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PHYSICAL AND CHEMICAL ATTRIBUTES AND CARBON STOCKS IN A YELLOW ACRISOL IN DISTINCT USE AND MANAGEMENT SYSTEMS IN WESTERN AMAZON

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ABSTRACT

Understanding and measuring the impacts of soil use and management systems on the soil physical, chemical properties and carbon stocks is fundamental for the development of sustainable systems in Western Amazônia. The present study evaluated the alterations in the soil physical, chemical properties, and carbon stocks after the substitution of a native forest (NF) into a pasture (PAST) and agroforestry system (AS) in a yellow Acrisol. In each soil use system, we opened four pits to collect soil samples with preserved structure, for the determination of soil bulk density (BD). We also collected samples with altered structure, for the determination of soil total organic carbon, pH- H_2O, Ca^{2+}, Mg^{2+}, K^+, P, remaining P, Al^{3+} and H+Al at the 0-5, 5-10, 10-15, 15-20, 20-30, 30-40 and 40-50 cm layers. The change in the soil use system from the NF, independently on the agroecosystem (PAST or AS), increased the soil bulk density values, mainly at the 5 to 20 cm layers, with higher values in the PAST. The nutrients evaluated and the soil total organic carbon presented low concentrations, being increased by the soil use change from the NF to PAST and AS. Thus, the basic cations and the available P are below the minimum thresholds and concentrated at the soil first layers. The PAST and AS increased the concentrations of these basic cations, and the soil carbon stock was not altered when compared to the NF, however, there was an increase in the soil bulk density, this increase was more profound in the PAST.

Keywords: Acre, agroforestry system, native forest, pasture, soil conservation

ATRIBUTOS QUÍMICOS E FÍSICOS E ESTOQUES DE CARBONO EM UM ARGISSOLO AMARELO EM DISTINTOS SISTEMAS DE MANEJO E USO DO SOLO NA AMAZÔNIA OCIDENTAL

RESUMO

Compreender e mensurar os impactos de uso e manejo nas propriedades físicas, químicas e estoques de carbono de solos é fundamental no desenvolvimento de sistemas agrícolas sustentáveis na Amazônia Ocidental. O presente estudo avaliou as alterações nos atributos físicos, químicos e estoques de carbono do solo após a substituição da floresta nativa para implantação de agro ecossistemas de pastagem e sistema agroflorestal em ambiente de Argissolo Amarelo. Em cada área, procederam-se a abertura de quarto mini trincheiras para a coleta de amostras de solos com estrutura preservada, para determinação da densidade do solo e amostras com estrutura alterada para determinação de carbono orgânico total, pH- H_2O, Ca^{2+}, Mg^{2+}, K^+, P, P rem., Al^{3+} e H+Al, nas camadas de 0-5; 5-10; 10-15; 15-20; 20-30; 30-40; 40-50 cm da superfície. A mudança de uso do solo sob floresta nativa, independente do agro ecossistema, incrementou os valores de densidade do solo, de forma mais expressiva na profundidade de 5 a 20 cm, com valores mais elevados no agro ecossistema de pastagem. Os nutrientes avaliados e o carbono orgânico apresentaram baixos teores, sendo incrementados com a mudança de uso do solo para pastagem e sistema agroflorestal. sendo assim, conclui-se que os cátions básicos e o fósforo disponível estão abaixo dos níveis críticos e concentrados nos primeiros centímetros do perfil do solo. Os sistemas de pastagem e Sistema Agroflorestal aumentaram esses cátions básicos, e o estoque de carbono não foi alterado em referência a floresta, contudo aumentou a densidade do solo, sendo os valores mais expressivos na pastagem.

Palavras-chave: Acre, sistema agroflorestal, floresta nativa, pastagem, conservação do solo

INTRODUCTION

Acre State, located in western Amazônia, possesses an area of approximately 170884 km^2, equivalent to 4% of the Brazilian Amazônia area, until 2020, nearly 14.4% of this area had been deforested (INPE, 2022).

