INPE-7521-PUD /42

PRESENTATION OF THE METHODOLOGY FOR CREATING THE DIGITAL PRODES[1]

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[1] Presentation of the methodological approach extracted from the report (INPE-7032-PUD/035)

PRESENTATION

The present report refers to the description of 36 slides, in the PowerPoint software format, presenting the methodology to create the DIGITAL PRODES. The methodological procedure, developed at INPE, was possible due to the joint efforts between photo-interpreters and the team responsible for the development of the Georreferenced Information Processing System (SPRING). This methodological procedure made possible to create the DIGITAL PRODES, which objective is to automate the operational tasks of PRODES (Project of Estimating the Gross Deforestation of Amazon region), consolidating a reliable georreferenced database that is easy to use by users. This methodology consists on generating fraction images derived from spectral linear mixing model, with the objective to reduce the data dimensionality to be processed. Following, it is used image segmentation of shade images, followed by the non supervised classification per region and the matricial edition done in the computer screen, in order to map the extension of gross deforestation of Brazilian Amazon occurred up to 1997. With the development of this methodology, it was possible to conceive the digital database of Brazilian Amazon (BADDAM), that it is a growing information source for the technical-scientific community and/or decision makers, involved in the elaboration of politics, analyses, planning and fiscalization of the resources of the Amazon region, with the objectives to preserve and/or for the sustained land use management.

DIGITAL PRODES

BADDAM PROJECT

(Methodology and Application)

Divisão de Sensoriamento Remoto – DSR
Divisão de Processamento de Imagem – DPI
Instituto Nacional de Pesquisas Espaciais - INPE

For each annual survey of PRODES (The Project of Estimating the Gross Deforestation of Amazon Region), new deforested areas are mapped using Landsat TM images. These values represent the increment of gross deforestation in km^2 and the mean rate of the gross deforestation in km^2/ano. In the manual interpretation of TM images, the accuracy of the area calculation of deforested areas is preserved by performing the adjustment of the previous deforestation polygons over the new images to be interpreted. This procedure causes geometric distortions, so preventing to generate a map showing the extension of gross deforestation. The advantage of using digital processing techniques is the elimination of geometric distortions of the deforestation polygons.

WHY DIGITAL PRODES ?

- **POSSIBILITY TO PRESENT THE GROSS DEFORESTATION DATA OF BRAZILIAN AMAZÔNIA ON A CARTOGRAPHIC BASE CONTAINING THE SPATIAL DISTRIBUTION OF THE ANTROPIC ACTIVITIES IN THIS REGION.**

- **POSSIBILITY TO UTILIZE THE GROSS DEFORESTATION DATA OF BRAZILIAN AMAZÔNIA TO CROSS OR INTEGRATE WITH OTHER INFORMATION.**

- **POSSIBILITY TO IMPLEMENT AND MAKE AVAILABLE A DIGITAL DATABASE (BADDAM PROJECT) CONTAINING SEVERAL IMPORTANT INFORMATION OF BRAZILIAN AMAZÔNIA FOR THE USERS COMMUNITY.**

OBSERVATION:

THE BADDAM PROJECT WAS CONCEIVED TO BE A BROAD DATABASE INCLUDING SPECIALLY THE INFORMATION GENERATED BY DIGITAL PRODES

PRODES (The Project of Estimating the Gross Deforestation of Amazon Region) is the largest project of forest monitoring in the world using Remote Sensing techniques. The National Institute for Space Research, INPE, has been performing the interpretation of images acquired by the North American satellite (Landsat) to accompany the evolution of gross deforestation of Brazilian Amazon. This effort generated results, in the tabular form, from 1978 to 1999 period.

OBJECTIVES OF DIGITAL PRODES

1) TO MAP THE EXTENSION OF GROSS DEFORESTATION OF BRAZILIAN AMAZÔNIA CONSIDERING 1997 AS THE BASE YEAR.

2) TO MAP THE DEFORESTATION INCREMENT AND THE REGROWTH AREAS USING THE 1998 LANDSAT TM IMAGE.

3) TO CHARACTERIZE THE BURNED AREAS OCCURRENCE OVER RECENT AND OLD DEFORESTED AREAS.

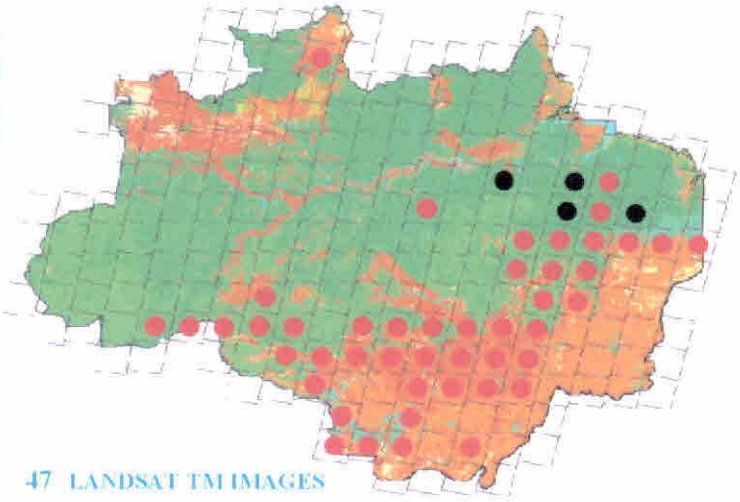
OBJECTIVES OF BADDAM PROJECT

TO CREATE AND MAKE AVAILABLE A DIGITAL DATABASE FOR THE BRAZILIAN AMAZ(

IN THE DIGITAL PRODES, EACH PROJECT REFERS TO ONE LANDSAT TM IMAGE (229 PROJECTS)

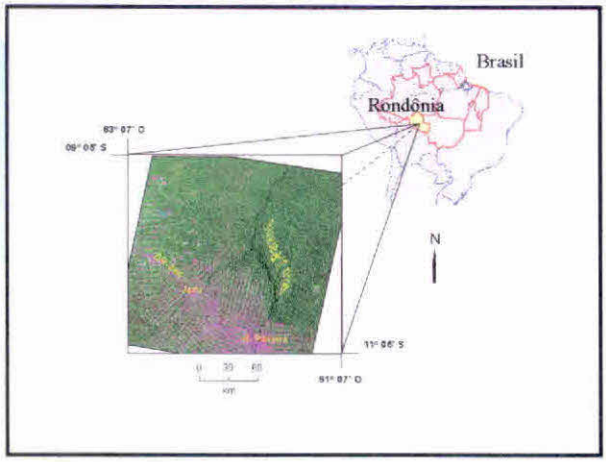
Brazilian Amazon comprises the entire states of Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima, Tocantins and part of Maranhão and Goiás states, corresponding to approximately 5 million km². The area with forest physiognomy occupies about 4 million km².

CRITICAL AREAS OF DEFORESTATION OCCURRENCE
(CORRESPONDING TO ~ 75% OF TOTAL GROSS DEFORESTATION)



47 LANDSAT TM IMAGES

The Brazilian Amazon region is covered by 229 Landsat TM images. However, 47 TM images of them cover a critical area, where 75% of gross deforestation is concentrated in this region.



For PRODES, this area is considered as having a high degree of difficulty for interpreting the images and calculating the annual rate of deforestation. This is due to the large number of polygons that compose the so called "fishbone" deforestation pattern which make difficult to adjust the deforestation increments over the deforested area identified in a sequential surveys.

LOADING LANDSAT TM IMAGE

IMAGE IMPORT AND CREATION OF PROJECTS

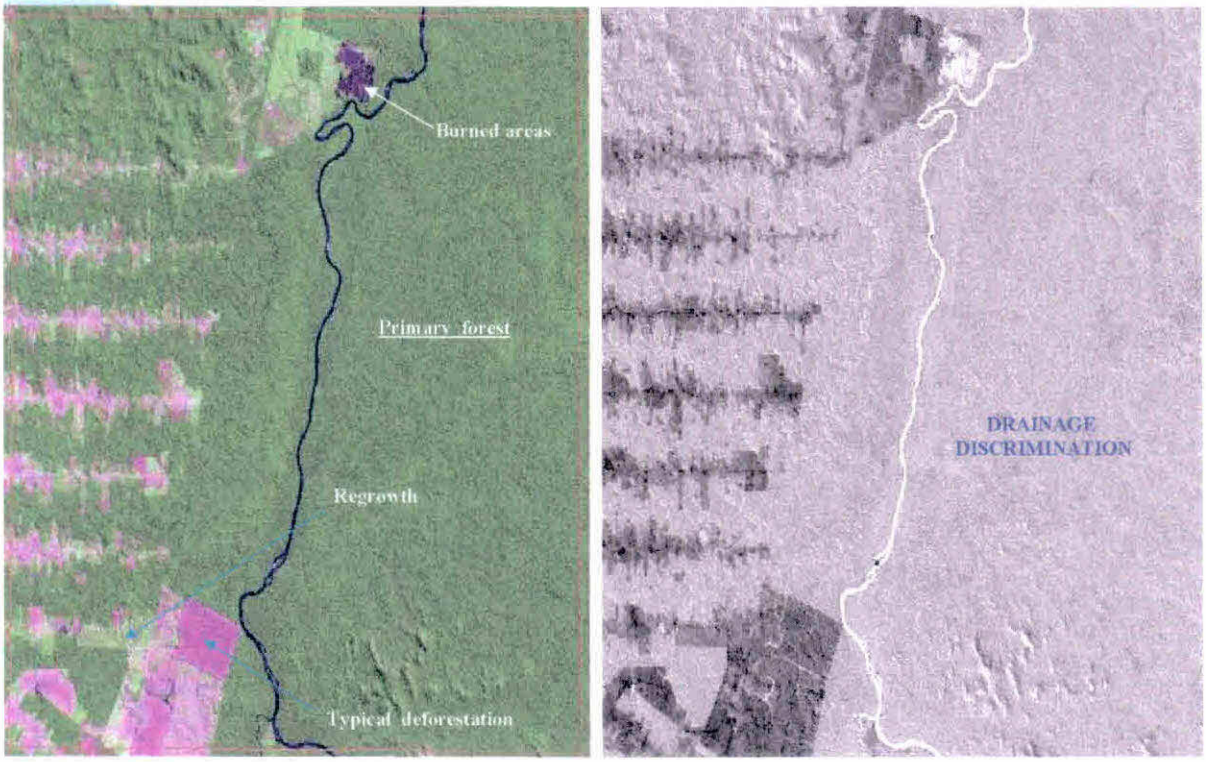
MEAN ERROR OF LANDSAT TM REGISTRATION USING THE TOPOGRAPHICAL CHARTS – 30 m (1 Pixel)

A database structure was created in order to normalize the data sets and the projects. It can be observed that either the name of the database and the name of the project are identified by the year of survey, path and row of Landsat TM image pertaining to the PRODES archive. The georreferencing, that is, the geometry control of the Landsat TM images was done by registration of images, associating the coordinates of the image (line and column) with the geographical coordinates (latitude and longitude). These coordinates are extracted from the topographic maps in the available scales published by FIBGE or DSG, organizations responsible for the national mapping. The unavailability of topographic charts in appropriate scales makes difficulty the task for registering the image.

