

REFLECTANCE PATTERN AND THE PHYSICAL AND CHEMICAL  
CHARACTERISTICS OF THREE BRAZILIAN OXISOLS

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ABSTRACT

Spectral data were obtained in three data collection levels: laboratory (400 to 1100nm), field (400 to 1050nm) and satellite (MSS and TM/LANDSAT) in two areas with different parent materials. The soil physical and chemical parameters were highly correlated with the spectral reflectance pattern of the three studied Oxisols. The results showed the importance of parent material and texture as influencing parameters of the soils spectral pattern. Also, for the soils originated from eruptive basic rocks, clear indications were found that inferences of soil properties related with iron oxides are possible due the strong absorption that occurs in the spectra of these soils.

1. INTRODUCTION

Developing countries, such as Brazil, are already in the technologic stage of constructing and launching in orbit remote sensing satellites for monitoring their natural resources.

In this manner, to select sensors bands, for example, increased knowledge and understanding of spectral properties of the very intensively weathered tropical soils are needed. This is true since the majority of soils spectral studies has been realized at the northern atmospheric and environment regions.

Considering agricultural remote sensing and multispectral imagery interpretation, it is widely known that there are strong soil influences in the crops spectral responses until a 100% soil coverage is achieved. These influences are due to several factors: the crop species, row spacing, maturity stage, leaf area index, percent soil cover, planting systems, relief, soil types and others.

New generation of sensors such as TM/LANDSAT and HRV/SPOT have different positions and numbers of bands, different spectral intervals and radiometric resolutions, comparing to the frequently used MSS/LANDSAT sensor. Thus, there are needs of better and wider knowledge of the soils and crop canopy spectral behaviours than we have presently.

In this context, the purpose of this study is to provide better understanding of the spectral reflectance pattern of three

important Brazilian Oxisols, utilizing data collected at three different levels: laboratory, field and orbit.

## 2. SPECTRAL CHARACTERISTICS OF SUPERFICIAL SOILS

Incident energy/target interactions for soils are restricted only to the absorption and reflection processes.

However, soils are disperse systems and they are composed by complex mixture with varied chemical and physical properties and characteristics. Thus, these characteristics and properties affect significantly the soil absorptions and reflections.

Literatures report that a reasonable number of parameters can react individually or in conjunction to influence soil spectral properties; both in the visible and infrared regions of the electromagnetic spectrum.

Agricultural scene is very dynamics in relation to the terrain superficial coverage. Thus, bare soils can be found in several conditions during the year, depending on crop types and their cultural managements. Clearly, the soil superficial conditions influence significantly the spectral responses obtained both by field spectrometry and by multispectral scanner (Stoner and Horvarth, 1978).

Nevertheless, Stoner and Baumgardner (1980) affirmed that it is very difficult to characterize appropriately soil superficial roughness, when it is under several plowing conditions. Thus, the roughness is one of the less understood parameters which influence the superficial soil reflectance.

Concerning the soil moisture, it is normally observed that most soils appear darker when they are wet and the reflectance decreases with increasing moisture throughout the reflective wavelengths. The amplitude and shape of soil reflectance curves are affected by the presence of strong water absorption bands at 1.45 and 1.95 $\mu\text{m}$  (Bowers and Hanks, 1965).

An absorption band at 2.2 $\mu\text{m}$  was not considered by Bowers and Hanks (1965), but Hunt and Salisbury (1970) identified the reflected energy in this region is influenced by the vibrational mode of the ion hydroxyl.

Soil reflectances are strongly influenced by soil organic matter content and its composition. Al-Abbas et al. (1972) found that organic matter plays a dominant role in bestowing spectral properties to soils when the organic matter content exceeds two percent. As the organic matter drops below two percent, it becomes less effective in masking out the effects of other soil constituents. Organic constituents including humic and fulvic acid and nonspecific compounds including decomposing plant residues are known to influence soil reflectance to different degrees, although the contribution of each has been difficult to quantify.

Soil texture (particle size) also appear to influence soil reflectance in varying manners. Stoner and Baumgardner (1980) observed that when particle size diminishes the reflectance increases for sandy soils; for medium to fine textured soils the reverse is true. Montgomery et al. (1976) found that the amount of silt present was the major factor influencing the level of reflectance in both visible and infrared wavelengths, with an increase in the amount of silt causing increases in reflectance.

