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Variations in soil properties among phytophysiognomies on different geological surfaces in the vegetation complex of Campo Maior in the ecotonal region of the Parnaíba basin in the state of Piauí

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José Sidiney Barros
State University of Piauí, Center for Technology and Urbanism.
E-mail: jsidneybarros@gmail.com

Mundayatan Haridasan
University of Brasilia, Department of Ecology.
E-mail: hari@unb.br

ABSTRACT
The determinants of the phytophysiognomies in the vegetation complex of Campo Maior in the ecotonal region of the Parnaíba sedimentary basin in the state of Piaui, an area of transition between the Brazilian savanna (cerrado) and the shrubland vegetation of northeastern Brazil (caatinga), are poorly documented in literature. We investigated the availability of nutrients in the soils associated with such phytophysiognomies. The main hypothesis was that soil properties under different physiognomies are conditioned by geomorphological compartments and soils associated with more open physiognomies have lower availability of nutrients. We sampled soils of six different physiognomies on different geomorphological surfaces. Composite soil samples were collected from the surface 0-20 cm of ten 50 m x 50 m plots of each physiognomy and analysed for soil texture and availability of macro and micronutrients. Principal component analysis of soil properties separated the phytophysiognomies along the first and second axes determined principally by gradients in soil texture and the concentrations of available nutrients. The clay content of forest soils was higher than that of other open physiognomies. Although all soils were dystrophic with less than 50% base saturation, the soil under forest had higher concentrations of organic C, total nitrogen available P, Ca and Mn, confirming the original hypothesis.

Keywords: Campo Maior, Carnaubal, Macronutrients, Micronutrients, Soil fertility.

1 INTRODUCTION

The Brazilian savannas or cerrados extended originally over 205 million hectares (Eiten 1972, 1990; Machado *et al*., 2004) in the states of Goiás, Bahia, Minas Gerais, Mato Grosso, Mato Grosso do Sul, Piauí, Maranhão, Tocantins, São Paulo and the Distrito Federal), accounting for 23,9% of the territory. Far from being a single phytophysiognomy, the cerrado, *senus lato*, is a mosaic of different vegetation forms of forests, open savannas and *campos* (Ribeiro & Walter 2008) with a highly diverse flora (Felfili & Silva Júnior 1993).

The cerrados of the state of Piaui in the Parnaiba basin, often designated as marginal cerrados, unlike the cerrados of the core area in central Brazilian Plateau, generally occur over sedimentary rocks, especially sandstones and pelitic rocks, with with inclusions of siliceous, ferruginous and carbonaceous materials. Geology, geomorphology, relief and soils act together (Figure 1) in conditioning the soil water regime and determine the different vegetation forms in this ecotonal region. The presence of

