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16.Summary/Notes

The objective of this research was to develop a methodology for the application of LANDSAT data to study the process of settlement and deforestation in the tropical rainforest of Brazil. The most prominent features analysed through visual interpretation of LANDSAT images were: drainage network, vegetative cover types and land use. Automatic interpretation was made using Image-100 to separate unimproved and improved pasture areas. The results showed that LANDSAT data can be utilized to develop monitoring programs in the tropical forest areas of Brazil.

17.Remarks *This paper will be presented to the Third UN/FAO Training Course on Remote Sensing Application (Rome, Italy: May 15 - June 2, 1978).*

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1. INTRODUCTION

The Amazon tropical forest constitutes approximately 40% of Brazilian Territory and is a region with a low population density; a small number of urban areas and an under-developed network of transportation.

In an effort to stimulate the region's growth, the Brazilian Government has concentrated on a program of economic incentives to provide for the rational development of the natural resources of the area.

The first major effort to conduct a wide-scale and comprehensive inventory of the region was initiated in 1970, with Project RADAM (RADAR AMAZON); its preliminary results became available in 1973. However, the single radar data was inadequate as a source of information to study the impacts of settlement and accompanying cattle industries in the Amazon Basin.

Since 1972 the Brazilian Space Research Institute (INPE) has been receiving multispectral remote sensing information from the LANDSAT series satellite. The repetitive (every 18 days) characteristic of the LANDSAT system has become extremely important to the study of the process of settlement in areas of tropical forests.

The objective of the present research was to develop a methodology for the application of LANDSAT data to study the process of settlement and deforestation in the tropical rainforest of Brazil.

2. GENERAL CHARACTERISTICS OF THE STUDY AREA

The study area selected for this research is located in Mato Grosso State between the Xingu and Araguaia Rivers Basin

(Lat. S $11^{0}00'$ - $12^{0}30'$; Long. W $50^{0}30'$ - $53^{0}00'$). This particular forested area is of notable importance, as it is rapidly being cleared for the implantation of cattle grazing (Figure 1).

Based on Köppen classification, the area is represented by two climate regimes: the AM climate of the North and Northwest, and the AW climate in the remaining area.

According to information from the National Department of Mineral Production (1975) the area is divided into three main geologic units: Quaternary Deposits, Tertiary Deposits and Paraguai-Araguaia Folding Zone. Reflecting these the area is divided into three geomorphological units: the Araguaia Plain, formed by quaternary sediments; the Xingu Plateau, formed by tertiary sediments and the Roncador Plateau.

The study area is characterized by five major vegetation groups, ranging from forest to scrub-grassland: semideciduous forest, *gallery* forest, Brazilian savanna (*cerrado*), grassland (*campos*) and floodplain vegetation (*campos de várzea*), (IBGE, 1977).

Semideciduous forest is a transition from the *terra firme* or upland rainforest in Amazonia to cerrado. This forest type forms a semi-circular belt on the southern fringe of the tropical rainforest (IBGE, 1977).

The *gallery* forest constitutes evergreen riparian zones dispersed throughout the savanna (*cerrado*) of the Brazilian Central Plateau (Magalhães, 1966).

Christofoletti (1966) and Santos (1970) consider *cerrado* (Brazilian Savanna) a two-layered vegetation: the first layer composed by grasses, herbs, sub-shrubs and shrubs, and the second of a sparse-twisted low tree layer, generally ten meters in height.

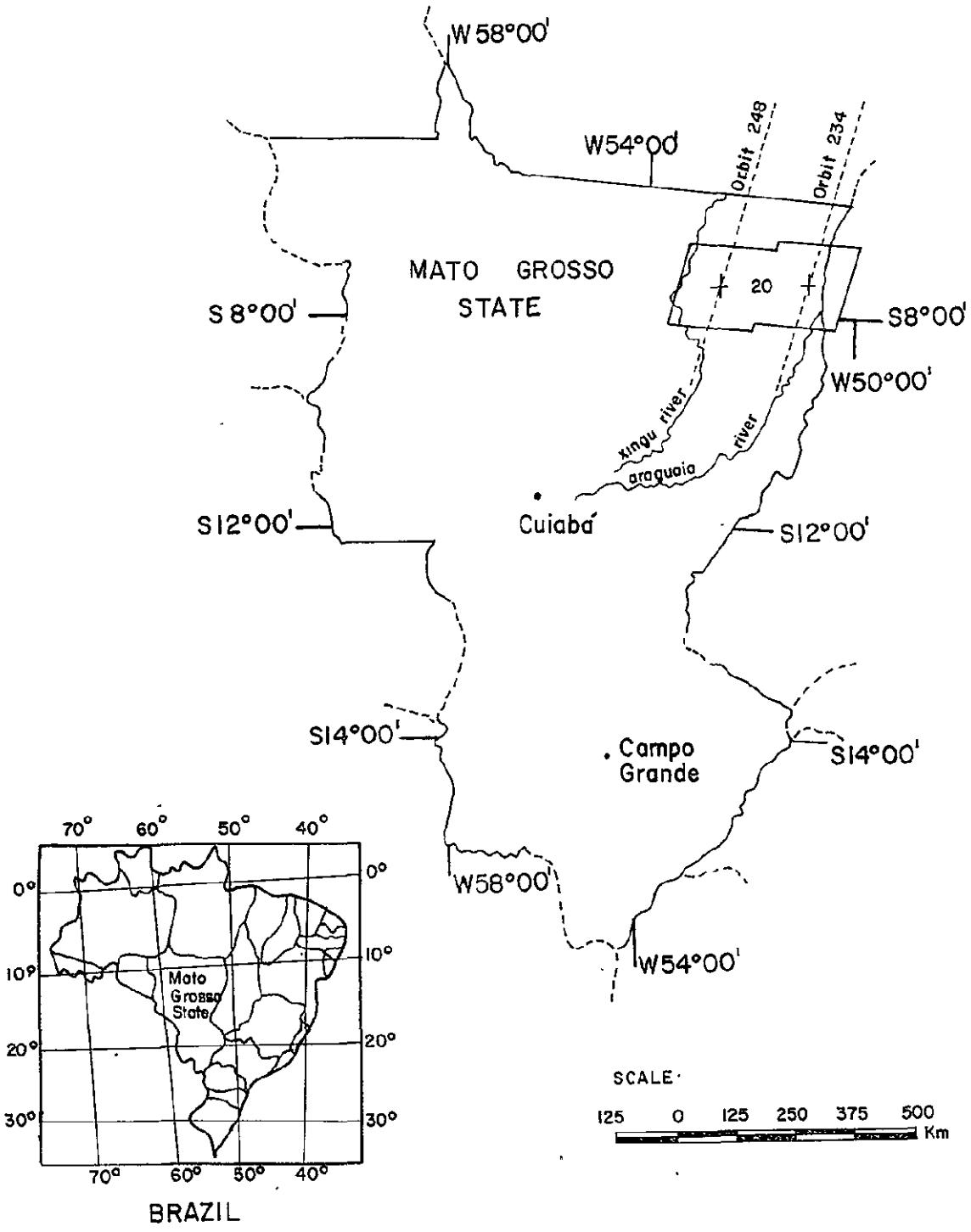

Fig. 1 - Location Map of the Study Area

Campos are characterized principally by herbaceous species associated with hillsides, slopes and floodplains of the Central Plateau's undulating topography (EMBRAPA, 1975).

