

Mapping of clay, iron oxide and adsorbed phosphate in Oxisols using diffuse reflectance spectroscopy



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ABSTRACT

Diffuse reflectance spectroscopy (DRS) provides a rapid, non-destructive, less expensive and sustainable complement to conventional methods of soil analysis. This study aims to assess the DRS ability to predict contents of clay, iron oxide and adsorbed phosphate (Pads), characterizing their spatial variability in Oxisols from Brazil. Soil samples collected from three geomorphic surfaces were scanned in the visible and near infrared spectral range. Moreover, chemometric calibration was obtained through partial least-squares regression (PLSR). Then, spatial distribution maps of the attributes were constructed using predicted values from calibrated models through geostatistical methods. The best accuracy of prediction models (residual prediction deviation >2.0) for clay, extractable Fe by dithionite–citrate–bicarbonate and hematite was obtained within the visible region (380–800 nm), and for adsorbed phosphate within the visible near infrared (380–2300 nm). Predicted values of these attributes had low error (<10%) with the exception of goethite, and enabled building maps similar to those with measured values, demonstrating the DRS importance for clay, iron oxide and adsorbed phosphate mapping of large areas and at detailed scale.

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1. Introduction

Clay and iron oxides are important soil components that affect phosphorus sorption in highly weathered soils (Mesquita Filho and Torrent, 1993). Spatial variability studies of mineralogical attributes at different scales (1–500 ha) and different landscape models have proved spatial dependence of these minerals (Camargo et al., 2008a, 2013a; Barbieri et al., 2009) and spatial correlation with physical and chemical attributes of other soil attribute such as adsorbed phosphate (Camargo et al., 2008b, 2012, 2013b, 2014). In this sense, the spatial variability of P forms usually found in agricultural soils indicates the need for variable-rate fertilization (Wong et al., 2012; Roger et al., 2014). The knowledge of spatial distribution of different P forms (total, organic and available) is required to obtain accurate fertilizer doses and minimize risks of loss, and optimizing costs. According to Roger et al. (2014), it is needed, among other variables, additional data points to improve spatial distribution prediction of different P forms at landscape scale, especially when using geostatistical methods. In general, the

greater the number of data points, the greater the accuracy is (Oliver and Webster, 2014). However, this greater number of samples usually hinders spatial variability studies unless an alternative soil analysis method to the conventional procedures is used.

Diffuse reflectance spectroscopy (DRS) is rapid, convenient, less expensive, non-destructive, simple and sometimes more accurate than conventional analysis. Furthermore, this technique allows the simultaneous characterization of many soil attributes with agronomic and environmental relevance (Viscarra Rossel et al., 2006, 2010; McBratney et al., 2006; Cañasveras et al., 2010; Kodaira and Shibusawa, 2013 and references therein), besides being adaptable for field use (Viscarra Rossel and McBratney, 1998).

Regression methods such as multiple linear (MLR), principal component (PCR), and partial least squares (PLSR) are used to predict attributes through DRS. Among which, PLSR should be highlighted as an efficient calibration model to predict various chemical (Malley et al., 2004; Viscarra Rossel et al., 2006, 2009) and physical (Cañasveras et al., 2010; Gomez et al., 2013) soil attributes. Nonetheless, in tropical soils, there are still few studies on iron oxide prediction and covariate attributes such as adsorbed phosphate (Pads). In brief, such research is necessary since prediction models for these attributes promote a