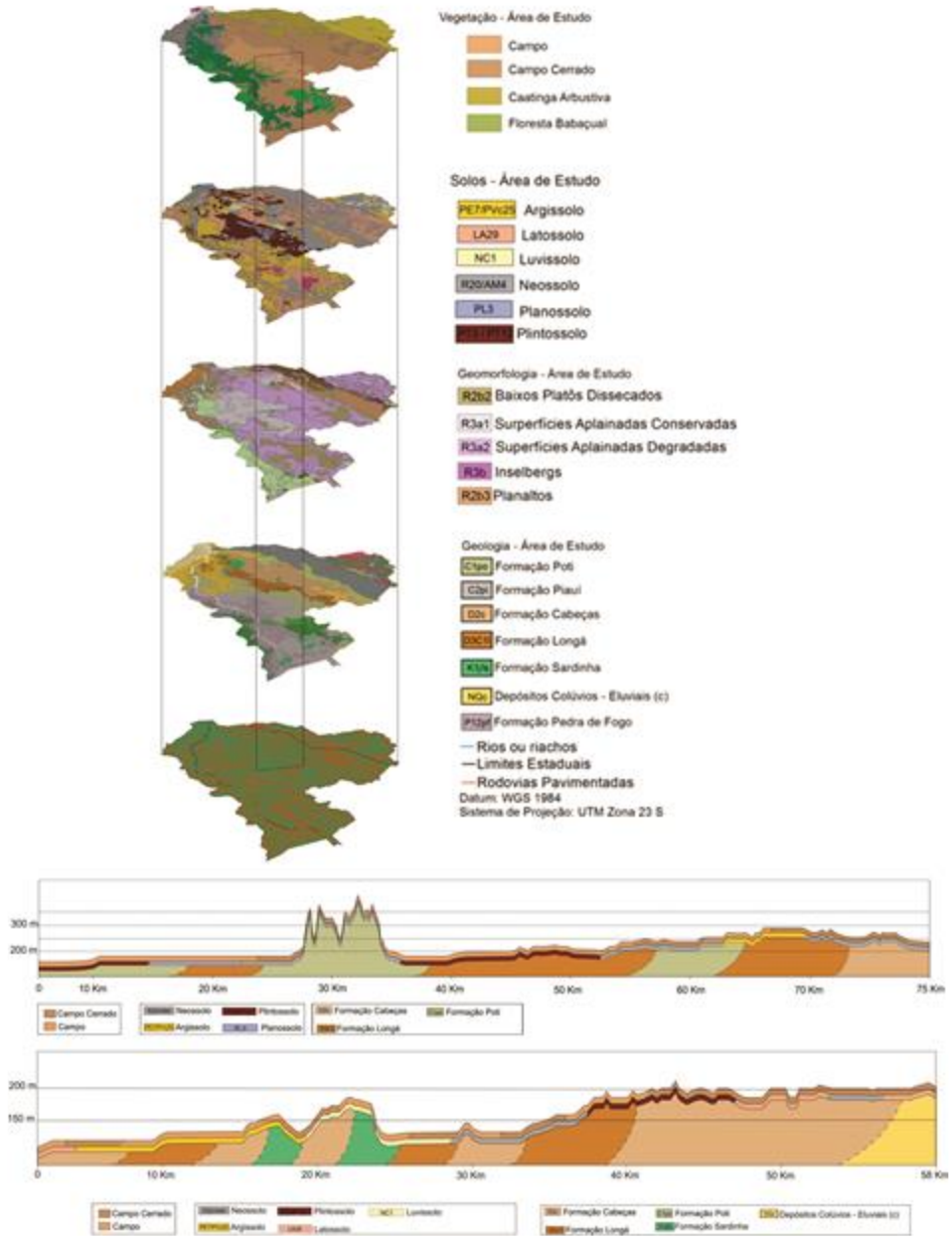
continuous ferruginous and lateritic concretions is of common occurrence and affects effective rooting depth and causes changes in phytophysiognomies (Barros & Castro 2006). The basin of Parnaiba is characterized by the presence of fragments of cerrado, *caatinga* and forests in a mosaic of ecotonal vegetations with characteristic flora e structural features, conditioned by local edaphic factors (Barros *et al*. 2010; Barros & Castro 2006; Rossi et al. 2005).

The relationship of the cerrado landscape to different lithologies of the South American Platform involves pre-Cambrian to tertiary and quaternary terrains. The occurrence of primitive cerrados dates back to the Cretáceo and subsequent evolution of the Central Plateau by the end of this period associated with climatic changes from dry to wet conditions (Machado et al. 2004, 2008). The intolerance of most of the woody species of the cerrado of the core area of central Brazil to excessive soil moisture for prolonged periods restricts the cerrado physiognomies to well drained soils. Forest formations occur on dystrophic and mesotrophic soils (Haridasan 2001; Haridasan & Araújo 1988; Ratter et al. 1978) and variations in floristic composition and structure even within small fragments have been attributed to heterogeneity in edaphic conditions (Durigan et al. 2000; Botrel et al. 2002; Carvalho et al. 2005; Rocha et al. 2005).

Reports on the floristic structure and composition of different vegetation forms in the cerrado-caatinga transition zone of Piaui state are still very few and isolated. (Castro 1987; Castro *et al*. 1998; Barros & Castro 2006; Farias & Castro 2004) in spite of their tremendous ecological significance. This region more isolated and with a more arid climate than the core area of the cerrado, presents lower richness of taxons than the central Plateau (Ratter et al. 2003; Mendonça et al. 2008).