The soil main classes in the Acre State, in a decreasing order of territorial importance are as follows: Acrisol, Haplumbrept, Alfisol, Gleysol, Oxisol, Vertisols, Plinthosol and Inceptisol (ACRE, 2010). The Acrisol class is the main class in terms of livestock activity, this is because most of the agriculture and livestock activities take place in this soil class, as this class is the most abundant in the Acre state (ACRE, 2010). However, these soils are the ones which demand a more specific management depending on the landscape where they occur, sandy texture in the A horizon and the clay increase along the depth.

Besides, it is not only this soil class, but all the other ones also present peculiar characteristics, mainly for being shaped by sediments derived from the Andes Mountain range, hence the diversity observed in these soils, vertic properties and eutrophication less common for Amazônia (ACRE, 2010). For the conditions of this study, West Acre, soils of sandy texture are more frequent, well drained, and deeper, despite presenting naturally less natural soil fertility than the other soils of the Acre State (ACRE, 2010; ANJOS et al., 2013). The soils characteristics in this Acre's region, allied to its climatic characteristics, hot, humid and high rainfall rates, make these soils more susceptible to soil chemical degradation which is caused by the loss of soil organic matter (SOM) and nutrients by soil erosion, high rate of SOM mineralization and nutrients uptake by crops and the non-reposition of these nutrients back to the soil. There is also the soil physical degradation, such as the soil erosion and compaction increase, being the main factors.

The Acre soils used in the majority involve the deforestation for the introduction of livestock activities, mainly for pasture systems. From the Acre soils characteristics, climatic conditions and the present agroforestry scenario, characterized by expansion, special attention should be given to the soil management in these agroecosystems, needing studies to evaluate the quality of soil chemical and physical attributes, in order to indicate the use and management systems which are more sustainable to cause soil degradation and also the ones which improve the soil quality, in order to guarantee the local population socioeconomic sustainability and the environmental preservation.

The main problem of the livestock activities in the Acre State is the pasture degradation, which from the 90s has increased because of the inadequate soil management, high rates of grazing and absence of different pastures (ANDRADE and VALENTIN, 2007).

The conversion of forest areas in Western Amazônia into pasture systems has degraded the soil physical quality, resulting in the increase of the soil bulk density and resistance to soil penetration (ARAÚJO et al., 2004) and chemical degradation, reducing the exchangeable cations capacity and active acidity increase (ARAÚJO et al., 2011; LOSS et al., 2014). In Bahia, the conversion of native forest into pasture and rainfed agriculture reduced the 100 cm depth soil carbon stocks by 37.3% and 30.3%, respectively (DIONIZIO et al., 2020).

In the studies conducted by Loss et al. (2014) and Araújo et al. (2011), forest conversion into pasture, reduced the soil carbon stocks and concentrations in the first years of the implantation, followed by an increase in the next years, until it reached a near or superior concentrations to the previous concentrations (before the conversion). Thus, the results are controversial, needing studies to better characterize these soil carbon stock dynamics in pasture agroecosystems derived from the deforestation process.

The uncertainties in the soil carbon estimations regionally in the soil compartments, plant, atmosphere in Western Amazônia is related, mostly, to the high heterogeneity of the soil classes observed in this state, due to the diversity of the soil parent material in the region, associated to the landscape, climate and vegetation. These factors determine the soil carbon stock capacity in Amazônia (NOVAIS FILHO et al., 2007).

The adoption of soil conservation management systems in Western Amazônia are important to recover, maintain or improve the soils chemical and physical quality. Thus, soil conservation practices are still incipient in this region. Besides, incipient are also the studies which evaluate the dynamics alteration and soil organic matter quantity and its reflexes on the soil physical and chemical properties after the substitution of native forest to agricultural and livestock uses (ARAÚJO et al., 2011; LOSS et al., 2014).

Recently in the Acre State, it has been stimulated the seek for sustainable agriculture and livestock activities, which aims not only to reach productive gains, but also the recovery of degraded areas and improvement of the environmental preservation, such as the integrated crop livestock or no tillage systems.

Acre state is part of the Amazon biome, and access to many areas in this region is very limited, resulting in a lack of information on soil properties (KOTLAR et al., 2020). The objective of this study was to evaluate the soil use impacts after the conversion of a native forest into a pasture and from a native forest into an agroforestry system on the soil chemical and physical attributes and carbon stocks of a yellow Acrisol in Western Amazon.

