Diffuse reflectance spectroscopy to estimate soil attributes of Brazilian wetlands

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Abstract— *The study of soils and characterization of its attributes are continually evolving, however, for the condition of wetlands, such information is still scarce and poorly distributed. Thus, the objective of this work was to characterize spectrally the soils of a wetland area. On the study area were collected georeferenced soil samples and sent for chemical and physical analysis routine and then subjected to spectral evaluation. Were identified seven soil classes with hydromorphic characteristics in their spectral curves? The information contained in these curves then led the development of equations for soil attributes. Sand was the physical attribute of a better correlation with laboratory data and Cationic Exchange Capacity (CEC), the chemical attributes that showed better results.*

Key words: hydromorphism, spectral curve, radiance, absorption band.

I. INTRODUCTION

The soil study and its inherent agronomic characteristics consist of a number of commonly used tools and extensive domain. Among these studies, we highlight those aimed at quantifying various chemical and physical attributes. Differences in environmental conditions where soils are located are frequent and, in this sense, it is important to emphasize the low amount of existing information on lowland soils and their potential for agricultural productivity (Chicati et al., 2009[1]). According Fageira et al. (2000)[2], these soils have productive potential to supply two to three annual crops, since properly managed, especially regarding fertilization.

In this sense, the diffuse reflectance spectroradiometry techniques are presented as an alternative way to obtain accurate results (Shepherd & Walsh, 2002[3]), to the management of soil properties, non-destructively and can be used in short studies or medium term (Udelhoven et al. 2003[4]; Viscarra-Rossel et al., 2006[5]). To quantify soil attributes from its spectral response, you must have good understanding of the relationships between its components and their interaction with electromagnetic radiation (Sousa Jr. et al., 2008[6]).

In such studies, seeks to establish a specific behavior or spectral signature of soils derived, according Stoner & Baumgardner (1981)[7], the inherent spectral behavior of heterogeneous combination of materials, such as particle size, soil structure, surface roughness, moisture, organic matter content, carbonate minerals content, presence or absence of quartz and iron oxides (Shepherd & Walsh, 2002; Dalmolin et al., 2005[8]; Nanni & Demattê, 2006[9]). Fiorio & Demattê, 2009[10]) also point out that the best way to understand the variations of the spectral data in orbital level is to know their behavior through radiometric measurements in the laboratory. This procedure tends to reveal the characteristics closer to reality for the study object.

Thus, the objective of this study was to obtain parameters to estimate soil attributes, in this case specifically floodplains, using for both the spectral characteristics inherent to them.

II. MATERIAL AND METHODS

The study area used is located in the northwest of Paraná state - Brazil, being included in the Environmental Protection Area (APA) Federal Islands and Floodplains of the Parana River. The pilot area delimits up by UTM coordinates, the meridian 51 WG, 238-252 km and 7428-7438 km. The sedimentary deposits present in this area correspond to "Rio Paraná Unit" and have highly asymmetric shape with a thickness ranging between 5 and 6 meters in the corresponding portion of the floodplain (Stevaux, 1994[11]). Within this unit, the study area is near the Ivaí River, being distributed on the three different sections of the same river that are the basalts of the Serra Geral Formation, sandstones of Caiuá Formation and sediments of the Paraná Sedimentary Basin (Barros, 2006[12]).

The soil sampling grid field is defined by photo-interpretation with the aid of a stereoscope mirrors, according to the methodology described by Nanni & Rocha (1997)[13], using aerial photographs of the year 1996 vertical panchromatic in scale

1:50.000 to define the physiographic units. Were also made observations of orbital images Landsat7/ETM orbit/point 223/076 and 224/076, from the year 2001 to better characterization of land use, according to Embrapa (1996)[14].

After setting the sampling grid, collecting and georeferencing of soil samples in the field was performed. The methodology of work, description and collection of the material followed the criteria established by Santos et al. (2005)[15]. With the aid of the Dutch auger type they were sampled 72 points, and these samples were taken from surface and subsurface layers of soil.

The samples were air dried and subjected to sieve 2 mm (TFSA). To determine the total sand, silt and clay levelswas used methodology of the hydrometer (Camargo et al., 1986[16]). Organic matter (OM), active acidity and reserve, pH, cation exchange capacity (CEC), exchangeable bases (calcium, magnesium, potassium) (S), base saturation (V%) and aluminum saturation (m%) were determined using methods recommended by Embrapa (1997)[17]. The textural groups of soils were defined as Embrapa (2006)[18].

