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Fertility, Microbial Biomass and Edaphic Fauna Under Forestry and Agroforestry Systems in the Eastern Amazon

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1. Introduction

In many countries the rate of deforestation is accelerating. For example, many forest areas of Bangladesh, India, Philippines, Sri Lanka and parts of the rainforest in Brazil could disappear by the end of the century (GLOBAL CHANGE, 2010). The primary forest, especially in the tropics like the Philippines, Malaysia and Thailand such as in Brazil began to be destroyed, because the growth of the agricultural expansion caused a significant decrease in natural resources. Over the past 50 years, the Philippines, there was a loss of 2.4 acres of vegetation every minute, which is attributed to two factors: growth of agriculture and illegal logging

The model of agriculture practiced in Brazil contributes significantly to the expansion of agricultural frontier, increase the production, the productivity and agriculture and the national livestock. However, this performance has led to great reduction of the cover native forest and, consequently, the supply of products of forest origin, besides exposing the lands to loss of fertility, erosion process and water pollution.

In the northeast of Pará state, as in other regions of the Amazon, the intense agricultural activity, with emphasis on removal the primary forest for pasture establishment, agriculture of overthrow and burn, indiscriminate deforestation caused by human activity in terms of economic activities and disorderly logging has been a major factor to accelerate the process of soil alteration.

To mitigate these imbalances, in the Pará state, especially in the northeast region, timber companies, large and small producers located in the cities of Tailândia, Bragança, Igarapé-Açu and Aurora do Pará, began the reforestation on degraded areas in there existent, through use of monocultives and agroforestry systems (ROSA, 2006; RUIVO et al., 2006, SOUZA et al. 2007; RUIVO et al., 2007, CODEIRO et al. 2009; OLIVEIRA, 2009). It was observed that with the reforestation of these areas the quality and quantity of soil organic matter were slow and continuously recovery .

The fertility of the soil, in edaphoclimatic local conditions, is associated with the content of organic matter in the soil (MOREIRA; COSTA, 2004). However the need to seek a sustainable agriculture, the pressure of national and international society requires techniques that protect the agricultural systems After all, the model of traditional agriculture practiced in the Amazon is unsustainable.

For the reduction of land degradation is necessary the use of conservataive techniques to identify the most profitable activities in the region allowing for a harmonious environment coexistence for agricultural economically viable and environmentally sustainable (SOUSA et al., 2007). The challenge is to identify the correct combinations of species to establish synergistic relationships ideals, so that ensure the key ecological services such as nutrient cycling, biological control of pests and diseases and conservation of soil and water (CARDOSO et al., 2005).

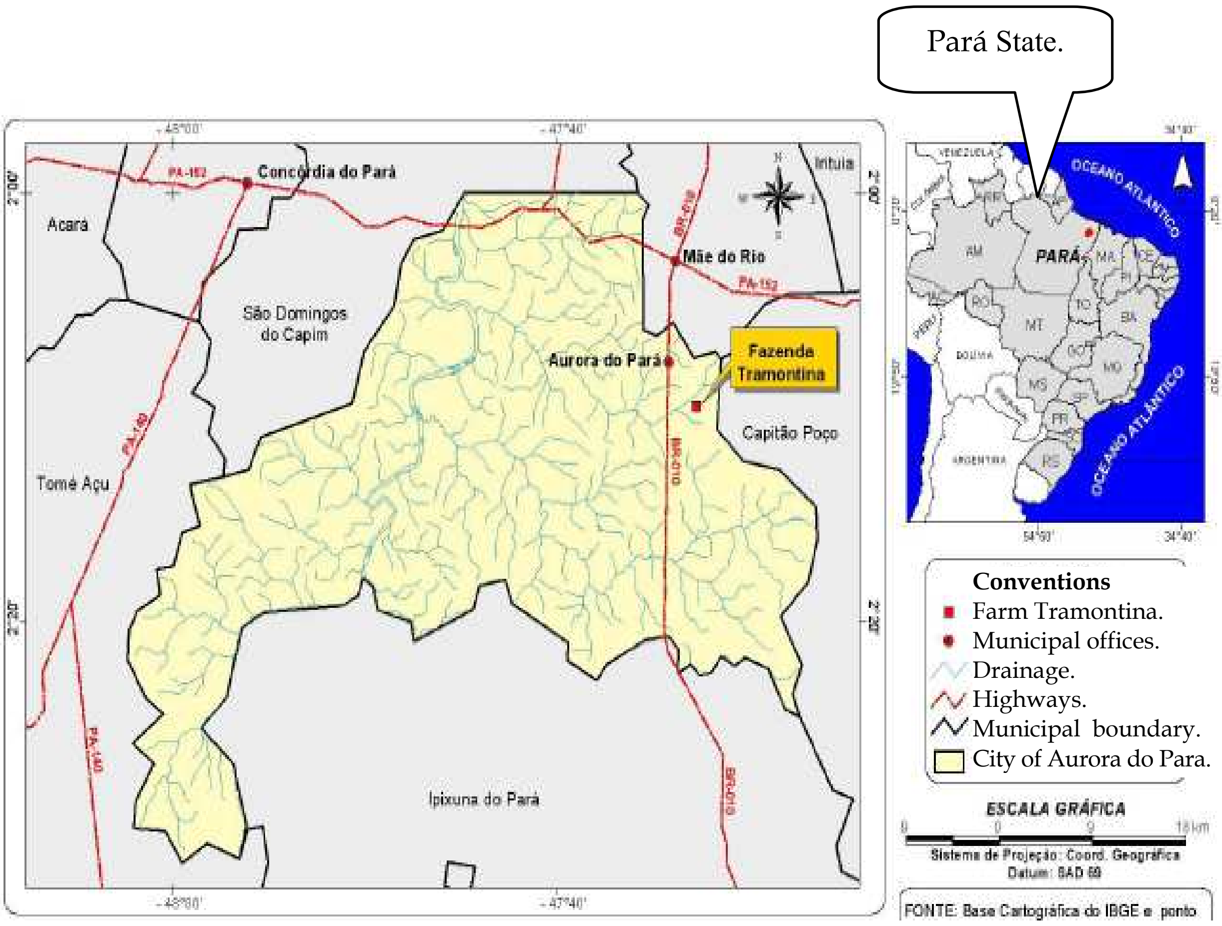
In the state of Para, reforestation with native and exotic species reaches high levels due to the great adaptability of these species in degraded soils. The answers obtained, either in monoculture agroforestry systems, have been effective in the recovery of deforested areas, providing excellent results both for this action as for commercial use, allowing a decrease in aggression to the primary forest and improving the quality of life of populations where this does occur (CORDEIRO, 1999; MONTEIRO, 2004; RUIVO et al., 2007).