MATERIAL AND METHODS

Study site, soil chemical and physical analyses

The study areas are located at the West of the Acre State in the municipality of Cruzeiro do Sul, latitude 07° 34’24’’ S, longitude 72° 49’24’’ W. According to the Köppen classification, the region climate is classified as Tropical humid Af with rains well distributed along the year, with more rainfall in the Winter period (November), being the annual average rainfall of 2200 mm, with more than 80% occurring from November to March (ACRE, 2010).

The soil is classified as a dystrophic yellow Acrisol, average texture, the landscape ranges from wavy to smooth wavy, deep and well drained (ACRE, 2010). The native vegetation is comprised by a mosaic of dense broadleaf forest and open broadleaf forest with palms. The predominant palms trees in the area are the species *Mauritia flexuosa* and the *Euterpe oleraceae* and in geological terms stand out the pleistocene terraces derived from coarser sediments from the Solimões formation (ACRE, 2010; CAVALCANTE, 2010), hence, the predominance of the sand fraction in the granulometric composition of the A horizon of these soils.

The soil use systems evaluated were as follows: a portion of a native forest (NF), an agroforestry system (AS) and a pasture (PAST). The AS was implanted in 1980 after the cutting and burning of the primary forest, fertilizers and correctives had not been used until soil sampling. The AS is comprised by a diversity of trees and herbaceous crops, being the crops açaí (*Euterpe oleraceae* Mart), coconut (*Cocos nucifera* L.), orange (*Citrus sinensis* L. Osbeck*)*, tangerine (*Citrus reticulata* Blanco), avocado (*Persea americana* Mill), cocoa (*Theobroma cacao* L.) and Ingá (*Inga edulis* Mart) the most abundant ones. The pasture system was implanted in 1995 after the cutting and burning of the primary forest beside the AS. For the pasture management two burnings were performed, one in 1995 and another one in 2008. The actual soil use system corresponds to pasture, comprised by *Brachiaria brizantha*, fertilizers and correctives have not been used. We performed the soil sampling in Winter (November), we opened four pits (in each soil use systems), then we collected soil samples with preserved structure using volumetric rings (5 cm height and 6 cm diameter), we also collected samples with unpreserved structure at the 0-5, 5-10, 10-15, 15-20, 20-30, 30-40, 40-50 cm layers. To evaluate the soil chemical attributes, soil samples with unpreserved structure were air dried and then sieved using a mesh of 2 mm mesh sieve. About soil chemical analyses, we measured the pH in water and in KCl, the exchangeable calcium, magnesium and aluminium were extracted by a KCl 1 mol L^{-1} solution and then quantified by atomic absorption spectrometry (Ca and Mg), exchangeable aluminium was extracted by titration using a NaOH 0.025 mol L^{-1} solution, exchangeable potassium was extracted by a HCl 0.05 mol L^{-1} solution and quantified by flame photometry, available phosphorus was extracted by a HCl 0.05 mol L^{-1} + H_2SO_4 0.0125 mol L^{-1} solution (Mehlich-1) and determined by colorimetry, remaining phosphorus was extracted by a phosphorus equilibrium solution of 60 mg L^{-1} in $CaCl_2$ 10 mmol L^{-1} and determined by colorimetry, potential acidity (H+Al) was extracted by a calcium acetate solution of 0.5 M pH 7.0 and quantified by titration with a NaOH 0.025 mol L^{-1} solution, soil organic carbon (SOC) was determined by wet oxidation of organic matter using $K_2Cr_2O_7$ with H_2SO_4 solution To quantify the soil bulk density (BD), the soil samples were weighed and oven-dried at 105 ^{0}C for 48 h and then the BD values were calculated. Through these analyses, we performed the following calculations: bases sum (BS), Al saturation (Al%) and bases saturation (V%), all these laboratory analyses were performed according to Embrapa (2011). The soil total organic carbon stocks were calculated based on the soil equivalent masses (ELLERT and BETTANY, 1995). The soil fertility discussion was based on the Amaral and Souza publication (1997).

Statistical analysis

Initially, we performed the Lilliefors normality test to verify the residuals normality and the Cochran and Bartlett’s variances homogeneity test to verify the homogeneity of the treatments variances. Then we conducted the analysis of variance at 5%, we performed the t test to compare the treatments means at 5% only in the cases where significant differences were observed in the analysis of variance. We also conducted a correlation analysis among the response variables. All the the statistical analysis was performed on the R programming language (2020).

