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 forests 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 availabitily of georeferenced data.

Key-Words: Geographic Information Systems, Deforestation, Amazon

BACKGROUND

The Brazilian Amazon is often refered 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 degrees (figure 1). 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 exemple, Watson et 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)* imagery would require at least 229 scenes to cover the region for one single year, as shown in figure 2.

Notwithstanding, comprehensive surveys are unvaluable for the assessment of deforestation on an yearly basis as well as for the study of the impact of human action on the different ecosystems. Besides, the scarceness of socio-economical data difficults 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 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 table 1.

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, on an yearly basis. Particularly, *TM* 30-meter resolution and the high geometric quality of its imagery has proved to be appropriate for that purpose. Also, Landsat imagery recorded at INPE since 1973 gives complete yearly coverages of the entire area.

It could be noted that data from other orbital sensors has 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.

TABLE 1

Deforestation rates in 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

(*) - included some 1987 imagery

The scale adopted for analysis of the imagery and mapping is 1:250,000. The 229 *TM* scenes (figure 2) that cover the area are coverted into the 334 1:250,000 maps of the region (figure 1). These maps are the basic units of the geographically referenced data base.

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 have been cleared each year is **where** are the cleared areas.

The technology of *Geographical 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 occuring 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 the changes in Amazon rain forests and its impacts.

AMAZONIA is based on INPE developed *SGI*, a geographical 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 (de Souza et all, 1990).

At present, five primary datasets comprehend *AMAZONIA* as shown in table 2.

The TM dataset 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 the 1:250,000 scale. MSS assembles maps elaborated in 1980 by the INPE/IBDF team (Tardin et all, 1980). VEGE and ZOPOT datasets 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 to extend the primary dataset to incorporate more information necessary for a better understanding of the impacts of deforestation. Also, derived datasets 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 that can be investigated by analysis of the datasets:

* the estimation of the rate of deforestation
* the assessment of how much deforestation has been occuring inside the different types of vegetation
* the assessment of deforestation by *municipios*

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

TABLE 2

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 projection
Contents:
Deforested areas from MSS 1975-1978 imagery

VEGE
1:1,000,000 scale
Lambert 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

* frequently, images are partially covered by clouds that can hide deforested areas

* to avoid too much 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 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 initial of a series of observations;

* the area under clouds was observed in past and recent surveys but there are clouds in the middle of the series;

* the area under clouds was not observed in the last 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 *TM* and *MSS* imagery (TM and MSS datasets). The poor geometric quality of *MSS* imagery and the differences of scale (*TM* at 1:250,000 and *MSS* at 1:500,000) causes a series of errors that difficult integration of the two datasets.

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 available 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, deforestation 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 difference in scales (TM at 1:250,000, MSS at 1:500,000 and VEGE at 1:1,000,000), and imprecisions 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 *municipios*

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

Considering the datasets available in *AMAZONIA*, some aspects that have to be considered in this type of data analysis are the very reduced scale of the available *municipios* 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 *municipio* and not only for the areas of forest as are collected deforestation data.

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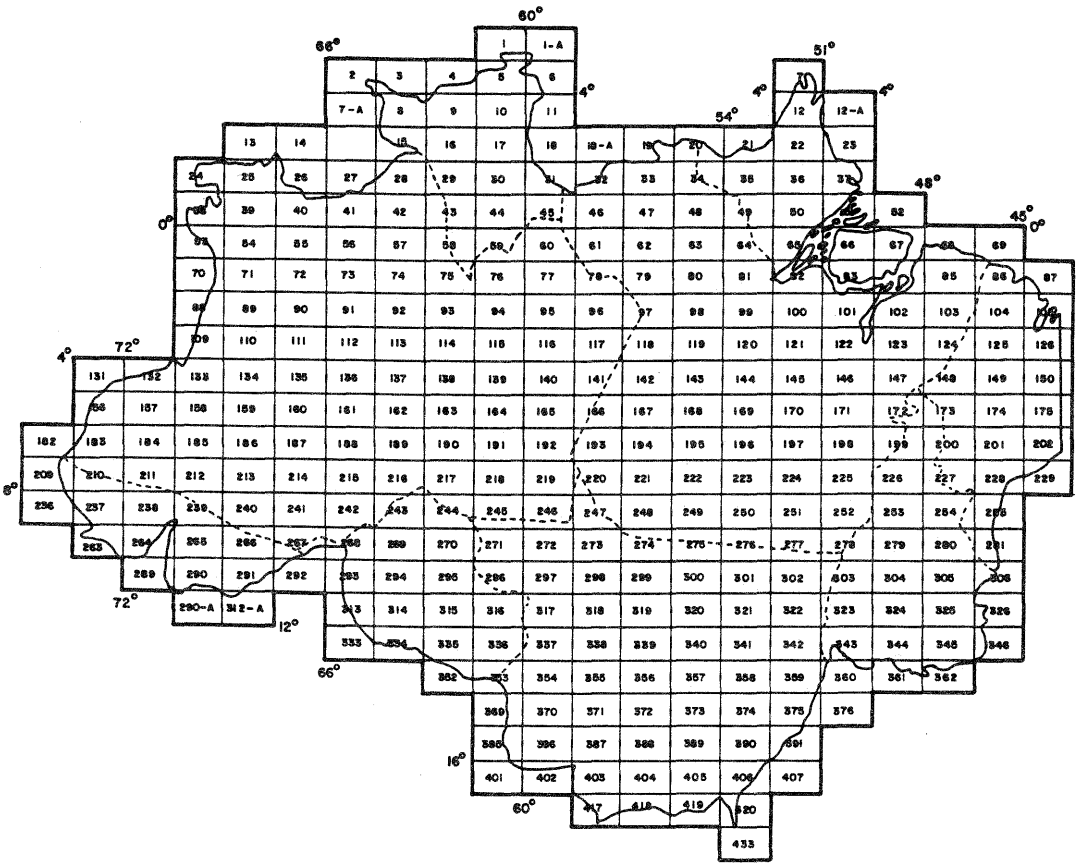

