Parâmetros Físicos e Químicos de Referência em Solos de Unidades de Conservação Florestal da Bacia do Paraná 3, Brasil (Physical and Chemical Parameters of Reference Soils in Fores...

Article *in* Revista Brasileira de Geografia Física · February 2018

DOI: 10.26848/rbgf.v10.6.p099-113

Juliane Bocardi
Federal University of Technology - Paraná/Brazil (UTFPR)

Anderson Sandro da Rocha
Federal University of Technology - Paraná/Brazil (UTFPR)

Sueli Percio
Universidade Estadual do Centro-Oeste do Paraná (UNICENTRO)

Revista Brasileira de Geografia Física v.11, n.01 (2018) 099-113.

Revista Brasileira de Geografia Física

ISSN:1984-2295

Homepage: https://periodicos.ufpe.br/revistas/rbgfe

Physical and Chemical Reference Parameters in Soils of Forest Conservation Units of the Paraná Basin 3, Brazil

Juliane Maria Bergamin Bocardi[1], Adelmo Lowe Pletsch[2], Anderson Sandro da Rocha[3], Sueli Pércio Quinaia[4]

[1]Docente na Universidade Tecnológica Federal do Paraná (UTFPR), campus Medianeira - PR e Doutoranda pelo Programa de Pós Graduação em Química da Universidade Estadual do Centro-Oeste (UNICENTRO) - julianebocardi@gmail.com, [2]Docente na Universidade Tecnológica Federal do Paraná (UTFPR), campus Santa Helena - PR - adelmo@utfpr.edu.br, [3]Docente na Universidade Tecnológica Federal do Paraná, (UTFPR), campus Medianeira - PR - andersonrocha@utfpr.edu.br, [4]Docente na Universidade Estadual do Centro-Oeste, Guarapuava - PR, spquinaia@gmail.com.

Artigo recebido em 09/11/2016 e aceito em 24/02/2018

A B S T R A C T

The characterization of standard pedological parameters in forest soils, free of anthropogenic contamination, is important, since it allows the variables analyzed to serve as the natural base level of a given region. In a country as large as Brazil, with different climates, reliefs and vegetation, each state should independently seek its own reference values in relation to the characteristics of the soils. In order to obtain basic information about soil physical and chemical properties in the Paraná Basin 3 (BP3), 73 soil samples were collected in Conservation Units and Forest Remnants. The samples were air dried, texture and chemical attributes, pH in water; organic carbon (OC), K^+, Na^+, Ca^{2+}, Mg^{2+}, Al^{3+}, H+Al, and P were determined (EMBRAPA, 1997). From the results obtained, the cation exchange capacity (CEC) at pH 7 and base saturation percentage (V%) were calculated. The data obtained were statistically evaluated through Principal Component Analysis, which showed the separation of the samples into three distinct groups according to their similarities. Among the characteristics studied, it was possible to verify the predominance of the Latosol, Nitosol and Neosol classes, which together added up to 92% of the total samples. The pH of the samples ranged from extremely acidic to almost neutral. Most of the samples showed a negative association between clay content and CEC. BP3 soils had a mean OC content of 23.60 g / kg and a positive association with CEC.

Keywords: Physical and chemical characterization, soils, reference parameters.

Parâmetros Físicos e Químicos de Referência em Solos de Unidades de Conservação Florestal da Bacia do Paraná 3, Brasil

RESUMO

A caracterização de parâmetros pedológicos padrão em solos de florestas, isentos de contaminação antropogênica, é importante, pois permite que as variáveis analisadas possam servir como nível de base natural de uma determinada região. Em um país de extensão tão grande como o Brasil, com diferentes climas, relevos e vegetação, cada estado deveria buscar, independentemente, seus valores próprios de referência com relação às características dos solos. Com o objetivo de obter informação de base sobre as propriedades físicas e químicas do solo na Bacia do Paraná 3 (BP3), 73 amostras de solos foram coletadas em Unidades de Conservação e Remanescentes Florestais. As amostras foram secas ao ar, a textura e os atributos químicos, pH em água; carbono orgânico (CO), K^+, Na^+, Ca^{2+}, Mg^{2+}, Al^{3+}, H+Al, e P foram determinados (EMBRAPA, 1997). A partir dos resultados obtidos foram calculados a capacidade de troca de cátions (CTC) em pH 7 e porcentagem de saturação por bases (V%). Os dados obtidos foram avaliados estatisticamente através da Análise de Componentes Principais que mostrou a separação das amostras em três grupos distintos conforme suas similaridades. Dentre as características estudadas foi possível verificar predominância das classes Latossolo, Nitossolo e Neossolo, que juntas, somaram cerca de 92% do total das amostras. O pH das amostras variou de fortemente ácido a quase neutro. Grande parte das amostras mostraram uma associação negativa entre o conteúdo de argila e a CTC. Os solos da BP3 apresentaram teores médios de CO na ordem de 23,60 g/Kg e associação positiva com a CTC.

Palavras chave: Caracterização física e química, solo, parâmetros de referência.

Introduction

The soil on the earth's surface is composed of rocks disintegrated by the action of physicochemical processes that occur in the environment. In addition to the decomposition of rocks, the soil is composed of organic matter produced by the degradation of plant and animal wastes, and can become quite complex due to the influence of environmental factors such as climate, relief and weather. The type of vegetation of a given region is extremely dependent on local soil (Schumacher and Hoppe, 1998; Ukut et al., 2014; Verboom and Pate, 2015; Ahukaemere et al., 2016; Demattê et al., 2017).

In a country as large as Brazil, with different climates, reliefs and vegetation, each state should independently seek its own reference values in relation to soil characteristics (Adhanom and Toshome, 2016). Standard pedological parameters such as grain size distribution, soil pH, cation exchange capacity and organic carbon content are important parameters for soil characterization. And this characterization must occur in soils free of anthropogenic contamination to serve as a natural base level (Baize and Sterckeman, 2001). In order to obtain a reference database in soils, a large number of samples must be analyzed in order to be representative of the site evaluated (Casarini et al., 2001). Thus, sampling processes are necessary in field surveys to ensure a reliable representation of the study site (Carter and Gregorich, 2006).

The state secretariat on environment defines a river basin as an area limited by a watershed (higher ground), which directs rainwater, forming from several tributaries, a main river. Paraná has 16 hydrographic basins: Litorânea Basin, Ribeira Basin, Cinzas Basin, Iguaçu Basin, Paraná Basins 1, 2 and 3, Tibagi Basin, Ivaí Basin, Piquiri Basin, Pirapó Basin, Itararé Basin , Paranapanema Basins 1, 2, 3 and 4 (SEMA, 2010). The Paraná Basin 3, located in the western part of the state of Paraná, covers an area of approximately 8,000 km², bringing together 28 municipalities (Instituto das Águas do Paraná, 2011). In the process of colonization of the West of Paraná favorable conditions for the development of agriculture provided a rapid territorial occupation. This was especially true during World War II (1930-1945) when it became clear that some sectors of the country needed to be expanded, including industrialization, basic industry, and the creation of a strong agricultural frontier. This system has led to accelerated deforestation and consequent depletion of natural reserves (Priori et al., 2012). Despite this, the Paraná Basin 3 still has a plant cover area of 81.463,72 (ha) corresponding to a percentage of 9,42% (Accioly, 2013). It is in this rate that are the Conservation Units and the Forest Remnants. Resolution no. 011/87 of the National Environmental Council, CONAMA (1987), defines Conservation Units as protected natural areas and ecological sites with relevant natural characteristics, in the public or private domain, legally established by the Government to protect nature, with objectives and defined limits and with specific regimes of handling and administration, applying adequate safeguards of protection. In addition to the regulation of this device, Law no. 9.985/2000, which created the National System of Conservation Units, (SNUC, 2000). The SNUC defines and regulates the categories of protected areas, separating them into two groups: areas of integral protection, mainly for the conservation of biodiversity, and areas of sustainable use that allow the rational use of natural resources and aim secondary to biodiversity protection (Pires, Zeni Junior and Gaulke, 2012).

An in-depth study of the characteristics and classification of the soil of an area provides basic information on the physical and chemical properties in order to obtain a reference database, which may serve as a basis for future research. Therefore, the objectives of the study were the characterization and classification of soils in Conservation Units and Forest Remnants in the Paraná Basin 3, Brazil.

