



Physical-chemical soil of agroforestry system and areas of natural regeneration in southeastern Pará, Brazil

Físico-química do solo de sistema agroflorestral e áreas de regeneração natural no sudeste do Pará

Emanoelen Bitencourt e Bitencourt¹; Juliana Cardoso Ferreira²; Kelvis Nunes da Silva³; Glauber Epifânio Loureiro⁴; Gleidson Marques Pereira⁵

¹Undergraduate student in Environmental and Sanitary Engineering, State University of Pará, Marabá, +5591991040415, e-mail: manuhbitencourt13@outlook.com;

²Undergraduate student in Environmental and Sanitary Engineering, State University of Pará, Marabá, e-mail: juuhferreira2199@gmail.com; ³Undergraduate student in Environmental and Sanitary Engineering, State University of Pará, Marabá, e-mail: kelvisnasilva@gmail.com; ⁴Master in Civil Engineering, Federal University of Pará, Belém. Assistant Professor, State University of Pará, Marabá, e-mail: epfanio@uepa.br; ⁵Master in Agronomy, Federal University of Ceará, Fortaleza. Assistant professor, State University of Pará, Marabá, e-mail: eng.gleidson.uepa@gmail.com.

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ABSTRACT

The soil is extremely important for the maintenance of a forest ecosystem, and the agroforestry systems allow considerable improvements in the resource. This study aimed to carry out the physical-chemical characterization of the soil in an agroforestry system and areas of natural regeneration in southeastern Pará. The study area is the Nossa Senhora do Perpétuo Socorro Settlement Project, in the municipality of Nova Ipixuna, Pará, which was divided into an Agroforestry System with five years of implementation and areas of natural regeneration with six and ten years, in which four samples, with three subsamples each, at a depth of 0-20 cm from the soil, to carry out chemical and soil texture analyzes. The data were subjected to the normality test and the principal components, using computer programs. Regarding the normality test, the probability distribution was normal, as for the analysis of variance, the treatments submitted did not show significant difference for all the variables analyzed, and in relation to the multivariate analysis, the formation of groups was not identified. Therefore, there was homogeneity between the physical-chemical characteristics of the agroforestry system and the areas of natural regeneration of six and ten years.

RESUMO

O solo é extremamente importante para a manutenção de um ecossistema florestal, e os sistemas agroflorestrais permitem consideráveis melhorias no recurso. Com este trabalho objetivou-se realizar a caracterização físico-química do solo em um sistema agroflorestral e áreas de regeneração natural no sudeste do Pará. A área de estudo é o Projeto de Assentamento Nossa Senhora do Perpétuo Socorro, no município de Nova Ipixuna, Pará, a qual foi dividida em Sistema Agroflorestal com cinco anos de implantação e áreas de regeneração natural com seis e dez anos, nas quais foram feitas quatro amostragens, com três subamostras cada, na profundidade de 0-20 cm do solo, para a realização das análises químicas e de textura do solo. Os dados foram submetidos ao teste de normalidade e dos componentes principais, por meio de programas computacionais. Sobre o teste de normalidade a distribuição de probabilidade foi normal, quanto à análise de variância os tratamentos submetidos não apresentaram diferença significativa para todas as variáveis analisadas, e em relação à análise multivariada não se identificou a formação de grupos. Portanto, houve homogeneidade entre as características físico-químicas do sistema agroflorestral e as áreas de regeneração natural de seis e dez anos.



INTRODUCTION

The balance of forest ecological systems depends on the management adopted for plant resources, therefore it is essential to understand the natural and anthropic processes (eg.: nutrient cycling and vegetation removal), and variables of influence on these resources, such as humidity, precipitation and heat. One of the most important constituents of the ecological system, tied to the biogeochemical cycles of the entire ecosystem is the soil, since the degradation of litter occurs in it, composed by leaves, branches and fruits, which are essential in the cycling of nutrients, which are released by the action of decomposers and later extracted by plants. Nutrient cycling is relevant mainly in soils with high weathering, where there are reduced nutrients, such as the amazonian (INKOTTE et al., 2019).

In order to achieve this balance in ecosystems, agroecological systems are emerging, such as the Agroforestry System - SAF. These models, regarding the use of the soil, associate woody perennial species and agricultural and/or animal cultures, constituting an environment favored by the similarity of the processes to what naturally happens, like the succession of matter and energy converted between beings through food and dependence on each other, resulting in a good cycling of nutrients. This cycling results from the large production of biomass, providing recovery of degraded areas by improving the physical (texture, porosity, permeability) and chemical (pH, nutrient content, organic matter) properties of the soil (MASCARENHAS et al., 2017; ARAUJO et al., 2018).

