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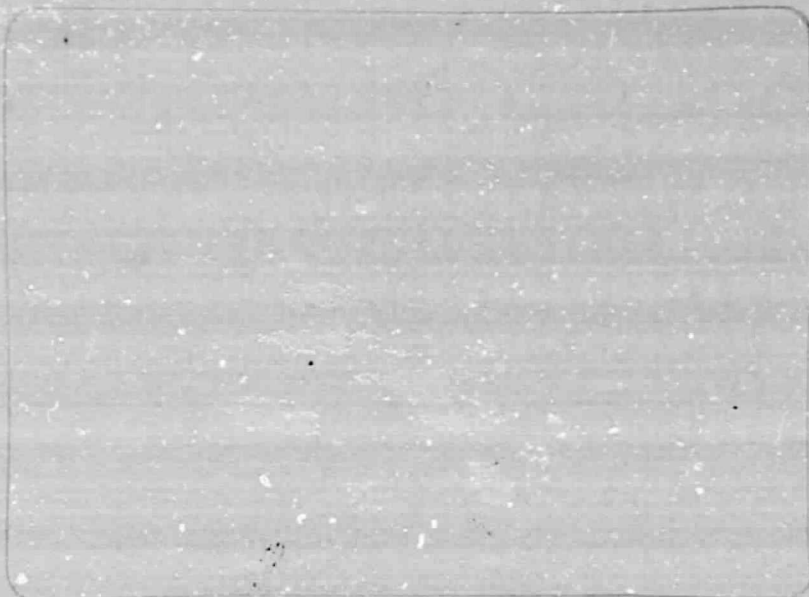
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CONSELHO NACIONAL DE DESENVOLVIMENTO CIENTÍFICO E TECNOLÓGICO

INSTITUTO DE PESQUISAS ESPACIAIS

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CHAPTER I

INTRODUCTION

Soil survey is one of the main methods to attain rational land utilization.

Among the difficulties encountered in carrying out traditional soil surveys are the high cost involved and long time required for the execution. In Brazil, these difficulties are aggravated by the size of the country and by the difficulties to access some areas.

New technologies and methods have been developed to minimize these problems. Now, imagery from the LANDSAT series of satellites allow a global, repetitive and multispectral coverage of the whole Brazilian territory. The purpose of this work is to evaluate the LANDSAT system capability for soil survey.

This evaluation was performed based on the comparison of the results obtained by visual interpretation of images, taking into consideration the following: land use, natural vegetation, relief, drainage pattern and spectral response, as well as comparison with results of other researchers who had used aerial photographs and existing soil maps.

## CHAPTER II

### MATERIAL AND METHODS

The selected area - Ribeirão Preto - is located in the NE of the state of São Paulo and the SE of the state of Minas Gerais (Fig. II.1). It lies between the latitudes  $20^{\circ}30'$  and  $22^{\circ}30'$ , South and the longitudes  $47^{\circ}00'$  and  $49^{\circ}00'$  West.

To accomplish this work, LANDSAT images (four bands) in the scales of 1:1,000,000 and 1:500,000 were used as well as transparencies in the scale of 1:3,369,000 and 1:1,000,000. The MSS images were acquired on July 21, and August 18, 1973.

Color compositions done in the Color Additive Viewer - I<sup>2</sup>S were utilized to aid in the interpretation. The transparencies in the 1:1,000,000 scale were used to quantify different hues, related to different soil groups, which were analyzed in the Image-100 System.

Spectral measurements for the various groups of soils were obtained with the Earth Ground Truth Radiometer. Spectral response curves were also determined in the Laboratory using a spectrophotometer operating in the visible range.

A study of the water balance for Ribeirão Preto, according to Thornthwaite's (1948) method was done to evaluate the soil capacity.

Visual interpretation was carried out in black and white images at the scale of 1:1,000,000, (channels 4,5,6 and 7) to map the following themes: land use, natural vegetation, superficial drainage and relief. After this initial mapping, these themes were also mapped on the 1:500,000 images.

Different categories of land use were characterized on the MSS images based on texture and spectral responses with the aid of color compositions. Based on available bibliographic information and sketches of land use, it was possible to infer the spatial distribution