MEDIUM LINE AMONG ADJACENT LANDSAT TM IMAGES, SHOWING THE USEFUL AREA OF EACH PROJECT

In the SPRING software, there is a routine of importing data in the GIS format, in which the project is created automatically, after importing the information plan called "cell".

DIMENSIONALITY REDUCTION OF (RGB) TM IMAGE BY GENERATING SHADE FRACTION IMAGE, WHICH ALLOWS THE DISCRIMINATION OF SURFACE TARGETS



The spectral linear mixing model estimates the proportion of the components: soil, vegetation, and shade, for each pixel. It is performed using the spectral response of three original bands (3, 4, and 5) of Landsat TM image, generating the soil, vegetation, and shade fraction images. From the three generated synthetic images, the shade fraction is preferentially used, because it provides a high contrast between forested areas (medium amount of shade) and non forested areas (low amount of shade), besides the good discrimination of the drainage.

MEAN TIME SPENT FOR PROCESSING THE 47 TM SCENES OF THE DIGITAL PRODES, INCLUDING ONLY THE MORE IMPORTANT ACTIVITIES

ATIVIDADES	(h)
1) REGISTRAR A IMAGEM TM/LANDSAT[1]	4,5
2) IMPORTAR E REGISTRAR OS AGREGADOS 97[1]	2,5
3) VETORIZAR OS AGREGADOS 97[1]	3,0
4) GERAR IMAGEM FRAÇÃO-SOMBRA DO MODELO DE MISTURA[1]	1,0
5) SEGMENTAR A IMAGEM FRAÇÃO-SOMBRA[1]	2,0
6) EXTRAIR OS ATRIBUTOS ESTATÍSTICOS DA IMAGEM TM/LANDSAT[1]	2,0
7) EDITAR O MAPA DE DESFLORESTAMENTO (PELO FOTOINTÉRPRETE)[2]	65,0
8) AUDITORIA DO MAPA DE DESFLORESTAMENTO BRUTO	8,0
TOTAL	88,0

[1]Pentium II, 300 MHz, RAM 128 Mb Disco 9 Gb [2]Pentium I, 200MHz, RAM 98Mb Disco 4 Gb

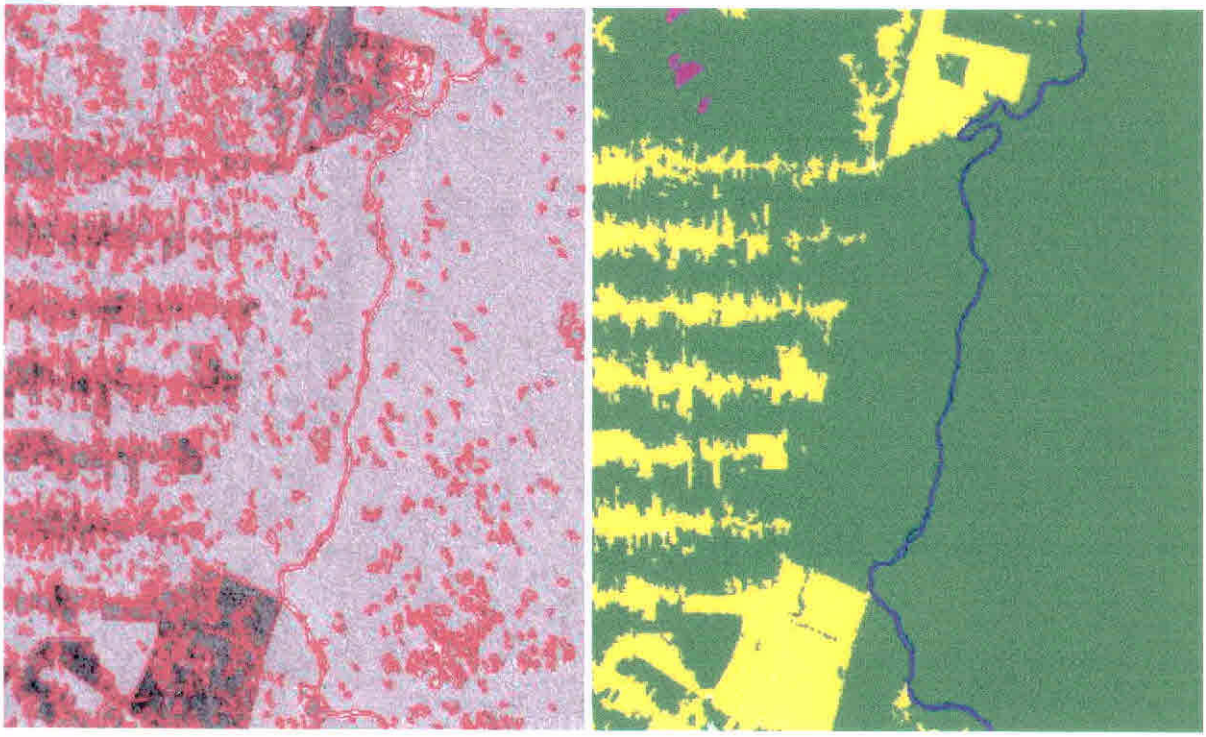
(OPERATIONAL ACTUAL TIME 88 - 73 = 15h)

COMPARAÇÃO ENTRE TEMPO DE PROCESSAMENTO PARA A IMAGEM LANDSAT (3 bandas) E A IMAGEM SOMBRA (1 banda)

IMAGENS	GEORREFERENCIAMENTO	MODELO DE MISTURA	SEGMENTAÇÃO	EXTRAÇÃO DE REGIÕES	CLASSIFICAÇÃO E MAPEAMENTO	TOTAL (HORAS)
LANDSAT	6 H	-	35 H	20 H	10 MIN	61:10
SOMBRA	2 H	1 H	6 H	5 H	10 MIN	14:10

SPARC-20 SUN WORKSTATION, 96 Mbytes RAM AND 270 Mbytes VIRTUAL MEMORY

The time spent to accomplish the image segmentation task using the shade fraction image was significantly reduced due to the distinction between forested and non forested areas presented in this image. The processing time of shade fraction image was 14.10 hours while the processing time to accomplish the task using three TM bands was 61.10 hours, that is, there was a decrease of approximately 80% in the processing time due to the reduction of the number of bands from 3 to 1.

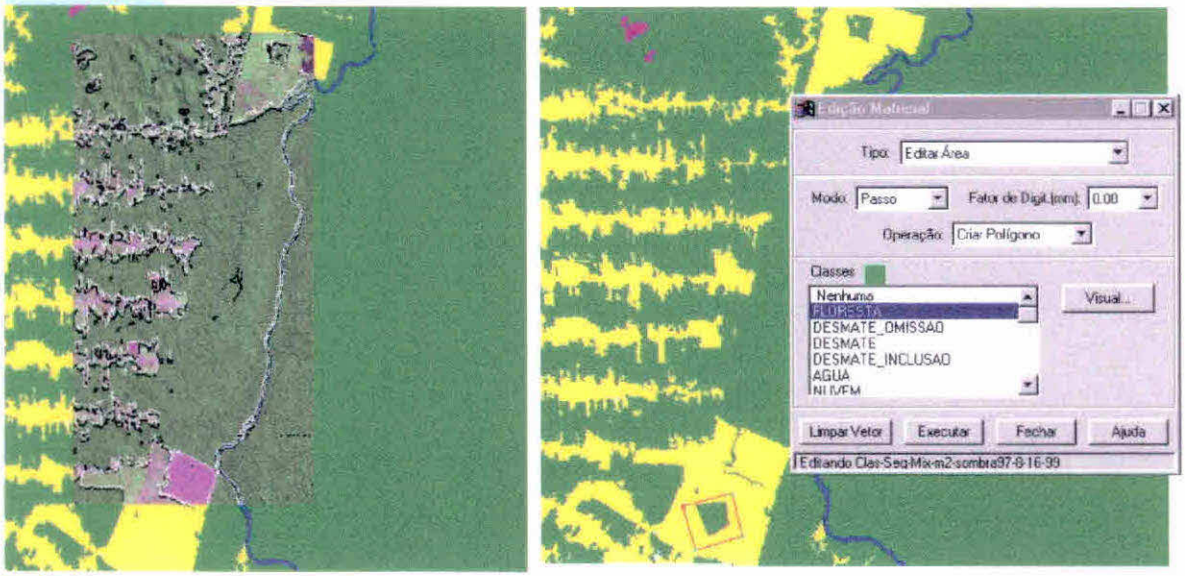


SIMILARITY (8) AND AREA (16) THRESHOLD VALUES (MINIMUM MAPPED AREA = 5.76 ha)

To perform the image segmentation is necessary to define two thresholds: 1) the similarity threshold, minimum threshold in which the value below it two adjacent areas are considered similar and grouped into one region; and 2) the area threshold, minimum value of area given by number of pixels, so that a region is individualized. The ISOSEG classifier was used, that is an available algorithm in the SPRING software for classifying regions of a segmented image. It is a non-supervised algorithm of grouping data, that was applied on the set of regions defined by the image segmentation task. After the classification of segmented image, the mapping task is performed where the thematic areas individualized by the classifier are associated to the thematic classes defined in the database. The result of identification and mapping the deforested areas can be presented either in a raster or vector format.