RESULTS AND DISCUSSION

The soil bulk density (BD) increased gradually from 1.08±0.03 g cm^{-3} in the 0-5 cm layer to 1.27±0.04 g cm^{-3} in the deepest layer (40-50 cm) in the NF, 1.25±0.02 to 1.37±0.01 g cm^{-3} in the AS, 1.19±0.10 to 1.42±0.03 g cm^{-3} in the pasture (PAST), respectively. Higher levels of soil density were observed in the PAST. There was no significant difference ($p > 0.05$) for the BD in any of the layers between the PAST and the AS and both systems presented differences in the 0-5 and 10-15 cm layers when compared with the NF (Figure 1).

For this soil condition and considering the soil texture, this soil density was considered critical as it is above 1.4 to 1.5 g cm^{-3} which are the thresholds proposed by Reichert et al. (2003), this was verified in the 5-10, 10-15 and 15-20 cm layers, in the AS and PAST, indicating soil compaction in these layers, this may be associated to the walking of the animals in the PAST (REICHERT et al., 2010). These processes rearranged the soil particles and reduced the soil porosity, mainly the macroporosity negatively affecting the soil physical and hydric properties (REICHERT et al., 2010; KLEIN, 2012).

The BD average variation between the layers in the AS and PAST in comparison with the NF was of 0.30 g cm^{-3} in depth. The lower BD in the NF, mainly in the initial layers is due to the soil organic matter (SOM) contribution and absence of human activities. The highest BD in the PAST is associated to the high livestock grazing intensity which increases BD, as also observed by Akhzari et al. (2015). The excessive hoof trampling by grazing animals leads to soil compaction, which can result in decreased soil pore space, reduced infiltration, and less plant available water (KOTZÉ et al., 2013; PULIDO et al., 2016). The BD increases are also associated to the soil exposition to moisture and drying cycles (ARAÚJO et al., 2004), as there is a negative linear relationship between the soil moisture and the BD (GUBIANI et al., 2015).

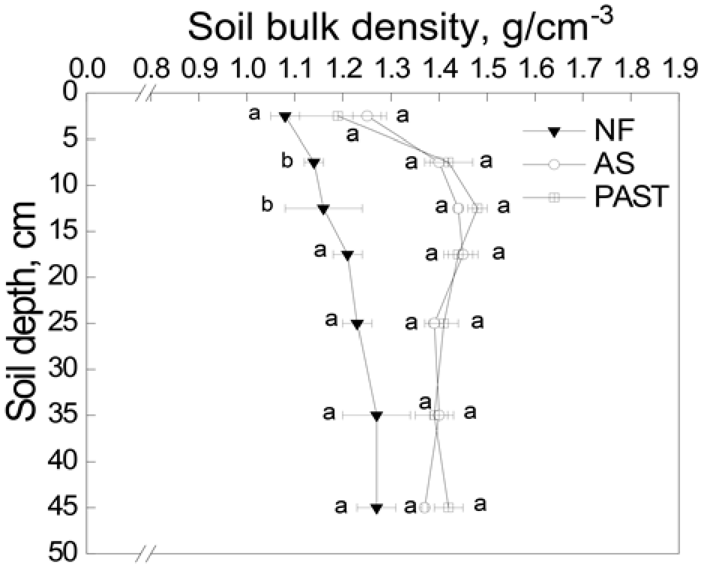

Figure 1. Soil bulk density of a yellow Acrisol in a native forest (FN), agroforestry system (SAF) and pasture (PAST), until the 50 cm depth. Horizontal bars indicate the mean standard error values. Means followed horizontally, in the same layer, with the same letter, do not differ by the t test at 5%. Cruzeiro do Sul, Acre, 2016.

These results agree to the others found by Araújo et al. (2011), and Campos et al. (2016) who verified BD increases in the PAST system after the NF substitution. They are also in agreement with Lanzanova et al. (2007) who verified that in different grazing levels the BD increase in the superficial layers. The soil organic carbon (SOC) decreased along the depth in an inverse way of the BD. The SOC average concentrations were higher in the PAST system until the 15 cm layer, being the lowest concentrations observed in the AS. There was significant difference only at the 0-5 cm layer I, where NF and PAST were similar and presented higher values than the AS.