In this perspective, the different properties of the soil must be analyzed to verify progress in the restoration of soil attributes. However, this recovery of soil quality depends on the variability of the species, since greater diversity helps in the regeneration of soil properties. Furthermore, the determination of the physical-chemical condition of the soil contributes to a more adequate planning of future use and occupation of the same, because through the information of porosity, pH and nutrient content, for example, it is possible to define actions of short (use of calcium and magnesium in the correction of soil acidity), medium (introduction of SAFs) and long term (improved management of poultry), for the recovery of areas (BAKONYI, 2012; STUMPF et al., 2016; NOVAK et al., 2018).

One of the techniques used to explain about the variance and covariance of an eventual vector constituted of a set of eventual variables, it is the Principal Component Analysis - PCA, method used in the grouping of variables according to the variation. The PCA, according to Hongyu et al. (2015 p. 83) "it is a statistical technique of multivariate analysis that linearly transforms an original set of variables, initially correlated with each other, into a substantially smaller set of uncorrelated variables that contains most of the information from the original set". Still according to the authors cited, these smaller assemblies are called the principal components, each of which represents a linear association of all original variables.

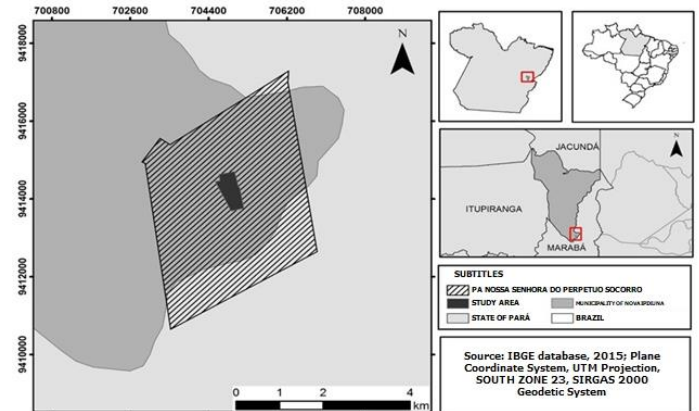
The study aimed to carry out the physical-chemical characterization of the soil in an agroforestry system and areas of natural regeneration in the municipality of Nova Ipixuna, southeast of Pará, in order to verify the capacity of the SAF

regarding the recovery of areas, using the principal component analysis technique for data analysis.

METHODS AND MATERIALS

The study area is located in the Nossa Senhora do Perpétuo Socorro Settlement Project, in the municipality of Nova Ipixuna / PA, bordering the municipalities of Itupiranga, Jacundá and Marabá at latitude 5 ° 17'57 "(S) and longitude 49 ° 08'58 "(O) (Figure 1).

Figure 1. Location of the Nossa Senhora do Perpétuo Socorro Settlement Project, Nova Ipixuna, Pará.



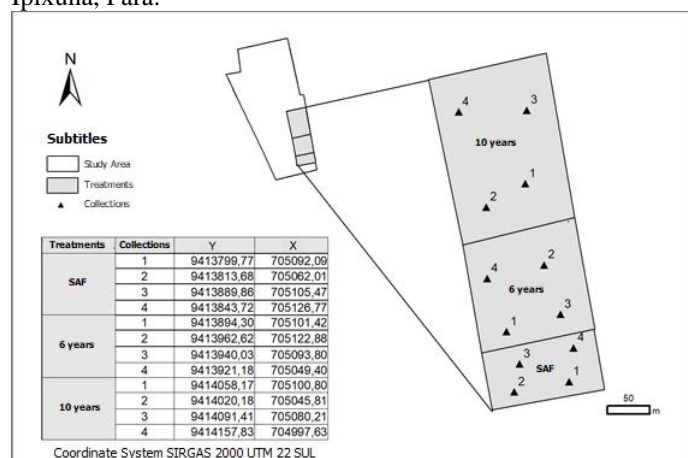
According to the Koppen classification, the region has a monsoon climate with extremely hot winter and very rainy summer, the average annual temperature is 26.9 °C and the average annual rainfall is 2,079 mm, with difference between the driest and wettest month of 377 mm (ALVARES et al., 2013). As for the soil, it was classified as a Dystrophic Red-Yellow Latosol, according to Teixeira et al. (2017).

