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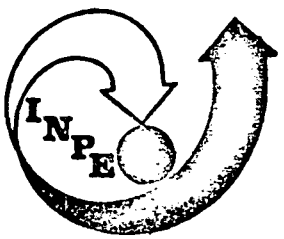
III



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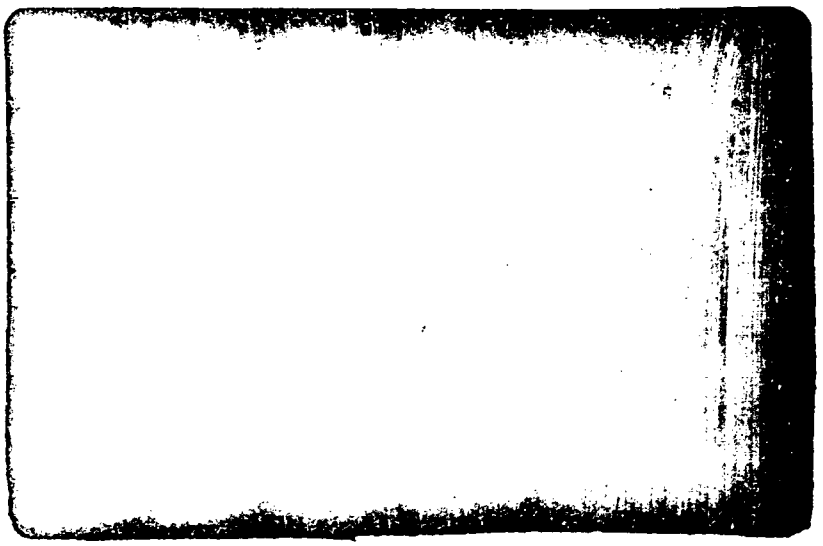

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SEPLAN-CNPq
Instituto de Pesquisas Espaciais - INPE
São José dos Campos - S.Paulo - Brasil

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REMOTE SENSING PROJECT (SERE)

TYPE III FINAL REPORT

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January 1975
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CHAPTER IV

SOIL RESOURCES

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GSFC ID-F0398 MMC 326-01

CHAPTER IV

SOIL RESOURCES

IV.1 - INTRODUCTION

The Soil Resources Group has used the MSS/ERTS-1 images since October 1972. It has tried to conduct researches in accordance to the Brazilian proposal to NASA for utilizing ERTS data but also keeping in mind the economical importance to define the priority of such studies.

First of all, the ERTS images have been analyzed for general purpose of surveying agricultural features. After that, the ERTS images were used in more specific researches such as natural vegetation mapping, forest inventory, deforestation control.

Other researches using ERTS and SKYLAB images are being carried out including soil maps, studies of crop forecast data and rangeland management.

The following pages present in more details the work the Soil Resources Group is dealing with.

IV.2 - PRELIMINARY ANALYSIS OF ERTS-1 IMAGES WITH SPECIAL REFERENCE TO AGRICULTURE AND FORESTRY

IV.2.1 - Introduction

The purposes of this work are to define the ERTS-1 images potentiality for agricultural surveys and to provide basic information for further research. Owing to the short period of study and the absence of ground truth data, the results reported here are therefore of a preliminary nature. We call attention that some vegetation types are described in item IV.3.2.2.1.

IV.2.2 - Methodology

The preliminary analysis presented here was basically done using black and white photographic copies, on the scale 1:1,000,000 of the four ERTS-1 channels. However, some particular cases appear where magnified images were used as well as other remote sensing information sources, in addition to the ERTS-1 images.

Figure IV.1 shows the Brazil map where the ERTS images were numbered to put in evidence the frames under study.

IV.2.3 - Image E-1047-12274 - Paraíba River Valley Region

IV.2.3.1 - Introduction

In this analysis use was made of the above mentioned image

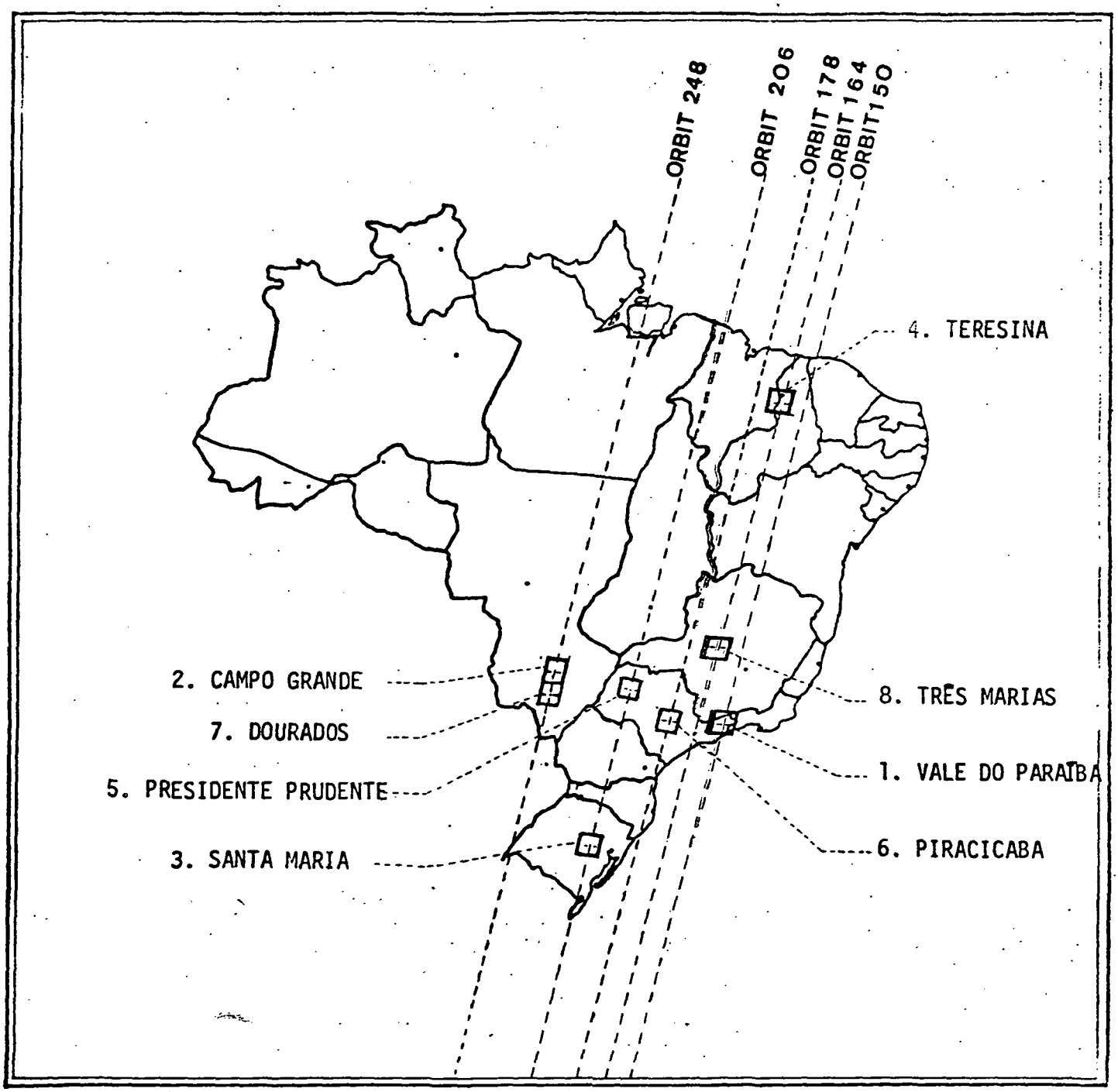


Fig. IV.1 - Brazil map showing the analyzed frames.

with image center coordinates 23°06'S and 45°17'W, dated September 8,1972. This image embraces the Paraíba River Valley, "Serra do Mar" and part of the Paulista coastland. This region varies greatly in topography, climate and vegetation. Cattle breeding is a major activity in the area.

IV.2.3.2 - Available Information

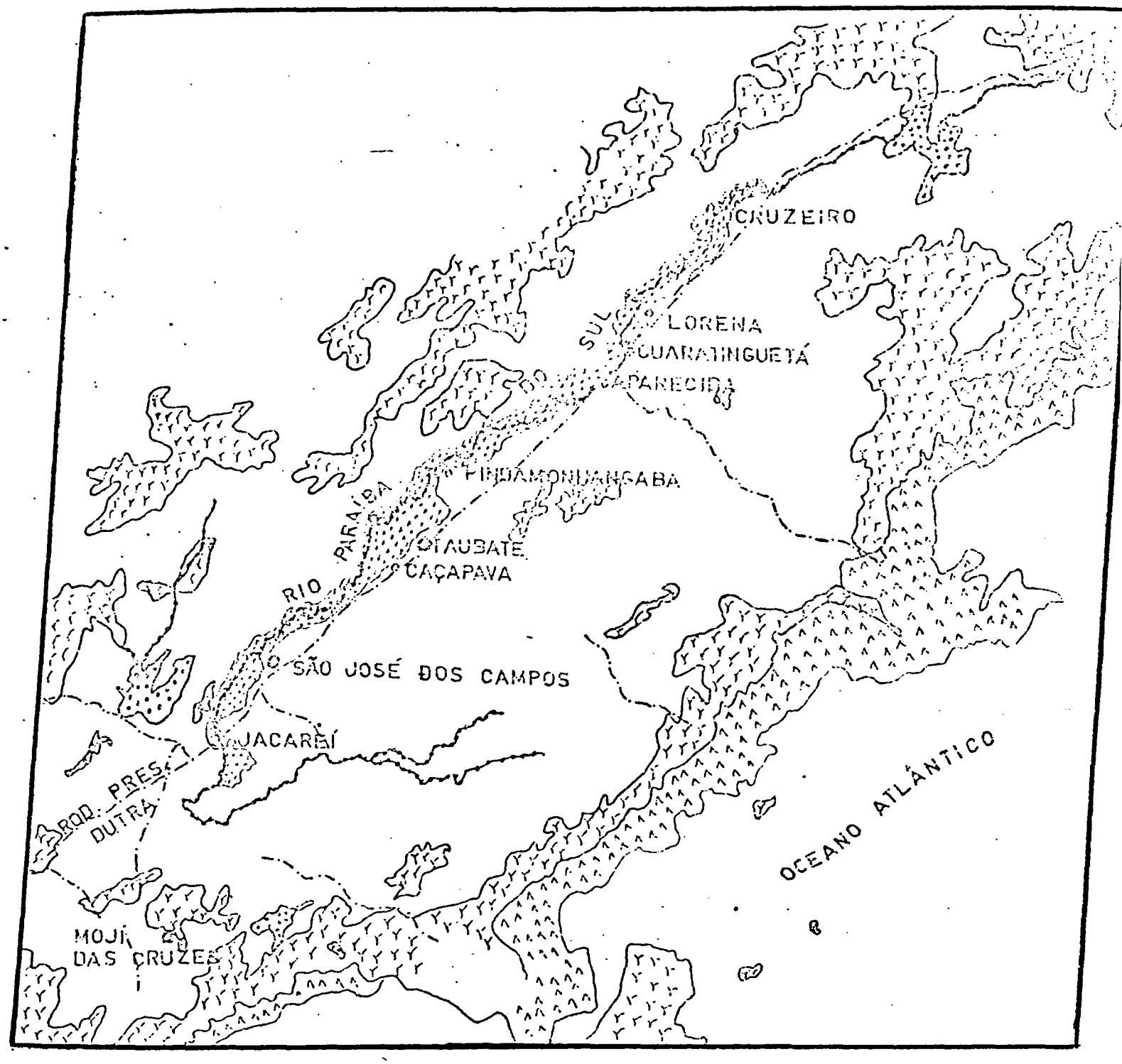
1 - Based on the analysis a thematic map was done (Fig. IV.2) which could be compared with the channel 5 image (Fig. IV.3). The boundary establishment of the mapped units was done over the channel 5, to present a better contrast, although the identification was done also using the other channels :

2 - the landforms aspects are better evidenced through channels 6 and 7.

3 - Vegetation information are more easily obtained using the channel 5 image where the variations from dark to light gray tones indicate a graduation from dense vegetation (forests) to sparse vegetation, corresponding to areas with herbaceous species and grassland.

IV.2.3.3 - Conclusions

1 - The information acquired from the orbital ERTS-1 images are of great importance to plain agriculture activities because it permits a previous knowledge of the area, when speaking in a global way.



DENSE VEGETATION (FOREST)

DAMS

HIGHWAY AND ROADS

RIVERS

FOREST ON THE "SERRA DO MAR" (MAR RANGE) SCARPS

PARAÍBA RIVER VALLEY

Fig. IV.2 - Thematic map of the Paraíba River Valley.

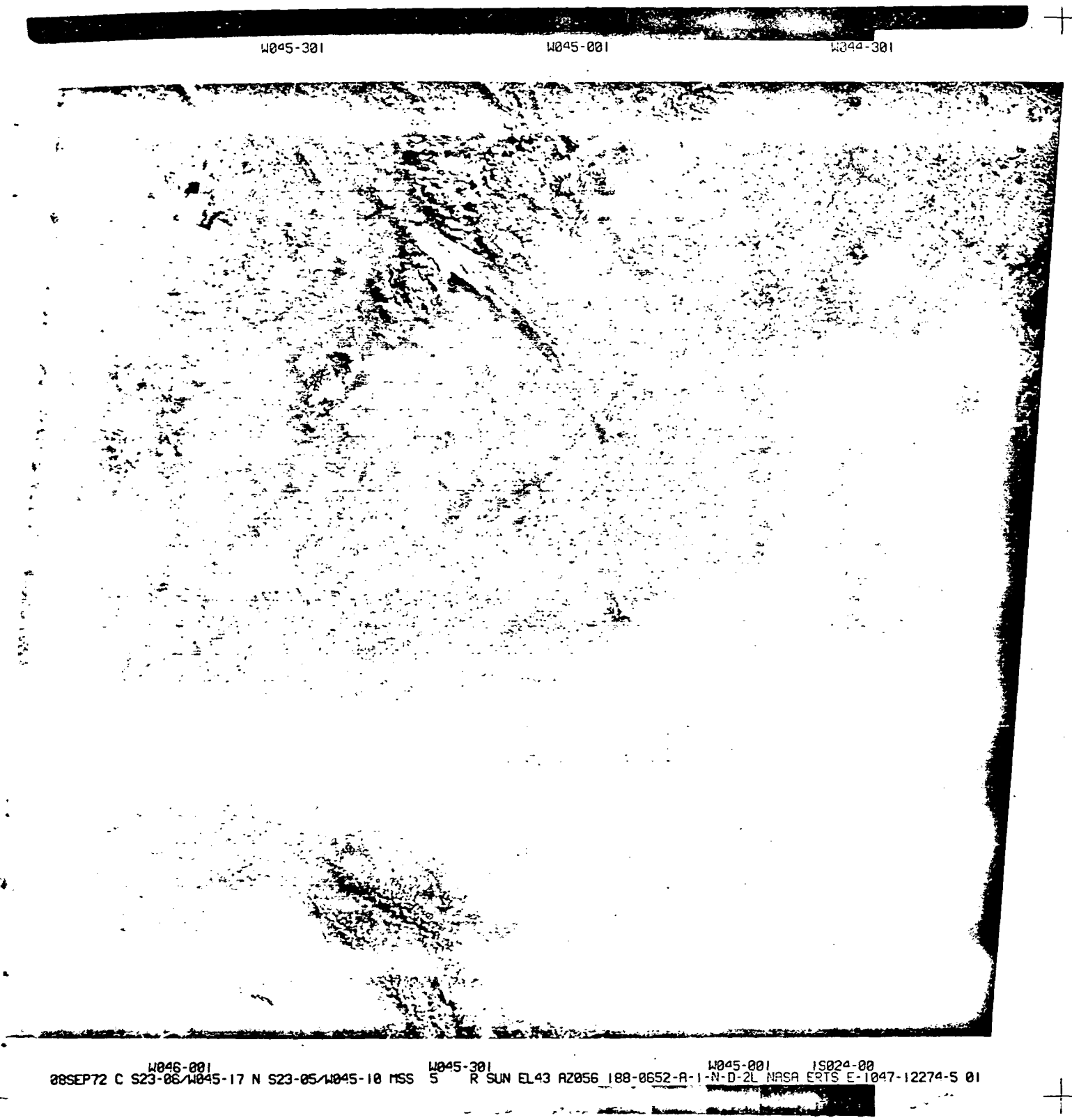


Fig. IV.3 - ERTS image E-1047-12.274 - Channel 5 - Paraíba River Valley Region.

2 - Based on a summary analysis of another image set for this same area, taken at different ERTS-1 coverage periods, it is possible to accompany the evolution of agricultural activities (crops evolution).
The ERTS-1 repetitivity permits a better forest monitoring due to the official government policy stimulating and controlling reforestation.

3 - It is important to point out that the thematic map presented here was obtained using only the MSS/ERTS-1 images, without additional costs for field works; besides it was done in a short time.

IV.2.4 - Image E-1054-13070 - Campo Grande Region

IV.2.4.1 - Introduction

The area selected is located in the center-west part of Mato Grosso State, with image center coordinates $20^{o}19'S$ and $54^{o}34'W$, taken in September 15, 1972. It shows the Campo Grande City in the image center.

IV.2.4.2 - Available Information

1 - The cities of Campo Grande, Bom Fim and Sidrolândia were easily located through channel 5 (Fig. IV.4). In this same channel the highway networks specially the

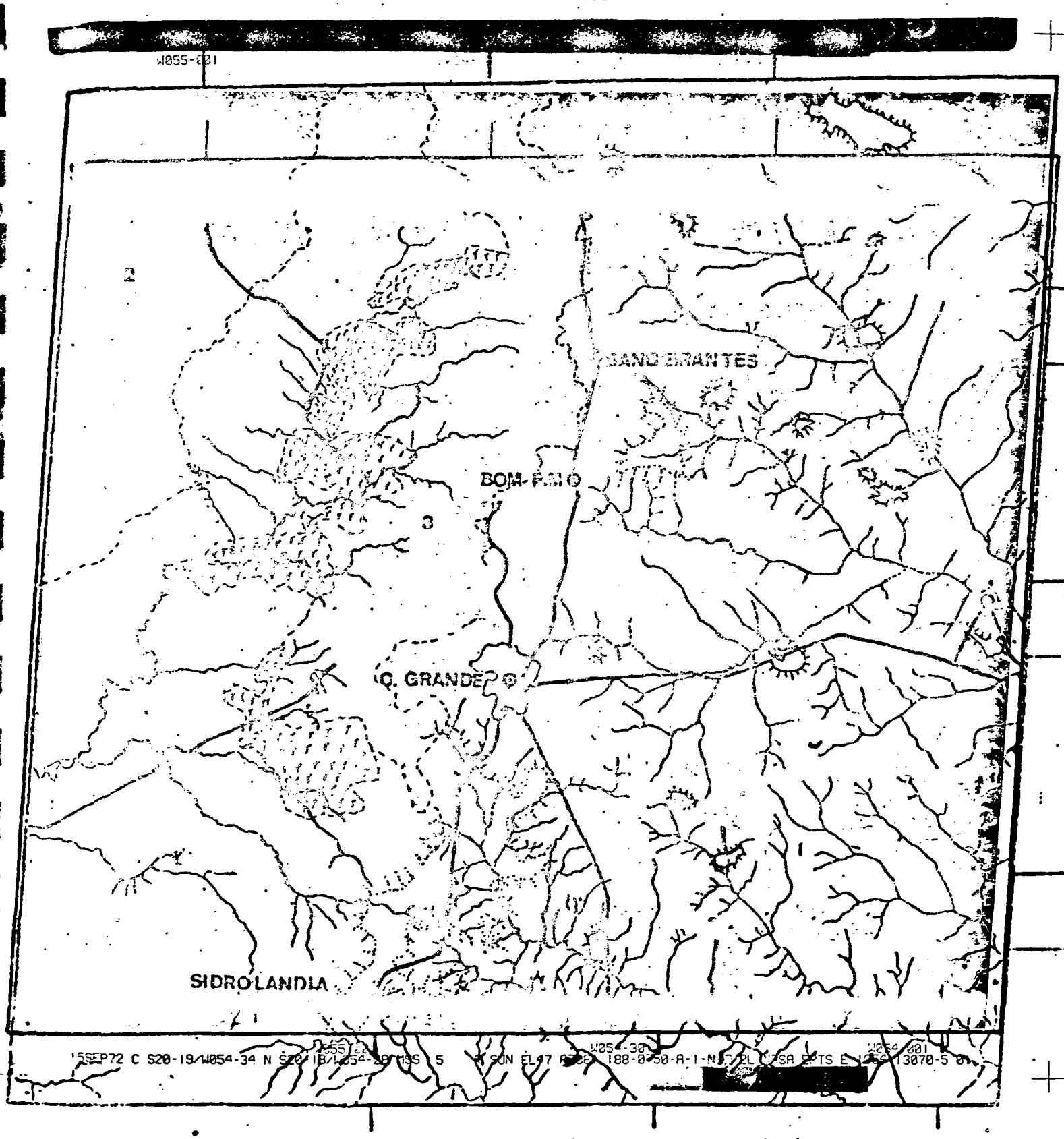


Fig. IV.4 - ERTS image E-1054-13.070 - Channel 5 - Campo Grande Region.

WET AREA
WET MIXED WITH DRY AREA
ROADS
CERRADÃO, FOREST
RIVERS
BASED ON CHANNELS 5 AND 7
1,2,3 UNITS

Cuiabã - Campo Grande and Campo Grande - São Paulo highways can be identified.

2 - Channel 5 shows two drainage systems oriented in different directions, one Southwesterly directed and the other to the West.

3 - Several vegetal units and land use are shown in the transparency over the figure IV.4 as:

unit 1: Area occupied with natural vegetation, typical of Central Brazil, named "cerrado". It appears in light gray tones to the East and Southeast of the area indicating soils which are more eroded. The left side of the image appears in darker gray tones, evidencing denser vegetation, with well integrated drainage pattern, with an erosion degree from light to moderate.

unit 2: Area with "cerrado" vegetation including pasture, situated at a higher level and which at a first sight appears as areas without agricultural uses.

unit 3: It presents mottled gray tones indicating strong agricultural activities related to crops and pasture. This is more evidenced in the vicinities of Campo Grande city expanding toward Cuiabã city.

4 - Channels 6 and 7 show areas in dark gray tones and with well defined geometric forms indicating irrigated rice crops.

IV.2.4.3 - Conclusions

1 - The areas with agricultural activities appear surrounding the urban centers.

2 - Some areas are suffering a strong erosion action needing some soil conservation measures.

3 - There exist two drainage systems. One in direction to the Paraguai River and the other, at the opposite side, in direction to the Paranã River.

4 - The area does not present a good transportation routes' system. Just some railways and few paved roads.

5 - This region possesses great variety of soil types indicated through the natural vegetation and land use differences. In the areas to the West the soils trend to be better.

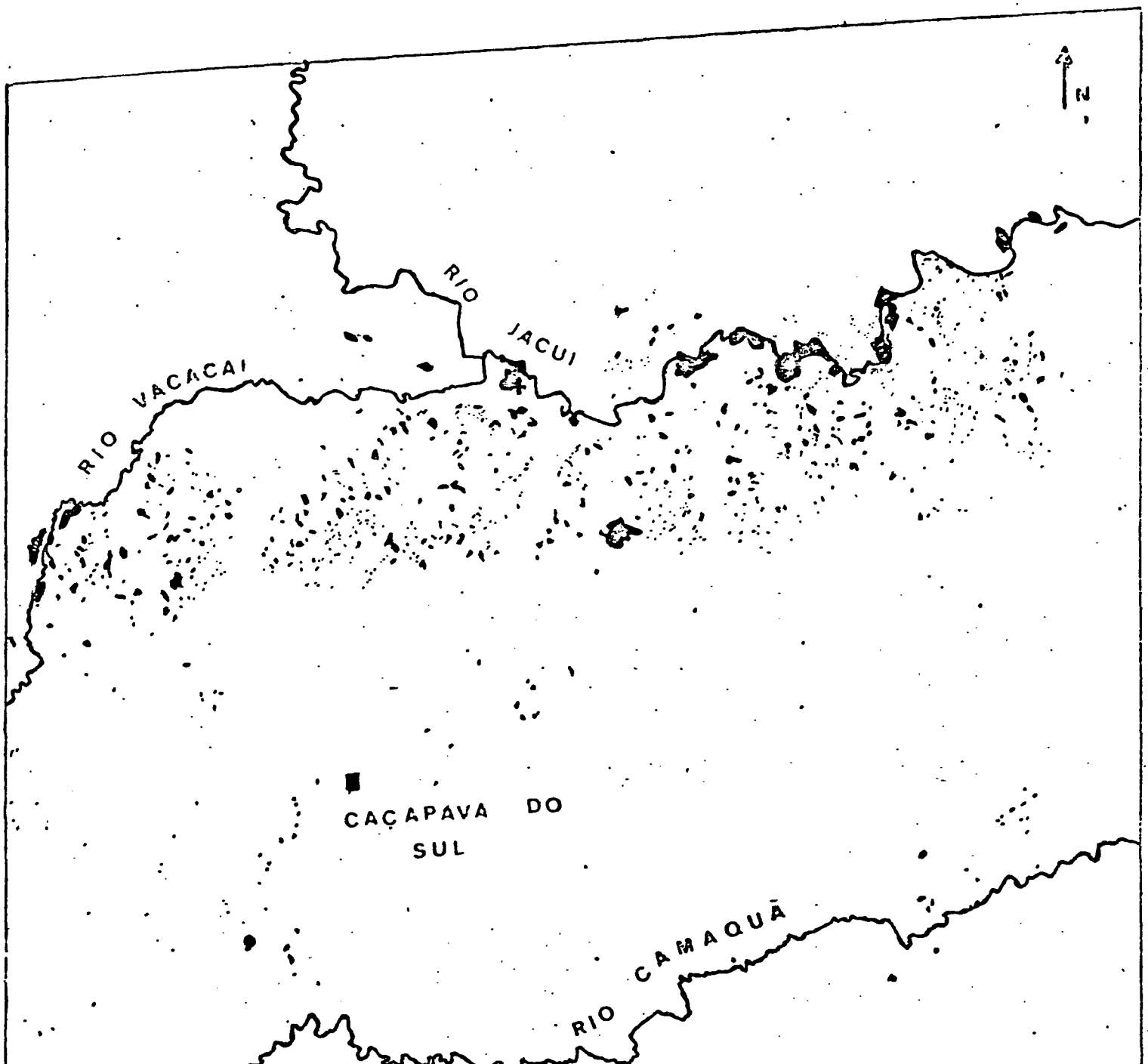
6 - There are great quantity of rivers in the area which permits one to say that a well-planned agricultural activity would not suffer from water shortage.

7 - The relief of this area is flat, presenting itself at the Northern and Northeastern regions a little more irregular.

IV.2.5 - Image E-1105-12532 - Santa Maria Region

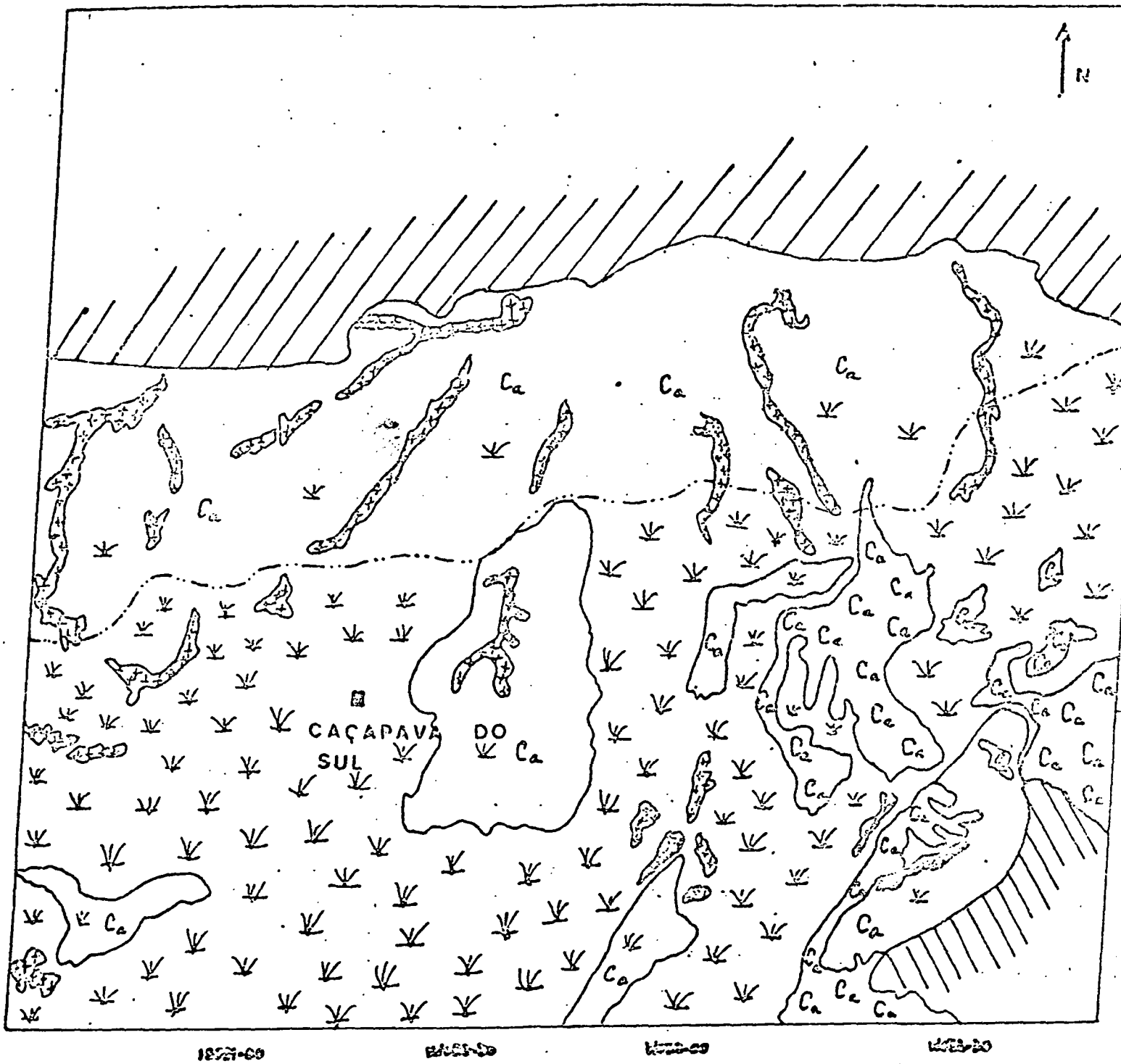
IV.2.5.1 - Introduction

The above referred image (center coordinates $30^{o}17S$-$53^{o}03W$),



Lakes, Sluices and flood areas.

Fig. IV.5 - Map done over the channel 7 image (scale 1:1,000,000).



- Forests
- Pastures
- Annual crops
- Sedimentary Basin with pasture and annual crops
- Cloud coverage

Fig.IV.6 - Land use thematic map - Santa Maria Region original scale 1:1,000,000.

obtained at 5 November 1973, was analyzed considering the soil plowing and planting period and the begining of some annual crops growing. The image shows the cities of Santa Maria, Cachoeira do Sul, Caçapava do Sul, etc.

IV.2.5.2 - Available Information

Information were obtained using, besides the four channels on the scale 1:1,000,000, an enlargement of channel 5 on the scale 1:500,000 and one color composite of channels 4,5 and 7.

1 - Utilizing the channels 6 and 7 it was possible to map lakes and sluice distribution along the right margin of the Jacuí River (Fig. IV.5).

2 - A thematic map (Fig. IV.6) was obtained through a combined analysis of the four MSS channels on the scale 1:1,000,000.

IV.2.5.3 - Conclusions

1 - It is possible to count the number of lakes and sluices as well as their superficial area using a channel 7 photographic enlargement.

2 - The great concentration of water bodies along the Jacuí River determines the great occurrence of rice crops.

3 - It was easy to separate the following categories: annual crops, pasture and forests.

4 - The outline of woodland, remaining in the area,could be delimited.

5 - The analysis of image sets, taken at different dates, through the different growing crop cycles, with regional specialists support and also with aircraft sampling, at intermediate scales over test sites areas previously selected on the ERTS images, would permit more detailed results about the present and potential land use in this region.

IV.2.6 - Image E-1048-12282 - Teresina City Region

IV.2.6.1 - Introduction

The image under analysis has the central coordinates: 05°49'S and 42°28'W, taken at September 9,1972. It includes the city of Teresina and parts of the Parnaíba and Poti Rivers. To the West of the Parnaíba River appears the Maranhão State and to the East part of this river the Piauí State.

The vegetation in this area is predominantly natural varying from small and sparse "cerrado" vegetation, used as pasture, to "cerradão" (vegetation of forestal size) with some agricultural activities. It also presents in its lowlands and river beds the "babaçu" vegetation,

one of the main sources of vegetal oil extration of that region.

IV.2.6.2 - Available Information

Information were obtained not only using ERTS images (1:250,000) but also from infrared photographies enlargements to the scale 1:130,000, SLAR (RADAR) mosaic on the scale 1:250,000 and previous field observations from part of this region.

The analysis of these images could be summarized through a thematic map as shown in figure IV.7 which was drawn over the channel 5 of the ERTS image (Fig. IV.8).

Several types of features were plotted on the ERTS image and in the case of some of them the RADAR image correlated quite well, while other features were not perceptible in the radar such as those microcosms with boundaries in tracing.

Basically the following were the types of vegetation and soil use established through the images:

Area 1 - Area 1 is characterized by a rather dense savanna vegetation, of the "cerradão" type, with a large number of cultivated areas. It presents good agricultural activity in spite of its rather accentuated relief. A patch, in the shape of horseshoe near the parallel of $6^{o}S$, crossed by the high-voltage power line

of the "Boa Esperança" Hydroelectric Company (COHEBE), has been identified. Both in the RADAR and in the infrared images cultivated areas are found near this horseshoe. In the ERTS image this area is unfavourably located, too near the left edge, and this resulted in blurred details.

Area 2 - This area is characterized by "cerradão" vegetation and small agricultural activity, which is due to relief (shown by vertical arrows) as a limiting factor. In this microcosm we find yet another area well characterized in the ERTS and in the RADAR images (area 2.1). Patches F and G, which are not well delimited in the RADAR image, but are well characterized in the ERTS images, belong to the type 4 vegetation. The vertical arrows indicate the most hilly part of the area.

Area 3 - Areas characterized by number 3 classified as "cerrado" vegetation, that is, a less dense savanna type identified by a fine texture in RADAR and a medium gray tone in the ERTS images. The index of each area indicates the variation of their respective reliefs as well as the parts where agricultural activity can be inferred.

Area 3.1 - This area shows parts covered by "cerrado" with flat relief as well as great agricultural activity in other parts. It comprises the environs of FEITORIA, ÁGUA BRANCA and SÃO PEDRO DO PIAUÍ. Cultivated areas can be perceived both in the RADAR as in the infrared images. The texture of this area in the RADAR is well

characterized (fine texture) and the relief is smooth.

Area 3.2 - The 3.2 areas differ from the foregoing only by the higher relief.