Materials and methods

Area of study - covered an extensive region located in the west of the State of Paraná, Brazil, between latitudes 24º 01 'S and 25º 35' S and longitudes 53º 26' W and 54º 37' W denominated Paraná River Basin 3, (BP3), Figure 1.

BP3 covers 28 municipalities and includes about 8,000 km² of tributaries that flow into the Paraná River, where Itaipu Lake (Instituto das Águas do Paraná, 2011) is situated, Figure 2.

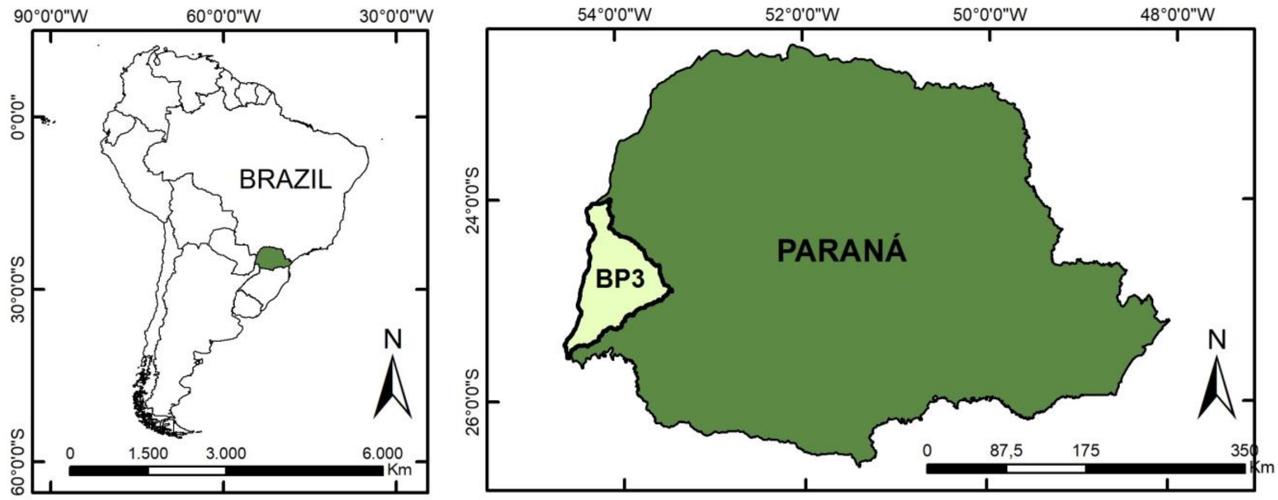

Figure 1. Location of the study area, Paraná Basin 3, Paraná, Brazil (Rocha et al., 2016).

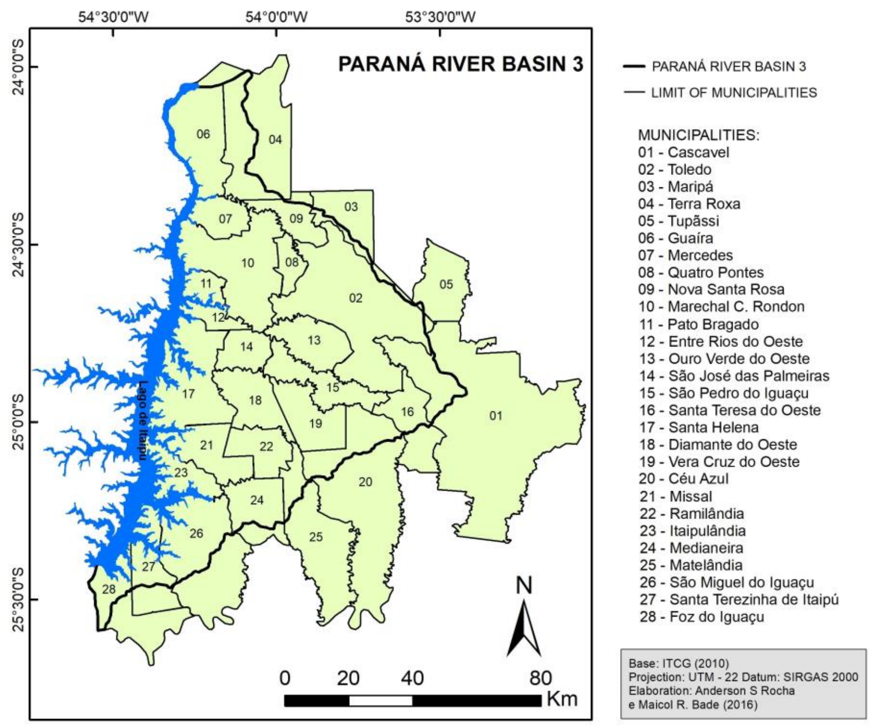

Figure 2. Municipalities that make up the Paraná Basin 3 (Rocha et al., 2016).

Demarcation and Sampling - after the spatial delimitation of the study area, the following parameters were selected: Conservation Areas and Forest Remnants, Paraná State Soil Map (scale 1:250,000) (EMBRAPA, 2008), Geology Maps (MINEROPAR, 2001) and Geomorphology (MINEROPAR, 2006).

The selection of collection points began with a survey of the main Conservation Units present in the study area (IAP, 2016). To locate them, information was used from the Environmental Management System (IAP, 2016), where it was possible to accurately obtain the geographical coordinates of the Conservation Units, and later obtain their respective aerial images in the *Google Earth Pro* software.

The remaining forests have also been identified through access to *Google Earth Pro* software, which made it possible to obtain high spatial resolution images. From this, the geomorphological and geological maps and geoprocessing tools with overlapping of the Soil Map of the region were used (Figure 3), so that in selecting the collection points, it was possible to contemplate a greater number of soil classes. Next, the most appropriate access route for the selected points was checked.

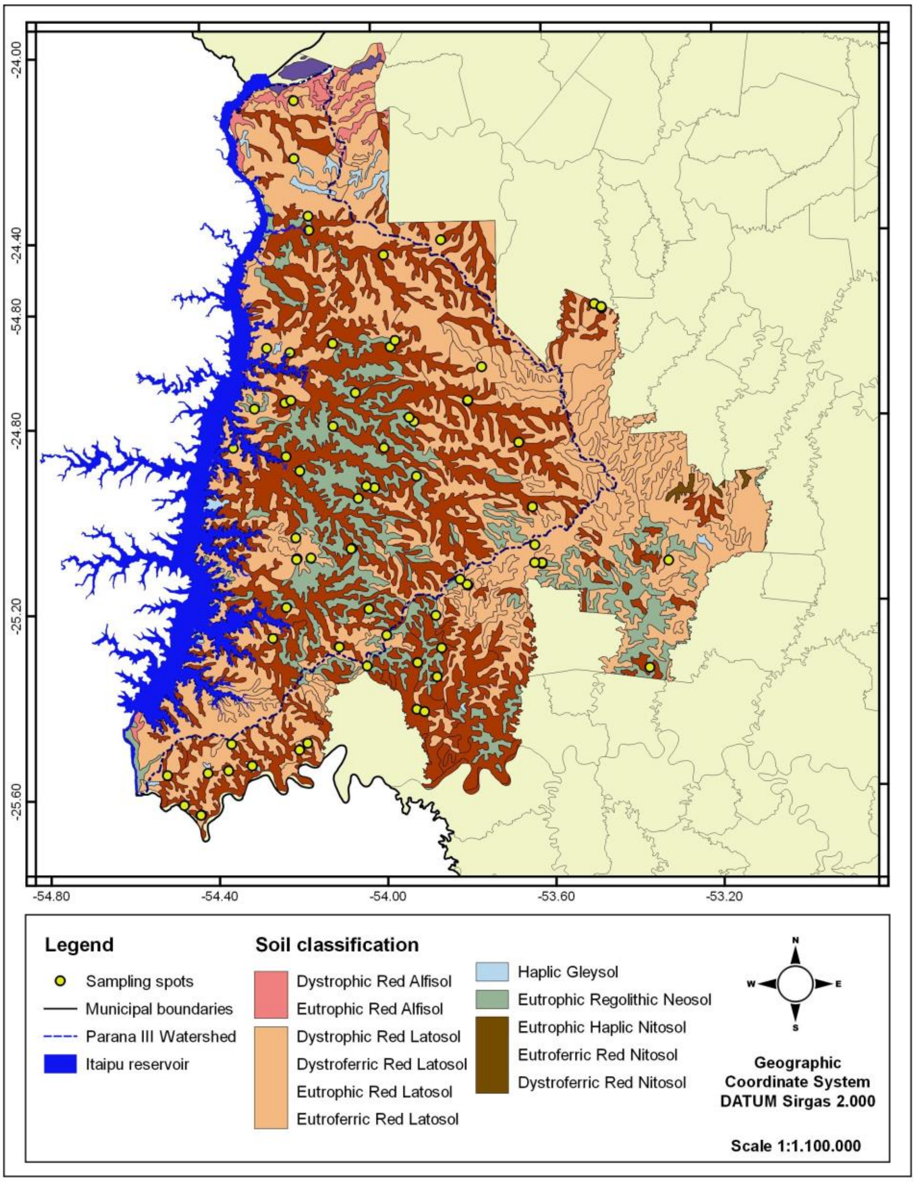

Figure 3. BP3 soil map (EMBRAPA, 2008).

