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CHAPTER I

INTRODUCTION

This study was carried out as part of a research program developed by both the Brazilian Institute for Space Research and SUDAM. SUDAM is responsible for planning and monitoring the Exploitation of Amazon Region.

Soil erosion in the region can be noticed where topography is highly dissected. This erosion is caused by appropriation of forest areas for pasture lands.

There is no cartographic information to help us choose topographic areas which are suitable for deforestation and grazing.

Several authors (Palabekiroglu, 1974; Valério et al, 1976 and Koffler, 1976) have reported that there might be some relationship between texture of LANDSAT image and topographic conditions.

Declivity variation is the most important topographic factor affecting soil erosion according to Strahler (1957), Keech (1968), Correa (1969) and Vieira (1974).

The influence of declivity variation on image texture was verified in order to use LANDSAT data to pinpoint areas which had better topographic conditions for pastures than others.

CHAPTER II

MATERIAL AND METHOD

2.1 - TEST SITE

Three test sites were selected (Fig. II.1). The Roncador Test Site, located in the northern region of the State of Mato Grosso, is one of the most representative areas under SUDAM management.(EMBRAPA,1975). This area presents a large number of image textural patterns under different ground cover conditions and under five astronomic control points. The remaining sites Canabrava and Serra das Almas, possessed precise cartographic material for the collection of declivity data. These test sites are located in the state of Minas Gerais. Their natural conditions are similar to Roncador.

2.2 - MATERIAL

Three LANDSAT images were used to perform this research work (Table II.1).

Declivity data were collected in topographic maps at scales of 1:1,000,000 (IBGE, 1970) and 1:100,000 (SGE, 1969).

The computer program for TREND SURFACE ANALYSIS was used to handle part of the data.

2.3 - METHOD

The LANDSAT image was first analyzed through visual interpretation. Band 7 was used in order to separate different units based upon texture of LANDSAT images.

Ground truth allowed us to observe the relationship between image texture variation and topographic conditions. The relationship was checked through the following selected parameters:

TABLE II.1

LIST OF IMAGES

TEST SITE	NUMBER	DATE	SCALE	CHANNEL
RONCADOR	175152-123820	01/06/1975	1:1,000,000	7
CANABRAVA	1066-12314	27/09/1972	1:1,000,000	7
SERRA DAS ALMAS	1048-12321	09/09/1972	1:500,000	7

CHAPTER III

RESULTS AND DISCUSSION

Image texture variations in channel 7 were correlated with topographic conditions observed during field studies.

Illumination changes caused by topographic conditions caused the image texture variation . Parameters were selected to verify which topographic conditions might be affecting image texture.

Channel 7 was considered better for characterizing image tex ure variation although Valerio Filho et al (1976) have used channel 6. Several areas were studied with channels 6 and 7 and the results indicated that the best channel choice depended on the characteristics of the area under study.

Nine texture classes were identified through a visual analysis of the image texture for the Roncador Test Site (Fig. III.1).

Wilcoxon's Test was applied to analyze the Roughness index, texture, drainage density and declivity parameters. The results are summarized on Tables III.1, III.2, III.3 and III.4. The imagery units can be Clustered into 6 classes according to the Roughness Index into 3 classes for the other indexes. The classifications may also be verified on Figure III.2 through diagrams 1, 2, 3 and 4.

Results demonstrated, however, that all parameters were sufficiently consistent to discriminate class 9. This class is well differentiated on the ground. It corresponds to the Araguaia Plain. This area is characterized by low drainage dissection and low declivity.

Table III.5 shows that class 9 had the lowest mean value, for all parameters.

FIGURE II.1 - TEST SITES LOCALIZATION.