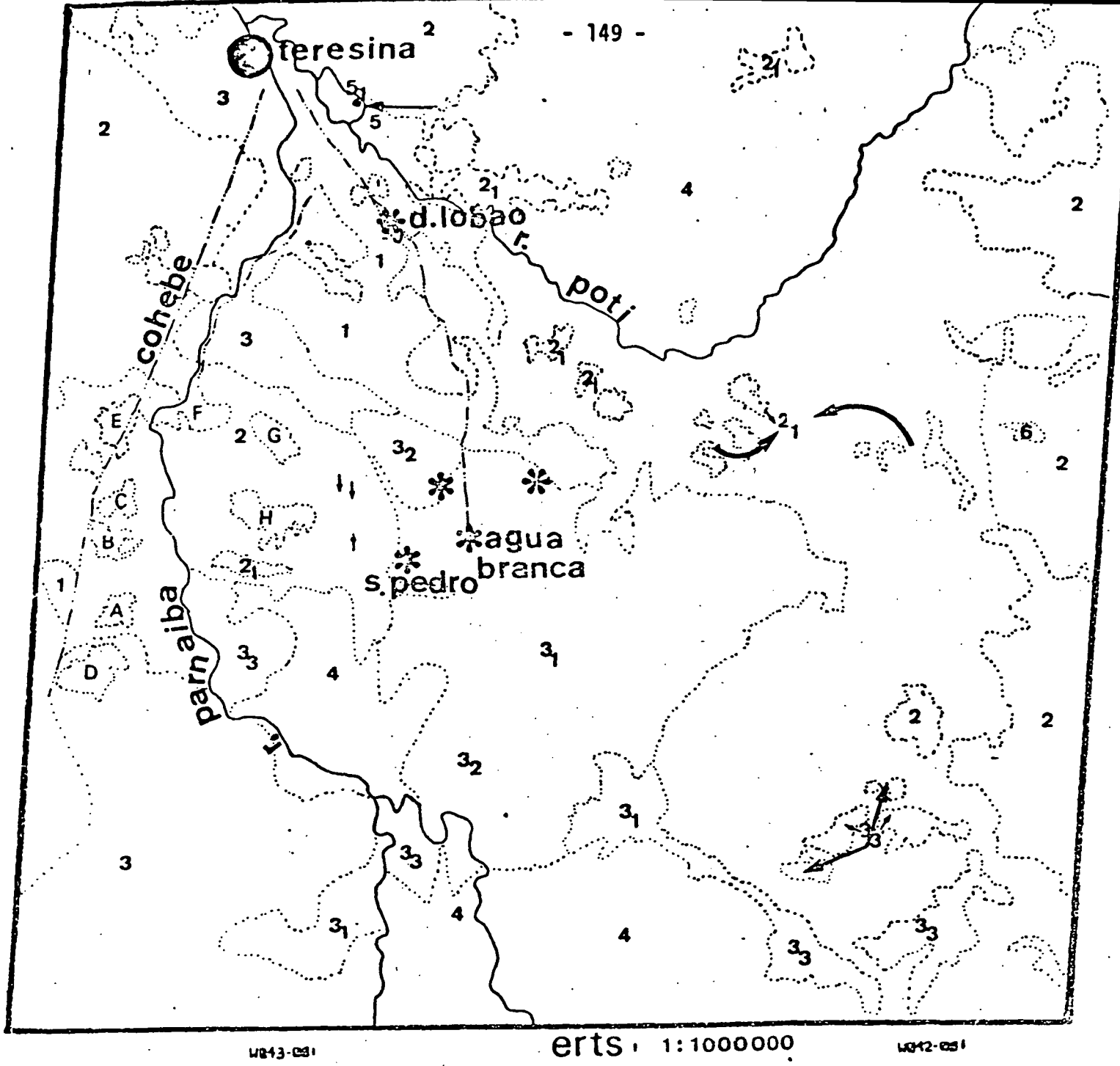
Area 3.3 - Areas in 3.3 show the same characteristics as the previous two, differeing only in the degree of certainty as to the existing agricultural areas. The area as a whole is of agricultural potential.

Area 4 - Microcosm number 4 comprises a large part of the wuadrilateral under study and is characterized by vegetation so sparse that the reflectance of the soil has influence on the light gray tone, characteristic of vegetation in the ERTS image under study. In the RADAR image individual areas are not well characterized in terms of relief and texture but some boundaries have been plotted which allow comparisons.

The whole number 4 area can be considered, in a general way, as sparse savanna unfit for agriculture.

Area 5 - The area delineated as nº 5 is similar to area nº 1, but shows well the agricultural areas near the poti River. Sub-area 5.1 is well evidenced, in the ERTS image, as a darker gray spot. Predominanting vegetation in the proximity is of "cerradão" type of almost like it. Area indicated by arrow, near this region, probably belongs to group 4 and is perfectly characterized in all the images.

The spots marked with letters A to H have sparse vegetation, with varied relief and no agricultural activity.



LEGEND

1) "CERRADÃO" WITH CULTIVATED AREAS
2) "CERRADÃO WITHOUT CULTIVATED AREAS
3) "CERRADO" 1 - FLAT LAND AND CULTIVATED AREAS
   2 - UNDULATING TO ROLLING LANDS AREAS
   3 - WITH POSSIBILITIES OF AGRICULTURAL ACTIVITIES
4) "SPARSE CERRADO" WITHOUT AGRICULTURAL ACTIVITY CONDITIONS
5) "CERRADÃO" WITH SEVERAL CULTIVATED AREAS
6) HUMID AREAS

A THROUGH H - SPARSE VEGETATION, DESCRIBED IN AREA 5.

Fig. IV.7 - Interpretation of ERTS images with the support of Radar Mosaic and Infrared False Color images.

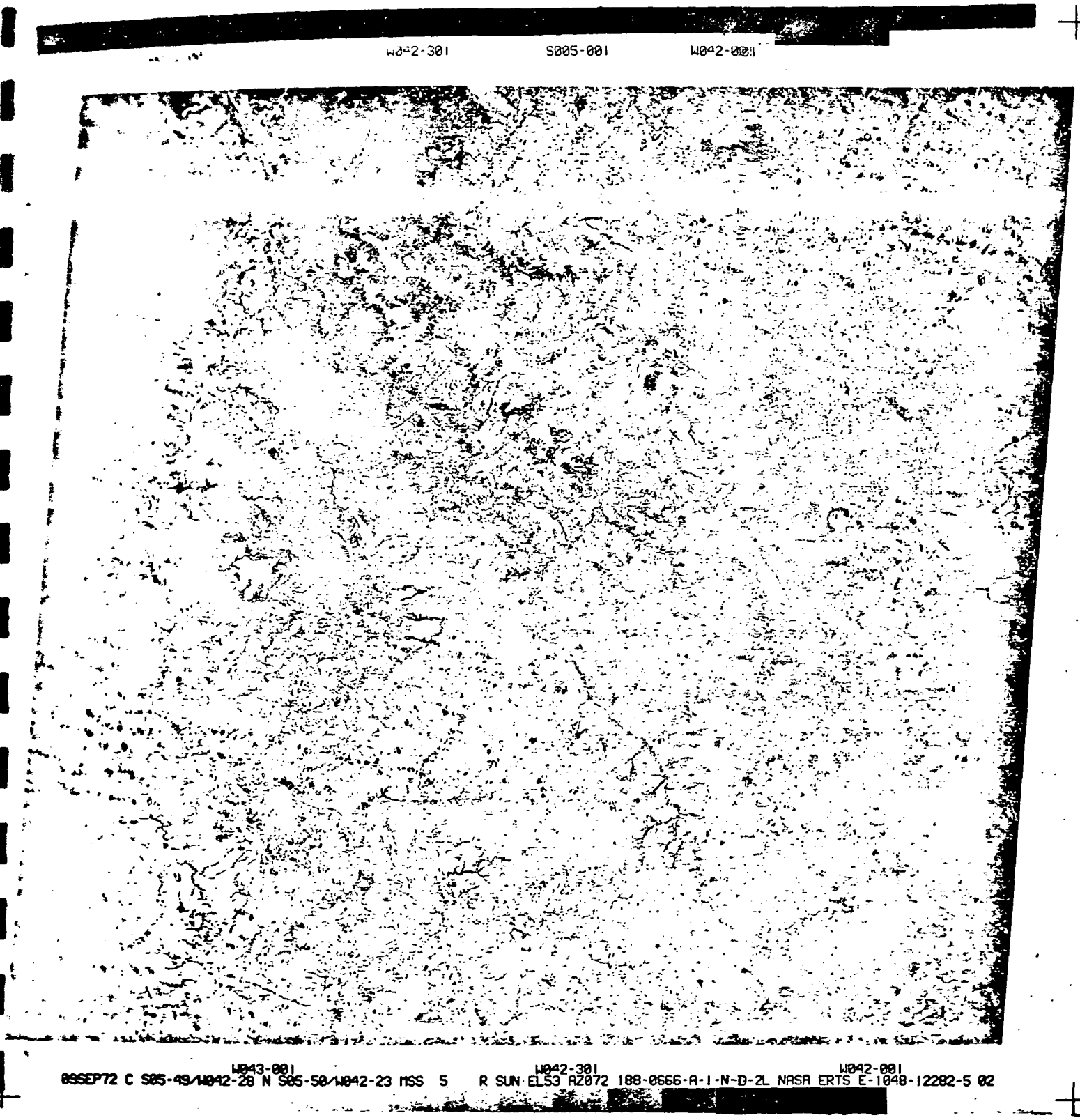


Fig. IV.8 - ERTS image E-1048-12.282 - Teresina Region. Channel 5.

They probably indicate soils of low fertility and appear all over the image quadrilateral.

Area 6 - These are humid areas which show up well in channel 7. They have fallen outside of the RADAR mosaic which does not fully correspond with the area covered by the ERTS image.

IV.2.6.3 - Conclusions

1 - Altough a thematic map is presented here only with the great mapped units, it is possible to obtain a more detailed level of study on a 1:250,000 scale map using a channel 5 photographic enlargement.

2 - The unit 1 area, in spite of being intensely cultivated, was not clearly evidenced in the MSS images due to the reduced size of the planted areas located closely together and from the same stage of growth, reducing in this way the contrast among them. In area 2, channels 4 and 5 show the existence of agricultural areas.

3 - Through this preliminar interpretation it was not possible to separate the "babaçu" vegetation from the "cerradão" neither at the false color infrared images, due to the inferior quality of the images.

4 - ERTS channel 5 images to the scales 1:1,000,000, 1:500,000 and 1:250,000 allow a good characterization of large vegetation types of the area under study. A good subsidy in relation to relief and texture was given by the RADAR 1:250,000 images. The joint use of the two

types of images makes for a much better interpretation than the use of either one of them in isolation.

5 - The additional information obtained from the 1:130,000 infrared images was of great importance in this stage, in which interpretation techniques is not yet fully developed. The infrared images gave details not perceptible in other two types of images studied, but unfortunately with bad quality in terms of cloud coverage and color enhancement.

6 - Water bodies are equally well characterized both in ERTS channel 7 as in RADAR images. Relief shows up better in the RADAR image but geometrical accuracy is better in the ERTS images.

IV.2.7 - Image E-1123-12510 - Presidente Prudente Region

IV.2.7.1 - Introduction

The analysis referred to the above mentioned image with center coordinates $21^{o}36'S$ and $50^{o}42'W$ taken at Nov. 23, 1972, corresponds to the region of Presidente Prudente, Marília and Andradina cities located at the São Paulo State.

IV.2.7.2 - Available Information

1 - In extense areas along the Tietê River it is possible to observe a defficient drainage evidenced by the dark

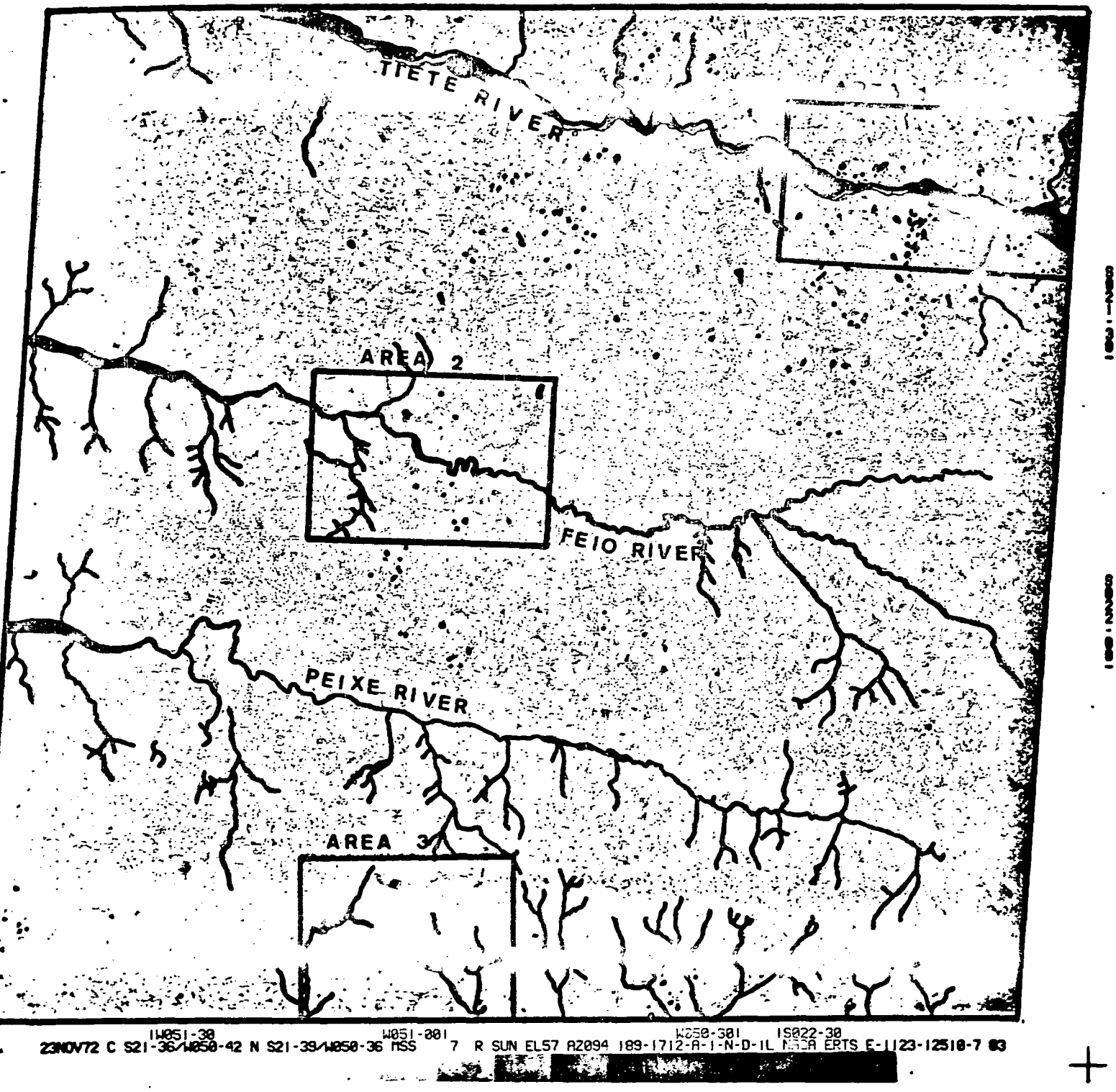


Fig. IV.9 - ERTS image E-1123-12.510 - Presidente Prudente Region channel 7.

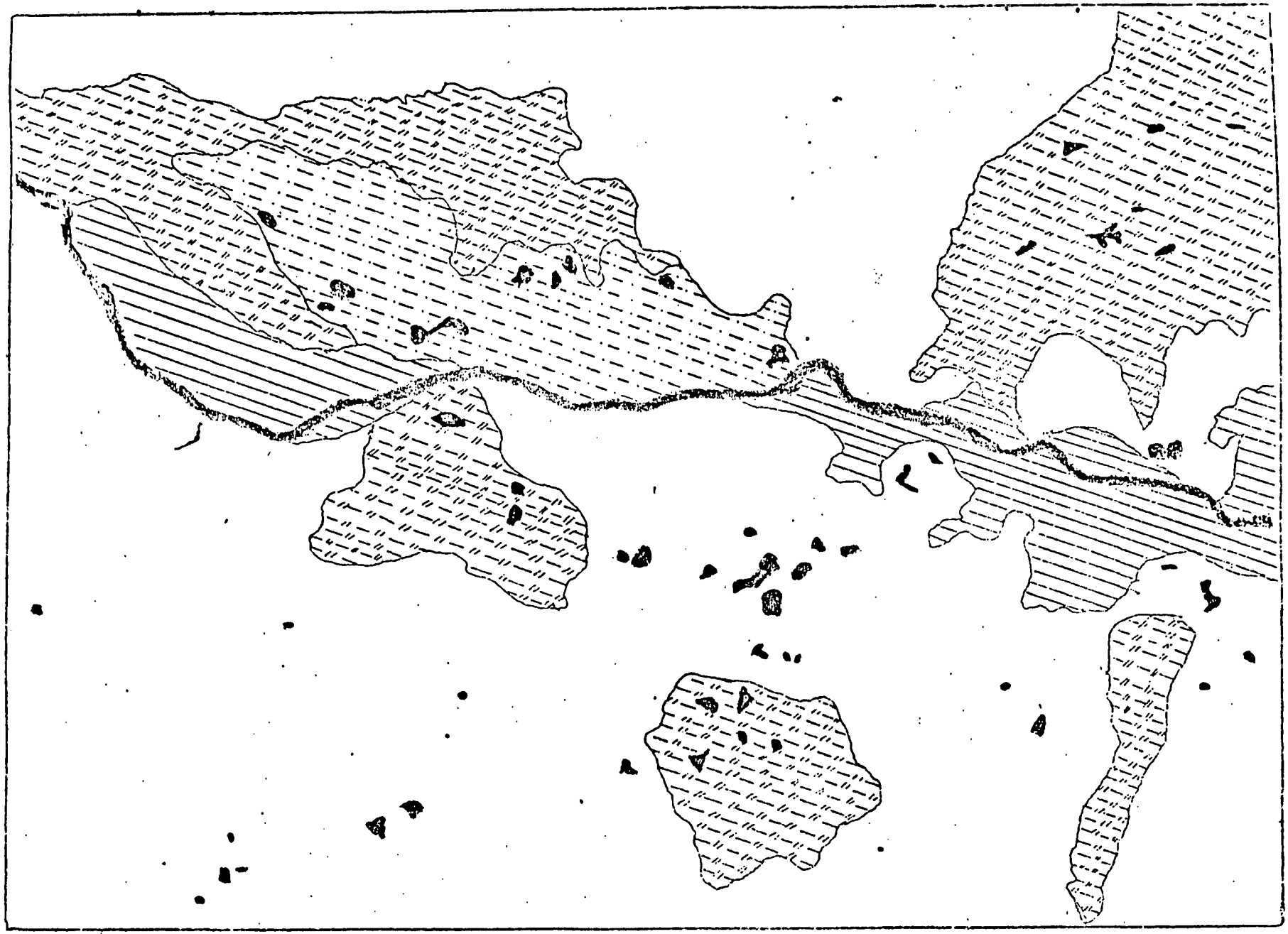


Fig. IV.10 - Map done over channel 7 image enlargement - Area 1 - Tietê River.

gray tone in channel 7. In this same area a great number of lagoons is also observed.

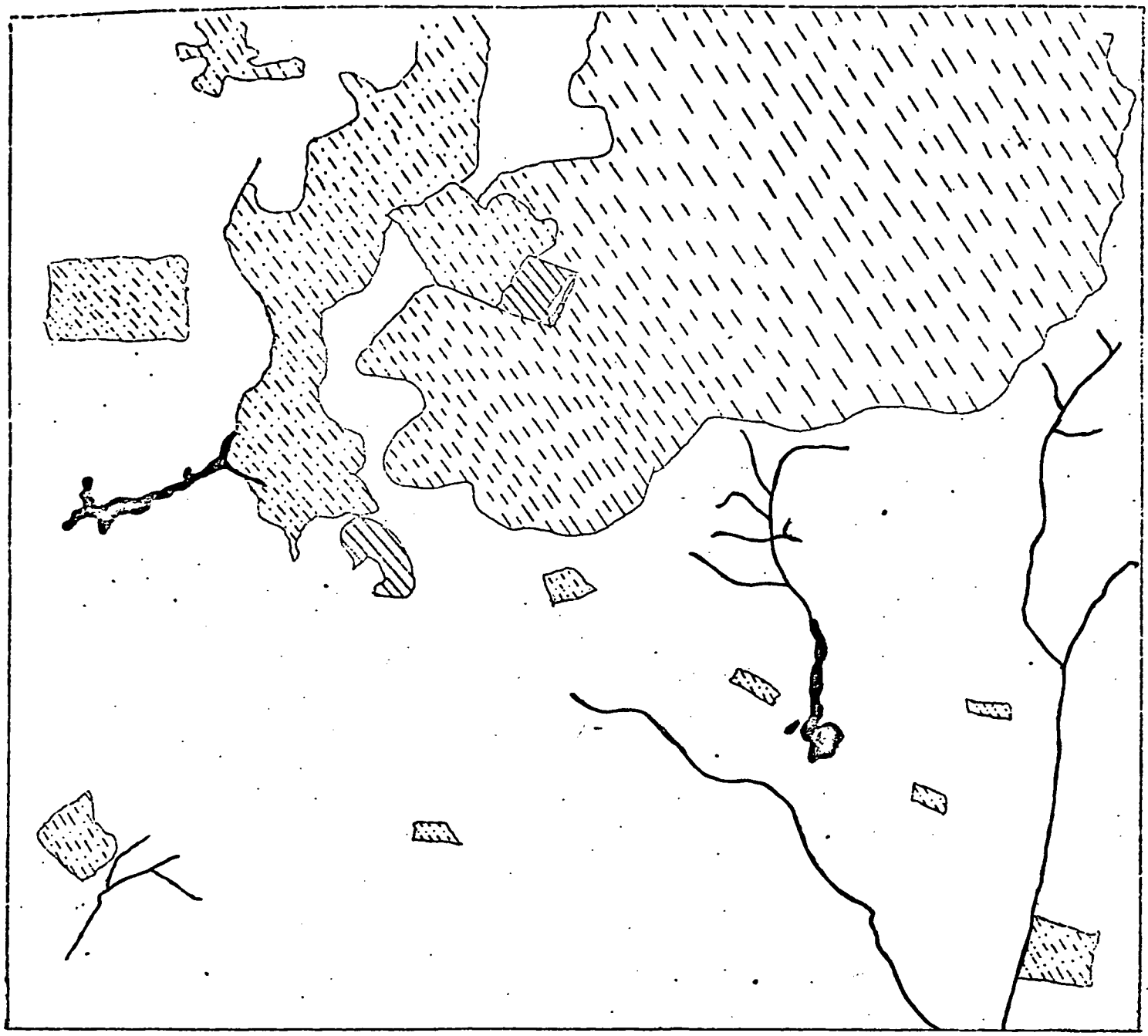
2 - Areas of bare soil, of a good drainage, evidenced by light tones in both 5 and 7 channels.

3 - The transparency done using channel 7 (figure IV.9) shows the main drainage system orienting itself parallelly toward the Paranã River, to the West of this image and not shown in the above mentioned figure, as well as innumerable small lakes, dams and areas influenced by flood along the Tietẽ River.

4 - Figure IV.10 shows a map done over the same photographic enlargement on the scale 1:130,000, of the marked area, at the upper right part of the channel 7 transparency (area 1). This area under the influence of the Tietẽ River shows lagoons, part of this river as well as areas close to its river bed with various degrees of humidity.

5 - Figure IV.11 shows the map done over the same channel 7 transparency, in its lower part (area 3), situated near the Presidente Prudente city. It is possible to note the presence of two dams and areas of bare soil, with *different moisture degrees, indicating differences in* the drainage capacity.

6 - Figure IV.12 shows the thematic map done over the channel 5 photographic enlargement on the scale 1:130,000, at the central part of the image, near the Feio River area (area 2). In this region the existance of forests areas and areas prepared for plating, etc. was verified.



DAMS WATERS

AREAS WITH LOW MOISTURE CONTENT

AREAS WITH HIGH MOISTURE CONTENT

AREAS WITH MIDDLE MOISTURE CONTENT

Fig. IV.11 - Map done over channel 7 image enlargement - Area 3 near Martinópolis São Paulo State.

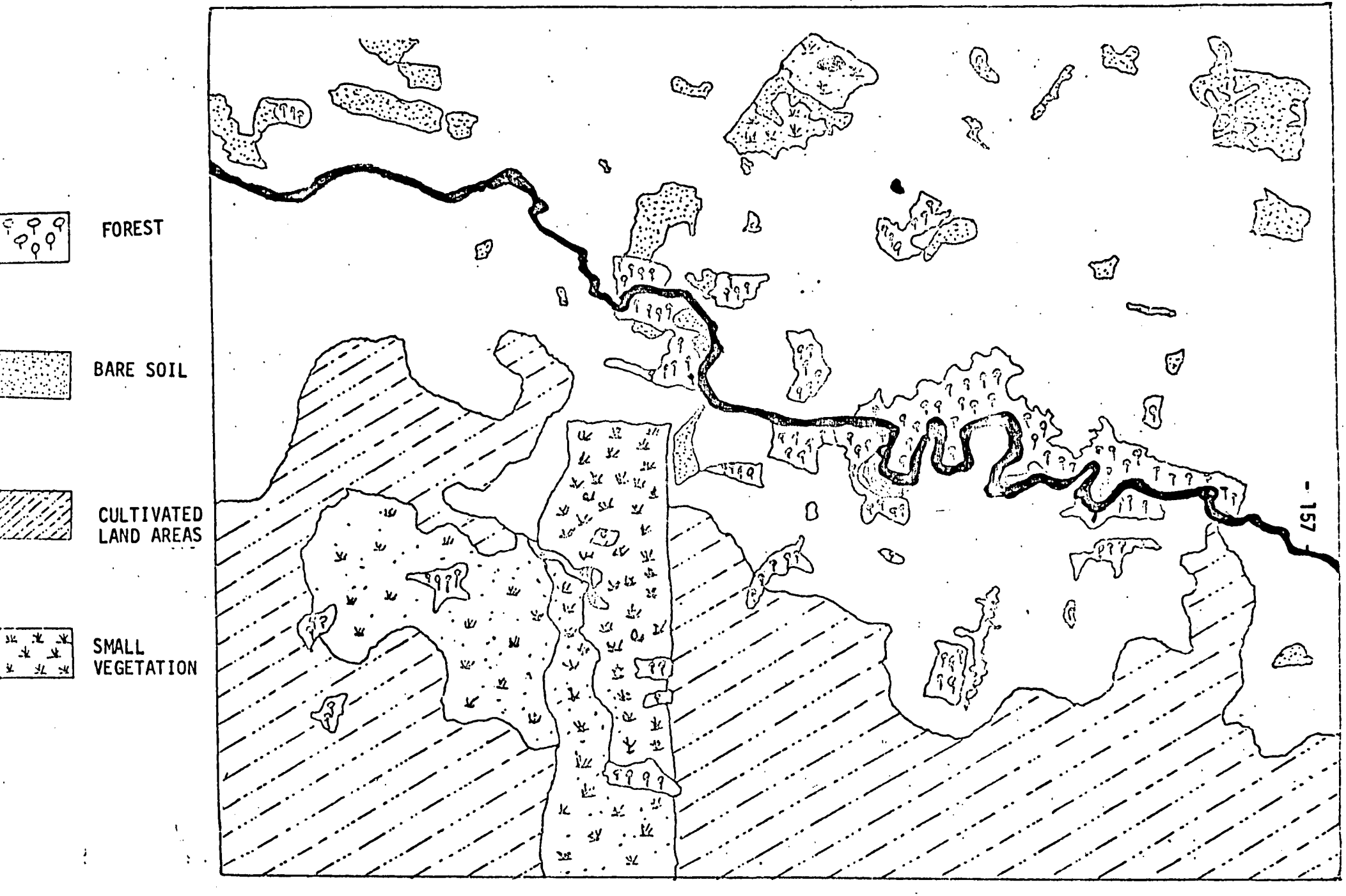


Fig. IV.12 - Map done over channel 5 image enlargement - Area 2 - Feio River Area.

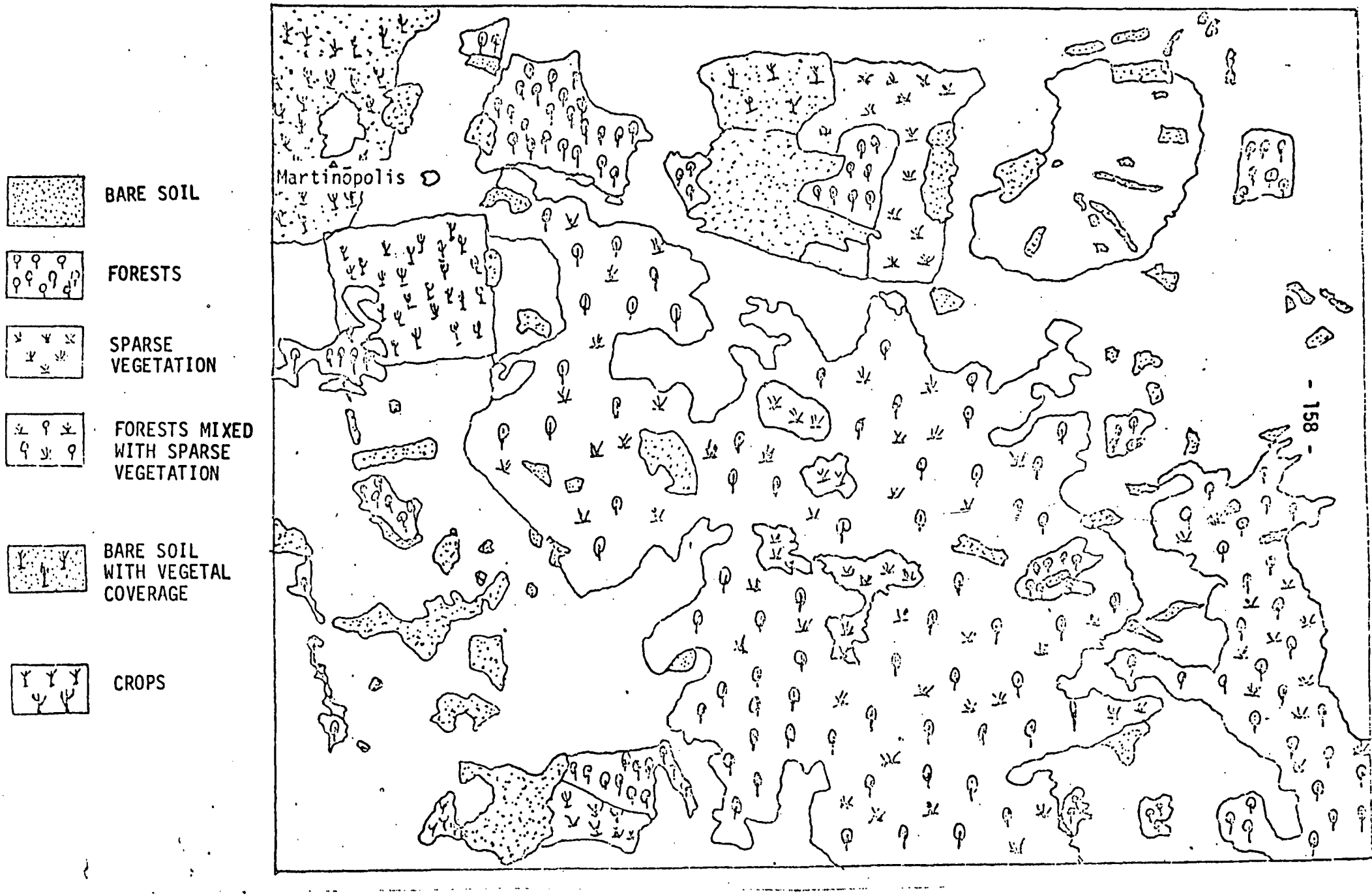


Fig. IV.13 - Map done over channel 5 image enlargement - Area 3 - Martinópolis Area - SP.

7 - Figure IV.13 shows a map done over the same photographic enlargement of channel 5 in the right part of Presidente Prudente region, at the lower part of the image (area 3).

IV.2.7.3 - Conclusions

1 - The area under study does not present great limitations to the agricultural exploitation practices. This fact was evidenced through land use, which in its great part shows some indication of agricultural activities. However, some areas along the Tietê River do not show cultivated lands which may be attributed to the defficient drainage.

2 - It is possible to separate soils according to their potential use by the different infiltration rate which they present.

3 - In this area dark spots could be detected and mapped principally in regions where the agricultural activities are poor as the ones along the Feio River. Otherwise at the Presidente Prudente area there exists strong agricultural practices areas and small areas with remainder forest.

IV.2.8 - Image E-1247-12042 - Piracicaba City Region

IV.2.8.1 - Introduction

This image under analysis is taken at March 27, 1973 with center coordinates $22^{o}56'S$ and $48^{o}11'W$ and includes the cities of Limeira, Rio Claro, Piracicaba, Botucatu, Avarē, Jaū, etc. at the São Paulo State. This image was chosen, although presenting two great cloud coverage spots, because of intense agricultural activities zones and reforesting areas.

IV.2.8.2 - Available Information

Information were obtained using besides the four channels on the 1:1,000,000 scale, the channels 5 and 7 photographic enlargements on the scale 1:500,000.

1 - Figure IV.14 synthetically contains the information related to vegetal coverage obtained through the MSS multispectral analysis.

2 - In spite of the cloud coverage occurrence disguising the dams area, their outlines are easily delineated in the channel 7 image.

3 - The channel 7 enlargement very much facilitates not only the dams tracing but also rivers outline. The drainage system is little evidenced what permits to infer that soils are of reasonable permeability and

porosity and the areas are formed by flat and undulating relief. Parallelly small lakes and irrigation deposits for small cultivated areas were mapped.

4 - The road system, even at channel 5, was not well characterized. Only at a section of the Presidente Prudente highway, between Avarē and Campinas is possible to be seen. To the West of the image the road system appears with a good integration degree.

5 - During the above mentioned thematic map preparation it was possible to isolate a category whose texture and tonality in the image do not approximate that of the natural or artificial forests, neither of the "cerrado" vegetation category or pasture. This category was defined as sugar cane because of its proximity to the Piracicaba city known as a sugar cane production region. In this region large cane fields, with other crop species appear inserted. They were not mapped due to the mapping scale.

6 - Figure IV.15 shows a thematic map done over a channel 5 photographic enlargement on the scale 1:500,000. This enlargement permitted a better definition of the outlines of mapped vegetal coverture units and the separation of new reforested areas.

IV.2.8.3 - Conclusions

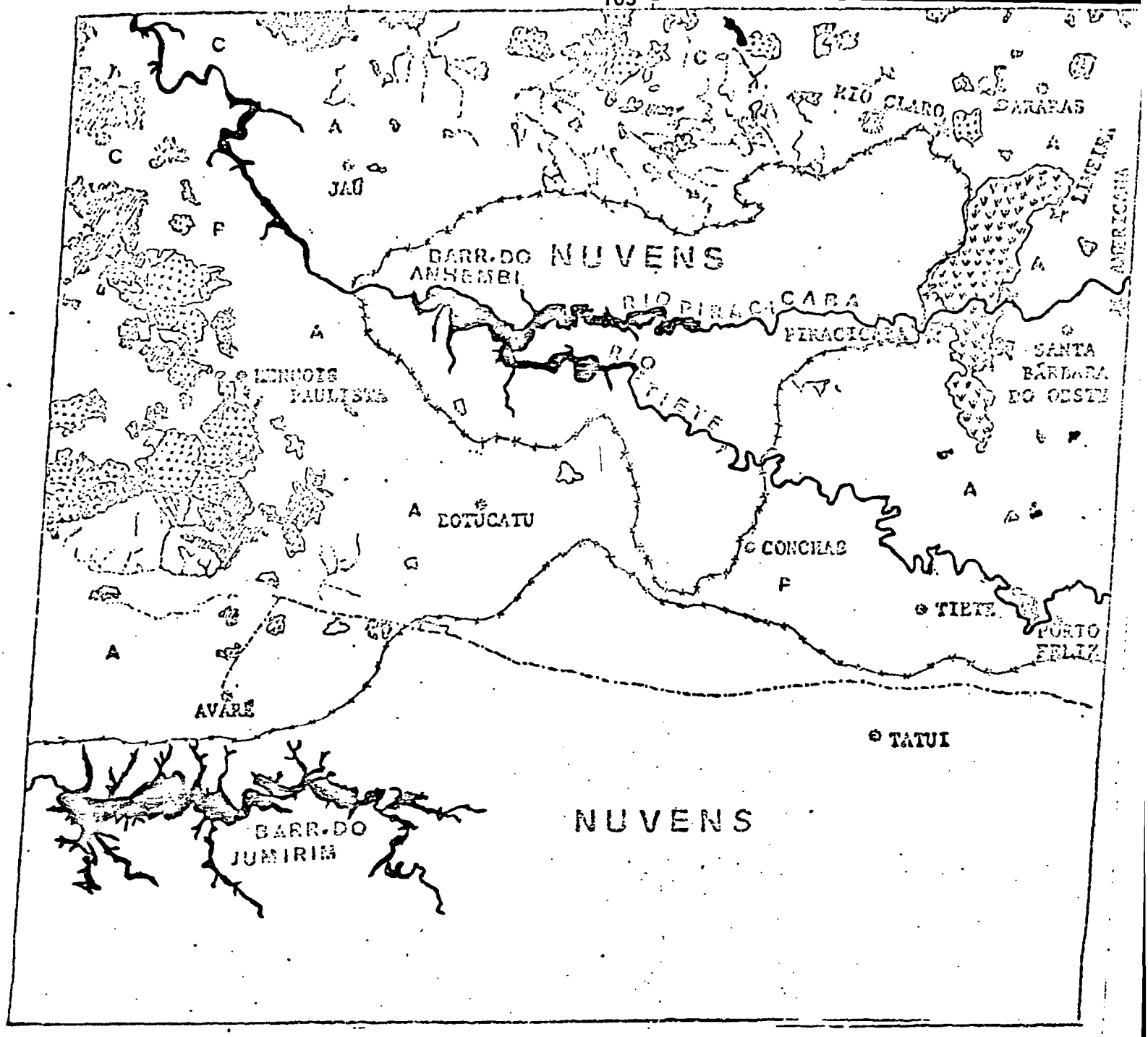
1 - The analyzed area possesses intense agricultural activities, flat and undulating relief. The reforestation and natural forests are concentrated to the West and Northwest zones of the image.

