DEFORESTATION ESTIMATES IN AVHRR/NOAA AND TM/LANDSAT IMAGES FOR A REGION IN CENTRAL BRAZIL

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Abstract

This paper presents a comparison of tropical deforestation estimates in AVHRR/NOAA and TM/Landsat images for a region in Central Brazil where large clearings in the forest prevail. A TM scene of 02/Sept/89 in the scale of 1:250,000 was visually interpreted to produce a map with four classes: natural forests, deforested areas, natural savannahs, and rivers. The AVHRR image of 17/Sept/89 with full 1.1 km resolution was digitally degraded to 2km resolution and classified to show forested and deforested areas. Comparison between deforested areas detected in the two data bases was done in a Geographical Information System for 54 grid cells of 10x10 minutes. AVHRR channel 3 (3.7um band) provided the best results. A linear relation was found with a Determination Coefficient of 0.93, higher than previously reported in the literature for other AVHRR channels. The methodology developed is recommended for early location and assessment of new tropical deforestation.

Key Words: Deforestation, Tropical Forest, AVHRR NOAA, TM LANDSAT

Introduction

Tropical forests in the Brazilian Amazonia originally covered about 3,370,000 km^2 (Fearnside, 1982) and have been the subject of intensive as well as extensive clearing in the last 30 years. Changes have occurred rapidly, with an average of $22x10^3 km^2$/year for the last decade (Fearnside, 1991). Forest conversion is considered a relevant factor in changes of local and global cycles of hydrology, geochemistry and climate, and also in habitat conservation and in species diversity (Smith, 1981, Sioli, 1987, Skula et al., 1990).

The monitoring of deforestation is necessary to evaluate its impact in the environment. Considering the size of Amazonia, orbital remote sensing is the only practical way to accomplish it. Two types of satellite imagery have been considered and used: high resolution, from Landsat MSS in the past and TM at present, or from SOPT/HRV sensors; or low resolution (1.1km) from the AVHRR sensor on-board NOAA meteorological satellites.

Because of their limited area coverage in each scene, TM (185kmx185km) and HRV (60kmx60km) require hundreds of images to map Amazonia. The cost of the imagery and of its processing is of many million dollars, a constrain if such work is made on a yearly basis. Several authors proposed the use of NOAA/AVHRR data simultaneously with TM and/or SPOT data to monitor tropical deforestation (Nelson and Holben, 1986, Woodwell et al., 1987, Malingreau and Laporte, 1988). Their suggestion is the combination of AVHRR high temporal frequency, extensive area coverage, but low spatial resolution, with TM/HRV high spatial resolution.

Studies to compare and correlate data from high and low resolution imagery have already been made. Stone and Schlesinger (1990) studied the region of Maraba, north Brazil, and obtained R^2 = 0.93 for the linear regression between the percent of forest determined from TM and from AVHRR images; a supervised maximum likelihood classification algorithm was used. They sampled blocks of AVHRR and TM data of 480km^2 and compared their classifications. More recently Cross (1991) proposed a methodology for tropical forest monitoring using AVHRR data, channel 4 (10.3-11.3um), towards an automated system for change detection in a Geographical Information System, using TM data as a reference plane. His estimate of deforested areas obtained with AVHRR and TM were moderately well correlated, with a correlation coefficient of 0.72.

The objective of this work is to improve and advance AVHRR detection and mapping of deforestation in tropical regions trough relatively simple and easy methodologies for operational applications to be used in operational monitoring.

Data and Methods

The study site chosen is in the Brazilian west-central state of Mato Grosso, between 11^o and 12^o South-latitude and 51^o and $52^o30'$ West-longitude. The region is caracterized by the contact between forest and savannah ("cerrado"), by extensive areas of pasture in large cattle farms, and also by some agriculture in deforested areas (RADAMBRASIL, 1981). It therefore contains different vegetation covers found in typical regions of deforestation and which demand careful analysis to be differentiated in remote sensing studies.

The data for this work was supplied by the "SEQE" project (burning monitoring project) and by the "Atlas de Desmatamento da Amazônia" (INPE, 1989), from INPE (Brazil's National Institute of Space Research). This data set consisted of one NOAA/AVHRR HRPT image (High Resolution Picture Transmission) of north Brazil and a Landsat-5/TM image in the scale of 1:250,000. The HRPT data was from 17/September/1989 and the TM image (WRS-224/68) from 02/September/1989.

The first step was the visual interpretation of the TM image color-composite, where the red color was assigned to channel 5, green to 4, and blue to 3. Four classes were defined: natural forests, deforested areas, savannahs, and rivers. The overlay obtained was next digitized to a infolayer in a INPE-developed a Geographical Information System (GIS), nd then converted to raster format.