3. MATERIALS AND METHODS

3.1 - MATERIALS

This study was conducted using LANDSAT system products. The necessary information for the development of this study was extracted from two LANDSAT MSS frames descriminated on Table 1.

TABLE 1

IMAGES USED IN THIS STUDY

IMAGE NUMBER	ORBIT	POINT	DATE	SCALE	CHANNELS
173 199 - 130 445	248	20	18-07-73	1:1,000,000 1: 250,000	5 and 7
173 216 - 125 848	234	20	04-08-73	1:1,000,000 1: 250,000	5 and 7
176 220 - 121 552	248	20	07-08-76	1:1,000,000 1: 250,000	5 and 7
176 237 - 120 812	234	20	24-08-76	1:1,000,000 1: 250,000	5 and 7

Interactive Multispectral Image Analysis System-Image-100 (G.E., 1975) was used to perform automatic interpretation.

3.2 - METHODS

The following approach was used to evaluate satellite data, to assess the settlement problems in the study area:

3.2.1 - BIBLIOGRAPHIC AND CARTOGRAPHIC SURVEY

This stage of research required the collection of available bibliographic information and maps of the study area.

3.2.2 - VISUAL INTERPRETATION

Visual interpretation was performed with channels 5 and 7 black and white imagery, at the scale of 1:1,000,000. The most prominent features analysed were:

a) Drainage Network

Channel 7 was used to map the primary streams. The major rivers, which are prominent in areal extent, are defined in channel 7 due to high water absorption in the infrared wavelength, resulting in dark-grey tones (Valério Filho et al., 1976; Koffler, 1976).

Secondary streams and lesser ordered drainage features, in areas of campos e cerrados, were mapped in channel 5. These areas are of typical sparse vegetation, and the dark grey tones of gallery forest indicating a denser riparian cover type, facilitated the identification of secondary drainage features.

The drainage map was produced at a scale of 1:1,000,000, and all streams were mapped regardless of whether they were intermitent or perennial.

A qualitative analysis was made of hydrologic characteristics of the region. The purpose of this was to subdivide the study area into zones of superficial drainage patterns and stream distribution (Ricci and Petri, 1965). This procedure was used to locate areas favorable to cattle grazing.

b) Vegetative Cover Type

A visual analysis of tonality in channel 5 provided for the separation of homogeneous vegetation areas as this band displayed large differences in spectral responses between different vegetation types.

The percentages of exposed soil vary with vegetation cover types. Areas of dense vegetation (minimal bare soil exposure) elicited dark grey tones due to higher absorption levels in channel 5. An increase in soil exposure diminishes the spectral response of vegetation resulting in lighter tones on the images.

The use of low contrast images permitted the identification of various homogeneous vegetative communities. Tonality differences in channel 7 provided for identification of periodic inundated areas, riparian vegetation, as well as areas in which vegetation distribution is associated with varying soil humidity.

c) Land Use

A classification system was established, to survey land use patterns for two different periods: July, 1973 and August, 1976. To inventory land use features, channels 5 and 7 were used at scales of 1:1,000,000 and 1:250,000. Areas of improved pasture were estimated using a dot grid (1 x 1 mm) overlay.

Visual analysis of channel 5 clearly showed transportation system, urban areas, locations of ranch complex and airstrip.

3.2.3 - GROUND TRUTH

A field itinerary was then designed to include as many representative sampled areas as possible. This was completed in two separate phases:

1.) A low altitude flight permitted the characterization of homogeneous vegetative communities and land use patterns;

2) A field reconnaissance by car provided a description of the same aspects viewed during the flight, only with greater details.

Following this work, final vegetation types and classification system were defined for vegetation types and land use, according to the data collected.

3.2.4 - AUTOMATIC INTERPRETATION

During the field research (Tardin et al., 1976) it was observed that several of the deforested areas existed in a state of natural regrowth without the presence of seeded grasses.

This observation led to the separation of unimproved and improved rangeland, which were also distinguished in channel 5 of LANDSAT imagery and assigned to Image-100 for classification.

4. RESULTS AND DISCUSSION

4.1 - VISUAL INTERPRETATION

4.1.1 - DRAINAGE NETWORK

The drainage network is a feature easily identified using LANDSAT imagery. It was consequently used as a base data for the construction of overlays.

During the dry season, differences were observed between the spectral responses of gallery forest and surrounding vegetation, owing to varying levels of humidity. Thus imagery in channel 7, for this period, was adequate for secondary drainage mapping in dense vegetation areas.

The drainage map (Figure 2) was used to separate homogeneous zones, based on superficial drainage patterns, with the objective of locating pasture areas.

The distribution and configuration of the stream systems were found to be one of the most important factors in locating pasture areas, considering the necessity of a constant supply of water for cattle (Petrone, 1970; Keller, 1970).

The criteria to decide which zones were most favorable for pasture establishment were based on the following:

a) size of streams;

b) intervals among streams;

c) stream distribution;

d) headwater regions.

