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ORIGINAL ARTICLE – Silviculture

Carbon and Nitrogen Stocks and Microbiological Activity Under Forest-Pasture System and Traditional Pasture in Pernambuco

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Abstract

An adequate amount of soil organic matter is considered essential for long-term sustainable agriculture, ensuring good productivity. Therefore, the present study quantified carbon and nitrogen stocks and microbiological activity in soil of three different areas: Forest-pasture System, Pasture System and preserved Caatinga - used as a reference of the experiment - located in a semi-arid region, in Watershed of Pajeú River, state of Pernambuco, Brazil. Eight trenches were opened in each system to collect soil samples at depths of 0 - 10, 20 - 30 and 50 - 60 cm, for chemical and microbiological analysis. In general, attributes of soil showed better results of land use in the following order: preserved Caatinga - Forest-pasture System - Pasture System.

Keywords: Fractionation of humic substances, Carbon stocks, Agroforestry Systems, Caatinga.

1. INTRODUCTION

Brazil ranks 6th in the world ranking of countries that emit Greenhouse Gases (GHGs), which 72% of them is derived from rural activity (Pata, 2021), due to changes in land use contributing to global warming, thus compelling the greenhouse effect (Magri & Baião, 2016).

Changes in land use and management can result in important carbon sources or drains (C) to the atmosphere (Schimmel et al., 2021). Soils are vulnerable to lose carbon through degradation, causing the release of gases, as a result of accelerated decomposition due to land use change and inadequate agricultural practices (Lal, 2010).

The soil's organic matter consists mainly of C and N, with the stocks of these nutrients varying according to the rates of their addition (Bongiorno et al., 2019). Soil management can affect the relative balance and its environmental impacts both in the Organic Matter of Soil (OMS), where part of the carbon is mineralized very quickly in CO_2, and in the losses of OMS through physical erosion. The organic nitrogen contained in the biodegradation of OMS is transformed from N_2O to another compound nitrogen oxide (NOx). However, some fractions of OMS are not easily degraded. The Total Carbon (TC) content therefore tends to increase as it develops in undisturbed soil over time. Decisive actions must be taken to limit soil carbon loss due to erosion and emissions of carbon dioxide and other greenhouse gases into the atmosphere (Nair et al., 2010; Toensmeier, 2016).

Carbon sequestration in the soil is considered a promising way to mitigate climate change, absorbing atmospheric carbon dioxide (CO_2) in plant residues, living biomass and recalcitrant organic matter (Paustian et al., 2016). The adoption of best agronomic management practices can lead to the Total Carbon (TC) hijacking, with an estimated potential of 0.90 to 1.85 billion tons of carbon per year (Mg C year), for 20 years worldwide. (Zomer et al., 2017).

One of the most important factors is changes in land use, with changes in conserved areas of pasture and forests for agricultural use, affecting Total Carbon (TC) stocks in different ways in different ecosystems and regions (Solomon et al., 2000). Therefore, understanding the potential for carbon storage in the soil and developing effective methods to decrease the concentration of CO_2 in the atmosphere is of vital importance (Fu et al., 2010).

In the semiarid region of Pernambuco, it is estimated that only 54% of native vegetation, known as "Caatinga", is preserved (Althoff et al., 2018), with approximately 33.3 million hectares, 34% of the entire region, used for agricultural purposes. According to Sampaio & Costa. (2011) the agricultural system that prevails in this region is rainfed agriculture, formed by family farmers, usually on small properties, who cultivate subsistence crops with the burning of vegetation and conventional tillage, concomitant with extensive livestock.

Thus this work aimed to evaluate changes in carbon and nitrogen stocks and microbiological activity in soil under different pasture systems in semiarid region of Watershed of Pajeú River, in Pernambuco state.

2. MATERIALS AND METHODS

2.1. Study area

The field experiment was carried out on the Cedro farm, with 200 hectares of area, located in Serra Talhada - PE, belonging to Watershed of Pajeú River, near to Exu stream (Figure 1). The epicenter area has the coordinates 7.982533° South and 38.431272° West.

Figure 1. Location of the study area of the Riacho Exu River Basin, Serra Talhada – PE.

The region's climate, according to Köppen classification is Bwh, called hot and dry semiarid, with autumn summer rains with average annual rainfall for the period 1911 to 2013 of 647 mm per year, with an average annual temperature above 30 °C (Oliveira et al., 2020).