21	RONCADOR
24	CANABRAVA
25	SERRA DAS ALMAS

a) Horton's Drainage Density Index (1945). It is expressed by:

$$Dd = \frac{L}{A}$$, where

Dd = Drainage Density
L = Total length of streams (km)
A = Sample area (Km^2)

b) França's Modified Topographic Texture Index (1968)
It is expressed by:

$$T_t = \frac{N}{P}$$, where

T_t = Topographic texture
N = Number of stream
P = Sample Perimeter

c) Declivity Index
It can be expressed by:

$$\theta = \operatorname{arctg} \frac{H}{D}$$, where

θ = Declivity Angle
H = Level Difference (m)
D = Horizontal Distance (m)

The declivity angle for each sample is represented by the average of three or more measurements.

d) Roughness Index
The roughness index was calculated to show texture on LANDSAT images. This index is defined as a tonal variation within each spectral band (Haralich and Shanmugan, 1973).

The tonal variation number within a sample represents the above Roughness Index.

The above mentioned parameters were collected using a 0,5 cm x 0,5 cm grid.

Drainage Density and Topographic Texture data were collected from a drainage map (Santos and Novo, 1977). A Goiás Chart was used to obtain Declivity data. Band 7 allowed us to obtain Roughness data.

Parametric and non-parametric analyses for Roncador Test Site were done by two different methods.

Thirteen samples were collected for each textural class. They allowed a non-parametric analysis. All the selected parameters were submitted to Correlation and Classification analysis (Steel and Torrie, 1960).

Three hundred and fifty samples covering all image surfaces permitted parametric analysis. Trend Surface Analyses were carried out on these data. The procedures used for this approach are described by Doornkamp (1972), Davis (1973), and Amaral (1976).

The Canabrava Test Site was selected to verify the influence of scale on the relationship between Declivity and Roughness data. Declivity data were collected on Canabrava Chart (SGE, 1969) at the scale of 1:100,000.

The Image Scale influence over the relationship between Roughness and Declivity data were checked at the Serra das Almas Test Site. Declivity data were collected over the Serra das Almas Chart (SGE, 1969) at the scale of 1:100,000.

The Canabrava and Serra das Almas data were analyzed through Sp man's Correlation Coefficient.

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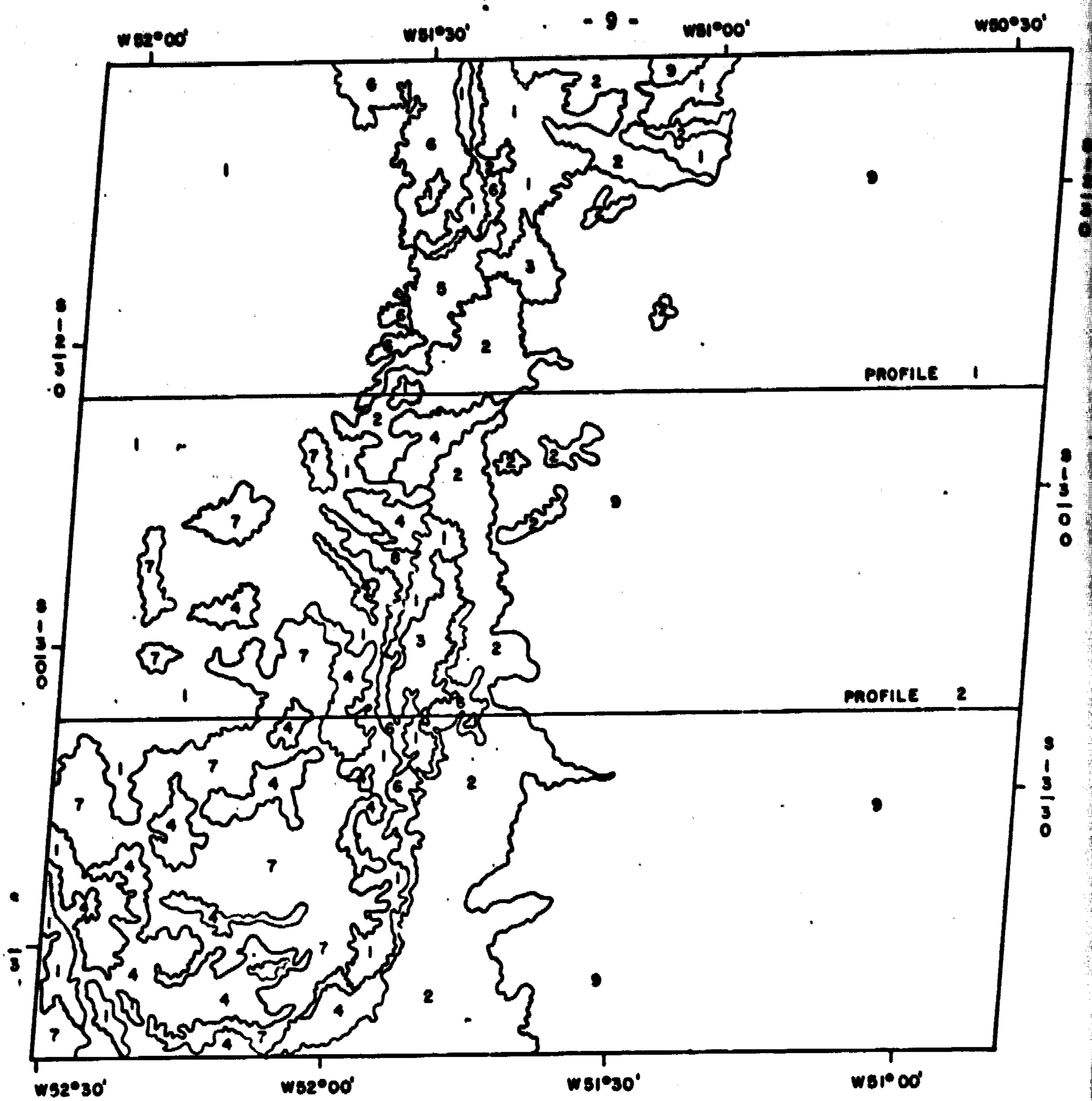