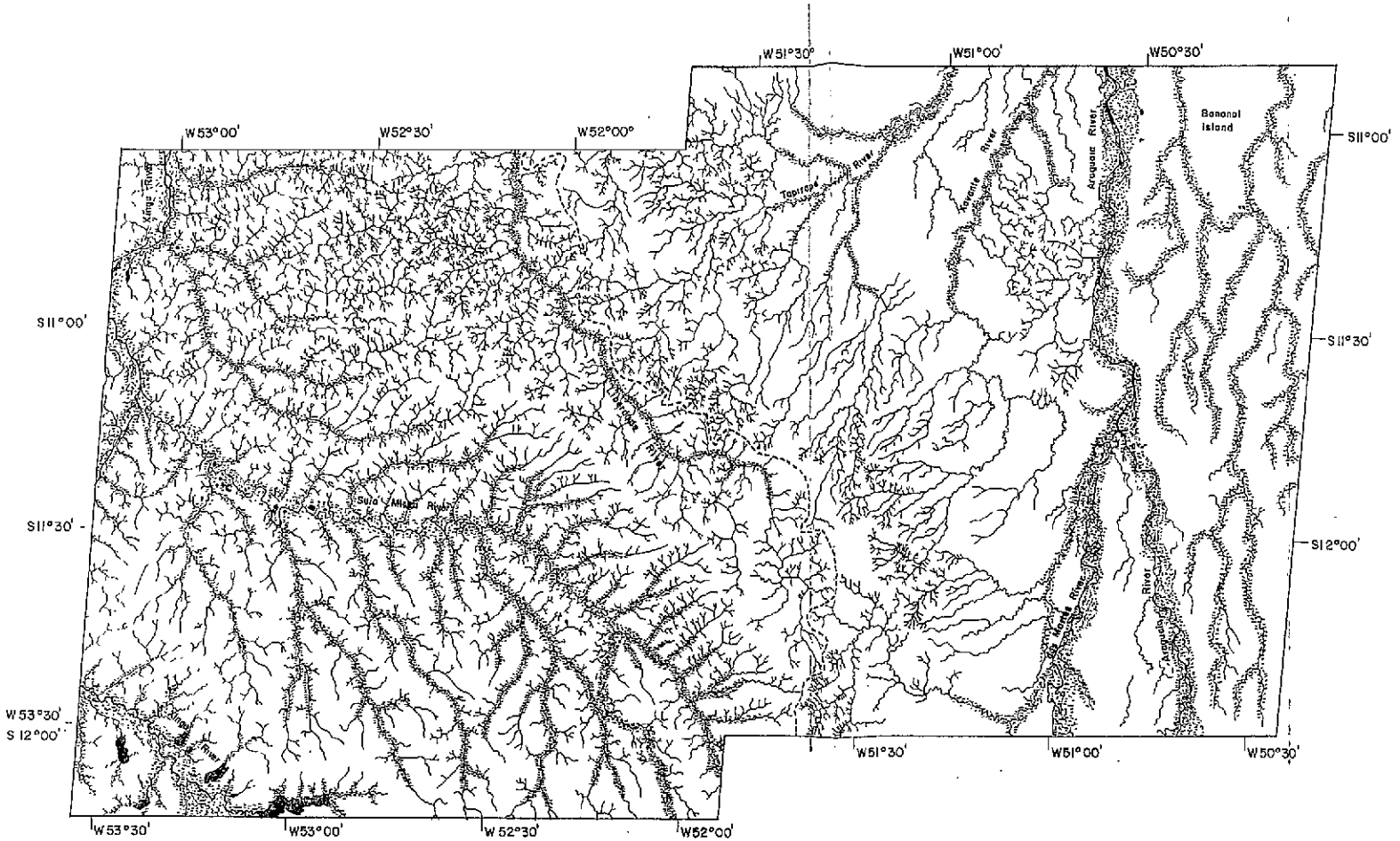

Fig. 2 - Drainage Network

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The qualitative analysis of the drainage network patterns permitted the identification of the following zones (Figure 3):

1) Zone A : Characterized by headwaters with a significant amount of small streams closely spaced;

2) Zone B : Characterized by medium-sized streams distributed regularly through the zone;

3) Zone C : Characterized by medium-sized streams, regularly distributed with wide intervals among them;

4) Zone D : Characterized by small number of streams, long and irregularly distributed;

According to the above classification the zone with high potential for the localization of pasture is characterized by medium-sized streams, regularly distributed and spaced.

The zones of low potential are characterized by small intermittent and irregularly distributed streams, and headwater regions which, if converted to pasture areas, would introduce rapid erosion. Other distinguishing features include: small intervals between streams, which possibly indicate unfavorable topography for pasture implantation, as well as widely spaced streams, which do not provide an adequate water supply for cattle.

The results of drainage interpretation produced the following three classes of regional pasture potential:

High: Zone B;

Medium: Zone C;

Low: Zones A and D.

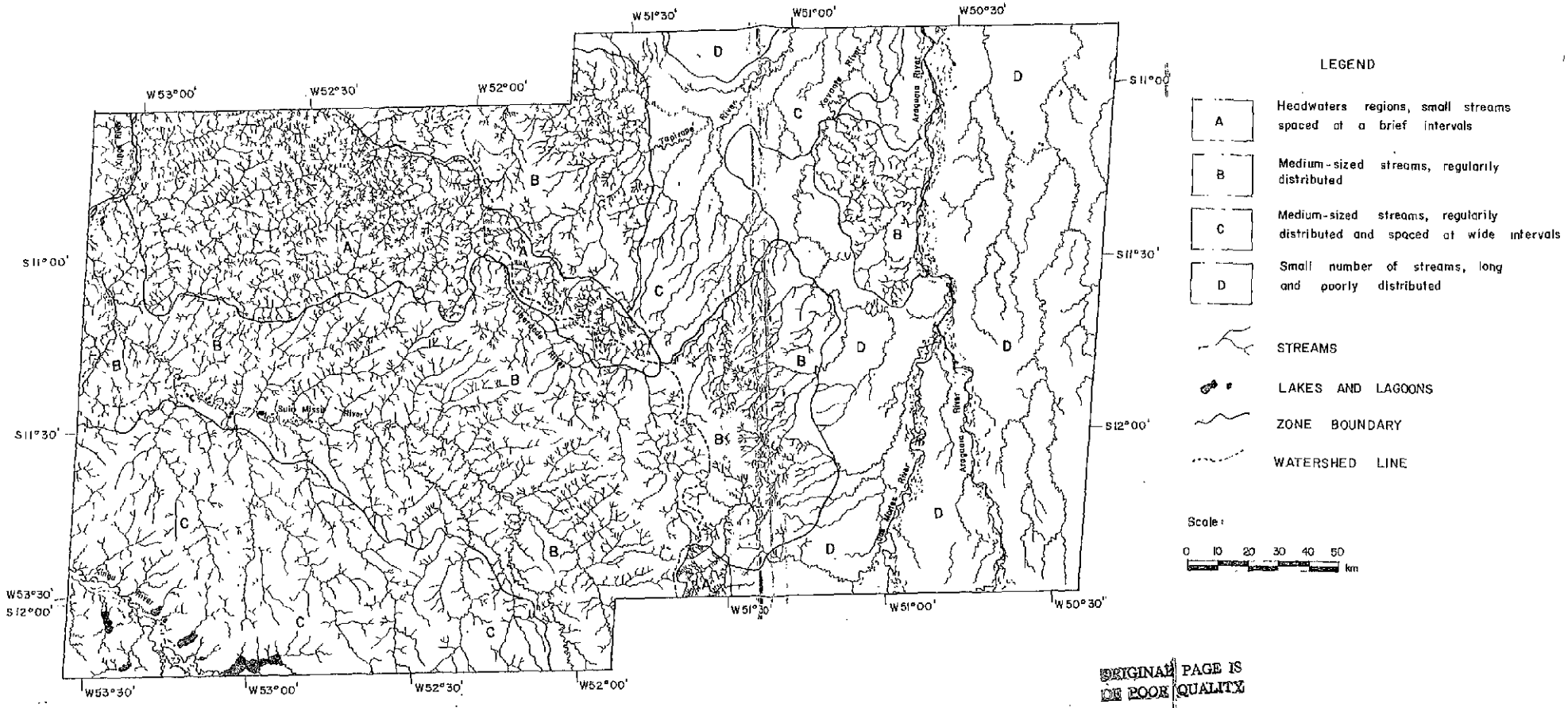

Fig. 3 - Potential Zones for Cattle Grazing Based on Drainage Patterns and Stream Distribution