THE CLASSIFICATION EDITION DONE BY PHOTOINTERPRETER IN THE COMPUTER SCREEN

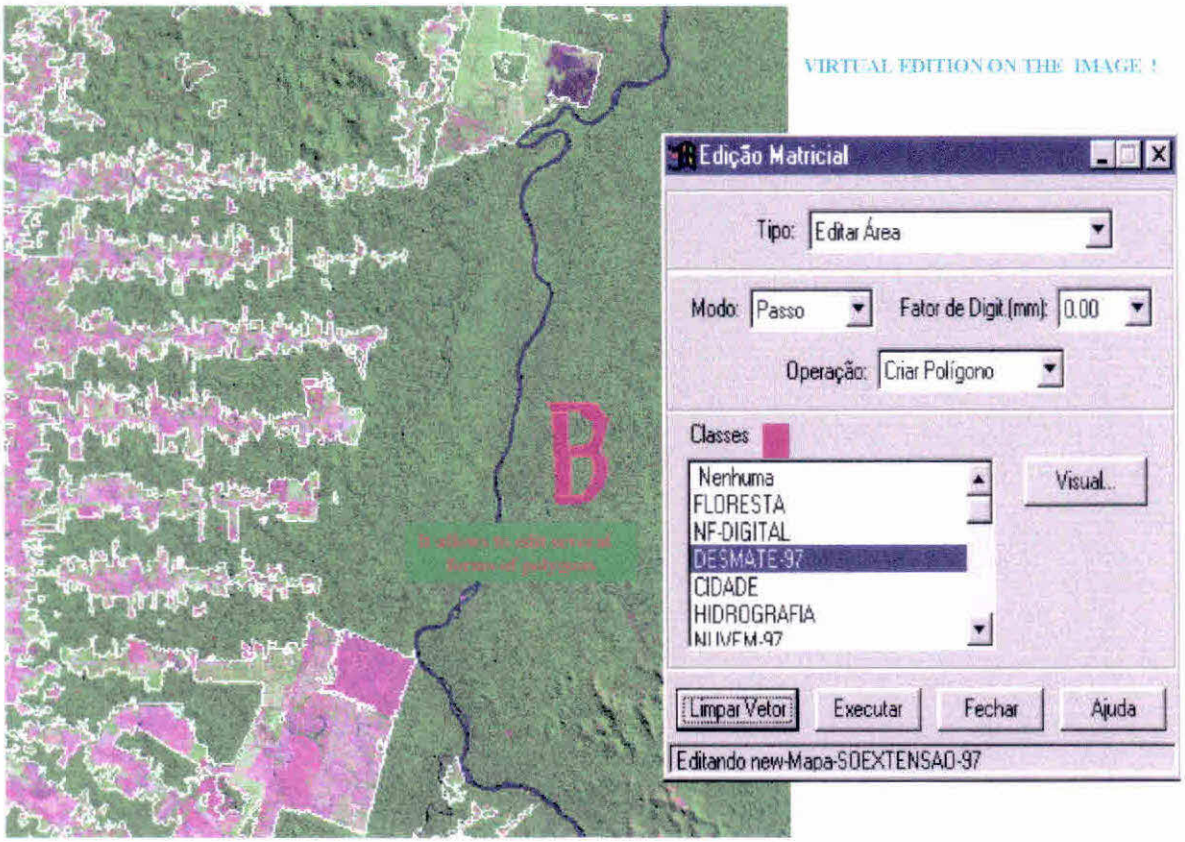
THE OVERLAP OF VECTOR DATA ALLOW TO EDIT OR TO ELIMINATE POLYGONS



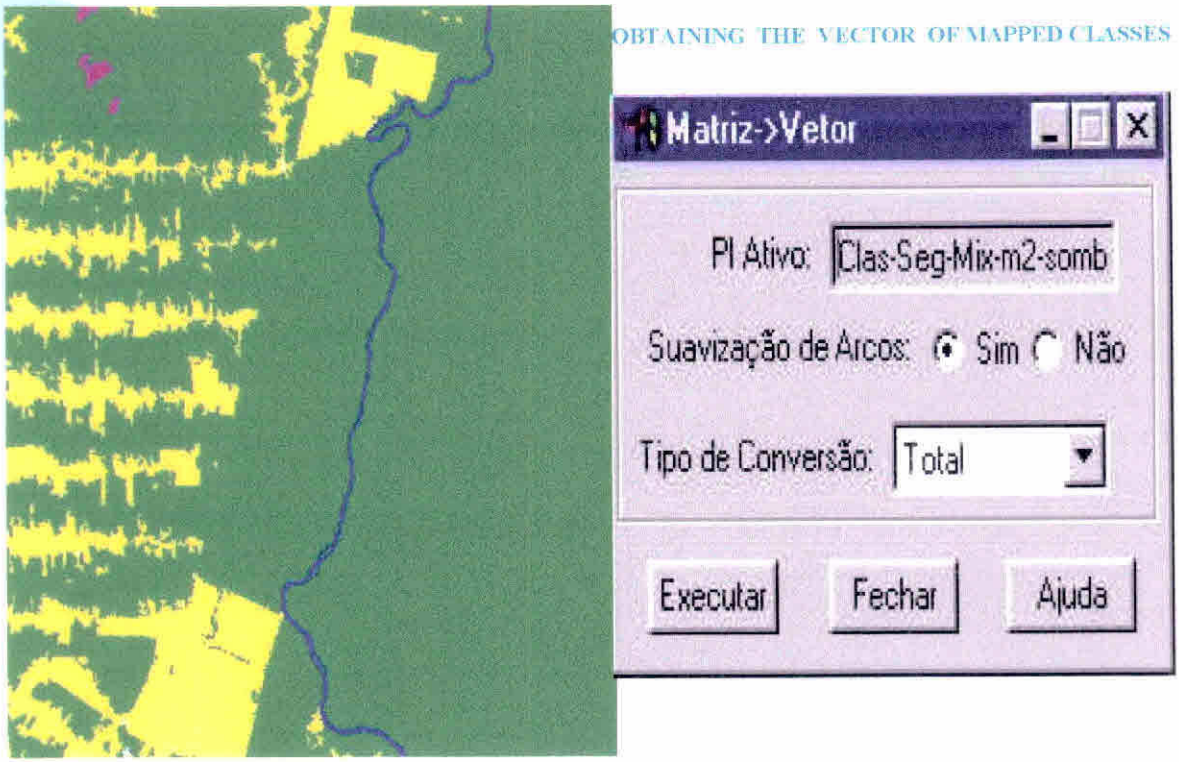
#AGREGADO-97 ASSURES AND MAINTAINS THE COHERENCE WITH THE HISTORICAL DATA OF ANALOGICAL PRODES

To maintain and to assure the coherence with the historical data of PRODES project, avoiding in this way some fails in basic premises of this project, the interpretation data of the last overlay was considered, relative to the extension of deforestation up to 1997. Later on, this overlay, that represents the all existent information up to 1997, was scanned, vectorized, and registered. The historical data, in the vector format, were superimposed, in the computer screen, to the Landsat TM color composite. This allows to the photo interpreter to improve the positioning of the limits of the historical data, to redefine and to edit the new limits among several classes.

VECTOR LINES OF THE DEFORESTATION EXTENSION OVER LANDSAT TM IMAGE

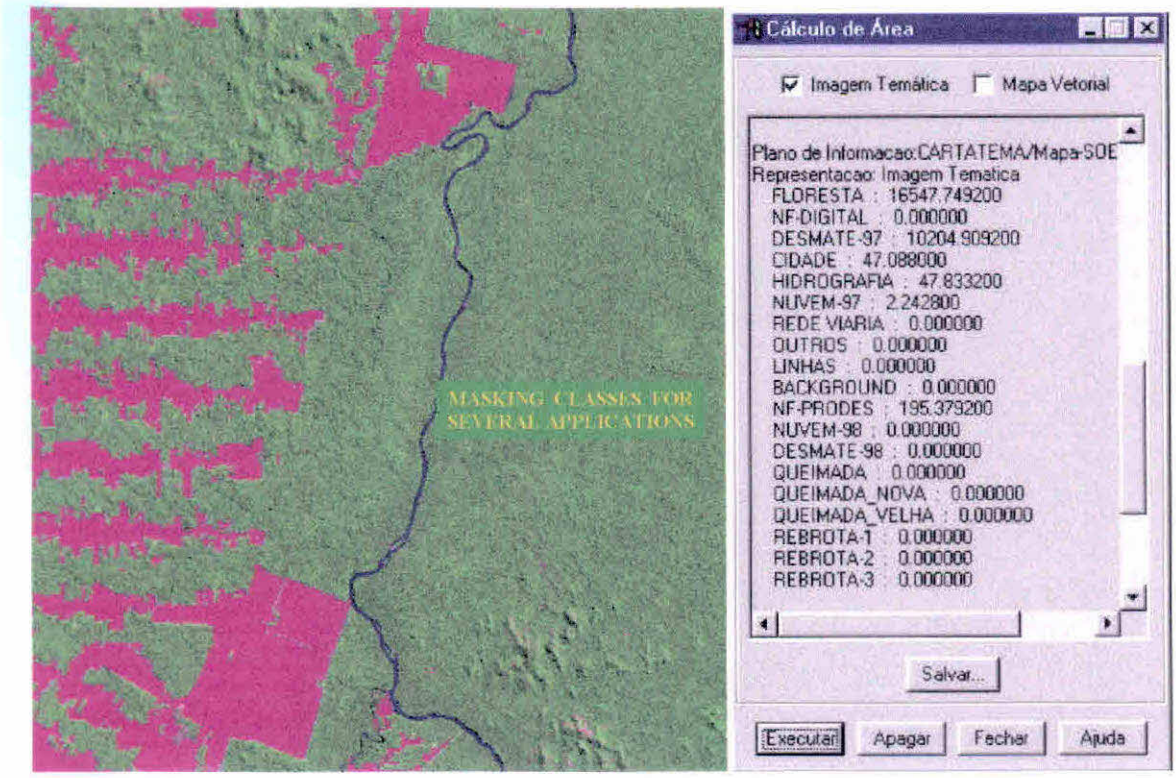


The product generated automatically, by using the digital method, is a map containing information that represent about 80% of the tasks accomplished currently by the analog method. The remaining tasks is done by a photo-interpreter, who analyzes the results of the deforestation polygons accepting them or reclassifying them in other land use categories. The edition accomplished by the photo-interpreter consists of analyzing the polygons obtained by the image segmentation and classification of shade fraction image. The mapped polygons are accepted or reclassified in other land use categories, based on the photo-interpreter experience who uses also the historical data of analog PRODES. The final result obtained is transparent because it is analyzed and audited using a TM color composite image as a reference.