Figure 1 - Map of the Legal Amazônia showing the 9 states and the 334 map sheets that cover the region

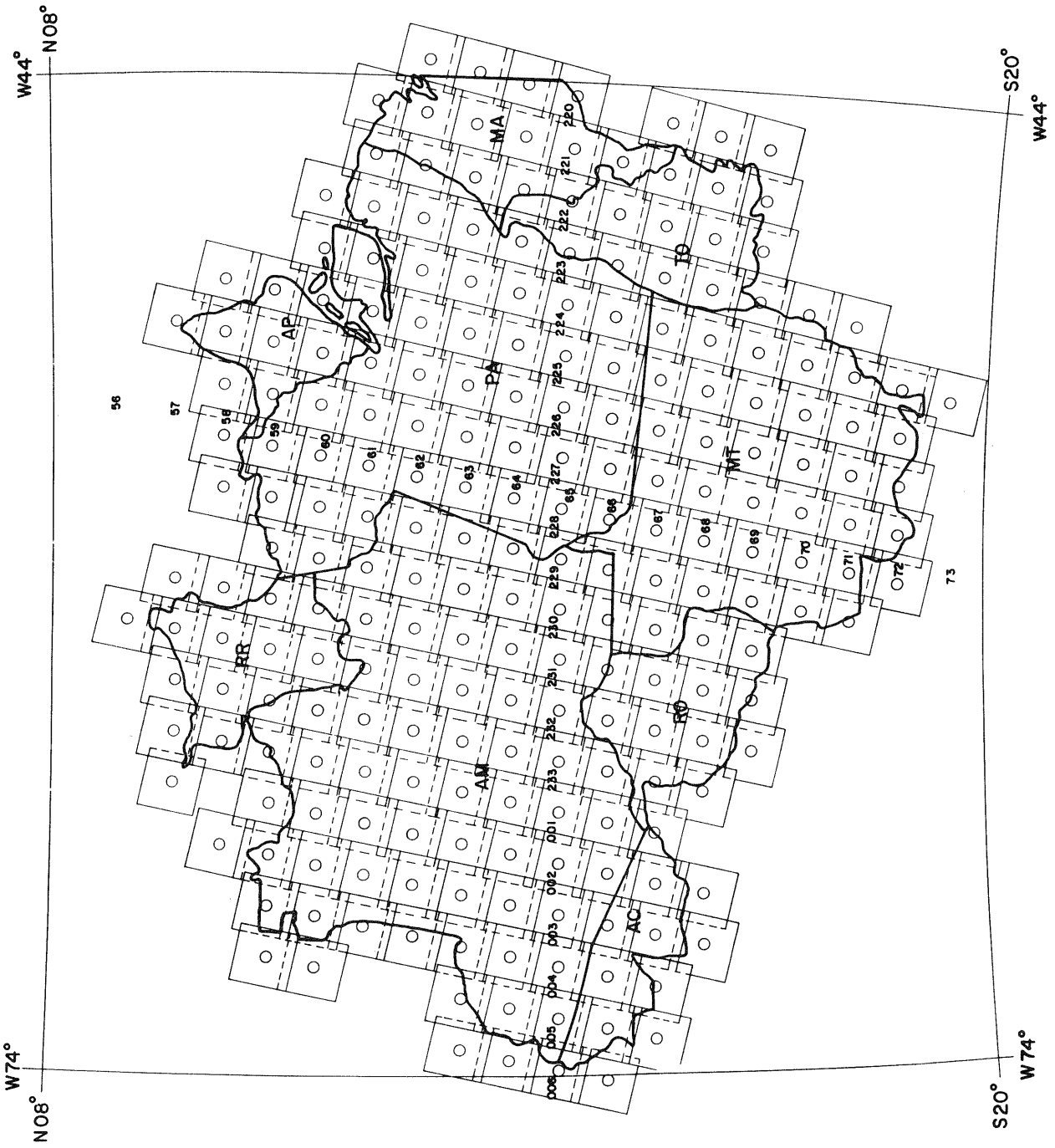

Figure 2 - Landsat scenes that cover Legal