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RESUMO-NOTAS/ABSTRACT-NOTES

The pixel size in the present day Remote Sensing systems is large enough to include different types of land cover. Depending upon the target area, several components may be present within the pixel. In forested areas, generally, three main components are present: tree canopy, soil (understory), and shadow. The objective of this report is to generate a shade (shadow) image of forested areas from multispectral measurements of LANDSAT MSS data by implementing a linear mixing model, where shadow is considered as one of the primary components in a pixel. The shade images are related to the observed variation in forest structure, i.e., the proportion of inferred shadow in a pixel is related to different forest ages, forest types, and tree crown cover. The Constrained Least Squares (CLS) method is used to generate shade images for forest of eucalyptus and vegetation of "cerrado" using LANDSAT MSS imagery over "Itapeva" study area in Brazil. The resulted shade images may explain the difference on ages for forest of eucalyptus and the difference on three crown cover for vegetation of "cerrado".

OBSERVAÇÕES/REMARKS

Presented at the Twenty-Second International Symposium on Remote Sensing of Environment, Abidjan, Côte d'Ivoire, October 20-26, 1988.

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SHADE IMAGES OF FORESTED AREAS OBTAINED FROM LANDSAT MSS DATA

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ABSTRACT

The pixel size in the present day Remote Sensing systems is large enough to include different types of land cover. Depending upon the target area, several components may be present within the pixel. In forested areas, generally, three main components are present: tree canopy, soil (understory), and shadow. The objective of this report is to generate a shade (shadow) image of forested areas from multispectral measurements of LANDSAT MSS data by implementing a linear mixing model, where shadow is considered as one of the primary components in a pixel. The shade images are related to the observed variation in forest structure, i.e., the proportion of inferred shadow in a pixel is related to different forest ages, forest types, and tree crown cover. The Constrained Least Squares (CLS) method is used to generate shade images for forest of eucalyptus and vegetation of "cerrado" using LANDSAT MSS imagery over "Itapeva" study area in Brazil. The resulted shade images may explain the difference on ages for forest of eucalyptus and the difference on tree crown cover for vegetation of "cerrado".

1. INTRODUCTION

LANDSAT digital images in computer-compatible tape are represented by dimensionless digital numbers ranging from 0 to 127 for bands 4, 5, and 6, and 0 to 63 for band 7 of MSS on current LANDSATs (Robinove, 1982; Nelson, 1985 a,b; Markham and Barker, 1986). The value associated with each picture element, called a pixel, represents the average radiance from a small target area on the ground in a corresponding spectral band. The spatial resolution of LANDSAT MSS is approximately 0.45 hectares (57m x 79m) at the earth's surface.

The radiance recorded by the satellite is an integrated sum of the radiances of all materials within the instantaneous field of view (IFOV) of the sensor. Thus, the radiation detected will be caused by a mixture of many different materials plus the atmospheric contribution. The "mixture" phenomenon has been considered by several investigators (e.g., Horwitz et al., 1971; Detchmendy and Pace, 1972). The non-uniformity of most natural scenes generally results in a large number of components in the mixture. The problem

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is further complicated by the fact that the proportion of specific materials within a pixel may vary from pixel to pixel.

Often an important component in a mixed target's response is the shadow component. It is well known that shadowing is generally present in all natural scenes and represents a special case of the mixtures problem. Heimes (1977), in his study, stated that shadowing has an important effect on scene spectral response, especially in forested areas. Ranson and Daughtry (1987) confirmed Heimes's conclusion showing that the spectral response from non-uniform scenes, such as forests, is greatly influenced by the shadow component.

The objective of this report is to generate a shade (shadow) image of forested area from LANDSAT MSS data by employing a linear mixing model where shadow is considered as one of the primary components in a pixel. Then, the resulted shade images for forest of eucalyptus and vegetation of "cerrado" obtained by the Constrained Least Squares (CLS) method are compared with field information from the forested areas within the "Itapeva" study area.

2. LINEAR MIXTURE PROBLEM: CONSTRAINED LEAST SQUARES METHOD

The linear mixture model for this study can be written as follows:

$$r_i = \sum_{j=1}^{n} (a_{ij}\, x_j) + e_i \qquad (1)$$

where

r_i = mean spectral reflectance for the ith spectral band of a pixel containing one or more components;

a_{ij} = spectral reflectance of jth component in the pixel for the ith spectral band;

x_j = proportion value of the jth component in the pixel;

e_i = error term for the ith spectral band;

j = 1, 2, ..., n (n = 3 components assumed for this problem: eucalyptus or "cerrado", soil, and shadow);

i = 1, 2, ..., m (m = 4 spectral bands for MSS/LANDSAT).