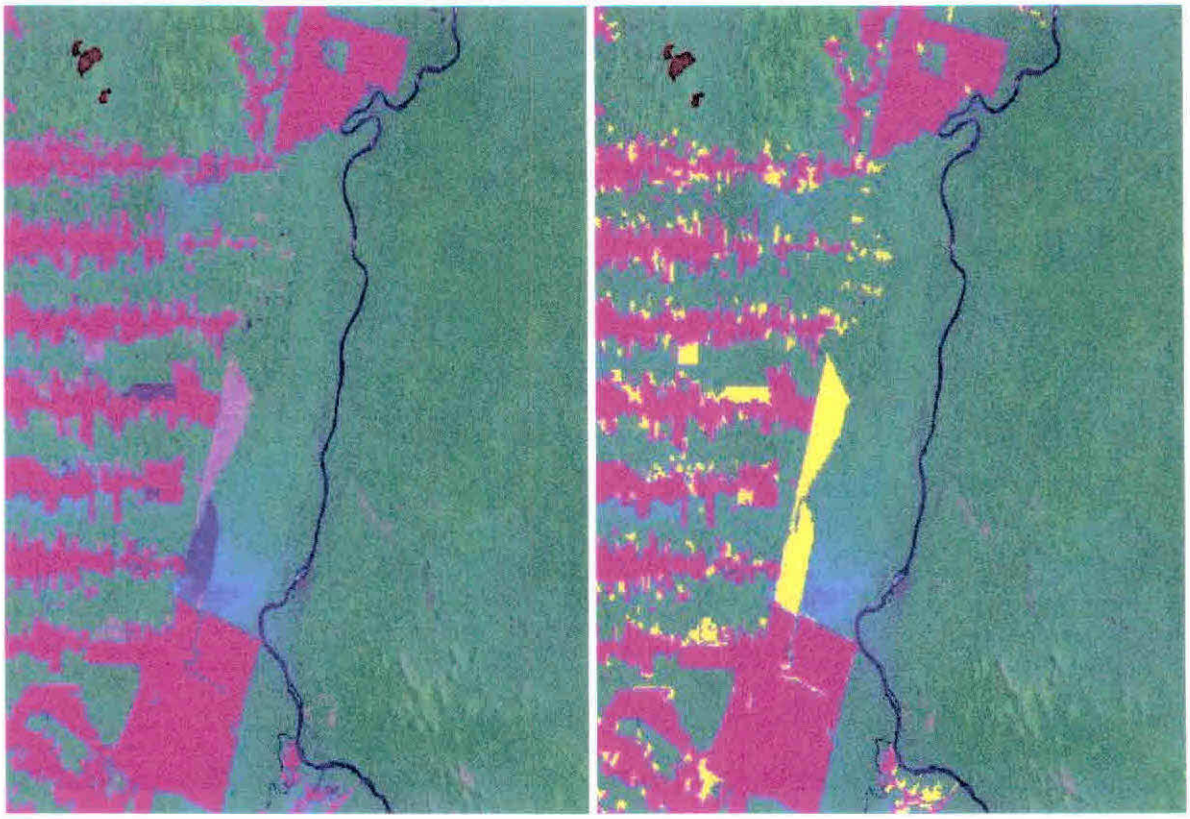


After the implementation of matricial edition algorithm in the SPRING software, a higher efficiency is observed in the edition process done by the photo-interpreter. In this matricial edition, the vector data, corresponding to the edited polygons, are obtained by the procedure of converting raster to vector format. The great difference observed in this procedure is because the edition is performed in the matrix and not in the vector data (vector data need to adjust the lines and to polygonalize).

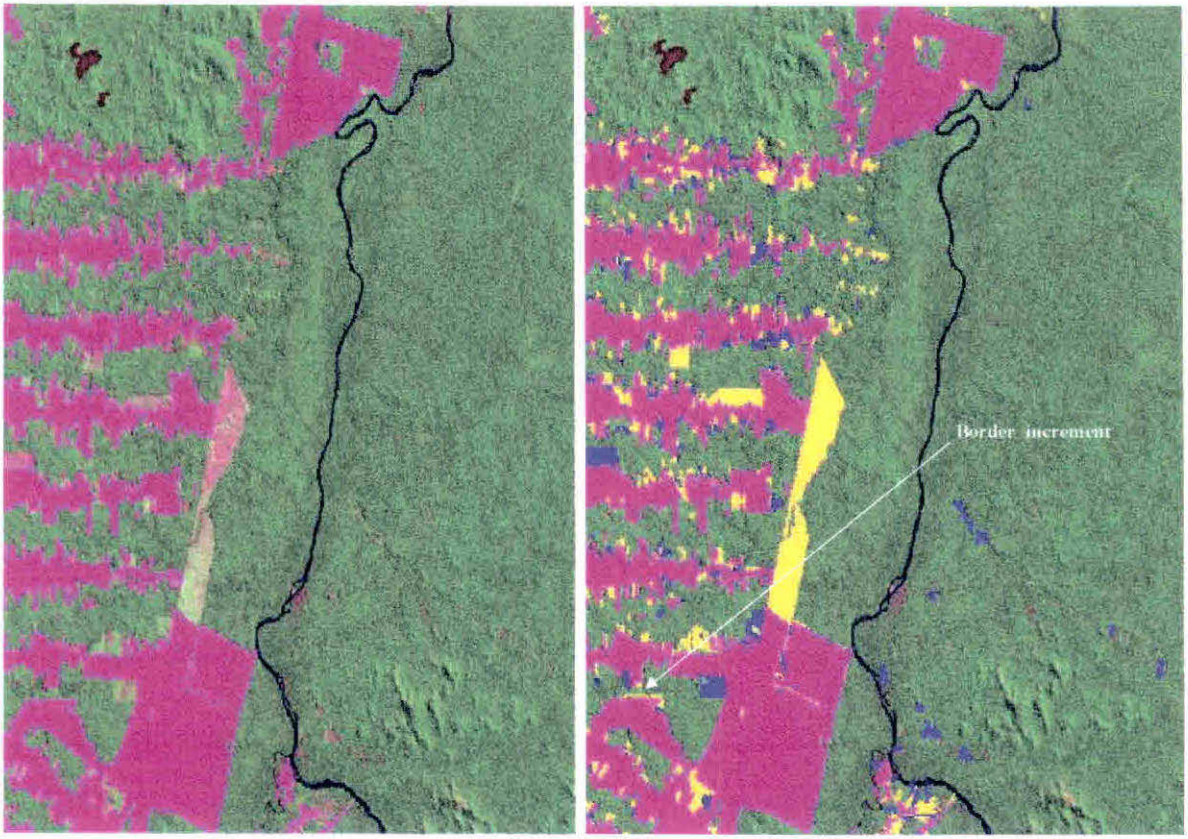
CALCULATION OF MAPPED CLASSES



After obtaining the final map of the extension of deforestation areas, product georreferenced, it was possible to integrate it with data originating from other sources, for example, vegetation type, or even it can be combined with other information plans available, either in a regional, state, or municipal level. One of the application of this map is the creation of masks for selecting areas of interest, as example, isolating the deforestation theme in order to study the probable regrowth areas. Or masking and isolating the primary forest theme for studying the annual increments of deforestation.