The present study was thus conducted in the vegetation complex of Campo Maior, taking into account the existence of different phytophysiognomies in the sub-basin of the river Longá, in the ecorregion of lower Parnaíba (PLANAP 2006). The main hypothesis was that soil properties under different physiognomies are conditioned by geomorphological compartments and soils associated with more open physiognomies have lower availability of nutrients.

Figure 1: Geology, geomorphology, soils and vegetation of the vegetation complex of Campo Maior in the ecotonal region of Parnaiba basin in the state of Piaui.



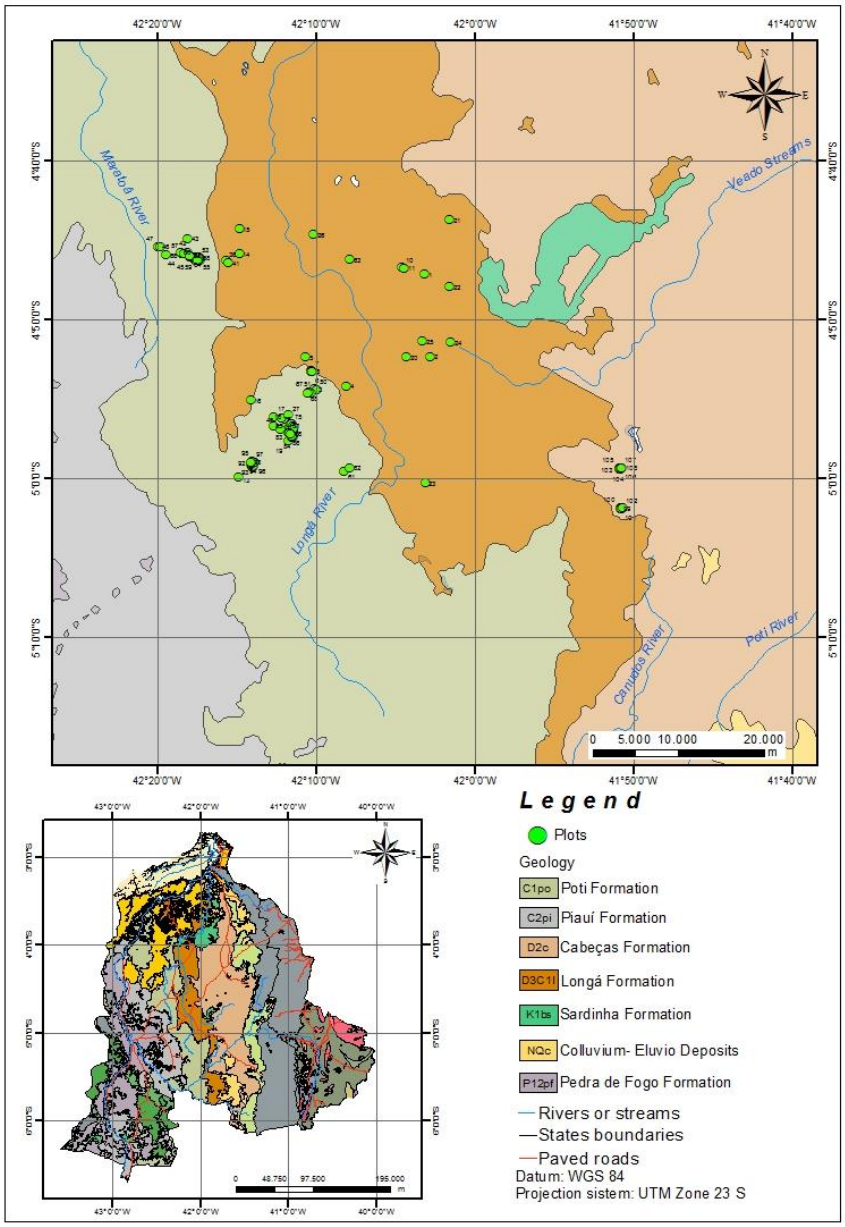
2 MATERIALS AND METHODS

Soils of six phytophysiognomies on different geomorphological surfaces in the vegetational complex of Campo Maior in the sedimentary basin of Parnaíba were investigated (Figure 2). The geographical area of the vegetational complex of Campo Maior extends along the sub basin of the Longá river, within the sedimentary basin of river Parnaíba, over an area of 23800 km^2, constituting physiographic zone of contact among three principal biomas of Brazil: Catinga, Cerrado and the Amazon forest (IBGE, 1993) resulting in a mosaic of ecotones (Barros et al. 2010). The physiognomies studies were cerrado *sensu stricto,* cerrado *rupestre*, *carnaubal*, *capões*, forest, and transitional forms. Detailed information on phytossociological surveys and floristic composition of ten 50 m x 50 m plots of each of these physiognomies are reported in Barros (2012). Composite soil samples were collected

from 0-20 cm depth from each 50 m x 50 m plot under different phytophysiognomies to determine soil texture, pH and concentrations of organic carbon, total N and available macro and micro nutrients. Soil texture was determined by the Bouyoucos method (Kiehl 1979). Soil pH was measured in water and in 1 M KCl. Available P, K, Fe, Mn, Zn and Cu were determined in Mehlich's extract (0,0125 M H_2SO_4 + 0,05 M HCl) and available Ca, Mg and Al were estimated in 1 M KCl. The cations in soil extracts were determined by atomic absorption spectrophotometry and P by colorimetry (Allen, 1989).

Principal component analysis of soil properties was carried out using the CANOCO program, version 3.1 (Ter Braak, 1988). Detrended Canonical Correspondence Analysis was run using the CANOCO program, version 3.1, to determine the relationships between species dominance and soil variables.

Figure 2: Localization of experimental plots in the study area: Cerrado *rupestre* (1-10; 41-50), Carnaubal (11-20), Cerrado *sensu stricto* (21-30), Transition (31-40), Forest (51-60) e Capões (61-70).