Although there are numerous studies on the growth and development of the species native species (CARVALHO, 2004; CORDEIRO, 2007; JESUS, 2004; LORENZI, 2002), comparative studies with the species subjected to different plantation systems and the nutritional behavior of soil in microbiological and biochemists terms are not commonly found in the literature, like as the influence of coverage with different systems involving the vegetables species and their influence on soil quality are still poorly understood. The addition of organic matter to soil, due to stay vegetables residues leads to creation of an enabling environment for better plant development, enhancing microbial activity and consequently the nutritional conditions of the soil. Based on this assumption this research was conducted in the city of Aurora to identifying the soils modifications under physical, chemical and biological properties in areas under reforestation in forestry cropping systems and agro forestry by antropic actions and their impact on edaphic fauna.

2. Materials and methods

2.1 Localization and characterization of the study area

The study was conducted at the Farm Tramontina Belém S/A, located in the city of Aurora do Pará (Figure 1), which belongs to the Mesoregion of Northeast of Pará state and Microregion Bragantina. This area suffered intense anthropogenic changes in the last 50 years due to high extractivist activity, food production and livestock that decimated almost completely their natural vegetation. Over the years a secondary forest (locally known as capoeira) was developed. Despite being a zone considered in environmental impact, this is an area that food supply the capital, mainly grains, greens and vegetables.



Source: Maps IBGE, 2011.

Fig. 1. Map of geographical location of FarmTramontina Belem S/A, Aurora do Pará.

In the locality where this work was developed, a former cattle ranch acquired by an industry of domestic utensils, that was reforested with purposes sustainable economic exploitation and controlled of forest species. The current vegetation is divided in areas of pasture (livestock) abandoned, predominating such as vegetation quicuio-da-amazonia (*Brachiaria humidicola*) among other invasive species, beyond agroforest systems consisting of native species, the main Mogno (*Swietenia macrophylla* King), Paricá (*Schizolobium parayba var. amazonicum* Huber ex Ducke), Freijó (*Cordia goeldiana* Huber) and few exotic, such as eucalyptus (*Eucalyptus* sp) and small areas with secondary forest (capoeira) started around 40 years ago, whose seeds have been used for reforestation native species. The selected capoeiras soil was used as a standard for comparison with the reforestations soil.

The in the region from, According to Thorntwaite (1948) the climate classification in the studied area is type Br A'a, ("humid tropical"). The average annual rainfall is 2,200 mm not equally distributed throughout the year. However, the period from January to June is its greatest concentration (OLIVEIRA, 2009). The average temperature and relative atmospheric humidity are 26 º C and 74% respectively (CORDEIRO 2007, CORDEIRO et al., 2009). Studies conducted in Brazil (CORDEIRO et al., 2009; 2010) allowed to classify the soil in Aurora do Pará area as Yellow Latossol sandy-clay and the occurrence of concretionary laterite levels in some areas, hydromorphic soils along streams and plain relief to gently rolling inserted on the plateau demoted from Amazon. The nutritional characteristics described in these studies show that they have a low supply of available essential nutrients and low tenor in organic matter (CORDEIRO et al., 2010).

2.2 Cropping systems studied

Since the 1990s were planted around 1,043 ha submitted to different types of planting reforestation with the use of species such as Mogno (*Swietenia macrophylla* King) by the great commercial value abroad, Ipê (*Tabebuia heptaphyta* Vellozo), Cedro (*Cedrella fissilis* Vellozo), Jatobá (*Hymenaea intermedia* Ducke var. *adenotricha* (Ducke) Lee & Lang.). Since 1994, the Paricá (*Schizolobium parayba* var. Amazonicum Huber ex Ducke), is the species with high commercial value used in the reforestation because of its applicability in the production of laminates. In 1996 the Freijó (*Cordia goeldiana* Huber) was introduced by the high referential commercial value in Europe. In 2003, was included in the reforestation process in the Tramontina area the Curauá (*Ananas comosus* var. *erectifoliu*s LBSmith), a bromeliad that in the Amazon, has a higher concentration in the municipality of Santarém, beyond the regions of Xingu River, Tocantins, Maicuru, Trombetas, Paru, Acará and Guamá. In the Pará state, the Curauá stands out in the Bragança and Santarém districts (OLIVEIRA, 2009).

The experimental design was completely randomized, with four systems under reforestation and three repetitions in each system. (S1) Monocultivation system with curauá, (S2) agroforestry system with paricá and curauá, (S3) monocultivation system with paricá, (S4) agroforestry system with paricá, freijó, mogno and (S5) varied capoeira (Table 1). All cropping systems such as the capoeira were subdivided into four parcels 24 x 19 m (456 m^2), which totals 1,824 m^2 of area analyzed.

At the time of planting was performed organic fertilization with manure of corral (500g/pit) and bed chicken (150g/pit) for agronomic and forest species, respectively. In the first year of the forestal planting were performed three fertilizations, at 45, 180 and 300 days, using 150 g/pl of the formula NPK 10-20-20. In the planting Curauá, we used 10 g/pl of the formula NPK 10-10-10 at the beginning and end of the rainy season, in the first two years of planting.