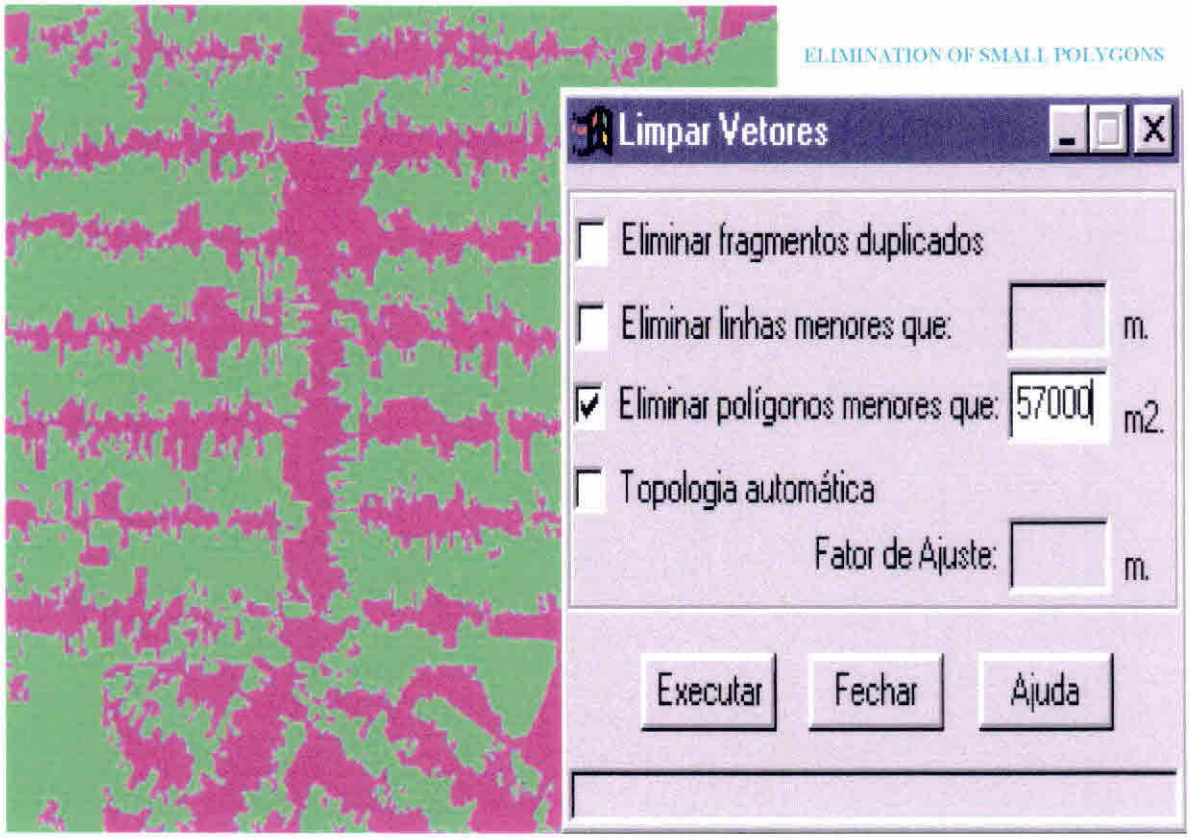


The increment of deforested areas occurred in the 1997 and 1998 period was obtained by image segmentation and classification of soil fraction image derived from 1998 TM data. It was done performing the image x image registration procedure and annual dynamics was investigated, after masking and isolating only the primary forest theme. The result obtained for the deforestation increment was edited by the photo-interpreter who analyzed the polygons generated by the segmentation and classification of the soil fraction image and it was decided to accept or to reclassify the polygons in other land use categories.



The increments of deforested areas occurred between 1997 and 1998 and 1998 and 1999 periods were obtained by image segmentation and classification of soil fraction images derived from 1998 and 1999 TM images, repectively. The obtained results either for the extension and for the deforestation increments were edited by a photo-interpreter. One should observe the overlapping of the extension of the deforestation and the increments referring to 1998 and 1999. If there is a 1 pixel error, then the deforestation in the border has to be double checked carefully.

ELIMINATION OF SMALL POLYGONS

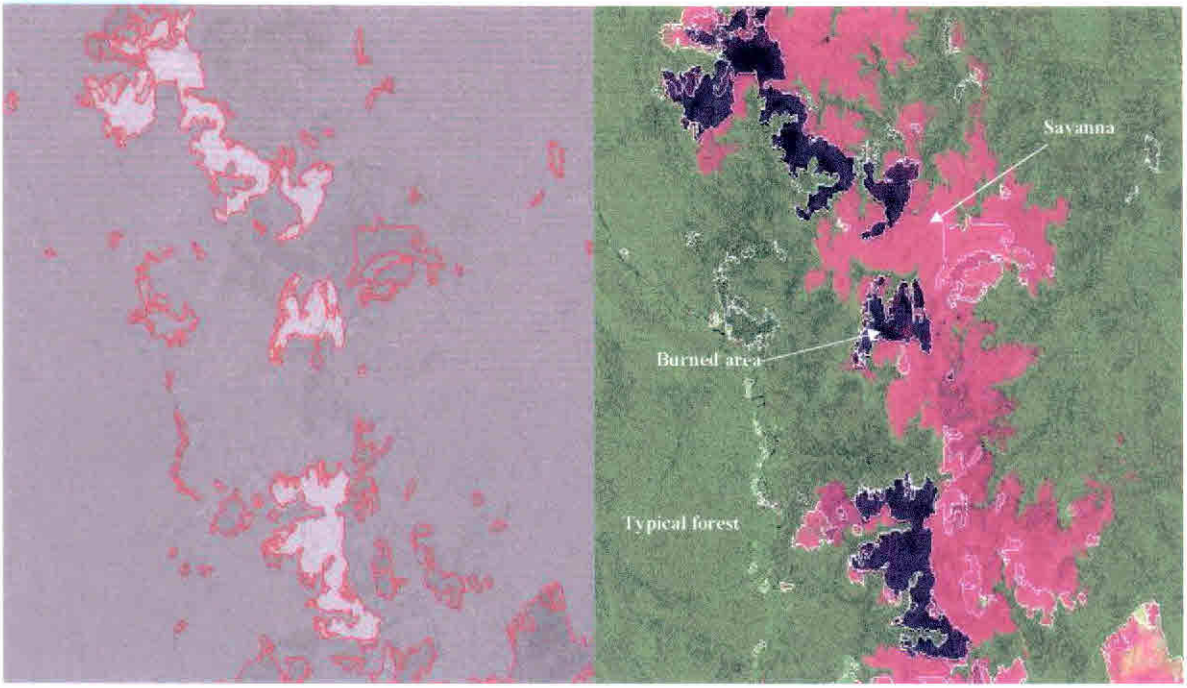


This procedure is applied in the final map of the extension of gross deforestation with the objective of making uniform the themes, that is, to eliminate isolated points, classified differently of its neighborhood. Hence a final map is generated with less noisy appearance.

EXAMPLE OF HOW TO COPY POLYGONS FROM DIFFERENT INFORMATION LAYER

LINES OF SEGMENTATION OF SHADE FRACTION IMAGE

LINES OF SEGMENTATION OVER RGB TM IMAGE

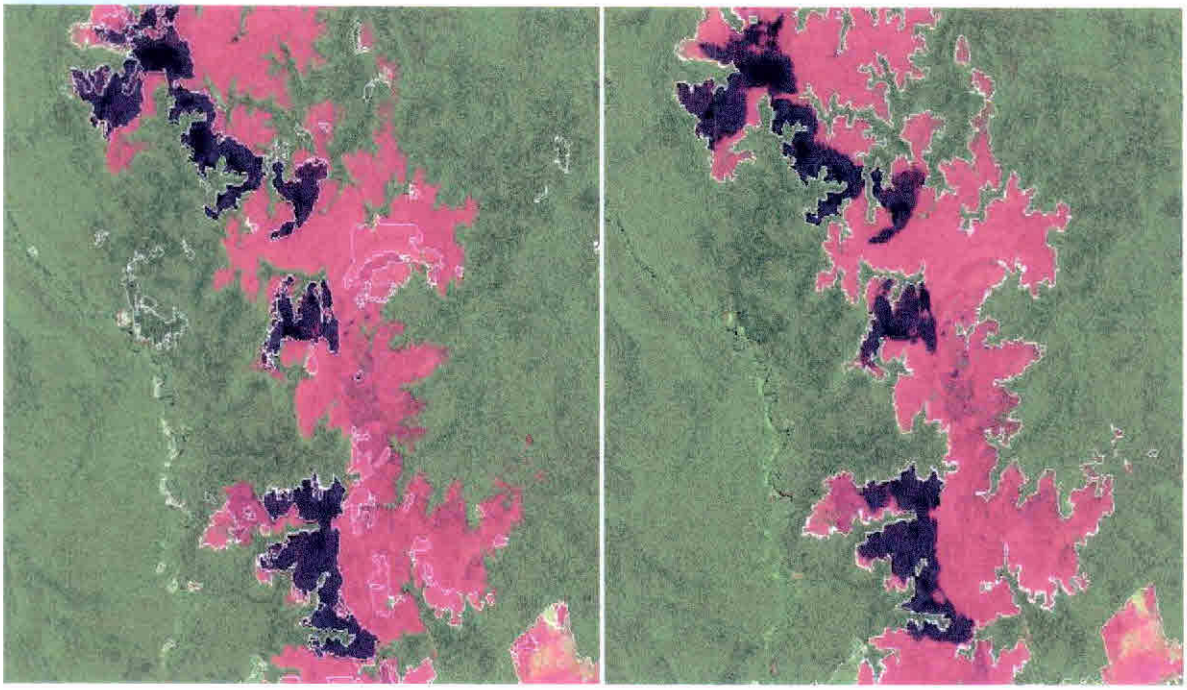


For some TM scenes, the lines of image segmentation of shade fraction image did not discriminate the savanna area that occurs in the middle of forested areas. But the matricial edition allows to copy polygon among different PIs, and this facilitates the import of polygon of savanna segmented using the soil fraction image.

COPIES OF POLYGONS FROM DIFFERENT INFORMATION LAYERS

LINES OF SEGMENTATION OF SHADE IMAGE

LINES OF SEGMENTATION OF SOIL IMAGE



For some TM scenes, the lines of image segmentation of shade fraction image did not discriminate the savanna area that occurs in the middle of forested areas. In the image on the right, this same area is perfectly discriminated in the soil fraction image. The matricial edition allows to copy polygon among different PIs, and this facilitates the import of polygon of savanna that appears only in the soil fraction image. It is possible, by matricial edition, to consider a basic PI of reference and to import polygons from other PIs in order to complement the PI considered basic.

