The Amazonia Information System

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Abstract

A research initiative for the assessment of the impact of human-induced changes in Brazilian Amazon rain forest is presented. Data from satellite imagery, topographic, vegetation and other maps are combined inside AMAZONIA, a geographic information system covering the entire region. As a result, the extent and the rate of deforestation are being more accurately estimated and the refinement of models to assess the impact of deforestation in different physical processes was made possible by the availability of georeferenced data.

Key words: geographic information systems, deforestation, Amazon.

Background

The Brazilian Amazon is often referred to as Legal Amazônia - the part of the territory formed by the states of Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima, Tocantins, and the part of Maranhão west to 44^{o}W. A region of more than 5 million square kilometers including forests, savannas and

some areas of intensive human activity, the Legal Amazônia has been object of different studies.

The extent and the rate of deforestation in Brazilian Amazônia has interested many researchers in the last decades (see, for example, Watson at al, 1992). Several estimates of deforestation were produced, most of them based on satellite imagery, a unique source of data due to the difficulties in access and the dimensions of the region.

The size of the region makes the assessment of deforestation a costly, laborious task. For example, a comprehensive survey based on LANDSAT Thematic Mapper (TM) would require at least 229 scenes to cover the region for one single layer.

Notwithstanding, comprehensive surveys are unavailable for the assessment of deforestation on a yearly basis as well as for the study of the impact of human action on the different ecosystems. Besides, the scarceness of social-economical data makes difficult the selection of representative areas for the adoption of non-comprehensive sampling approaches.

The availability of LANDSAT Multispectral Scanner (MSS) and TM imagery at INPE made it possible to perform comprehensive surveys of deforestation in the Amazon. In 1980, results of the first wall-to-wall assessment of deforestation based on MSS data were published by INPE and the former Brazilian Institute for Forest Development (IBDF) (Tardin et al, 1980). Starting in 1988, INPE has been developing a series of studies using LANDSAT TM imagery, which allowed to estimate the rate of deforestation over the last decade, as shown in the next table.

DEFORESTATION RATES IN THE BRAZILIAN AMAZON

Period (years)	Rate of deforestation (km^2)
1978 – 1989	21,500
1988 – 1989	18,800
1989 – 1990	13,800
1990 – 1991	11,100

Assessment of deforestation

The use of MSS and TM imagery for the assessment of deforestation has allowed to measure both the extent and the rate of deforestation for comparatively short time intervals, in some cases for a yearly basis. Particularly, TM 30-meter resolution and the high geometric quality of its imagery have proved to be appropriate for that purpose. Also, LANDSAT imagery recorded at INPE since 1973 gives complete yearly coverage of the entire area.

It could be noted that data from other orbital sensors have been used in some studies. However, available data are either scarce, as in the case of the Satellite Pour l'Observation de la Terre (SPOT), or do not have an adequate resolution for the identification of many small areas deforested each year, like 1.1-km NOAA Advanced Very High Resolution Radiometer (AVHRR).

Combinations of Thematic Mapper bands 3 (red), 4 (near infrared) and 5 (short wave infrared) are used to identify deforested areas. Also, this combination allows to distinguish and map areas of forest, non-forest (typically savannas) and major water bodies.

The scale adopted for the analysis of both imagery and mapping is 1:250,000. The 229 TM scenes that cover the area are converted into the 334 1:250,000 maps of the region. These maps are the basic units of the geographically referenced database.

Building a geographically referenced database

Deforestation may have different consequences and impact depending on local conditions such as ecosystems, soils, vegetation types or climate. Because of this, the first question to ask after how much forest has been cleared each year is where the cleared areas are.

The technology of Geographic Information Systems (GIS) provides means to investigate where deforestation is. GIS are tools dedicated to storing, analyzing, and visualizing geographically referenced data. One of their basic functions is to combine different types of data and find relationships among them, such as how much deforestation is occurring in different types of vegetation or soils, how much of it is close to rivers and water bodies, etc.

To have data on deforestation in a georeferenced form, INPE started to develop the AMAZONIA Information System, a GIS that integrates deforestation areas and several other data for the study of changes in the Amazon rain forest and their impact.

AMAZONIA is based on INPE developed SGI, a geographic information system that handles vector (e. g. administrative boundaries) and raster (such as satellite imagery) data and provides functions for data acquisition, storage, analysis and presentation (Souza et al, 1990). At present, five primary data sets comprehend AMAZONIA, as shown in the next table.

AMAZONIA DATA SETS

TM	1:250,000 scale; UTM projection; contents: deforested areas from TM 1984-1991 imagery, forest domains from TM imagery and vegetation maps, water bodies from TM imagery and existing maps, state boundaries from existing maps, clouds from TM imagery.
MSS	1:500,000 scale; Lambert conformal conic projection; contents: deforested areas from MSS 1975-1978 imagery.
VEGE	1:1,000,000 scale; Lambert conformal conic projection; contents: vegetation types from RADAM maps.
ZOPOT	1:2,500,000 scale; Polyconic projection; contents: vegetation types from IBGE/SUDAM map.
MUNI	1:2,500,000 scale; Polyconic projection; contents: municipal boundaries from IBGE digital map.