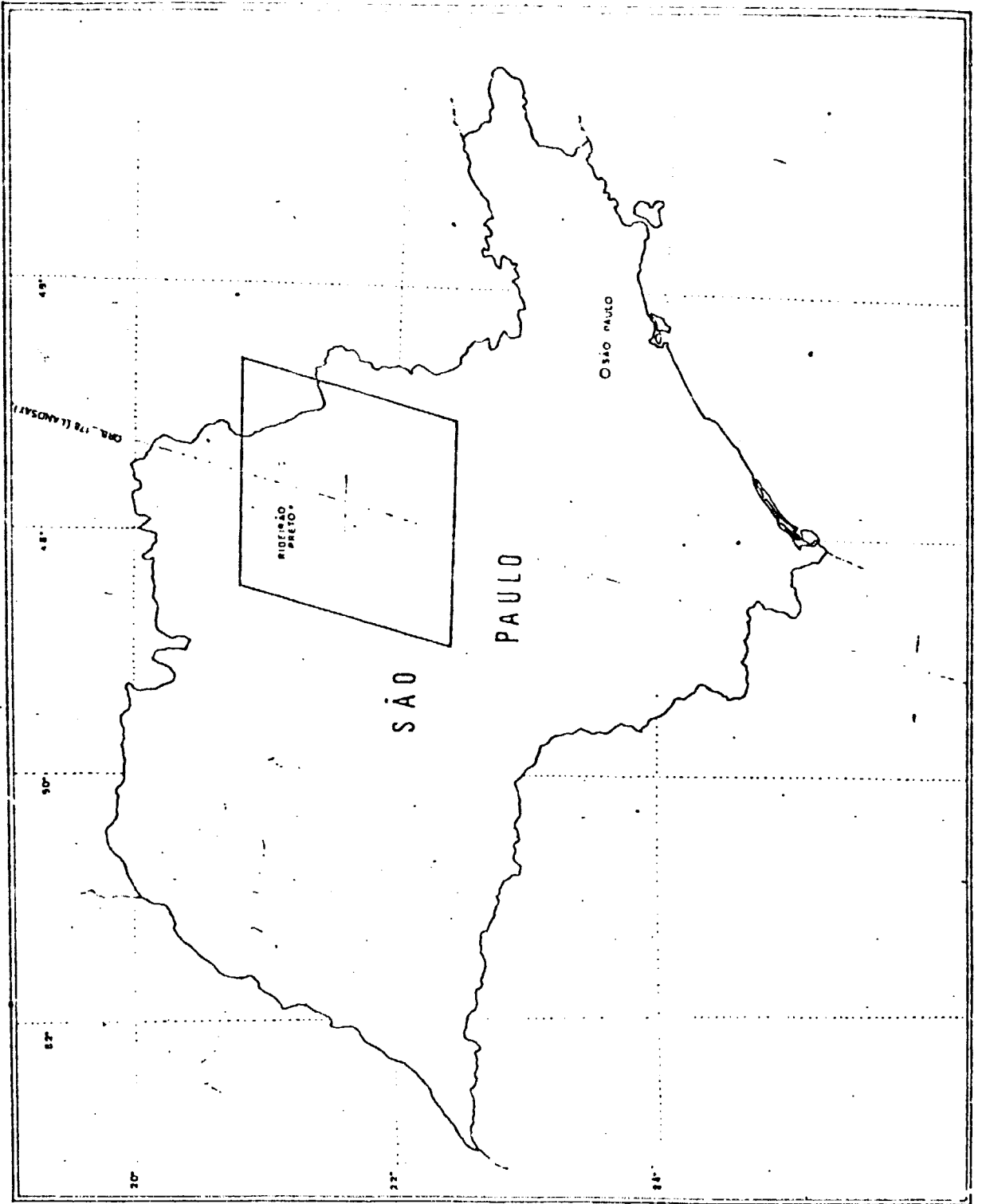


Fig. II.1 - Localization of the area under study.

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of different types of vegetation likely to exist or having existed in a certain area.

Qualitative and quantitative studies of the drainage patterns obtained by manual interpretation were done to evaluate the possibility of using drainage pattern for soil classification.

The qualitative study was developed according to Lueder (1959). The quantitative factors analyzed were: drainage density (Ray and Fischer 1960), stream frequency and texture ratio in circular samples (Souza, 1975). These calculations were based on circular samples with an area of 170 km<sup>2</sup>. For each homogeneous drainage area, the average indices values were submitted to a Correlation and Regression Analysis.

The final results were compared to those found by other researchers who had used aerial photographs and conventional soil maps.

## CHAPTER III

### RESULTS AND DISCUSSION

#### 3.1 - CLIMATIC CONDITIONS

The Ribeirão Preto climatic study was based on meteorologic data obtained as monthly averages over several years prior to 1973 and more detailed data for 1973.

The conclusions are summarized in Figure III.1. Inferences on natural vegetation and soils were made based on water content. It has been observed that the spectral response of the soil and the vegetation changes with the water content of the soil.

#### 3.2 - LAND USE

Channels 5 and 7 proved to be better for distinguishing land use categories. Visual interpretation of the images permitted the classification of land use into 6 classes: crop areas and grassland, "campo cerrado", natural forest, gallery forest, artificial forest and urban areas. (Fig. III.2).

Comparing a conventional soil map shown in Fig. III.3 with the land use map obtained from LANDSAT images (Fig. III.2), it was possible to identify soils in good agricultural conditions like Latossols. Observations of land use were helpful to infer the soil groups in the area. These observations agree with Elbersen's (1973), Cipra's (1973) and Hilwig's (1974) results.

#### 3.3 - NATURAL VEGETATION

A map of natural vegetation was prepared based on information gathered from a conventional soil map (Buckmans and Brady, 1968), climatic maps, and remaining natural vegetation (Fig. III.4).