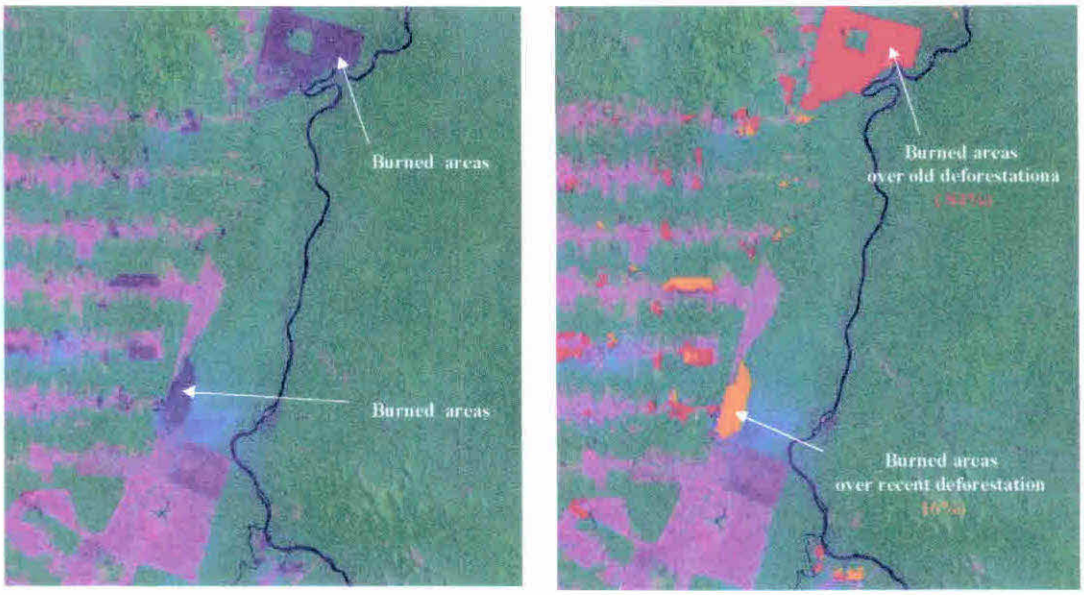
DIGITAL PRODES :

EXAMPLES OF PRACTICAL APPLICATIONS

1) EVALUATION OF BURNING OVER DEFORESTED AREAS

2) MAPPING OF REGROWTH AREAS

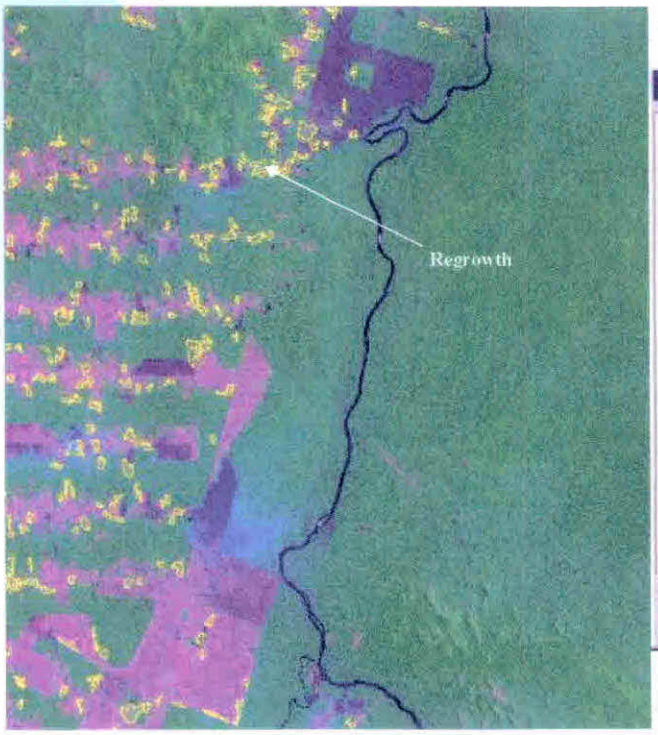
3) EVALUATION OF REMAINING FORESTS IN THE THEOBROMA (RO) DISTRICT



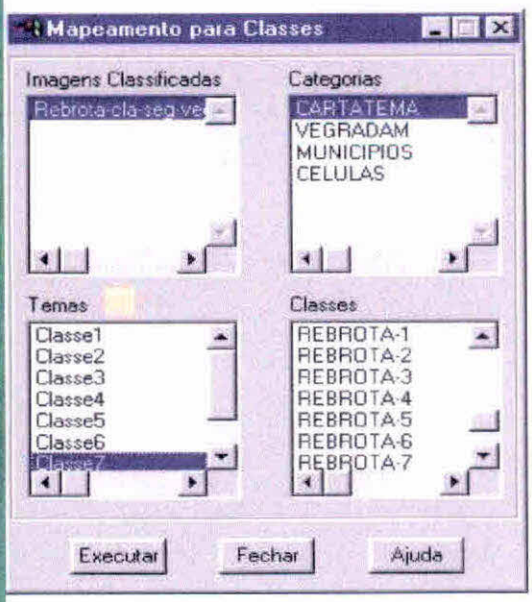
Burning occurred over recent deforested areas (orange color, 186 km2) were discriminated from those occurred over old deforested areas (red color, 964 km2) mapped using 1998 TM image.

The burned areas, occurred in areas of recent deforestation (for example, year of 1998), were discriminated from those occurred in old deforestation areas by crossing the classification of burned areas with the map of the extension of gross deforestation occurred up to 1997, and/or with the map of the increment of deforestation obtained from 1998 TM image.

MAPPING OF REGROWTH AREAS

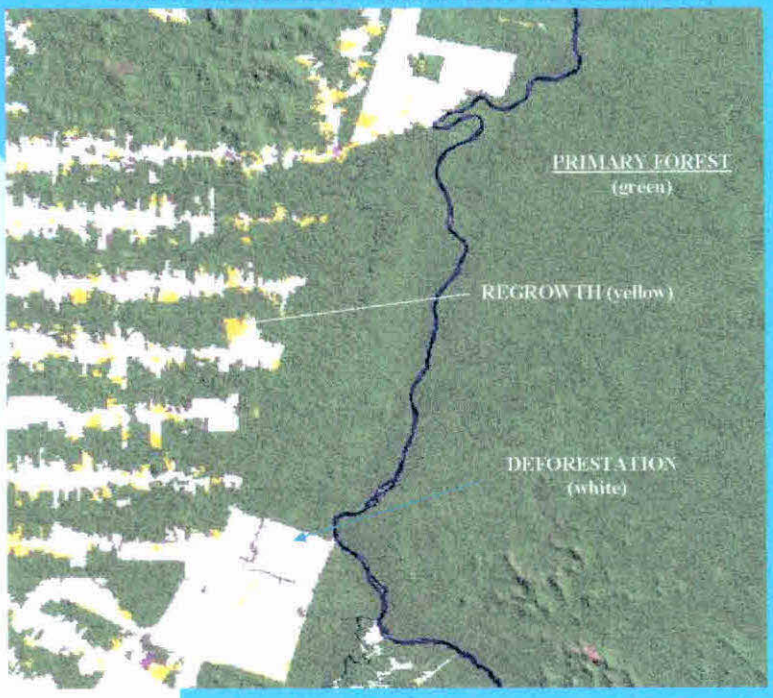


CLASSIFICATION OF SEVEN REGROWTH CLASSES



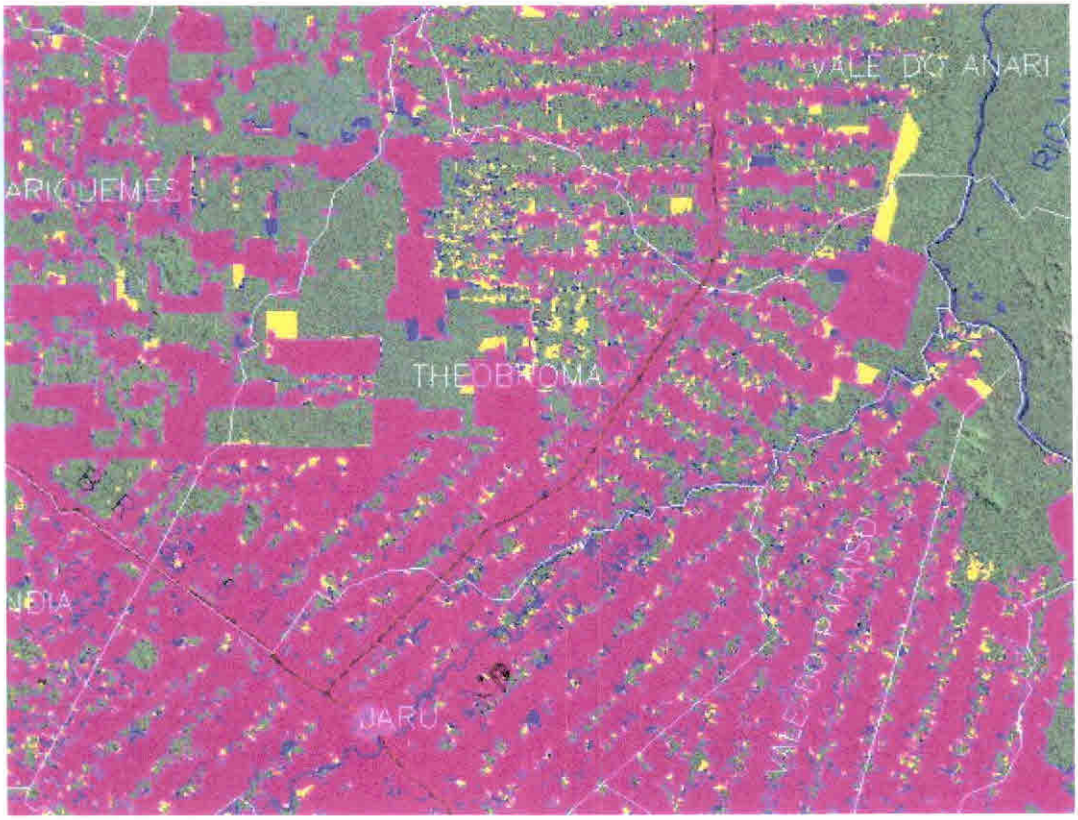
The mapping of regrowth areas was obtained by image segmentation and classification of vegetation fraction image derived from Landsat TM acquired on September 12, 1998. Firstly, a mask was created to isolate the 1997 deforestation theme in this image, where the procedures of image segmentation and classification of regrowth areas were performed.