The TM data set is formed mainly by data extracted from TM imagery. After analysis of the images, all identified features (deforested areas, forest, non-forest, major water bodies) are digitized to create maps at 1:250,000 scale. MSS assembles maps elaborated in 1980 by the INPE/IBDF team (Tardin et al, 1980). VEGE and ZOPOT data sets are the result of digitization of existing maps. Finally, MUNI was created by importing available digital data from IBGE, the Federal Government mapping agency.

It is expected the extension of the primary data set to incorporate more information necessary for a better understanding of the impacts of deforestation. Also, derived data sets can be produced from the primary ones in data analysis procedures.

Data analysis

Considering the volume of data already gathered inside AMAZONIA, there are at least three major problems, which can be investigated by analysis of the data sets:

- the estimation of the rate of deforestation;
- the assessment of how much deforestation has been occurring inside different types of vegetation;
- the assessment of deforestation by *municípios*.

Each of these problems has to be solved considering its specificity. Different methods of data analysis and, also, GIS techniques have to be used in each case. Several aspects of analyzing data within the spatial context are not sufficiently explored and may be challenging for research on statistics applied to the problems of environment and spatial data.

Estimation of the rate of deforestation

The rate of deforestation can be estimated by determining how deforestation changes over time. Theoretically, having a complete coverage of images for a series of years, the rate of deforestation between any pair of years could be

calculated as the difference between the total deforested area divided by the time interval.

In practice, however, two problems with data (image) sampling have to be dealt with:

- frequently, images are partially covered by clouds that can hide deforested areas;
- to avoid too many clouds, the best image for each year is selected for analysis, causing the moment of sampling to be distributed all over the year for the different images.

Cloud presence has to be considered because the area under clouds is not surveyed. As a result, the amount of deforestation under clouds has to be estimated under four different circumstances:

- the area under clouds was never observed;
- the area under clouds was not observed in the beginning of a series of observations;
- the area under clouds was observed in the past and recent surveys but there are clouds in the middle of the series;
- the area under clouds was not observed in the end of a series of observations.

Having different dates for the images requires an understanding of how deforestation behaviors over time and the estimation of the amount of deforestation accumulated at a defined moment.

Another issue to be investigated is how to calculate deforestation rates over periods of time covered by both MSS and TM imagery (MSS and TM data sets). The poor geometric quality of MSS imagery and the differences of scale (MSS at 1:500,000 and TM at 1:250,000) causes a series of errors that difficult integration of the two data sets.

Finally, there are other sources of errors that have a direct effect on estimates of deforestation: errors of image analysis, digitization, and georeferencing, due to the poor quality of some maps in the Amazon.

Deforestation versus vegetation types

The Amazon forests are formed by various types of vegetation cover, that shelter different species and exchange energy and elements differently with the nearby environment. Also, deforestation is often associated to biomass burning which varies according to the type of vegetation. Therefore, may have different impacts depending on the type of vegetation in which it occurs.

The relationship between vegetation types and the areas of deforestation could be assessed by superposing maps with each kind of information. This can be accomplished by using the classical GIS functions available in AMAZONIA.

Some of the aspects that have to be considered in this kind of analysis are the differences in scale (MSS at 1:500,000, TM at 1:250,000, and VEGE at 1:1,000,000) and imprecision in the boundaries of RADAM vegetation maps.

Also, in some cases it may be valuable to model the distribution of some point-collected data over a region of study. Data on biomass may be one interesting example of this. Due to the scarcity of data this is one challenging problem related to this kind of analysis.

Deforestation by *municípios*

The amount of deforestation inside each *município* may be important for different socio-economical studies. *Municípios* are administrative units for which several socio-economical data are collected, such as population and crop and harvested areas.

Considering the data sets available in AMAZONIA, some aspects that have to be considered in this type of analysis are the very reduced scale of the available *municípios* boundary map (1:2,500,000), the 5-year interval for some socio-

economical data, and the fact that socio-economical data are collected for the entire *município* and not only for the areas of forest as the deforestation data.

References

Souza, R. C. M.; Alves , D. S.; Câmara, G. Development of Geographic Information and Image Processing Systems at INPE. Proceedings, Brazilian Symposium on Geoprocessing, São Paulo, 1990.

IBGE. Projeto Zoneamento das Potencialidades dos Recursos Naturais da Amazônia Legal. Anexo 3: Vegetação. Rio de Janeiro, 1990.

IBGE. RADAM/RADAMBRASIL project reports. Various years.

Tardin, A. T. et al. Projeto Desmatamento. Relatório, INPE-1649-RPE/103, 1980.

Watson, R. T.; Meira Filho, L. G.; Sanzuela, E. Janetos, A. Greenhouse gases: sources and sinks. Climate Change, pre-published copy, 1992.