Amazônia according to Landsat Thematic Mapper World Reference System (WRSTM)

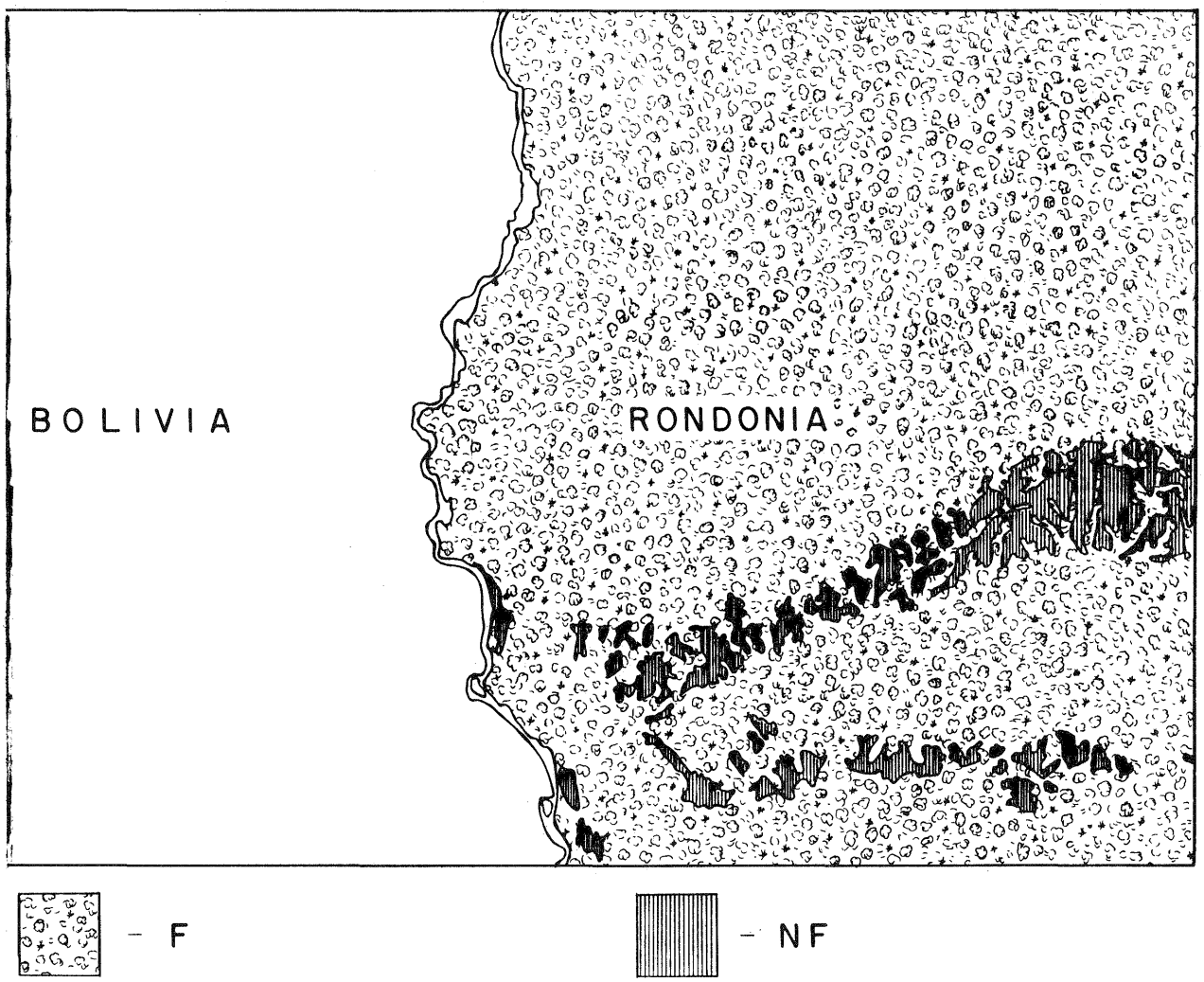

Figure 3 - MIR-293 map sheet showing areas of forest (F) and no-forest (NF)