In order to obtain the permit for access and collection of soils in the Conservation Units of BP3, the norms established by Portaria 017/2007 of the Environmental Institute of Paraná - IAP (2016) and Normative Instruction No. 03, dated September 1, 2014 of the Chico Mendes Institute for Biodiversity Conservation - ICMBIO (2015), which regulates the availability, access, collection and use of data and information received for scientific research was employed. In the case of Private Reserves of the National Patrimony - RPPN, contacts were established for the authorization and scheduling of collections.

All maps, orbital images and information generated in the geoprocessing environment were referenced according Geographic Coordinate System DATUM, Sirgas, 2.000.

In the field, the sampling site was geo-referenced with the *Garmin eTrex Legend*® GPS. In addition, notes were made on the description of the landscape, vegetation, types of soils and outcrops of rocks found.

In the case of roads, a minimum of 200 m of high-traffic asphalted roads, 100 m of lower flow asphalted roads and 50 m of vicinal roads of land were described by Abraão and Marques (2012).

The tools used for sampling were picks made of stainless steel and shovel free of coating or painting. Samples were collected from the center and at the vertices of a square approximately two meters apart, north (N), south (S), East (L) and west (W), totaling five simple subsamples to form a single composite sample, as proposed by Abraão and Marques (2012), Figure 4. The five points were swept before collection to eliminate branches, fragments of rocks and leaves present on the surface.

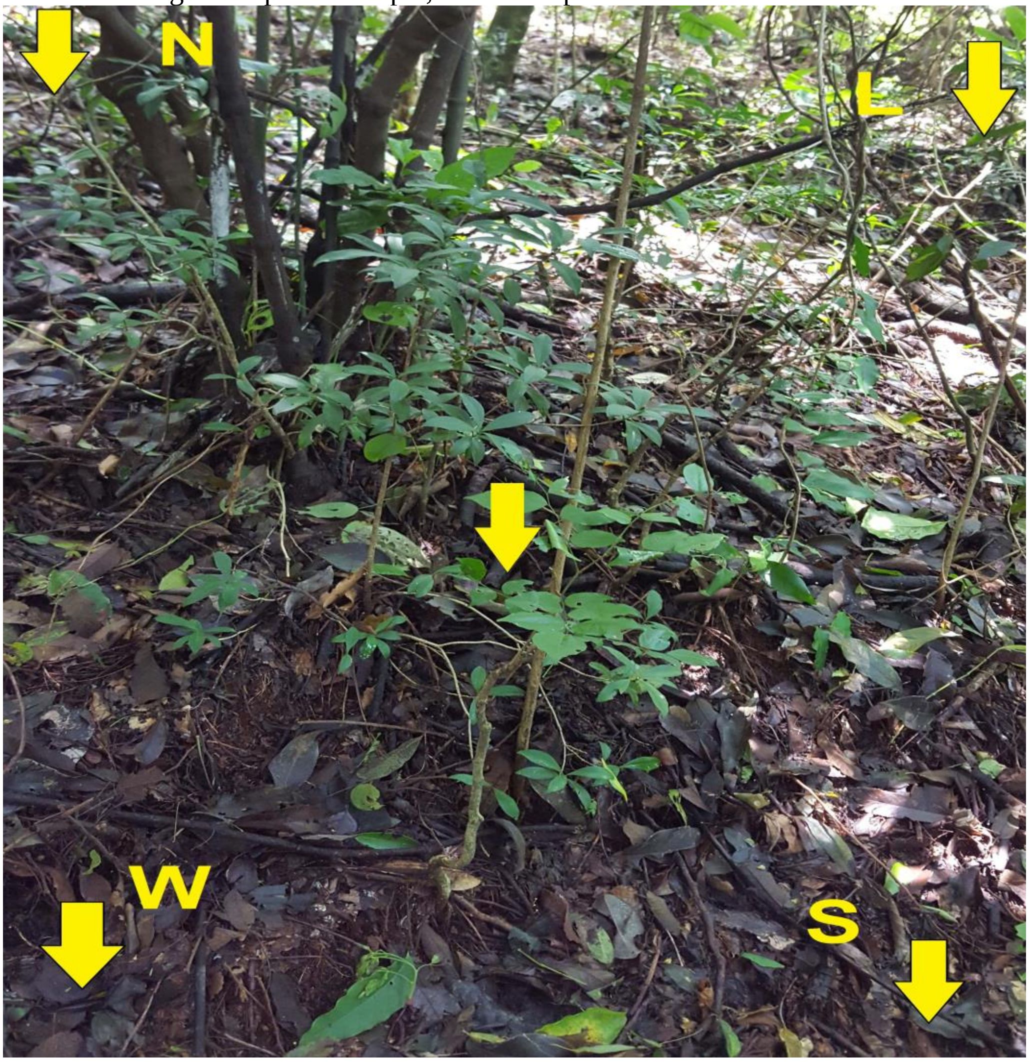

Figure 4. Sampling composed of five subsamples: one central sample and others in the directions of the cardinal points (N, S, L and W).

About one pound of surface soil, from the A horizon, (about 20 cm depth) was obtained. The soil samples were stored in Zip Lock plastic bags with hermetic closure and identified.

A total of 73 soil samples were obtained from the 28 municipalities of BP3 (Figure 5). Due to the proximity of some collection points and the projection scale used, some points were superimposed (Figure 5).