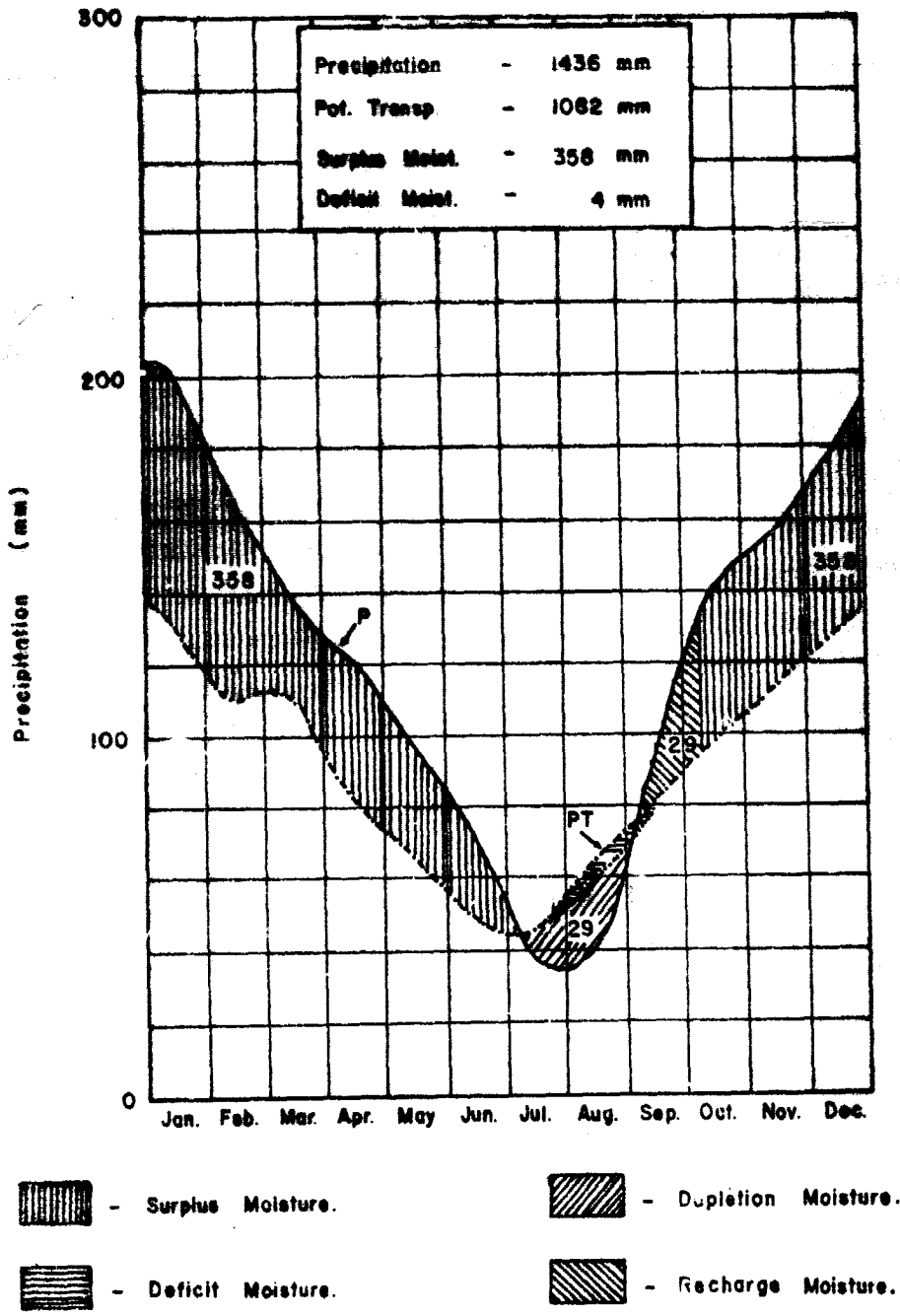


Fig. III.1 - Water balance for the "Ribeirão Preto" region.

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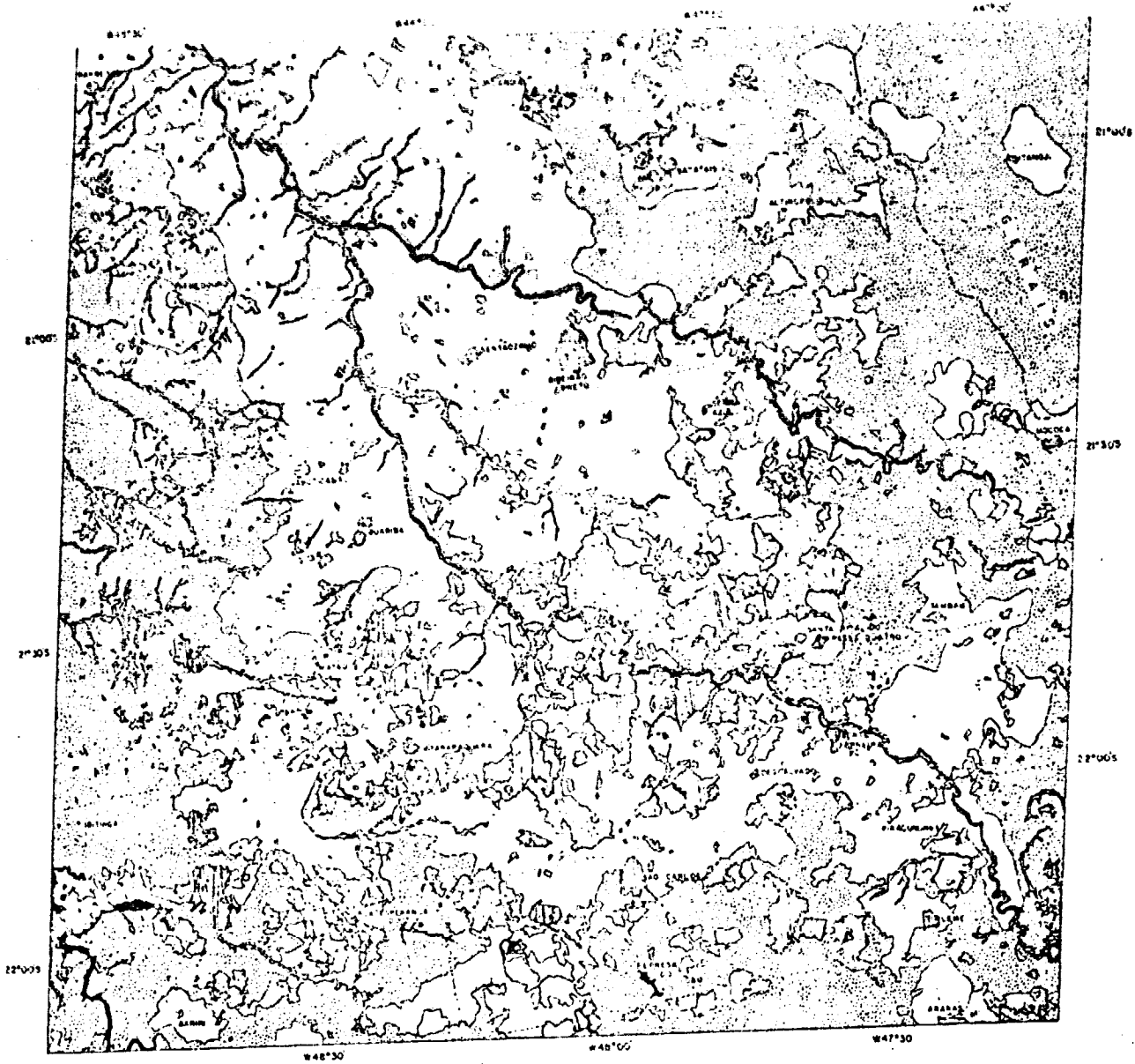