In the Settlement Project, object of the study, the research areas were divided into treatment I, II and III. Treatment I is the Agroforestry System (SAF) with five years of implantation, a place with 9,473 m², which can be considered a dynamic and more biodiverse unit, where various cultures are introduced, such as cupuaçu, banana and açaí.

Treatment II comprises a six-year natural regeneration area, with 17,884 m², in which there is ground cover by grasses, in addition to the secondary succession of tree vegetation, typical of equatorial forests. Treatment III, an area of 27,469 m², is related to the natural regeneration area of ten years, in which characteristics similar to treatment II are observed. However, the vegetation is already at a more advanced stage of development noted by the size of the trees.

Regarding the collections of the topsoil, they were carried out in September 2018 and followed the methodology of Filizola et al. (2006), of simple random sampling, which avoids subjectivity in sampling and occurs with the marking of a network or grid of points over the area. For each defined treatment, four samples were sampled entirely randomly, with three subsamples each at a depth of 0-20 cm from the soil in the three treatment areas (I, II and III) (Figure 2).

Figure 2. Collection points in the three treatment areas in the Nossa Senhora do Perpétuo Socorro Settlement Project, Nova Ipixuna, Pará.



The collected samples were submitted to laboratory procedures to determine the chemical properties and texture of the soil, by the methods described by Teixeira et al. (2017). The chemical attributes analyzed were: active acidity (pH in water), organic matter (MO), phosphorus (available P), potassium (K), aluminum (Al^{2+}), calcium (Ca^{2+}), magnesium (Mg^{2+}), potential acidity ($H + Al$), sulfur (S), base saturation (V%) and cation exchange capacity (effective CEC). And the soil texture, obtained by sifting, was expressed in clay, silt and sand (TEIXEIRA et al., 2017).

The data were submitted to the normality test, by the Shapiro-Wilk method, according to Shapiro and Wilk (1965), and standardized (Equation 01) so that the new variables (Z) are

equivalent, they were subsequently submitted to the Principal Component Analysis (PCA), to associate the chemical variables with the samples and locations, in order to indicate the behavior of fertility in each treatment and the correlation between them.

$$Z = (X - \mu) / \sigma \quad (01)$$

Where: Z = Standardized variable; X = Non-standardized variable (raw data); μ = X mean; σ = Standard deviation of X.

In addition, Descriptive Statistics, Analysis of Variance were also performed to compare means (significance equal to 5%) and Multivariate Analysis was performed with the aid of the software STATISTICA version 7.0 (STATSOFT, 2004).

RESULTS AND DISCUSSION

The normality test applied to the variables showed a normal probability distribution, indicating normal data distribution. Regarding the physicochemical of the soil, the treatments evaluated do not differ ($p < 0.05$) in any of the analyzed parameters. As for the mean values, treatment III showed higher values for the variables of pH, MO, P, K, Ca^{2+} , Mg^{2+} , S, V%, CEC and Clay, followed by treatment I (Table 1).

Similar concentrations of macro and micronutrients may indicate that the interventions made by family farming systems, even if carried out in a simplified manner with SAF's technology, did not cause high negative impacts on soil attributes. This is because the occurrence of competitiveness, caused when different groups of plants are combined in agroforestry systems, it can generate the facilitation of essential elements for the life of the plants (JOSE et al., 2004). In addition, the availability of these elements can indicate the health and the ability of the soil to remain productive (DOLLINGER; JOSE, 2018).

Table 1. Descriptive Statistics and Analysis of Variance of physical-chemical parameters in treatments at the Nossa Senhora do Perpétuo Socorro Settlement Project, Nova Ipixuna, Pará.

Variables	Unit	Treatment I	Treatment II	Treatment III	Significance ($p \leq 0.05$)
		Means \pm SD	Means \pm SD	Means \pm SD	
pH	Water	5.05 \pm 0.54	4.68 \pm 0.33	5.28 \pm 0.51	0.25
MO	g/kg	1.78 \pm 0.77	1.38 \pm 0.31	1.90 \pm 0.79	0.53
P	mg/dm ³	4.00 \pm 2.94	1.25 \pm 0.50	6.00 \pm 3.37	0.08
K		55.00 \pm 26.46	40.00 \pm 11.55	65.00 \pm 19.15	0.26
Al^{2+}	cmolc/dm ³	0.70 \pm 0.32	0.78 \pm 0.21	0.58 \pm 0.33	0.63
Ca^{2+}		0.98 \pm 0.43	0.75 \pm 0.24	1.15 \pm 0.29	0.28
Mg^{2+}	0.50 \pm 0.28	0.38 \pm 0.17	0.60 \pm 0.18	0.38	
H+Al	%	3.50 \pm 0.52	3.85 \pm 0.30	3.28 \pm 0.35	0.18
S		1.40 \pm 0.58	1.23 \pm 0.40	1.90 \pm 0.52	0.20
V%	28.50 \pm 10.66	24.00 \pm 6.78	36.25 \pm 8.66	0.19	
CEC	cmolc/dm ³	4.90 \pm 0.44	5.05 \pm 0.17	5.18 \pm 0.17	0.43
Clay	%	41.50 \pm 14.11	29.75 \pm 6.60	46.25 \pm 11.21	0.15
Silte		31.25 \pm 2.50	39.25 \pm 13.99	33.25 \pm 2.36	0.40
Sand		27.25 \pm 13.55	31.00 \pm 11.86	20.50 \pm 9.71	0.47