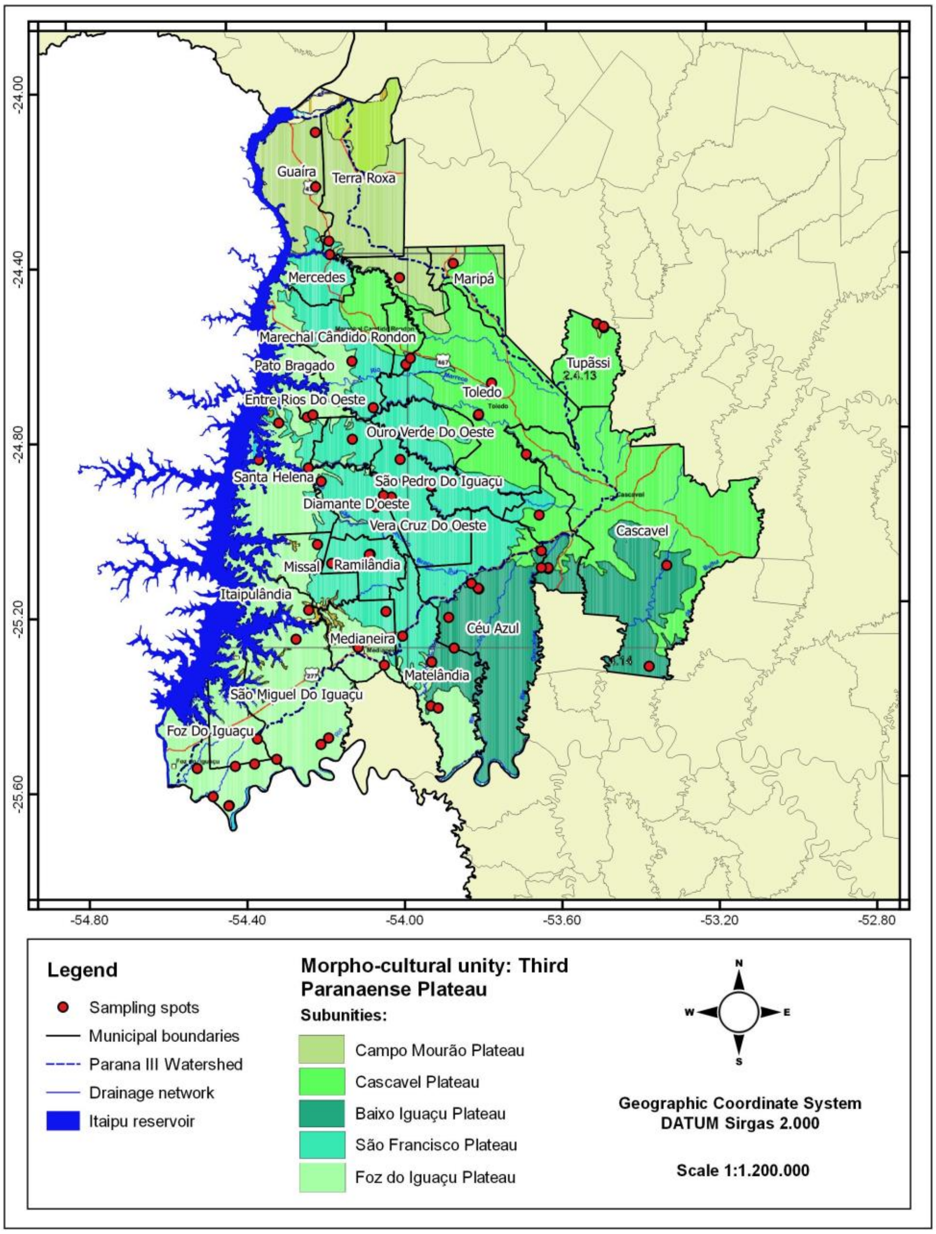

Figure 5. Map of the study area with the soil collection points in BP3.

In Table 1, it is possible to verify the municipality and the geographical coordinates of the place where the sampling was done and the respective classes of soils according to the first categorical level of EMBRAPA (2008).

Table 1. Location, municipality and soil class of BP3.

Point	Latitude	Longitude	Municipality	Soil[1]
1	24°50'55.38"S	54°20'35.99"W	Santa Helena	Latosol
2	24°45'54.74"S	54°17'27.49"W	Santa Helena	Neosol
3	24°50'57.26"S	53°40'9.82"W	Cascavel	Nitosol
4	24°57'47.17"S	54° 3'3.19"W	Diamante do Oeste	Neosol
5	24°56'27.04"S	54° 0'41.47"W	Vera Cruz do Oeste	Nitosol
6	24°52'10.73"S	54°13'8.68"W	Diamante do Oeste	Nitosol
7	24°54'4.57"S	54°11'14.75"W	Diamante do Oeste	Neosol
8	24°47'59.26"S	53°54'55.98"W	Ouro Verde do Oeste	Neosol
9	24°47'26.15"S	53°55'36.36"W	Ouro Verde do Oeste	Neosol
10	25° 4'13.95"S	54° 4'5.46"W	Ramilândia	Nitosol

11	25° 4'18.01"S	54° 4'13.80"W	Ramilândia	Neosol
12	25° 5'22.39"S	54° 9'56.93"W	Ramilândia	Neosol
13	24°45'29.25"S	53°47'17.99"W	Toledo	Nitosol
14	24°45'21.30"S	53°47'14.66"W	Toledo	Neosol
15	24°41'4.46"S	53°45'11.70"W	Toledo	Latosol
16	24°38'15.73"S	53°58'3.87"W	Quatro Pontes	Nitosol
17	24°37'26.37"S	53°57'22.12"W	Quatro Pontes	Nitosol
18	24°26'20.10"S	53°58'45.11"W	Nova Santa Rosa	Latosol
19	24°24'31.72"S	53°50'37.19"W	Maripá	Latosol
20	24°45'13.29"S	54°13'8.35"W	Entre Rios do Oeste	Nitosol
21	24°44'55.22"S	54°12'16.62"W	Entre Rios do Oeste	Gleysol
22	24°38'42.97"S	54°12'15.39"W	Pato Bragado	Nitosol
23	24°38'6.07"S	54°15'31.00"W	Pato Bragado	Latosol
24	24°44'6.82"S	54° 3'8.04"W	Marechal Cândido Rondon	Neosol
25	24°37'40.01"S	54° 6'11.79"W	Marechal Cândido Rondon	Nitosol
26	24°22'56.60"S	54° 9'11.00"W	Mercedes	Neosol
27	24°21'6.12"S	54° 9'15.88"W	Terra Roxa	Nitosol
28	24°13'36.63"S	54°11'3.97"W	Guaíra	Latosol
29	24° 6'6.87"S	54°10'55.60"W	Guaíra	Alfisol
30	25° 6'44.20"S	53°37'10.17"W	Santa Tereza do Oeste	Chernosol
31	24°59'20.33"S	53°38'23.74"W	Santa Tereza do Oeste	Latosol
32	24°51'18.31"S	53°59'14.98"W	São Pedro do Iguaçu	Nitosol
33	24°48'23.22"S	54° 6'23.79"W	São José das Palmeiras	Neosol
34	24°33'11.08"S	53°29'6.96"W	Tupãssi	Latosol
35	24°33'45.51"S	53°28'5.60"W	Tupãssi	Latosol
36	24°33'34.25"S	53°28'7.82"W	Tupãssi	Nitosol
37	25°19'12.12"S	53°55'9.23"W	Matelândia	Nitosol
38	25°15'34.91"S	53°59'27.24"W	Matelândia	Neosol
39	25°12'9.03"S	54° 1'53.72"W	Medianeira	Nitosol
40	25° 5'32.20"S	54°11'59.87"W	Missal	Neosol
41	25° 5'24.88"S	54°11'55.40"W	Missal	Gleysol
42	25° 2'43.70"S	54°12'2.27"W	Missal	Latosol
43	25°11'42.85"S	54°13'36.27"W	Itaipulândia	Nitosol
44	25°15'40.56"S	54°15'37.85"W	São Miguel do Iguaçu	Nitosol
45	25° 9'19.80"S	53°47'45.02"W	Céu Azul	Neosol
46	25° 9'13.25"S	53°47'52.12"W	Céu Azul	Neosol
47	25° 8'32.17"S	53°48'51.84"W	Céu Azul	Latosol
48	25°16'57.50"S	54° 6'15.37"W	Medianeira	Nitosol
49	25°16'59.34"S	54° 6'13.61"W	Medianeira	Neosol
50	25°13'9.26"S	53°52'24.58"W	Céu Azul	Latosol
51	25°17'22.58"S	53°51'41.15"W	Céu Azul	Nitosol
52	25°21'6.18"S	53°52'25.14"W	Matelândia	Nitosol
53	25°19'13.60"	53°55'8.63"W	Matelândia	Nitosol

Table 1. Location, municipality and soil class of BP3 (continued)

Point	Latitude	Longitude	Municipality	Soil[1]
54	25°25'34.27"S	53°54'18.65"W	Matelândia	Nitosol
55	25°25'15.55"S	53°55'23.85"W	Matelândia	Latosol
56	25°20'24.66"S	53°22'8.46"W	Cascavel	Neosol
57	25° 4'16.06"S	53°38'9.36"W	Santa Tereza do Oeste	Neosol
58	25° 6'34.54"S	53°38'13.36"W	Santa Tereza do Oeste	Latosol
59	25° 6'36.25"S	53°37'10.70"W	Santa Tereza do Oeste	Chernosol
60	25° 6'34.14"S	53°19'12.46"W	Cascavel	Latosol

61	24°56'12.80"S	54° 1'52.82"W	Vera Cruz do Oeste	Nitosol
62	25°29'20.52"S	54°11'2.47"W	São Miguel do Iguaçu	Latosol
63	25°30'11.90"S	54°12'13.68"W	São Miguel do Iguaçu	Nitosol
64	25°32'5.95"S	54°19'0.64"W	São Miguel do Iguaçu	Nitosol
65	25°38'19.74"S	54°26'28.41"W	Foz do Iguaçu	Latosol
66	25°38'16.94"S	54°26'24.25"W	Foz do Iguaçu	Latosol
67	25°37'0.55"S	54°28'48.94"W	Foz do Iguaçu	Nitosol
68	25°33'4.79"S	54°31'6.69"W	Foz do Iguaçu	Latosol
69	25°29'14.28"S	54°21'51.94"W	Santa Terezinha de Itaipu	Latosol
70	25°32'39.66"S	54°22'23.24"W	Santa Terezinha de Itaipu	Nitosol
71	25°32'54.95"S	54°25'19.78"W	Santa Terezinha de Itaipu	Gleysol
72	24°55'5.20"S	53°54'44.24"W	São Pedro do Iguaçu	Nitosol
73	25°19'30.80"S	54° 2'19.76"W	Medianeira	Latosol

[1] Classification of the 1st Categorical Level - Orders, according to the Brazilian Soil Classification System (EMBRAPA, 2008).