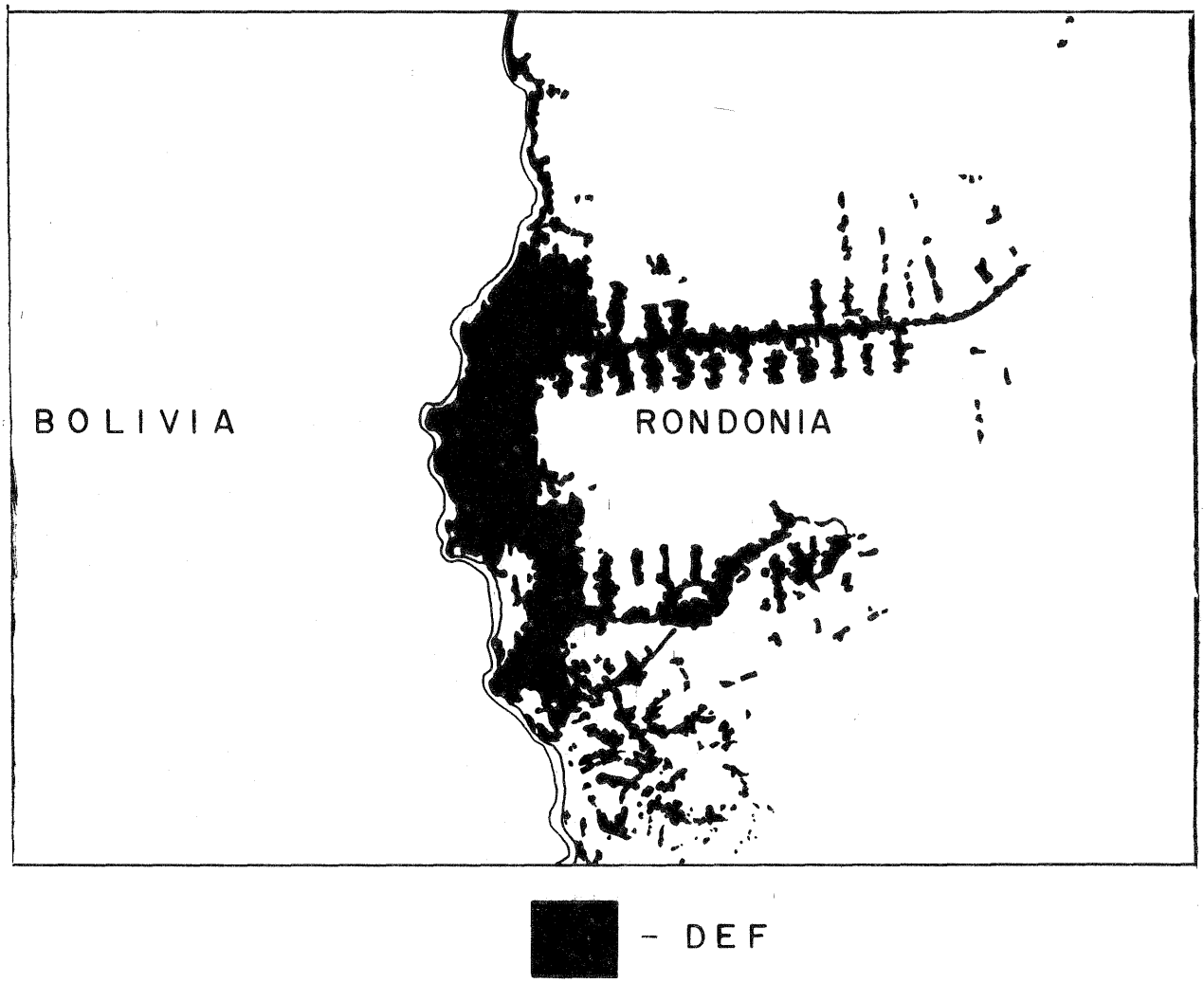

Figure 4 - Deforested areas through 1990 (DEF) in MIR-293 (Rondonia state, close to border with Bolivia