Treatment I: agroforestry system; Treatment II: six-year natural regeneration area; Treatment III: ten-year natural regeneration area; SD: standard deviation; pH: Hydrogenionic potential; MO: organic matter; P: phosphorus; K: potassium; Al^{2+} : aluminum; Ca^{2+} : calcium; Mg^{2+} : magnesium; H + Al: potential acidity; S: sulfur; V%: base saturation; CEC: cation exchange capacity.

The average amount of phosphorus, for example, in the five-year agroforestry system, was close to that of the ten-year natural regeneration area. This corroborates the fact that the SAF does not cause major negative effects on the soil, and perhaps

this lower average value can be corrected with natural or chemical practices, increasing the productive performance of the soil, since phosphorus is important for plant metabolism, as it is a limiting nutrient for the production of biomass in terrestrial

areas, in natural forests (FISHER et al., 2012) and forest plantations (TRUAX et al., 2012).

Regarding the amount of organic matter, the values obtained in the five-year agroforestry system were also similar to those in the area of natural regeneration in ten years. In the ecosystem, the supply of organic material, found in the superficial layer, indicates the accumulation of biomass incorporated in the soil due to the greater number of species in the SAF. Therefore, the application of SAF's makes it possible to improve the physical-chemical properties of the soil, potentiating the fertility of the soil as a whole, and favoring the raising of productivity levels in smallholder crops (XAVIER et al., 2012; SILVA et al., 2014).

Some previous studies have also compared the physical-chemical attributes of the soil in different areas, Bertacchi et al. (2012) found in a study carried out in the interior of São Paulo, that the physical and chemical characteristics of the soil in regeneration areas of different ages had significant differences; Silva et al. (2019) observed that the amount of macronutrients in the soil of the planting systems (monoculture and SAF's) differed; Rodrigues et al. (2016) indicated a low level of soil fertility in a system of paricá (*S. parahyba* var. *Amazonicum*) x acacia (*Pueraria phaseoloides*). The results described by the authors were different from those observed in this study.

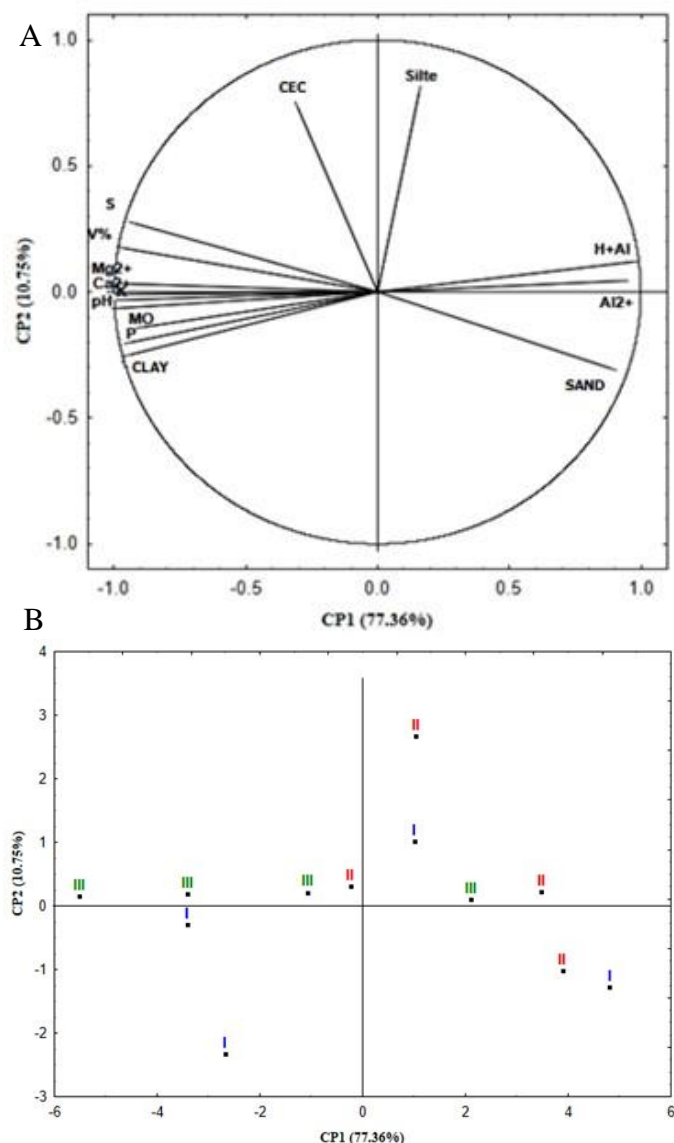
For the analysis of principal components, components 1 and 2 (CP1 and CP2) were enough to explain the total variation, with a variation rate equal to 88.11%, with CP1 responsible for 77.36% and CP2 for 10.75%. CP1 was characterized by not presenting variables with high discrimination power. However, in relation to CP2, the weights of the CEC (0.60) and Silte (0.65) variables stood out (Table 2, Figure 3A). The scores graph (Figure 3B) highlights the non-formation of groups in relation to the samples collected in treatments I, II and III, which are dispersed.