Systems	Forest species	Age (years)
S1 Monocultivation	Curauá (*Ananas comosus var. erectifolius* L.B.Smith)	06
S2 Agroforestry	Paricá/Curauá (*Ananas comosus var. erectifolius* L.B.Smith)	06
S3 Agroforestry	Paricá, Mogno (*Swietenia macrophylla* King), Freijó (*Cordia goeldiana* Huber)	08
S4 Monocultivation	Paricá	06
S5 Capoeira varied		15

Table 1. System of crops, forest species and ages of reforestation, in the Farm Tramontina Belém S/A, Aurora do Pará.

In cropping systems with curauá (S1), agroforestry system with paricá, mahogany, freijó (S3) and in the cropping system with paricá (S4) occured just the cut of the grass, that was left on the soil of these cropping systems, no irrigation in any of them. In agroforestry cropping system with paricá/curauá was made fertilization with manure of corral (500 g/pit) and bed chicken (150 g/pit) (CORDEIRO et al., (2009).

2.3 Collection and preparation of the soil samples for physical, chemical and biological analysis

In all locations were collected soil samples deformed and undeformed in December 2009. Samples were collected by opening mini-trenches where soil samples were extracted from the depths: 0-10, 10-20, 20-40 cm, from transects in areas previously determined.

In each study area were collected 3 composite samples of soil from 5 single samples and were stored in plastic bags, conditioned in cool boxes containing ice for stagnate or decrease the microbial activity. The chemical, physical and biological analysis were made by technicians in the soil laboratory of the Museu Paraense Emílio Goeldi - MPEG.

2.4 Collection, preparation and identification of the soil fauna

The Pedofauna collections was performed using kind traps "pitfall-traps" (Figure 2).

These traps were consisted of plastic containers (08 cm x 12 cm) buried in the soil to a depth of 12 cm, with the leaked extremity leveled with the surface of soil, where they remained for three days (AQUINO et al, 2006).

In each plot of each treatment, the same depth, were placed four (04) traps, and inside each one of them, was added 60 ml of the preservative substance: 70% alcohol, distilled water (ratio 3:1, regarding the use of alcohol); biodegradable detergent (3 drops) and formaldehyde (10 ml). The fall of undesirable objects was prevented with a cover plate of polystyrene, supported by small wooden rods (AQUINO et al, 2006). The edaphic fauna, after collected, was taken to the laboratory where they were sieved (0.2 mm) to remove the fragments of plant and residues of soil. The identification of edaphic fauna was at the level of Order, with the aid of a stereomicroscope and the specific literature (BORROR, DELONG, 1988, BARRETO et al., 2008).

Fig. 2. Trap for capturing the edaphic fauna implanted in the Farms of Aurora do Pará, Bragança and Tailândia.

2.5 Determination of the physical and chemical caracteristics of soil

The granulometric composition was determined by densimeter method (EMBRAPA, 1997) and textural classification of soil in each system was performed using the textural triangle (LEMOS & SANTOS, 2006). The soil density (Ds) was determined by the volumetric ring method type Kopecky.

In the characterization of soil were performed the following measurements: total N, by distillation in semimicro Kjeldahl (BREMNER, MULVANEY, 1982), pH in potentiometer in the relation soil:water 1:2.5, organic C, by volumetric method of oxidation with $K_2Cr_2O_7$ and titration with ammonium ferrous sulphate, Ca, Mg and Al exchangeable in extractor of KCl 1 mol L^{-1} and measured in atomic absorption, exchangeable K and Na in Mehlich-1 extraction solution and determination by flame photometry, P available in Mehlich-1 extraction solution and determination by calorimetry, H + Al were extracted with calcium acetate 0.5 mol L^{-1}, pH 7.0 and determined volumetrically with NaOH solution.

From the values of potential acidity (H + Al), exchangeable bases and exchangeable aluminum, the capacity of total cation exchange (CTC) and cation exchange capacity effective (CTCe) were calculated. Relations were also calculated C/N of soil and the organic carbon stock (EstC), using the formula EstC = Corg x Ds x e/10, according to Freixo et al. (2002).

2.6 Determination of carbon (CBM) and nitrogen (NBM) of the soil microbial biomass

We used the fumigation-extraction method to estimate microbial biomass carbon (CBM) (Vance et al., 1987, Tate et al., 1988). The determination of microbial biomass carbon (C-BMS) of the fumigated and not fumigated extracts was made by titration (dichromatometry) according to De-Polli, Guerra (1999). For CBM calculation , the C content of fumigated samples were subtracted from the values of non-fumigated samples, the difference being divided by the value kc = 0.26 (FEIGL et al., 1995). The estimate of Nmic was made from Kjeldahl digestion. The correction factor (Kn) used for the calculation was 0.54 (BROOKES et al. 1985; Joergensen; Mueller, 1996). From the original values were calculated relations between C_{mic} and C_{org} of soil (C_{mic}/C_{org}), and N_{mic} and N_{total} of soil (N_{mic}/N_{total}), by the following equations: $(C_{mic}/C_{org})x100$ and $(N_{mic}/N_{total})x100$, respectively. These indices indicate the fractions of C_{org} and N_{total} that are incorporated in BM, expressing the quality of MOS (GAMA-RODRIGUES, 1999).

2.7 Determination of basal respiration of microbial biomass and the soil metabolic quotient

The basal respiration was estimated by the amount of C-CO_2 released within 10 days of incubation (JENKINSON & POWLSON, 1976). This technique allows the determination of the soil microbial activity, being quantified from the evolution of CO2 produced in respiration of the microorganisms in samples free of roots and possible insects. The metabolic quotient (qCO_2) is calculated as the ratio between the rate of basal respiration and the microbial biomass carbon (ANDERSON & DOMSCH, 1993).

2.8 Statistical analysis

The two-way ANOVA was used to verify differences between the cropping systems studied. When found a significant (5%), the averages of each variable were tested by the

Tukey test ($p < 0.05$). Additional analysis was also the determination of principal components (PCA) and cluster analysis to determine the degree of correlation between physical, chemical and biological data to be analyzed by soil grouping. Them, according to the variation of its characteristics a multivariate analysis can be use.