FIGURE III.1 - PHOTOGRAPHIC TEXTURE CLASSES OBTAINED BY VISUAL ANALYSIS.

SCALE:

10 0 10 30 50 Km

TABLE III.1

SIGNIFICANCE LEVEL AMONG CLASSES OF PHOTOGRAPHIC TEXTURE RELATIVE TO THE ROUGHNESS INDEX.

	9	1	2	7	4	3	8	5	6
9		xx	xx	xx	xx	xx	xx	xx	xx
1			x	xx	xx	xx	xx	xx	xx
2				x	xx	xx	xx	xx	xx
7					NS	x	xx	xx	xx
4						NS	xx	xx	xx
3							NS	NS	xx
8								NS	xx
5									xx
6									

TABLE III.2

SIGNIFICANCE LEVEL AMONG CLASSES OF PHOTOGRAPHIC TEXTURE RELATIVE TO THE TOPOGRAPHIC TEXTURE INDEX.

	9	1	2	3	7	8	4	5	6
9		xx	xx	xx	xx	xx	xx	xx	xx
1			NS	NS	xx	xx	xx	xx	xx
2				NS	x	x	x	xx	[illegible]
3					NS	NS	NS	xx	xx
7						NS	NS	NS	xx
8							NS	NS	NS
4								NS	NS
5									NS
6									

TABLE III.3

SIGNIFICANCE LEVEL AMONG CLASSES OF PHOTOGRAPHIC TEXTURE RELATIVE TO THE DRANAIGE DENSITY INDEX.

	9	2	1	3	7	8	4	5	6
9		x	xx	xx	xx	xx	xx	xx	xx
2			NS	NS	NS	x	xx	xx	xx
1				NS	NS	NS	x	x	xx
3					NS	NS	NS	x	xx
7						NS	NS	x	xx
8							NS	NS	x
4								NS	x
5									NS
6									

TABLE III.4

SIGNIFICANCE LEVEL AMONG CLASSES OF PHOTOGRAPHIC TEXTURE RELATIVE TO THE DECLIVITY INDEX.