For spectral analysis portions of all samples were separated for both surface layers and for subsurface a total of 144 sub-samples. The radiometric data collection procedure took place in properly prepared for spectral readings environment, following geometry described by Demattê et al. (2005)[19], where the samples were subjected to evaluation in Fieldspec Pro spectroradiometer with spectral resolution of 1 nm from 350 to 1,100 nm and 2 nm between 1,100 nm and 2,500.

The first procedure for combining basic spreadsheet data which served to further analysis was the selection of bands as the methodology used by Nanni & Demattê (2006). By this method, the average wavelength ranges among different points are located, or at any single point detached from the analyzed spectrum as shown by Madeira Netto (1996)[20]. Thus, they were determined 22 bands (B1_HA to B22_HA) surface and other 22 (B1_HB to B22_HB) in the subsurface.

The second procedure for evaluating the spectral data was performed by means of values obtained to calculate the difference between the reflectance factor values centered on the lower inflection point (absorption bands) and its next point on a larger scale, also called Crest. These ranges are called as Nanni & Demattê (2006), Reflectance Inflection Difference (RID) and constituted in 13 RID's in each sampled layers (h1_HA to h13_HA and also h1_HB to h13_HB).

Two other procedures were performed to obtain parameters that could differentiate the soils analyzed. The first method is to obtain the tangent angle value formed by the starting point of the spectral curve and its point of maximum reflection (tg_HA and tg_HB) (Fig. 1a). The second method took into account the area formed by turning two distinct points in the spectral curve, and these inflection caused by water in 1900 nm (A1, being A1_HA and A1_HB) and kaolinite inflection at 2265 nm (A2, being A2_HA and A2_HB), common to all samples analyzed in this study (Fig. 1b). This calculated area was determined with the aid of tablet and software "System Georeferenced Information Processing" (SPRING). Each spectral curve was plotted on paper and properly defined, the point of the previous crest turning to the next peak point, through own inflection.

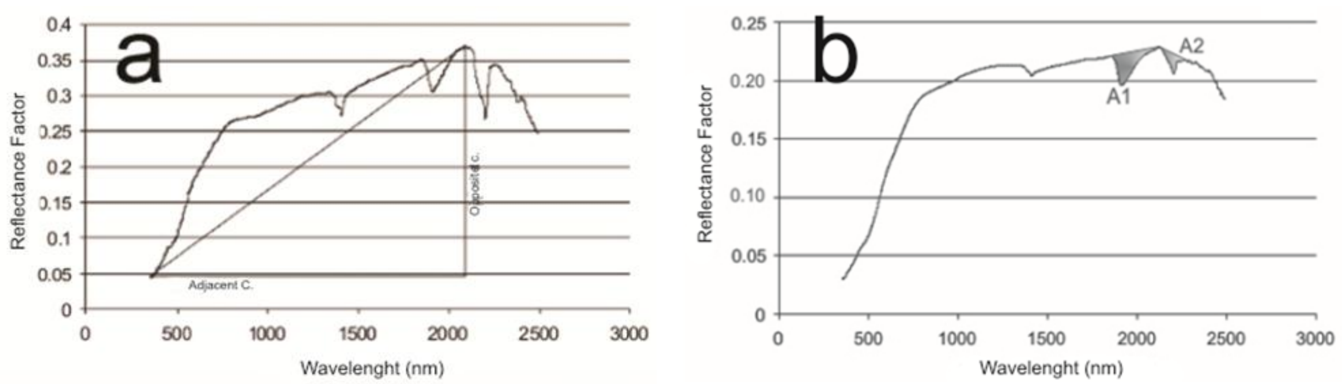

FIGURE 1:(A)METHODOLOGY FOR OBTAINING THE TANGENT OF REFERENCE; (tg = opposite c. / adjacent c.) (B) METHODOLOGY FOR DEMARCATION OF THE CALCULATED AREAS SUBSEQUENTLY USED IN THE DISCRIMINANT ANALYSIS OF SOILS

To establish more representative variables and they could have more say in production models that were to explain the proposed problem, we used the STEPDISC procedure of SAS program. So that there was no bias in the analysis, we used the collinear assessment procedure of the variables through the SAS software STEPWISE function.

For the characterization of the soil and its attributes through the statistical analysis was used in the SAS program, CORR procedures (correlation) and REG (Regression). These methods analyzed and showed the correlation coefficients (r) and determination (r^2), and the linear regressions to the 5% level of significance relating the reflectance (independent variable x) of each wavelength band selected with the respective soil parameter (dependent variable, y).

Through guided analysis procedure of the SAS data it was possible to achieve the "refinement" of the data aiming to the improvement of the prediction model conditions, also checking with it if it had not violated any condition. Thus, equations were obtained that made it possible to estimate the analytical characteristics of the soil in question. Thus, it sought to demonstrate the possibility of using the method in estimating soil attribute values the same as those obtained commonly in everyday laboratory analysis.