3. Results and discussion

3.1 Physical and chemical properties of soil under forestry and agroforestry systems

The production systems studied showed differences in soil physical properties. The type of soil in cropping systems S1 (monocultivation with curauá), S3 (agroforestry system with paricá, mogno, freijó and curauá) and S4 (monocultivation with paricá) is classified as franc sandy loam and only in the S2 (agroforestry system with paricá and curauá), presented soil type franc sandy clay (Table 2). Study conducted in a Latossoil in the Amazon (SILVA JUNIOR et al, 2009) showed that the study of this aspect of the soil is important because it is related to the dynamics of organic matter. This justifies the textural classification made in our study.

NOTATION	**DPT (cm)**	**Ts**	**Fs**	**Cl**	**S**	**RSC**	**TC**	**Ds**
			g/kg					g/cm^3
	0 - 10	729	157	68	46	0,67	S L	1,50
S1	10 - 20	716	147	83	54	0,65		1,43
	20 - 40	610	160	137	93	0,67		1,54
MEAN	**---------**	**685**	**155**	**96**	**64**	**0.66**		**1.47**
	0 - 10	491	189	184	136	0,73	S C	1,37
S2	10 - 20	408	169	289	134	0,46		1,62
	20 - 40	362	149	343	146	0,42		1,60
MEAN	**---------**	**420**	**169**	**272**	**139**	**0.54**		**1.53**
	0 - 10	687	148	80	85	1,06	S L	1,42
S3	10 - 20	672	130	80	118	1,47		1,58
	20 - 40	627	156	122	95	0,77		1,51
MEAN	**---------**	**662**	**145**	**94**	**99**	**1.10**		**1.50**
	0 - 10	651	204	96	49	0,51	S L	1,36
S4	10 - 20	630	222	80	68	0,85		1,48
	20 - 40	588	170	90	152	1,68		1,57
MEAN	**---------**	**623**	**199**	**90**	**88**	**1.01**		**1.47**

DPT: Depths; **Ts**: thick sandy; **Fs:** fine sand; **Cl:** clay; **S**: silt; **RSC**: relation silt clay; **TC**: textural classification; SL: Sandy loam; SC:Sandy clay; **Ds:** density of soil.

Table 2. Granulometry, textural classification and density of soil of cropping systems studied. Farm Tramontina Belém S/A in Aurora do Pará.

With regard to the clay content in the culture system S2 (agroforestry system with paricá and curauá), in the depth from 0 – 10 cm high levels were detected when compared with other systems in this same depth, as shown in Table 2. Study conducted (LAVELLE et al, 1992) in the humid tropics, showed as a result a lateral variation in the soil granulometry and, according to the researchers, this may influence the training capacity of the stocks of exchangeable cations on the surfaces of colloids, this case, clay mineral. Then, the results found in this study for the S2 cultivation system may be indicative of the improved in the capacity of formation of the exchangeable cations.

The lowest content of clay fraction occur in the cropping systems S1 (monocultivation with curauá), S3 (agroforestry system with paricá, mogno, freijó and curauá) and S4 (monocultivation with paricá). The value for the lowest average was found in the cropping system S4 compared with the other cropping systems studied. Freire (1997) reports that the natural fertility of the soil depends on the adsorptive capacity of clay-minerals and organic colloids, with that, it's possible to affirm that in the cropping system S4, despite the low clay content, there are adsorption capacity and organic colloids in balance that allows the maintenance of natural soil fertility of this cropping system.

The relation silt *versus* clay proved to be higher in the cropping system S3 (Table 2), this demonstrates that the degree of weathering occurred in this area decreases with the depth, ie, the degree of weathering of the soil is high, as occur in the Latosoils.

The analysis of soil density showed that, among the systems studied, soil is more dense in the cultivation system S2 (agroforestry system with paricá and curauá). But, as pointed out Santana et al. (2006) density can be an attribute for analysis on the cohesion of the soil horizons, however there is a limitation for such use, ie, the density of the soil suffers from interference of granulometry that can presents high values, this would correspond to cohesive horizons, and this would affect the penetration of root of vegetables.

In this aspect, it was verified that, in the cropping system S2, the density is more pronounced between 10 to 20 cm when compared with other systems. In addition, this cultivation system, based on the exposed by Santana et al. (2006), we can consider this soil as "cohesive" as a results contained in Table 2.

The results indicate very low acidity ($pH > 4.5$), and as clay-minerals react with water from the soil, absorbing $H +$, this may explain the variation of acidity occurred in the cropping system S2, although present statistically significant effect. Was verified that in the cropping systems S1 (curauá monocultivation) and S3 (agroforestry system with paricá, mogno, freijó and curauá) the pH value, on average, has no statistically significant effect (Table 3). This can be explained by the content of total clay and sand which is also equivalent between them, as shown in Table 2.

In the cropping system S4 (paricá monocultivation), the pH was found to be constant in the three depths, and this may be due to small variations in the levels of sand and clay that were lower compared to other cropping systems, and this may explain the decrease of pH value in relation to the cropping system S2 and a slight increase in relation to cropping systems S1 and S3 (Table 2).

The tenors of Corg in cultivation system S2 (agroforestry system with paricá and curauá) were superior to other treatments evaluated (Table 3), even with scarce cover vegetation. Study conducted (Silva Junior et al, 2009) in Amazonian Oxisols after transformation to pasture, showed that carbon concentrations are high in clay soils, independent of vegetation cover. But the most plausible explanation is provided by Cordeiro et al. (2009), because the authors report that the area where this system of crops is located was fertilized with cattle manure (500 g/pit) and bed chicken (150 g/pit). This proves that even on degraded land, the use of organic cover helps soil fertility and improving the quality of it (Monteiro, 2004).