This model assumes that the spectral response of a pixel is a linear combination of the spectral response of each one of the components within the pixel. For this problem, the reflectances r_i and a_{ij} are assumed to be known and the proportional values for each component (x_j) are the problem unknowns. The Constrained Least Squares (CLS) method solves the system (1) by minimizing the sum of the squares of the errors subjected to two conditions:

- for any pixel the proportion values x_j must be nonnegative;
- for any pixel the sum of the proportions should add to one.

Both conditions have an obvious physical meaning.

The function to be minimized is:

$$\sum_{i=1}^{4} e_i^2 = e_1^2 + e_2^2 + e_3^2 + e_4^2 = \sum_{i=1}^{4} \{r_i - \sum_{j=1}^{3} a_{ij}\, x_j\}^2 \qquad (2)$$

Subjected to the constraints:

$$0 \leq x_1 \leq 1$$
$$0 \leq x_2 \leq 1$$
$$0 \leq x_3 \leq 1$$

and

$$x_1 + x_2 + x_3 = 1$$

The theoretical concepts of the Constrained Least Squares method are presented in Shimabukuro (1987).

3. MATERIAL AND METHOD

The mixture model presented in Section 2 was utilized in the "Itapeva" study area described below. LANDSAT MSS image over this study area was acquired on July 27, 1978 and was converted from digital number to reflectance values according to Markham and Barker (1986). The Constrained Least Squares method is used to generate shade images for forest of eucalyptus and vegetation of "cerrado".

3.1 - STUDY AREA "ITAPEVA"

The study area "Itapeva" is located at 20° 30'S and 53° 20'W in the state of Mato Grosso do Sul (Figure 1). This site includes most of the eucalyptus plantation of the Itapeva Florestal Company (Hernandez Filho et al., 1978). Besides the eucalyptus plantation, there is a large area covered by the natural vegetation of "cerrado".

Brazilian "cerrado" is the general name of xeromorphic woodland, scrub, savanna, and grassfield vegetation of central Brazil (Eiten, 1978). There are several types of "cerrado": "campo limpo," "campo sujo," "campo cerrado," "cerrado," and "cerradão" as described by Sarmiento (1983).

Some information about "cerrado" in the study area "Itapeva" can be found in the research reported by Medeiros (1987). As described in this work the "cerrado" present in the study area features different structural patterns (varying from sparse vegetation to dense vegetation) which can yield areas with different concentrations of shadow.

The field data and forest cover maps were provided by the Itapeva Florestal Company and used to classify reforestation areas using LANDSAT MSS data as can be seen in Hernandez Filho et al. (1978). Field works in this area for checking purposes were done by the authors.

3.2 - EXPERIMENT

The composite reflectance (r_i's) data are obtained by converting the digital numbers on the CCTs corresponding to the LANDSAT MSS image over the study area "Itapeva" acquired on July 27, 1978.

Based on work done by Hernandez Filho et al. (1978), two experiments can be performed using the MSS image. The experiments can consider a forest composed of eucalyptus and a vegetation type called "cerrado". For the forest of eucalyptus, three primary components in the mixture were assumed-eucalyptus, soil, and shadow. Similarly, for the vegetation of "cerrado," three primary components-"cerrado," soil, and shadow-were assumed to be in the mixture. In this case, the reflectance of eucalyptus and "cerrado" are extracted from the current image based on the results presented by Hernandez Filho et al. (1978). The reflectance of soil was extracted from the current image and was assumed to be the same for the two experiments. Also, the reflectance of shadow is considered as the same obtained from Heimes's data by Shimabukuro (1987).

4. RESULTS

Figures 2 and 4 show two study sites for eucalyptus forest and two study sites for vegetation of "cerrado," respectively, in the channel 5 of MSS LANDSAT image of July 27, 1978. Figures 3 and 5 show the shade images for forest of eucalyptus and vegetation of "cerrado," respectively.

The shade images for eucalyptus forest were obtained by applying the CLS method to MSS data using the component (eucalyptus, soil, and shadow) reflectances data as described in Sub-section 3.2. Comparing Figure 3 and the ground information available in Hernandez Filho et al. (1978), the shade images show the difference in concentration of shadow in the two age groups of eucalyptus plantations. The results shown in this figure show that the young eucalyptus (considered as the age ranging from eight months to two years) presents a smaller amount of shadow than the old eucalyptus (the age greater than two years).