	9	1	5	2	3	4	6	7	8
9		x	xx	xx	xx	xx	xx	xx	xx
1			NS	NS	x	x	x	NS	xx
5				NS	NS	NS	x	NS	xx
2					NS	NS	NS	NS	xx
3						NS	NS	NS	NS
4							NS	NS	NS
6								NS	NS
7									NS
8									

xx - SIGNIFICANT AT LEVEL 0.01
x - SIGNIFICANT AT LEVEL 0.05
NS - NON-SIGNIFICANT

ROUGHNESS

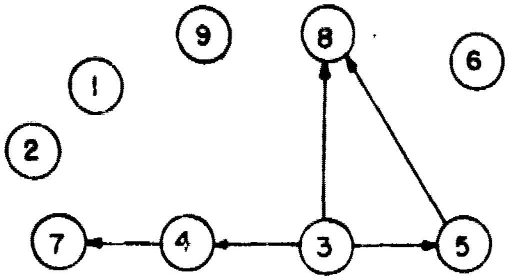


DIAGRAM 1

CLUSTERING: 9, 1, 2, (7, 4), (3, 8, 5), 6

TOPOGRAPHIC TEXTURE

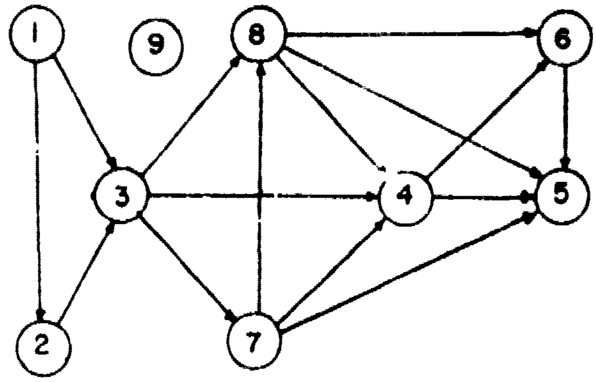


DIAGRAM 2

CLUSTERING: 9, (1, 2), (3, 7, 8, 4, 5, 6)

DRAINAGE DENSITY

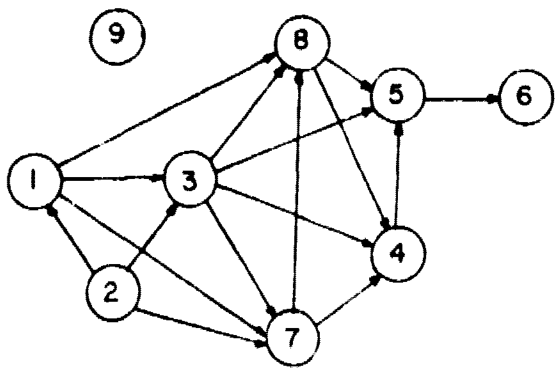


DIAGRAM 3

CLUSTERING: 9, (1, 2, 3, 4, 5, 7, 8), 6

DECLIVITY

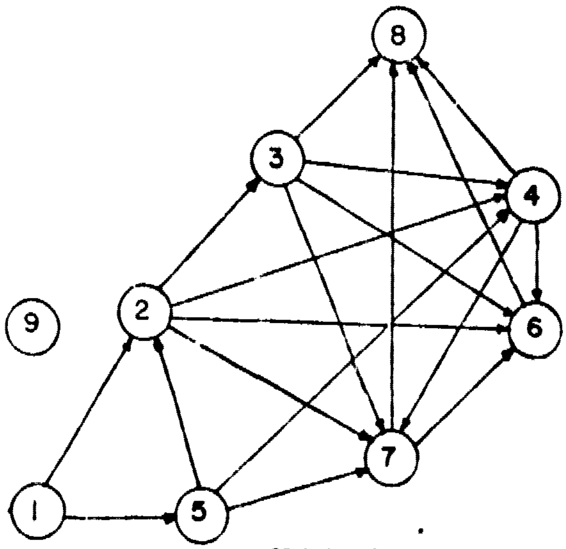


DIAGRAM 4

CLUSTERING: 9, 1, (5, 2, 3, 4, 6, 7, 8)

FIGURE III.2 - REPRESENTATIVE DIAGRAMS OF PHOTOGRAPHIC TEXTURE CLASSES CLUSTERS RELATIVE TO THE SELECTED PARAMETERS.