2 - For the mapped units characterization in this area the channels 5 and 7 are the ones which provide more information.

3 - Through texture type, tonality and man made aspects (as for instance roads among the plots of land) presented in the image by both categories, it was possible to separate areas with natural forests from the one with artificial forests.

4 - It was possible to identify the following kind of vegetal coverture (Figs. IV.14 and IV.15): natural forests, artificial forests, prepared soils for cultivation, "cerrado" vegetation areas, pasture and zones with intense agricultural activities. The last three cathegories could not be delimited.

5 - In the natural forests category it was not possible to separate areas with pinus and eucalyptus, because of the absence of field information.



NATURAL VEGETATION

REFORESTED AREAS

AREAS PREPARED FOR CULTIVATION (BARE SOIL)

GALLERY NATURAL VEGETATION

SUGAR CANE

ROADS

LIMITS OF THE CLOUD COVERED AREAS

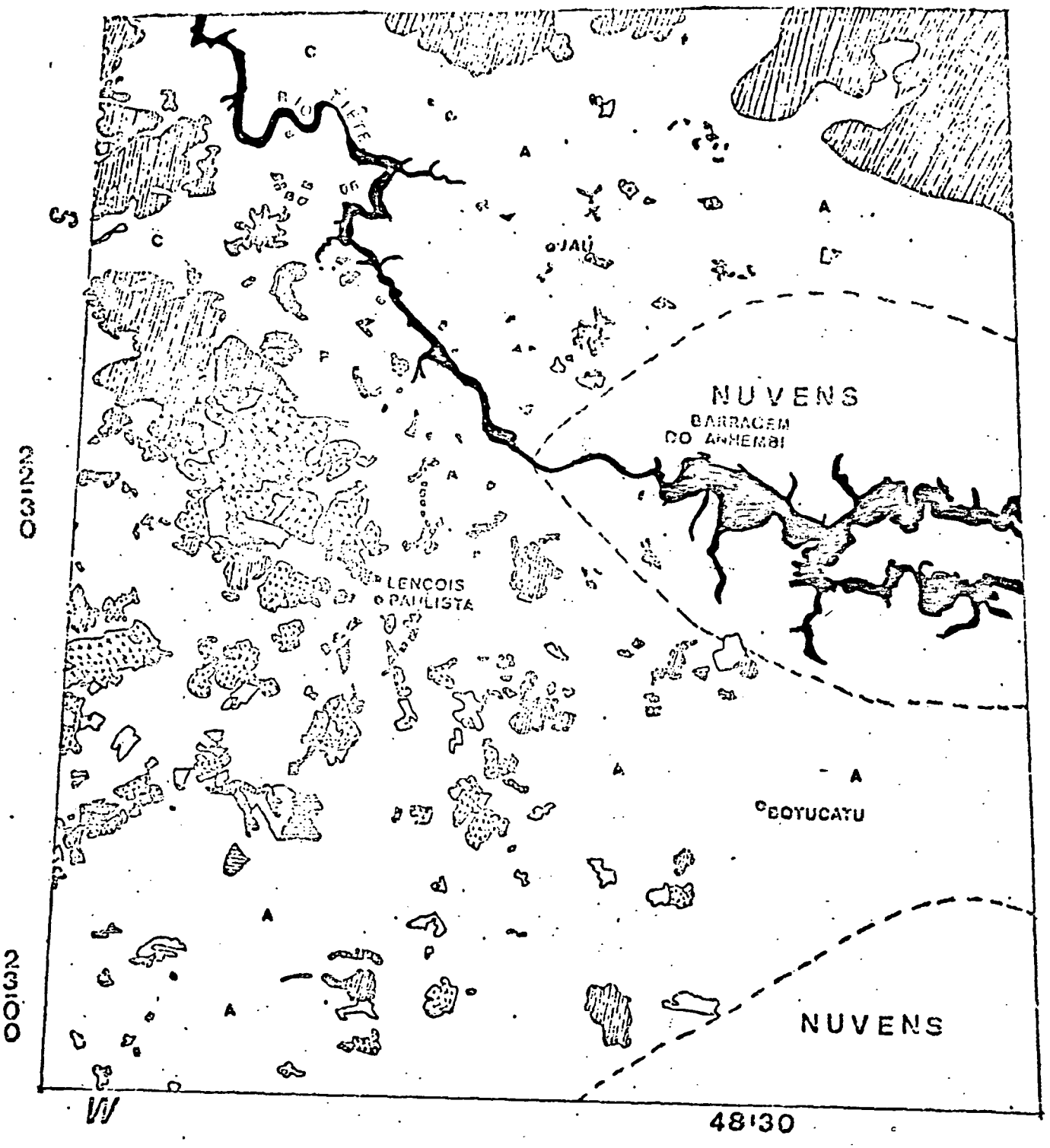
DAMS, RIVERS AND LAKES

A - ZONES WITH INTENSE AGRICULTURAL ACTIVITIES

C - "CERRADOS"

P - PASTURES

Fig. IV.14 - Thematic map of the Piracicaba Region.



- NATURAL VEGETATION
- REFORESTED AREAS
- DAMS, RIVERS, LAKES
- RECENTLY REFORESTED AREAS
- AREAS PREPARED FOR CULTIVATION (BARE SOIL)

A - ZONES WITH INTENSE AGRICULTURAL ACTIVITIES

C - "CERRADOS"

P - PASTURES

Fig.:IV.15 - Thematic map done over an enlargement of channel 5.

IV.2.9 - Image E-1054-130.73 - Dourados Region

IV.2.9.1 - Introduction

The above mentioned image, with center coordinates 21°45'S and 54°56'W, dated September 15, 1972, comprises the South region of the Mato Grosso State. This region was chosen because of the existence of a soil map permitting a comparison with the image information.

IV.2.9.2 - Available Information

1 - The drainage system is easily visible in channel 5 as shown in the transparency over figure IV.16. Generally the drainage streams appear under gallery forests which produce dark tones, easily delineated in the image.

2 - There appeared some remainder natural forested areas evidenced by the dark gray tone in channel 5,principally to the West and Southeast of the image. The forest Southwesterly directed are regrowing forests (brushwood) evidenced by light gray tones.

3 - The agricultural settlement of Dourados appears at the Southeast of the image.

4 - The comparison between channel 5 with a soil schematical map showed a good relationship principally in the occurrence of areas of quartzose sands to the Northeast of the area and

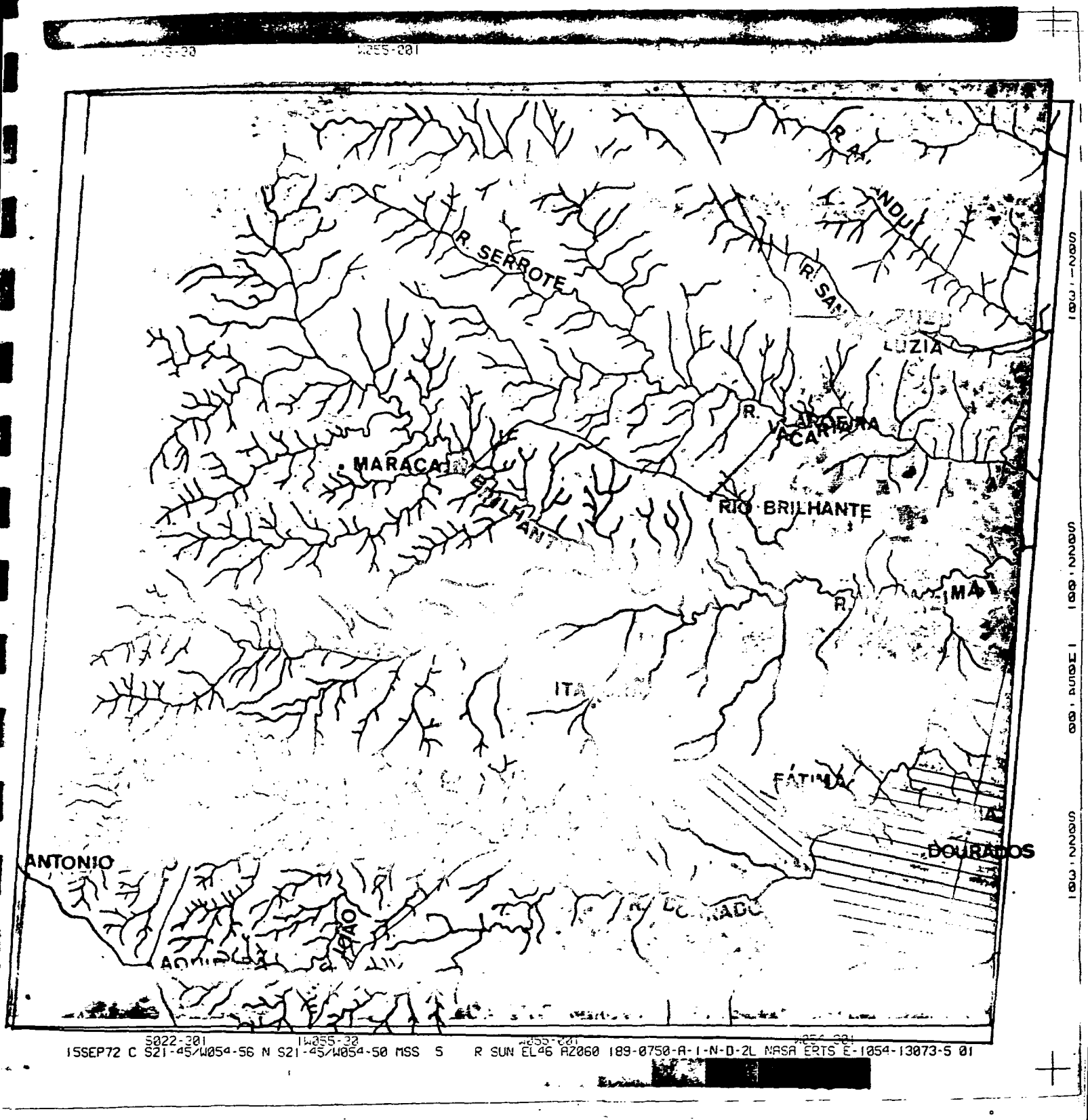


Fig. IV.16 - ERTS image E-1054-13.073 - Channel 5 - Dourados Region.

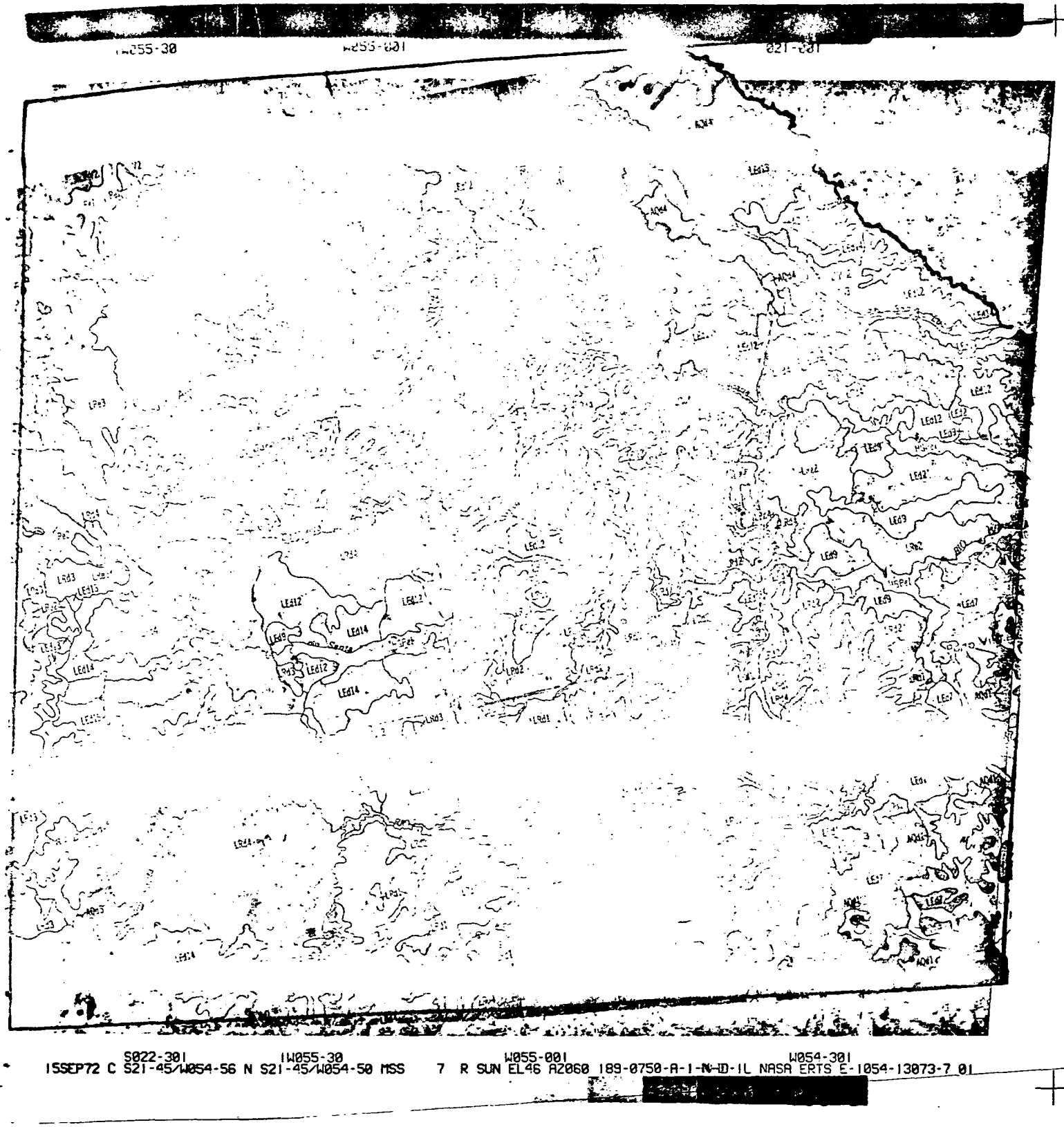


Fig. IV.17 - ERTS image E-1054-13.073 - channel 7 - Dourados Region.

the association of dark red latossol with quartzose sands in the agricultural settlement area. Although the right upper corner of the image is not mapped yet, it is possible to infer the existence of several areas with quartzose sands.

5 - The image in channel 7, figure IV.17, shows with a sharp contrast the purple latossol spot (darker gray tones) and also the great spot of dark red latossol, in lighter gray tones.

6 - There exists an area in the soil map down in the Dourados River, near the Agricultural settlement, classified as purple latossol, but through the image analysis it could be classified as dark red latossol. However it would be important to have a field checking.

IV.2.9.3 - Conclusions

1 - It is possible to map areas occupied by forests on the scale 1:1,000,000, as well as areas under cultivation or prepared for planting, besides the drainage system.

2 - Basing on the already done interpretation over this image, it is possible to conclude that the utilization of the several ERTS-1 channels, principally 5 and 7 channels, for soil mapping purposes, mainly at a schematical level or even at a reconnaissance level, would be of great importance. Besides allowing a multispectral vision of

the area, the ERTS images allows the observation of different soils moisture contents, vegetal coverage, and a synoptical view of the area.

IV.2.10 - Image E-1048-12.321 - Três Marias Dam Region

IV.2.10.1 - Introduction

The image under analysis has as central coordinates $18^{o}48'S$ and $45^{o}36'W$, dated September 9, 1972, comprising the Três Marias Dam Region at the Minas Gerais State.

IV.2.10.2 - Available Information

1 - The exact evaluation (high contrast) of the Três Marias Dam surface is possible through direct measurements over channels 5,6 and 7 images, as shown in figure IV.18 - channel 5. Such information increases its importance when we consider that ERTS-1 data repetitiveness could be used for accompanying the water volume variations stored during the year. In fact, the comparison done between the ERTS-1 images (taken at the end of the dry season) and the USAF map, based on photographies obtained in March 1964 (end of the rainy season), clearly shows differences in stored water volume inferred by the variation in the dam outline. The ERTS-1 repetitivity

Fig. IV.18 - ERTS image E-1048-12.321 - Channel 5 - Três Marias Dam Region.

would permit a relationship between the water collected by a hydrographic basin and the precipitation.

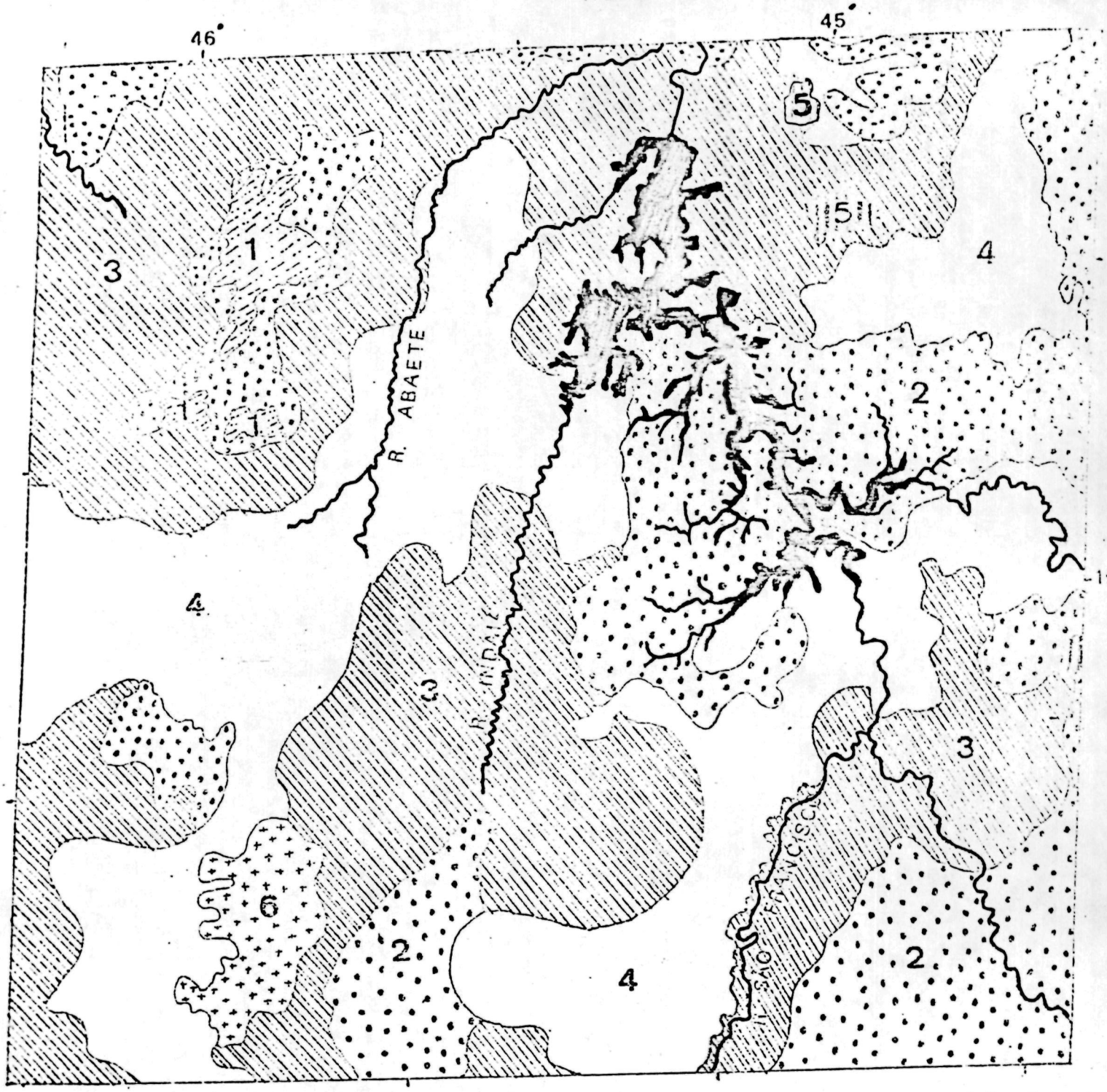
2 - A strong and frightening erosion could be observed in dam vicinities due to the improper deforestation and to a bad use of the soil. The strong erosion in the Paraopeba and São Francisco Rivers Basins is causing the silting up of one of the headwaters of the Três Marias Dam, clearly seen in channel 5.

A protection program, after the field checking, will be carried out because the above mentioned phenomena is diminishing the dam storage capacity.

IV.2.10.3 - Conclusions

1 - A relatively rapid analysis of the four MSS images channels permitted the preparation of a vegetation mapping in great ecological groups and the indications of erosion and soil moisture content conditions. Such map (Fig. IV.19) was obtained with minimal efforts, in small periods of study, and with costs highly compensatory, when compared with the necessary effort to the execution of a same kind of work using traditional methods.

2 - It is possible to infer, from observable image surface characteristics, areas with greater agricultural potential.



1 FOREST/"CERRADÃO"

2 "CERRADÃO"/"CERRADO"

3 "CERRADO"

4 SPARSE "CERRADO"/FIELDS

5 ERODED SOIL OR SOIL PREPARED FOR CULTIVATION

6 "CERRADO" IN UNDULATED RELIEF

Fig. IV.19 - Thematic map of the "Três Marias" Dam Region.

3 - It is possible to identify areas with agricultural activities and estimates the occupation intensity.

IV.2.11 - Conclusions

Even through a preliminary analysis it is possible to conclude that the ERTS-1 images are useful for the following soil resources survey:

1 - Natural vegetation mapping in great phytosociological comunities. That mapping could be obtained with little effort, in a record time, and with costs highly compensatory when compared with conventional methods.

2 - Mapping and calculation of the areas occupied with spots related to remainder forests.

3 - Identification of areas with agricultural activities and its intensity occupation estimation, as well as the identification of crops in particular cases.

4 - Delineation of the drainage system, soil permeability indication, its moisture degree and eroded areas.

5 - Pedologic survey, although through a superficial analysis: these images demonstrate great potentiality principally related to schematical surveys or even

reconnaissance level on the 1:500,000 scale. In this case it is good to keep in mind the necessity of a field check.

6 - Channels 5 and 7 were the ones which best provided information for the observation of the resources here analyzed. However for particular features analysis it is important a four channel analysis.

IV.3 - MAPPING OF NATURAL VEGETATION DISTRIBUTION OVER CENTRAL EASTERN BRAZIL FROM DATA OBTAINED BY ERTS-1

IV.3.1 - INTRODUCTION

Multispectral information specially about vegetation types, obtained by ERTS-1 through its MSS sub-system, fits very well with the essential need of a large country like Brazil, to develop a natural resource program. Natural vegetation units of central-eastern Brazil (an area of 622.616 km^2) are mapped. An interpretation key has been established and presented over five training areas, located in different vegetation types. Plant morphology, physiognomy and geomorphological characteristics are considered to identify each habitat. A special legend developed by our group illustrating different vegetation habitats of Brazil, is presented.

These habitats have been verified by prominent botanist and plant-ecologists. Boundaries for the area under study are sharp between: Atlantic, mixed and seasonal forests (spiny and sclerophyllus), Brazilian savannah (cerrado, campo limpo) and grasses (campo). The results are presented in the form of a vegetation map which shows the location of vegetation types in terms understandable to the users: governmental planning authorities, public services agencies, investment and special research institutes.

Natural vegetation results from the struggle for existence between various plant species and wildlife factors, in order to reach a natural balance. Under protected conditions, this balance is true nature, since the influence of man can be neglected. The ideal way to develop a natural resources management program, without destroying the resources, is to collect enough information in order to understand the working of the environment.

Therefore the main objective of this topic is the identification of the vegetation habitats through ERTS-1, MSS imagery interpretation. These vegetation habitats can be applied by the end users to develop their specific programs for planning, checking and detailed specialized researches.

IV.3.2 - Studied Area and Methodology

IV.3.2.1 - Area

The area of study under consideration includes the two states, Minas Gerais and Espírito Santo; a total area of 622.616 km^2 (Fig.IV.20).This area has been chosen because of the wide variations in its environmental parameters. Following Thornthwaite climatology classification [1], the area varies from super humid climate in the eastern coastal part - covered by rainy forest - to semiarid climate on the northeastern part - covered by seasonal deciduous spiny vegetation (Caatinga). The topography also varies from low plan topography - at sea level, to mountains higher than 1500 meters.Between these two extremes, there are different geomorphological formations.

From a space sensing point of view, this area has been chosen, with its many variations, to test the capacity of the ERTS's multispectral scanner (MSS) in offering the basic information necessary to identify different vegetation habitats. The integration of the information from the four MSS bands provide a better image for identifying the target and its environment than would be obtained from each individual bands.

The area under study is one of the most important regions in the Brazil's development plan because of its water resources potential, forest resources, hydroelectrical and mineral resources. The lack of sufficient regional information is one of the major limiting factors in the plan's progress. For this reason INPE selected three test sites of

different natural formations to develop its remote sensing study.

IV.3.2.2 - Methodology

The data obtained to develop this survey is from the MSS imagery scale 1:1,000,000. By looking at any plant reflectance curve, obtained in the laboratory by spectrophotometer or in the field by spectro-radiometer (such as Fig.IV.21) [2], and placing the four MSS bands on the curve, we can see that there are different information in reflectance units. Different plants reflect incoming radiation in different wavelength depending on the cell wall, shape and its contents [3,4,5] . This means the plant reflectance depends on the plant itself, rather than on the physiological and environmental conditions. The existance of chlorophyll β causes high absorption in channel 4 (0.5 - 0.6μ) and 5 (0.6 - 0.7μ). The high reflectance in channel 6 (0.7 - 0.8μ) and 7 (0.8 - 1.1μ) is a result of the cell wall reflectance, its state or maturity and physiological activities. The larger the leaf area index, and the denser the vegetation canopy cover per unit area, the higher the reflectance would be [4]. Figure IV.21 can also be taken as an example of air dry soil reflectance. Soil reflects relatively higher in channel four compared to vegetation. In channel five the situation is nearly the same by comparing the total area under each curve and considering it as the reflected energy value.This might erroneously lead one to assume that both channel can provide the same information. However channel four is suffering atmospheric interference and appears hazy. This filters the information and reduces its quantity on the frame and enables us to identify the low reflected areas as vegetation, in spite of the low

contrast vegetation canopy cover density data can be obtained from channel five, because of the relatively high soil reflectance and low vegetation reflectance. In the near infrared wavelength, the phenomena works in an inverted way. Canopy cover reflects more than soil. Channel 6 (0.7-0.8μ) provides information between the end of the visible and the beginning of the infrared. Bodies of water and plants growing under moisture stress looking darker in this band. The difference in the reflectance between soils and canopy cover in this band is greater than in the other channels. Close, dense canopy cover reflects more than an open shallow one.

By comparing the reflectance on each band-in view of the previous considerations, and having sufficient background about vegetation cover, its physiography, leaf morphology, soil properties and the geomorphological feature of its habitat - a precise identification can be made with the MSS imagery. In order to do this work it was necessary to develop a legend which defines each vegetation class in an ecological manner. There are many published specialized work about each Brazilian vegetation type and their environmental parameters [6,7,8,9,10,11,12] . Almost all these work have been made in small areas because of the limited transportation and technology [13] . Very few researchers have used black and white aerial photography. Other research has been made on the ground, only in accessable areas. Therefore new technology - such as the ERTS-1, MSS - is necessary in order to undertake to map the vegetation of all Brazil. It has also been necessary to develop a new legend for identifying these vegetation habitats in terms useful to the end users.

IV.3.2.2.1 - Legend

The purpose of this legend is to identify the different vegetation habitat by interpreting the reflected energy units in ecological terms.

Specialists in different field can use the legend to know the biological components, climate, geomorphology, wildlife and any other environmental properties of each habitat. The legend has been developed to obtain the maximum possible quantity of information offered by the MSS imagery in order to define each habitat. Four parameters were considered; climate, plant physiognomy, plant morphology and geomorphological features. The legend is divided into three physiognomy types (Table IV.1). Forest; defined as tree vegetation canopy completely covering the ground unit. In a remote sensing interpretation, this means that the all reflectance belongs to vegetation and there are no other ground reflected targets. Cerrado; is another vegetation type containing medium high trees, not covering the ground unit completely, but leaving spaces which vary according to its density, under the trees there is grass cover. The third class is campos, which is non-tree vegetation canopy, covering the ground completely or partially.

The legend is further divided into three climatic categories; Rain (pluvial) forest, which is the super humid region (Thornthwaite classification) [1] , having undefined rainy seasons. Seasonal vegetation, occurs where a dry winter and a rany summer are well defined. Between these two vegetation types, a mixed forest can be identified which is forest

composition vegetation, evergreen because of high precipitation index which varies slightly each month. The forest is evergreen, loosing the old leaves, but at the same time forming new ones through the year - not in a specific season. This forest occurs over mountainous topography where the temperature is relatively low. Sometime on higher altitude and toward to the south of the country, it appears mixed with coniferous, Paranã pine (Araucaria braziliensis) [14], up till the pure stand of (Araucaria) in the south. Thus, we divided the habitat (1.2.1) of the mixed forest into; 1.2.1.1-without Araucaria and 1.2.1.2 with Araucaria.

Other two habitats can be found in the mixed evergreen forests, which are not on the mountains. These are: gallery forest (1.2.2), which results from sediments in the depressions or valleys with high organic matter and moisture content soils. Swamp forest is the other habitat appears with the mixed forests.

Seasonal forest includes three habitats in which soils - as the result of geological and geomorphological formation - are the main limiting factors. Climatic characteristics generally remain in each habitat. Caatinga (1.3.1) is a deciduous spiny forest loosing its leaves completely during the semi-arid season, this reducing the leaf area index which is in contact with the dry air, in turn reducing its evapotranspiration.This habitat is found in the depressions over stony clayey soils. The second habitat is the forestic stage of cerrado - Cerradão. It is sclerophyllous, semi-deciduous forest on the brazilian plateau deep well drained mainly latossol soils which suffer mineral nutrients deficiency and aluminium

excess. Plants in the cerrado adapt their leaves to this environment by having hairy leathery leaves which create a static layer of air between the tiny hairs and isolate the leaf surface from the dry air. Cerrado plants do not suffer soil moisture shortage, but only mineral. [6,7,8,9,10]. The third seasonal forestic habitat is what would be called in Brazil, "Mata Seca" (1.3.3). It is deciduous to semi-deciduous mesophytic forest [12] . It can be found on the Brazilian plateau over rich soils.

The second class in the legend is Cerrado (2), The word "Cerrado" is used in two senses in Brazil: In a wide sense, it is a regional, large-scale vegetation type which forms both a vegetation and forestic province. In a strict sense, it refers to a particular range of structural forms of this vegetation [12] . In this paper cerrado (2) is used in a large-scale sense, to indicate the non-forestic, but seasonal sclerophylous vegetation forms. Then it is divided into two habitats. The first is cerrado in the strict sense (2.1.1), of medium high on a continuous graminea grass canopy. The second is campo limpo (2.1.2), is the grassland forms of the cerrado, where is almost no trees in the habitat, This indicates shallower soil than in the cerrado, found mainly on the slight slopes.Cerrado is sometimes referred to as "savana" or "savana-like" it is in fact quite different.Eiten [12] reported: Cerrado is different than savanna because it is an upland vegetation, which is never inundated and with excellent internal drainage of its soil, so that soil does not remain waterlogged for long periods after rain.

The third class in the legend is the campos. This is

herbaceous vegetation which corresponds to the first class, the forestic one. It is divided into four habitats. The mountainous (3.1) which corresponds to the mixed evergreen to semi-deciduous forest of the mountains (1.2.1) and its two habitats. The swampy (3.2), corresponds to the (1.2.3) and the galery campos corresponds to (1.2.2). It is a vegetation of sediment inter-mountainous depressions which are now mainly in agriculture use. The fourth habitat is the vegetation of the coastal dunes (3.4).

IV.3.2.2.2 - Interpretation Key

Five areas have been selected in the region under study to see how each habitat appears in the four MSS imagery channels. The selected areas are located in both the pure ecosystem and the transitional zones. Three of them are INPE's test sites. These were flown over by INPE's own aircraft mounted sensors for callibration and detailed studies. The other two areas have been selected on the basis of recent published work which were based on black and white photointerpretation. Table IV.2 shows the materials used and the information obtained. The work has been done using printed MSS imagery in the scale of 1:1,000,000 for the four channels. Generally speaking, although channel four is always hazy, it can be used to distinguish the vegetation covered areas from non vegetation, because of the relatively low reflectance of all plants in this band (Fig. IV.21). Channel four provides very little information.

The comparison between the different areas has to be made on the same frame. It can then be extrapolated to the other frames in a relative sense, because the sun elevation angle is a changing variable. The angle changes during the ERTS tracking and also varies from one orbit to another, changing the characters of the incoming radiation, in turn, changing the reflected radiation from the terrestrial targets. The leaf area index has been examined through infrared imagery. The greater the leaf area index is,the higher is the reflected energy per unit area [3,4,5,13] . In this way, we distinguished the forestic cerrado form (Cerradão), from the vegetation form. Channel five offers more information in the visible band and thus geomorphological information can be obtained. Vegetation canopy density can also be obtained from this channel in an inverted value from channels 6 and 7.

Based on the previous considerations, the habitats under study have been characterized as follows:

- Rainy evergreen, broad leaved Atlantic forest (1.1.1.2)

These are low reflected areas in the visible bands 4 and 5. But they are very high reflected in the infrared because they remain evergreen throughout the year. These are very dense forests, demonstranting relatively more reflected radiation than the other less dense vegetation types. The eastern boundary of this habitat could also be obtained clearly from channels 6 and 7. The habitat extends over nearly plan area, with slight variations, extending toward the interior of the country until the

base of the mountains generally coinciding with the contour line of 500 meters.

- Mixed, evergreen to semi-deciduous, mountainous forest without Araucaria (1.2.1.1)

This habitat can be distinguished as a forest, following the previous criterion. Topography features obtained through channel five show the drainage system, indicating the mountainous topography. Where the forest is growing on relatively low lands, it appears darker than upland forest in channel 6. Itmight be that this is because of the soil moisture excess on the depression, which appear in a different image tone than the gallery forest.

- Mixed evergreen to semi-deciduous mountainous forest with Araucaria: (1.2.1.2)

This habitat is different from the previous habitat in two aspects. The ecological difference is the misture of evergreen broad-leaved forest with the coniferous Paranã Pine (Araucaria braziliensis). The second aspect is the climate, which permits the appearance of the coniferous species. This is because of the altitude-higher than 1500 meter-which presents low temperature and high humidity indexes.

The last two habitats are an ecoton between the high latitude coniferous forest and the broad-leaved deciduous forest [14]

- Mixed, evergreen, gallery forest (1.1.2)

These are evergreen forests and can be found with mixed forest, seasonal forests, or even campos. These have low reflectance in the visible bands and high reflectance in the near infrared bands. They always occur in valleys, where the soil is rich in organic matter and soil moisture content, creating a special micro-climate. Forest reflectance is not only feature to identify this habitat. The ground feature of the drainage pattern can also indicate the valley direction, the sediment resources and the valley mouth. The forest density is always lesser on the top of the gallery than on its mouth following the soil depth direction.

- Seasonal, deciduous spiny forest (Caatinga 1.3.1)

This is a forestry habitat of thorny leaf plant, which adapt their leaves to be able to live under semi-arid climate. During the dry season plants loose their leaves and have a low leaf area index. These two properties present low reflectance in the infrared bands. The trees usually cover the soil, which do not permit detectance of high soil reflectance in the visible bands. For this reason it appears dark in both visible and near infrared bands. Caatinga habitat can be also distinguished, with high precision, through geomorphological feature. It is always found on the depressions, inter-mountains or inter-plateaus, on stony clayey and poor drained soils. This information could be obtained from channel 5.

- Semi-deciduous, sclerophyllous forest (Cerradão 1.3.2)

In this habitat the forest plants adapt to the dry season in a different way, leaves are hairy leathery sclerophyllous [6,7,8,9,10] . The importance of this characterisitc is that the cell wall is harder and the cuticle is thicker, causing relatively high reflectance in both visible and near infrared bands; especially in channel 6 due to the well drained soils.

- Mixed, semi-deciduous to deciduous forest (1.3.3)

It grow over richer soils than cerradão. It does not loose its leaves completely during the dry season and does not suffer from lack of nutrients or moisture content. For this reason, the leaves are thiner than cerradão, reflect less in the visible bands. Moreover it can suffer water stress, and this can be seen on channel 6.

- Seasonal, sclerophyllous cerrado (2.1.1)

This is the habitat which follows the same characteristics of the cerradão, but with higher reflectance in the visible bands,because of the lesser vegetation canopy density, permitting high soil reflectance to be detected, in some percent, by the sensors. Channel five shows here the soil condition and the geomorphological level of the plateau.