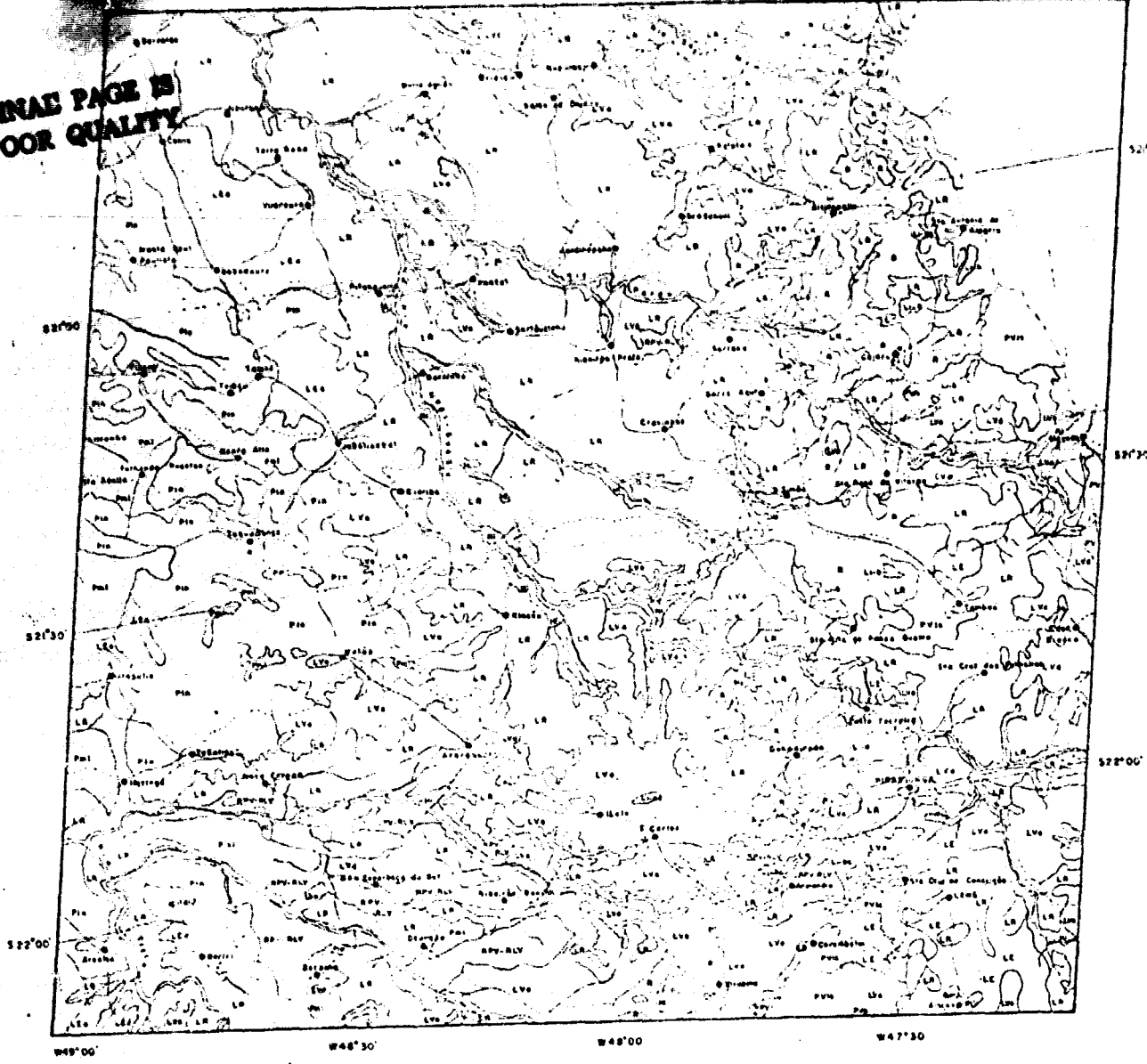
Fig.III.2 - Land Use Map of "Ribeirão Preto" region, São Paulo State, Brazil based on LANDSAT image interpretation(channels 5 and 7).

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-  - Crop areas and grassland.
-  - "Campo cerrado".
-  - Natural forest.
-  - Gallery forest.
-  - Artificial forest.
-  - Roads.
-  - Urban areas.
-  - State boundary.

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**Fig. III.3 - Soil Map of "Ribeirão Preto" region, São Paulo State, based on the Brazil's Commission Soil Map (1960).**

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**LEGEND**

- PV - Ortho Red-Yellow Podzolic Soils.
- PVp - Red Yellow Podzolic Soils Piracicaba Variation.
- PVI - Red Yellow Podzolic Soils Laras Variation.
- PII - Podzolized Soils on Calcareous Sandstone Lima Variation.
- PVI - Podzolized Soils on Calcareous Sandstone Marilia Variation.
- LR - Terra Rossa.
- LE - Ortho Dark Red Latosol.
- LEa - Dark Red Latosol Sandy Phase.
- HI - Hydromorphic Soils.
- A - Alluvial Soils.
- Li.b - Lithosol Basalt substratum Phase.
- Li.gr - Lithosol Granite-Gneiss Substratum Phase.
- Li.ac - Lithosol Calcareous Sandstone Substratum Phase.
- R - Regosol.
- RPV/RLV - REGosol Intergrade to Red-Yellow Podzolic Soils and Intergrade to Red-Yellow Latosol Undifferentiated Soil Group.
- LVa - Red Yellow Latosol Sandy Phase.

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Natural Vegetation was classified into three groups:

- a. Forest and "Cerradão";
- b. "Cerrado";
- c. "Campo Cerrado".