Iron oxides content is another parameter of very high importance in the soil reflectance properties. Stoner et al. (1980) found that ferric iron absorption bands can be seen in certain soil reflectance curves in the 0.8 and 0.9 $\mu$ m wavelength regions. Broad absorption bands at these wavelengths frequently occur in high iron content soils; while a sharp, narrow absorption band at 0.9 $\mu$ m is evident in many soils of relatively low or even negligible iron content. Different forms of iron oxides are known to impart red and yellow colours to soils.

Bauer et al. (1980) added that an increase in iron oxide can cause a decrease in visible reflectance.

### 3. THE STUDIED SOILS

The three types of soils, found in two study areas, are classified according to the 7<sup>th</sup> Approximation (USDA, 1973) as Oxisols. By the Brazilian System of Soil Classification they belong to the following soil great groups: Latosolo Roxo (LR), Latosolo Vermelho-Escuro (LE) e Latosolo Vermelho Amarelo (LV). According to Comissão de Solos (1960) and Oliveira et al. (1982) these soils are described as follows:

- (a) Oxisol/LR: soils originated from basic igneous rocks, consequently they show high hematite contents and the colour is redder than 3,5. Generally these soils are very deep, clayey and the relief is almost smooth. They show high total iron contents (more than 18%), and have high nutritional potentials.
- (b) Oxisol/LE: they are deep mineral soils and are quite permeable and well drained. In this case, there are two soil subtypes: (b.1) LE-1, which is clayey textured, with high aluminium and iron sesquioxides contents; it is originated from the weathering of fine sediments and from varied contributions of basic rocks; (b.2) LE-2 is sandy textured and its parent material is Bauru Sandstone without carbonatic cement; it has low nutritional potential.
- (c) Oxisol/LV: these soils are deep, sandy with low contents of iron oxides; the dominant clay type is kaolinite and they have low bases contents; their parent material are sandy sediments.

### 4. METHODOLOGY

The Oxisols: LR, LE-1 and LV were found in AREA-1 (São Paulo State, Brazil - approximately at 22°10'S and 47°15'W). In this

area, spectral data were collected in three different levels: laboratory spectrometry, field spectrometry and, finally, digital numbers (DN) extraction from MSS-LANDSAT/CCTs (Compatible Computer Tapes) utilizing a Digital Imagery Analyzer.

In AREA-2 (São Paulo State, Brazil - approximately at 20°30'S and 48°30'W) the Oxisols: LR, LE-2 and LV were found. In this area spectral data (DN) were only obtained from TM-LANDSAT-5/CCTs (TM 3, TM 4, TM 5 and TM 7 bands).

## 5. RESULTS AND DISCUSSION

The radiance of a scene depends not only on its own properties, but also on its irradiance. In this manner, every time it is possible, it will be better to take its reflectance (or its reflectance factor) (Kriebel, 1978), which only depends on its properties and enables comparisons in space and in time.

Spectral reflectance factor of a surface can be defined as the ratio of the radiative flux reflected by the surface in a determined cone (defined by the utilized radiometer) to that which should be reflected in the same direction by a perfect diffusing surface (white lambertian surface) and receiving the same irradiance (Kriebel, 1978).

Figure 1 shows the soil spectral curves of AREA-1 obtained in the laboratory (1.a) and in the field (1.b) levels.