THEMATIC REPRESENTATION OF THE EXTENSION OF THE DEFORESTATION AND OF THE OCCUPIED AREAS WITH REBROTA (YEAR 1998)



Regrowth areas mapped using 1998 TM image (yellow color, 1,754 km2) representing 16% of the total gross deforestation (white color).

It was calculated an area of 1,754 km2 occupied by regrowth in the total area occupied by the deforestation theme (10,947 km2), representing 16% of the total gross deforestation existent up to 1998.



After obtaining the georreferenced digital data, it was possible to integrate them with information originating from other sources. In the municipality of Theobroma, in the Rondônia state, it was possible to combine the digital data of BADDAM project with vegetation map of FIBGE.

AVALIAÇÃO DOS REMANESCENTES FLORESTAIS DO MUNICÍPIO THEOBROMA-RO

Classe de vegetação	Área original (Km²)	Desmatamento até o ano 1997 (Km²)	Remanescentes florestais (Km²)	Incremento de desmatamento no ano 1998 (Km²)	Queimadas em desmatamento no ano 1998 (Km²)
Floresta Tropical Densa (Aluvial)	2,7	0,0	2,7	0,0	0,0
Floresta Tropical Densa (Submontana)	35,0	20,5	14,5	2,2	0,5
Floresta Tropical Aberta (Dissecado)	1.556,5	854,6	701,9	84,5	29,4
Área de Tensão Ecológica (Dissecado)	589,1	214,9	374,2	38,8	13,7
TOTAL	2.183,3	1.090,0	1.093,3	125,5	43,6

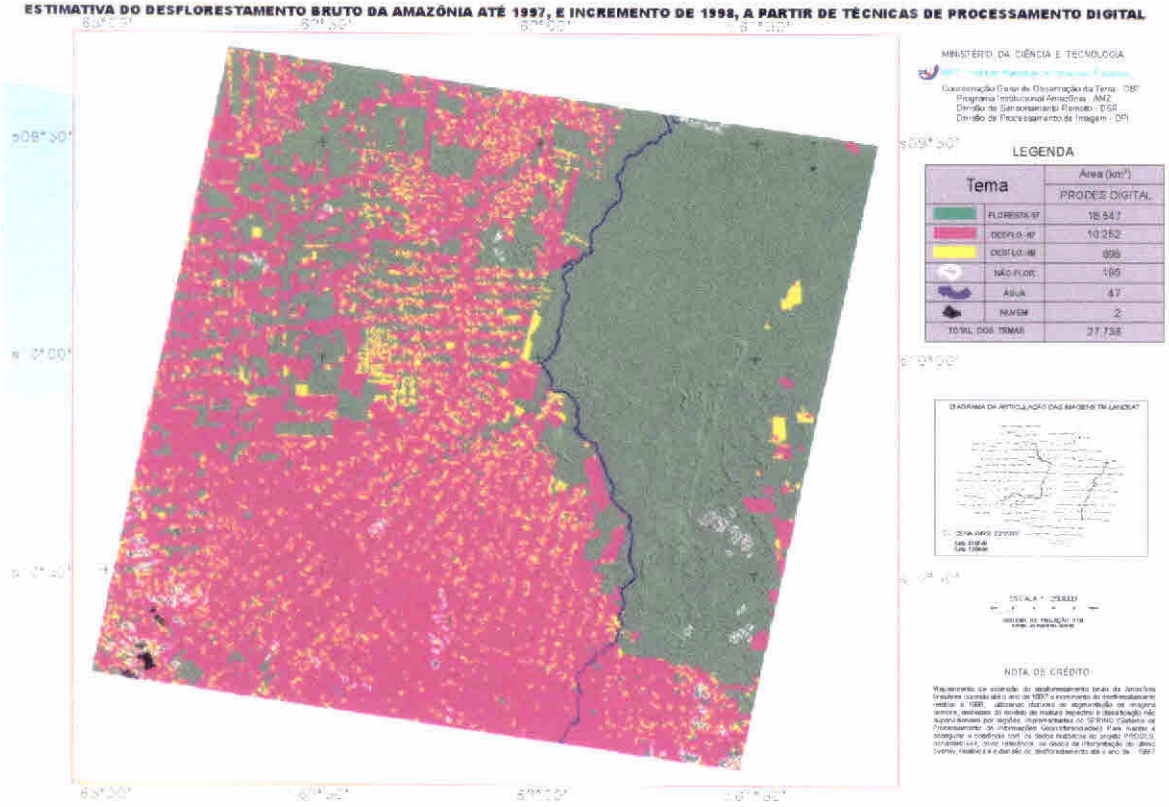
Obs.: Áreas queimadas em desmatamentos antigos totalizam 95,1 km²

Then, it was possible to monitor the remaining forest of the municipality of Theobroma, estimating the deforestation occurred up to July 07, 1997. It was also possible to identify the increment of deforestation areas occurred between 1997 and 1998 period. Besides it was evaluated the burned areas occurred on recent deforested areas in 1998. As can be observed in the table, the monitoring of remaining forest was accomplished for the four existent forest physiognomy classes in this municipality based on the information of the FIBGE map.

FINAL RESULTS

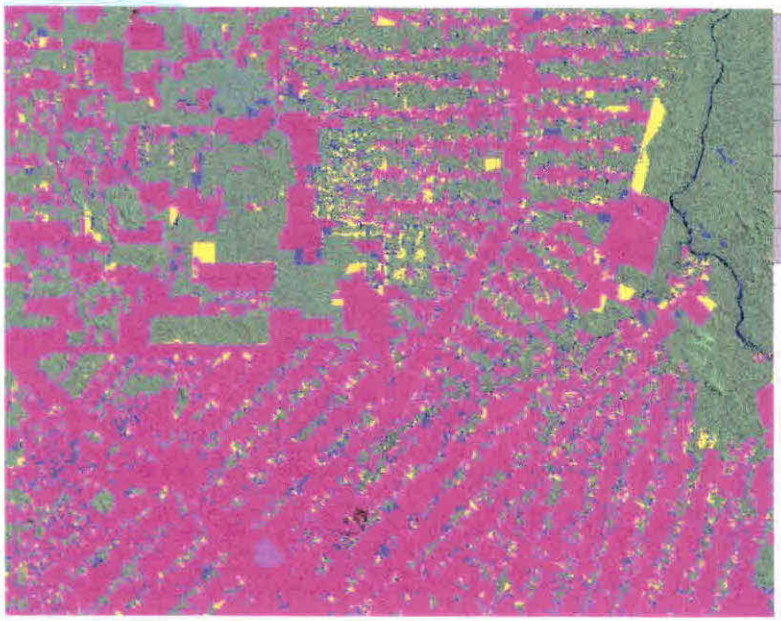
PROPOSED REPRESENTATIONS:

DIGITAL PRODES AND BADDAM



EXAMPLE OF FINAL REPRESENTATION PROPOSED FOR THE DIGITAL PRODES PROJECT

Mapping of the extension of gross deforestation of Brazilian Amazon region occurred up to 1997 and the increment of deforestation related to 1998, using image segmentation of shade images, derived from spectral linear mixing model and non supervised classification per region, implemented in the SPRING software. In order to maintain and to assure the coherence with the PRODES historical data, it was considered, as a reference, the data of the interpretation of the last overlay, relative to the extension of the deforestation up to 1997.



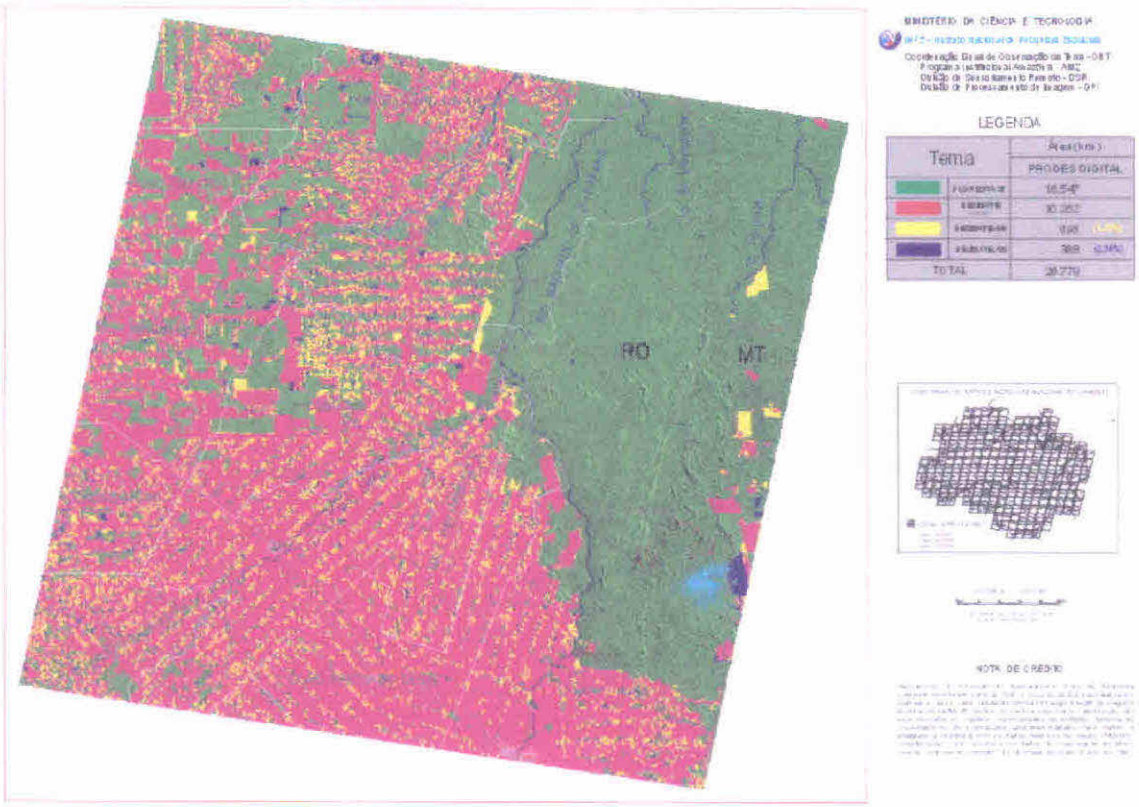
LEGENDA

Tema	Área (km) PRODES DIGITAL
FLORESTA-97	16.547
DESMATE (ATE 97)	10.252
DESMATE.-98	695 (4,26%)
DESMATE.-99	388 (2,34%)
TOTAL	26.779