In the systems studied, we observed that the Corg content decreases according to depth and clay content (Table 2) in the depth of 0 - 10 cm, the Corg content of the soil surface within the studied systems are high. The research conducted about the relation of Corg contents and soil depth (Dejardins, et al. 1994; Koutika et al., 1997) showed that the trend of content of Corg is in decreasing accordance with increasing depth. This pattern of behavior on the content of Corg was observed in our study. Study carried out in a toposequence in central Amazonia (Marques et al., 200) report that the Carbon content are high in the surface layers to 25 cm (4.48 ± 0.08). Then, the high content of Corg found in cropping systems study corroborates the assertion of those authors.

The highest average of Carbon stock was found in the cultivation system S2 (Table 2), where was found the highest granulometric average, especially the clay and Ds. In descending order, the cultivation system S1 has the second highest average. In the cultivation systems S3 and S4 the average of carbon stock decreases, although the clay content is approximate to that contained in the cropping system S1. However the content of sand has an average ranging from 800 to 840 g/kg, and the variation in average clay content is between 90 and 96 g/kg (Table 1). This may be one explanation for the carbon stocks present a decrease in average of these treatments compared in the cropping system S2 (Table 2).

NOTATION	DPT	**pH**	**Corg g/kg**	**Cs**
	(cm)			Mg C.ha^{-1}
S1	0 - 10	4.5	13,84	20.76
	10 - 20	4.4	11,70	33.46
	20 - 40	4.1	6,90	42.50
MEAN	**---------**	**4.3**	**10.81**	**32.24**
S2	0 - 10	4.9	24,52	33.61
	10 - 20	4.9	12,96	41.99
	20 - 40	5.0	7,04	45.05
MEAN	**---------**	**4.9**	**14.84**	**40.22**
S3	0 - 10	4.4	8,59	12.02
	10 - 20	4.3	7,89	24.93
	20 - 40	4.3	7,73	46.68
MEAN	**---------**	**4.3**	**8.70**	**27.88**
S4	0 - 10	4.4	9,88	13.34
	10 - 20	4.4	7,38	21,84
	20 - 40	4.4	5,83	36.31
MEAN	**---------**	**4.4**	**7.07**	**23.93**

DPT: Depths; **Corg**: carbon organic; **Cs**: Carbon stock.

Table 3. Values pH (H_2O), tenors of carbon organic (Corg in g/kg) and carbon stocks (Mg C.ha^{-1}).

3.2 Relation between physical and chemical attributes

The result of the correlation (r) between the high content of Corg, clay and sand fraction in the cropping system S2, showed an increasing content of Corg in this cropping system (Table 4).

Attributes analyzed	Total clay (g/Kg)	Sand (g/Kg)	Ds (g/cm^3)	Relation Silt x clay
pH	0.98 ($p < 0.05$)	- 0.98 ($p < 0.05$)	0.77 (ns)	- 0.66 (ns)
Corg (g/kg)	0.81 (ns)	- 0.57 (ns)	0.90 (ns)	- 0.88 (ns)
Carbon stock (Mg C.ha^{-1})	0.82 (ns)	- 0.75 (ns)	0.86 (ns)	- 0.92 (ns)

Corg: carbon organic; Ds: Density of soil.

Table 4. Analysis of canonical correlation between the physical and chemical attributes of soil in the cropping systems studied. Farm Tramontina Belém S/A in Aurora do Pará.

Study ever done on the relation Corg versus clay content (TELLES, 2002) explained that high clay content allows the formation of macroaggregates and microaggregates that promote physical protection to the Corg, and avoid rapid decomposition of the same. Correlating this result with what was obtained in our study; it is possible to explain the high content of Corg found in S2 culture system, using the same argument. As for the stock of carbon (Cs) results showed that this stock decreases in relation to the increased depth in cropping systems studied.

The determination of the hierarchical clustering (HCA) revealed a approximated relation between physical and chemical attributes of soil subjected to analysis, because, according to Barreiro & Moita Neto (1998) this suggests a correlation between the variables of this data set. The results (Figure 3) show that there is formation of two groups where in the group A there was a split in the A1 and A2. In this group there was a correlation between the pH - Ds (Group A1), Ds - Silt/Clay (group A2) and Silt/Clay - Corg (group A3).

Another group, silt and clay (group B), confirm that these two variables are heterogeneous with respect to those that make up Group A. These results show that there is variability in the functioning of studied soils in the cropping systems SI, S2, S3 and S4. S3 and S4 are more similar across pH and relation attributes of silt/clay. The cultivation system S1 showed lower similarity with cropping systems S3 and S4 for the same attributes. Thus, one can verify which variables that differentiate the systems studied each other and can interfere or not in the edaphic fauna.