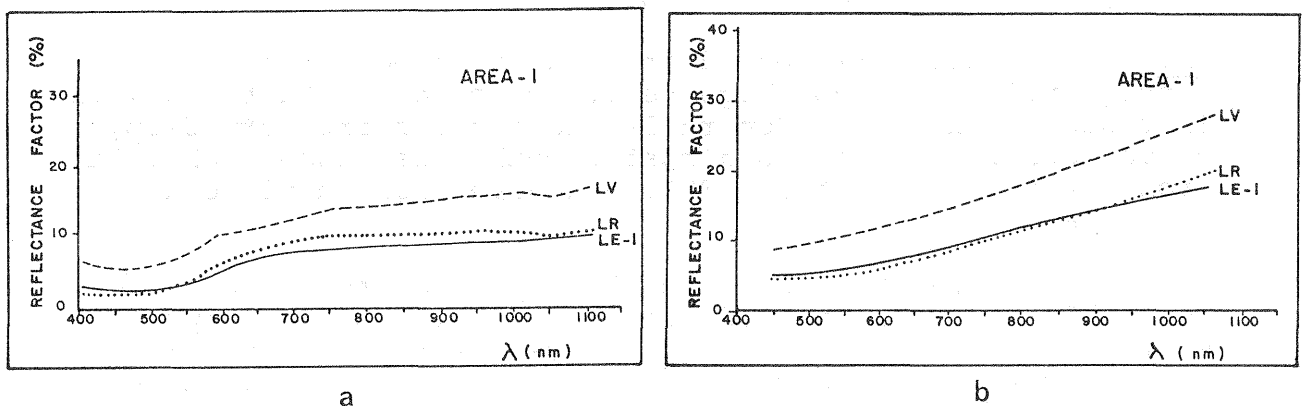


Fig. 1 - Mean spectral curves of the Oxisols: LR, LE-1 and LV from AREA-1, obtained in laboratory (1.a) and in field (1.b) conditions.

Analysing these curves, it is clearly verified that large relative correspondences among spectral behaviours of the three studied soils were observed at both data collection data.

Table 1 shows the correlation coefficients of the laboratory and field curves, considering the spectral intervals corresponding to those of MSS/LANDSAT bands.

TABLE 1

SIMPLE LINEAR CORRELATION COEFFICIENTS FOR LABORATORY AND FIELD SPECTRAL CURVES (ACCORDING TO THE FOUR MSS/LANDSAT CHANNELS)

SIMULATED MSS CHANNELS	CORRELATION COEFFICIENTS (r)
CH 4	0.9036**
CH 5	0.8747**
CH 6	0.8813**
CH 7	0.6876**

N = 17 observations

\*\* = significant to the 1% level

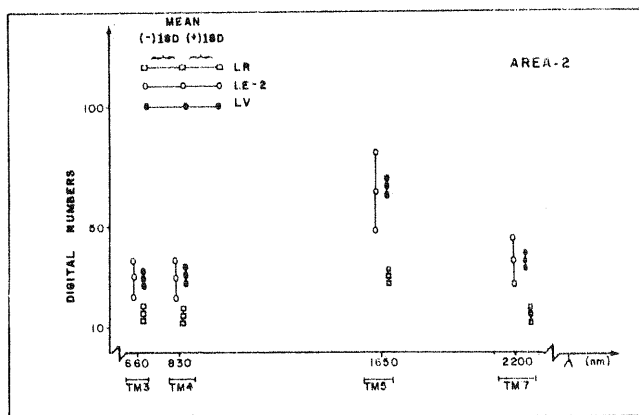
The correlations are highly significant statistically in every simulated MSS channels. This indicates that the laboratory and the field spectral soil measurements are reproducible.

This fact can be considered interesting for utilizing the spectroradiometric techniques for an accurate and quantitative characterization of the spectral properties of the soils, as it proposed by Costa (1979), since these measurements can be realized in both conditions.

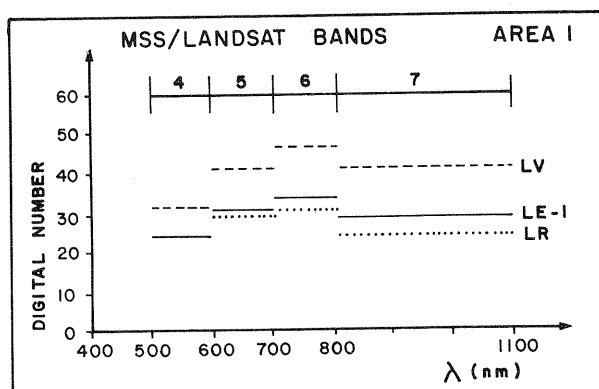
Stoner et al. (1979) comment that the capability of extending soils spectral curves obtained in laboratory to the field conditions has important implications in the use of remote sensing techniques for soil surveys, for soil degradation studies and for agricultural inventories. Controlled environment of the laboratory enables studying several soils spectral properties, whose samples were obtained from several geographic and climatic regions, without the need of transporting a spectroradiometer to distant field sites.

In the Figure 2, mean spectral behaviours (digital numbers) for soils from AREAS 1 and 2 are showed.