The soil of three areas were evaluated, corresponding to a Forest-pasture System (FPS), a Pasture System (PS) and a preserved Caatinga System (CS) area that was used as a reference for comparison, seeking to consider the land uses and the spatial and temporal heterogeneity that characterize the semiarid regions. The type of soil occurring in FPS and PS was classified as Neossolo Flúvico, where as in the CS area was a Cambissolo Háplico (Santos et al., 2018).

In the semi-shrubby Caatinga area, was found the following native species: Jurema Preta (*Mimosa tenuiflora* (Wild) Poir), Canafístula (*Peltophorum dubium* (Spreng) Taub, Anjico (*Anadenanthera colubina* (Vell) Brenan), Juazeiro (*Ziziphus joazeiro* Mart.), Marmeleiro (*Croton blanchetiamus* Baill.), Mandacaru (*Cereus Jamacaru* DC.), Quipá (*Tacinga quipa* (F. A. C. Weber) N. P. Taylor & Stuppy.), Catingueira (*Poincianella pyramidalis* (Tul) L. P. Queiroz.) e Pata-de-vaca (*Bauhinia cheilantha* (Bong) Steud).

2.2. Soil samples

Soil samples were collected in the three study areas. In each area, 8 points were randomly chosen, with their positions obtained by GPS System, in which trenches of 0.5 x 1.0 m were opened. The samples were collected at depths of 0 - 10; 20 - 30 and 50 - 60 cm.

Deformed and undisturbed soil samples were collected in each trench. Undisturbed samples were obtained using a sampler auger containing a metal ring. The deformed soil samples were placed to air dry, then they were removed and passed through a 2 mm sieve to obtain the air-dried fine soil (TFSA). The undisturbed samples were then dried in an oven at 105 °C to obtain the kiln-dried fine earth (TFSE) for later determination of soil density (Ds), obtained through the volumetric core method (Almeida et al., 2017).

2.3. Chemical analysis

The total carbon (TC) and total nitrogen (TN) were determined using an elemental analyzer, the sample being subjected to the combustion process and with that the C was converted into CO_2 and the N into N_2 gas. After the combustion stage, the gases generated in the combustion chamber were separated in a gas chromatography column, followed by detection by thermal conductivity (Fontana & Bianchi, 2017). The labile carbon was determined by oxidation with a 0.033 mol solution of $KMnO_4$ a 0,033 mol L^{-1} (Blair et al., 1995).

The light organic matter was determined by flotation, according to Fraga & Salcedo (2004), and the soil sample was washed in a 0.053 mm sieve, removing the clay and silt fractions. In the material retained in the sieve, the light fraction was separated through flotation.

The chemical fractionation of humic substances occurred through the differential solubility technique (Swift, 1996), using TFSA with 0.1 mol $L^{-1}$of NaOH solution. After mixing and centrifuging, a precipitate was obtained which included the humine fraction, which was placed in an oven at 45 °C. After drying, a solution of concentrated H_2SO_4 was used to precipitate the humic acid (HA) fraction. After centrifugation, the fraction of fulvic acids (FA) was separated and after further precipitation, the humid fraction (HUM) was obtained.

2.4. Microbiological analysis

The basal respiration rate (C - CO_2) was determined from the released CO_2, using 20g of soil, incubating it for 72 hours. CO_2 was captured by 0.05 mol NaOH solution. L^{-1} and titrated with HCl to 0.05 mol L^{-1} (Isermeyer, 1952). The quantification of carbon from microbial biomass (CMB) was obtained through the oxidation of C using potassium permanganate, through the colorimetry method (Bartlett & Ross, 1988).

For the reason of the C - CO_2 and CMB data, the metabolic quotient (qCO_2) was calculated, which represents the amount of C - CO_2 released in a given time, per unit of microbial C. The microbial quotient (qMic) was calculated by the ratio between CMB and TC - Total Carbon (Anderson & Domsch, 1985).

From the ratio of C - CO_2 and CBM data, the metabolic quotient (qCO_2) was calculated, which represents the amount of C - CO_2 released in a given time, per unit of microbial C. The microbial quotient (qMic) was calculated by the ratio between CBM and TC - Total Carbon (Anderson & Domsch, 1985).