3 RESULTS AND DISCUSSION

Principal component analysis of soil properties separated the phytophysiognomies along the first and second axes determined principally by gradients in the concentrations of available nutrients (Figure 3). The eigenvalues for the first two axes were 0.425 and 0.148, thus accounting for 57.3% of the total variation. These results confirm the influence of the heterogeneity of edaphic conditions, resulting from the geological and geomorphological variations, on the vegetation of the Campo Maior complex in the Parnaíba basin. The correlations between soil variables and the first and second axes of the PCA analysis are presented in Table 1. The more important variables with higher coefficients of correlations were N, C, Ca, Zn and Mn along the first axis, and Al, sand, pH, silt and clay along the second axis.

The variation in soil texture under different physiognomies is highlighted in Figure 4. The percentage of sand varied from 56 to 93%,. Forest physiognomies occur on more clayey soils (sandy clay loam) of the region and cerrado *sensu stricto* and other open forms are more common on more sandy soils (loamy sand and sand). The taxonomic classification of soils of the different physiognomies included Entisols (cerrado *sensu stricto*, cerrado *rupestre*, *carnaubal* and forest) and Oxisols (*capões*).

All soils were dystrophic with less than 50% base saturation, but the soil under forest had higher concentrations of organic C, total N, available P, Ca and Mn (Figure 5). Higher levels of available Al were observed in the forest, cerrado *sensu stricto* and cerrado *rupestre* than other formations. High levels of Fe under all physiognomies probably reflect the influence of geological parent material common to all soils in the study area. The dystrophic nature (low base saturation) and low levels of essential nutrients in the soils under cerrado vegetation are similar to the characteristics of the Oxisols in the core area of the cerrado in the Planalto central (Eiten 1994; Haridasan 1992, 2001). Besides the availability of nutrients, and the differences in soil texture, variations in other factors such as topography, seasonal flooding and soil water regimes contribute to environmental gradients in the region. These factors are discussed by Barros *et al*. (2010) and Barros (2012).

Table 1. Corrlelations between soil variables and first and second axes of Principal Component Analysis.