Analysing the Figures 1a, 1b and 2b (referring to AREA-1 Oxisols), it is verified that MSS spectral data show the same trends as the laboratory and field data in the 0.4 to 1.1 $\mu$ m interval. Consequently, any spectral data collection level can be utilized to the appropriate methodology and possibilities for each specific case. In a addition, anyone of the data collection level can assist in the comprehension of the soil spectral information of the other two levels.



a



b

Fig. 2 - Mean digital numbers for: (a) Oxisols LR, LE-2 and LV (AREA-2); (b) Oxisols LR, LE-1, and LV (AREA 1).

Basically, observing the curves of the Figures 1a, 1b and 2b, two trend groups can be suggested: firstly the LR/LE-1 group, and on the other hand, the LV soil, in the AREA-1. The soils in the first group showed similar spectral behavior. However between the two trend groups there were differences.

LV Oxisols showed higher reflectance values than the LR/LE group. This is due to that the LV soils have greater sand contents, they are drier, they have less organic matter, iron oxides and bases contents and their mineralogy is kaolinitic. These results confirm the observations of Bower and Hanks (1965), Hoffer and Johannsen (1969) and Stoner and Baumgardner (1980) on temperate climate soils.

Analysing the Oxisols of the AREA-2, it is possible to verify that LE and LV showed similar means of digital numbers; while LE showed greater standard deviation, indicating that their physical and chemical characteristics are more heterogeneous.

There was a differentiated spectral behaviour between LR and LE/LV soils. This can be explained by clay and iron oxide contents, which are different for both cases.

In the AREA-2, the LR is originated from eruptive basic rocks, which have high clay and iron oxides contents (nearly 60% and 25%, respectively). While the LV and LE Oxisols are originated from Bauru Sandstone without carbonatic cement as parent material; thus, the LV and LE Oxisols have small clay and iron oxides contents (nearly 20% and 9%, respectively) and they are very sandy.

It should be emphasized that soil LE was grouped with LV in AREA-2, but in AREA-1 it was grouped with LR. Another interesting

point to be noted is the good separability between the LR and LV/LE in AREA-2. The possible explanation for this grouping discrepancy can be attributed to the fact that in AREA-1 Oxisols/LE-1 are clayey (parent material are shales and argillites) and their textural characteristics are more similar to those of the LR soils. On the other hand, in the AREA-2, LE-2 are originated from sandstones and have greater sand content, which is a characteristic similar to the LV/Oxisols.

This is a very interesting and important verification. If only AREA-1 data were analysed separately, one could conclude that LR and LE always have indistinct spectral behaviours. In the same way, analysing AREA-2 data only, one could wrongly suppose that LV and LE always have identical spectral behaviours. Thus, it's important to notify the influence of the parent material on the soil texture, as much as on the other physical and chemical parameters. Consequently this influence is also extended to the soils spectral properties. In each distinct geographic region of a country this verification must be appropriately considered, in order to avoid errors of generalization.

In the field, when one analyses visually LR and LE soil colours of the AREA-2, these colours are very similar. Nevertheless, when one verifies the spectral responses of those soils, it's perfectly possible to distinguish one and the another. This occurs because they have distinct physical and chemical parameters, which determine their distinct spectral patterns.

Thus, it's possible to affirm that the spectroradiometry - both at laboratory and at field conditions - could be very helpful to the pedologists as an excellent tool in the soil survey studies.

## 6. CONCLUSIONS AND FINAL REMARKS

Considering the materials and methods utilized in this research work, it was possible to conclude and consider what follows.

Spectral data collection levels utilized (laboratory, field and satellite) ratified one another in the 0.4 to 1.1 $\mu$ m spectral interval. Consequently one or another spectral data collection level can be utilized according to the possibilities of each specific case.

There was significant correlation between the field and the laboratory spectral data. So, spectroradiometry shows good potential to be used as auxiliary tool in pedologic studies.

Parent material affects significantly the soil parameters (as texture, colour, cation exchange capacity and others). Thus, LE-1 in AREA-1 is spectrally identical to LR, while LE-2 in AREA-2 is spectrally similar to LV Oxisols.

In this context, the influence on soil spectral response caused by the physical and chemical parameters (texture, organic matter content, moisture and iron oxides contents, between others) - were clearly showed.

Thus, the quantitative and less subjective tools in collection soil spectral data by using spectroradiometric techniques appear very promising.

Spectroradiometric measurements in the near and medium infrared regions should also be carried out to investigate the possible contributions of these reflected energies on soil information such as soil moisture and iron oxides contents.

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