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4.1.2 - VEGETATIVE COVER TYPES

The vegetation survey was conducted with the objective of identifying areas with vegetative coverage favorable for clearing and the establishment of pasture land.

Plant formations were used as an index of water availability. The use of dry season imagery revealed this association through different spectral response. During this period some species lost their leaves or became yellow, while the others remained green.

Through image analysis the following vegetation types were identified (Figure 4):

1) Dense Forest : Characterized by homogeneous dark grey tones in channel 5, and light tones in channel 7, due to dense foliage and minimal exposure of bare soil (Figure 5);

2) Open Forest : In channel 5 the open forest was represented by dark grey tones as in the case of dense forest. However, the tonality of open forest is not homogeneous due to the openings in the canopy. In channel 7 the open forest showed a darker grey tone than that of the dense forest (Figure 6);

3) Gallery Forest : This vegetation type showed a dark grey tone in channel 5 in contrast with the light tone of the adjacent areas. In channel 7 this category did not display definite spectral limits (Figure 7);

4) Cerrado : In channel 5 the tonality of cerrado was medium-grey with little homogeneity, the dark-grey tones in spots were caused by sporadic dense crown coverage of cerrado plants (Figure 8);

5) Campos : The tonality of campos vegetation was light grey in channel 5, due to the predominance of grass. Generally this occurred in areas of undulating topography (Figure 9);

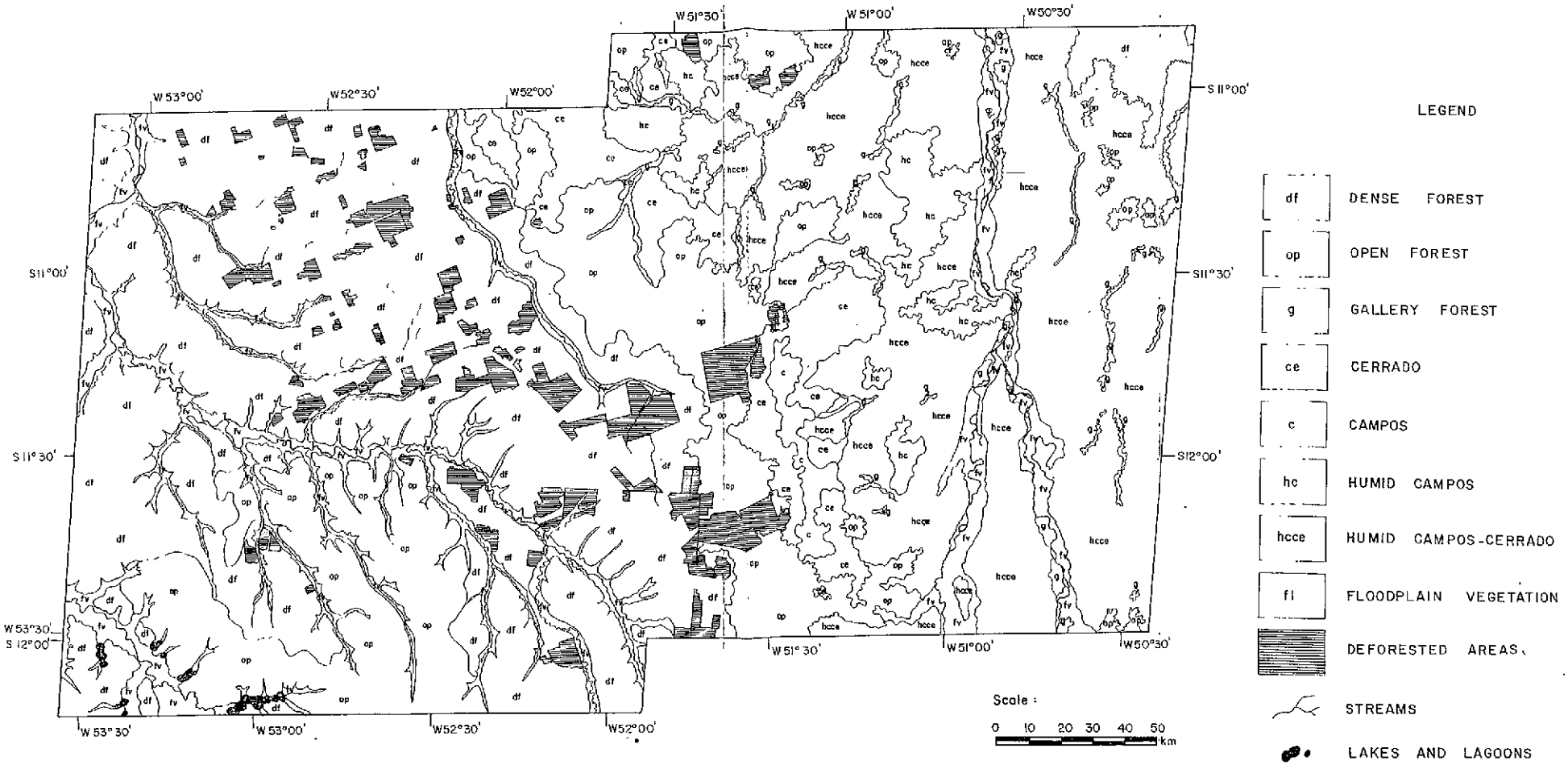

Fig. 4 - Vegetation Cover Map

Fig. 5 - Dense Forest

Fig. 6 - Open Forest

Fig. 7 - Gallery Forest

Fig. 8 - Cerrado

Fig. 9 - Campos

6) "Humid" Campos : The image represented this category by a light-grey tone in channels 5 and 7, with spotted dark areas corresponding to the inundated areas reminiscent of the wet season (Figure 10);

7) "Humid" Campos - Cerrado : This vegetation type was only differentiated from the cerrado in channel 7, and the tone appears a very dark grey due to greater humidity in the soil (Figure 11);

8) Floodplain Vegetation : This region is characterized by a grey tone lighter than the gallery forest in channel 5, and by dark grey tones in channel 7, due to the soil humidity. Permanent inundations are constantly found within the flood--plain area (Figure 12).