- Campo limpo (2.1.2)

This is the grassland form of the cerrado which indicates shallower soils than the previous habitat (2.1.1). It has a higher reflectance in the visible bands because of the poor canopy cover, which enables the high soil reflectance to be detected. There is less reflected energy in the near infrared because of the small leaf area index. This habitat has a shallow soil frequently occuring on the slight slopes on the boundary of the Brazilian plateau. The drainage patterns obtained from channel five indicate the slope degree and direction.

- Campo (3.0)

This class is a short grass type. It has high reflectance on channel four and five due to the high soil reflectance and relatively low leaf reflectance. This class indicates four habitats with respect to different ground features:

- Campos of the mountains (3.1)

This is the grassy stage of the mixed evergreen to semi-deciduous mountains (1.2.1). It has shallower eroded soils, causing higher reflectance in the visible bands in comparison with the mountainous forest. At the same time there is low infrared reflectance because of these eroded and lesser vegetation density canopy cover.

- Swampy campos (3.2)

This is a vegetation canopy habitat over shallow water table level. It has low reflectance in both visible and near infrared bands, because of the low reflectance of the wet soils in the visible bands, the low vegetation reflectance in the near infrared bands, and water absorption. The absence of drainage patterns indicate its boundary. If this swamp is near the Atlantic coast, then it would be salt marsh with saline water table. If it is in the interior, then it would be fresh water table swamp. Of course plant communities are different in each case.

- Gallery campos (3.3)

This is wide valley habitat between the forest covered mountain. They are now developed for agriculture use and are distinguished geomorphologically, and in any channel by the man made patterns.

- Coastal dunes campos (3.4)

The dunes themselves are high reflectance targets. If there is vegetation growing on the dunes, then dark patches will be detected in channel five. It is easy to draw the boundary of this habitat through both channel six and seven, because it is contrasted with neighbour habitats; the ocean to the east and the swamp or Atlantic forest to the west.

This is basically the way we interpreted the ERTS-1, MSS imagery to develop the map.

IV.3.3 - RESULTS AND CONCLUSIONS

1 - The map enclosed (Fig. IV.22 - "Mapa de Vegetação Natural" Natural Vegetation Map) is the final output of this work, having transferred the reflected energy units into a common understandable language. It shows the following vegetation distribution: The Atlantic coast in the eastern boundary, with the presence of the sand dunes in a discontinuous strip, broken sometimes by swamps or directly by the Atlantic forest (1.1.1.2). Moving toward the west, the mixed evergreen forest (1.2) and the mountains campos (3.1) appear on the mountains topography. Upward, toward the west, the sclerophyllous forestic vegetation can be found. If there are deep soils, then cerradão (1.3.2) will be found. Shallower soils would be covered by the cerrado (2.1.1). On the slight slopes the vegetation cover is campo limpo (2.1.2). The sharp slopes do not permit sclerophyllous vegetation to grow, this is campo (3.1) on the slopes and mixed forest frequently present. In the northern part of the region, on the inter-mountain depressions, the canopy is piny forest-Caatinga (1.3.1). The mixed semi-deciduous forest"mata seca"(1.3.3), is also a plateau vegetation, but is found over richer soils in some shallow wide depressions, especially near rivers.

2 - It is therefore possible to get the basic ecological information, presented on the map, through the MSS imagery. Geographical location of the mixed forest that it is a transitional geomorphological zone between the Atlantic forest (1.1.1.2) and the cerrado (2). This agrees with the Brazilian geomorphological explanation of AB'SABER [15].

3 - The same map proves that the mixed forest (1.2.1.1) is an ecoton between the evergreen and the coniferous forest (1.2.1.2), which agrees with the ecology point of view of EYER [14].

IV.3.4 - DISCUSSION

We have classified the end users of remote sensing technology into: Special research institutes, governmental planning authorities, public service agencies, and investment and development organizations. The MSS imagery has been shown to offer enough multispectral data to be used to obtain basic ecological information using a well oriented legend and interpretation key.

The relation between the vegetation cover and its environment also provides information for the other specialists, who are concerned with natural resource investment and management. The fact that a large area can be scanned in a short period of time is an important advantage in a multi-spectral interpretation. It can also provide information for a large area

under the same physical conditions, such as: sun elevation angle,air temperature and humidity which may change the reflectance of the vegetation to adapt its physiological function to the environment. Care must be taken to compare each frame independently since different frames are scanned under different atmospheric conditions.

The special research institutes can work inside each habitat to get more detailed data and compare the different locations of the same habitat to better understand the different phenomena.

Governmental planning authorities can use the habitats as indicator to the land potentiality. On combination with other socio-economic factors, knowledge of land potentiality will enable authorities to establish well planned programs.

Public services agencies can, with this knowledge investigate whether or not land is being used most efficiently.

Investment and development organizationscan establish priorities and a credit system based on the knowledge of how to best use the land.

We have then demonstrated the capacity of multispectral scanner in providing the basic information necessary to develop a Brazilian natural resources program.

IV.3.5 - References

[1] Departamento de Meteorologia, Atlas climatológico do Brasil, Rio de Janeiro, Brasil, 1969.

[2] R.M. HOFFER, ADP of Multispectral Scanner Data for Land Use Mapping. Information Note 080372. LARS - Purdue University, West Lafayette. Indiana,U.S.A., 1972

[3] W.E. LOOMIS, Ecology 46, 182, (1965).

[4] W.A. ALLEN, and A. J. RICHANDSON. "Interaction of Light with a Plant Canopy; Proceeding of the Fifth Symposium on Remote Sensing of Environment, University of Michigan, Ann Arbor, Michigan, P.219, (1968).

[5] D.M. GATES, et al. Applied Optics, 4, 1: 11 - 20 (1965).

[6] M.G. FERRI, Contribuição ao Conhecimento da Ecologia do Cerrado e da Caatinga. Estudo Comparativo Balanço D'água de sua Vegetação. Bol. Filgs. Univ. São Paulo, 195, 1-170 (1955).

[7] M.G. FERRI, Problems of Water Relations of Some Brazilian Vegetation Types with Special Consideration of the Concepts of Xeromorphy and Xerophytism. In plant-water relationships in arid and semi-arid conditions, pp. 191-197,UNESCO, Madrid Symposium (24 - 30 Sept. 1959)

[8] K. ARENS, "Consideração sôbre as Causas do Xeromorfismo Foliar". Bol.Fac.Filos.Univ. São Paulo, 224, Bot.15: 25 56.(1958).

[9] K. ARENS, "O Cerrado como Vegetação Oligotrófica" bid. pp.59-77 (1958).

[10] K. ARENS, "As Plantas Lenhosas dos Campos Cerrados como Flora Adaptada às Deficiências Minerais no Solo". Em simpósio sobre o cerrado, pp. 255-303. Editora. Univ. São Paulo (1963).

[11] L.G. AZEVEDO, "Tipos Eco-Fisionômicos da Vegetação da Região de Januária (MG). Em II Simpósio sobre o Cerrado. Anais da ACA. Br. de Ciências, Rio de Janeiro, pp: 39-57 (1966).

[12] E. EITEN, "THe Cerrado Vegetation of Brazil, In the Botanical review, 138, 2, pp. 201-341 (1972).

[13] L.H. ALLEN, and K.W. Brown, "Shortage Radiation in Corn Crop", Agr. J. 57, pp. 575-580, (1965).

[14] S.R.EYER, "Vegetation and Soils - A World Picture". Second edition London, England (1968).

[15] A.N.AB'SABER, "A Organização Natural das Paisagens inter e sub-tropicais Brasileiras. III Simpósio sobre Cerrado. Editora da USP São Paulo (1971).

TABLE IV.1 - LEGEND

1.0 - Forests

1.1 - Rain
1.1.1 - Evergreen, Broadleaved
1.1.1.1 - Amazonic: a - Terra firme (UP LAND)
b - Várzea
c - Igapó (LOW LAND)
1.1.1.2 - Atlantic
1.1.1.3 - Palm dominated

1.2 - Mixed
1.2.1 - Mountain
1.2.1.1 - Without Araucaria
1.2.1.2 - With Araucaria
1.2.2 - Gallery
1.2.3 - Swamp
1.3 - Seasonal
1.3.1 - Deciduous, Spiny (CAATINGA)
1.3.2 - Semideciduous, Sclerophyllous (CERRADÃO)
1.3.3 - Mixed, Semideciduous to deciduous (MATA SECA)

2.0 - Cerrado

2.1 - Seasonal, Sclerophyllous
2.1.1 - Cerrado
2.1.2 - Campo limpo

3.0 - Campos of:

3.1 - Mountains
3.2 - Swamps
3.3 - Gallery
3.4 - Coastal Dunes

Table IV.2- The training areas for establishment of the interpretation key

NAME OF THE AREA	MATERIALS USED		INFORMATION OBTAINED HABITATS
Vazante	Black and white photos, scale 1:60,000 Multispectral images Ground truth information	(1964) (1972) (1972/73)	Mata Seca (1.3.3) Cerradão (1.3.2) Cerrado (2.1.1) Campo limpo (2.1.2)
Ipatinga	Black and white photos, scale 1:25,000 Ground truth information	(1972) (1972/73)	Mixed evergreen, mountainous forest without Araucaria (1.2.1.1) Campos of mountains (3.1)
Lafaiete	Black and white photos, scale 1:25,000 Colour Infrared photos, scale 1:15,000 1:10,000	(1969) (1969) (1971)	Cerrado (2.1.1) (Campo limpo (2.1.2)
Furnas	Vegetation map, scale 1:200,000 Uncontrolled photo mosaic 1:100,000	(1964)	Mata Seca (1.3.3) Cerrado (2.1.1) Campo Limpo (2.1.2)
Januária	Vegetation map, scale 1:134,000 Geomorphologic map, scale 1:500,000	(1966) (1966)	Caatinga (1.3.1) Cerrado (2.1.1)

Note: The first three areas are INPE's test sites.

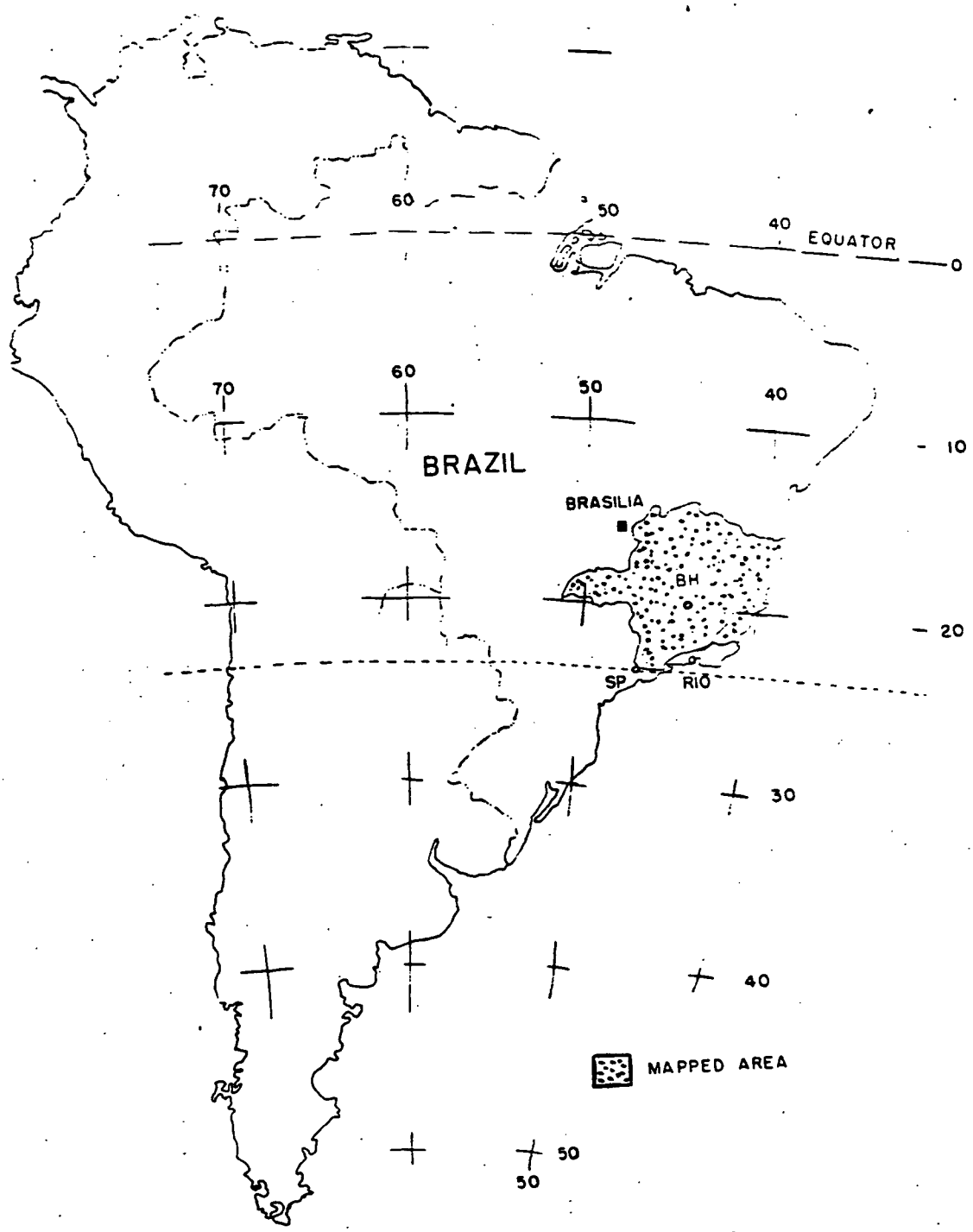


Fig. IV.20 - Location of the studied area.

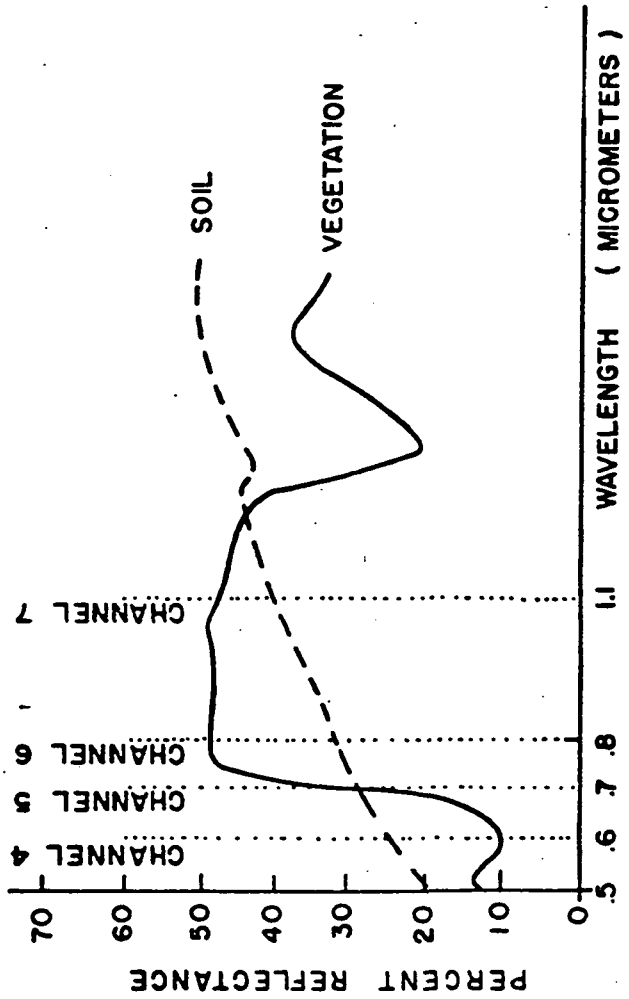


Fig. IV.21 - Average spectral reflectance curve of 240 spectra from vegetation and 154 spectra from air dry soils. (Adopted from Hoffer, R.M.) [2]

(Following map Not Signed)

IV.4 - ESTIMATION OF PASTURE PROJECTS USING ERTS-1 IMAGES

IV.4.1 - Introduction

This work is executed in cooperation with the Superintendence for the Amazon Region Development - SUDAM. It is a planning and coordination Federal agency for the legal Amazon Region. In the private field one of its objective is the analysis, the approval and supervision of the Pasture Projects introduced in this region through fiscal incentive given by the Brazilian Government.

The research under study aims to obtain, using ERTS-1 images a rational and productive methodology to the control and following of the implanted Pasture Projects evolution, through specific studies of the following objectives:

- To survey areas under dense forest, "cerrado" vegetation areas and flat lands.
- To delineate different drainage patterns.
- To determine the road system and estimate its extension.
- To control the deforestation using the ERTS-1 images repetitivity.
- To evaluate areas with pasture.

IV.4.2 - Methodology

To attain the objective of this work, it was selected a test site (described below) to permit the evaluation of the MSS/ERTS-1 images capability for this kind of study.

IV.4.2.1 - Test Site Selection

The area under study is located at the Northeast of the Mato Grosso State, comprising an area between the parallels $10^{o}00'$ and $16^{o}00'$ South and meridians $51^{o}00'$ and $54^{o}00'$ West, embracing parts of the Xingu and Araguaia Rivers Valleys and the Bananal Fluvial Island (about 300,000 km^2).

This area was chosen because is suffering an accelerated change due to the great number of farms (cattle breeding and cropping) already established.

There is not a recent photographic coverture of this area, which is out of the designated area for the RADAM Project (natural resources surveys through the SLAR system in the Amazon Region). Besides this, the area is under the jurisdiction referred to the 50% of forestal reserve as established by the law nº 4771, dated September 15,1965 (Forestry Code) in its article 16, letter b.

IV.4.2.2 - Approach

After the preparation of basic maps (vegetation,drainage and road system), the properties delimitation should be done over this area mosaic (ERTS images on the scale 1:1,000,000), with the help of data of the SUDAM Office, general information as well as natural features.

After this phase, periodical evaluations should be done at 6 months interval of this region through the ERTS-1 images mosaic interpretation on the scale 1:1,000,000. The mosaic analysis will permit the selection of frames, where visible changes appeared in the region for image enlargement to the scale 1:250,000 with a better precision and with pasture areas measurements.

Periodically, after mosaics interpretation, a field checking should be done to improve the limits of each Pasture Project as well as to verify the accuracy of areas measurements on images and also provide information such as grassland, planting orientation, carrying capacity,etc.

For illustration purposes two ERTS images in channel 5, taken at different data, are presented here in figures IV.23 and IV.24. They are areas comprising this test site under study greatly justifying the viability of this project in that special region. It should be observed with what contrasts degree these pastures areas could be separated from natural forests and from the accentuated deforestation this region is suffering, through the comparison of the two different gathering data of the ERTS images.

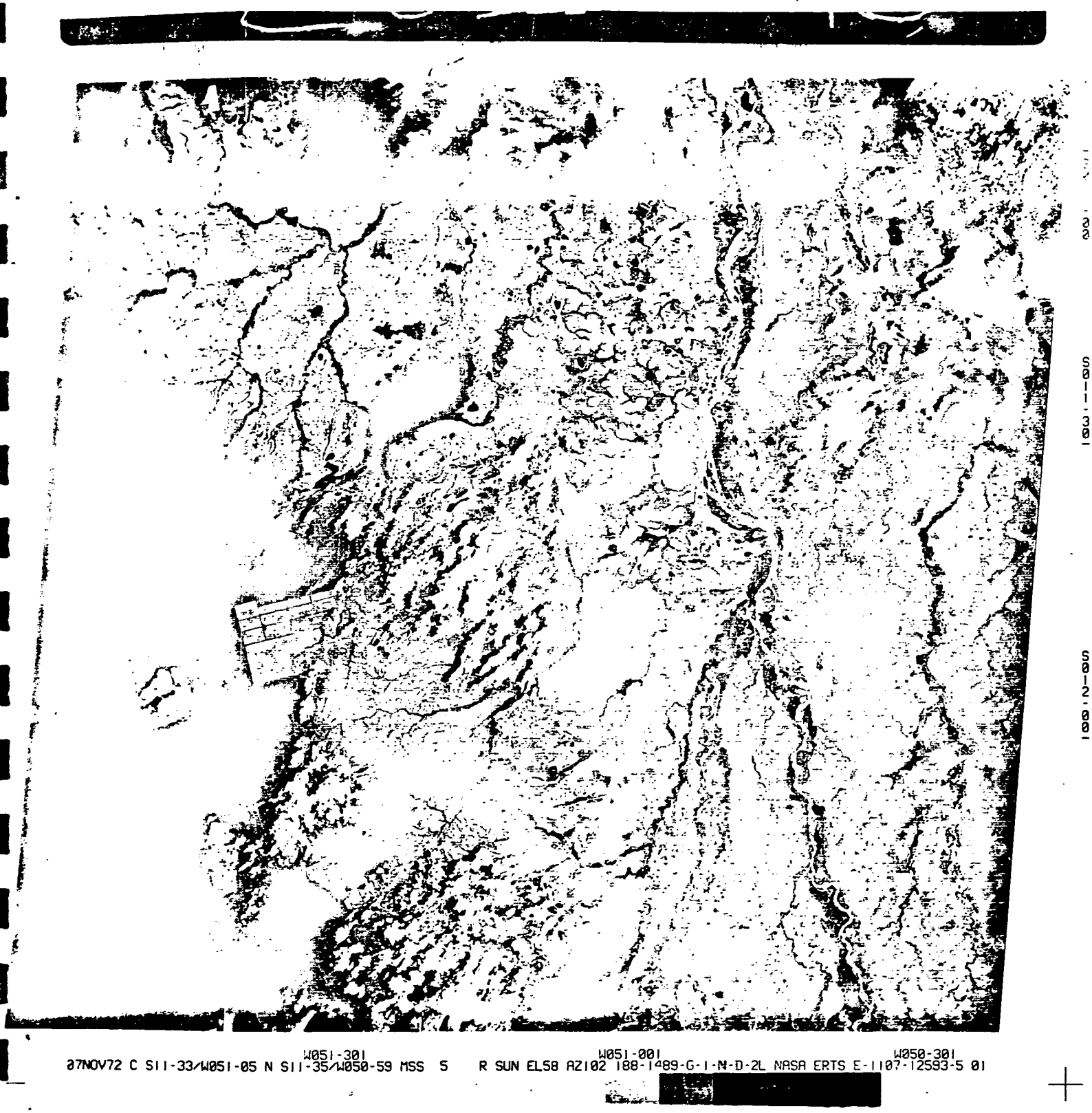


Fig. IV.23 - ERTS image E-1107-12.593 - Channel 5.

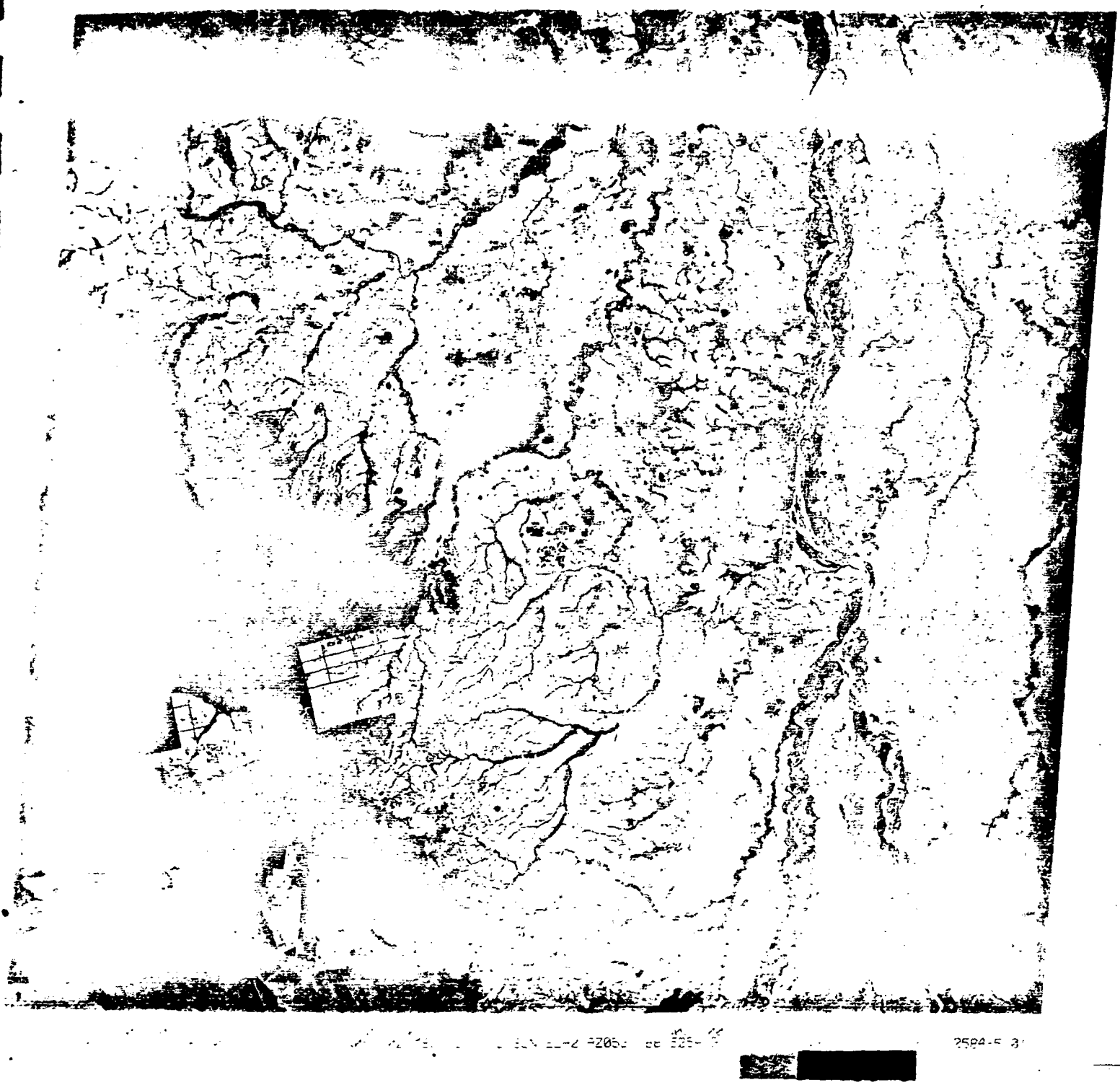


Fig. IV.24 - ERTS image E-1377-12.584 - Channel 5.

IV.4.3 - Preliminary Results

The final report related to this topic is expected to be ready by the end of 1975.

Up to now two basic maps (enclosed - Figs. IV.25 and IV.26) were done based on the ERTS images. The first one shows the drainage system, the road system and cities and the second one shows the natural vegetation map as well as the delimitation of projects already installed. The mapped units as well as their patterns appearing in the ERTS images could be seen as follows:

IV.4.3.1 - Preliminary Interpretation

The MSS channels 5 and 7 were used.

IV.4.3.1.1 - Channel 7

It was used to have the hydrography overlayed.

- The riverbeds are not covered by vegetation presenting themselves in dark gray tones, as well as lakes and lagoons.
- Soils with sparse vegetation or bare soil which present a high degree of moisture, appear in dark gray tone as for instance the lowlands between the Xingu and Mortes Rivers as well as the Bananal Fluvial Island.

(Following 2 MAPS Not Filmed)

- The small water bodies, circled by dense vegetation, shown in the image lighter grey tones, and as this vegetation enters in a degradation phase, passing to the arboreous and shrubby formations, the tonality tend to go to the darker grey tones.
- Through the ERTS images E-1305-4501 and 1305-2501 (1E and 2E) it is possible to note sparse darker grey tones spots (almost black) due to their localization always close to the water bodies. In areas which the surface drainage pattern is highly dense, it is supposed they are denser "cerrado" vegetation areas with a high content of moisture in the surface.
- Roads and cities appear badly in this channel.
- A comparison was done between the map done using the ERTS images (Fig. IV.26) and the USAF navigation map on the scale 1:1,000,000.

Superimposing the two above mentioned maps the main water-bodies are with their forms and localizations correct, excluding the Mortes River, at the South of the area, which has its form strongly different from that one presented by the ERTS images.

Another observation done is that some lagoons showed in the image do not appear in the USAF and IBGE charts. For instance a lagoon in the margins of a Culuene River tributary, seen in the image.

IV.4.3.1.2 - Channel 5

Without any previous field work in this area, our main objective was to map the main forestry formations, to delimit artificial pastures, to localize road systems, cities and small towns of the region.

1 - Vegetal Coverage

Basing principally on the grey tones and through the comparison of channels 5 and 7, it was possible to preliminarly map the following:

1.1 - Dense Natural Vegetation (M)

It approximately embraces 2/5 of the area and presents itself in dark grey tones (almost black).

Due to the penetration facilities in this forest area through the road nº BR-080 (Barra do Garças-Cachimbo),and with the increasing implantation number of Pasture Projects, mentioned before, it could be deduced that this region will suffer a continuous deforestation for artificial pasture formation, what is currently happening as could be seen in the images.

It is known that the forest areas are preferred for the above mentioned purpose because they generally have better soils for artificial

pastures development.

1.2 - "Cerradões" (CC)

"Cerradões" areas are presented in intermediate grey levels tending to the dark. In some images they were not separately mapped because they are strongly mixed with "cerrado" vegetation.

1.3 - "Cerrado" (C)

It was tried to map three units with "cerrado" as follows:

1.3.1 - (C1)

It was characterized because it presents little surface drainage and more rough texture. It is supposed to be more permeable type of soils.

1.3.2 - (C2)

It is characterized by a dense surface drainage system, making us suppose to be a more compact type of soil.

1.3.3 - (Cμ)

It presents a lighter gray level in channel 5. Comparing channels 5 and 7 it is noted an area with a very sparse and humid "cerrado" vegetation, comprised between the Araguaia and Mortes Rivers. There exists in the area several pasture farms leading us to suppose that these humid "cerrado" were used for natural pasture in its great part.

1.4 - Galery Forests

They are easily mapped along the water courses.

2. Artificial Pastures

They are easily seen because of their geometrical forms, principally when localized inside a dense vegetation. When situated in the "cerrado" field zone, due to the lack of contrast (light gray tones) there are not many clearings needing comparisons in the field for a better delimitation.

Calculations of the pasture areas will not be done due to the inadequancy of the ERTS images scale for this kind of study.

IV.4.3.1.3 - Cities

The major cities were mapped based on their radial forms

C-2

and their proximities to roads, but small towns and villages are confounded with other features in the area.

IV.4.3.1.4 - Roads

They are possible to be mapped and are very clear.

IV.4.4 - Other Considerations

1. Through the ERTS image number 1304-5501 (3E), channel 5, it is noted that in the margins of Xingu, Culuene Rivers and others, a lighter tonality appear, contrasting with the dark gray tone of natural forest. It is inferred that they are hydromorphic soils with little infiltration capacity, forming extense lowlands with less dense vegetation related to the adjacent forests. This lowland was planimetered, possessing about 1,185 km^2.
2. Some lagoons present a lighter gray tone similar to those showed by rivers while other seem very dark. It could be explained by the great quantity of suspended material in the first mentioned ones. It is also inferred that those lagoons should have a direct communication system with the river.

IV.5 - IDENTIFICATION OF FORESTAL COVERAGE THROUGH THE ERTS-1 IMAGES

IV.5.1 - Introduction

This work was developed in collaboration with the U.F.V. (Federal University of Viçosa - Minas Gerais State) and the ESALQ (Luís de Queiroz University - Piracicaba - São Paulo State) .

Its main purpose was to determine the capacity of certain remote sensing system to provide useful information to the forestry problems solution, through studies of:

- mapping of native and artificial forests using the data obtained from the ERTS-1 satellite.

IV.5.2 - Materials and Methods

IV.5.2.1 - Materials

The following materials were used:

- ERTS image E-1388-12.205, dated August 15,1973, on the scale 1:1,000,000.
- The same ERTS image enlarged to the scale 1:250,000
- Black and white aerial photographies on the scale 1:30,000.

IV.5.2.2 - Methods

- Test Site

The Ipatinga Test Site was chosen due to its localization between two large rivers: Doce and Piracicaba and related to vegetal coverage it presents a great natural forest named the State Park of Doce River. In this State Park there are lakes with more than 5 km of extension and clues of old lakes where characteristic vegetation developed. Round about this forestal park it was found great Eucalyptus plantations from several growing ages.

This test site is located at the Minas Gerais State presenting the following coordinates: $19^{o}25'30"$ North - $42^{o}25'00"$ East and $20^{o}00'00"$ South - $42^{o}37'30"$ West.

- Approach

An aerial photography mosaic was done in the scale 1:30,000. From this mosaic a basic map of the area was done containing vegetation, drainage, road system information, and so on. This basic map was made from photographic interpretation on the scale 1:30,000. This map presents several types of vegetation verified in the photographies, with some of these areas checked in the field.

In the ERTS image 1388-12.205, scale 1:1,000,000, a localization

of the test site was done and it is shown in figure IV.27. After the localization, this part of the image was enlarged to the scale 1:250,000 - channels 5 and 7 - which were used for interpretation.

IV.5.3 - Results

In this image was possible to identify the following units: old reforestation, new reforestation, natural forest in flat lands and natural forest in rolling lands as shown in figure IV.28.

That interpretation was done basing on gray tones, units geometrical aspects, comparing with the basic map and with some field knowledge. Channel 7 was used to delineate water bodies (rivers, lakes) which present themselves with a very dark gray tone in this channel contrasting with light gray tones of the vegetation. Channel 5 was used to delineate the mapped units limits, considering the gray level and also geometrical aspects of these units.

Related to these parameters, the mapped units appear in both channels as follows:

- The natural forest present itself with an homogeneous aspect related to texture and tonality. It appears in a darker gray tone in channel 5 and in a lighter gray tone in channel 7.

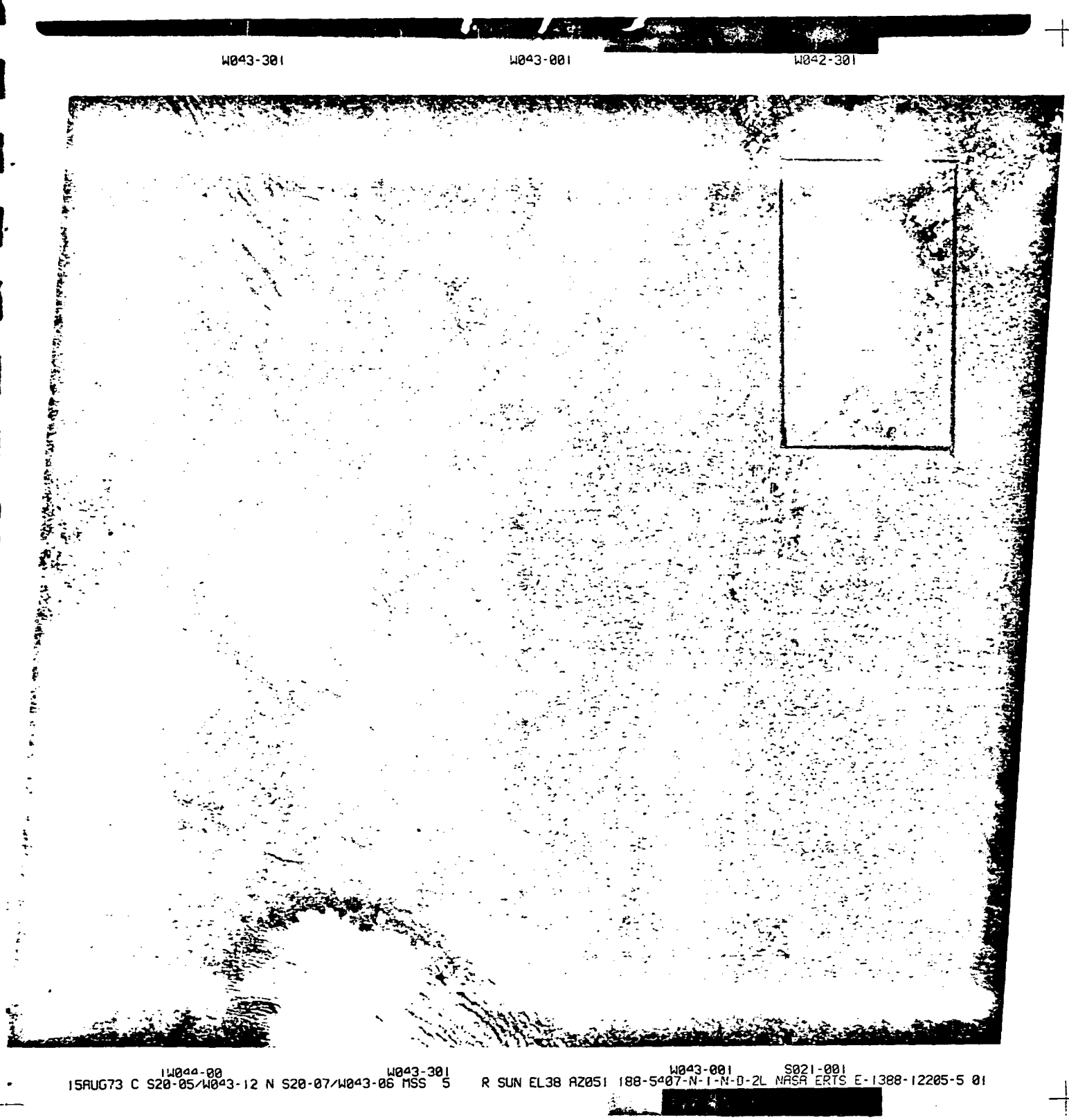


Fig. IV.27 - ERTS image E-1388-12.205 - shows the test site location.