TABLE III.5

AVERAGE VALUE OF IMAGE TEXTURE CLASSES RELATED TO ROUGHNESS (R), TOPOGRAPHIC TEXTURE (Tt), DRAINAGE DENSITY (Dd) AND DECLIVITY (D) INDEXES

$\bar{X}$	1	2	3	4	5	6	7	8	9
R	2,31	3,69	8,62	6,46	11,62	15,54	5,08	9,85	0,85
Tt	0,42	0,36	0,48	0,60	0,68	0,80	0,50	0,56	0,14
Dd	0,30	0,23	0,33	0,40	0,45	0,52	0,34	0,37	0,10
D	0,22	0,49	0,56	0,70	0,31	0,95	1,05	1,49	0,04

Class 6, as shown on Figure III.2, was well discriminated by both Roughness and Drainage Density Indexes. These indexes showed the highest value for class 6. This class is distinguished by the high declivity of the Roncador scarps. The scarp zone is highly dissected by streams. This unit is also represented by an area with a hilly topography.

Image texture of class 6 showed a high Roughness Index value. This unit, however, could not be separated by the Topographic Texture Index because of the great difficult in mapping the small streams flowing down the Roncador scarps.

The Declivity Index was not able to discriminate class 6. Two important aspects must be considered:

a) Class 6 is represented by the scarp zone of a plateau, so the average declivity was affected by planning surfaces at the top and at the base of the scarp;
b) Declivity data were collected at the scale of 1:1,000,000, so equidistance between countour curves (100 meters) was larger than the scarp zone and declivity variation could not be detected.

Results showed that the Roughness Index could express texture variation in the LANDSAT image. The number of texture classes were reduced from nine to six classes. The reducing can be explaining by human eye capacity to register both small variations in the roughness level and differences in texture patterns. The Roughness Index registered only the amount of tonal variation but not the tonal distribution pattern within a class.

Wilcoxon's test suggested a relationship between image texture variation and the selected parameters. The Roughness Index was utilized to express texture variation numerically and a correlation test was applied to the data.

Spearman's correlation coefficient (Table III.6) showed

TABLE III.6

SPEARMAN'S CORRELATION COEFFICIENT

CORRELATION	TOPOGRAPHIC TEXTURE	DRAINAGE DENSITY	DECLIVITY
ROUGHNESS	0,90**	0,90**	0,57*

** significance level of 0.01

* significance level of 0.05

TABLE III.7

SPEARMAN'S CORRELATION COEFFICIENT FOR ORIGINAL VALUES OF THE PROFILES

CORRELATION COEFFICIENT		
	ROUGHNESS/DECLIVITY	ROUGHNESS/TOPOGRAPHIC TEXTURE
FIRST CROSS SECTION	0,68	0,87
SECOND CROSS SECTION	0,72	0,80

that there is a high positive correlation between the Roughness Index and the Topographic Texture and Drainage Density Indexes. However, the correlation coefficient between Roughness Index and Declivity Index was low. This low value is not in accordance with theoretical studies which already have demonstrated that increases in Topographic Texture Values and Drainage Density Values are related with increases in Declivity Values (Freitas, 1952; Christofoletti, 1974).

This low correlation could be related to the following aspects:

a) Declivity data were affected by variations between the topographic chart and images;
b) The topographic chart scale was not able to detect declivity variation within the sample area;
c) Due to the small scale of 1:1,000,000 it was not possible to express the real topographic variation.

TREND SURFACE ANALYSIS techniques were applied to verify the first item. These techniques allowed us to inspect the regional data tendency (Koch and Link, 1971; Doornkamp, 1972; Davis 1973 and Amaral, 1976).