2.5. Statistical analysis

The data obtained were submitted to the calculation of means, standard deviation and the Shapiro-Wilk normality test. Thereafter, the Tukey test was applied at 5% significance, using the SISVAR statistical program.

3. RESULTS AND DISCUSSION

3.1. Carbon and Nitrogen Stocks

Organic Soil Carbon (OSC) is one of the most used soil quality indicators in conjunction with pH and available P and K (Bünemann et al., 2018), playing an important role in terrestrial ecosystems from the carbon cycle, in maintaining soil quality in agrosystems (Balesdent et al., 2018). OSC consists of several compounds, from simple to more complex molecules, thus being able to present a different stability (Deb et al., 2015).

Total Carbon Stocks (TCStock) had the highest averages for CS, differing significantly from the other systems as provided in (Table 1). The depth with the greatest carbon storage was 0 - 10 cm, which for CS also differed from the other depths. The second best average was found for FPS, in this case with a reduction of 48% when compared to CS. Throughout the depths, their values behaved in decrease, however in the depth 50 - 60 cm their average did not differ significantly from PS. In this system, the lowest levels of carbon storage in the soil occurred, at depth 0 - 10 cm, and its reduction was 57% when compared to the system with preserved vegetation.

Table 1. Total Carbon Stocks (TCStock), Total Nitrogen Stock (TNStock) and C/N Ratio, in the three systems of land use, in the three depths studied.

Systems	TCStock	TNStock	C/N
	Mg ha^{-1}		
Depth 0 - 10 cm			
PS	10.73 Ca	0.90 Ba	11.85 Aab
CS	25.3 Aa	2.16 Aa	11.72 Aa
FPS	12.98 Ba	1.10 Ba	11.78 Aa
Depth 20 - 30 cm			
PS	9.42 Cab	0.77 Bab	12.21 Aa
CS	18.71 Ab	1.62 Ab	11.51 Aa
FPS	11.04 Bab	0.93 Bab	11.78 Aa
Depth 50 - 60 cm			
PS	7.88 Bb	0.70 Bb	11.32 Ab
CS	12.69 Ac	1.08 Ac	11.75 Aa
FPS	9.5 Bb	0.81 Bb	11.68 Aa

Averages followed by the same uppercase letter in the column and lowercase in the row do not differ by the Tukey test at 5% probability. PS – Pasture System; CS – Caatinga System and FPS – Forest-pasture System.

Santos et al. (2019) studying the stocks of organic carbon in different land uses in Santa Catarina, also found the highest averages in the superficial layers of the soil, decreasing along the depth, with native vegetation being the one with the highest average, differing statistically from the other types of land use.

Pegoraro et al. (2018) comparing soil carbon and nitrogen stock levels in different types of use in the semiarid region, also found the highest averages for the native forest environment, attributing these values to a greater accumulation of dry matter from plant residues on the surface of the ground. The PS had the lowest averages of TCStock and Total Nitrogen Stocks (TNStock), accompanied by the renewed banana plantation, old banana plantation and sugar cane. There was also a decrease in the levels of TCStock and TNStock with an increase in depth.

The low values of TCStock in PS (Table 1), are justified by the low productivity of the grasses, soil turnover, low amount of organic matter and deficiencies of nutrients in the soil. The highest averages of the TCStock were found in the CS and these values occurred due to the continuous deposition of litter, as well as the absence of anthropic action in this environment, which guarantees the maintenance of organic matter contents (Melo et al., 2016).

Mascarenhas et al. (2017) studying total carbon stocks in different soil uses, found the highest concentration in native vegetation at depth 0 - 40 cm. In the face of the land use systems, the pasture showed greater storage of carbon at depth 0 - 20 cm when compared to Caatinga vegetation and Forest-pasture System. This discrepancy in values may be related to the quality of their management. Pastures can reach levels close to natural Caatinga and Forest-pasture System, depending on the development of their root system, since it is a system that is constantly renewed and provides large amounts of organic matter. The greatest contribution of pastures and annual crops to the accumulation of carbon in the soil comes from its root system (Sant-Anna et al., 2016).