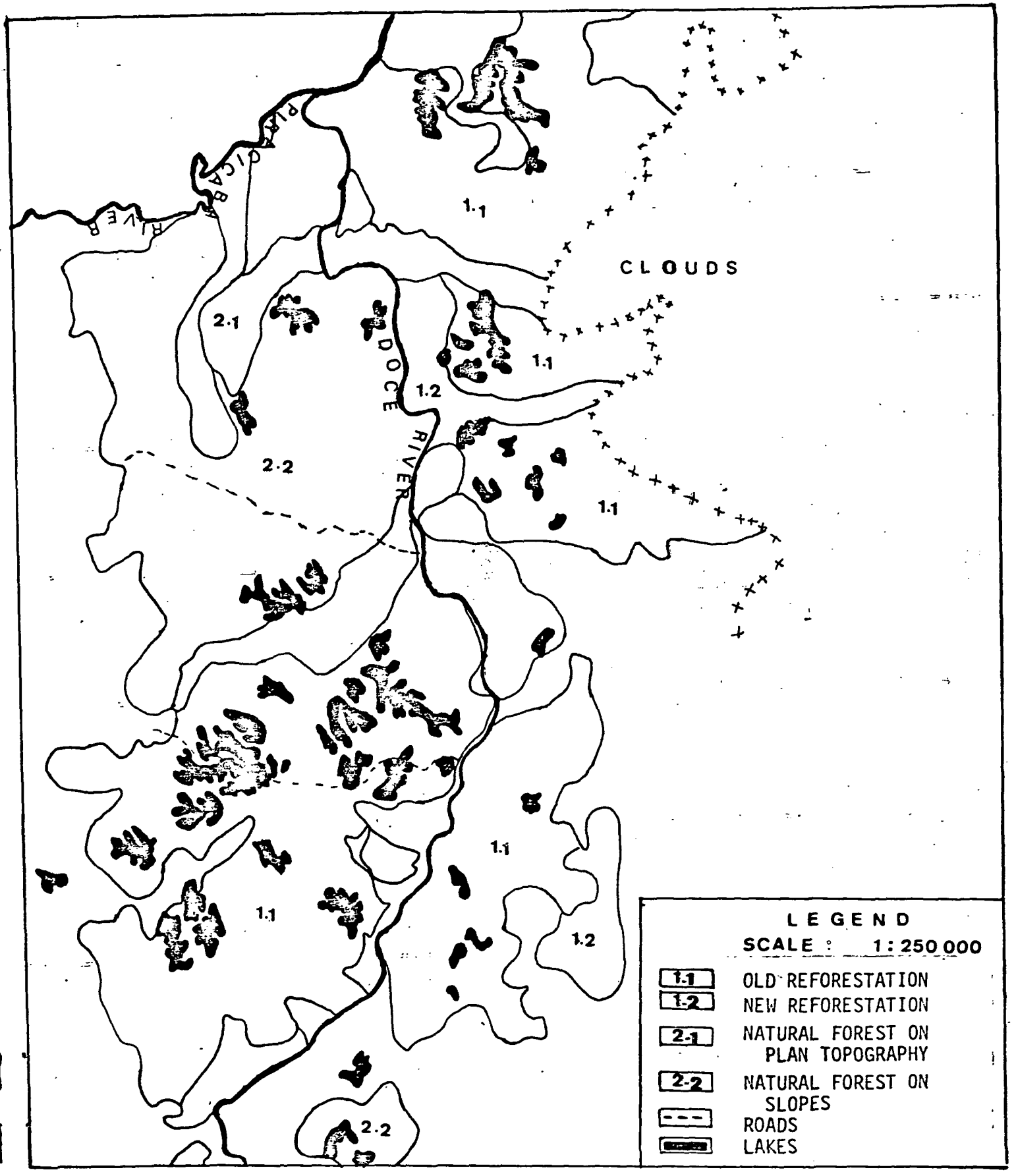


Fig. IV.28 - Thematic map of the Ipatinga Test Site.

- The reforestation appears with an mottled aspect due to the presence of inserted small areas with definite geometrical forms, caused by human activity.

The distinction between old and new reforestation was done considering the responses on both channels. The old reforestation presents itself with a dark gray tone at channel 5 and at a light gray tone at channel 7, while the new reforestation presents itself with a middle gray tone at channel 5 and a light tone at channel 7.

IV.6 - ORBITAL IMAGES UTILIZATION (ERTS-1 AND SKYLAB) FOR - PEDOLOGICAL SURVEYS

IV.6.1 - Introduction

With the appearance of artificial satellites to survey natural resources and the great potential it offers, it was decided to demonstrate the ERTS-1 and SKYLAB capabilities to the pedologic surveying of some type of soils which appear at the South of Mato Grosso State and to the North of Paranã and São Paulo State. The viability of such a project will bring great benefits to the Ministry of Agriculture and to Agriculture State Secretaries for the elaboration of a Brazil schematical soil chart.

IV.6.2 - Test Sites

For the realization of this project test sites were selected in the Mato Grosso State (Dourados and Amambaí region), São Paulo State (Ribeirão Preto region) and Paraná State (Maringá region) as shown in figure IV.29. In these test sites there exist a great variation of soils and are, in their great part, occupied by an intensive agricultural activity, embracing an area of approximately 140,000 km^2.

The relevant facts for test sites selection are the agreements INPE maintains with the Agricultural Secretaries of the above mentioned States. So, researchers from these agencies will contribute providing such ground truth information as well as soil maps in a reconnaissance level of the above referred areas, which will be fit for comparison works with the orbital interpretations.

In the selection of the areas some factors were taken into consideration. Among them we considered the commom elements of different regions and the basic substructure for the soil mapping project development.

These areas will be used as support points to the ground truth missions. These missions consist in the identification of basic

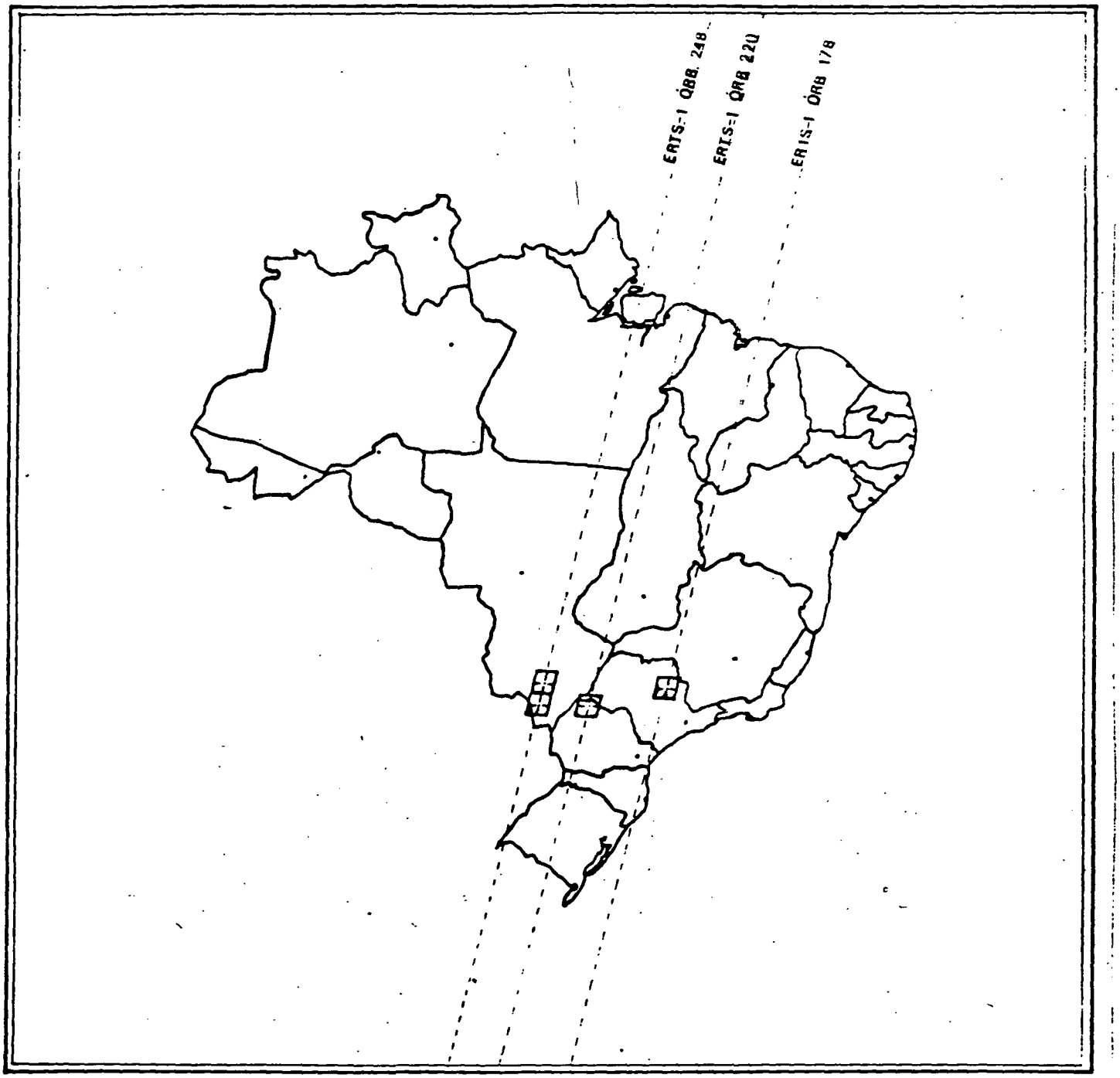


Fig. IV.29 - Test site location.

parameters and their relation to laboratory measurements.

IV.6.3 - Material and Methods

The project will utilize 70 mm transparencies of the MSS/ERTS images on 4 channels and color infrared composite, as well as paper images on the scales 1:1,000,000 and 1:500,000.

The infrared color SKYLAB transparencies and compositions done with MSS transparencies will be used as support to preliminary interpretations of different types of soils basing on the different spectral responses of the areas under study.

The methodology to be used is based on bibliographical information of regional works related to the test sites under study. Contacts with local research institutions will be carried on.

During the ground truth missions for the gathering of ground truth data these will be surveys of physical, temporal and spectral parameters of the interested target. Soil sample's collection (which will be submitted to physical, chemical and spectral laboratories analysis) will be related to bibliographical information and soil maps of the areas under study. This process aims at the establishment of limits occupied by the different types of soil through ERTS images.

After the preliminary images interpretation related to soil types, densitometric measures will be done of the respective patterns and submitted to a computer program for a possible boundary correction.

Soil maps of the different test sites will be done as final products following classical presentation patterns aiming at a practical and immediate utilization by the users.

IV.7 - STUDY OF THE CHANGES IN THE LAND USE ASSOCIATED WITH THE "TRANSAMAZÔNICA" ROAD DEVELOPMENT, USING ERTS-1 IMAGES

IV.7.1 - Introduction

The "Transamazônica" road crosses regions with great climate, soil types and vegetal variations, from the Brazilian coast to the frontier with Peru.

The deforestation along this road occurs in large intensity caused by the human settlements in this road region. It is really important to carry out studies to follow the ecological changes caused by the deforestation and the consequent land use by man associated with the "Transamazônica" road development.

The ERTS images permitted a regional study of these changes and its repetitivity will permit the follow up of the pasture projects development during one year period.

This work is practically in its initial phase and in collaboration with the "Escola Superior de Agricultura Luís de Queiroz" (Luís de Queiroz Agriculture University) and with the Amazon Development Office - SUDAM.

This study will be based on the ERTS-1 images visual interpretation on the scale 1:1,000,000, and occasionally image enlargements to the scale 1:250,000 in channels 5 and 7 in more detailed studies. RADAR mosaics, available at scale 1:250,000, will also be utilized. The approach to be used in this interpretation is of a multidisciplinary character to permit an ecological estimation which should be done at every 6 months interval.

IV.7.2 - Methodology

The main objectives of this project are:

- To study land use development represented by pasture, crops and forests.
- To study erosion resultant of deforestation.
- To determine sediments source and flow as results of this mentioned deforestation.

- To study the "Transamazônica" road influence over the environment.
- To estimate changes in rural and urban patterns.

IV.7.3 - Activities already done

As previously mentioned, this work is in its initial execution phase.

Up to now a survey of all the ERTS images covering this specific area was done.

Afterwards a preliminary study was done of all the test sites to establish relevant areas in view of the great human occupation as well as to good ERTS images availability to this region.

IV.8 - PASTURES EVALUATION BY ERTS IMAGERY (MULTISPECTRAL REMOTE SENSING APPLICATION IN RANGELAND CAPABILITY EVALUATION FOR GRAZING)

IV.8.1 - Introduction

Animal production is still the main protein resource to

supply man's needs. Ecologists, botanists and economists are always working hard to give range managers new and important information to manage ranches in the most efficient way. Almost 90% of the livestock production of Latin America is dependent on natural range grassland, but the mentality of conservation of natural grazing lands is not deep-rooted (3). The shortage of meat and milk in the Brazilian market raises the need to look for a more efficient technology to evaluate the range resource capability for grazing. It is vitally important to have an accurate up-to-date knowledge of the structure, use and condition of the vast areas of the Brazilian natural grazing land. The job is very complex and expensive, that is why it has never been done.

Remote sensing techniques offer up-to-date information and rapid feedback on changing environmental conditions. It is also necessary to know what season of the year, difference in characteristics can best be detected, on which kind of film, and using what filters (1). We want to demonstrate that remote sensing techniques can do this job more efficiently with fewer specialists over a shorter time period for large areas. Multispectral analysis was used to obtain information for a two-year-protected native pasture, by flying over the area with a multispectral cameras system from an altitude of 500 meters above the ground.

IV.8.2 - Methodology

The chosen area is located inside INPE's test site in Cachoeira Paulista, 200 kilometers from São Paulo. The vegetation cover is mainly a grass known in Brazil as Capim Gordura (Melinis minutiflora) and very few mixed areas of Capim Colonião (Panicum maximum). The two main invaders are Sapē (Imperata brasiliensis) and Vassourinha (Baccharis rufescens). Taboa (Thyfa sp.), an unpalatable plant, indicates the presence of highly humid lowlands soils, and a high water table. Some other species appear in some scattered plots because of the human use of this area before it was placed under protection. Napir elefante (Pannisetum purpureum), Batatais (Paspalum notatum), Bambu and some bushes appear in the area also. During June-September, the dry season of São Paulo State, the palatable species such as (Melinis) are usually dry having lost their leaves after the flowering stage and the seed apreading stage. The invaders such as Sapē and Vassourinha stay fresh and strong extracting their needs from soil moisture but provide a less dense canopy cover. The dry season was chosen for the flight because of the contrast between palatable and unpalatable plants. Laboratory spectrophotometer analysis was done to study the leaf reflectance along wavelength bands, using a Perkin-Elmer 450 model, with integrated sphere. In the growing stage of both (Melinis) and (Imperata), the leaf reflectance curves (Fig. IV.30), show high chlorophyll absorption around 500 and 650 mμ wavelength. But (Melinis) shows higher absorption than (Imperata). (Imperata) has the same reflectance curve pattern as (Melinis), but it is

displaced about 10 mμ towards the shorter wavelength, in the all bands, comparing with (Melinis) curves. Using this information an estimated leaf reflectance curve was established (Fig. IV.31). It showed that there is high contrast between areas covered by (Imperata) and (Melinis) in the spectral regions of 500, 600 mμ and after 700 mμ . For this reason four filters have been chosen to be used with the selected films, (Table IV.3). The combination of filter transmissions and plant reflectance curves are also illustrated (Fig. IV.31).

The flight took place on the 6th of July 1973, using a Hasselblad 500 EL/70mm system from an altitude of 1500 feet. Photos at a scale of 1:9144 were thus obtained. Four filters were used: yellow, orange, red and Kodak Wratten 89B. The primary purpose of the yellow filter is the correct reading of those color tones in the gray value. The orange filter is more contrasted filter and over corrects for the blue sky, so that, sky tones become darker than they appear to the eye and distant details appear stronger. The red filter goes further in over correction (4). Table IV.3 shows the flight parameters. The operation time was around 12:00 o'clock to avoid vegetation shade.

IV.8.3 - Interpretation

The data was collected from four bands, each filter transmitting information about the ground cover. The summation of the

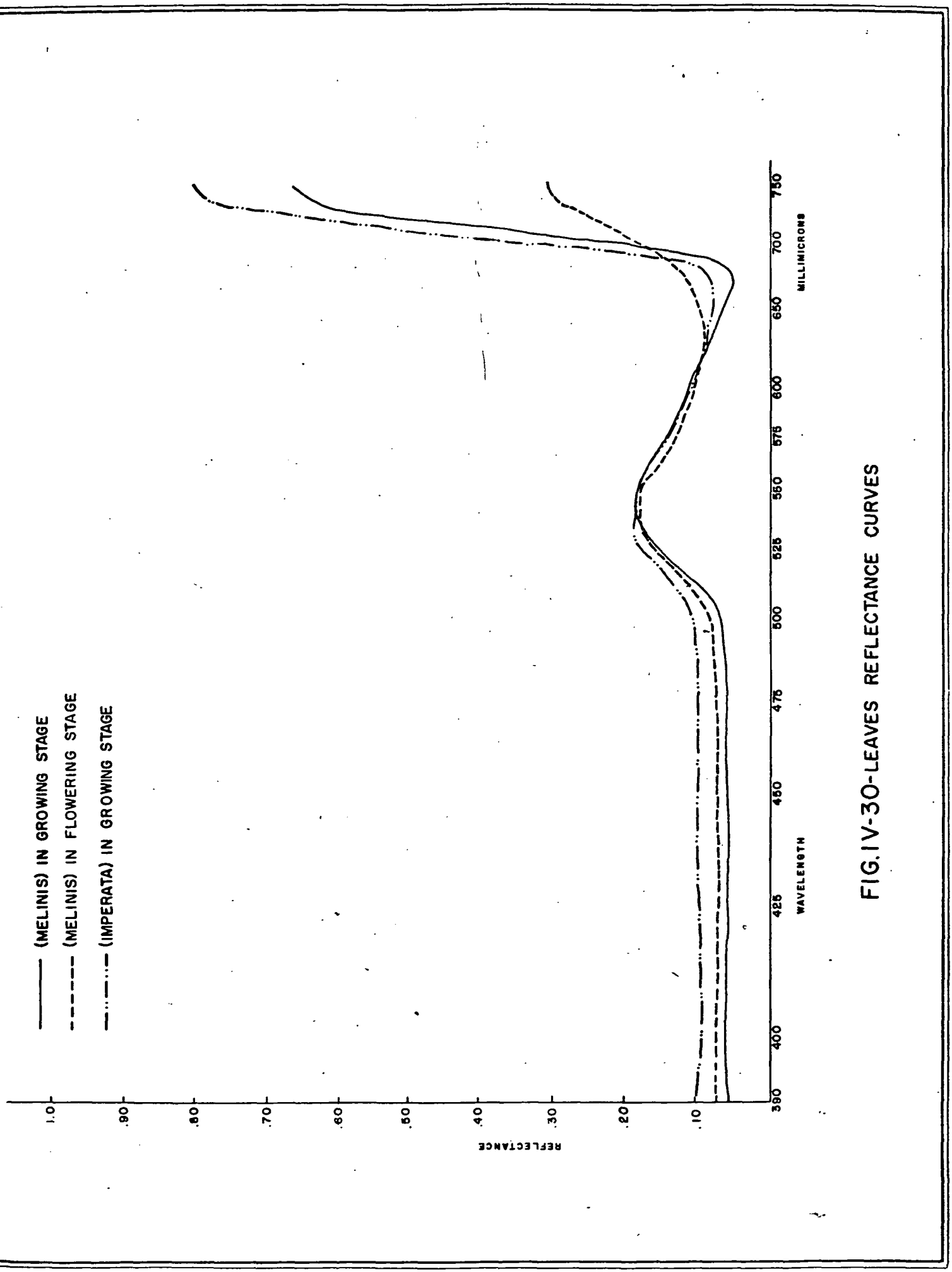
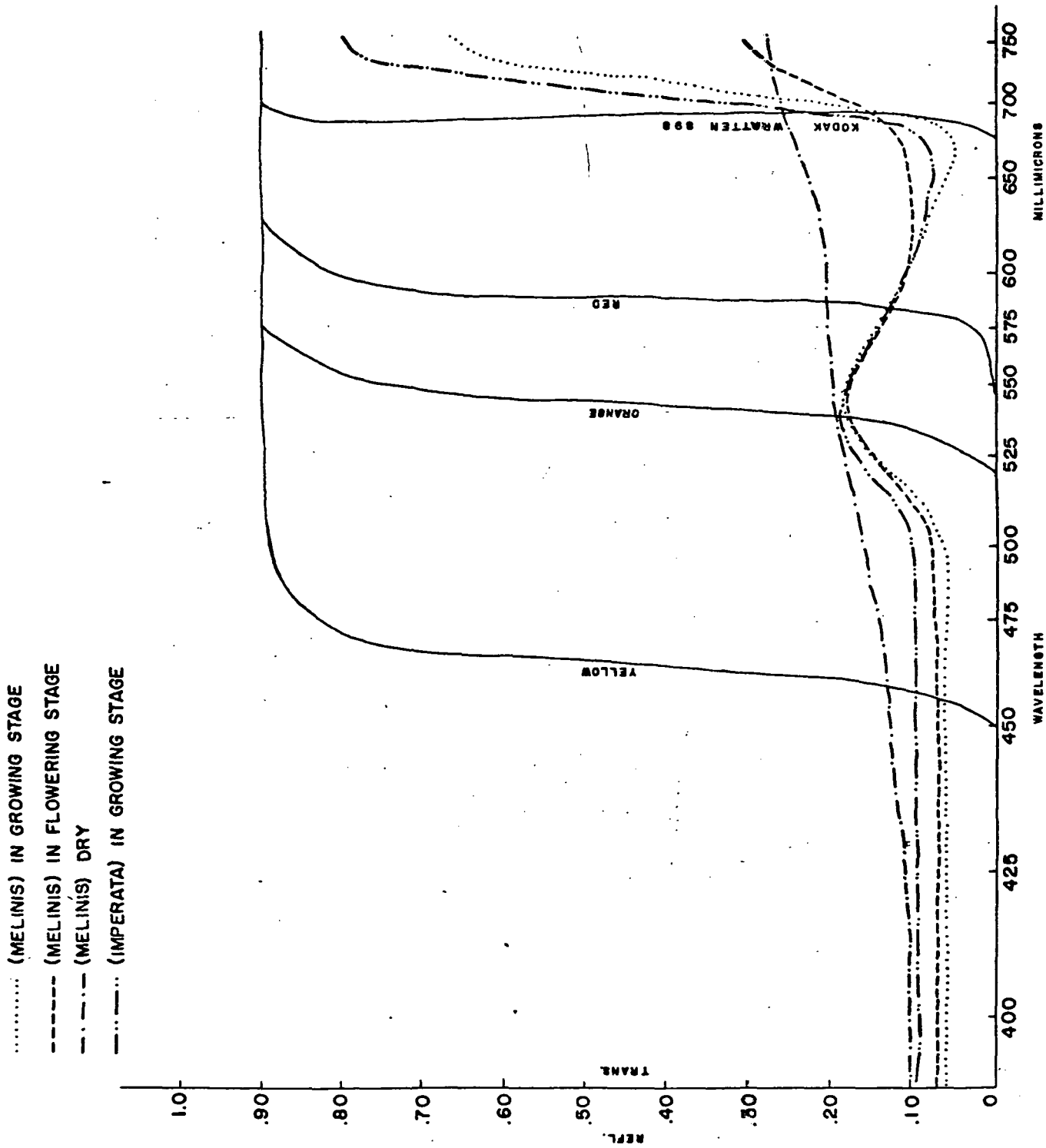


FIG. IV-30-LEAVES REFLECTANCE CURVES



-FIG.IV.31- COMBINATIONS BETWEEN PLANT REFLECTANCE AND FILTER TRANSMISSIONS ALONG THE WAVELENGTH

TABLE IV.3

FLIGHT PARAMETERS

Relative Altitude: 500 meters

Date: July 6, 1973

Time: 12:15 local time

FILM	FILTER	VELOCITY	APERTURE OF DIAPHRAM OR f/STOP
Plus-X Aerographic 2402 Estar Base SP 494	Yellow	1/250	f/11
Plus-X Aerographic 2402 Estar Base SP 494	Red	1/250	f/8
IR-Aerographic 2424 Estar Base SP 494	89B	1/250	f/8
Aerochrome IR 24443 Estar Base SP 494	Orange	1/250	f/4

data obtained from the four bands made accurate and efficient interpretation possible. The yellow filter transmits reflected radiation by the plant surfaces longer than 0.45μ wavelength. The red filter eliminates reflected radiation in wavelength shorter than 0.575μ . Thus the red filter gives information in a more contrasted format than the yellow by absorbing some information that appears with the other filters. This facilitates the interpretation by emphasizing a smaller quantity of data. It is important to remember that the other filters must be used to obtain the information screened out by the red filter.

Another parameter which has to be considered is the film sensitivity to the different wavelength radiations. The aerographic infrared film with Wratten 98B filter is sensitive to wavelength longer than 0.7μ. This band gives the plant condition from the physiological point of view. Thus for the healthy dense plants the response will be dark on the positive transparency. If the plant is not dense enough, therefore, permiting the film to receive soil high reflectance in the visible portion, it will be presented as light red. If the plant looses infrared reflectance the positive image will be more cyan to green. Figure IV.32 shows this reaction on the area covered by dry (Melinis) which appears green on the color infrared image and dark on the black and white.Areas covered by (Imperata) appear pink to white because of the lighly dense canopy cover on the colored infrared and, in light gray scales on the black and white infrared image. The high moisture content areas appear in darker tones because of the low soil reflectance. A comparison between the plant reflectance patterns, and

filter transmissions curves allowed the establishment of an interpretation key to obtain the requested results.

The color infrared film has three sensitive layers. The bottom one is sensitive to red reflected radiation and responds in magenta color on the positive transparency. The middle layer is green sensitive and shows up yellow on the positive image. The top layer is infrared sensitive and shows in cyan on the positive image (6).

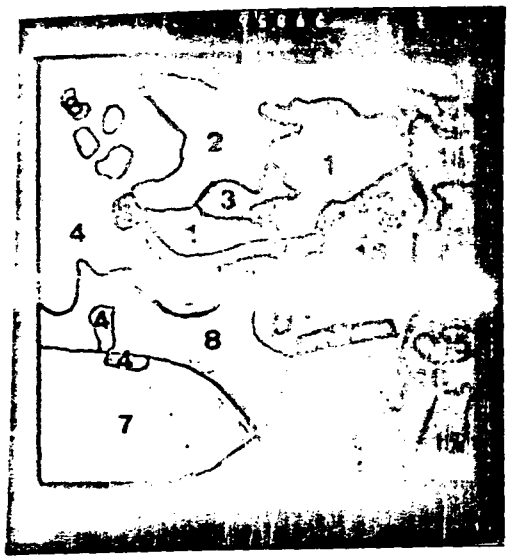
IV.8.4 - Results

Figure IV.33 shows the final map of rangeland capability for grazing. The area could be classified into four classes:

Class A - Areas which are able to receive animals for grazing immediately during the rainy season. These areas are covered by such palatable species as Capim gordura (Melinis minutiflora), Colonião (Panicum maximum), or Napir elefante (Pannisetum purpureum).

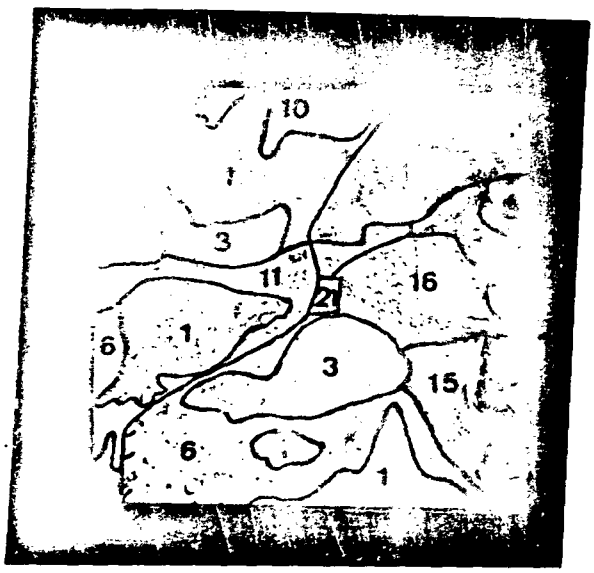
Class B - Areas which are not available for grazing because they are occupied by unpalatable species. These invaders are mainly Sapé (Imperata brasiliensis), Vassourinha (Bacchoris rufescences). Batatais (Paspalum notatum) or other bushes. The range manager can think about improving his range by controling the invaders.

Class C - Areas which are in need of land reclamation before grazing because they are suffering from drainage problems. These are classified by

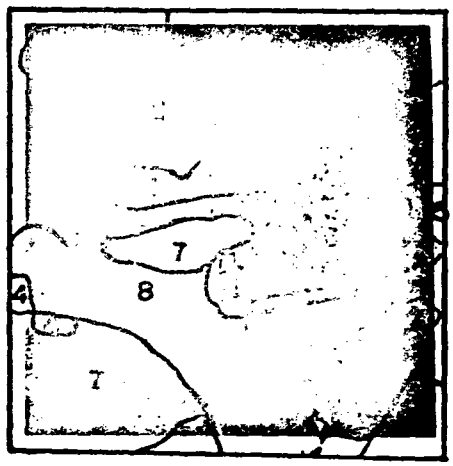


Panchromatic Film
with
Yellow Filter

Panchromatic Film
with
Red Filter



IR-Aerographic Film
with
Wratten 89B



Aerochrome IR Film
with
Orange Filter

Fig. IV.32 - Multispectral photos of the same area in four film/filter combinations.

SCALE : 100 0 100 200m

LEGEND

CLASS A

CLASS B

CLASS C

CLASS D

FIG. IV - 33 - RANGELAND CAPABILITY MAP

vegetation type cover. Taboa (Thypha sp.) is the indicator of high water table soils.

Class D - Uncovered areas which are occupied by roads, water channels or buildings.

On the map there are some areas which are presented in a mixture of Class A and Class B, this means exactly that they are covered by a mixture of palatable and unpalatable species. This highlights an important decision to be faced by the rangeland manager: whether to control the invaders first and then institute system, or to use the area for grazing directly, considering that it has 50% palatable plants, or 50% of the carrying capacity of an area of Class A type.

Two unclassified areas are shown on the map because of the appearance of cloud shade on the photos.

Table IV.4 shows the detailed classification into 21 categories and how they are summarized into four classes.

IV.8.5 - Conclusions

Different plant species could be identified by multispectral remote sensing during an adequate period of the year. The combination of information obtained along different wavelength bands provides essential data for the range manager to evaluate his range and to establish a suitable policy. A red filter with aerographic plus-X film (Panchromatic) gives more contrasted information, in this period. Plus-X film with yellow filters

provides a general idea about the green cover. Infrared black and white and color infrared films give specific information about plant condition, stage and maturity and show if the reflected surface is a living fresh body due to the high reflectance of the cell, walls and shape, in this band. Multispectral analysis gives integrated data. Choosing the right season for multispectral remote sensing operation is the most important factor to get useful results. This choice depends on the range manager's requirement for grassland evaluation. Application of remote sensing in range management decreases the number of specialists needed, decreases the time necessary for data collection and analysis, and replaces a major part of the field work to be done, but requires highly efficient interpretation, of the images. Remote Sensing techniques provide the range manager with real time information, but he should become acquainted with how to use this data to optimize his rangeland use.

IV.8.6 - Further Applications

More research and publications are necessary about the application of remote sensing in the range management field. Spectral properties of plants in the range are required to enable the selection of the right sensors, altitude and combination between film and filters for each purpose are required studies. Estimating the carrying capacity, grazing pressure and calculating the pasture productivity through the application of remote sensing are important further applied research.

TABLE IV.4

SUMMARY OF RANGELAND CAPABILITY FOR GRAZING

CLASSES / CATEGORIES	A	B	C	D
	1. Melinis 2. Melinis mixed with Colonião 3. Dry short Melinis 4. Very short Melinis 80% ground cover 5. Pannisetum	6. Imperata 7. Imperata with 5% red top leaves 8. Imperata on slopes 9. Baccharis 10. Imperata mixed with melinis 11. Bushes 12. Melinis mixed with bushes 13. Paspalum	14. Thyfa 15. Thyfa mixed with Imperata 16. Thyfa mixed with bushes 17. Bambu	18. Bare soils 19. Water channels 20. Roads 21. Buildings

IV.8.7 - References

1. ARNOLD, R. D., "The Environment - Where Do We Stand? From the Vantage Point of Space". J.Range Management 25:413-414 (1972).

2. BLYDENSTEIN, J., "Developing Range Management in Latin America", J. Range Management 25:7-9 (1972).

3. CARNEGGIES, D.M. and J.N. REPPERT. "Large Scale 70mm Aerial Color Photography". Photogrammetric Engineering. Vol. 35 Nº 3:249-257.(1969).

4. DRISCOLL, R.S., et.al. "Identification and Measurement of Herbland and Shrubland Vegetation from Large Aerial Color Photographs" Proceedings of the XI International Grassland Congress: 95-98 (1970).

5. FREYTAG, H. "The Hasselblad Way". The Focal Press. London and New York. 423 p. (1973).

CHAPTER V

GEOGRAPHY

CHAPTER V

GEOGRAPHY

V.1 - ACTIVITIES OF THE GEOGRAPHY GROUP RELATED TO THE USE OF ERTS IMAGES

The Geography Group using the ERTS-1 images for natural resources studies developed its activities in two phases. Firstly, the black and white images, of the four channels, were analyzed and the group concluded that for the type of Geographic investigations carried by the group, the largest amount of information was contained in channels 5 and 7. This conclusion was based on direct visual inspections of the earth's surface spectral responses on ERTS-1 images in the scale of 1:500,000. Thus, the interpretation of the images followed the conventional procedures used for regular aerial photographies and the results were checked against available cartographic and bibliographic information.

At a second phase it was possible for the Geography Group to develop two projects using only the ERTS-1 images. Their preliminary results will be presented next:

V.2 - GEOMORPHOLOGICAL MAPPING OF THE UPPER SÃO FRANCISCO RIVER BASIN

V.2.1 - Introduction

The area studied is covered by the Belo Horizonte Chart of

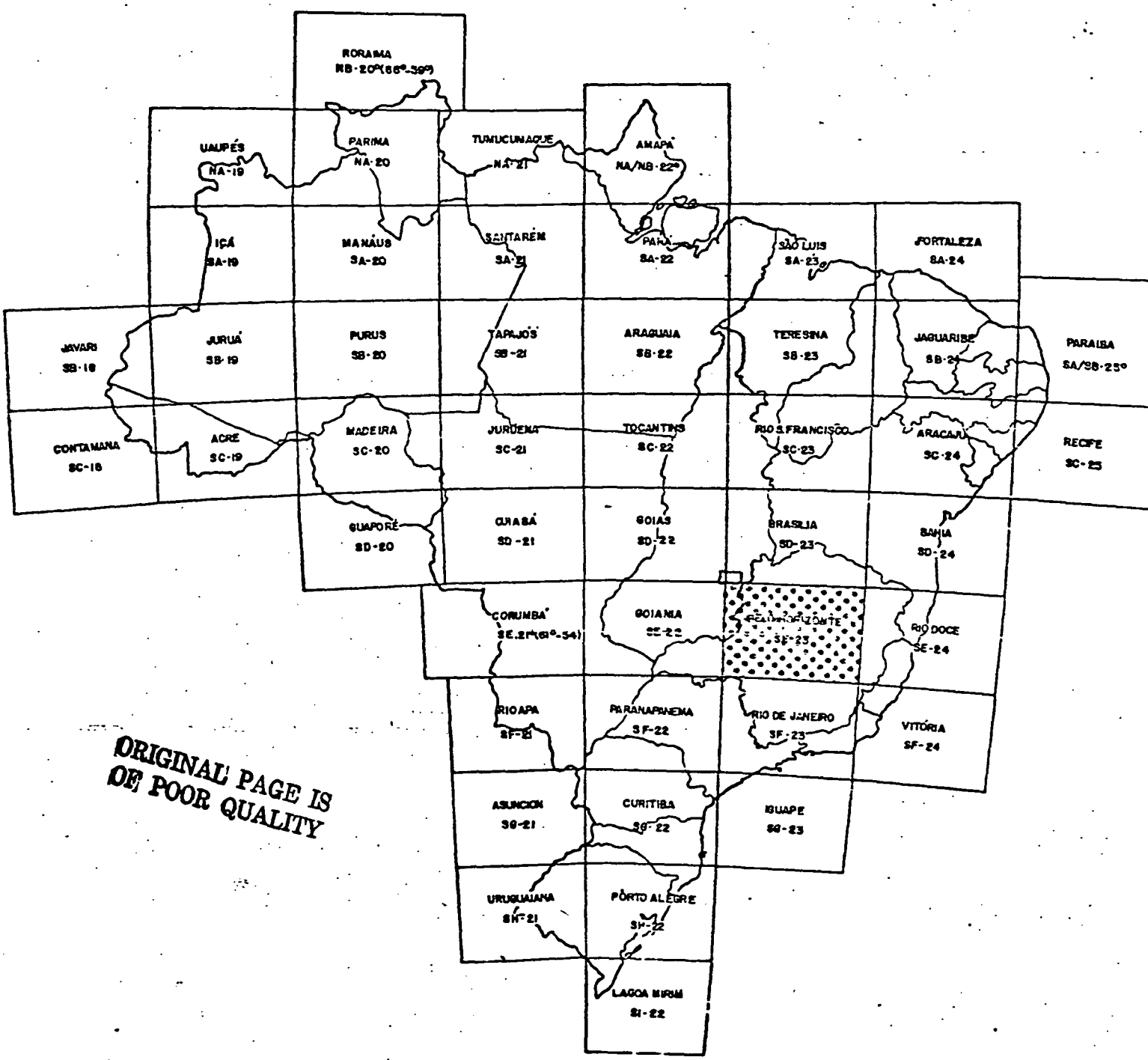


Fig. V.1 - Localization of the Belo Horizonte Chart in the Brazil map.

the 1:1,000,000 cartographic coverage of the Brazilian territory (Fig. V.1). This specific zone was chosen because it allow the concentration of studies of geology, geomorphology, vegetation and soils presently being developed by the SERE Project of INPE. It displays an interesting diversity of ecological characteristics and consequently can be considered particularly suitable to generate identification and interpretation keys for geomorphological and natural resources surveys based on remote sensing imagery.