Significant differences were not observed in the other layers. The SOC concentrations ranged from 13.81±0.80 g kg^{-1} in the 0-5 cm layer to 2.56 ±0.35 g kg^{-1} in the 40-50 cm layer in the PAST and respectively 12.1±1.29 to 3.2±0.37 g kg^{-1} in the NF and 5.95±0.36 to 3.1±0.09 g kg^{-1} in the AS (Figure 2). The higher SOC increases in the subsurface in the PAST system are related to the crop residues decomposition from the shoots and grass roots (KOUTIKA et al., 2000). The SOC reduction is due mainly to the low contribution from the shoots and roots, as the contribution is higher in surface layers. It may be also due to the cations reduction and soil physical quality, aggregates stability which tend to reduce along the depth. These processes contribute for the reduction of the SOM physical and chemical protection.

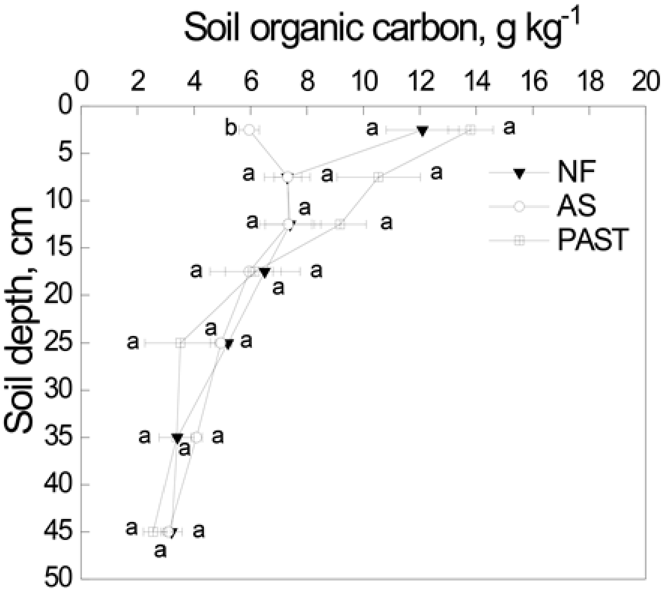

Figure 2. Soil organic carbon of a yellow Acrisol in a native forest (FN), agroforestry system (SAF) and pasture (PAST), until the 50 cm depth. Horizontal bars indicate the mean standard error values. Mean followed horizontally, in the same layer, with the same letter, do not differ by the t test at 5%. Cruzeiro do Sul, Acre, 2016.

The active acidity was of 3.8 in the 0-5 cm layer to 4.5 in the 40-50 cm layer in the NF and respectively 4.4 to 4.5 in the AS and from 4.8 to 4.8 in the PAST (Table 1), being classified as high acidity (<5), agreeing with the high exchangeable Al concentrations and low nutrients availability (AMARAL and SOUZA, 1997). In general, the active acidity was lower in the first centimetres, the PAST presented the lowest active acidity until the 20 cm depth, this is related to the high quantity of exchangeable bases observed in this system.

The highest active acidity observed in the NF is due to low concentrations of exchangeable Ca^{2+} and Mg^{2+} and the low active acidity in the AS and PAST is due to the increase of basic cations in the soil. This fact is supported by the linear correlations found between the pH and Ca ($r = 0.75$; $p < 0.05$, $n =63$) and pH x Mg ($r = 0.65$; $p<0.05$, n 63). These results disagree to the ones obtained by Araújo et al. (2004, 2011) and Loss et al. (2014), who observed higher active acidity in the PAST after the substitution of the NF. However, the basic cations found by both authors were lower in the PAST, explaining the reason for the higher active acidity.

The Ca^{2+} and Mg^{2+} concentrations were considered low (< 2.0 and < 0.5 $cmol_c$ dm^{-3}, respectively) and restrictive to crops mineral nutrition (AMARAL and SOUZA, 1997) in the three systems. The Ca^{2+} concentrations ranged from 0.0 to 0.44 $cmol_c$ dm^{-3}, Mg^{2+} concentrations from de 0.0 to 0.34 $cmol_c\ dm^{-3}$, having the NF presented the lowest Ca^{2+} and Mg^{2+} concentrations (Table 1). This indicates that the forest growing is related to the efficient nutrients cycling as reported in another Amazônia ecosystems studies (ARAÚJO et al., 2004).