Natural vegetation was considered a poor parameter to make the correlation between soil and vegetation because of man made modifications. This was observed also by Amaral and Aud' (1972).

### 3.4 - RELIEF

Based on textural features of the images of channels 6 and 7, the relief was classified as:

- a. slightly undulating to flat land;
- b. undulating land;
- c. and mountainous.

The results of the interpretation are shown in Figure III.5.

### 3.5 - DRAINAGE

Figure III.6 shows the drainage pattern of the area. It was obtained from conventional interpretation of channels 5 and 7. Main rivers were well characterized in channel 7. Secondary rivers were better displayed in channel 5 because of gallery forest and the vegetation of poorly drained soils.

Table III.1 summarizes quantitatively and qualitatively the data. The analysis of the drainage pattern was separated in homogeneous areas. Table III.2 presents data of correlation and regression analysis of quantitative features disclosing highly significant correlation.

The results obtained were compared with aerial photographic results of França (1968), Fadel (1972), Vasques Filho (1972) and Souza (1975). The Computed image indices were similar to those calculated in the above investigations when the drainage was not dense.

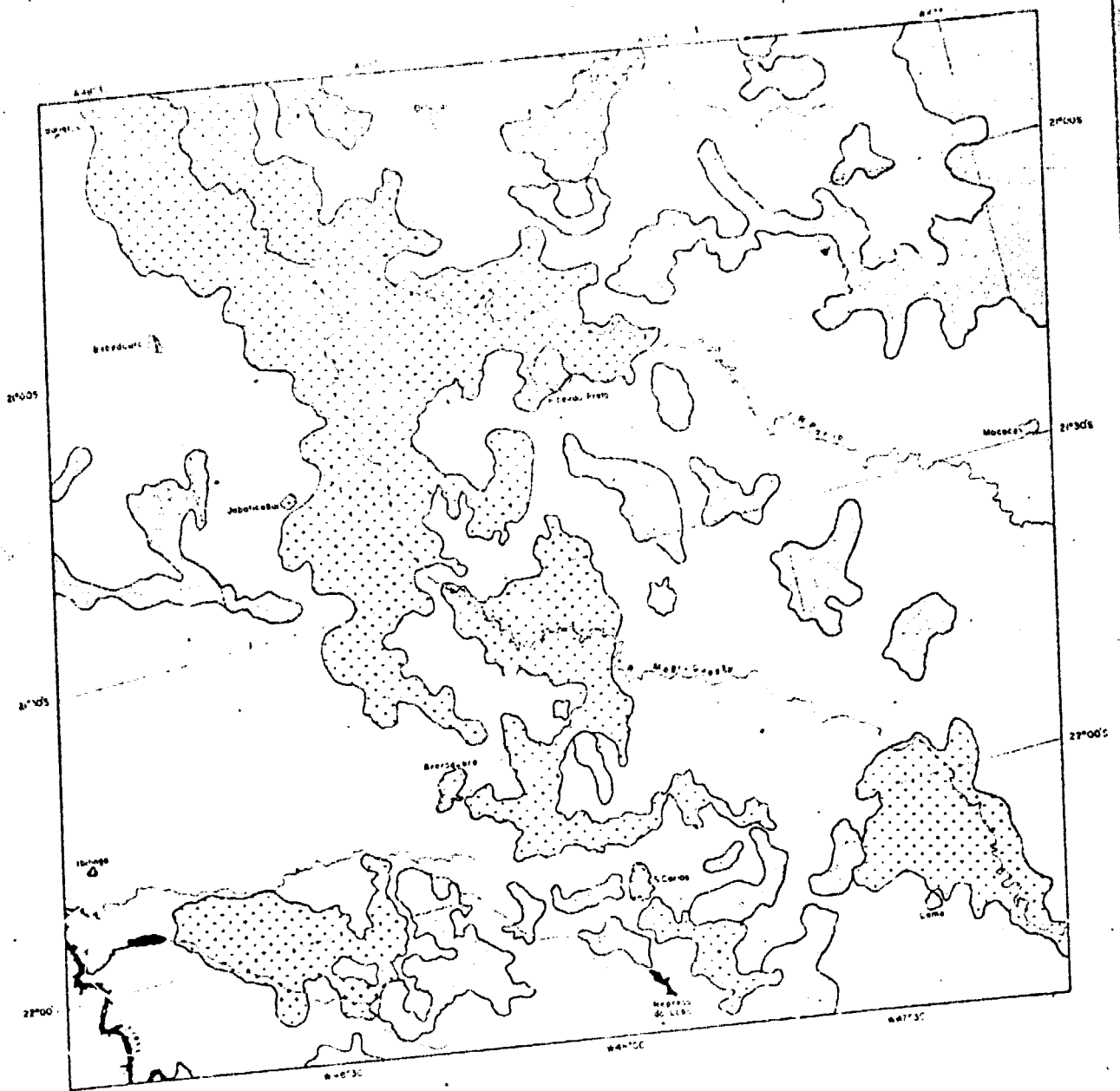






Fig.III.5 - Map of Relief Classes of "Ribeirão Preto" region, São Paulo State, Brazil based on LANDSAT interpretation images (channels 6 and 7).

LEGEND

-  - Slightly Ondulated to Flat Land.
-  - Rolling to Ondulated Land.
-  - Mountains.
-  - Urban Areas.