V.2.2 - Materials and Methods

The basic material used to prepare geomorphological maps were the ERTS-1 images on the scale 1:1,000,000 in channels 5 and 7. A mosaic was also done for the area under study in the same scale and respective channels aiming to obtain a global vision and the articulation among the geomorphological units to be mapped.

As auxiliary material to support images interpretation use was made of geological, topographical, vegetation and soil maps as well as available bibliography.

Channels 5 and 7 were considered the most useful to geomorphological mapping because channels 4 and 6 do not present a contrast level to make possible the geomorphological units distinction.

It was observed that channel 7 furnishes information for mapping the different types of scarps, lineaments and other structural

features. The water bodies appear well delineated in this channel facilitating their delimitation by water absorption in the infrared band of the electromagnetic spectrum.

Secondary drainage is mapped in channel 5 through the ciliary forest that absorbing radiation in wavelengths from 0,6 to 0,7μ will appear dark.

Comparing these two channels it is possible to have an idea of the vegetation cover. The grey tones at the different 5 and 7 channels will indicate the grade of vegetal density. Through textural differences it is possible to obtain information related to relief erosion degree.

Drainage, grey tone and texture permit initial delimitations of geomorphological units.

For each type of desired information an overlay was done. Thus for each image we studied the drainage system, grey tones, texture and structural characteristics. Superimposing these overlays it was possible to delimitate the geomorphological units.

The additional necessary information of altimetry were obtained through schematical profiles in the images, compared with topographical profiles of the Belo Horizonte Chart. Through the comparison of data and delimitated units in the images it was possible to obtain the altimetric amplitude of the relief area.

V.2.3 - Interpretation Criteria

The adopted criteria for geomorphological interpretation were directly based on image characteristics and bibliographic examination.

a - Drainage System

Through spatial drainage arrangements it is possible to infer a series of important facts to relief forms mapping. A drainage system of a region reflects its structure, permeability, topography, vegetation, etc.

The ERTS-1 image permits a synoptical vision of the drainage system thus furnishing a preliminary separation of geomorphological units. A dendritic pattern, for instance, provides information about a region's declivity, permeability and predominant fluvial geomorphical processes.

b - Structural Characteristics

To the delimitation of geomorphological units the presence of faults, scarpments, circular structural surfaces, folds, alluvial slopes are important when associated to a drainage system.

c - Information on Morphoclimatic Systems

The interaction among the morphoclimatic systems and

structural conditions and lithology define morphogenetic systems. So in macrocompartments, from local variations of structure and climate, it is possible to infer morphogenetic systems.

d - Altimetry

The relative compartment's altitude as well as the uneveness amplitude are important information to a final geomorphological interpretation composition. These data could not, at this moment, be quantitatively defined in the image, but could be infered by the behavior of other information which the image can offer.

From these criteria an interpretation was done of the mapped units and a compatible geomorphological legend adopted with a chosen scale. The mapped units are described in terms of the characteristics presented in the image and of the possible corresponding characteristics in the soil.

V.2.4 - Results

The geomorphological mapping using ERTS images, considering the scale and the absence of stereoscopy, restrict itself, at the moment, to the great relief structural compartments or macrogeomorphological units, permitting the principal types of inference of the dominant morphogenetic processes.

As an example, to have the interpretation of two images in the channels 5 and 7 of the area under study, figures V.2, V.3, V.4, V.5 were selected by their great potentiality showing practically almost all the geomorphological units types occuring in the area comprised by the Belo Horizonte Chart. The area corresponding to these images is shown in figures V.6 and V.7.

Generally speaking the area covered by the Belo Horizonte Chart presents a satisfactorily differentiated relief shaped in Pre-Cambrian and Paleomesozoic rocks.

Through image analysis it was possible to find large compartments as well as to differentiate the regional sub-units (Fig. V.8) listed as follows:

A - The Plateaux and the Espinhaço Range (Serra do Espinhaço)

This is a well defined unit in the image because of its distinct photomorphological characteristics from the rest of the area.

Due to its structural and geomorphological complexity there appears several texture types, tonalities and the drainage pattern varies from sub-dendritic to parallel.

Geologically speaking it is formed by soils of the Minas and Lavras Series constituted by tilits, quartzites, phyllites, sandstones and metasandstones.

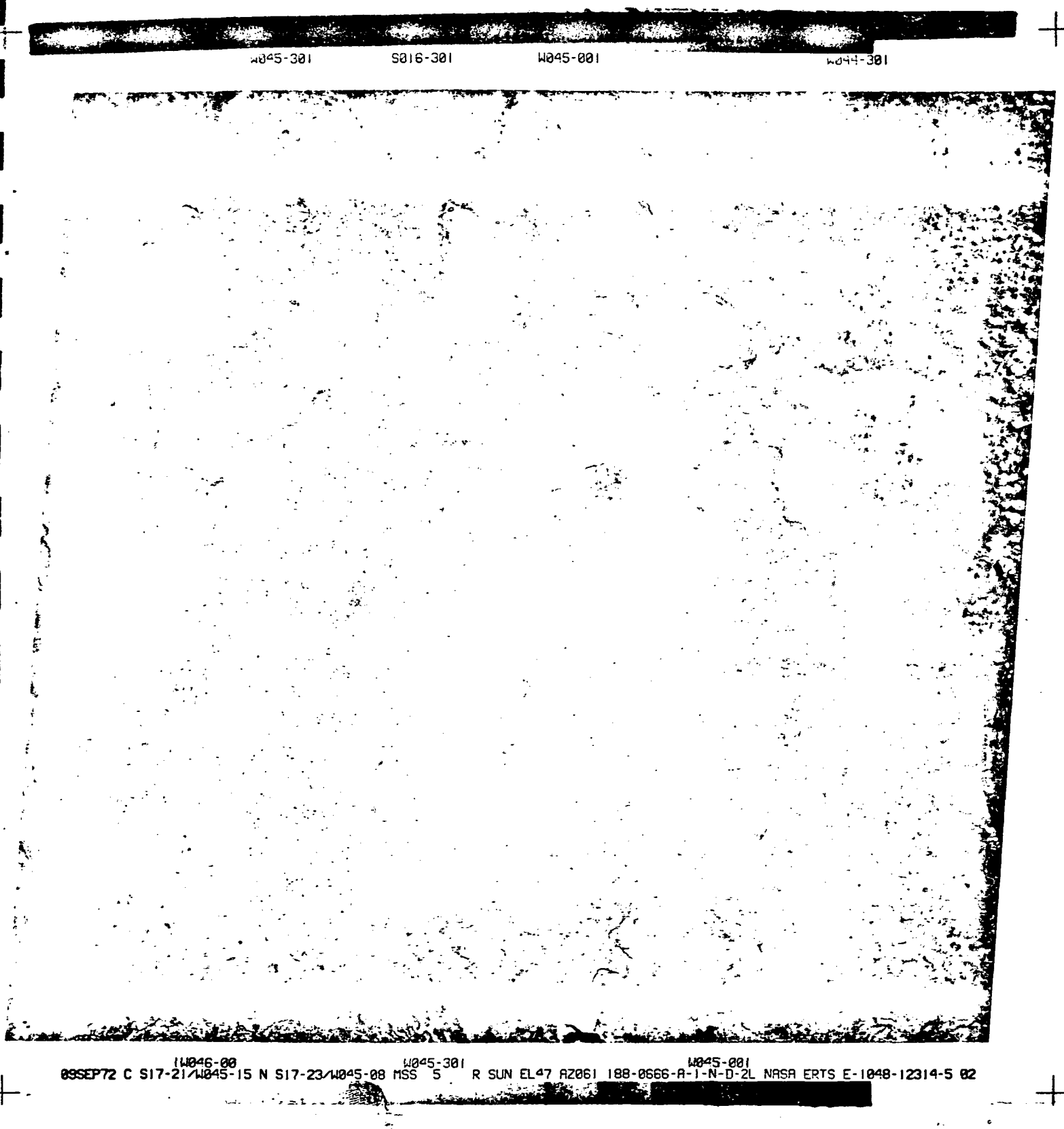


Fig. V.2 - ERTS image E-1048-12.314 - Channel 5.

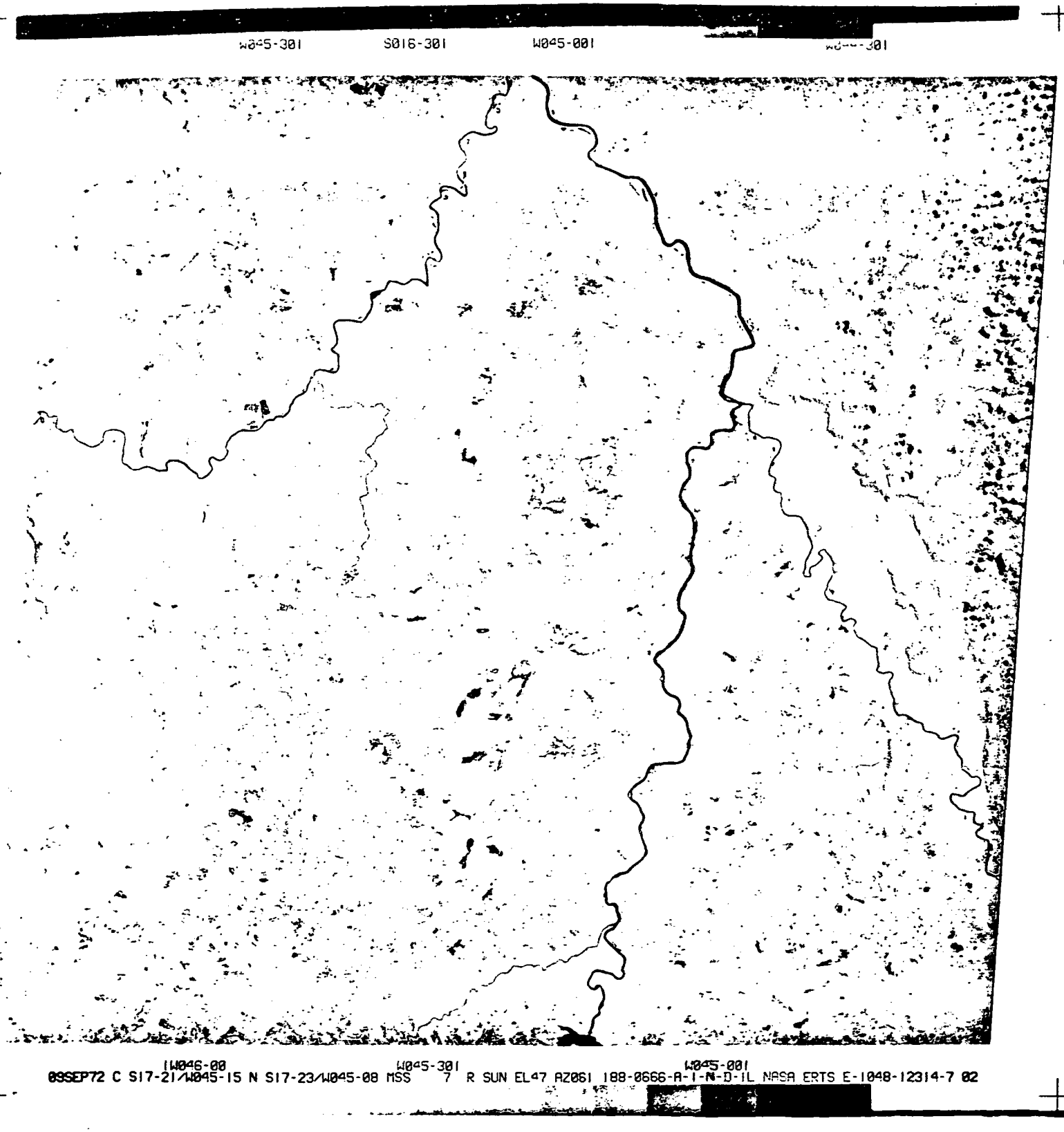


Fig. V.3 - ERTS image E-1048-12.314 - channel 7.

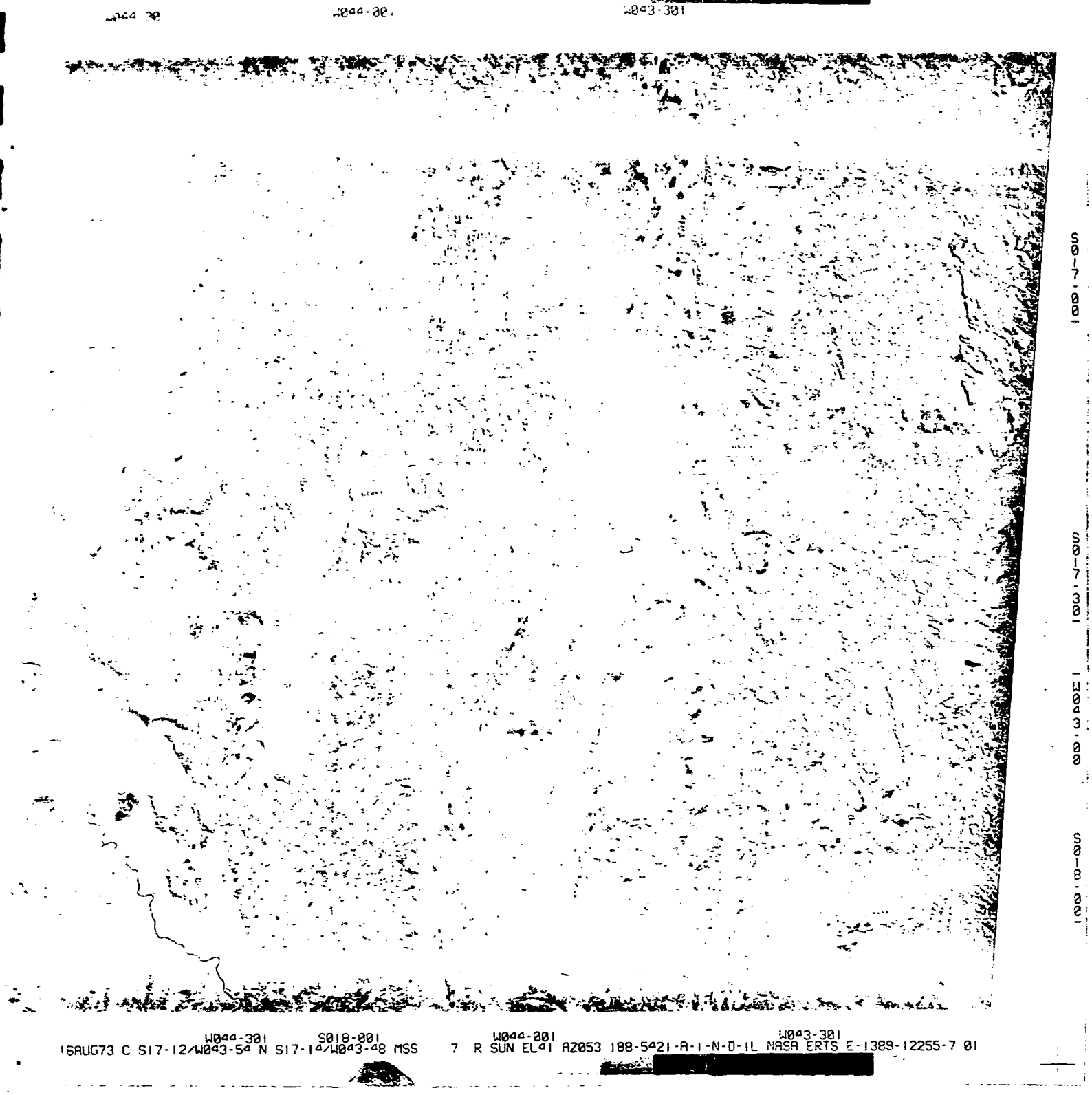


Fig. V.4 - ERTS image E-1389-12.255 - Channel 5.

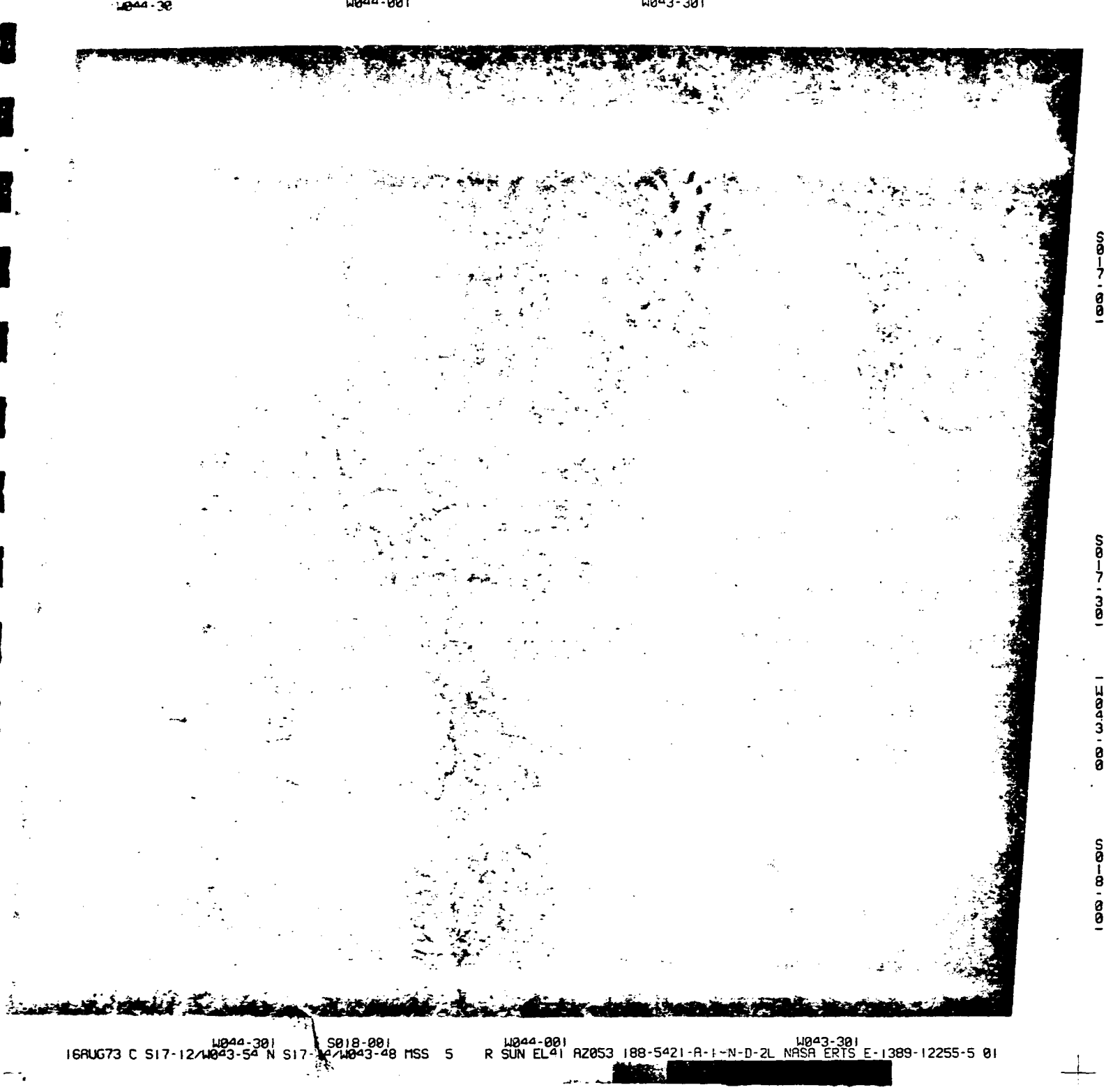


Fig. V.5 - ERTS image E-1389-12.255 - Channel 7.

Westerly it is delineated by a distinct fault scarpment forming an abrupt contact with the Bambuí Series rocks. This unit represents the water divisor between the rivers flowing to the São Francisco River and the ones draining to the Atlantic Ocean, represented here by the Jacuí River drainage and its tributaries. Easterly the drainage is represented by the Jequitinhonha River and its tributaries. Although it appears as a macro unit, it does not present a lithologic geomorphological or paleogeographic unit presenting individualized sectors as:

1 - Relief with Parallel Crests

The relief appears in the image with rough texture showing great variety of alignments, with predominant North-South direction. Their grey tones are dark in channel 5 and lighter in channel 7, although appearing in this channel as dark gray when compared with adjacent areas.

The drainage system is relatively dense and many rivers present a clear structural control.

This is the sub-unit which takes up great extension in area and it is a typical Appalachean relief with phases of the Jurassic type or inverted, where appears a sequence of parallel and sub-parallel quartzitic crests that resisting erosion give to the group a montainous and sloped relief, associated to a fault, fractures and folding system.

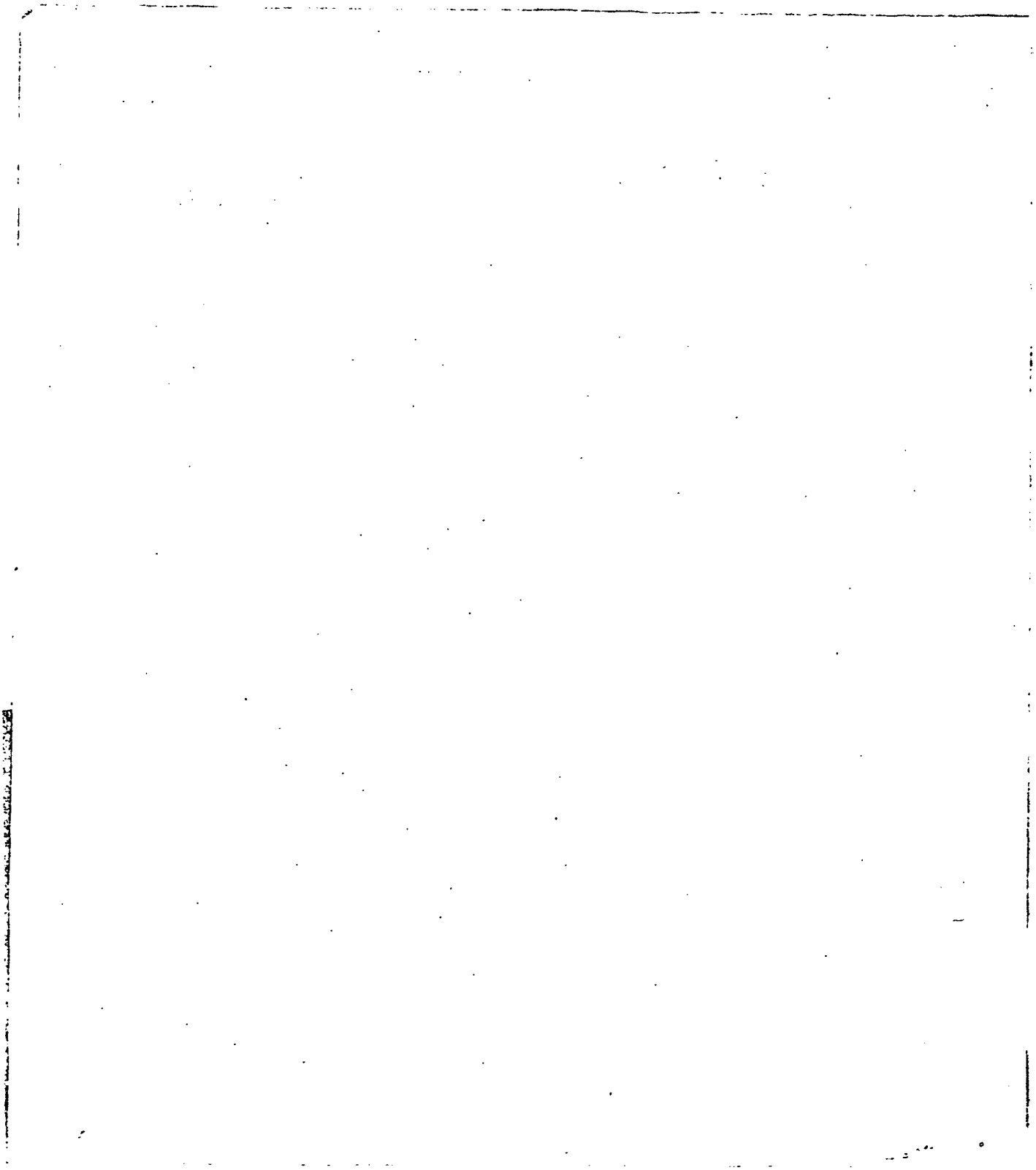
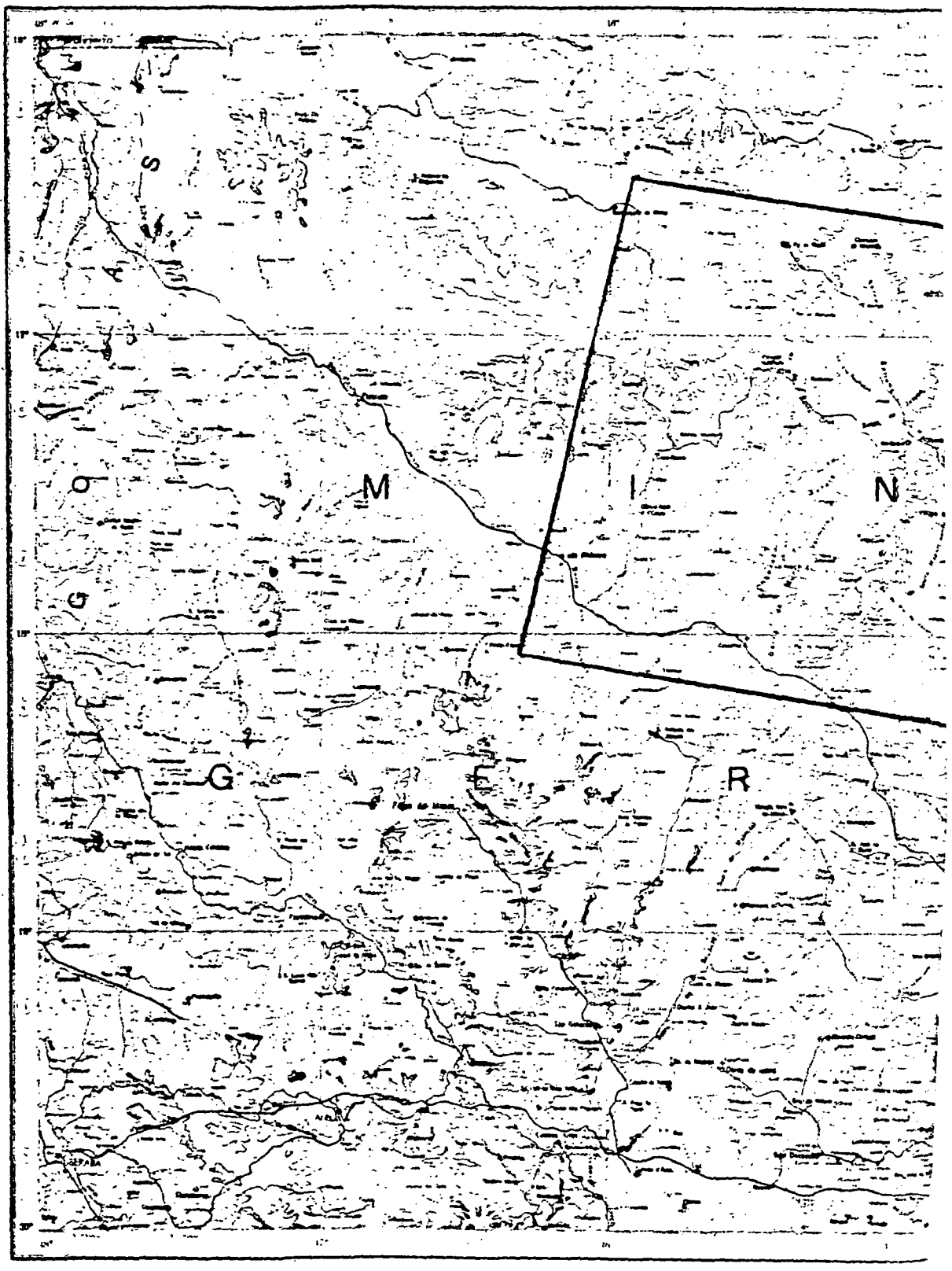
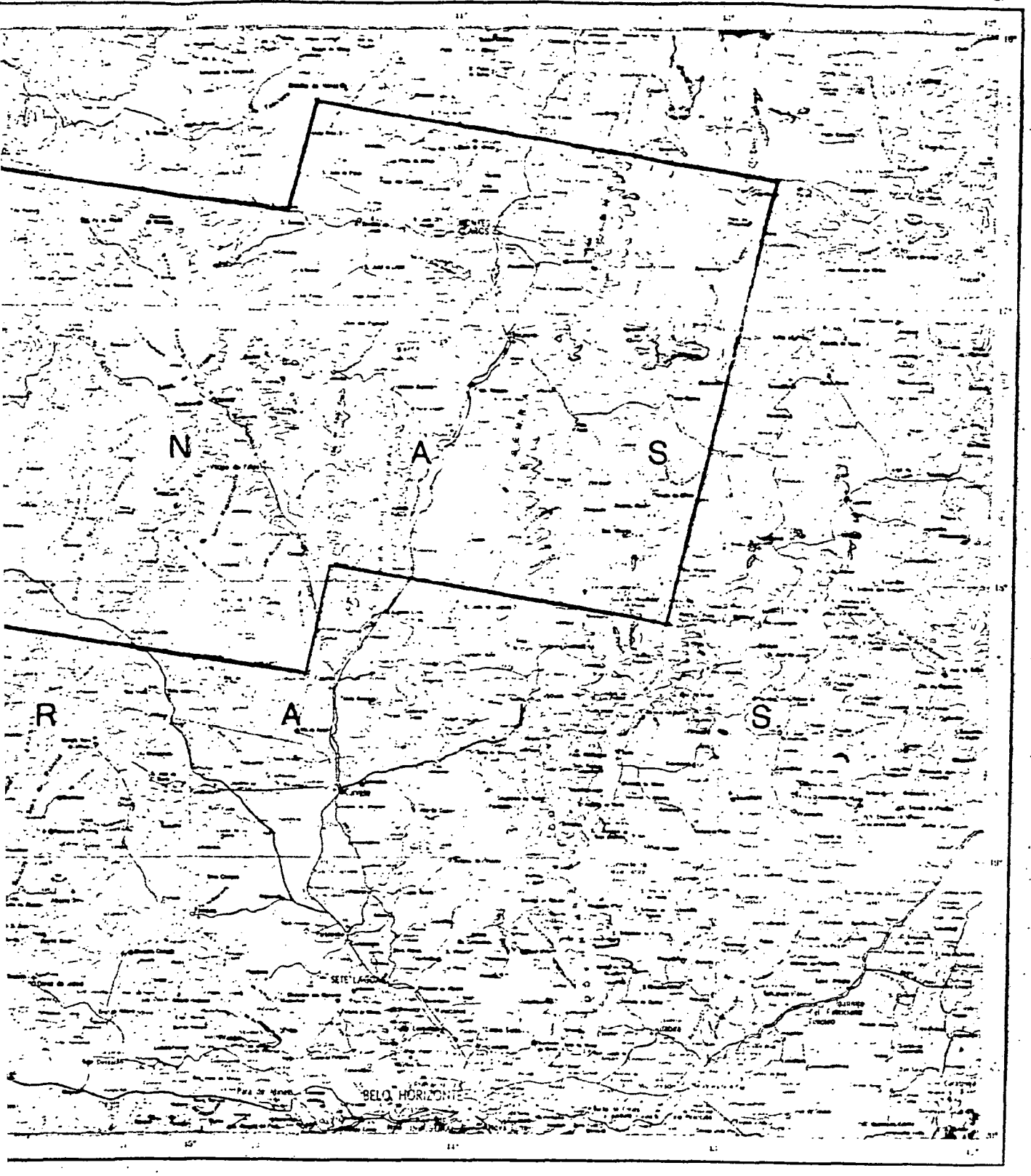


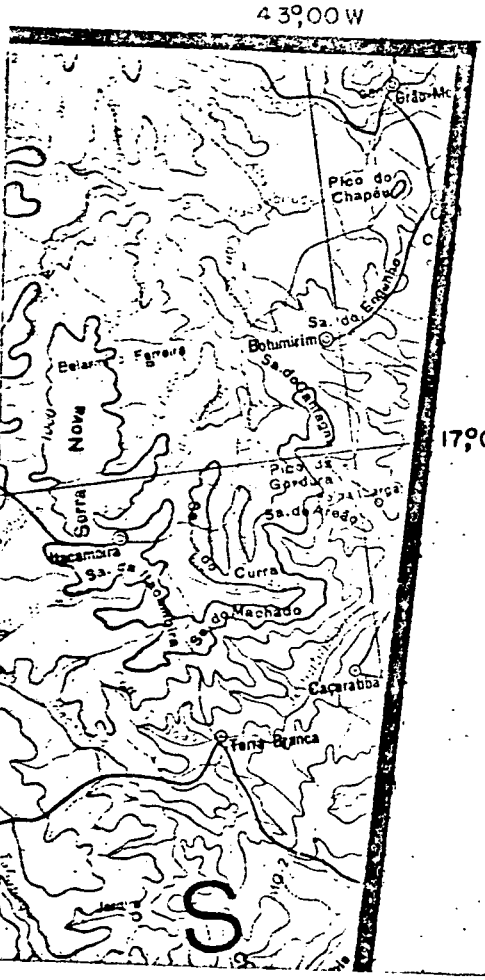
Fig. V.6 - Localization of the studied area in the Belo Horizonte Chart.