III. RESULTS AND DISCUSSION

The distribution of soil classes in the study area showed a predominance of young soils, with relatively recent development processes, considering the local geomorphology, and the absence of advanced weathering processes.

The class of Argissolos vermelho-amarelos (PVA) [18] attended the largest portion of the ground, suffering evident ferric process along the profile, mainly characterized by grayish observed. In spectral profiles (Fig. 2a) was observed in this class action of low organic matter (47.74 $g.kg^{-1}$), the presence of characteristic features of secondary minerals, in addition to low activity of iron oxides, unlike in [6] Sousa Jr. et al. (2008).

The Neossolos Quartzarênicos (RQ)and Neossolos flúvicos (RY) [18] observed showed behavior hydromorphic soils with low spectral activity of iron oxides (30.72 and 24.08 $g.kg^{-1}$ Fe_2O_3 respectively) and reduced albedo, even with sand content higher than 65%. They were observed in these classes, attendance spectral curves of types 1 and 2 (Fig. 2b), according Stoner & Baumgardner (1981), with slight modifications caused by activity of organic matter.

The Plintossolos Pétricos (FF) and Plintossolos Concrecionários (FC) [18] characteristic of the regions of floodplains, showed remarkable spectral influence caused by the content of iron oxides (33.97 $g.kg^{-1}$ Fe_2O_3). It was also observed low albedo of the spectral curves (Fig. 2c) due to the clayey nature (26.97%), and the secondary minerals activity.

Classes Latossolo Vermelho-amarelo (LVA), Organossolo Háplico (OX)and Cambissolos (CX)[18] (Fig. 2d) correspond to smaller portions of the study area, with different behaviors, however, less representative to the general amount of ground samples. Due to the low number of individuals also were the classes with greater error rates as the spectral estimation of attributes.

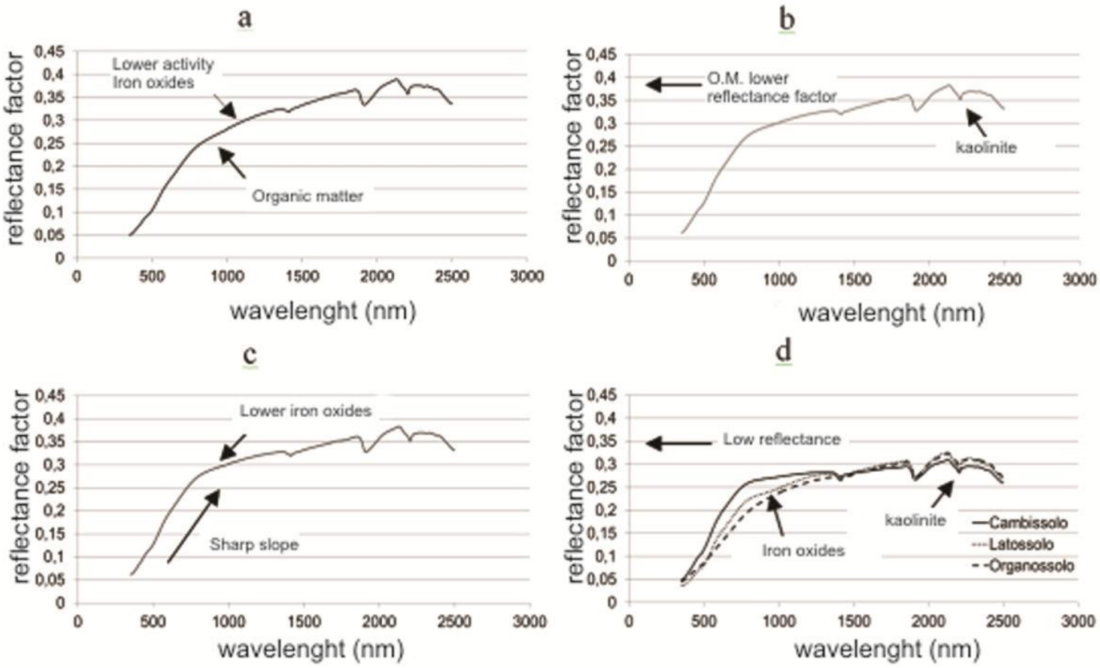

FIGURE 2:SPECTRAL DATA OBTAINED WITH THE AVERAGE VALUES OF THE SAMPLES OF CLASSES PVA (A), RQ AND RY (B), FF AND FC (C),LVA,OX AND CX (D) THE DEPTH 0-20 cm

The statistical procedure performed in SAS software with spectral laboratory data for both soil layers had linear multiple regression analyzes, individualized for each attribute, where it was possible to obtain the equations contained in Table 1.