Similarly, the shade images for vegetation of "cerrado" are obtained by applying the CLS method to MSS data and using the component ("cerrado","soil, and shadow) reflectances data as described in the previous section. Figure 5 presents the variation in shadow concentration caused by canopy cover structure. This canopy structure may be associated to the difference in tree height, tree density and/or species composition. The ground information of "cerrado" was not available at this time.

5. CONCLUSIONS

The results presented in Section 4 for forests of eucalyptus and vegetation of "cerrado" lead to the following conclusions. The shade images for forest of eucalyptus showed that young eucalyptus has smaller amounts of shadow than the old eucalyptus. This pattern is related to forest structure since the young eucalyptus has a uniform canopy cover (i.e., it is homogeneous in tree heights and generally tree leaves cover the understory completely), while old eucalyptus presents nonuniform canopy cover caused by higher tree heights and the understory is more exposed. The shade images for vegetation of "cerrado" have a variation in shadow concentration which is related to canopy cover structure.

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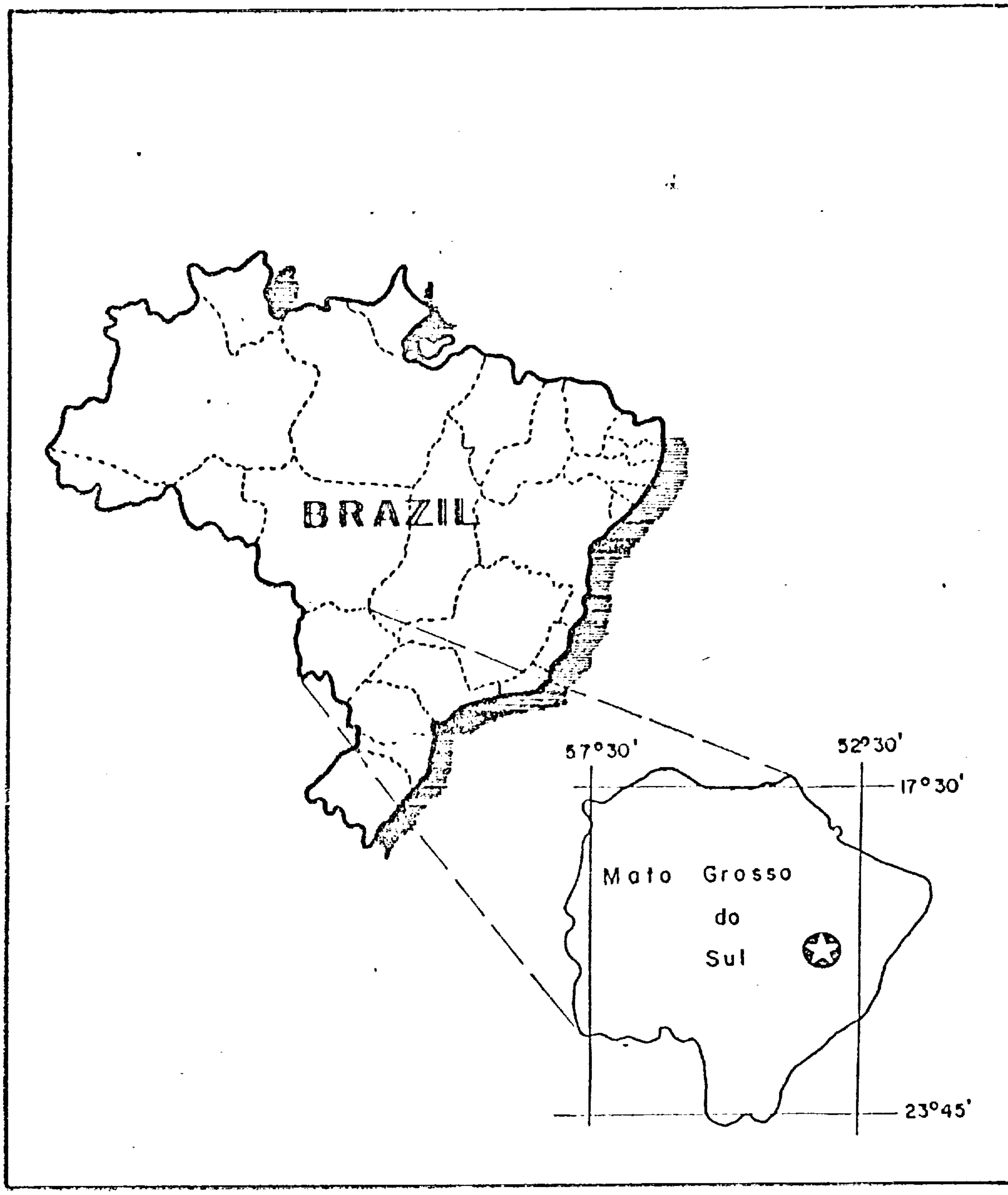