The criteria of choosing the favorable vegetation type for the implantation of pasture were:

a) Dense Forest and Gallery Forest should be preserved;

b) Inundated areas are unfavorable for the establishment of pastures.

The areas considered for potential pasture implantation were divided into three classes:

High: Cerrado and Campos;

Medium: Open Forest;

Low: Dense Forest, Gallery Forest, Humid Campos, Humid Campos - Cerrado and Floodplain vegetation.

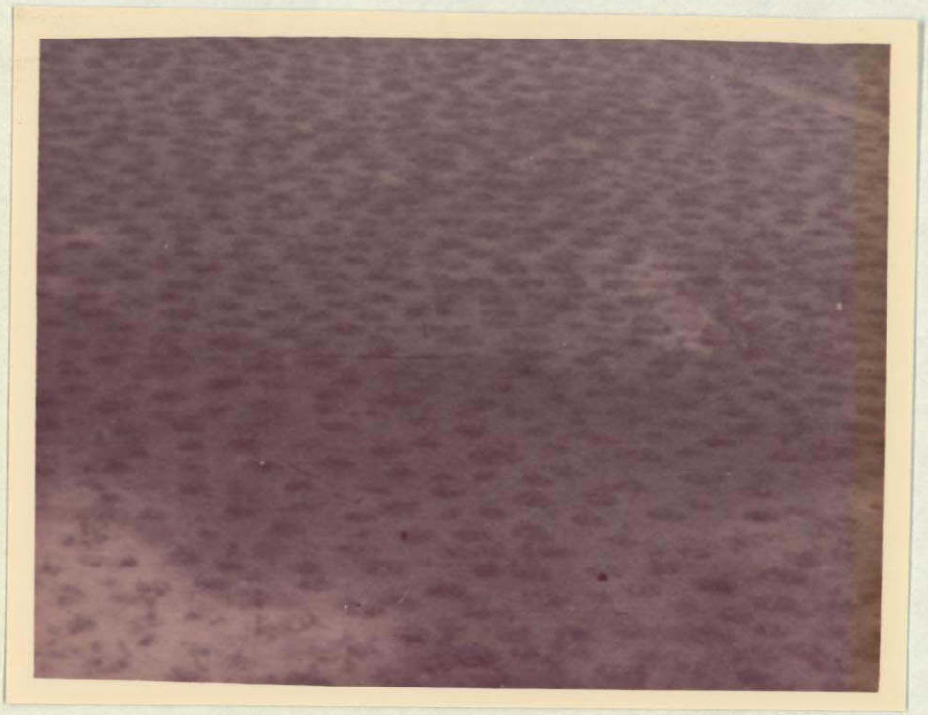

Fig. 10 - Humid Campos

Fig. 11 - Humid Campos - Cerrado

Fig. 12 - Floodplain Vegetation

4.1.3 - LAND USE

The following land use classes were identified:

1) Cattle Ranching : Areas occupied predominantly by cattle raising activities, which can be grouped into two sub-classes:

a) Improved Pasture : Improved pasture appears as a light grey tone in channel 5 due to the presence of grasses whose spectral response is affected by soil reflectance. Channel 7 presented a dark grey tone corresponding high amounts of soil exposure while surrounding natural vegetation showed higher reflectance (Figure 13).

Another important aspect in this category was the spacial features. Improved pasture was generally characterized by regular forms.

b) Rangelands : Grazing areas, including the cerrado, campos--cerrado and campos, often subjected to seasonal inundation. This category was clearly observed in the field work but a definite criterion for its identification on LANDSAT imagery is lacking (Figure 14).

2) Constructed Areas : This class can be subdivided into two following categories:

a) Ranch Complex : Characterized by the concentration of ranch buildings and connecting roads for the adjacent pasture land. On the image in channel 5 this complex appeared merely a light grey point within the pasture areas, but was commonly located close to the road system (Figure 15).

b) Urban Areas : The urban centers, located within the study area, function as political, administrative and commercial centers.

Fig. 13 - Improved Pasture

Fig. 14 - Rangeland

Fig. 15 - Ranch Complex

3) Occasionally Occupied Areas : These are the areas which are not occupied long enough to seriously disturb natural conditions.

   a) Forest : This heavily forested region showed negligible evidence of human occupation on any economic scale, while trees in the borders of this category are frequently cut for fence posts.

   b) Floodplain : The floodplain is occasionally occupied during the dry season for cattle raising activities.

4) Transportation Systems : The following categories were distinguished within the region:

   a) Road Systems : These are basically unimproved roads, constructed primarily for the clearing activities in the region, and resulting in a network which connects the pasture lands. These roads were identified on the images in channel 5 due to the high contrast between exposed soil and adjacent vegetation.

   b) Airstrip : Runways were always located near the ranch complex or within the forest. They are usually constructed before the deforestation process. Once the airstrip constructed, the area is deforested and a ranch complex develops.

A comparison between the land use maps of 1973 (Figure 16) and 1976 (Figure 17) clearly demonstrates a large scale deforestation of the area, for pasture establishment and, consequently, an intensification of the construction of new roads and ranch complexes.

Table 2 shows the quantitative estimates of deforested areas between 1973 and 1976. It was observed that 27 new areas were cleared, amounting to 44,266 hectares. Out of the 45 cleared areas which existed in 1973, 11 (or 24%) remained stable while 14 (or 31%) increased more than 100% in size. In the study area, deforested areas