Determination of physico-chemical parameters - the samples were air-dried, homogenized and passed in a stainless steel sieve with a 2 mm opening. The granulometric analysis (texture) was performed by the densimeter method, based on sedimentation of soil constituents. Chemical attributes such as pH in water; organic carbon (CO), K^+, Na^+, Ca^{2+}, Mg^{2+}, Al^{3+}, H + Al, and P were determined according to the EMBRAPA Manual of Soil Analysis Methods (1997). From the obtained results were calculated the cation exchange capacity (CEC) at pH 7 and percentage saturation by bases (%V).

Results and discussion

The study area was chosen not only on the basis of its representativeness but also due to the absence of studies of this nature in the region. The use of the river basin as a unit of study is considered an appropriate approach, since it allows the elaboration of a database on biogeophysical, economic and social components; being a physical unit, with well defined limits, guarantees a basis of institutional integration (Tundisi, 2003). The soils of the BP3, basically comprise two distinct lithological groups, with predominance of extrusive igneous rocks (volcanic rocks) of the Serra Geral Formation, such as the Mesozoic basalt and the Cretaceous period. Only a small area in the north of the basin is composed of sandstones of the Caiuá Formation, also of the Cretaceous. On the banks of the Paraná River, sediments of the Quaternary age formed by deposits of fluvial and alluvial origin are observed, Figure 6, (MINEROPAR, 2001).

Basalts gives rise to the excellent quality soils of western Paraná. In this study, it was possible to identify six classes of different soils; however, three predominant classes represented 92% of the total samples: Nitosol, Latosol and Neosol with 36, 29 and 27%, respectively.

In the classification of the evaluated soils there was predominance of clayey textures to very clayey (70%), the other samples did not present values as expressive (average texture 24,6%, silt 2,7% and sandy texture 2,7%), (Santos et al., 2013). The presence of clay in the soil indicates a history of weathering (Schoonover and Crim, 2015).

All measures of the characterization parameters were performed in replicate and are presented in Table 2 through the mean, minimum, maximum, standard deviations and coefficients of variation obtained between the 73 soil samples collected at different points. It can be verified that there are differences between the samples collected, since the variation between determined minimum and maximum was significant.

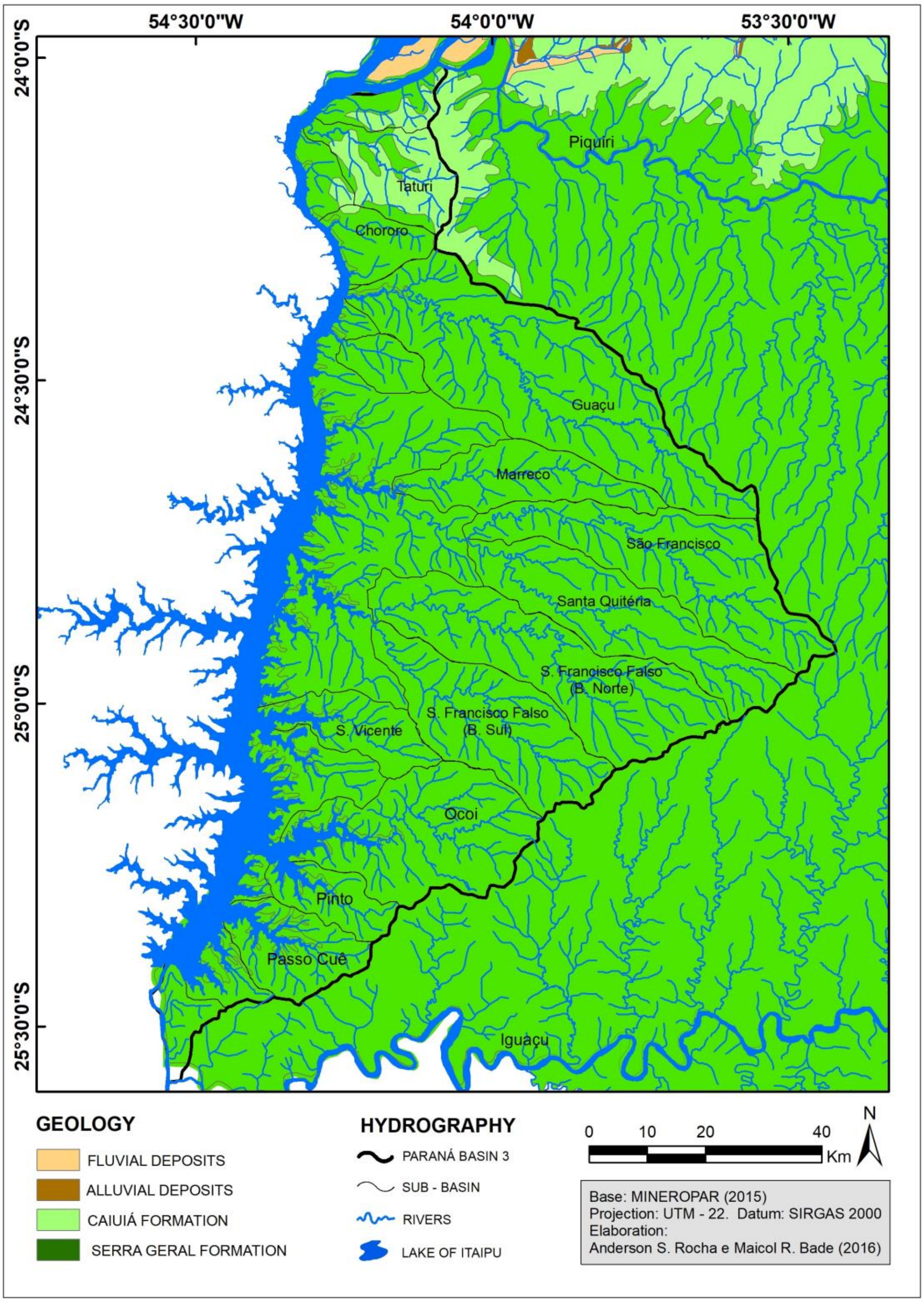

Figure 6. Map of Geology of BP3 (Rocha, 2016).

Table 02. Chemical and physical characterization of soil samples collected in BP3.

Variables	Mean	Minimum	Maximum	Standard Deviation	[1]CV %
pH H_2O	5,68	3,42	6,80	0,66	0,12
OC (g/Kg)	23,60	5,57	61,44	9,86	0,42
Na^{+} (cmolc/dm^3)	0,02	0,00	0,36	0,04	2,22
K^{+} (cmolc/dm^3)	0,35	0,01	1,32	0,28	0,80
Ca^{+2} (cmolc/dm^3)	6,25	0,00	21,03	4,84	0,77
Mg^{+2} (cmolc/dm^3)	3,21	0,04	10,55	2,23	0,69
Al^{+3} (cmolc/dm^3)	0,11	0,01	1,11	0,22	2,00
H^{+} + Al^{+3} (cmolc/dm^3)	6,08	1,81	16,09	2,84	0,47
CEC pH 7 (cmolc/dm^3)	15,90	4,68	34,73	6,06	0,38
V (%)	56,81	2,80	91,57	21,65	0,38
P (mg/dcm^3)	7,51	0,79	76,62	11,47	1,53
Sand (g/Kg)	118,90	1,84	854,00	156,30	1,31
Silt (g/Kg)	366,90	47,54	692,00	138,20	0,38
Clay (g/Kg)	502,90	50,64	825,00	180,80	0,36

[1]CV- Coefficient of variation of 73 samples used for analysis. OC - Organic carbon, CEC - Cation exchange capapcity at pH 7, V - base saturation.

Pearson correlations (positive and negative) were investigated and observed among the variables determined in soil samples with a 95% confidence level (Table 3). The results indicated that the Ca^{+2} content showed a correlation with CO, P, K^{+}, pH and extremely strong with CEC (r = 0,87), Mg (r = 0,73) and% V (r = 0,83). Inverse correlation of Ca was verified with acidity (exchangeable and potential), that is, when the Ca^{+2} variable increased in the samples, the acidity of the soils decreased. The parameter %V was evidently shown to be correlated with the variables K^{+}, Ca^{+2}, Mg^{+2}, pH and CEC and inversely proportional to the acidity of the samples. Among the exchangeable bases, it was possible to verify that Ca^{+2} was the variable that contributed most to the %V, since it showed a higher correlation with %V (r = 0,83).