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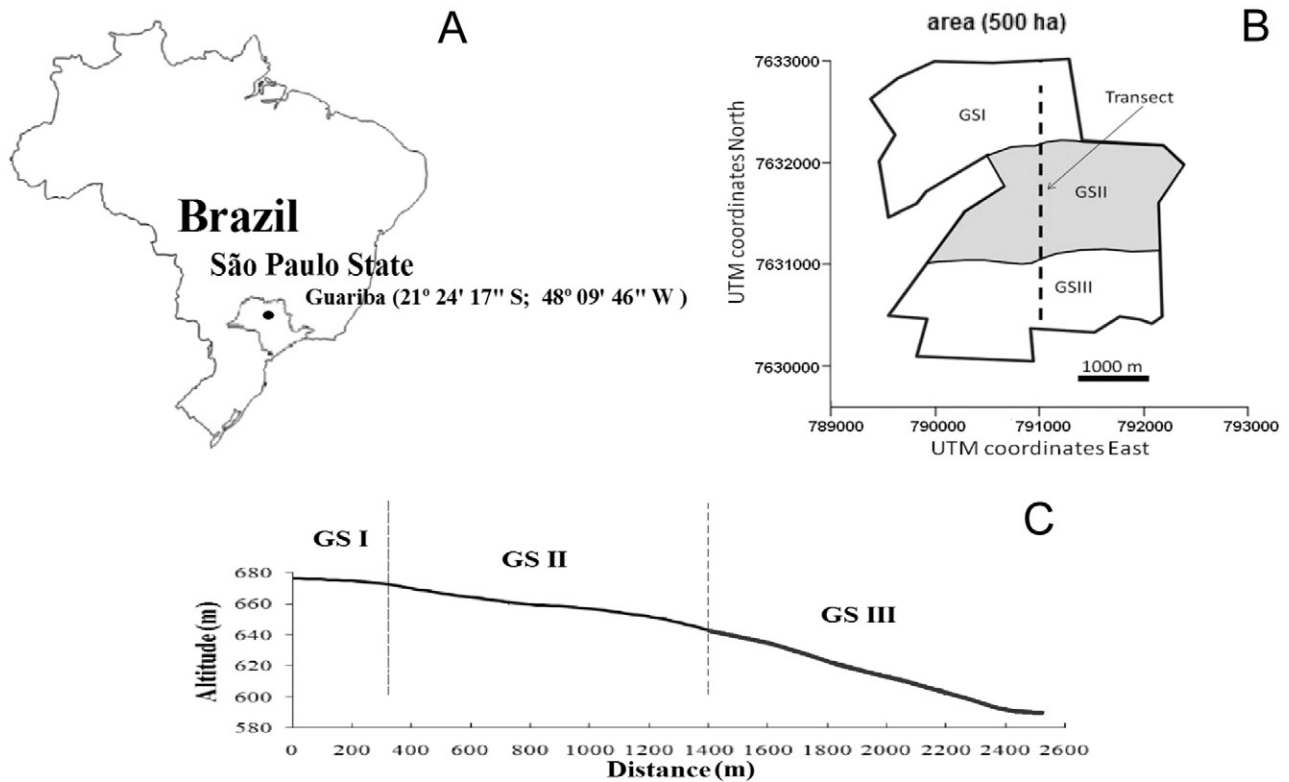


Fig. 1. Study area. A) Guariba town location, B) Five-hundred hectare area and transect, C) Transect profile.

new perspective on site-specific management and a large database can be acquired in a short time cheaply.

Therefore, we aimed to evaluate the ability of diffuse reflectance spectroscopy in predicting contents of clay, iron oxide and Pads in Oxisols to characterize the spatial variability.

2. Material and methods

2.1. Soil sampling

The experimental area is located in Guariba town (Northeastern São Paulo State, Brazil) on sandstones from the Adamantina formation and currently under sugarcane cultivation.

For calibration, one-hundred surface soil samples (series 1) were collected each 25 m along transect, which cuts three different geomorphic surfaces (GSs) (Fig. 1). GS I was approximately 400 m long and had 0 to 4% slope; it was assumed to be the oldest surface in the study area and to have a depositional nature. The boundary between GS II and III was approximately 1400 m from the top. GS II and GS III were erosional in nature and GS II had the shape of a gentle slope plan. GS III has a typically steeper slope (7%) than the other two surfaces. The soil in GS I was a Typic Hapludox, in GS II was a Typic Hapludox and a Typic Eutrudox, and in GS III a Typic Eutrudox (Soil Survey Staff, 1999), the whole area has an average organic matter content of 2%. Area characterization detailing is presented in Camargo et al. (2014). To predict unknown values, other two hundred and six soil samples (series 2) were collected from the upper horizon from subareas, each representing 2.5 ha, around transect.

2.2. Laboratory methods

Grain-size analysis was performed by using a 0.1 M NaOH as dispersant under slow stirring and clay content was determined through the pipette method (Day, 1965).

Total pedogenic iron oxide content (Fed) was determined by extraction with dithionite–citrate–bicarbonate by means of the Mehra and Jackson (1960) method, except that the extraction temperature was 25 °C during 16 h. The low crystallinity iron oxide content (Feo) was determined by extraction with ammonium oxalate (Feo) according to McKeage and Day (1966).

Table 1

Statistics of clay, Fe extracted by dithionite–citrate–bicarbonate (Fed), Fe extracted by ammonium oxalate (Feo), goethite (Gt), hematite (Hm) and adsorbed phosphate (Pads) contents.

		Mean	Minimum	Maximum
Clay (g kg ⁻¹)	GS			
	I	346	328	377
	II	331	285	390
	III	434	326	569
	Transect	357	285	569
Fed (g kg ⁻¹)	I	40.2	26.8	44.8
	II	37.7	27.9	50.3
	III	65.1	39.6	100.2
	Transect	51.0	26.9	100.2
	Feo (g kg ⁻¹)	I	5.4	2.2
II		5.2	2.6	9.0
III		6.7	3.1	9.6
Transect		5.7	2.2	9.6
Gt (g kg ⁻¹)		I	17.3	9.6
	II	16.3	7.9	20.8
	III	21.1	6.9	55.7
	Transect	18.4	6.9	55.7
	Hm (g kg ⁻¹)	I	33.9	22.7
II		31.5	16.7	50.8
III		66.5	38.8	99.4
Transect		47.9	16.7	99.4
Pads (mg kg ⁻¹)		I	420	360
	II	401	338	505
	III	552	379	759
	Transect	499	338	759

GS = geomorphic surface.

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