The forest-pasture system studied by Silva et al. (2020) also showed better carbon storage when compared to pasture at a depth of 10 - 20 cm. At the other depths, the values were statistically equal for the pasture system, differing only from the Caatinga vegetation that presented the highest averages. This demonstrates that, even in the short term adoption, Forest-pasture System can contribute to increase the stocks of total carbon. This performance is related to the fact that thes system is formed by different components (trees, grasses and animals), benefiting from this interaction.

After converting native vegetation to cultivated land, it is reported that soils lose organic carbon, reaching a lower balance, about 25 to 75% less carbon than in undisturbed native vegetation (Lal, 2004). The loss of organic soil carbon in cultivated lands is mainly due to disturbances of soil aggregates through cultivation, which accelerates the microbial activity of the soil, the oxidation and mineralization of organic matter (Swanepoel et al., 2016). Soil erosion, runoff and leaching lead to an additional loss of organic carbon from the soil of arable land (Roose & Barthes, 2001).

The TNStock presented the best averages in CS (Table 1), just as the TCStock differed significantly from the other systems, presenting the highest values of 2.16 g Kg^{-1} at depth 0 - 10 cm. However, FPS and PS did not differentiate between each other in any of the depths, as well as in CS, with their highest values found at depths 0 - 10 and 20 - 30 cm, which are considered equal. The nitrogen decrease in CS when compared to FPS and PS in layer 0 - 10 being 49% and 58.3% or 1.06 g Kg^{-1} and 1.26 g Kg^{-1}, respectively.

Menezes et al. (2021) studying the stocks of carbon and nitrogen in different types of land use, in the Sertão of the state of Paraiba, also found significant differences between the values of TNStock, with native vegetation and sparse vegetation being the areas with the highest averages, with the lowest rates for pasture system, annual crops and permanent cultivation areas. Along the depth its values also decreased, an expected situation due to the greater entry of plant residues on the soil surface, allowing a slow and gradual decomposition of the organic matter in the soil.

The C/N ratio values for the different environments and depth levels are shown in (Table 1). There were no significant differences between the systems or between the depths studied, with an average value of 11.7. Such values demonstrate a higher lability of the residues of these systems. Under semi-arid conditions, residues with a higher N content and lower C/N ratio show a net N mineralization capacity in the soil (Nasrollahi et al., 2021).

Soil nitrogen not only has an important impact on soil carbon sinks through the interaction between nitrogen and soil carbon, but it also has an important impact on maintaining the ecological function of areas with shrubs (Li et al., 2017). Thus, the quantitative assessment of TCStock and TNStock, as well as their dynamics, is crucial for understanding the carbon sink capacity of terrestrial ecosystems (Li et al., 2019).

The Carbon of Light Organic Matter (CLOM) in (Table 2) follows the same behavior as TCStock. The highest value of 2.16 g/kg was found in CS vegetation at depth 0 - 10 cm, with statistical difference from the others in the three depths studied. At depth 0-10 cm the reduction was 49.07% for FPS and 58.3% for the PS area when compared to CS. The FPS and PS had statistically equal results, at depths of 20 - 30 and 50 - 60 cm, with averages for these two systems considered equal. In CS, the values decreased as the depth increased. Loss et al. (2010) also found the highest CLOM values at a depth of up to 10 cm, for areas under Forest-pasture System, indicating a more complex organic material for decomposition.

Table 2. Carbon from Light Organic Matter (CLOM), Fulvic Acid Carbon Stocks (FACStock), Humic Acid Carbon Stocks (HACStock), Humic Fraction Carbon Stock (HFCStock) and Labile Carbon Stock (LCStock) in the three systems studied, at depths 0 - 10; 20 - 30 and 50 - 60 cm.

Systems	Carbon Stocks				
	CLOM	FACStock	HACStock	HFCStock	LCStock
	Mg ha^{-1}	Mg ha^{-1}			
			Depth 0-10 cm		
PS	0.21 Ca	1.18Ba	1.71Ba	3.65Ba	1.07 Ba
CS	0.5 Aa	2.27Aa	5.05Aa	11.13Aa	2.78 Aa
FPS	0.25 Ba	1.29Ba	1.81Ba	4.54 Ba	1.29 Ba
			Depth 20-30 cm		
PS	0.18 Bab	1.03Bab	1.51Bab	3.20Bab	0.94Bab
CS	0.37 Ab	1.68Ab	3.74Ab	8.23Ab	2.05Ab
FPS	0.20 Bb	1.10Bab	1.54Bab	3.86Bab	1.10Bab
			Depth 50-60 cm		
PS	0.15 Bb	0.86Bb	1.26Bb	2.68Bb	0.78Bb
CS	0.23 Ac	1.14Ac	2.53Ac	5.58Ac	1.39Ac
FPS	0.17 Bb	0.94Ab	1.33Bb	3.33Bb	0.95Bb

Averages followed by the same uppercase letter in the column and lowercase in the row do not differ by the Tukey test at 5% probability. PS – Pasture System; CS – Caatinga System and FPS – Forest-pasture System.