The P content showed a simple correlation with the CO (r = 0,37), indicating that P is combined with the organic fractions of the soil (Costa et al., 2017).

Table 03. Pearson Correlation Matrix for 14 Soil Variables of BP3.

Variable	Potential acidity	Al^{+3}	OC	Sand	Silt	Clay	P	Na^{+}	K^{+}	pH	CEC	Mg^{+2}	V%	Ca^{+2}
Potential acidity	1,00000													
Al^{+3}	**0,67786**	1,00000												
CO	**0,34404**	0,13862	1,00000											
Sand	-0,04989	-0,06297	-0,04420	1,00000										
Silt	-0,05100	0,01822	0,13315	-0,13428	1,00000									
Clay	-0,09443	0,04551	-0,17680	**-0,59651**	**-0,48581**	1,00000								
P	-0,07711	-0,04239	**0,37530**	**0,30233**	0,02325	**-0,25088**	1,00000							
Na^{+}	**0,37588**	**0,47517**	**0,26627**	-0,06256	-0,01982	0,09512	0,09390	1,00000						
K^{+}	**-0,35325**	-0,20178	0,19772	**-0,36916**	0,08711	0,23236	-0,03299	-0,11593	1,00000					
pH	**-0,72464**	**-0,69167**	0,11151	-0,09071	0,22040	-0,03902	0,14316	**-0,27588**	**0,34455**	1,00000				
CEC	-0,00698	-0,08652	**0,59163**	0,14466	**0,23426**	**-0,31323**	**0,25234**	0,12929	0,09687	**0,37393**	1,00000			
Mg^{+2}	**-0,31362**	**-0,29865**	**0,25194**	0,18642	0,19449	**-0,26792**	0,18389	-0,01319	0,00426	**0,55398**	**0,80831**	1,00000		
V%	**-0,71618**	**-0,59450**	0,15742	-0,01898	0,19130	-0,03929	0,16421	-0,21488	**0,39129**	**0,86463**	**0,60803**	**0,71472**	1,00000	
Ca^{+2}	**-0,43485**	**-0,36155**	**0,40901**	0,14633	0,22888	-0,22749	**0,27765**	-0,05520	**0,27071**	**0,62141**	**0,87730**	**0,73583**	**0,83236**	1,00000

Al^{+3} - Exchangeable acidity, OC - Organic carbon, CEC - Cation exchange capacity at pH 7, V - Base saturation.

For a broad view of the results determined on the 73 soil samples collected in BP3, the data obtained from Principal Component Analysis (PCA) were applied in order to associate similar variables and reduce the size of the number of data (Golobočanin et al., 2004; Kardanpour et al., 2014). The PCA was able to relate the variables involved in the analysis (sand, clay, exchangeable acidity, potential acidity, pH, OC, P, CEC, % V) with the soil samples, Figure 7 (a) and (b). The closer the points were to the PCA, the greater their similarities. Figure 7 shows the graphs of variables (a) and samples (b) indicating that the PCA explained 61,45% of the data evaluated.

Soil samples were grouped in the PCA in three distinct regions (b1, b2, and b3), Figure 7 (b) and a more isolated point (collection point 2). In the negative x and positive quadrant of y, Figure 7 (b), we found group b1, these soil samples presented similarity, since 60% of them belong to the Class of Neosols, with a slightly sandy texture and average levels of CEC of 23.56 cmol/dm^3. Soil 2 separation in the upper left quadrant was mainly due to its high OC content and high CEC. The physical appearance of the sample collected in point 2 presented a dark color, typical of the presence of humus. The amount of humus in a sample is one of the factors affecting soil CEC, because humus is a source of negative charge, colloidal in size (<0,002 mm), due to the dissociation of hydrogen from organic pH-dependent functional groups (Lepsch, 2011).

The b2 region in PCA, positive axes of x and y (Figure 7b), brought together samples 7, 15, 29, 31, 46, 60 and 71, due to the higher potential acidity, exchangeable acidity (Al^{+3}) and lower pH values. Some peculiarities were observed in this group: sample 29 was the only one of the class Alfisol obtained in this study. This soil presented a very sandy texture (85,4% sand), from materials of sedimentary origin, with visible erosion characteristics. These results corroborate with the descriptions in the EMBRAPA Soil Classification map (2008). Sample 71 also presented singular characteristics, it is classified as Haplic Gleysol, exhibited hydromorphic characteristics and manifested a grayish color. Samples 15, 31 and 60 (region b2, Figure 7b) were located nearby in the PCA, since they are classified as Dystroferric Red Latosols, having poor exchangeability or base saturation indexes (% V) and high levels of Al^{+3}, indicating low fertility soils (Fernández-Getino and Duarte, 2015).

Among the analyzed variables, it was possible to verify that the pH of the samples ranged from extremely acidic to almost neutral (EMBRAPA, 2006). Acidity in soils can be attributed to several factors, such as soil source material, loss of basic cations in crops, relief characteristics, CO_2 and water reaction products, and cation removal by precipitation (Eyre, 1963; Van Breemen; Mulder, Driscoll, 1983). Thus, acidic soils are common in regions of tropical climate, where high rainfall contributes to alkaline ions being leached and replaced in colloids with H^+ ions (Schoonover and Crim, 2015; Zenero et al., 2016). BP3 presents a humid subtropical climate with average temperature in the coldest month below 18ºC and average temperature in the warmer month above 22ºC, with hot summers, uncommon frosts and tendency of rainfall concentration in the summer months, however, without dry season defined. Based on the climate charts of the state of Paraná, mean annual precipitation in the basin ranges from 1600 to 2000 mm (Caviglione et al., 2000).

In the PCA (Figure 7a), the inverse relationship between the pH and the exchangeable acidity (Al^{+3}) of the samples is confirmed (Walna, 2007), i.e the samples with lower pH values showed high exchangeable acidity (consistent with Pearson's correlation (r = -0,69), Table 3. The explanation of this consequence is that under conditions of low pH, the dissolution of soil minerals that contain appreciable levels of Al, such as clay minerals and aluminum oxides occurs, this dissolution promotes the appearance of the exchangeable cation Al^{+3}, as indicated by reaction 1 (Raij, 1981):

$$Al(OH)_3 + 3H^+ \rightarrow Al^{3+} + 3H_2O \quad (1)$$

The PCA showed that the values of base saturation (%V) of the samples presented was inversely associated with their respective acidity levels (Figure 7a). The value of %V, indicates the percentage of negative charges of the colloids with sites occupied by basic cations such as Ca^{+2}, Mg^{+2} and K^+ in relation to the acid cations H^+ and Al^{+3}; therefore, the higher the percentage of V, the higher the pH and lower the incidence of H^+ and Al^{+3} acid cations, in agreement with Pearson's correlation (Table 3).

A third group (b3) in PCA (Figure 7b) formed close to zero in the x and y axes, grouped 77% of the samples indicating that they have a similar profile as a function of their evaluated variables. These samples had similarities due to the high percentage of clay. Moreover, it was found that a great part of them had a negative association between the clay content and the CEC (r = -0,31), Table 3. This parameter was estimated

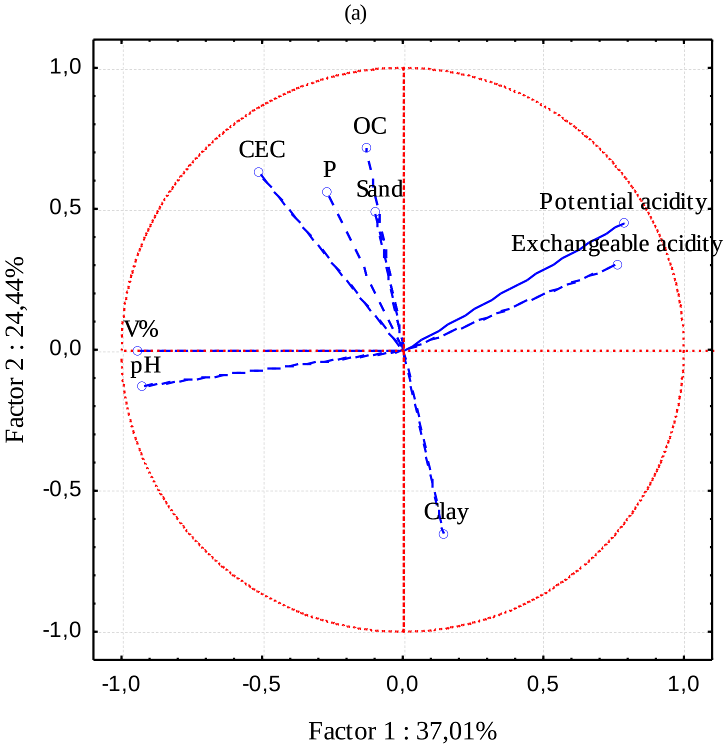

Figura 7 (a). Principal components analysis with the circle of eigenvectors of nine variables and 73 samples of surface horizons. OC - organic carbon, CEC - cation exchange capacity at pH 7, V - base saturation.