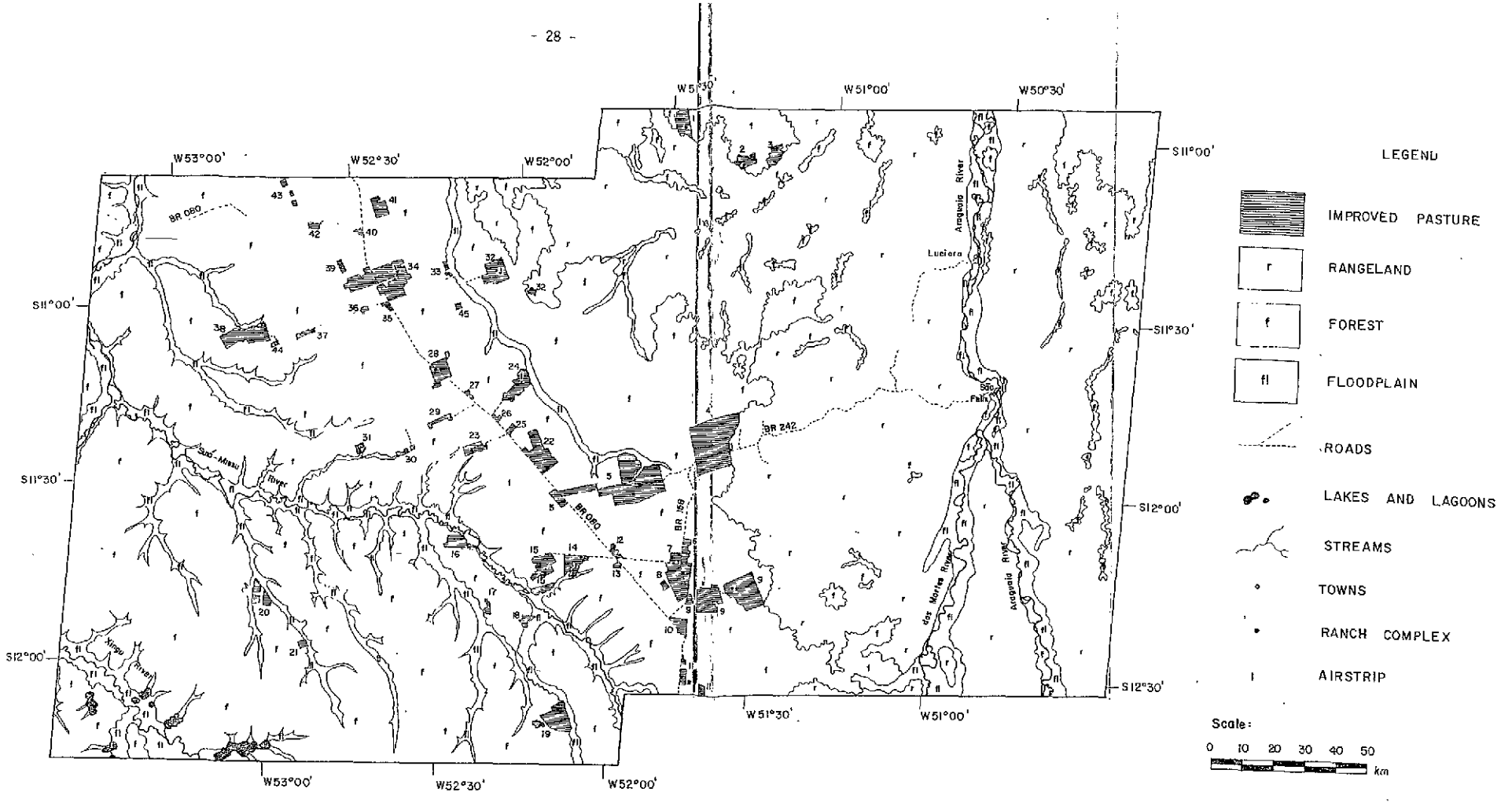

Fig. 16 - Land Use Map of July, 1973

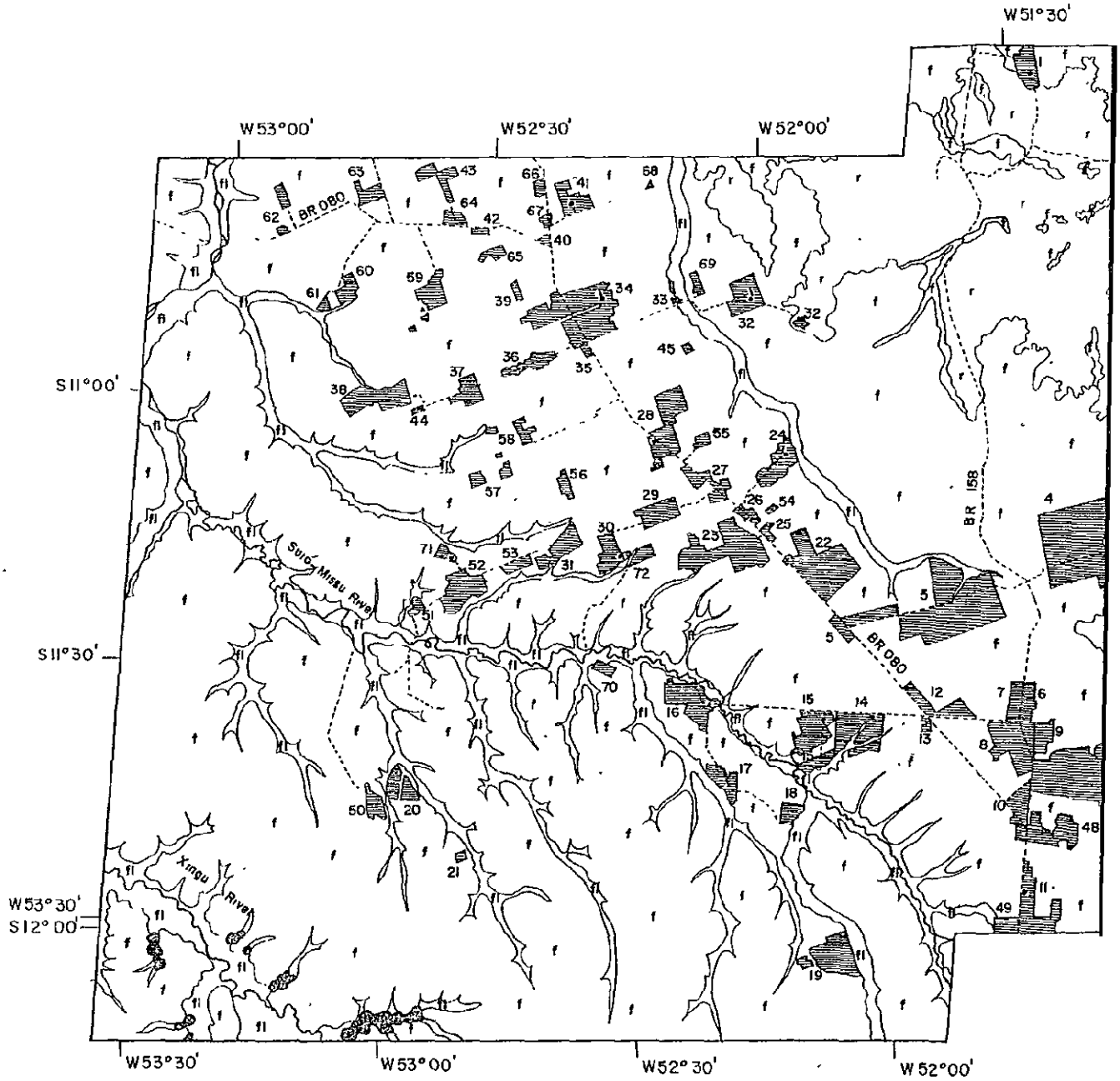

Fig. 17 - Land Use Map of August, 1976

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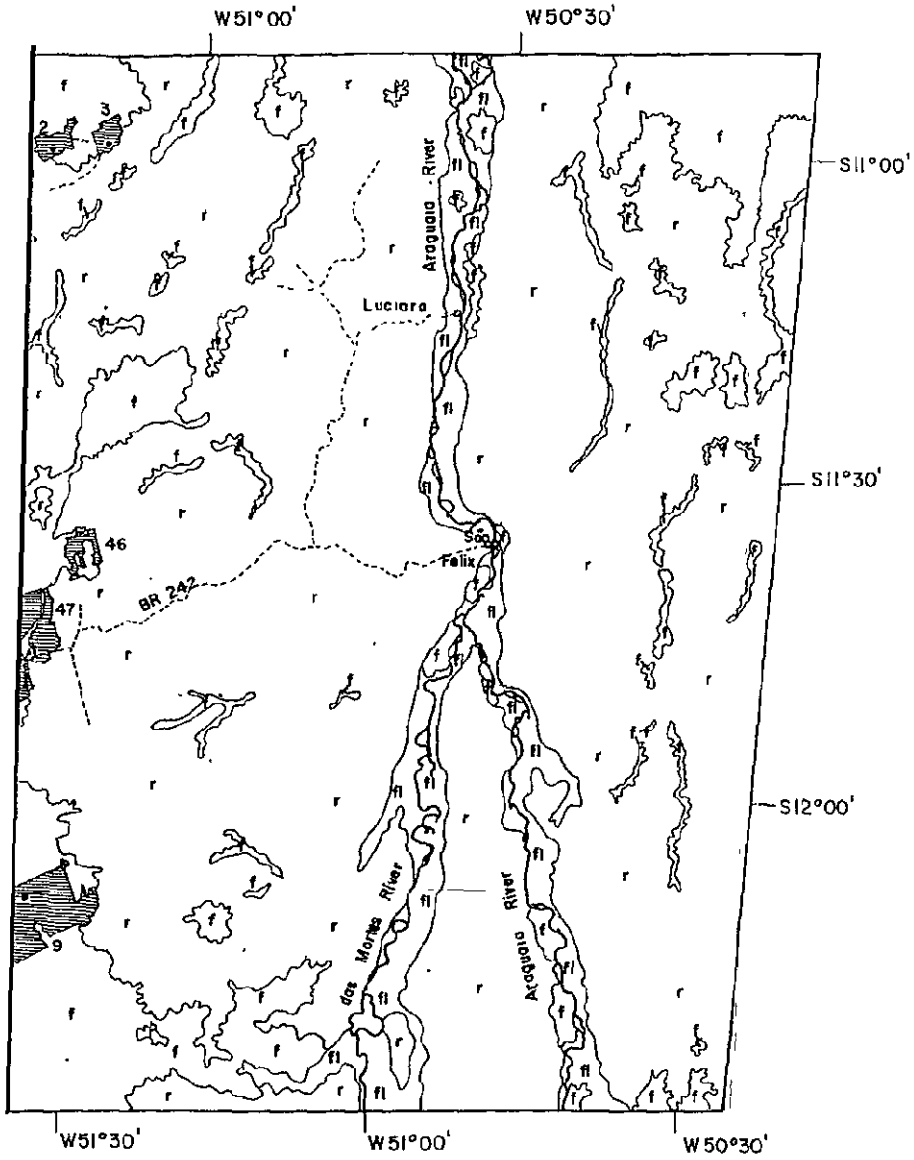

LEGEND

- IMPROVED PASTURE
- r — RANGELAND
- f — FOREST
- fl — FLOODPLAIN
- ROADS
- LAKES AND LAGOONS
- STREAMS
- TOWNS
- RANCH COMPLEX
- AIRSTRIP

Scale:

0 10 20 30 40 50 km

2

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TABLE 2

COMPARISON BETWEEN DEFORESTED AREAS OF JULY, 1973 AND AUGUST, 1976

AREA	DEFORESTED AREA (HA) JULY, 1973	DEFORESTED AREA (HA) AUGUST, 1976	DIFFERENCES IN HA	PERCENT INCREASE IN AREA
1	5 022	5 022	—	0.0
2	2 080	2 702	622	29.9
3	1 968	2 218	250	12.7
4	22 179	23 299	1 120	5.0
5	20 864	24 485	3 621	17.4
6	1 024	2 074	1 050	102.5
7	896	2 551	1 655	184.7
8	6 415	8 240	1 825	28.4
9	16 752	29 304	12 552	74.9
10	1 984	2 341	357	18.0
11	2 176	5 654	3 478	159.8
12	880	3 481	2 601	295.6
13	384	555	171	44.5
14	2 448	5 309	2 861	116.9