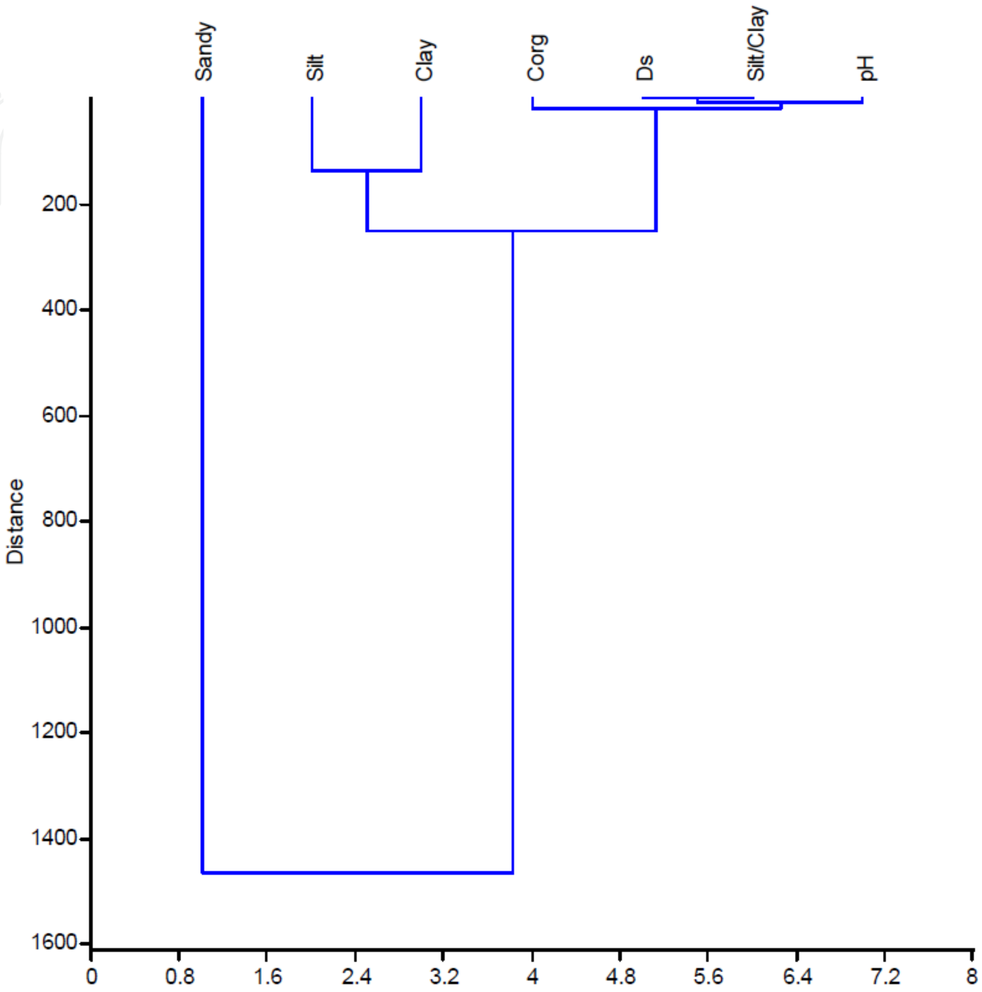


Fig. 3. Grouping of physical and chemical attributes of the cropping systems studied. Farm Tramontina Belém S/A. Aurora do Pará.

3.3 Microbiological attributes

The average content of microbial biomass carbon (CBM) (Figure 4) and the values of the microbial quotient (qMIC) (Figure 5) were higher in the system S4 and S5. In the system S4 the soil was covered with coarse vegetable waste, besides presenting a spontaneous vegetable regeneration between the lines of planting paricá such factors may have favored the maintenance of microorganisms in the soil and therefore increase the microbial carbon content.

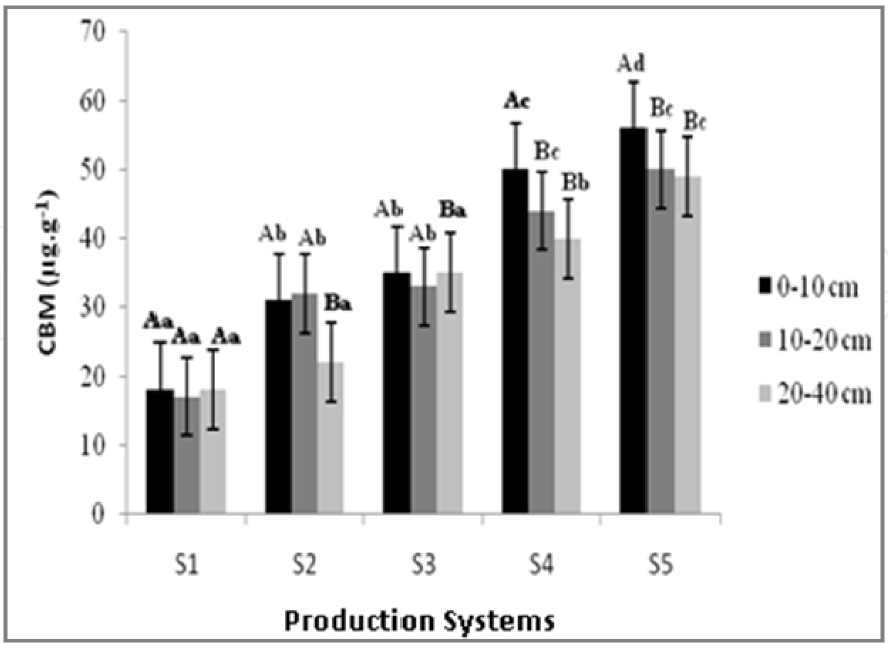


Fig. 4. Values of microbial biomass carbon (CMB) in different production systems.

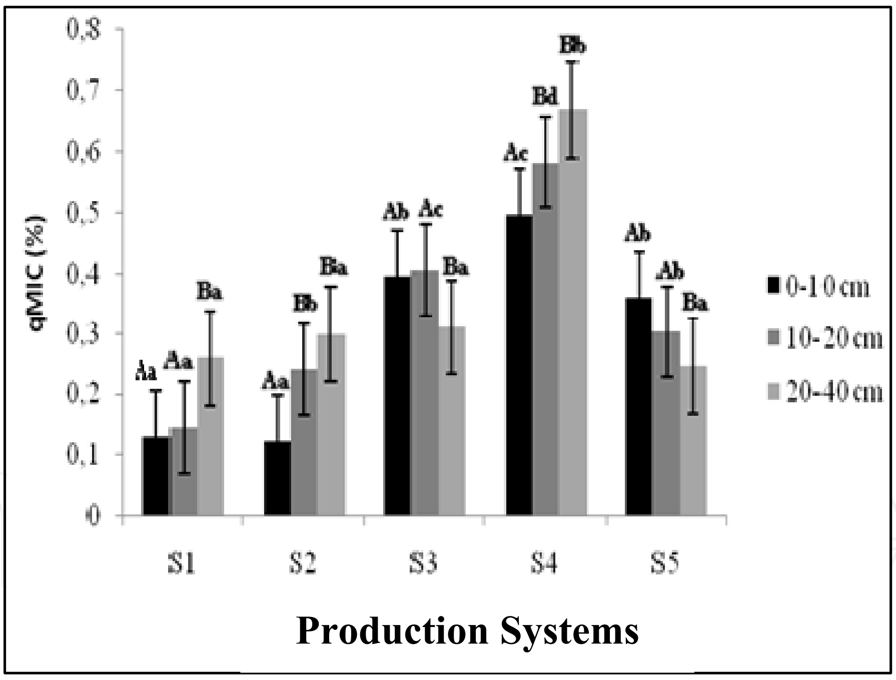


Fig. 5. Values of microbial quotient (qMIC) in different production systems.