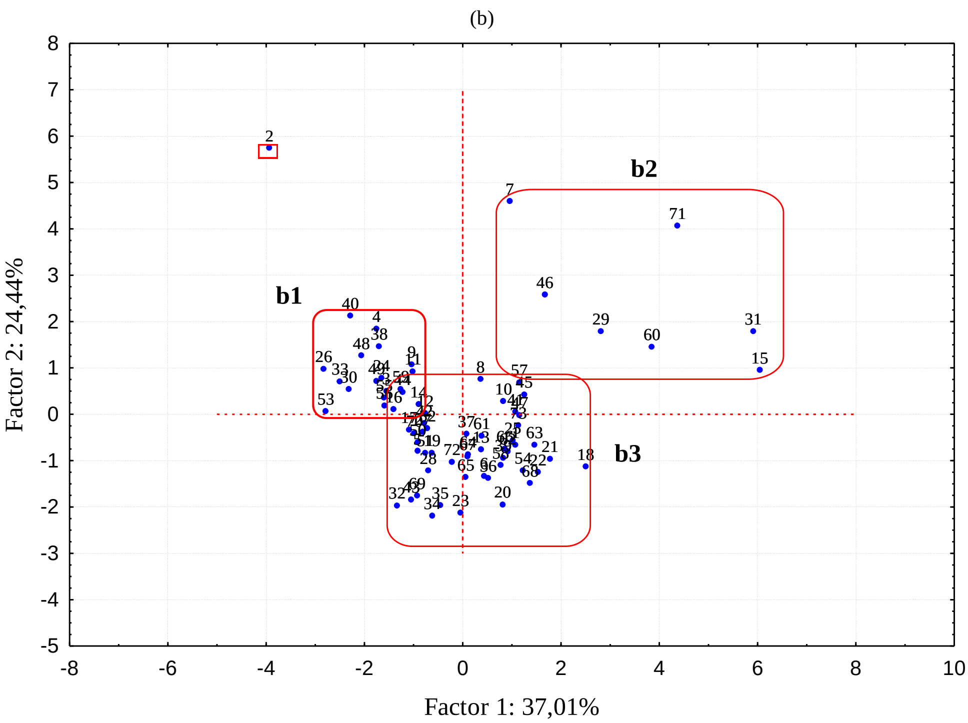

Figura 7 (b). Principal components analysis of main components with the dispersion of 73 points representing the soil samples collected in BP3. OC - organic carbon, CEC - cation exchange capacity at pH 7, V - base saturation.

by the sum of its exchangeable cations adsorbed in their colloids (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, H^{+} + Al^{+3}) ranging from 4,68 to 28,63 cmolc/dm^3. In general, more clayey soils have higher CEC (Schoonover and Crim, 2015), since clays are sources of negative charges and cations are retained in them. However, depending on the mineral type of the clay, it may have low CEC values, such as 1: 1 type clays such as kaolinite or oxidic clays. The kaolinite has its crystallographic structure formed by layers of silicon tetrahedron combined with layers of aluminum octahedron (Miranda-Trevino and Coles, 2003). The bond between these layers occurs by hydrogen bonding, forming a non-expansive structure with a low adsorptive capacity of cations, and therefore of low activity (Lepsch, 2011). The soils that predominate the oxidic clays constituted by the metallic elements iron or aluminum, also display a small capacity to retain cations. These minerals are common on fairly weathered soils because they resist heat and heavy rainfall conditions where most of the silica from primary minerals are removed. Thus, since the formation of the source material and the degree of soil weathering determine the types of minerals present and their amounts (Lyband et al., 2011; Watanabe et al., 2017), it is often possible for CEC, to give a perception of the minerals that predominate in the clay fraction, without resorting to direct determinations (Raij, 1969).

The soils of BP3 had average OC contents of 23,60 g/kg, corresponding to 40,12 g/kg of organic matter. This result can be related, among other factors, to the deposition of organic material, which accumulates in the surface horizon of the preserved areas, with dense vegetation, where the samples were collected (Schoonover and Crim, 2015). Lower OC results were observed in surface soils in the Amazon rainforest, where high temperatures and abundant rainfall favored the mineralization of organic matter and reduced stability and deposition in soils (Garcia et al., 2013; Zenero et al., 2016).

Sample 29 was the one with the lowest OC content, 5,57 g/kg, a result consistent with the sandy granulometry to which it belongs. The OC content showed a positive association with CEC (r = 0,59) (Table 3), and the results were also observed in other studies (Gomes et al., 2004; Kummer et al., 2010; Gruba; Mulder, 2015). This correlation is explained by Raij (2010), who stated that the most superficial layer of the soil may have a predominance of negative charges (greater cation retention), resulting from the dissociation of organic radicals and / or iron and aluminum super-oxides due to the organic matter in the soil.

In the study of soil physical and chemical characterization proposed by Kemerich et al. (2012), it was verified that among the analyzed parameters, the high values of clay and organic matter for the same types of soils that are under native forest and native field stand out, indicating that the preservation of the soil contributes to the maintenance of these parameters. However, the high values of the chemical attributes K^+, P and acidity, correlated with soils that suffered anthropic action, such as those cultivated.

Conclusion

The study of soil characterization in the areas of conservation and remnants of the forest made possible the definition of physical and chemical reference parameters of preserved soils, in which the study area, BP3, as well as geological and soil class variations were represented. The use of Principal Component Analysis was presented as an efficient resource in the grouping of the 73 soil samples in three distinct regions according to the similarities of nine attributes of chemical and granulometric characteristics.

Among the characteristics studied, it was possible to verify the predominance of the Latosol and Nitosol classes with clayey textures, which together added up to 92% of the total samples. This great homogeneity corroborates with the descriptions in the EMBRAPA Soil Classification map (2008).

The pH of the samples ranged from strongly acidic to almost neutral. Most of the samples showed a negative association between clay content and CEC. BP3 soils had a mean OC content of 23.60 g/kg and a positive association with CEC.

The results obtained in this research can be used as reference parameters in future investigations.

Acknowledgement

The authors acknowledge UNICENTRO, UTFPR, CNPq and Capes for their research support.

References

Abrahão, W.A.P., Marques, J.J., 2013. Manual de coleta de solos para valores de referência de qualidade no Estado de Minas Gerais. Belo Horizonte.

Accioly, P., 2013. Mapeamento dos Remanescentes Vegetais Arbóreos do Estado do Paraná e Elaboração de um Sistema de Informações Geográficas para fins de Análise Ambiental do Estado. Tese (Doutorado). Curitiba, UFPR.

Adhanom, D., Toshome, T., 2016. Characterization and Classification of Soils of AbaMidan Sub Watershed in Bambasi Wereda, West Ethiopia. International Journal of Scientific and Research Publications 6, 390-399.

Ahukaemere, C.M., et al., 2016. Nwamadi, N. J. Characterization and Classification of Soils Of Egbema in Imo State, South-Eastern Nigeria. Futo Journal Series 2, 41-47.

Baize, D., Sterckeman, T., 2001. Of the necessity of knowledge of the natural pedo-geochemical background content in the evaluation of the contamination of soils by trace elements. The Science of the Total Environment 264,127-139.

Carter, M.R., Gregorich, E.G., 2006. Soil sampling and methods of analysis, 2 ed. Taylor & Francis Group, LLC, Boca Raton.

Caviglione, J.H., et al., 2000. Cartas climáticas do Paraná. IAPAR, Londrina.

