images were segmented and non-supervised classification per region algorithm was applied. The results of the classification were edited.

To estimate the extension of deforested areas for the 1997 TM image, the shade fraction image was used, which enhances the difference between forest and deforested areas. To estimate the increment of deforested areas between 1997 and 2000, 2000 and 2001, 2001 and 2002, 2002 and 2003, the soil fraction images

were used, after the extension of deforested areas had been masked over the soil fraction image related to the following year. Soil fraction image enhances the difference between forest and recent clear cut areas.

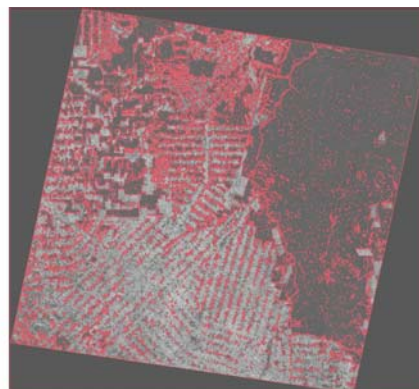


Figure 2 – Results of the segmentation algorithm shown for shade fraction image (red). The WRS 23167-TM/LANDSAT

The methodology was applied for 182 WRSTM/LANDSAT Amazon Brazilian images acquired in 1997, 162 Landsat TM images acquired in 2000, 192 Landsat TM images acquired in 2001 that cover the Amazon area, 156 Landsat TM images acquired in 2002, and 80 Landsat TM images acquired in 2003 which cover the critical area in terms of deforestation.

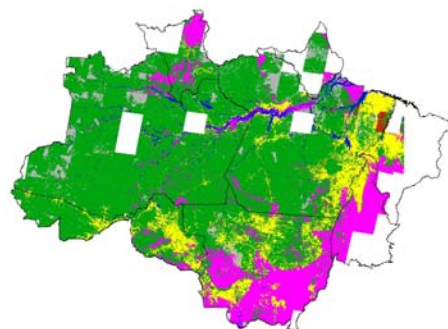


Figure 3 – Deforestation map of Brazilian Amazon showing the extension up to 2001 (yellow), 2002 increment (red). The forestry areas are showed in green, the no-forestry areas are showed in pink and the areas covered by clouds are showed in white.

3. CONCLUSIONS

The results clearly indicate the commitment of the BRAZILIAN GOVERNMENT to treat with transparency the issue of deforestation in the Amazon. Moreover, it gives parameters to understand the causes and to develop mechanisms to control the depletion of the forest resources. We presented an automated procedure to estimate deforestation including mapping and area extent estimations. The PRODES DIGITAL PROJECT data is stored in a GIS system, properly georeferenced, forming a database of multi-temporal layers with easy access and integrated with different information sources and or computer systems (www.obt.inpe.br/prodes).

The following developments may be considered in the future:

The GeoCover Orthorectified Landsat Thematic Mapper Mosaics (Figure 3) are delivered in a Universal Transverse Mercator (UTM) / World Geodetic System 1984 (WGS84) projection. These mosaics will be used to georeference the satellite images using **Automatic image registration system** (Figure 4).

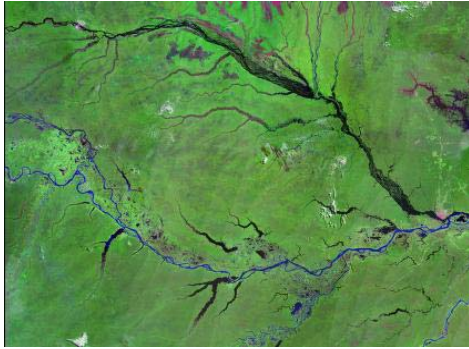


Figure 3- GeoCover Mosaic - Chart S.20-00 (<https://zulu.ssc.nasa.gov/mrsid/>)

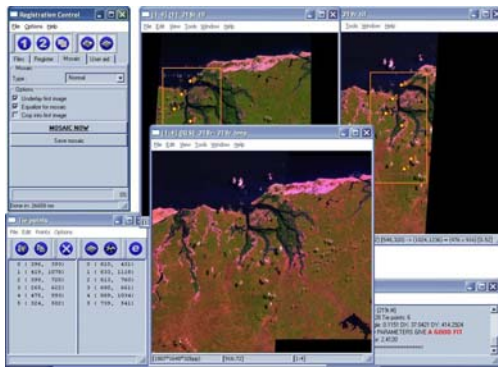


Figure 4 - Automatic image registration system (<http://regima.dpi.inpe.br>).

4. REFERENCES

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