15	4 713	6 600	1 887	40.0
16	3 068	4 888	1 820	59.3
17	434	2 355	1 921	442.6
18	1 283	1 731	448	34.9
19	6 079	6 079	—	0.0
20	2 551	2 551	—	0.0
21	304	449	145	47.7
22	7 152	11 660	4 508	63.0
23	2 144	10 091	7 947	370.0
24	4 610	4 610	—	0.0
25	464	574	110	23.7
26	272	973	701	257.7

(Cont.)

AREA	DEFORESTED AREA (HA) JULY, 1973	DEFORESTED AREA (HA) AUGUST, 1976	DIFFERENCES IN HA	PERCENT INCREASE IN AREA
27	352	3 241	2 889	820.7
28	4 032	7 274	3 242	80.4
29	1 056	3 269	2 213	209.6
30	624	3 066	2 442	391.3
31	576	2 935	2 359	409.5
32	4 401	4 785	384	8.7
33	586	586	—	0.0
34	12 736	14 160	1 424	11.1
35	586	586	—	0.0
36	464	1 441	977	210.6
37	1 088	2 451	1 363	125.3
38	5 497	5 497	—	0.0
39	672	672	—	0.0
40	430	430	—	0.0
41	2 496	2 689	193	7.7
42	655	655	—	0.0
43	672	2 052	1 380	205.4
44	449	449	—	0.0
45	380	380	—	0.0
46	—	2 105	2 105	—
47	—	3 488	3 488	—
48	—	5 754	5 754	—
49	—	1 160	1 160	—
50	—	1 700	1 700	—
51	—	742	742	—
52	—	5 094	5 094	—
53	—	1 447	1 447	—
54	—	446	446	—
55	—	786	786	—
56	—	1 054	1 054	—

(Cont.)