Three parameters were considered for Trend Analysis: Roughness, Topographic Texture and Declivity. The results showed that all the parameters had similar regional behavior. They showed a decrease in their value from the central part of the graphic to the borders. Contour curves in the central portion of the area were closely arranged, indicating the heterogeneity of the topographic condition.

These statistical surfaces express the real trend of the area. In fact, on the ground, the area is characterized by dissected topography at Roncador Scarp. Topography is lowered from this zone toward Araguaia Basin at the east side and toward the Xingu Basin at the west side.

Results showed different gradients among the surfaces. Fig. III.3 best shows these gradients. Declivity and Roughness curves had approximately the same shape but there was a great difference in the data amplitude between them. Using standardized data this difference was reduced (Fig. III.4). Cross sections were drawn in the East West direction which was shown to have more data variability.

Cross sections of the area were drawn to verify the effects of ground cover on the relationship among the parameters.

Figure III.4 demonstrates that all the parameters had the same distribution over the area. Spearman's Correlation Coeficient between the parameters was calculated with the original data from the cross sections (Table III.7).

The results showed that there was an increase in the correlation value from the Profile 1 to the Profile 2 regarding Roughness and Declivity. This increase can be explained by the effect of vegetation cover, since Profile 1 crosses an area with dense forest.

Vegetation cover had attenuated texture variations on the image but even so it was possible to recognize topographic variation under dense forest.

Data collected on the Canabrava Test Site was used to verify the effect of the topographic chart scale over the relationship between Roughness and Declivity Indexes. Spearman's Correlation Coefficient increased from 0.57 at the Roncador Test Site to 0.72 at the Canabrava Test Site. This increase can be explained by the fact that declivity data were collected at the scale of 1:100,000 for the Canabrava Test Site while for the Roncador Test Site a scale of 1:1,000,000 was used. Large scale charts present small distances between countour-curves, making declivity data more precise.

The variation coefficient calculated for declivity data on the Roncador Test Site was close to 40%. This large variability was