ESCALA — SCALE
1:1 000 000

FOLDOUT FRAME 2


43°00 W
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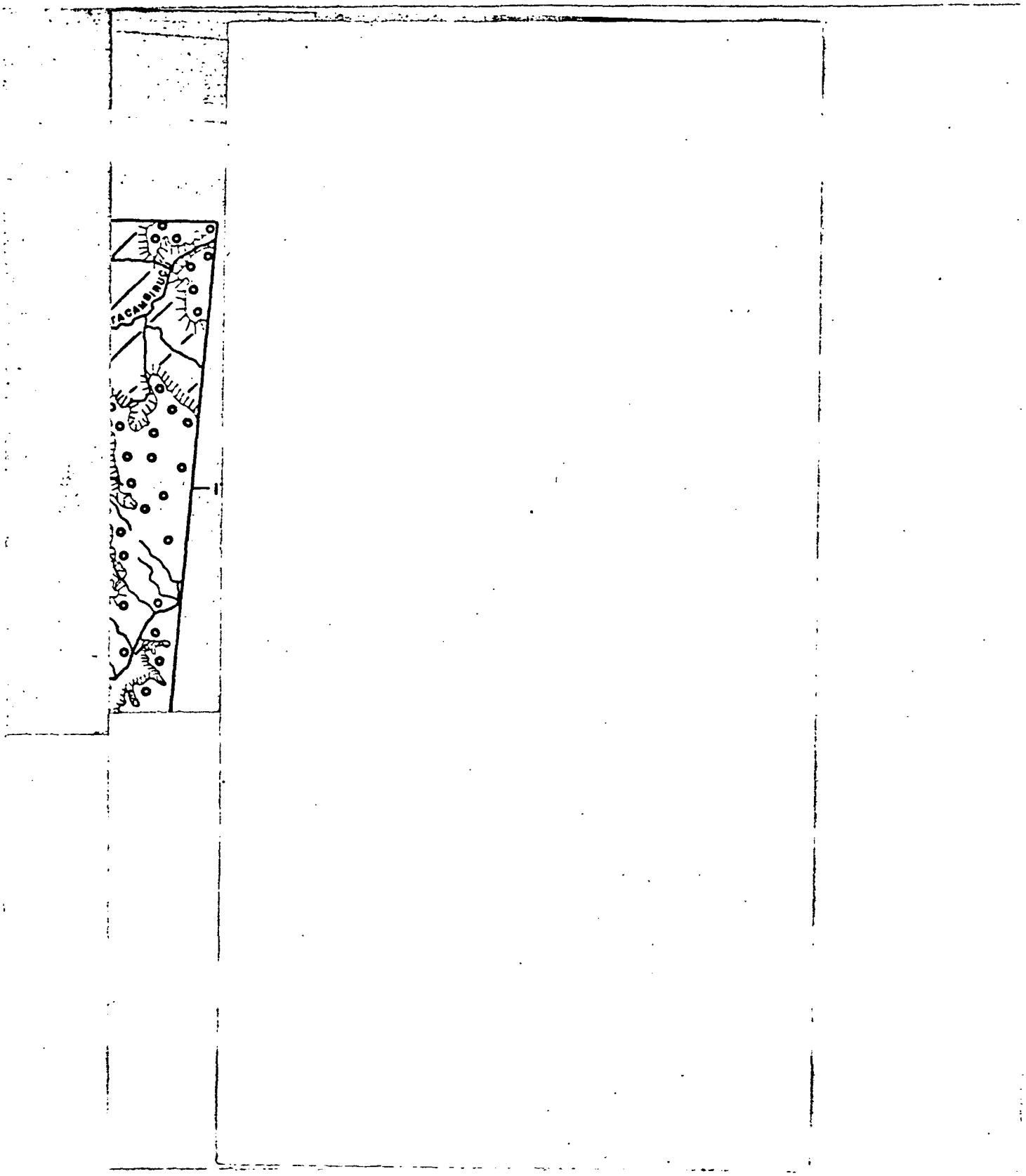
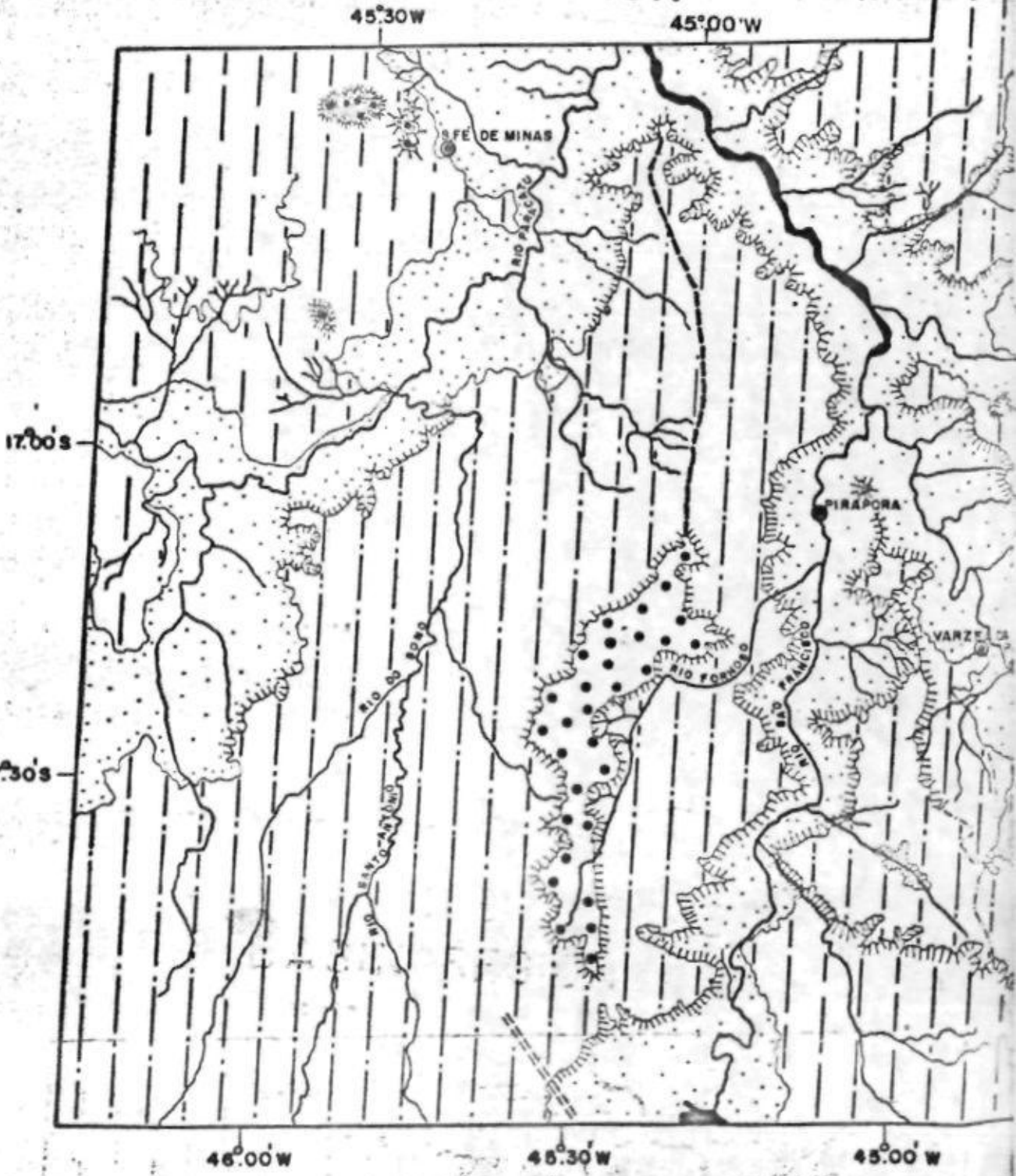


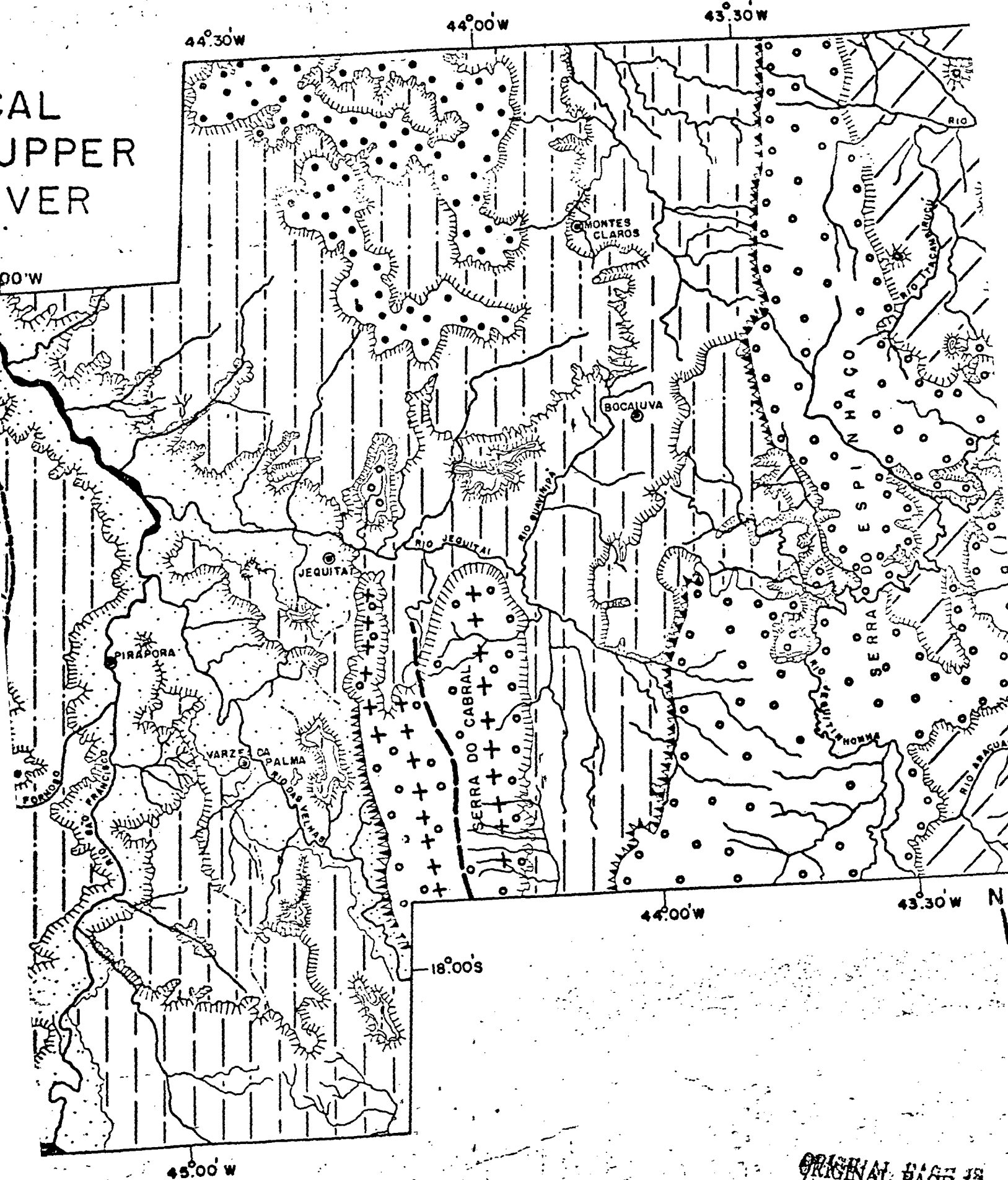
Fig. V.8 - Geomorphological outline of the Upper São Francisco River Basin Region.

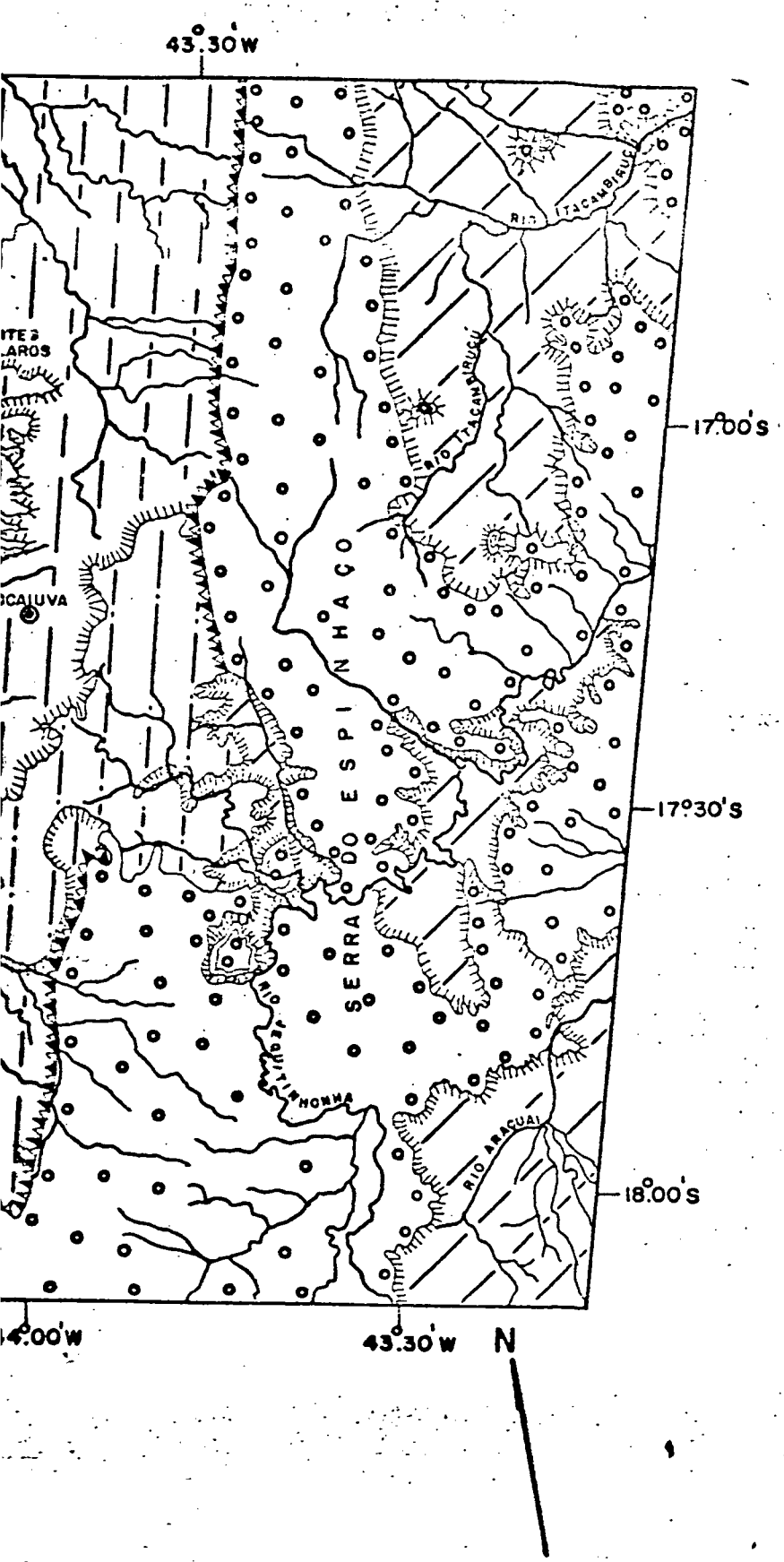
FOLDOUT FRAME 1

353a

GEOMORPHOLOGICAL OUTLINE OF THE UPPER SÃO FRANCISCO RIVER BASIN REGION







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TABLELANDS LE

LE

INTRUDED VALLEYS IN

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FAULT SCARPS

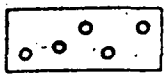
RESIDUAL PEAKS

DRAINAGE

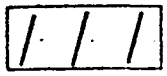
WATER DIVISOR

253 C

L E G E N D



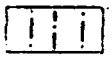
RELIEF WITH PARALLEL CRESTS
THE PLATEAUS AND THE "SERRA DO ESPINHAÇO" (ESPINHAÇO RANGE)



INTERMOUNTAINOUS DEPRESSIONS

SEDIMENTARY PLATEAUS

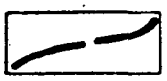
TABLELANDS



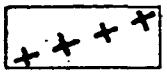
LEVEL I

LEVEL II

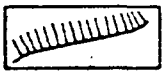
INTRUDED VALLEYS IN THE TABLELANDS



SYNCLINAL



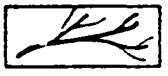
ANTICLINAL



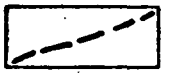
EROSIVE SCARPS

FAULT SCARPS

RESIDUAL PEAKS



DRAINAGE



WATER DIVISOR

The "Serra do Cabral", although spatially separated from the great Espinhaço structure, is part of it through similarities of lithology, structure, geomorphology, drainage system and image photogeomorphological characteristics. It is formed by two big anticlines and one syncline, besides other foldings perceptible in the image. In the axis of these two anticlines appear quartzits highly resistent from the Lavras Series, whose altitude is reflected in the saw format.

2 - Intermountainous Depressions

They appear in the image with rough texture and light grey tones for both channels, although lighter in channel 7. Distinguish itself perfectly as an eroded area, emerging older subjacent rocks which are delimitated by clear erosive scarpments in the contact among soils of the Minas Series, formed by sandstones, clays, conglomerate and pebble of metasandstone.

A clear example seen in this image is the Itacambiruçu River and its tributaries depression, whose sub-dendritic drainage is truely representative.

These scarpments were originated from erosive processes and constitute themselves in a water division between the Itacambiruçu and Jequitinhonha River Basins.

B - Sedimentary Plateaux

This unit was identified in the image through a very dark gray tone in channel 5 and light in channel 7 with smooth and uniform texture and with low drainage density and limitated by well defined scarpments.

Geologically it corresponds to sandstones dated from the Cretaceous Period, highly porous, horizontally disposed furnishing the necessary conditions to the appearance of structural tableforms surfaces.

Spatially present itself descontinuous and is an example for more intense surfaces westerly localized in the São Francisco River Basin.

It is covered by denser "cerrado" vegetation than the adjacent areas, infered through the light tonality in channel 7,representing the high vegetation reflectance in the near infrared band.

Topographically represents surfaces maintaining altimetric levels from 800 to 900 m.

C - Tablelands

They were differentiated in the image through a light tone in channel 7 and a dark one in channel 5. the rough texture on this unit boards clearly shows the erosive scarpments that constitute the link element with inferior levels of the tablelands.

Over all this unit the drainage presents a sub-dendritic pattern suggesting the presence of horizontal or sub-horizontal rocks with uniform resistance and with a smooth regional slope.

Geologically speaking this is a unit formed by rocks of the Bambuí Group, where limestones, slate and conglomerates emerge.

Morphologically it is represented by plateaux strongly eroded with occurrence of erosive scarpments and forms of Karstique relief in the areas of calcareous rocks outcrops.

Among the Espinhaço Range and the cretacic sedimentary tablelands this unit presents two distinct altimetric levels: one westerly located in the "Serra do Espinhaço" and at the east of the sedimentary plateaux and the other intruded between both, at an lower altimetric level. This compartment division is specially done by the presence of scarpments at both size of the Guavinipã River Valley.

An evident image aspect is the tablelands at west of

the "Serra do Espinhaço" which is less eroded than the one located at east of the sedimentary plateaux.

D - Intruded Valleys in the Tablelands

This unit was delimitated through its smooth and uniform texture, through the localization close to the principal channels and through low density of secondary drainage.

Geologically they correspond to rocks of Vazante Formation which are deposits of the Quaternary Period, already consolidated and in an reimprovement phase. They follow the São Francisco River Valley and the valley of their main tributaries.

The horizontally layers form smoothly inclinated tableland reliefs in direction to river beds which maintain themselves at middle altitudes of 500 m.

Close to the Velhas and São Francisco Rivers in the limit of this unit through relatively abrupt scarpments.

At the right border of the Paracatú River also appear small scarpments while at the left border they do not appear.

V.2.5 - CONCLUSIONS

From the preliminary results of this geomorphological mapping one can conclude that:

- The MSS/ERTS-1 images could be considered as a valuable instrument for a synoptical vision of the relief compartmentation and of the structural influences.
- Related to localization, extensions and limits of the geomorphological units the images permit the introduction of modification in the already existing maps.
- The images offer possibilities to infer about morpho-climatical processes and their dynamism through repetitive analysis of the same area.

V.3 - HYDROGRAPHIC MAP USING ERTS IMAGES

V.3.1 - Introduction

The hydrographic system is subordinated to geomorphological, structural, lithologic and climatic conditions of a given region.Therefore it is a valuable element for environmental research. A detailed study of the drainage system furnish a series of important information to the determination of a region ecological scene. It is considerably important in the preparation of hydrographic maps as an auxiliar element in the investigation for other parameters.

This map was initially made aiming to support geomorphological interpretation of the area covered by the Belo Horizonte Chart and exemplifying the drainage mapping. The images used corresponded to the same area used to exemplify the geomorphological mapping of the previous work (Fig. V.7).

Through the above mentioned map it was possible to have an idea of the area compartment division in function of drainage and of the drainage patterns.

Till the present moment only a qualitative analysis has been done of the hydrographic system, although quantitative studies will be done with the use of Hortton and Sthraler morphometric indexes.

V.3.2 - Drainage: General Organization

Through visual analysis of a drainage system (Fig. V.9) it was possible to distinguish two great hydrographic sets separated one from the other by the Espinhaço range and plateaux.

The Espinhaço alignment operates as water divisor separating the drainage oriented to the east (Jequitinhonha River and its tributaries) from the westerly oriented system (São Francisco River and its tributaries)

The rivers flowing to the São Francisco River present a

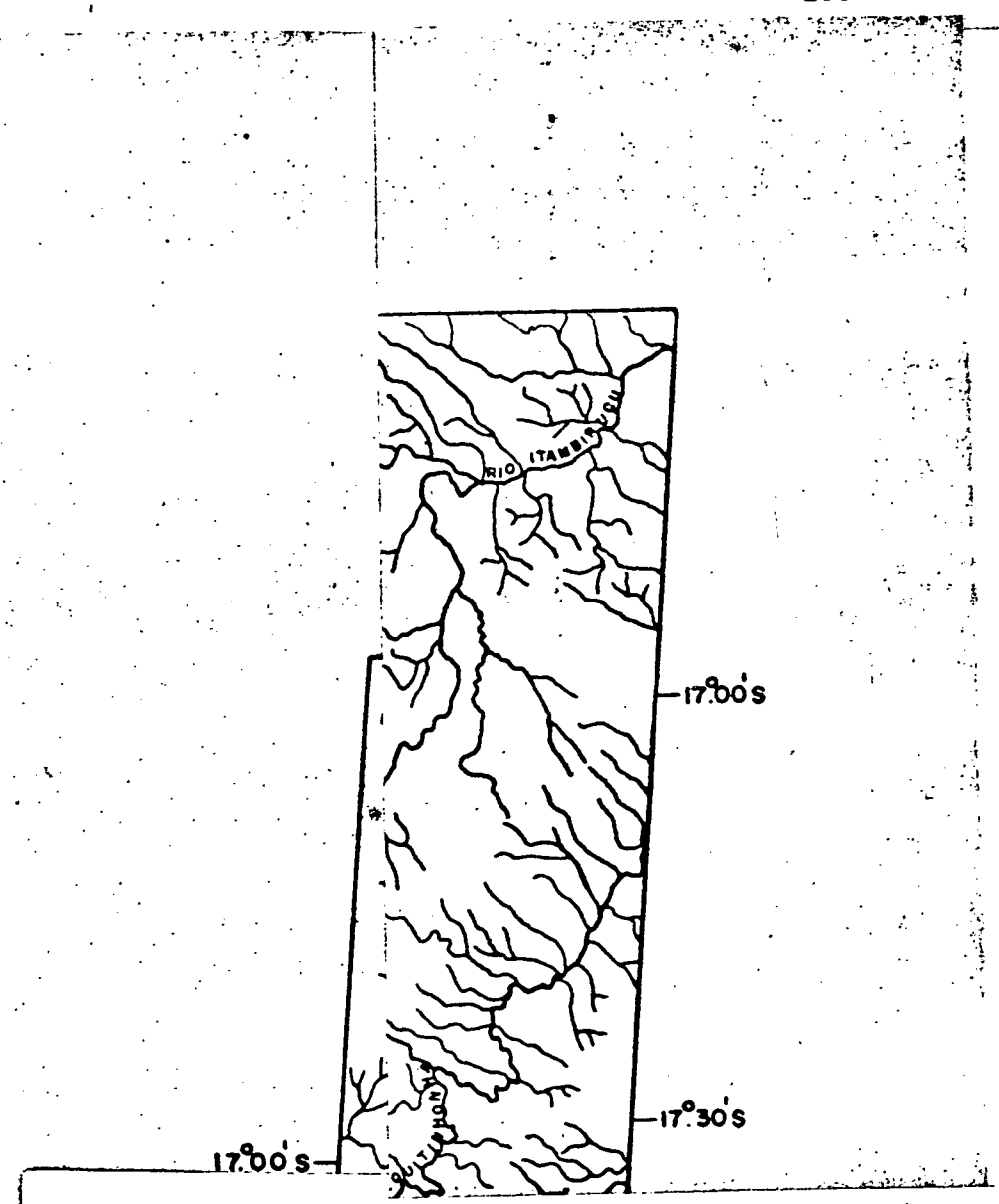
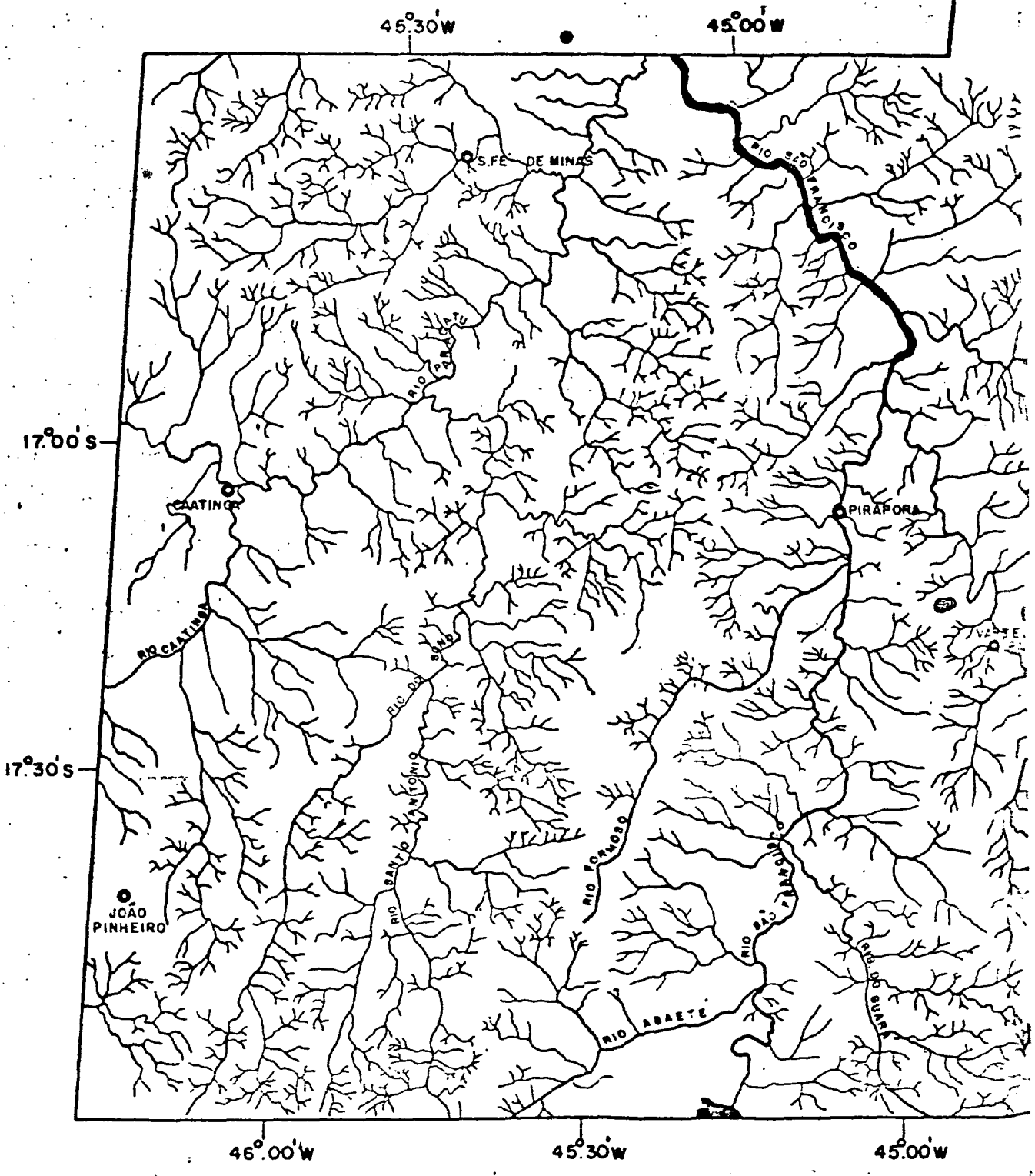


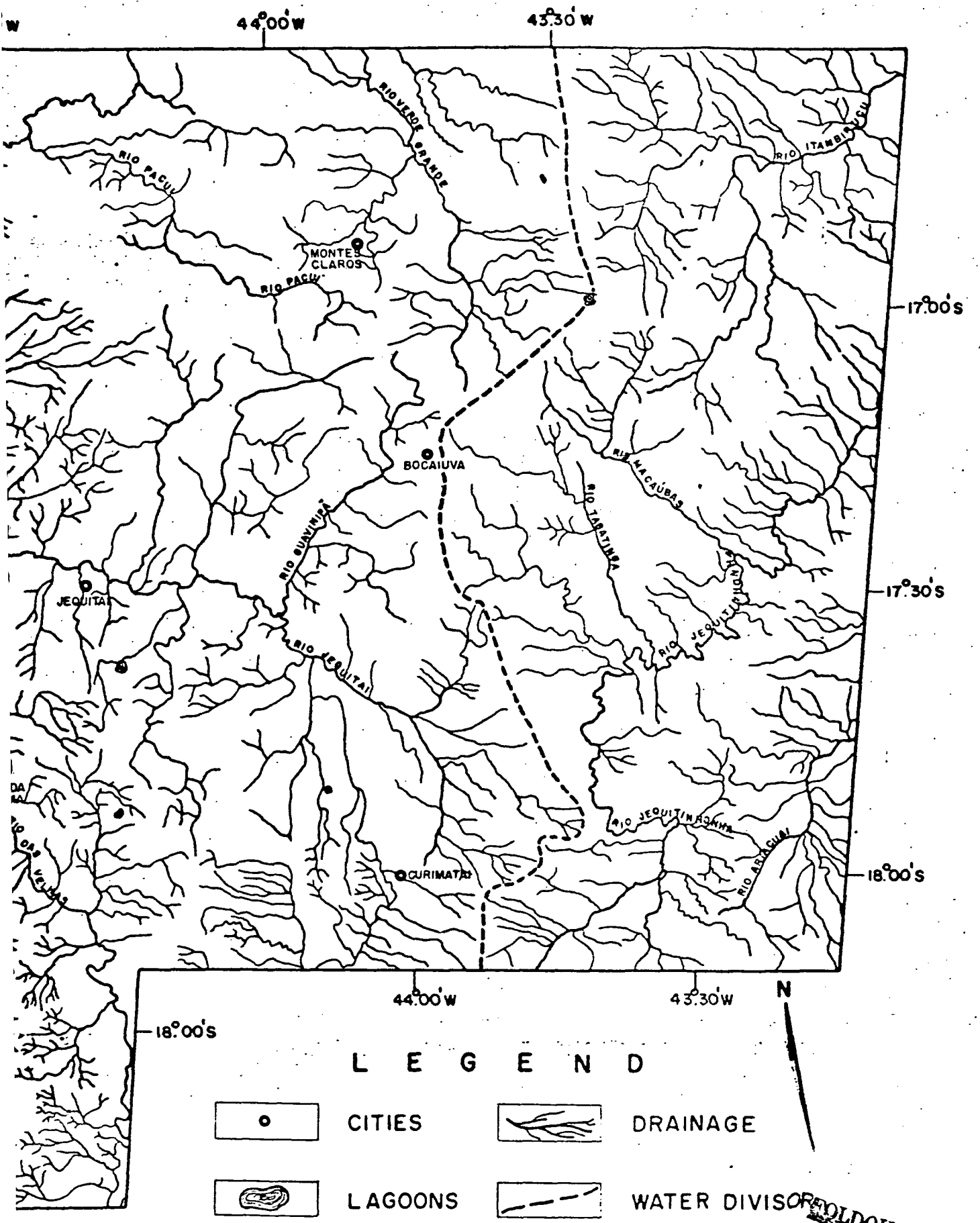
Fig. V.9 - Hydrographic Map of the Upper Courses of the São Francisco and Jequitinhonha Rivers.

HYDROGRAPHIC MAP OF THE UPPER COURSES OF THE SÃO FRANCISCO AND JEQUITINHONHA RIVERS



FOLDOUT FRAME

10 0 10 20 30 40 50 Km



superficial dendritic pattern and a high density of secondary rivers. The Jequitinhonha River Basin drainage already present itself less dense, reflecting even in the less important tributaries a great structural control with a sub-retangular pattern.

Correcting the drainage map with the geologic map of the area, it is possible to verify whether the drainage is denser and dendritic in the areas of rocks occurrence of the Bambuí Group. In the areas of calcareous occurrence Karst topography can be found. The superficial circulation in the Karstique region equally elaborate deep cannyons as the one formed by the Velhas River in the region of Santa Lagoon.

Where the climatic conditions do not permit the appearance of Karstique relief, the calcareous works as a non-permeable rock making possible a rich superficial drainage.

In the recent alluvium areas from the Vazante Formation, the drainage is less dense, perhaps reflecting an increase in the porosity of the rocks.

In the place where occurs more ancient terrains of the Brazilian Shield the drainage appears less dense in the images. This, however, does not totally reflect the reality. What happens is that in these regions it is difficult to obtain drainage details through the images which allows to map only the most important rivers. This is due to two facts: Firstly this region present itself covered by humid forest

diminishing the contrast in the targets and this reduces the image resolution. Secondly, this is an area where the drainage branching is great, presenting small and narrow rivers, more difficult to be detected.

V.3.3 - Conclusions

By the drainage analysis using ERTS-1 images it is possible to conclude:

- The image provide information very close to reality, attaining a level of detail much better than the ones of the chart in the same scale.
- By the facility of drainage mapping, the ERTS-1 images are favorable to hydrical potential studies, as well as to the study of fluvial channels with the objective to plan river transport.

V.4 - DEMOGRAPHIC INFERENCE USING ERTS IMAGES

V.4.1 - Introduction

Among the different ERTS satellite image application possibilities, those concerned with demographic studies seem to be some of the most appealling.

In general it is possible to observe that urbanized areas in ERTS images are well defined which really facilitates the delimitation of these areas with fair accuracy. This fact inspired us to verify the viability of the ERTS images utilization in demographic inferences in the Brazilian territory.

At present, Brazil has approximately 100 million inhabitants, with a population growth of 2.9% per year, in the period of 1960-1970. Demographic Census are done here every 10 years, hence some appropriate techniques are necessary to estimate the population in the inter-census periods as well as to accompany the main urban expansion trends. Frequently it is noted that the Brazilian population is concentrated in highly populated agglomerations. The percentage of people living in clusters of more than 10,000 inhabitants has been increasing considerably in the last few years.

Due to the intense urbanization process presently occurring in Brazil it is necessary to keep track of the increasing growth rate within the urban areas as well as to monitor the expansion of the urbanized areas.

The frequent ERTS satellite data acquisition makes possible the detection of the urban expansion tendency and the observation of regional developments, making it possible to update regional planning related to urbanization studies.

Trying for the first time in Brazil to use ERTS images applied to population inference, this work verified the correlation existing between the data of urbanized areas, as infered from the images, and the respective population data, obtained in the last Brazilian Demographic Census (1970).

Images used in this work were selected according to their clarity in defining urban areas.

V.4.2 - Methodology

The data used in the development of this research were obtained by ERTS-1 Satellite MSS Sensor. Channel 5 (0.6 - 0.7μ) was used because it was the one which best identified urban areas. The urban areas present high reflectance in this channel compared with their surroundings. Through the radiation density cities could be delineated with a relative accuracy. An example of two utilized images in the work are shown in figures V.10 and V.11.

The scale of the images used in the determination of the urbanized areas was 1:500,000.

Cities were identified using 1:1,000,000 map of Brazil published by the I.B.G. (Brazilian Geography Institute).

The determination of city areas in the ERTS images was made with a planimeter. The arithmetic average of 5 area measurement was used.

Fig. V.10 - ERTS image E-1372-12.333 - Channel 5.