For the attribute qMIC very low values were obtained, except in the S4 system, where it was recorded the highest values of qMIC, especially in the layers of the first depth of soil. Jenkinson & Ladd (1981), considered normal that 1-4% of total soil C corresponds to the microbial component, how the collection was done during the dry season, and it is known that water is an important element for microbial activity, it is possible that low values are justified by this fact.

Overall, the results indicate that the incorporation of organic matter is favoring the edaphic conditions and the different systems, especially the S3 and S4 suffering the biggest addition of organic matter, equaling the soils are of capoeira, eventually tending to an equilibrium (OLIVEIRA, 2009; BERNARDES, 2011, PEREIRA Jr, 2011). The Table 5 presents the principal components that shows this relationship. It's possible verify that saturation of bases (V), EC, aluminum saturation (m), Na, and Al were the variables that showed more differences between the systems. In systems S2 and S3, the values of these attributes, in general, are more similar to those found in capoeira.

Attributes	Principal components				
	Comp. 1	Comp. 2	Comp.3	Comp.4	Comp.5
pH	-0,027	0,144	**0,419**	0,195	0,204
Al	**-0,273**	0,003	**-0,314**	0,005	-0,016
H+Al	**-0,303**	0,075	-0,180	-0,018	0,055
Ca	-0,235	**-0,253**	-0,160	0,152	-0,059
Mg	**-0,294**	-0,171	0,119	0,017	-0,008
K	**-0,290**	-0,180	0,095	-0,047	0,032
P	-0,114	**0,371**	-0,206	-0,07	0,071
Na	**-0,254**	0,042	0,091	**0,458**	-0,084
SB	**-0,298**	-0,182	0,074	0,037	-0,024
CTC $_{ef}$	**-0,312**	-0,095	-0,143	0,021	-0,019
CTC $_{pH7}$	**-0,324**	-0,03	-0,086	-0,022	0,022
V%	-0,099	**-0,303**	**0,300**	0,243	-0,063
m%	0,111	-0,176	**0,406**	**-0,326**	-0,064
Cot	-0,164	**0,303**	0,231	0,030	-0,199
EC	-0,126	**0,308**	0,048	**-0,421**	0,002
NT	-0,147	0,153	**0,433**	0,008	-0,161
C/N	-0,132	**0,358**	-0,086	0,036	-0,123
CBM	0,158	**0,304**	-0,018	**0,484**	-0,035
NBM	-0,065	-0,011	0,064	0,02	**0,908**
*q*MIC	**0,279**	-0,078	-0,134	**0,366**	0,031

Table 5. Correlation coefficients between original variables of response and principal components.

The principal component 1 (Comp. 1), that explains 54.00% of the variability of the data, presents the highest correlation for the SB, K, Mg, CEC, Ca and H + Al. The largest negative correlations, which also showed low values occurred with the CBM and qMIC. The principal component 2 (Comp. 2) explains 21.9% of the variability and has the highest correlations for P and COT. The largest negative correlation occurred with the V%.

The principal component 3 (Comp. 3), that explains 12.2% of the variability, presents the higher correlations for P and Ca, and the largest negative correlations were found for pH and COT. In the case of principal component 4 (Comp. 4) explains 5.2% of the variability and was negatively correlated for almost all attributes except for COT. Among the negative correlations stand out CBM qMIC and Ca.

3.4 Edaphic fauna of the forestry system and agroforestry

The faunistic analysis performed on the Farm Tramontina Belém S/A, recorded 2.568 specimens distributed in eighteen (18) taxon of invertebrate and one (01) taxon of vertebrate of the Order Squamata (Gekkonidae) (Table 6) in five culture systems studied, where the prevailing order was Hymenoptera, composed mainly by family Formicidae with 2.151 individuals followed by Coleoptera (78), Collembola (40), Homoptera (67) and Diplopoda (74).

	SYSTEMS						
	S1	S2	S3	S4			
TAXONS	Fi				Total	Fr (%)	(Mean)
INSECTA							
Hymenoptera (Formicidae)	808	667	416	260	2.151	82,82	537,75
Coleoptera	21	15	27	15	78	3.0	19,5
Collembola	6,0	11	21	2,0	40	1.54	9.75
Diptera	13	1,0	11	5,0	30	1.15	7,50
Hemiptera	0,0	1,0	0,0	0,0	01	0.03	0,25
Homoptera	9,0	10	34	14	67	2.57	16,75
Blattariae	0,0	2,0	0,0	2,0	04	0.15	1,00
Odonata	0,0	0,0	1,0	0,0	01	0.03	0,25
Orthoptera	2,0	3,0	5,0	12	22	0.84	5,50
Psocoptera	1,0	0,0	3,0	3,0	07	0.26	1,75
Lepdoptera	0,0	28	0,0	0,0	28	1.07	7,00
Thysanoptera	0,0	0,0	1,0	0,0	01	0.03	0,25
ARACHNIDA							
Acari	8,0	28	14	5,0	55	2.11	13,75
Aranae	3,0	2,0	4,0	6,0	15	0.57	3,75
Opilionida	4,0	3,0	7,0	0,0	14	0.53	3,50
CRUSTACEA							
Isopoda	0,0	1,0	0,0	0,0	01	0.03	0,25
MYRIAPODA							
Chilopoda	1,0	0,0	1,0	0,0	02	0.07	0,50
Diplopoda	17	12	15	30	74	2.84	18,5
SQUAMATA							
Gekkonidae	1,0	3,0	3,0	1,0	08	0.30	1,25
Total	894	785	563	355	2.597	100	

Ordination of taxons second Brusca & Brusca, 2007.