AREA	DEFORESTED AREA (HA) JULY, 1973	DEFORESTED AREA (HA) AUGUST, 1976	DIFFERENCES IN HA	PERCENT INCREASE IN AREA
57	—	1 117	1 117	—
58	—	1 447	1 447	—
59	—	2 670	2 670	—
60	—	1 887	1 887	—
61	—	412	412	—
62	—	1 129	1 129	—
63	—	1 634	1 634	—
64	—	1 341	1 341	—
65	—	774	774	—
66	—	599	599	—
67	—	399	399	—
68	—	75	75	—
69	—	674	674	—
70	—	1 235	1 235	—
71	—	1 828	1 828	—
72	—	3 269	3 269	—
TOTAL	155 898	270 680	114 782	

155,898 hectares in 1973 had grown to 270,680 hectares in 1976 - an increase of 74%.

4.2 - AUTOMATIC INTERPRETATION

During the dry season the spectral response of grasses in pasture areas (Figure 18) is affected by soil reflectance, which showed light tones in channel 5.

The contrasting dark tones of natural vegetation regrowth, in channel 5 readily revealed areas that had been mismanaged. An analysis of pasture quality indicated the mal-utilization of such areas after deforestation (Figure 19). In automatic interpretation, the deforested areas were classified into: *Pasture Area Predominantly Grass (PG)* and *Pasture Area with Secondary Arboreal Regrowth (PR)*.

Sixteen deforested areas were sampled for automatic classification (Figures 20, 21 and 22). The areal extents of class PG and PR are presented in Table 3. Three deforested areas (no.1, 19, 46) show over 50% secondary arboreal regrowth while the percentage of the improved pasture ranges from 8.7% to 91.8%.

Of the 135,000 hectares examined (16 areas) only 87,202 hectares (≃65%) were under utilization during the period of study.

5. CONCLUSIONS

The results obtained through this research showed that LANDSAT data can be utilized to develop monitoring programs in the tropical forest areas of Brazil.

This research did not show the total potential of the LANDSAT system, but tried to open up new research aspects for the utilization of LANDSAT data in natural resource control.

Fig. 18 - Deforested Area

Fig. 19 - Natural vegetation regrowth in Pasture Area

Fig. 20 - Infrared Color Composite obtained through Image-100 system showing the number 5 deforested area.

Fig. 21 - Image-100 Classification of the Deforested Area of Area no. 5

Fig. 22 - Image-100 classification of the class "pasture area predominantly grass" of area no. 5

TABLE 3

PERCENTAGE ESTIMATIONS OF THE IMPROVED GRASS AND SECONDARY ARBOREAL REGROWTH IN DEFORESTED AREAS

AREA	DEFORESTED AREA (NA) AUGUST, 1976	PASTURE PREDOMINANTLY GRASS (HA)	PERCENTAGE OF IMPROVED GRASS IN DEFORESTED AREA	PERCENTAGE OF SECONDARY ARBOREAL REGROWTH
1	5022	1360	27.1	72.9
3	2218	1565	70.6	29.4
4	23299	21379	91.8	8.2
5	24485	17209	70.3	29.7
7	2551	1947	76.3	23.7
8	8240	5784	70.2	29.8
9	29304	15938	54.4	45.6
10	2341	1650	70.5	29.5
12	3481	2530	72.7	27.3
15	6600	4759	72.1	27.9
16	4888	3969	81.2	18.8
18	1731	991	57.3	42.7
19	6079	2486	40.9	59.1
24	4610	2564	55.6	44.4
32	4425	2569	58.1	41.9
46	5754	502	8.7	91.3
TOTAL	135028	87202	—	—

BIBLIOGRAPHY

CHRISTOFOLETTI, A. Considerações a propósito da Geografia Física dos Cerrados. *Notícia Geomorfológica*, 6 (11) : 5-32, Jun., 1966.

DEPARTAMENTO NACIONAL DA PRODUÇÃO MINERAL (DNPM). *Carta Geológica do Brasil ao Milionésimo, Folha Tocantins (SC-22) e Goiás (SD-22).* Rio de Janeiro, 1975.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA (EMBRAPA). Centro de Pesquisa Pedológica. *Mapa Esquemático dos Solos das Regiões Norte, Meio Norte e Centro-Oeste do Brasil.* Texto Explicativo, Brasília, 1975. (Boletim Técnico, 17).

GENERAL ELECTRIC COMPANY. *Image-100 - Interactive Multispectral Image Analysis System.* (User Manual). Daytona, 1975.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA (IBGE). *Geografia do Brasil - Região Centro Oeste.* Rio de Janeiro, 1977. V. 4.

KELLER, E.C. de S. O "Habitat" Rural. In: AZEVEDO, A.de, *Brasil: A Terra e o Homem.* São Paulo, USP, 1970. V. 2, p. 291-345.

KOFFLER, N.F. *Utilização de Imagens Aerofotográficas e Orbitais no Padrão de Drenagem em Solos Originados do Arenito Bauru.* Tese de Mestrado em Sensoriamento Remoto e Aplicações. São José dos Campos, INPE, 1976. (898-TPT/029).

MAGALHÃES, G.M. Sobre os Cerrados de Minas Gerais. *Anais da Academia Brasileira de Ciências*, 38: 59-69, Dez., 1964.

PETRONE, P. Povoamento e Colonização. In: AZEVEDO, A. de, *Brasil: A Terra e o Homem.* São Paulo, USP, 1970. V. 2, p. 128-158.

RICCI, M.; PETRI, S. Fatores - Guia na Interpretação Geológica. In: ———, *Princípios de Aerofotogrametria e Interpretação Geológica.* São Paulo, Nacional, 1965. V. 2, Cap. 8, p. 98. (Ciências Aplicadas, Biblioteca Universitária, 4).

SANTOS, L.B. dos Aspectos da Vegetação do Brasil. In: *TIPOS e Aspectos do Brasil* - Separata da *Revista Brasileira de Geografia*. p. 459-472, 1970.

TARDIN, A.T.; SANTOS, A.P. dos; MORAES, E.M.L. de; TOLEDO, F.L.; ARAUJO, P. *Relatório do Trabalho de Campo no NE do Mato Grosso como Apoio na Utilização de Imagens LANDSAT no Monitoramento do Uso da Terra*. São José dos Campos, INPE, Mar., 1976. (837-RVi/009).

VALÉRIO FILHO, M.; HIGA, N.T.; CARVALHO, V.C. de *Avaliação das Imagens Orbitais (LANDSAT-1) como Base para Levantamento de Solos*. Tese de Mestrado em Sensoriamento Remoto e Aplicações. São José dos Campos, INPE, 1976. (912-TPT/030).