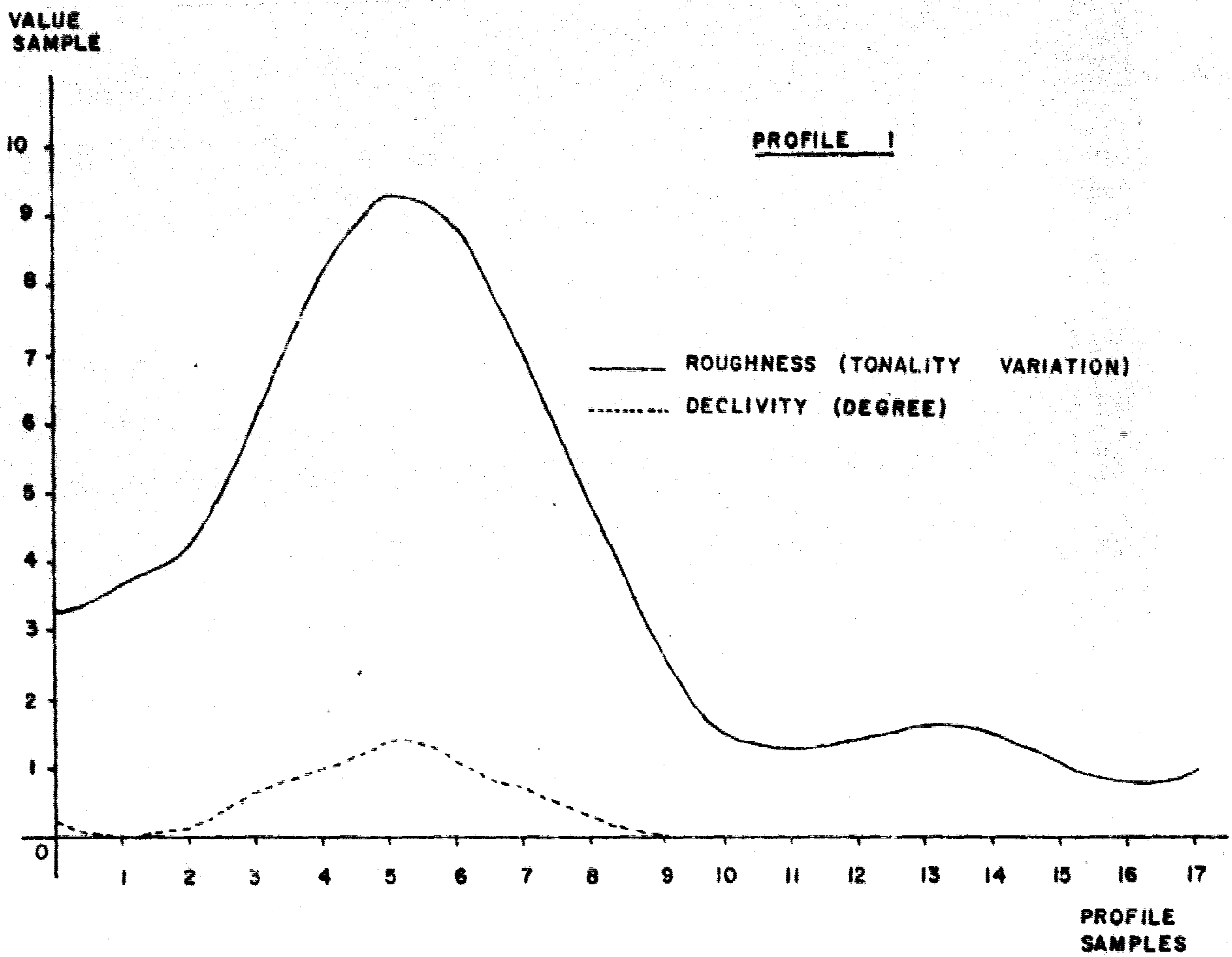
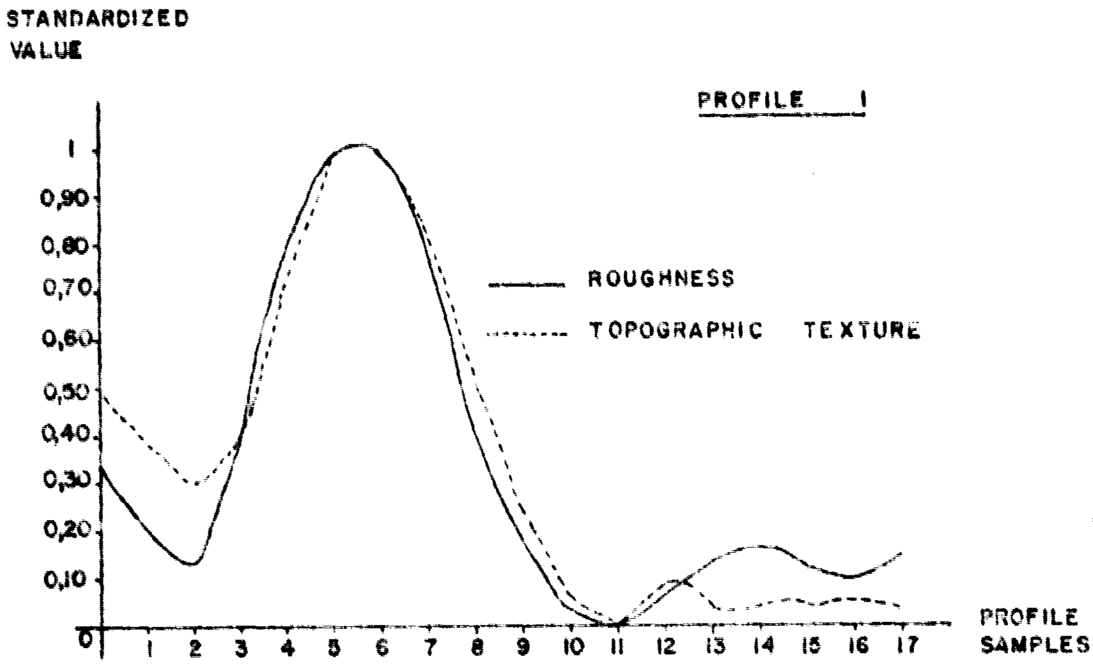


FIGURE III.3 - ROUGHNESS AND DECLIVITY INDEX PROFILES RELATIVE TO THE ORIGINAL VALUES ACQUIRED FROM THE EIGHTH DEGREE TREND SURFACE.