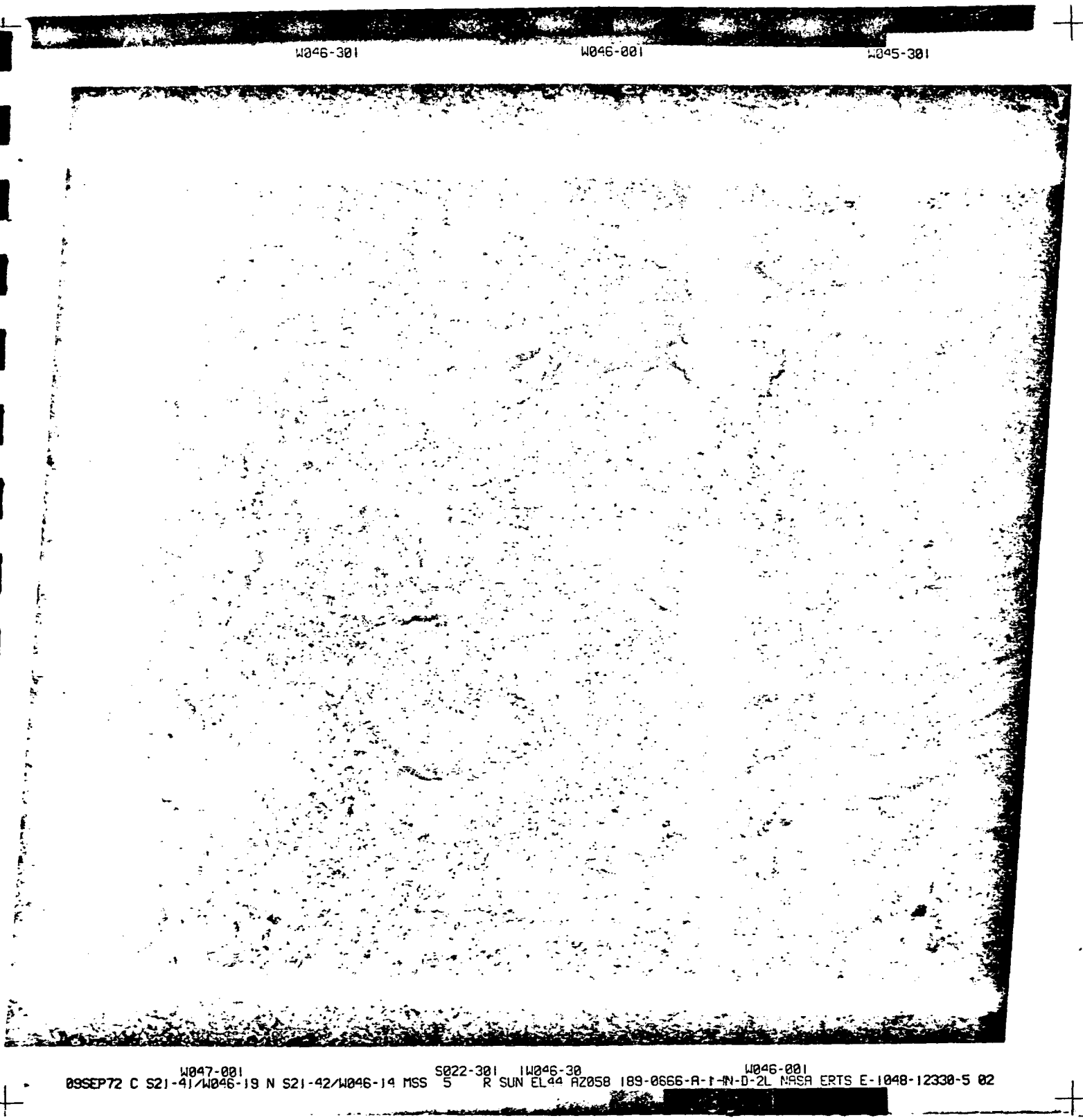


Fig. V.11 - ERTS image E-1048-12.330 - Channel 5.

The area data were correlated with official statistical population data of the Brazil 1970 Demographic Census.

As the first step to analyse the data an attempt was made to establish the correlation index between two variables: the area and the population. Then a linear regression was used in order to estimate the population corresponding to a given urban area. The next step was to apply the Student Test with 90% probability.

Intervals were established from the data obtained by the simple linear regression methods with a statistical distribution of population resulting for each area interval.

V.4.3 - Discussion of the Results

This work is still in the first phase of development and the results to be discussed here should be considered as preliminary ones.

From the ERTS images selected for analysis, 280 Brazilian cities were identified (Fig. V.12). A list was made with information about the place of each city by state, data on spatial area obtained from the images, and population totals acquired from the last Brazilian 1970 Demographic Census. The 280 Brazilian cities identified vary greatly with area ranges of 0.5 km^2 to 45.20 km^2 and population totals from 559 inhabitants to 185,000 inhabitants.

Fig.V.12 - Brazil map with the localization of the studied cities.

LIST OF THE 280 BRAZILIAN CITIES ALREADY STUDIED

NAME	STATE	AREA (KM^2)	POPULATION
ABADIANIA	GO	1,60	985
ADAMANTINA	SP	4,10	21000
AGRICOLANDIA	PE	,50	1302
AGUA BRANCA	PI	2,80	5589
AGUA LINDA	GO	2,00	672
AGUAI	SP	2,00	9508
AGUAS DE LINDOIA	SP	5,00	5362
AGUDOS	SP	4,80	11001
ALEXANIA	GO	4,80	2627
ALFENAS	MG	5,00	20306
ALTEROSA	MG	5,20	2856
ALTINOPOLIS	SP	10,40	5328
ALVORADA DO SUL	PR	1,00	3016
AMARANTES	PI	0,50	4410
AMERICANA	SP	14,00	42387
ANDRADAS	MG	2,60	7477
ANDRADINA	SP	9,00	43465
ANHANGUERA	GO	,50	983
APARECIDA	SP	8,00	23136
APUCARANA	PR	7,20	41900
ARACATUBA	SP	35,00	85560
ARAGOIANIA	GO	3,20	941
ARAGUARI	MG	34,40	48792
ARAPONGAS	PR	7,50	36428
ARARAS	SP	10,00	40985
ARARUAMA	RJ	1,20	8801
ARAUJOS	MG	2,00	2505
ARCOS	MG	4,80	9479
ARIZONA	GO	6,00	2746
ASSIS	SP	21,80	49991
AVANHANDAVA	SP	2,00	3733
AVARE	SP	5,60	29879
BACABAL	MA	8,20	29251
BAGE	RS	15,80	57936
BANDEIRANTES	MT	2,50	2522
BARRA MANSA	RJ	4,00	75006
BARRO DURO	PI	2,20	1875
BARROSO	MG	4,00	9993
BELA VISTA DO PARAISO	PR	1,40	7295
BETIM	MG	17,60	17571
BILAC	SP	4,00	2535
BIRIGUI	SP	9,50	27158
BLUMENAU	SC	4,00	85402
BOA ESPERANCA	MG	6,60	12093
BOITUVA	SP	2,00	5466
BOM DESPACHO	MG	8,20	18783
BOM JESUS DA PENHA	MG	1,40	638
BOM SUCESSO	MG	2,60	7846
BOTUCATU	SP	15,60	42252

NAME	STATE	AREA (KM^2)	POPULATION
BRAGANCA PAULISTA	SP	12.00	39573
BRUSQUE	SC	3.50	32027
BURITAMA	SP	2.50	5646
CACAPAVA DO SUL	RS	3.60	0528
CACHOEIRA DE MINAS	MG	1.80	1866
CACHOEIRA DO SUL	RS	5.50	50000
CACHOEIRA	MA	2.00	1500
CAETE	MG	4.20	18524
CALDAS NOVAS	GO	3.70	2636
CAMPE	PR	3.20	13382
CAMBORIU	SC	4.50	2076
CAMBUQUIRA	MG	2.20	4488
CAMPO ALEGRE DE GOIAS	GO	1.60	578
CAMPO BELO	MG	11.00	20174
CAMPO DO MEIO	MG	2.60	3870
CAMPOS ALTOS	MG	8.20	5803
CAMPOS GERAIS	MG	5.00	6316
CANDIDO MOTA	SP	1.40	8837
CARAGUATATUBA	SP	4.30	10755
CARAVELAS	BA	5.40	3650
CARMO DA MATA	MG	2.80	6672
CARMO DO CAJURU	MG	3.80	3888
CARMO DO PARNAIBA	MG	5.80	10203
CASA BRANCA	SP	4.60	11660
CASTELO DO PIAUI	PI	2.60	8500
CATANDUVA	SP	20.20	15223
CATANHEDE	MA	1.20	1788
CENTENARIO DO SUL	PR	1.00	5810
CERQUEIRA CEZAR	SP	6.40	5000
CERQUILHO	SP	3.20	3978
CIANORTE	PR	4.80	22957
CONCEICAO DAS ALAGOAS	MG	4.40	5230
CONCEICAO DOS OUROS	MG	3.60	2023
CONCHAS	SP	1.00	4469
CORNELIO PROCOPIO	PR	8.00	25021
CORUMBAIBA	GO	4.40	2012
CRISTAIS	MG	2.80	2681
CRISTALINA	GO	7.60	5638
CROMINIA	GO	2.80	1508
CUBATAO	SP	12.00	37255
CUMARI	GO	2.60	2308
DIVINOPOLIS	MG	17.80	68872
DORES DO INDAIA	MG	1.90	12511
DRACENA	SP	20.00	23007
EDEIA	GO	3.20	2637
ELOI MENDES	MG	4.40	6789
ENCRUZILHADA DO SUL	RS	1.10	6706
ESPERANTINOPOLIS	MA	1.00	2276
FLORESTAL	MG	4.20	1605
FLORINEA	SP	3.30	1612

NAME	STATE	AREA (KM^2)	POPULATION
FORMIGA	MG	10.00	28719
FORMOSA	GO	6.80	12255
FRANCA	SP	36.60	84852
GARUVA	SC	4.00	1007
GOIANDIRA	GO	8.00	3517
GUAPO	GO	11.60	3579
GUARAMIRIM	SC	7.60	2289
GUARATINGA	BA	3.00	3120
GUARATINGUETA	SP	7.80	55069
GUARIBORA	GO	11.00	24302
GUAXUPE	MG	5.00	17310
HELIODORA	MG	2.60	1241
IBIPORA	PR	3.10	12991
IBIRACI	MG	1.20	2200
IGARATINGA	MG	1.20	1280
INDAIATUBA	SP	4.00	22359
IPAMERI	GO	20.80	11572
IPIXUNA	MG	1.80	2104
ITABIRA	MG	16.00	80183
ITABIRITO	MG	3.00	17849
ITAGUARA	MG	2.40	3258
ITAIAI	SC	11.00	58138
ITAMARAJU	BA	2.80	10689
ITAPECIRICA	MG	4.80	8757
ITAQUAQUECETUBA	SP	1.60	22004
ITATIBA	SP	3.00	20745
ITAUNA	MG	7.40	32731
ITIRAPINA	SP	3.60	4376
ITU	SP	13.00	35907
ITUIUTABA	MG	10.40	84780
ITUMBIARA	GO	5.60	29017
JACAREI	SP	2.10	88488
JALES	SP	5.40	21468
JANDAIA DO SUL	PR	1.60	1038
JAU	SP	6.40	80399
JOAO MONLEVADE	MG	14.80	38489
JOAO PINHEIRO	MG	3.80	8654
JOINVILLE	SC	38.00	77760
JUNDIAI	SP	41.00	105785
JUNQUEIROPOLIS	SP	7.30	8723
LAGOA FORMOSA	MG	4.20	3871
LARANJAL PAULISTA	SP	2.40	7599
LAVRAS	MG	14.20	35089
LAVRAS DO SUL	RS	1.20	3910
LEANDRO FERREIRA	MG	2.00	1038
LEOPOLDO DE BULHOES	GO	2.20	2119
LIMEIRA	SP	24.00	77283
LONDRINA	PR	24.00	156670
LORENA	SP	2.20	39465
LUIZIA	SP	4.20	1110

NAME	STATE	AREA (KM^2)	POPULATION
LUZ	MG	5.40	7041
LUZTANIA	GO	5.50	9132
MAIRINQUE	SP	2.00	5723
MAIRIPOTABA	GO	2.80	790
MANDAGUARI	PR	2.40	11452
MARGARIDA	GO	2.00	684
MARIALVA	PR	2.60	6912
MARILIA	SP	26.24	73165
MARINGA	PR	15.00	51620
MARTINHO CAMPOS	MG	4.20	3478
MARTINOPOLIS	SP	3.00	8807
MATEUS LEME	MG	3.40	2851
MATOES	MA	.50	1020
MEDEIROS NETO	MG	2.80	899
MIRADOR	MA	1.70	973
MIRANDOPOLIS	SP	8.40	11033
MOCOCA	SP	6.80	21082
MOEMA	MG	1.60	2450
MOGI DAS CRUZES	SP	24.00	90330
MONCAO	MA	2.00	1945
MONTANHA	ES	2.60	9861
MORRINHOS	GO	5.10	18100
MUCURICI	ES	1.80	1337
NANUQUE	MG	5.20	30714
NEPOMUCENO	MG	3.40	6326
NOVA ODESSA	SP	3.80	6260
NOVA SERRANA	MG	1.00	2507
NOVA VENEZIA	ES	2.40	9417
NUCLEO BANDEIRANTES	GO	8.00	11133
OLIVEIRA	MG	8.80	18557
OURO FINO	MG	3.40	9122
OUVIDOR	GO	2.00	705
PACAEMBU	SP	3.70	5935
PALMEIRAS DE GOIAS	GO	3.20	5847
PAPAGAIOS	MG	5.60	3121
PARA DE MINAS	MG	5.40	24071
PARACATU	MG	18.20	17053
PARAGUACU	MG	12.20	7114
PARAGUACU PAULISTA	SP	6.00	13318
PARAIBUNA	SP	3.80	8991
PARANAGUA	PR	16.00	51510
PARQUE GAMA	GO	18.50	71556
PASSA TEMPO	MG	1.40	3251
PASSOS	MG	13.80	39184
PEDREIRAS	MA	6.00	19539
PEDRO LEOPOLDO	MG	6.20	11858
PENAPOLIS	SP	13.50	24597
PERDIGAO	MG	1.00	1965
PIAUI	MG	2.80	11960
PINDAMONHANGABA	SP	1.70	28211

NAME	STATE	AREA (KM^2)	POPULATION
PINHAL	SP	4,00	18172
PINHEIROS	ES	1,60	8336
PIRACEMA	MG	1,00	1063
PIRACICABA	SP	18,40	125000
PIRAPEMAS	MA	1,20	2060
PIRES DO RIO	GO	11,30	13362
PITANGUI	MG	3,00	8687
PLANALTINA	GO	5,00	18080
PLATINA	SP	5,00	667
POCAO DE PEDRAS	MA	1,40	3725
POCOS DE CALDAS	MG	12,00	51800
POMPEU	MG	5,20	7001
PONTE NOVA	BA	5,00	20665
PORECATU	PR	3,60	7261
PRADOS	MG	6,80	3005
PRESIDENTE PRUDENTE	SP	25,00	91188
PROMISSAO	SP	10,00	15262
RESENDE	RJ	10,00	25517
RIBEIRAO DAS NEVES	MG	3,60	3908
RIBEIRAO DO PINHAL	PR	3,00	5360
RIO BONITO	RJ	6,40	16720
RIO CLARO	SP	20,00	60200
RIO DAS PEDRAS	SP	1,60	5021
ROLANDIA	PR	0,60	19302
RUBINEIA	SP	6,00	1010
SALTO	SP	13,00	10060
SANTA BARBARA	SP	5,20	22358
SANTA BARBARA	GO	1,00	922
SANTA CRUZ DE GOIAS	GO	2,60	550
SANTA INES	MA	4,00	10805
SANTA ISABEL	SP	3,30	9211
SANTA LUZIA	MG	7,20	13000
SANTA MARIA	RS	35,00	120667
SANTA RITA DO SAPUCAI	MG	3,20	11605
SANTA TEREZINHA DE GOIAS	GO	3,00	1262
SAO BENTO DO SUL	SC	5,20	9406
SAO BERNARDO	MA	3,00	1331
SAO FRANCISCO DO SUL	SC	2,80	12868
SAO GABRIEL DA PALHA	ES	1,10	6572
SAO GONCALO DO SAPUCAI	MG	3,80	10186
SAO GOTARDO	MG	2,20	7515
SAO JERONIMO DA SERRA	PR	2,00	1202
SAO JOAO DA BOA VISTA	SP	23,00	33051
SAO JOSE DO RIO PARDO	SP	7,80	16025
SAO JOSE DOS CAMPOS	SP	33,90	130118
SAO JOSE DOS PINHAIS	PR	5,20	21180
SAO LOURENCO	MG	2,60	18120
SAO PEDRO DA ALDEIA	RJ	1,80	5260
SAO PEDRO DO PIAUI	PI	2,80	2287
SAO ROQUE	SP	3,80	16070

NAME	STATE	AREA (KM^2)	POPULATION
SAO SEPE	RS	2,10	7402
SAO TOME DAS LETRAS	MG	1,60	630
SERRANIA	MG	0,80	2383
SINOPLANDIA	MT	2,40	2920
SOBRADINHO	GO	10,00	38988
SOROCABA	SP	80,00	165200
SUMARE	SP	1,60	11731
TAGUATINGA	GO	15,00	106320
TAPIRATIBA	SP	0,80	2338
TATUI	SP	5,20	30805
TAUBATE	SP	12,00	88933
TEIXEIRAS	MG	3,00	2876
TERESINA	PI	31,80	185000
TERRA ROXA	PR	3,00	5006
TIETE	SP	4,00	19602
TIMON	MA	7,60	14338
TRÊS CORACOES	MG	6,00	25707
TRES POSTAS	MG	4,20	10289
TRES RANCHOS	GO	0,40	1073
TUPA	SP	7,80	38753
TUPACIGUARA	MG	6,00	12909
UBATUBA	SP	7,00	8834
UBERABA	MG	85,20	198576
UBITAL	GO	6,00	1575
VARGINHA	MG	7,50	34447
VERISSIMO	MG	8,80	893
VESPASIANO	MG	4,20	5287
VICOSA	MG	4,60	15552
VINHEDO	SP	4,80	7817
VOLTA REDONDA	RJ	22,00	129605
VOTUPORANGA	SP	11,68	38138

With the application of the correlation coefficient to the variables, areas and population, the obtained index was 0.80 which indicates a relatively high correlation between the two variables.

The Dispersion Diagram (Fig. V.13), shows a linear dependence between area and population. The dispersion from linearity observed for some points in this figure probably indicates a peculiar space expansion of these cities with respect to its population distribution. In these cases some parameters should be taken into account, such as: regional localization, topographic characteristics, functional and economic characteristics of the city, etc.

Later on, with the application of the simple linear regression statistical method it was possible to classify the area and the population in intervals, resulting for each area interval a statistical population distribution. About 21 classes were obtained as shown in Table V.1.

These classes were established in order to infer the population of a given sample area.

The results obtained for the less populated cities are quite different from the more populated ones. For the less populated cities the relationship between their areas and respective population was found to be quite linear. However this linearity does not exist for the most populated areas. Table 1 displays the area intervals used in this work. The corresponding classification and population data are also shown

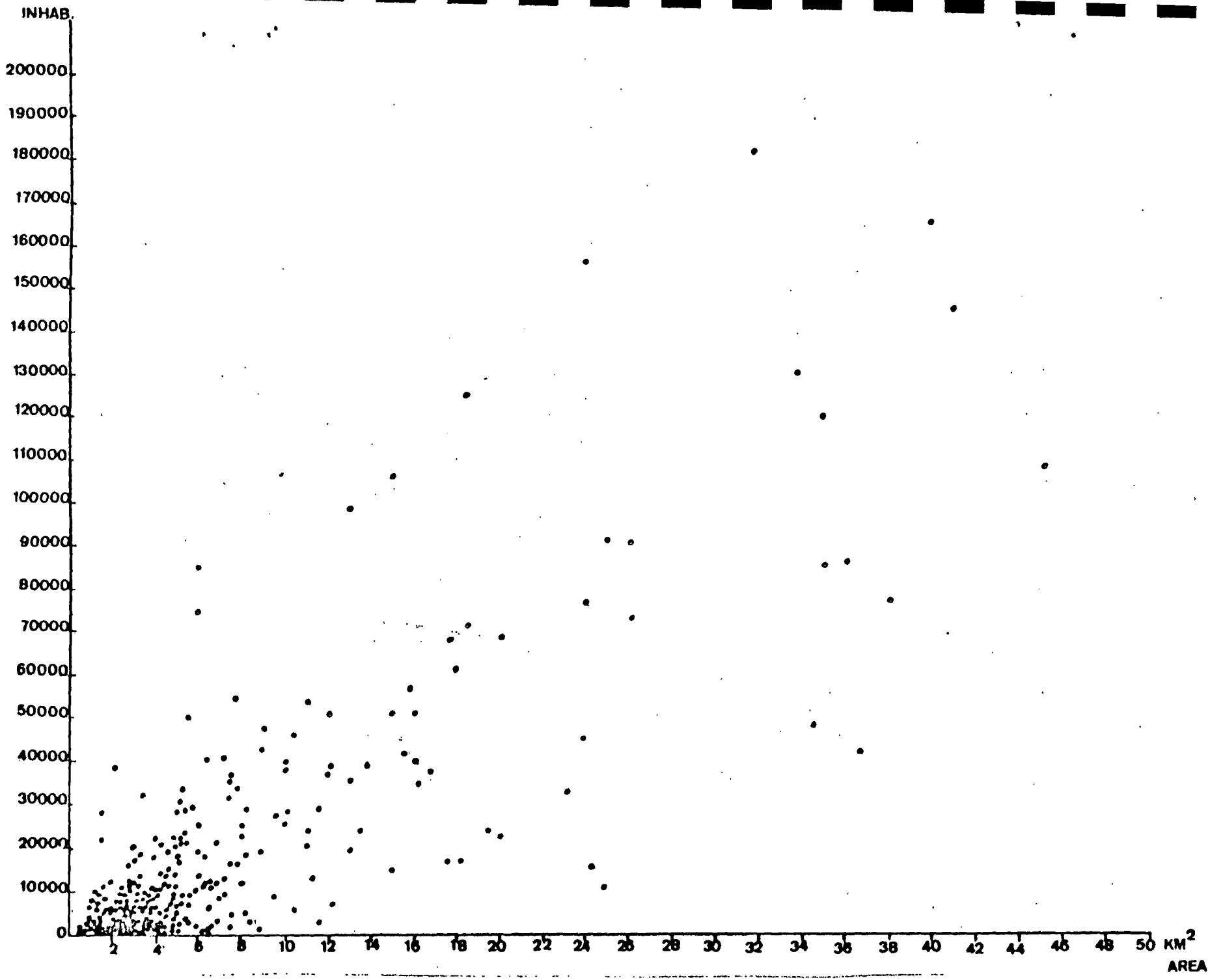


Fig. V.13 - Dispersion Diagram.

in Table 1 and in Figure V.14.

These results (although relatively good for the population estimate can be considerably improved if more samples are considered. There is the need of data collection for a larger quantity of cities, and also the need of other parameters which influence the geographical expansion of the cities. Parameters such as regional localization, kind of relief, economic and functional characteristics should be analized and computed in order to obtain more precise results in demographic inference.

Based on these preliminary results one concludes that the ERTS images really offer great potential in demographic studies and in tracking the expansion of urban areas. However in the case of demographic inference more precise results are necessary and could perhaps be obtained in a further phase of this research.

The next phase of this research will be developed utilizing the IMAGE-100 GE equipment. Through this equipment more precise results of the urban areas will be obtained. Other parameters interfering in the urbanization process will be used in this second research phase. The objective of this investigation will be the reaching of models to permit the inference of urban areas population with the best possible precision grade.

TABLE V.1

CLASSES	AREA	POPULATION	CITIES NUMBER
1	0 to 2 km^2	0 to 6,838 inhabitants	49
2	2.1 to 4 km^2	2,941 to 12,702 "	77
3	4.1 to 6 km^2	9,222 to 18,653 "	57
4	6.1 to 8 km^2	15,720 to 24,710 "	29
5	8.1 to 10 km^2	21,801 to 25,322 "	14
6	10.1 to 12 km^2	28,365 to 37,135 "	11
7	12.1 to 14 km^2	33,654 to 43,466 "	7
8	14.1 to 16 km^2	41,775 to 49,847 "	6
9	16.1 to 18 km^2	45,228 to 56,262 "	5
10	18.1 to 20 km^2	50,958 to 62,702 "	5
11	20.1 to 22 km^2	61,787 to 69,158 "	1
12	22.1 to 24 km^2	64,628 to 75,626 "	4
13	24.1 to 26 km^2	68,034 to 82,103 "	4
14	26.1 to 28 km^2	73,818 to 82,881 "	1
15	30.1 to 32 km^2	89,552 to 100,920 "	1
16	32.1 to 34 km^2	95,486 to 107,740 "	1
17	34.1 to 36 km^2	96,899 to 111,314 "	3
18	36.1 to 38 km^2	103,113 to 121,065 "	2
19	38.1 to 40 km^2	112,711 to 127,568 "	1
20	40.1 to 42 km^2	115,534 to 130,819 "	1
21	44.1 to 46 km^2	127,384 to 144,481 "	1

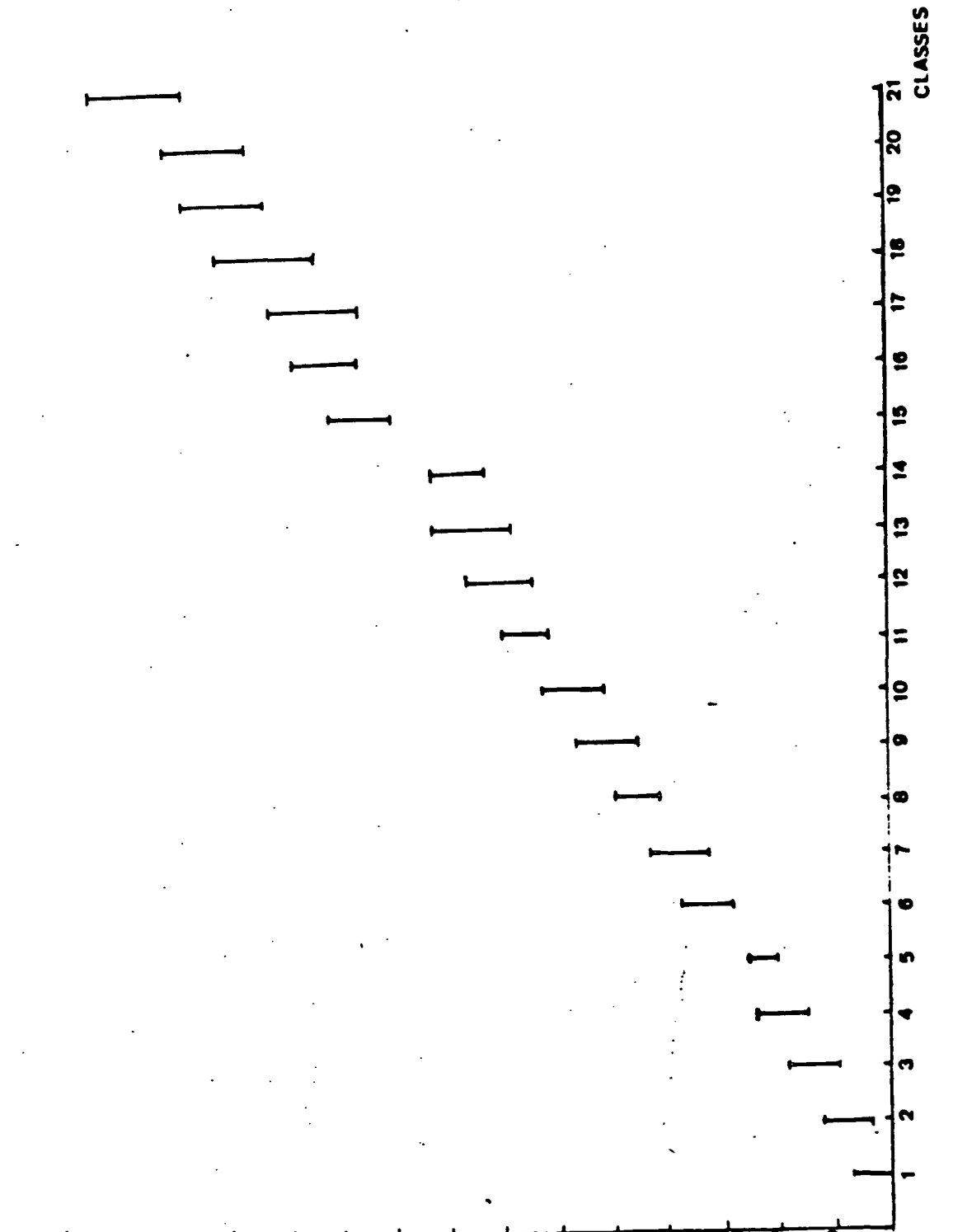


Fig. V.14 - The vertical bar represents the probability of 90% of the population interval for a given class (area).

V.5 - BIBLIOGRAPHY

AB'SABER, AZIZ NACIB, O Relevo Brasileiro e seus Problemas, Brasil: A Terra e o Homem - Vol. I, Cia. Editora Nacional, 1964.

ALMEIDA, FERNANDO F.M., Os Fundamentos Geológicos, Brasil: A Terra e o Homem - Vol. I, Cia. Editora Nacional, 1964.

COELHO, ARNALDO GUIDO DE SOUZA, Ecologia e Potencial de Estudos com Base nas Modernas Técnicas do Sensoriamento Remoto, I. G., 1973.

DOMINGUES, ALFREDO JOSÉ PORTO - Relevo , Paisagens do Brasil - Fundação IBGE, Instituto Brasileiro de Geografia, Rio de Janeiro, 1973.

EYRE, L.A., B. ADOLPHUS and M. AMIEL, Photogrammetric Engineering, 5, 460 1970.

HOWARD, A. D., Photogeologic Interpretations of Structure in the Amazon Basin: A Test Study, Geol. Soc. American Bull.,1965,V.76, pp.395-406.

HSU-SHIN-YI, Photogrammetric Engineering, 5, 449, 1971.

LOWMAN, D. PAWL, Multispectral Scanner Imagery of the Sierra Nevada: Geologic Analysis, Earth Resources Technology Satellite-1 Symposium Proceedings, September 29,1972, Goddard Space Flight Center, Greenbelt, Maryland, NASA.

LYON, R.J.P., Exploration Application of Remote Sensing Technology (Image forming systems): Mining Cong. Jour 1972,V.58,Nº 6,pp 20-26.

MOREIRA, AMÉLIA ALBA NOGUEIRA, Relevo, Grande Região Leste, Volume V,IBGE, Conselho Nacional de Geografia, 1965.

PENTEADO, M.M. and RANZANI, G., Relatório de Viagem ao Médio Vale do São Francisco, I.G., 1973.

WAY, J. R., Third Annual Earth Resources Program Review, Vol.I, Geology and Geography, 2, 1, 1970.

YAMANE, T., In Statistics, An Introductory Analysis, A. Harper International Edition, N. York, 368, 1964.

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND 20771

AMERICAN REVOLUTION BICENTENNIAL 1776-1976

REPLY TO ATTN OF: Code 902

Fill 15508
MAY 28 1975

Dr. Fernando de Mendonca
Director General, I.N.P.E.
C.P. 515 - Sao Jose dos Campos
Sao Paulo, Brazil

Dear Dr. de Mendonca:

In accordance with the Provisions for Participation in the NASA LANDSAT (ERTS) Project, a review was made by the Scientific Monitor of the drafts of the Type III Final Reports which represented the completion of the Institute for Space Research's (INPE) multidisciplinary program for the study of LANDSAT imagery. The volume of the reports demonstrated that an in-depth study of the utility of this imagery was made. It was noted that the large amount of information produced by the three Principal Investigators was screened and combined into a single report. This is an excellent mechanism for cataloging the relevant results of the INPE program. It effectively demonstrated the outstanding contribution of the Brazilian investigators to the LANDSAT program.

In his review of the Volume I, Chapter II, SEA RESOURCES (CF Emmanuel Gama de Almeida) investigation, the Scientific Monitor stated that it was a complete, well prepared and well organized report with an appropriate format that adequately addressed each of the objectives outlined in the original proposal. The report gives a good introduction to the investigation and touches lightly on the interaction of LANDSAT, Nimbus, Apollo-8, and Skylab video data products. Elaborate background information is supplied for each study area. Excellent use is made of transparent overlays on the LANDSAT images. The major detriment in this chapter is the lack of an introductory map of Brazil showing the locations of the five test sites.

Unfortunately, there are a number of content deficiencies that should be corrected before the Final Report is submitted. These are:

- Page 27 to 30: Reference is made several times to MSS channel 4, 5, and 6 imagery but only a channel 5 image is included in the text. In fact, channel 5 imagery is duplicated on pages 24 and 28. Is this in error?

- Page 45, first paragraph: Last sentence, "1500 m" should read "15.00 m".

- Page 45, third paragraph: Author refers to oceanic tides of the "daytime kind". Author probably means "diurnal - a tide having only one high water and one low water each tidal day (every 24.84 hours)".

- Pages 56, 67, and 59: Reference to Fig. 11.20 and 11.22 is made by stating the acquisition date of the image, 26 June 1973. Reference to this illustration should be by Fig. number. Near bottom of page 56, reference to this Fig. is 26 July 1973. One of these must be incorrect.

- Page 62, Paragraph II.3.1: The first sentence in this paragraph needs clarification.

- Page 76, Paragraph II.3.5.3: Reference is made to a blowup of Guanabara Bay showing river discharges. No LANDSAT image is included to show this important result.

- Page 81, third paragraph, line 3: "the isoline of 35% surface salinity" should be "isohaline of 35 0/00 "since salinity is measured in parts per thousand (0/00).

- Page 88, third paragraph: Reference is made to items B, C, and D in Fig. II.32 but not to item A.

In his review of the Volume I, Chapter III, MINERAL RESOURCES (Dr. Gilberto Amaral) investigation, the Scientific Monitor stated that it represented a detailed and well illustrated report with an appropriate format that addressed most of the objectives outlined in the original proposal. An objective not addressed was the proposed study of the "main geotectonic units of central and southern Brazil and their relation to known mineral deposits". No discussion of the application of the structural data to these mineral deposits was made. In addition, no information regarding the "establishment of the best parameters for aircraft mission planning for specific problems" was presented.

In addition, there are some content deficiencies that should be corrected before the Final Report is submitted. These are:

- Page 114, line 12: The sentence "The main differences..." is not a complete sentence.

- Page 114, line 22: "geologists who have"

- Page 115, line 8: "implementation of software..."

- Page 117, line 19: "... has surveyed..."

- Page 117, line 20: "... were spent for the acquisition of the imagery alone."
- Page 122, line 7: "... diagnosis..."
- Page 123, line 9: "...maintenance..."
- Page 123, line 11, 12: "costs about US $0.15 while the... have cost about..."
- Page 123, line 16: "cost/effectiveness ratio... when compared with the SLAR ratio.
- Page 123, line 21: "Cambrian age"
- Page 125, line 3: "...the previously available map."
- Page 126, line 11: "...geological community."
- Page 126, line 14: "...cost/effectiveness..."
- Page 126, line 18: Should read: "Only conventional photo-interpretation techniques were used."

APPENDIX III

- Page 13, line 15: "different"
- Page 25, line 10: A period should follow "differentiation." The next word, "they" should be the first word of the following sentence.
- Page 25, line 19: "fine grained", "graywackes"
- Page 26, line 2: "are mainly dates"
- Page 26, line 11: "argillaceous", "siltstone"
- Page 27, line 1: "Ladeira et al", "designated"
- Page 28, line 7: "graywacke and arkosic sandstone."
- Page 31, line 3: "...separated mainly by tonality;..."
- Page 31, line 12: "...are in unconformable contact with..."

- Page 32, line 21: "It is unconformably overlying the units mentioned above."

- Page 33, line 1: "The area north of the Furnos Dam belongs to..." (no comma needed).

- Page 34, line 16: "thoroughly"

No reference is made to Plate 2 in the text. Also, the plates are referred to in a random order (Plate 3, Palte 1, Plate 1, Plate 4, etc.). Additionally, the plates should follow immediately after the first reference to them, rather than being grouped together at the end.

Map 1 should follow after the first reference to it on page 20. Likewise, Map 2 should follow directly after on page 31.

In his review of Volume II, Chapter IV, SOIL RESOURCES (Dr. Fernando de Mendonca) the Scientific Monitor stated that this report completed the analyses relevant to the stated objectives of the investigation. The investigation went a long way in identifying promising and economical applications of remotely sensed earth resources data in the field of agronomy. Technical details in the form of LANDSAT imaging illustrations, overlays, and maps were amply provided. In addition, the usefulness of LANDSAT imagery in other discipline areas of land use and demographic studies was explored. Unfortunately, the study is labeled as preliminary because of the absence of ground truth data.

The content deficiencies that should be corrected before the Final Report is submitted are:

- Page 141, Paragraph IV.2.4.3.6: This statement needs clarification.

- Page 145, Paragraph IV.2.5.3.4: This statement needs clarification.

- Page 149, Fig. IV.7: Only 4 area types are described in the Legend although 6 area types are discussed in the accompanying text.

- Page 150, Fig. IV.8: No reference is made to this Fig. in the text.

- Page 151, Paragraph IV.2.6.3.2: This statement needs clarification.

- Page 155, Paragraph IV.2.7.2.3: There is a discussion of the Parana River but it is not designated in Fig. IV.9.

- Page 161, Paragraph IV.2.8.2.5: This statement needs clarification.

- Page 177, line 16: Refernece to Fig. IV.20 should be Fig. IV.21.

- Page 179, Section IV.3.2.2.1 Legend: It is unfortunate that the terms "cerrado", "cerradao", etc. were not defined earlier in the text.

Will you kindly consider incorporating these comments into your draft before submitting eight (8) copies of the Final Report to:

Goddard Space Flight Center
Greenbelt, Maryland 20771
Attn: Scientific Investigation Support
Code 902.6

Sincerely,

James C Broderick

James C. Broderick
LANDSAT Technical Monitor