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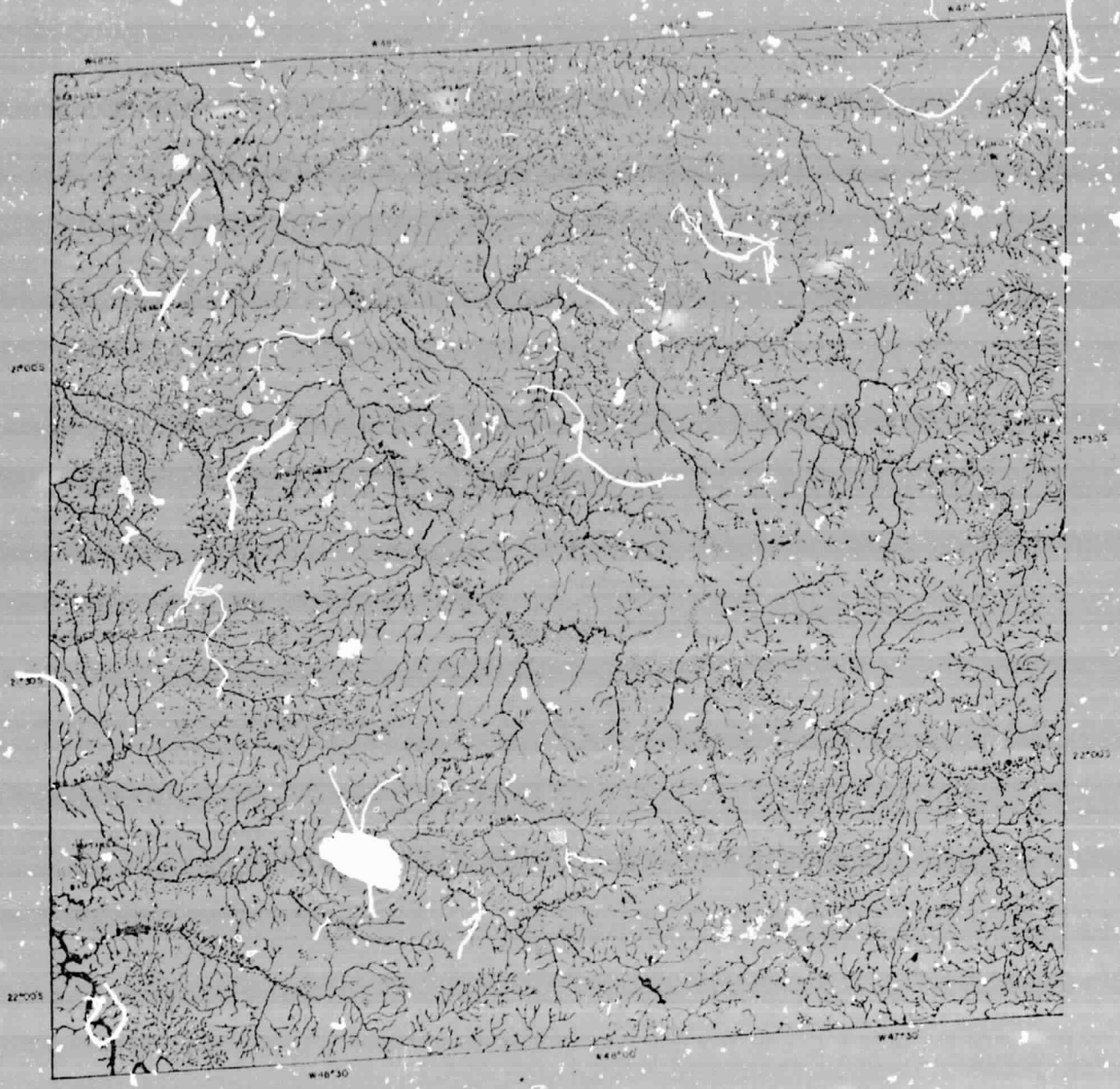






Fig. III.6 - Drainage Map of "Ribeirão Preto" region, São Paulo State, based on LANDSAT interpretation images (Channels 5 and 7).

LEGEND

-  - Drainage.
-  - Alluvial Plains.
-  - Lakes.
-  - Urban Areas.

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TABLE III.1

CHARACTERISTICS OF DRAINAGE

AREA	SOIL GROUP	DRAINAGE PATTERN		Dd <sub>m</sub> (mean)	STANDARD DEVIATION	F <sub>s</sub> <sub>m</sub> (mean)	STANDARD DEVIATION	Tr <sub>m</sub> (mean)	STANDARD DEVIATION	
		BASIC	MCUIFIED							
RIBEIRÃO PRETO, STATE OF SÃO PAULO	TERRA ROSSA (LR)	PARALLEL	VARIED	0.74	0.07	0.39	0.04	1.11	0.12	
	RED-YELLOW LATOSOL SANDY PHASE (LV <sub>a</sub> )	RECTANG- ULAR	ANGULAR	0.86	0.10	0.50	0.10	1.40	0.29	
	DARK RED LATOSOL SANDY PHASE (LE <sub>a</sub> )	PARALLEL	SUBPARALLEL	0.79	0.09	0.65	0.16	1.83	0.45	
	PODZOLIZED SOILS ON CALCAREOUS SANDSTONE (PIn, Pm1)	DENDRITIC	SUBDENDRITIC		0.85	0.00	0.66	0.05	1.85	0.13
			PINNATE		1.63	0.14	1.80	0.32	5.06	0.90

TABLE III.2  
RESULTS ACQUIRED BY ANALYSIS OF CORRELATION AND REGRESSION

RATION'S	CORRELATION COEFFICIENT	LINEAR EQUATION
MEAN DRAINAGE DENSITY/MEAN STREAM FREQUENCY ( $D_{dm}/F_{sm}$ )	0.9973	$F_{sm} = - 0.4678 + 1.2294 D_{dm}$
MEAN DRAINAGE DENSITY/MEAN TEXTURE RATIO ( $D_{dm}/TR_m$ )	0.9624	$TR_m = - 1.3107 + 3.4537 D_{dm}$
MEAN STREAM FREQUENCY/MEAN TEXTURE RATIO ( $F_{sm}/TR_m$ )	1.0000	$TR_m = - 0.0035 + 2.8091 F_{sm}$



### 3.6 - SPECTRAL MEASUREMENTS

Multispectral characteristics of five soil groups were measured in the field (Table III.3) and a statistical analysis was performed on the data obtained (Table III.4). Laboratory analysis was performed for four different soil groups, and Figure III.7 shows the corresponding spectral curves.