CLASSES TEMÁTICAS DO PROJETO BADDAM

1) FLORESTA
2) DESFLORESTAMENTO-97
3) INCREMENTO DESFLORESTAMENTO 98
4) NÃO-FLORESTA
5) NUVEM-97
6) NUVEM-98
7) HIDROGRAFIA
8) CIDADES
9) ESTRADAS
10) MUNICÍPIOS
11) LIMITES

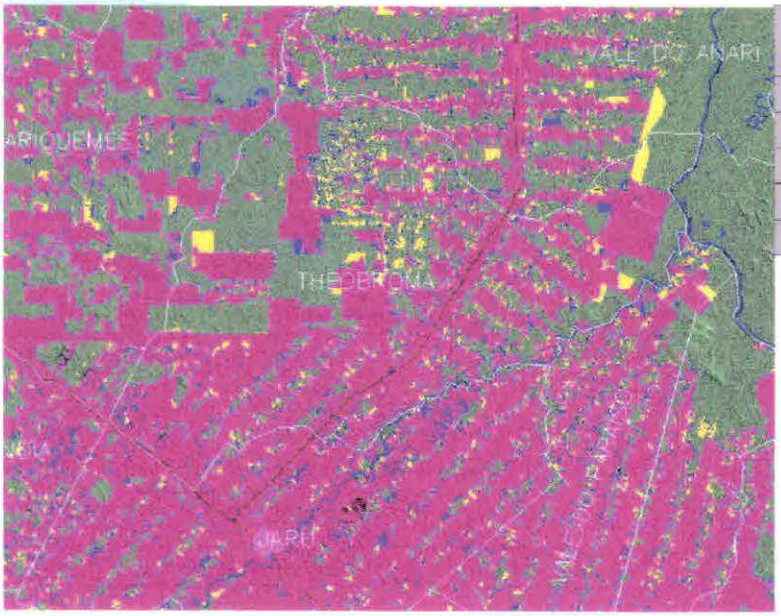
Os itens de 1 a 6 referem-se ao projeto PRODES



#EXAMPLE OF FINAL REPRESENTATION PROPOSED FOR THE BADDAM PROJECT

Mapping of the extension of gross deforestation of Brazilian Amazon region occurred up to 1997 and increments of deforestation relative to 1997 and 1998 and 1998 and 1999 periods, using image segmentation of shade images, derived from spectral linear mixing model and non supervised classification per region, implemented in SPRING software. The BADDAM project was conceived to be a large database including the information generated by digital PRODES. The mapping procedure idealized for BADDAM project contemplates new information plans, such as, hidrography, cities, highways, municipality limits, and state limits.

DETAIL OF THE FINAL REPRESENTATION PROPOSED FOR THE BADDAM PROJECT



LEGENDA

Tema		Área (km²) PRODES DIGITAL	
	FLORESTA-97	16.547	
	DESMATE (ATÉ 97)	10.252	
	DESMATE.-98	695	(5,20%)
	DESMATE.-99	388	(2,34%)
TOTAL		26.779	

CLASSES TEMÁTICAS DO PROJETO BADDAM

1) FLORESTA
2) DESFLORESTAMENTO-97
3) INCREMENTO DESFLORESTAMENTO-98
4) NÃO-FLORESTA
5) NUVEM-97
6) NUVEM-98
7) HIDROGRAFIA
8) CIDADES
9) ESTRADAS
10) MUNICÍPIOS
11) LIMITES

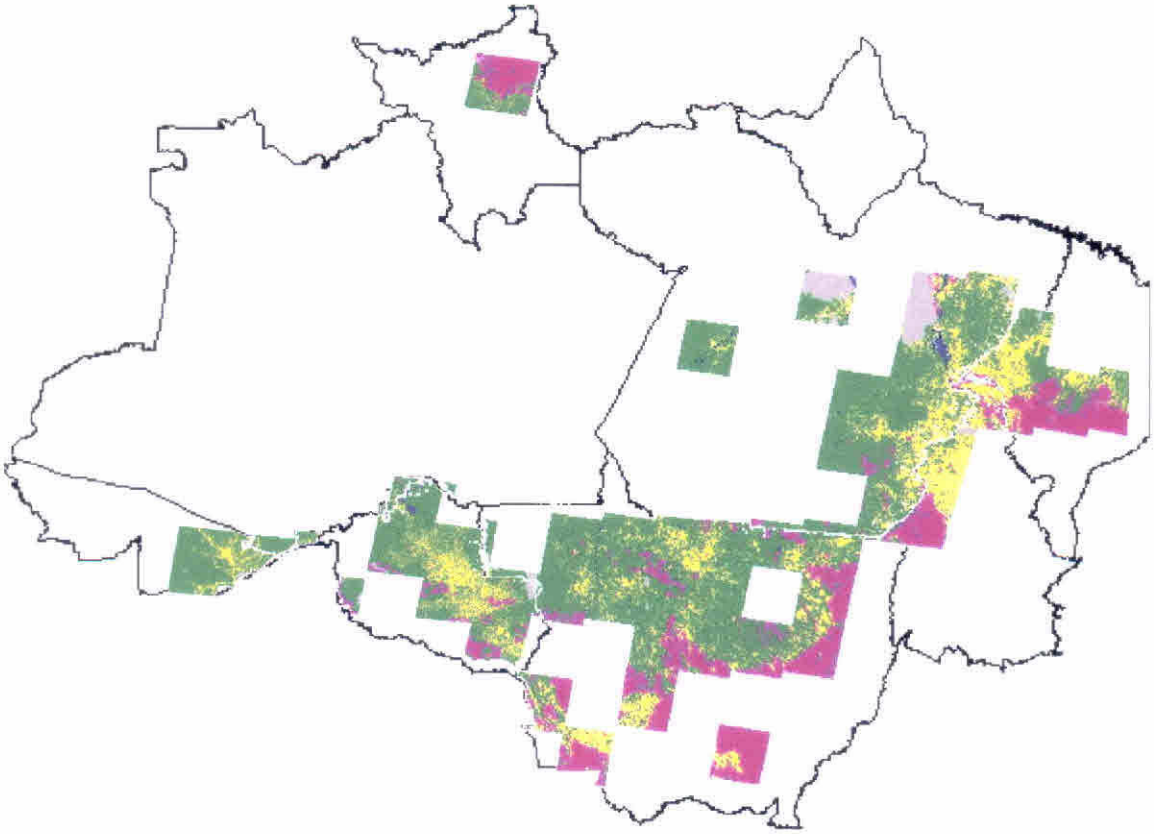
Os itens de 1 a 6 referem-se ao projeto PRODES

FINAL CONSIDERATIONS

THE METHODOLOGY UTILIZED MADE POSSIBLE TO ACCOMPLISH THE DIGITAL PRODES AND ALLOWED TO CREATE THE DIGITAL DATABASE OF BRAZILIAN AMAZÔNIA (BADDAM)

The experience gained in this new approach of digital PRODES, demonstrates the progress in the process of monitoring deforested areas of Amazon region. The methodology of digital analysis, based on the segmentation by region growing and classification of shade fraction image, appear as an adequate procedure for mapping the extension of deforested areas using Landsat TM images. Besides, this similar approach applied to the vegetation and soil fraction images, allows to characterize regrowth and increment of deforestation areas. Consequently, this methodological procedure makes possible the digital PRODES, consolidating a reliable georreferenced database which is easy to handle by the user. It also allows to implement the digital database of Brazilian Amazon (BADDAM), that is a growing information source for technical and scientific community and/or decision makers, involved in the elaboration of politics, analyses, planning and fiscalization of the Brazilian Amazon resources, with the objectives to preserve and/or sustained land use management.

ÁREAS CRÍTICAS DE OCORRÊNCIA DE DESFLORESTAMENTO



CORRESPONDEM À 47 IMAGENS LANDSAT

Mosaic of 47 Landsat TM scenes, covering part of some states of Legal Amazon. This area is inside of the so called " arch of the deforestation", because it has been presenting high deforestation index along the years. This mosaic represents the critical areas of deforestation occurrence, representing about 75% of the total annual gross deforestation. For this critical area, it is already finished the tasks of mapping the extension of gross deforestation, considering 1997 as a base year. It was used image segmentation of shade images, derived from spectral linear mixing model and non supervised classification per region, implemented in the SPRING software, developed by INPE and available in the network.

OBSERVED PROBLEMS

1) SYSTEMATIC DISPLACEMENT OF THE VECTORS IN RELATION TO THE RGB IMAGE

2) QUALITY OF THE VECTOR LINES WHEN PLOTTED IN A HARDCOPY FORM

3) PROBLEM WITH FILLING THE THEMATIC CLASSES

4) PROBLEM WITH DEFINING THE PROJECT CREATED

5) SECONDARY FOREST - HOW TO DEAL WITH IT ?

6) PROBLEM WITH ELIMINATING VECTOR LINES

7) PROBLEM WITH MAPPING HYDROGRAPHY USING SOIL FRACTION IMAGE

8) DESFORESTATION IN THE BORDER - MEAN ERROR OF IMAGE REGISTRATION (1 PIXEL)