Figure 1 - Location of the study area "Itapeva" in the state of Mato Grosso do Sul.

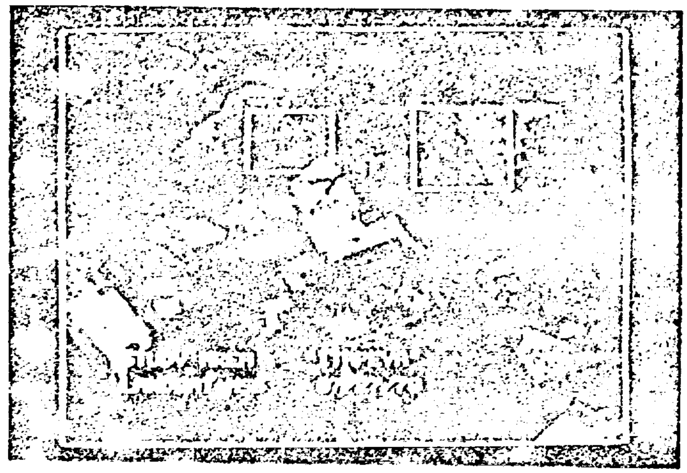

Figure 2 - Location of the study sites for forest of eucalyptus (LANDSAT MSS-5).

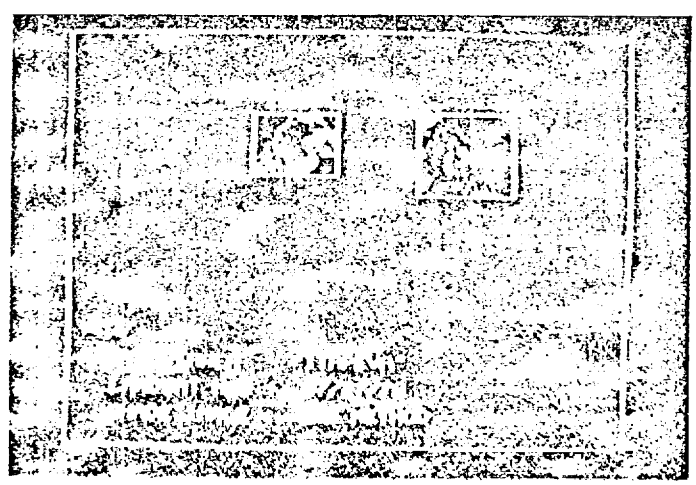

Figure 3 - Shade images for forest of eucalyptus.

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Figure 4 - Location of the study sites for vegetation of "cerrado" (LANDSAT MSS-5).

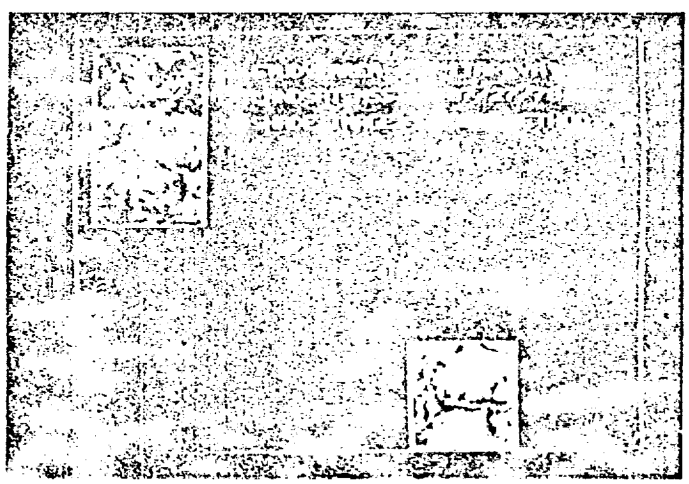

Figure 5 - Shade images for vegetation of "cerrado".