TABLE 1
REGRESSION EQUATIONS FOR ESTIMATING ATTRIBUTES OF THE SURFACE LAYER (A) AND SUBSURFACE (B) OF THE SOIL WITH THE USE OF LABORATORY SPECTRAL DATA

Attribute	Equation	r^2
Clay (A)	Log10 (1,521 + 2,229 B1_HB + 17,83 B20_HB – 8,718 B21_HB – 9,766 B22_HB)	0,35
Clay (B)	Log_{10} (1,338 + 11,26 h9_HA – 27,36 h10_HA + 14,85 h11_HA)	0,60
Silt (A)	Log10 (1,422 – 1,036 B21_HB + 9,218 B4_HB – 19,37 h5_HB + 11,33 h6_HB)	0,33
Silt (B)	Log_{10} (0,913 – 0,115 B13_HA + 10,46 h8_HA – 10,41 h10_HA + 1,965 B2_HA – 0,266 B5_HA – 0,018 B6_HA + 0,0467 B9_HA)	0,74
Total sand (A)	3,00 + 940,9 B21_HB – 215,8 B1_HB – 1749 B20_HB + 838,3 B22_HB	0,41
Total sand (B)	Log_{10} (1,351 – 0,043 B11_HA + 1,644 h5_HA – 4,120 h8_HA + 3,399 h10_HA)	0,90
CEC (A)	Log10 (1,710 + 23,49 B19_HB – 71,18 B18_HB + 45,79 B17_HB – 0,973 B13_HB)	0,47
CEC (B)	Log_{10} (1,890 – 1,883 h6_HA – 1,733 h7_HA – 0,040 B11_HA)	0,76
S (A)	Log10 (1,331 – 13,71 B18_HB + 9,885 B19_HB)	0,27
S (B)	Log_{10} (0,631 – 21,05 h10_HA + 11,63 h11_HA + 7,841 h9_HA + 0,148 h6_HA)	0,49
V% (A)	49,70 – 1015 B19_HB + 3891 B18_HB – 2944 B17_HB	0,24
V% (B)	Log_{10} (1,481 – 0,105 B3_HA)	0,82
m% (A)	$\sqrt{4,843}$ – 0,233 B3_HA	0,15
m% (B)	-	-
OM (A)	Log_{10} (0,277 + 1,944 B12_HB – 9,881 B18_HB + 6,910 B19_HB)	0,24

By observing Table 1 note that the attributes sand total, silt and clay, physical character, showed high correlation coefficients between the estimated and actual data and, in the case of total sand obtained the best result among all attributes analyzed with r^2 of 0.90. Clay and silt, even below the total sand coefficient obtained good indices of 0.60 and 0.74 respectively. According to Demattê et al. (2004)[21], such a high rate of physical attributes are expected due to their greater influence on the spectral response.

The chemical nature of the attributes shown irregularity between mistakes and generally hits. However, we obtained good results for CEC and V%, with coefficients 0.76and 0.82 respectively, the approximate values obtained by Dunn et al. (2002)[22]. The correlation to the sum of bases (S) showed worse results than the others, with r^2 of 0.49, as also observed by work as Fiorio & Demattê (2009). The value obtained for the organic matter can be considered relatively low (r^2 0.40) when compared to work as Ben-Dor et al. (1997)[23] who obtained r^2 approximate 0.50. The correlation value for m% was low, reaching a correlation coefficient of only 0.15.

The data presented for the subsurface horizon showed that the correlation values for this layer are, for all attributes that are smaller than previously observed. Even the attributes with the highest hit rates for the surface layer had r^2 fall, as was the case of the total sand that fell from 0.90 to 0.41. This can be explained by the great similarity observed among the set of individuals analyzed, that is, even being substantially different soil classes in the field, the preparation of samples for laboratory analyzes removed possible pre-existing singularities, increasing the degree of similarity between samples.

In general, the attributes obtained low correlations, and r^2 values thereof are presented on the home 0,3 to 0,4. The CEC was the best attribute resulting (r^2 0.52). As for m%, it was not possible to establish correlation significance level of 5% of the test, which was not observed in works like Demattê et al. (2004) or Nanni & Demattê (2006).

IV. CONCLUSION

The equations generated by the statistical model showed to be efficient in the characterization of the attributes relating to lowland soils, and the best correlations to the surface layer thereof. The sand content was the physical attribute with better accuracy rate in estimating the equations, while among chemical attributes, CEC showed better results.

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