The K^+ concentrations ranged from 0.06 $cmol_c\ dm^{-3}$ in the 0-5 cm layer to 0.01 in the 40-50 cm layer in the NF, and respectively from 0.12 to 0.03 $cmol_c\ dm^{-3}$ in the AS and from 0.11 to 0.01 in the PAST, in general there were not differences among the systems.

The available P was considered low (<10 mg dm^{-3}) in the three systems, in all the depths. The P concentration was higher in the 0-5 cm layer and reduced along the depth (40-50 cm) (Table 1) agreeing with the soil behaviour of this region. This suggests that the higher P concentrations are due to the nutrients cycling processes which are favoured by the crops residues and roots. This result agrees with the ones obtained by Araújo et al. (2011) who yet suggests that SOM is the main variable which controls the P and basic exchangeable concentrations in these systems.

The higher exchangeable bases concentrations (Ca, Mg, K) in the PAST may be related to fire use as a management practice causing the increase of nutrients availability, about the AS, it may be due to the crops species diversity causing the nutrients uptake in different proportions and bring them back into the soil through a more gradual SOM decomposition from the crops shoots.

It is important to highlight that in the three soil use systems, the soil fertility is very low, agreeing with the soils of this region in Acre, soils of low natural fertility, more important is to highlight the calcium absence in the NF, mainly in the surface layers. This happened may be because the concentrations of these elements were so low that the determination method was not enough sensitive to determine the concentration of this cation.

The results explain yet more the need to use soil conservation systems to maintain the agricultural production to guarantee the socioeconomic sustainability of the local production, which depends basically on the households agriculture and livestock activity.

The exchangeable acidity (Al^{3+}) ranged from 2.01 $cmol_c\ dm^{-3}$ in the 0-5 cm layer to 1.67 $cmol_c\ dm^{-3}$ in the 40-50 cm layer in the NF and respectively from 0.74 to 1.61 $cmol_c\ dm^{-3}$ in the AS and 1.02 to 1.28 $cmol_c\ dm^{-3}$ in the PAST (Table 1). There was a general tendency in which lower concentrations occurred in the first layers. This phenomenon may be related to the nutrients cycling effect, i.e., more accumulation of exchangeable bases at the surface and more SOM content which may be complexing the aluminium.

The exchangeable acidity increase with the depth, does not depend on the soil use system, as well as the increase in the NF in comparison with the AS and PAST are related to the lower SOC concentration and exchangeable cations. This fact is supported by the correlations between SOC and Al Al ($r= - 0.56$, $p < 0.05$, $n=63$), between Ca and Al ($r= - 0.41$, $p < 0.05$, $n=63$), Mg and Al ($r= - 0.21$, $p < 0.05$, $n=63$).

The potential acidity (H+Al) ranged from 6.54 $cmol_c/dm^3$ in the 0-5 cm layer to 3.66 $cmol_c/dm^3$ in the 40-50 cm layer in the NF and respectively from 3.18 to 3.43 $cmol_c/dm^3$ in the AS and 4.57 to 2.84 $cmol_c\ dm^3$ in the PAST (Table 1).

The nutrients concentrations found here are an example of high variation on the soil fertility in the Acre State. In cases like these, low soil fertility emphasizes the importance of using more sustainable soil use and management practices such as the AS due to the chemical fragility for some soil classes, although in this study the systems showed an increase of the soil fertility specially in the first layers of the soil.

The total carbon stocks in the soil ranged from 6.53±0.70 Mg ha^{-1} in the 0-5 cm layer to 4.09±0.48 Mg ha^{-1} in the 40-50 cm layer in the NF and respectively 4.85±0.20 Mg ha^{-1} to 3.94±0.11 Mg ha^{-1} in the AS and 7.48±0.43 Mg ha^{-1} to 3.26±0.45 Mg ha^{-1} in the PAST (Figure 3). In the PAST were observed the highest carbon stocks until the 10-15 cm layer with reduction along the depth (Figure 3). The total organic carbon stocks in the soil are concentrated in higher proportions in the first soil layers, being 56% of the total carbon stocks of the NF concentrated until the 20 cm depth and respectively 53% in the AS and 65% in the PAST.