The results observed agree with the studies done by Crown and Pawluk (1974). The spectral responses of the soils under natural and laboratory conditions are a direct function of their physical and chemical properties.

Only three soil groups could be distinguished by the analysis of the spectral response according to the gray levels of the positive transparencies in the scale of 1:1,000,000 (Fig. III.8). The results obtained agree with those of Hoffer and Anuta (1972).

**TABLE III.3**  
**MEAN REFLECTANCE OF FIVE DIFFERENT SOIL GROUPS MEASURED WITH EARTH GROUND TRUTH RADIOMETER.**  
**(VALUES IN PERCENTAGES)**

	CHANNEL 4	CHANNEL 5	CHANNEL 6	CHANNEL 7
"TERRA ROSSA" (LR)	5,4	11,0	13,3	11,2
DARK RED LATOSOL SANDY PHASE (LEa)	9,3	16,7	20,7	19,4
RED-YELLOW LATOSOL SANDY PHASE (LVa)	10,9	18,2	21,8	20,9
RPV/RLV	15,8	23,6	26,5	25,9
REGOSOL (R)	20,8	30,1	33,7	30,8

RPV/RLV= Regosol intergrade to Red-Yellow Podzolic soils and intergrade to Red-Yellow Latosol indifferenciated soil group.

TABLE III.4

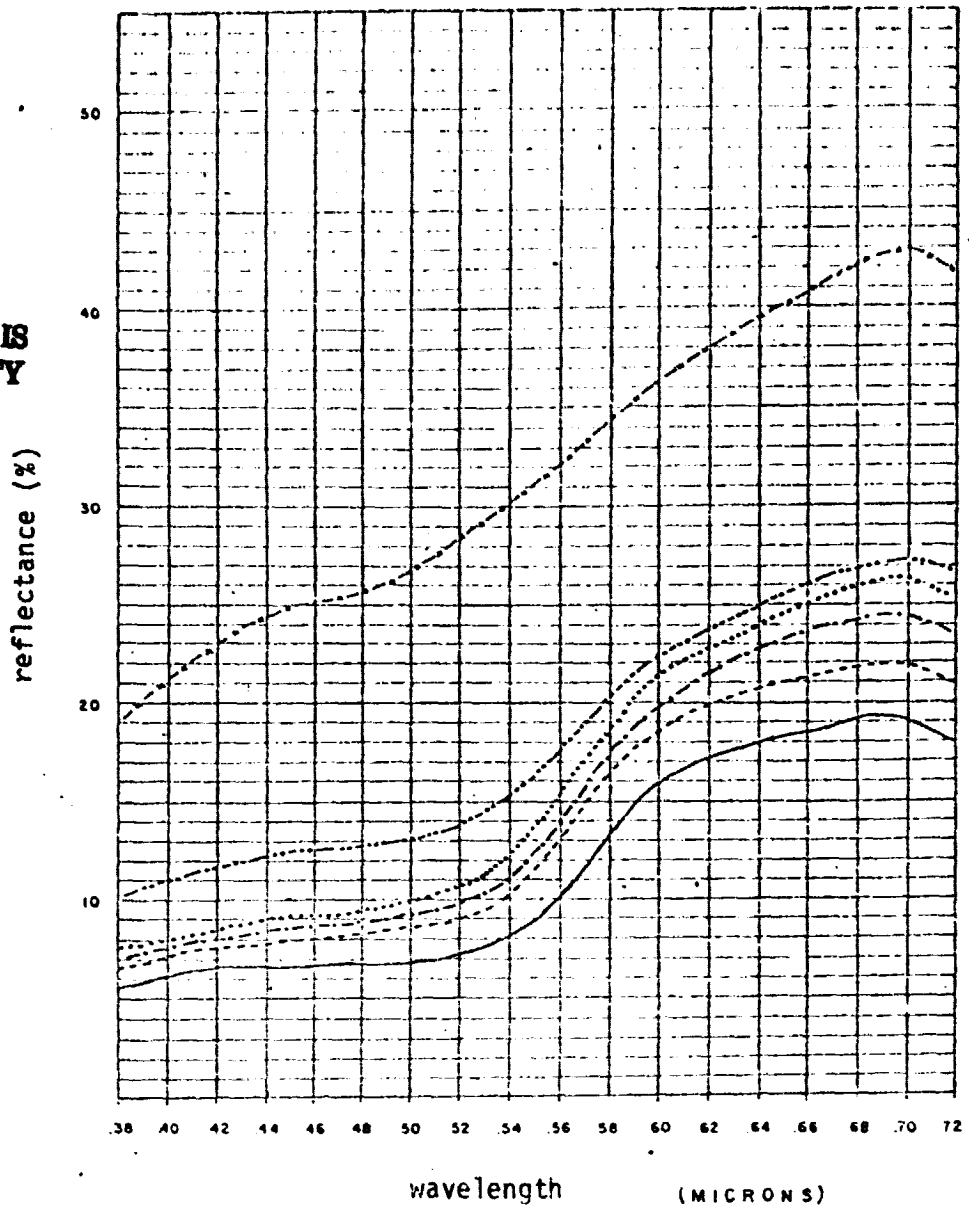
STATISTICAL ANALYSIS OF THE MEAN REFLECTANCE OF THE FIVE DIFFERENT SOIL GROUPS

	TUKEY'S TEST $\alpha = 0,05$		F	CV <sup>1</sup>	$S_X^2$	DUNCAN'S TEST $\alpha = 0,05$	
CHANNEL 7	LR	LEa LVa RPV/RLV R	***	16%	0.44	LR	LEa LVa RPV/RLV R
CHANNEL 6	LR	LEa LVa RPV/RLV R	***	17%	0.50	LR	LEa LVa RPV/RLV R
CHANNEL 5	LR	LEa LVa RPV/RLV R	***	15%	0.39	LR	LEa LVa RPV/RLV R
CHANNEL 4	LR	LEa LVa RPV/RLV R	***	15%	0.24	LR	LEa LVa RPV/RLV R

1 - Coefficient of variation

2 - Standard deviation

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SIMBOL	SOIL GROUP
————	Terra Rossa
-----	Red-Yellow Latosol
-.-.-.-.	Dark Red Latosol Sandy Phase
.....	Podzolized Soils on Calcareous Sandstone
-.-.-.-.	Regosol Intergrade to Red-Yellow Podzolic Soils and Intergrade to Red-Yelloy Latosol
.....	Undifferentiated Soil Group
-x-x-x-x	Regosol

Fig.III.7- Spectral curves of six (6) different soil groups.