Axis	I	II
% Variation	42,5	15,2
Soil pH	-0,08	0,37
Organic C	-0,34	0,08
Total N	-0,35	-0,01
Available P	-0,27	0,12
Exchangeable Al	-0,01	-0,5
Exchangeable K	-0,31	-0,00
Exchangeable Ca	-0,34	0,12

Exchangeable Mg	-0,21	0,03
Available Fe	0,01	-0,27
Available Mn	-0,30	0,16
Available Zn	-0,34	0,12
Available Cu	-0,15	-0,14
Sand	0,29	0,38
Silt	-0,17	-0,36
Clay	-0,28	-0,31

Figure 3: Results of principal component analysis of soil properties and ordenation of the sampling sites of different phytophysiognomies in the vegetation complex of Campo Maior in the ecotonal region of Parnaiba basin in the state of Piaui.

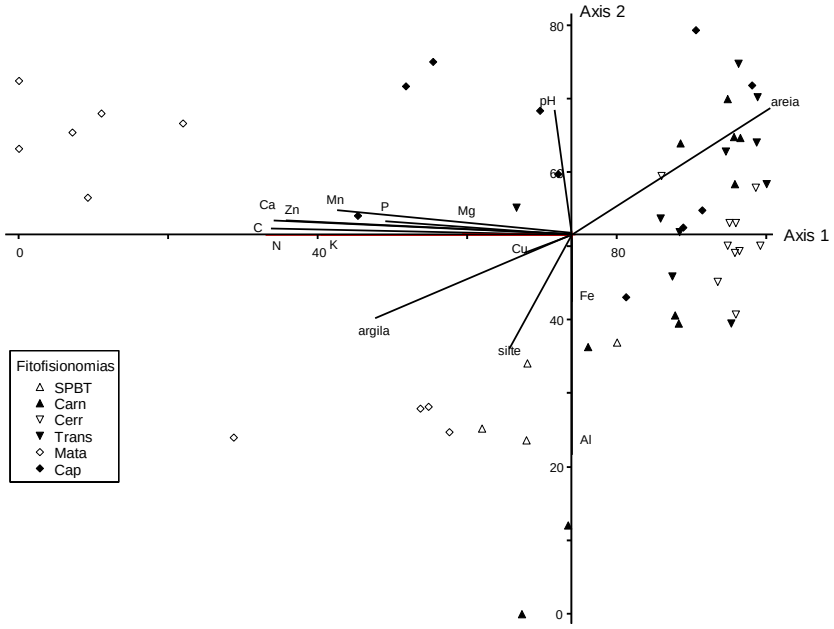


Figure 4: Textural class of soils associated with different phytophysiognomies in the vegetation complex of Campo Maior in the ecotonal region of Parnaiba basin in the state of Piaui.