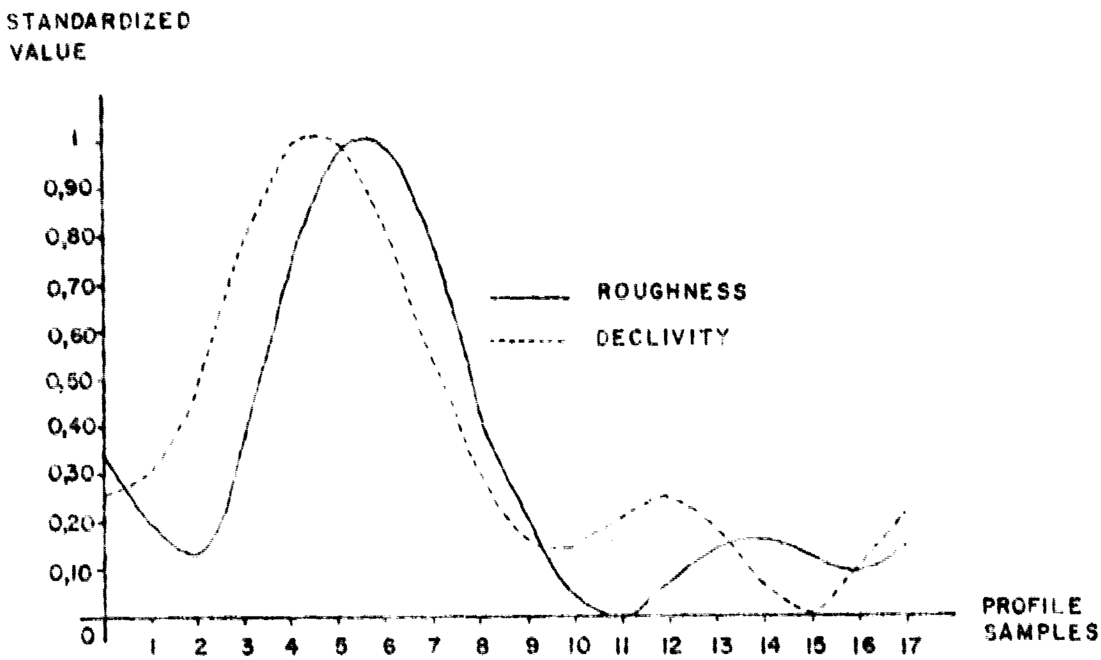


FIGURE III.4 - COMPARISON BETWEEN ROUGHNESS INDEX AND TOPOGRAPHIC TEXTURE, ROUGHNESS INDEX AND DECLIVITY RELATIVE TO THE PROFILES WITH STANDARDIZED VALUES ACQUIRED FROM THE EIGHTH DEGREE TREND SURFACE.

related to the image scale (1:1,000,000). The data were collected over a 0.5 cm x 0.5 cm grid . Because of the small-scale, declivity data were collected for a large area on the ground where there was great topographic variation.

A LANDSAT image at the scale of 1:500,000 was used to collect Roughness data at the Serra das Almas Test Site. Increasing image scale, the square sample defined a smaller area on the ground. The average declivity angles became more representative. The Spearman's correlation coefficient value increased from 0.72 to 0.79 showing that image scale affects the relationship between Declivity and Roughness.

CHAPTER IV

CONCLUSION

The results suggested the following conclusions:

- Topographic units can be identified through the analysis of the Roughness Index.
- The texture of LANDSAT images allows the characterization of topographic variation.
- High values of declivity are related to high Roughness Indexes values.
- The Roughness Index may be utilized to select areas with suitable topographic conditions for establishing pastures.