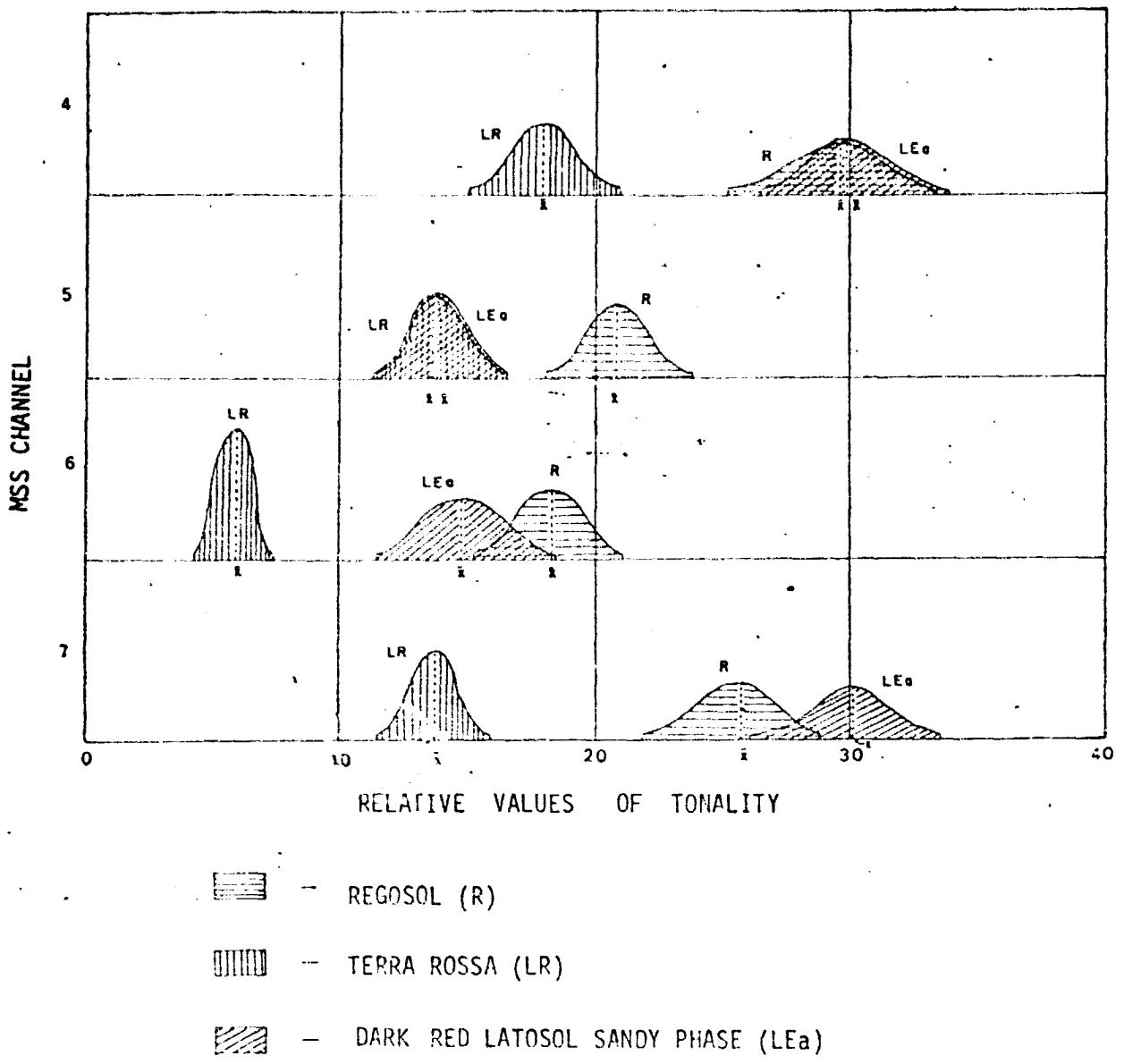


Fig.III.8 - Graphic presentation of the relative tonality of MSS positive transparencies for three soil groups.

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## CHAPTER IV

### CONCLUSIONS

To characterize soils, based on LANDSAT images, it has been concluded that:

It is necessary to survey annual water balance to know the apparent superficial modifications in the images due to soil water content.

Land use, drainage pattern, relief and tonality measurements are useful elements to characterize major soil groups.

Channels 6 and 7 are considered the best to study the relative tonality of different spectral responses of soils. Channels 5 and 7 are considered the best for studying natural vegetation, drainage pattern and land use. Channel 6 is considered the best to study the relief.

A better contrast of the interpretation elements was obtained in the scale 1:1,000,000 but the scale 1:500,000 was considered more efficient to delineate the interpretative elements.

Natural vegetation and land use are factors that should be used carefully when characterizing major soil groups.

Frequency ratio is the recommended index for use when analysing drainage pattern quantitatively. The type of drainage pattern is the most important factor in the qualitative analysis.

It is possible to correlate relief and soil types in the images.

"Terra Rossa", Dark Red Latosol Sandy phase, Regosol "were characterized by relative tonality over positive transparencies.