According to Oliveira Filho et al. (2017), the high similarity between CMOL and Total Carbon (TC) may explain the low response of CMOL in identifying changes in Organic Matter (OM) between the areas assessed, in addition to indicating a high dependence on CMOL in the content fraction of TC.

Humic substances are among the main components of Organic Soil Matter (OSM), playing a central role in the stabilization of Soil Organic Carbon (SOC) reservoirs and can be classified, according to their solubility, into fractions of humic acids (HA), fulvic acids (FA) and humines (HU). Since the distribution of the OSM composition is a deposit of information about the main processes that occur in the soil (Doupoux et al., 2017; Xu et al., 2018; Tadini et al., 2019).

Carbon stocks in organic matter fractionation followed the same trend as shown in (Table 2). The highest concentration of carbon was in the Humine fraction as expected. The Fulvic Acid Carbon Stock (FACStock) presented the highest averages in CS with 2.27 Mg ha^{-1}, which gradually decreased over the depths, until reaching an average value of 1.14 Mg ha^{-1} in the depth 50 - 60 cm, with a decrease of 49.7%. At this depth, the values were considered equal for CS and FPS. However, in the other depths FPS had averages equal to PS, with a significant decrease in depth from 20 - 30 to 50 - 60 cm.

The Humic Acid Carbon Stocks (HACStock), following the behavior of TCStock, presented the greatest storage in CS at depth of 0 - 10 cm, with a decrease of 64% for FPS and of 66.1% for PS (Table 2). These two systems were considered statistically equal for the three depths studied. Over the depths, the values decreased for CS. In the PS and FPS, they were statistically equal in the first 2 depths and lower in the depth of 50 - 60 cm. The fraction with the highest concentration of carbon also stored the largest amount. The Carbon in the Humine Fraction Stock (CHUStock) followed the behavior line of HACStock. The highest averages occurred in CS, differing significantly from the other environments, which throughout the depths had statistically equal averages. The greatest storage occurred at depth 0 - 10 cm for CS, with 11.13 Mg ha^{-1}, a reduction of 59.2% for FPS and 67.2% for PS. Over the depths, storage decreased for CS; in the other two systems there were equal averages in depth 0 - 10 and 20 - 30 cm, with a decrease only in depth of 50 - 60 cm.

Pulrolnik et al. (2009) studying carbon and nitrogen stocks in labile and stable fractions of organic matter, also found the highest levels of carbon in the humine fraction, at all levels of soil cover studied, a behavior that is associated with the interaction of organic matter with the mineral fraction of the soil. Cardoso et al. (2010) analyzing carbon and nitrogen stocks in soil under native forests and pastures, also found most organic carbon in the humine fraction. This fact is the result of a greater polymerization of humic compounds together with a marked accumulation of Organic Soil Matter (OSM) in natural ecosystems.

Pegoraro et al. (2018), analyzing carbon stocks in humic fractions under different land uses, did not find the largest stocks in preserved native vegetation. At a depth of 0 - 20 cm, the FACStock values were equivalent to a pasture system, where as the HACStock of the pasture was higher than those found in the native forest, showing a totally different behavior. In the depth of 0 - 40 cm, for FACStock, HACStock and CHUStock, there were no significant differences. Pulrolnik et al. (2009) in a Cerrado biome also found equal averages between native vegetation and pasture for FACStock and CHUStock, whereas HACStock had the highest averages in soil under *Eucalyptus*.