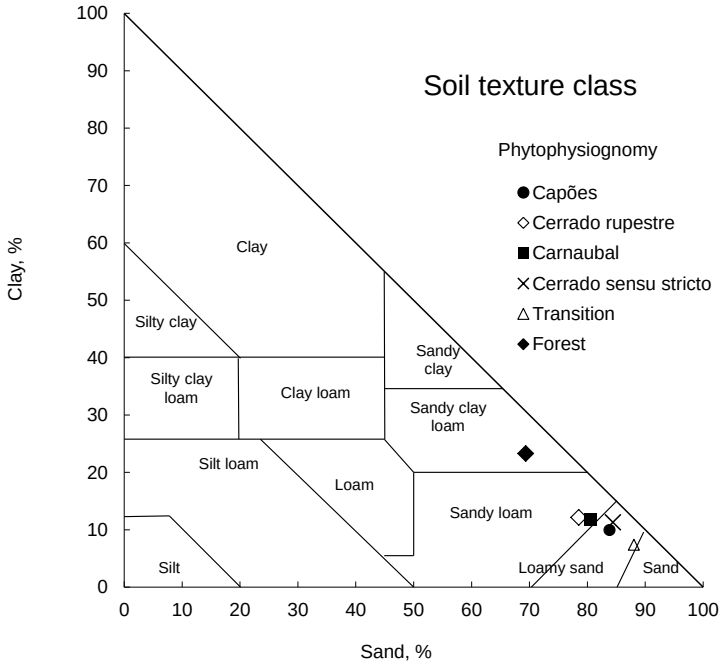
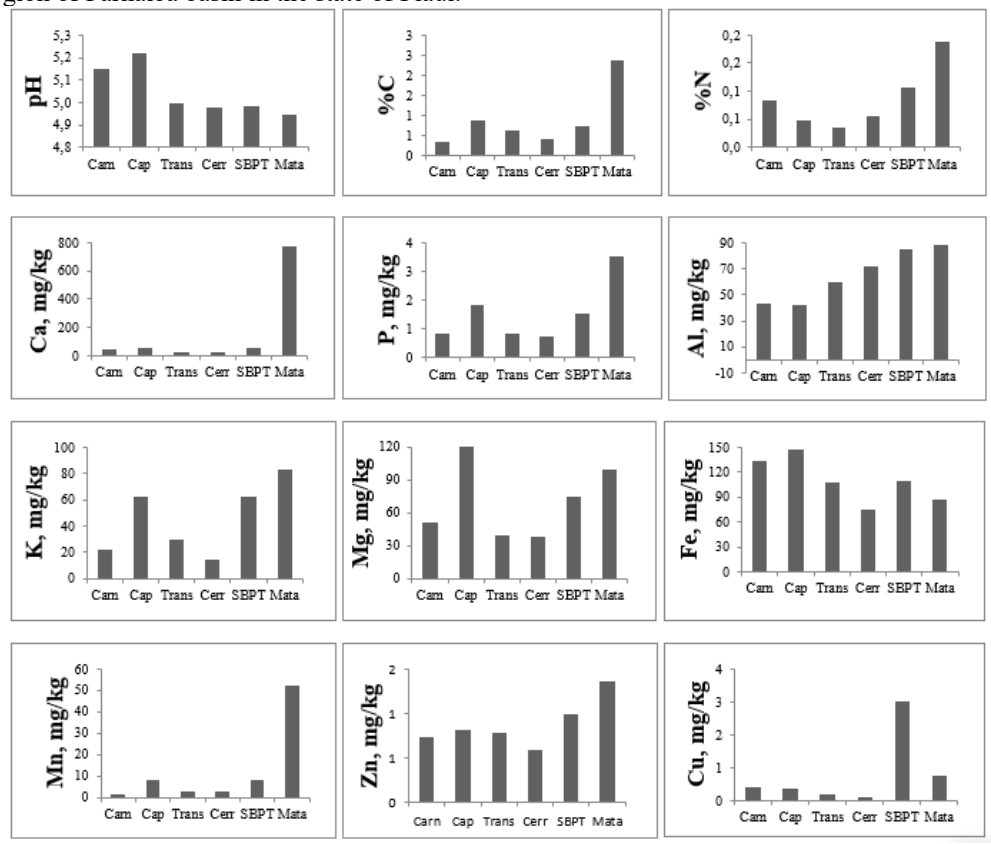


Figure 5: Properties of soils associated with different phytophysiognomies in the vegetation complex of Campo Maior in the ecotonal region of Parnaiba basin in the state of Piaui.



4 CONCLUSIONS

Principal component analysis of soil properties separated the phytophysiognomies along the first and second axes determined principally by gradients in soil texture and the concentrations of available nutrients. The eigenvalues for the first two axes were 0.425 and 0.148, thus accounting for 57.3% of the total variation. These results confirm the influence of the heterogeneity of edaphic conditions, resulting from the geological and geomorphological variations, on the vegetation of the Campo Maior complex in the Parnaíba basin. Forest physiognomies occur on more clayey soils (sandy clay loam) of the region and cerrado sensu stricto and other open forms are more common on more sandy soils (loamy sand and sand). All soils were dystrophic with less than 50% base saturation, but the soil under forest had higher concentrations of organic C, total nitrogen available P, Ca and Mn, confirming the original hypothesis.

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