Table 2. Contribution of variables to the principal components (CP) 1 and 2 in the Nossa Senhora do Perpétuo Socorro Settlement Project, Nova Ipixuna, Pará.

Variables	Unit	CP1	CP2
pH	Water	-0.30	-0.05
MO	g/kg	-0.27	-0.11
P	mg/dm ³	-0.28	-0.16
K		-0.30	-0.03
Al ²⁺		0.28	0.04
Ca ²⁺		-0.30	-0.01
Mg ²⁺	cmolc/dm ³	-0.29	0.03
H+Al		0.29	0.10
S		-0.28	0.22
V%	%	-0.29	0.14
CEC	cmolc/dm ³	-0.09	<u>0.60</u>
Clay		-0.28	-0.20
Silte	%	0.05	<u>0.65</u>
Sand		0.27	-0.25

pH: Hydrogenionic potential; MO: organic matter; P: phosphorus; K: potassium; Al²⁺: aluminum; Ca²⁺: calcium; Mg²⁺: magnesium; H + Al: potential acidity; S: sulfur; V%: base saturation; CEC: cation exchange capacity.

Figure 3. Graph of loadings (A) and scores (B) of soil samples at the Nossa Senhora do Perpétuo Socorro Settlement Project, Nova Ipixuna, Pará.



The results of the analysis of principal components reinforce the results obtained in the analysis of variance, in which similarities were observed in the physical-chemical properties of the soil between the agroforestry system and the areas of natural regeneration of different years, due to the fact that there is no formation of patterns that differentiate them, in addition to the means that do not have significant differences, indicating that the use of SAF did not generate significant impacts on the soil.

In general, converting forests to agricultural land causes damage to soil stability and leads to increased erosion (LE BISSONNAIS et al., 2018). However, it was verified in this study, that the area with agroforestry system had similar characteristics to the area in recovery of ten years. Therefore, the use of SAF in the recovery of areas is beneficial, as often there is an increase in productivity growth rates (MARTORANO et al., 2016).

These crops, on an organic basis, help to maintain nutrients and biomass, given that the variation of species (tree, fruit and leguminous) in the system makes the agricultural environment conducive to recovery and production conditions (KAMIYAMA et al., 2011). Therefore, conservation management practices assist in the process of reversing degradation and adding organic matter, resulting in improvements in soil attributes (SIQUEIRA-NETO et al., 2010; VEZZANI; MIELNICZUK, 2011).

So, the presence of a consortium of species as a silvicultural practice is important to facilitate the recovery of the environment, and can reduce costs related to pest control, since due to the variety of species this occurs naturally (RODRIGUES et al., 2008; PAUL; WEBER, 2016; MARTINS et al., 2019). In addition, agroforestry plantations, managed by family farmers, can also be a source of food for the producer nucleus, as well as economic activities, in which family survival and reproduction lead to the generation of profits (RIBEIRO et al., 2004).

CONCLUSIONS

The use of an agroforestry system is beneficial for the soil, since it presents physico-chemical characteristics similar to the natural regeneration area of ten years, even though it has only been implanted for five years. Therefore, the SAF can be used to recover areas, as well as being a source of production and income.

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