The Labile carbon stock (LCStock) had the highest averages in CS (Table 2), differing statistically from the others Systems, with the greatest storage of labile C at 2.78 Mg ha^{-1} occurring at depth 0 – 10 cm. The FPS and PS were considered equal, with a reduction of 53.5% and 61.5% when compared to CS. Along the depths the values descreased for CS in the three depths, while in FPS and PS there was no decrease between depths 0 - 10 and 20 - 30 cm, with a lesser storage in depth 50 - 60 cm. The labile fraction, in turn, showed a high rate of decomposition and a short period of permanence in soil, helping plants through the supply of nutrients and energy. Silva et al. (2011) state that the high carbon content in the labile fraction reflects a fragility in the sustainability of the system, since soil management can enhance the carbon mineralization present in that fraction.

3.2. Microbiological activity

Soil quality refers to the monitoring and evaluation of soil attributes, functions and conditions, including its ability to function within the limits of the ecosystem, sustaining biological productivity and maintaining environmental quality (Legaz et al., 2017; Zhang et al., 2019). Therefore, monitoring the microbiological quality indexes of the systems (Table 3), the carbon of the microbial biomass (CMB) differed significantly for the systems, with the highest average found in CS with a value of 425.54 mg kg^{-1} of C, with a decrease of 55% for FPS and 68% for PS. Similar behavior was found by Santos et al. (2019) studying several land uses in a semiarid environment, where the highest value of CMB was found in the dry tropical forest, however the difference between the means was smaller when the Caatinga areas were converted to trees and intercropped systems. Assis et al. (2019), state that the non-revolving soil contributes to higher levels of CMB in the soil, preserving fungal hyphae and root systems.

The same behavior of means was maintained for the values of Basal Respiration (BR) and microbial quotient (qMIC), with a significant difference between the means, with the highest value for CS, followed by FPS and the lowest averages in PS. In BR there was a decrease of 48% for FPS and 64% for Pasture. The values of the Metabolic Quotient (qCO_2) did not differ between the three systems.

Table 3. Carbon of the Microbial Biomass (CMB), Basal Respiration (BR), Soil Metabolic Quotient (qCO_2) and Microbial Quotient (qMIC), in the three systems of soil use studied, at a depth of 0 - 10 cm.

Systems	MBC	BR	qCO2	qMIC
	mg kg^{-1} C	mg kg^{-1} h^{-1} C-CO_2	mg kg^{-1} h^{-1}	%
	Depth 0 - 10 cm			
PS	133.10 C	0.23 C	1.68 A	1.76 C
CS	425.54 A	0.68 A	1.72 A	2.20 A
FPS	189.33 B	0.35 B	1.86 A	2.00 B

Averages followed by the same uppercase letter in the column and lowercase in the row do not differ by the Tukey test at 5% probability. PS – Pasture System; CS – Caatinga System and FPS – Forest-pasture System.

Pedrotti et al. (2018), studying various land uses in a semiarid environment, pointed out that the more conservationist systems of land use provided better results in microbiological indicators. In this case, the highest mean values of BR were found in treatments with native vegetation of Caatinga and in the treatment with Tanzânia grass intercropped with algaroba (*Prosopis juliflora* (Sw) DC). This indicator reflects the biological activity of the soil, relating the production of CO_2 and the consumption of O_2. As a result, the areas with the highest averages have a higher amount of organic waste in the soil and better structure.

The levels of the microbial quotient (qMIC) were good in all environments (Table 3), since they were above 1%, thus not presenting a limiting factor to microbiological activity and in general the carbon of microbial biomass represents 1 to 4% of organic carbon total (Wang et al., 2021). Therefore, the CS reflects a greater balance resulting from a greater supply of organic matter and consequently carbon.

Similar qCO_2 results were also found by Cherubin et al. (2015), assessing changes in soil quality through physical, chemical and biological indicators, not finding significant differences in treatments with qCO_2. Thus, these values reflect soils with a low level of disturbance, since the microorganisms are sensitive to the degree of disturbance.

4. CONCLUSIONS

The carbon stocks in the studied systems varied between 7.88 Mg ha^{-1} and 25.3 Mg ha^{-1}, while nitrogen stocks varied between 0.70 Mg ha^{-1} and 2.16 Mg ha^{-1}.

The highest averages of carbon and nitrogen stocks were obtained respectively in the CS, FPS and the PS, at all depths studied.

The CS also showed the highest carbon storage averages for fulvic acids, humines and labile carbon.

Finally, among the studied systems, it was demonstrated that most of the chemical and microbial attributes are more sensitive to the advance of land use in the following order: CS - FPS - PS.

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