The second step was the processing of AVHRR image, including the navigation and the geometrical correction of the image. It was done with the software developed by Figueiredo (1990), which adjusted the image to cylindrical equidistant projection, and altered its resolution to 2 km pixels. The AVHRR image was then classified at an image processing system called SITIM-150, developed at INPE, and using threshold definition and the maximum likelihood algorithm. Channels 1, 2, 3 and a "vegetation index" ((C2-C1)/(C1+C2)) image were used in the classifications. The classified images were imported to the GIS.

In the third step both TM and AVHRR images were divided into 54 grid cells with dimensions of 10x10 minutes of a degree. Estimates of deforested areas were obtained for each of the cells in the four AVHRR and TM classification images. These grid cells provided the basis used in the statistical analysis.

The statistical analysis used was the simple correlation and linear regression between TM and AVHRR data. The TM classification was assumed as correct "ground truth" in this analysis, thus becoming the independent variable. The residual analysis was done to verify the model consistency regarding randomness, sign study, and constant variance, and included the plot of their standard residuals.

Results and discussion

Initially, a visual inspection of the matching between the TM and the corrected AVHRR images was made in the digital image processing system used; this was necessary because the registration of the TM and AVHRR images is essential to allow adequate comparison of deforestation detection and of estimates of deforested areas. The software used to correct the AVHRR geometric distortion and to redraw the image with resolution of 2km presented very good results since no significant discrepancies were observed between the images of the two satellites.

The AVHRR image classification was better performed by the technique of threshold definition and for channel 3, in agreement with other authors that had classified deforested areas (Tucker et al.,1984, Woodwell et al.,1986, Malingreau and Tucker, 1987).

The correlation between AVHRR and TM estimates of deforested areas resulted in a correlation coefficient of 0.97. This implies that AVHRR and TM data are strongly correlated for the pattern of deforestation in the test area. This result was better than that of Cross (1991), who found a correlation coefficient of 0.72 also for a region in Mato Grosso, but using an AVHRR channel 4 image for classification.

The result of the linear regression between TM and AVHRR deforested area estimates yielded the following least squares solution:

$$Y = -6.57 + 1.001X$$

where X and Y refer to the AVHRR and TM estimates respectively. The slope is almost unity, what suggests little bias in the use of AVHRR image. Figure 1 illustrates this relation.

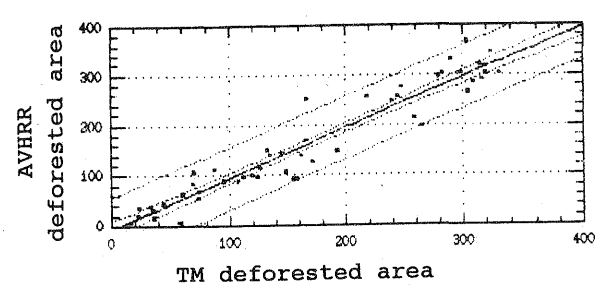

Figure 1- Linear regression between TM (X) and AVHRR (Y) deforested areas - km^2.

The coefficient of determination of this analysis was 0.93, about the same value obtained by Stone and Schlesinger (1990) using the five AVHRR channels, and higher than the value of 0.63 found by Santos et al.(1991) also using the five channels AVHRR. The residual analysis confirmed the randomness of the data, with 21 changes of signs and equal distribution of them. In the plot of residuals against the TM values, shown in Figure 2, one can see that the residuals were well distributed; only 2 outliers occured, corroborating the consistency of the linear model adopted.

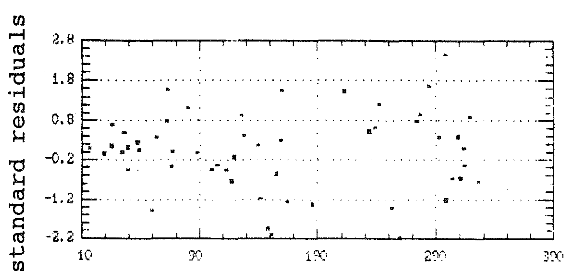

Figure 2- Relationship between deforested area estimates from AVHRR data (X) and standard residuals (Y).

These results indicated that a strong relationship exists between AVHRR channel 3 and TM data for estimates of deforested areas obtained through image classification. AVHRR data overestimated the forested area and underestimated the deforestation areas contrary to the results of Stone and Schlesinger (1991) and of Santos et al.(1991). This fact may be due to the methodological difference in the AVHRR image classification.

Conclusions

The methodology used was appropriate to generate geometrically corrected AVHRR images allowing their digital comparison with TM images or with TM-based geographical information systems.

The results indicated a strong linear relationship between estimates of areas deforested detected in AVHRR channel 3 and in TM images (R^2=0.93), and also that channel 3 is better than other AVHRR channels or channel combinations to detect deforestation. Results refer to a test region with deforestation caused by cattle ranching in extensive areas. Despite the 2km resolution used, the AVHRR X TM correlation coefficient found is higher than previously reported in the literature.

This simple AVHRR technique is the initial step of an AVHRR-based deforestation monitoring system being developed at INPE. Tests in areas with different deforestation patterns are in progress and are required before the system becomes operational.

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