The total carbon stocks were higher in the PAST, concentrations around 34.40±3.74 Mg ha^{-1} until the 50 cm depth, and respectively of 33.70±1.11 Mg ha^{-1} in the NF and 31.84±0.44 Mg ha^{-1} in the AS (Figure 4). However, there was no difference among the systems, indicating that the PAST and the AS maintain or tend to increase the carbon stock capacity in the soil along the time. These results agree with Araújo et al. (2011) who in a red yellow Acrisol in Western Amazonia found higher carbon stocks in a PAST with 10 and 20 years when compared to the NF.

Table 1. Results of the soil chemical attributes of a yellow Acrisol submitted to three different soil use systems in the Acre State.

Soil use	pH	Ca^{2+}	Mg^{2+}	K^{+}	H+Al	Al	P	P.rem.	BS	V%	Al%
		------------------ $cmol_c\ dm^{-3}$ ----------------					---- $mg\ dm^{-3}$ ----		------- $cmol_c\ dm^{-3}$ --------		
					0-5 cm						
NF	3.7a	0.00a	0.09a	0.06a	6.4a	2.0a	3.68a	36.68ab	0.15a	2a	94a
AS	4.5b	0.44b	0.14b	0.12b	3.2ab	0.7b	6.60ab	45.36a	0.71a	18bc	52bc
PAST	4.8b	0.36b	0.34c	0.11b	4.6b	1.0b	1.43c	21.61b	0.81a	14c	58c
CV (%)	11	72	57	27	28	45	54	54	52	60	27
					5-10 cm						
NF	4.1a	0.00a	0.14c	0.04a	4.9a	2.1a	2.68a	25.90a	0.18a	3a	92a
AS	4.2ab	0.26bc	0.07a	0.08a	4.8a	1.7ab	3.73a	25.53a	0.41bc	8bc	79bc
PAST	4.9b	0.21c	0.16c	0.07a	4.1a	0.9b	1.86a	18.16a	0.44c	9c	79b
CV (%)	8	72	31	27	8	32	28	15	34	39	7
					10-15 cm						
NF	4.0a	0.02a	0.07a	0.06a	4.7a	2.3a	1.90a	14.91a	0.15a	3a	94a
AS	4.3a	0.21bc	0.16a	0.07a	4.6a	1.6b	1.86a	18.16bc	0.44bc	9bc	79bc
PAST	4.8c	0.16c	0.14a	0.05a	4.1a	1.2b	0.77a	10.65b	0.34bc	8c	78bc
VC (%)	8	62	31	14	6	27	35	21	39	39	9
					15-20 cm						
NF	4.2a	0.00a	0.08a	0.03a	4.8a	2.4a	1.20a	11.45ab	0.09a	2a	96a
AS	4.4ab	0.21bc	0.06a	0.06a	4.5ab	1.6b	1.10a	13.591b	0.33bc	7bc	85bc
PAST	4.7c	0.12ac	0.07a	0.04a	4.1b	1.3b	1.10a	7.04c	0.23b	5c	85c
CV. (%)	5	78	12	29	6	26	4	100	45	44	6
					20-30 cm						
NF	4.4a	0.01a	0.06a	0.02a	4.1a	2.4a	0.49a	8.26ab	0.08a	2a	96ab
AS	4.5a	0.14bc	0.03a	0.05a	4.5ab	1.7b	0.75bc	10.75b	0.22bc	5bc	90b
PAST	4.6a	0.14c	0.05a	0.02a	3.2c	1.4b	0.33ac	6.35ac	0.22c	6c	84c
CV (%)	2	63	27	47	14	23	33	21	38	39	5
					30-40 cm						
NF	4.5a	0.01a	0.02a	0.01a	3.9a	1.7a	0.28a	5.65a	0.06a	2a	96a
AS	4.6a	0.18bc	0.00a	0.04a	4.0a	2.0a	0.26a	8.46abc	0.22bc	5bc	89bc
PAST	4.7a	0.11c	0.08a	0.01a	3.1b	1.4a	0.17a	4.59c	0.20c	6c	85c
CV (%)	2	70	100	71	11	14	20	26	44	39	5
					40-50 cm						
NF	4.5a	0.02a	0.04ab	0.01a	3.9a	1.6a	0.00a	5.73a	0.07a	2a	96a
AS	4.6a	0.12bc	0.011b	0.03a	3.9a	1.7a	0.00a	8.33bc	0.16bc	4c	91ab
PAST	4.7a	0.09c	0.07ac	0.01a	3.0b	1.5a	0.23b	6.12ac	0.18c	6bc	87bc
CV (%)	2	55	60	57	12	5	100	17	35	41	5