Casarini, D.C.P., et al., 2001. Relatório de estabelecimento de valores orientadores para solos e águas subterrâneas no estado de São Paulo. CETESB, São Paulo.

CONAMA. Conselho Nacional do Meio Ambiente, 1987. Resolução nº 011, de 03 de dezembro.

Costa, A.R., et al., 2017. Forms of soil organic phosphorus at black earth sites in the Eastern Amazon. Revista Ciência Agronômica 48, 1-12.

Demattê, J.A.M., et al., 2017. Soil class and attribute dynamics and their relationship with natural vegetation based on satellite remote sensing. Geoderma 302, 39-51.

EMBRAPA. Empresa Brasileira de Pesquisa Agropecuária, 1997. Manual de Métodos de Análise de Solo, 2 ed. Embrapa, Rio de Janeiro.

EMBRAPA. Empresa Brasileira de Pesquisa Agropecuária, 2006. Sistema brasileiro de classificação de solos, 2 ed. Embrapa-SPI, Rio de Janeiro.

EMBRAPA. Empresa Brasileira de Pesquisa Agropecuária, 2008. Carta do levantamento de reconhecimento dos solos do estado do Paraná. Atualização do Mapa de Solos – SiBCS.

Eyre, S.R., 1963. Vegetation and Soil: A World Picture. 2 ed. Edward Arnold, London.

Fernández-Getino, A.P., Duarte, A.C., 2015. Soil management guidelines in Spain and Portugal related to EU Soil Protection Strategy based on analysis of soil databases. Catena 126, 146-154.

Garcia, C.H.P., et al., 2013. Chemical properties and mineralogy of soils with plinthite and petroplinthite in Iranduba (AM), Brazil. Revista Brasileira de Ciência do Solo, 37, 936-946.

Golobocanin, D.D., et al., 2004. Principal component analysis for soil contamination with PAHs. Chemometrics and Intelligent Laboratory Systems 72, 219-223.

Gomes, J.B.V., 2004. Análise de Componentes Principais de atributos físicos, químicos e mineralógicos de solos do bioma cerrado. Revista Brasileira de Ciência do Solo 28, 137-153.

Gruba, P., Mulder, J., 2015. Tree species affect cation exchange capacity (CEC) and cation binding properties of organic matter in acid forest soils. Science of the Total Environment 511, 655-662.

IAP. Instituto Ambiental do Paraná, 2016. Disponível: http://www.iap.pr.gov.br/modules/conteudo/conteudo.php?conteudo=1260 Acesso: 23 jan. 2016.

IAP. Instituto Ambiental do Paraná, 2016. Disponível: http://www.sgageo.iap.pr.gov.br/sgageo/pages/interfaceusuario.html. Acesso: 25 jan. 2016.

IAP. Instituto Ambiental do Paraná, 2016. Disponível: http://www.iap.pr.gov.br/iap/modules/conteudo/conteudo.php?conteudo=1278. Acesso: 19 jan. 2016.

ICMBIO. Instituto Chico Mendes de Conservação da Biodiversidade, 2015. Disponível: http://www.icmbio.gov.br/sisbio/images/stories/instrucoes_normativas/INSTRU%C3%87%C3%83O_NORMATIVA_ICMBio_N%C2%BA_3_DE_2014__com_retifica%C3%A7%C3%A3o_do_DOU18062015.pdf. Acesso: 21dez. 2015.

Instituto das Águas do Paraná. 2011. Plano da Bacia Hidrográfica do Paraná 3: Características Gerais da Bacia. (Produto 1, versão 6). Disponível em: http://www.aguasparana.pr.gov.br/modules/conteudo/conteudo.php?conteudo=239. Acesso em: 17 out. 2016.

Kardanpour, Z., Jacobsena, O.S., Esbensen, K.H., 2014. Soil heterogeneity characterization using

PCA (Xvariogram) – Multivariate analysis of spatial signatures for optimal sampling purposes. Chemometrics and Intelligent Laboratory Systems 136, 24-35.

Kemerich, P.D.C., et al., 2012. Caracterização física e química do solo sob diferentes usos em bacia hidrográfica. Revista do Departamento de Geografia 24, 92-107.

Kummer, L., et al., 2010. Uso da Análise de Componentes Principais para agrupamento de amostras de solos com base na granulometria e em características químicas e mineralógicas**.** Scientia Agraria 11, 469-480.

Lepsch, I.F., 2011. 19 Lições de Pedologia. Oficina de Textos. São Paulo.

Lybrand, R., 2011. The effects of climate and landscape position on chemical denudation and mineral transformation in the Santa Catalina mountain critical zone observatory. Applied Geochemistry 26, 80-84.

MINEROPAR. Minerais do Paraná, 2001. Atlas Comentado da Geologia e dos Recursos Minerais do Estado do Paraná. Curitiba.

MINEROPAR. Minerais do Paraná, 2006. Atlas Geomorfológico do Estado do Paraná. Curitiba.

MINEROPAR. Minerais do Paraná, 2014. Mapas Geológicos 1:250.000. Disponível: http://www.mineropar.pr.gov.br/modules/conteudo/conteudo.php?conteudo=106. Acesso: 11 nov. 2014.

Miranda-Trevino, J.C.; Coles, C.A., 2003. Kaolinite properties, structure and influence of metal retention on pH. Applied Clay Science 23, 133-139.

Pires, P.T.L., Zeni Junior, D.M., Gaulke, D., 2012. As unidades de conservação e a Floresta Ombrófila Mista no estado do Paraná. Revista Ciência Florestal 22, 589-603.

Priori, A., et al., 2012. História do Paraná: séculos XIX e XX. Eduem, Maringá.

Raij, B.V., 1969. A capacidade de troca de cátions das frações orgânica e mineral em solos. Bragantia 28, 85-112.

Raij, B.V., 1981. Avaliação da fertilidade do solo, 2 ed. Instituto da Potassa e Fosfato, Piracicaba.

Raij, B.V., 2010. Fertilidade do solo no Brasil – Contribuições do Instituto Agronômico de Campinas. Informações Agronômicas 132, 1-13.

Rocha, A.S., et al., 2016. Mapeamento da Fragilidade Potencial e Emergente na Bacia Hidrográfica do Paraná 3. Estudos Geográficos 14, 43-59.

Rocha, A.S., 2016. As vertentes características e os sistemas pedológicos como instrumentos de análise para a identificação das fragilidades e potencialidades ambientais na Bacia Hidrográfica do Paraná 3. Tese (Doutorado). Maringá, UEM.

Santos, H.G., et al., 2013. Sistema brasileiro de classificação de solos. 3 ed. rev. e ampl., EMBRAPA, Brasília.

Schoonover, J.E., Crim, J.F., 2015. An Introduction to Soil Concepts and the Role of Soils in Watershed anagement. Journal of Contemporary Water Research & Education 154, 21-47.

Schumacher, M.V.; Hoppe, J.M., 1998. A floresta e a água. Pallotti, Porto Alegre.

SEMA. Secretaria de Estado do Meio Ambiente e Recursos Hídricos, 2010. Bacias Hidrográficas do Paraná - Série Histórica. Disponível em: http://www.meioambiente.pr.gov.br/arquivos/File/corh/Revista_Bacias_Hidrograficas_do_Parana.pdf. Acesso: 21 set. 2016.

Tundisi, J.G., 2003. Água no século XXI: enfrentando a escassez, RiMa IIE, São Paulo.

Ukut, A.N., Akpan, U.S., Udoh, B.T., 2014. Characterization and classification of soils in steep sided hills and sharp-crested ridges of Akwa Ibom State, Nigeria. Net Journal of Agricultural Science 2, 50-57.

Van Breemen, N., Mulder, J., Driscoll, C.T., 1983. Acidification and alkalinization of soils. Plant Soil 75, 283-308.

Verboom, W.H., Pate, J.S., 2015. An integrated approach to mapping and understanding of vegetation: soil systems. Catena 126, 134-145.

Walna, B., 2007. Composition and variability of soil solutions as a measure of human impact on protected woodland áreas. Central European Journal of Chemistry 5, 349–383.

Watanabe, T., et al., 2017. Parent Materials and Climate Control Secondary Mineral Distributions in Soils of Kalimantan, Indonesia. Soil Science Society of America Journal 81, 124-137.

Zenero, M.D.O., et al., 2016. Characterization and Classification of Soils under Forest and Pasture in an Agroextractivist Project in Eastern Amazonia. Revista Brasileira de Ciência do Solo 40, 1-17.