V%= Bases saturation, Al%= Al saturation, SB= Bases sum. Means followed by the same letter in the column, do not differ by the t test at 5%. CV = coefficient of variation

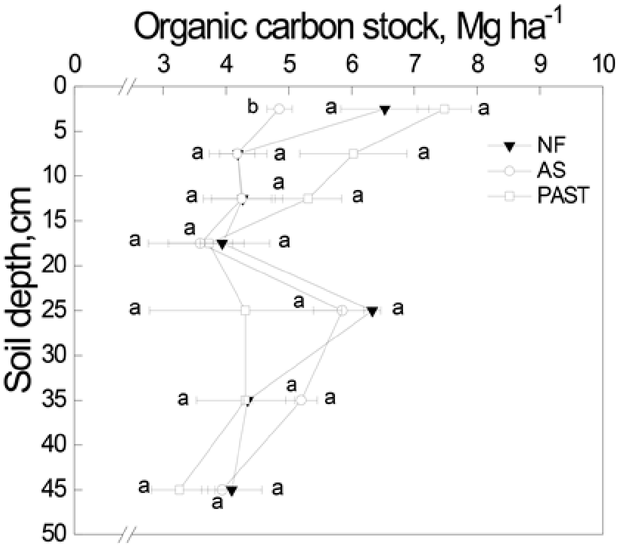

Figure 4. Soil organic carbon stocks of a yellow Acrisol in a native forest (FN), agroforestry system (SAF) and pasture (PAST), until the 100 cm depth. Horizontal bars indicate the mean standard error values. Mean followed horizontally, in the same layer, with the same letter, do not differ by the t test at 5%. Cruzeiro do Sul, Acre, 2016.

The organic carbon stocks in the PAST had an increase of 4% (1.28 Mg ha^{-1}) and reduced 6% (1.86 Mg ha^{-1}) in the AS when compared with the NF, respectively (Figure 5).

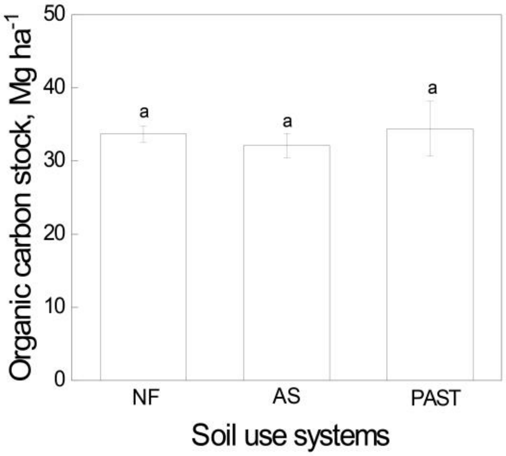

Figure 5. Organic carbon stocks of a yellow Acrisol in a native forest (FN), agroforestry system (SAF) and pasture (PAST), until the 50 cm depth. Horizontal bars indicate the mean standard error values. Mean followed horizontally, in the same layer, with the same letter, do not differ by the t test at 5%. Cruzeiro do Sul, Acre, 2016.

CONCLUSION

The basic cations (Ca^{2+}, Mg^{2+}, K^{+}) and the available P are below the critical levels and are concentrated in the first soil centimetres. The pasture and agroforestry systems increased these basic cations.

The substitution of the forest to pasture and to an agroforestry system did not alter the carbon stocks, however, increased the soil density, being the highest values in the pasture.

The carbon stocks values found in this study are lesser when compared with other Amazonia regions.

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