Table 6. Taxons identified, absolute frequency (Fi), relative frequency (Fr) and average of individuals in the cropping systems studied in the Farm Tramontina Belém S/A in Aurora do Pará.

The Diplopoda taxon is present in all treatments, but the highest concentration is in the systems of monocultivation (S1 and S4). In a study of community of invertebrates in litter in agroforestry systems, this order was the second most important (Barros et al., 2006). This importance is due to mobility that they present in the soil, surface and underground, which influences the physical nature of the soil changing porosity, moisture and transport of substances (Correia; Aquino, 2005).

The order Acari is a grouping of vertical habitat in three levels, euedaphics, hemiedaphics and epiedaphics, and the epiedaphics are more tolerant to desiccation (Lavelle & Spain, 2001), although there is low frequency of individuals, it is higher when compared with those obtained in studies in savannas of Pará (Franklin et al., 2007).

Ants have been widely used as biodindicadores in various types of impacts, such as recovery after mining activities, industrial pollution, agricultural practices and other land uses (Smith et al, 2009). In addition, the class Insecta, which belongs to the ant, often grouped according to trophic groups, and the availability of nutrients in the ecosystem (Leivas & Chips, 2008). They are important in below-ground processes, by altering the physical and chemical properties and the environment, its effects on plants, microorganisms and other soil organisms (Folgarait, 1998).

These may be the possible explanations for the faunistic results of this taxons (Hymenopetera) Family Formicidae, with the highest absolute frequency (Fi) in the cropping system S1 (curauá in monocultivation) and lower absolute frequency in the cropping system S4 (paricá in monocultivation) as well as in other culture systems studied (Table 7).

Adult and immature Coleoptera, Collembola, Diplopoda, Diptera and Homoptera adults had higher absolute frequency in the cropping system S3 (paricá + mogno + freijó + curauá) (Table 7). This may show a variety nutritional or of habitat, or still an increase in the prey - predator relation. The same was not found in the monocultivation systems for these taxons.

Macroarthropods of soil has an important role in tropical terrestrial ecosystems, exerting a direct influence on the formation and stability, an indirect influence on the decomposition process through strong participation in the fragmentation of necromass (ARAUJO; BANDEIRA; VANSCONCELOS, 2010). Work already carried out in terra firma forest ecosystems in the state of Pará, also found the presence of Hymenoptera, Coleoptera, Collembola, Homoptera, Acari and Diplopoda, grouped or not (Macambira, 2005; & Garden Macambira, 2007; Ruivo et al. 2007), which corroborates with the edaphic fauna found in Aurora do Pará

The greatest diversity of species occurred at S3 (Table 7), this can be attributed, among other factors, the variety of nutrients, because S3 is an agroforestry system where there is occurrence of paricá, mogno, freijó and curauá. In addition, there may be no natural predators of these species or still the ephemeral life cycle leads to a reproduction in greater numbers, but these factors were not analyzed in this study.

The lowest levels of the Shannon-Wiener diversity, therefore the greater species diversity occurred in the cropping system S1 (curauá in monocultivation) and S2 (agroforestry system paricá + curauá). This may be due to movement of other species of invertebrates through of ecotones that over there exist. It is possible that this displacement has occurred in search of food or place to reproduction, or even to escape from possible predators in areas near to these cultivation systems. It should not be ruled out the hypothesis that the curauá produces some substance that is palatable to invertebrate species diversity and this is a nutritional option for them because this plant is present in both cropping systems that had the lowest diversity indices of Shannon -Wiener.

	Systems			
	S1	S2	S3	S4
Diversity index (H’)	0,22	0,26	0,51	0,48
Population density (individuals/m^2)	0,69	0,58	0,43	0,26

Table 7. Diversity index Shannon-Wiener (H') and population density found in cropping systems studied at Fazenda Tramontina Belém S/A in Aurora do Pará.

The highest indexes of diversity of Shannon-Wiener occurred in cropping systems S3 (parica + magno + freijó + curauá) and S4 (parica in monocultivation). This shows lower diversity of species, although in S3 there is differents plant species, which would cause nutritionals offerings and different habitats, and this would promote greater diversity of species. Study performed about plant diversity and productivity of plants and the effects on the abundance of arthropods (Perna et al, 2005) showed that productivity in the plant structure, local abiotic conditions, physical disorders of the habitats are factors that interact with the diversity of plants and which also influences the abundance of arthropods. This can be an explanation for the low diversity found in the cropping system S3 in our study.

In S4, occurs monocultivation with paricá. This features a lower nutritional diversity and of habitats, which in turn attracts lower diversity of macrofauna, especially ants. Suggest the hypothesis that this plant produces some substance not palatable or that act on the reproductive cycle in the majority of taxons identified. It is also possible that there are a greater number of predators in relation to other systems cultivation studied, or even occurred edaphic variations that did not allow the diversity of species and greater population density because this cropping system, the highest number of absence (seven taxons) among the eighteen taxons identified (Table 6). When the population density, the highest concentration indivíduos/m^2, occurs in S1, where there is a monocultivation of curauá. As this culture system does not present sub-forest for vegetal cover and shading that would mitigate the temperature at the soil surface, it is possible that the solar radiation incident directly on the ground promotes an increase in photosynthetic rate, increasing the supply of nutrients, as well as raises the temperature of the same and is one of the factors that contribute to the reproduction of these ants (Harada & Banner, 1994, Oliveira et al., 2009). But do not dismiss as a possible explanation for the results obtained in two cropping systems, the hypotesis of correlated interferences, for example, environmental variables, ephemeral life cycle, presence or absence of predators, temperature, precipitation, brightness, among other variables in this study were not analyzed.

3.5 Edaphic fauna and attributes of soil

The relation between edaphic fauna and soil attributes (pH, Corg, Ds, relation silt/clay) is shown in Figure 6.

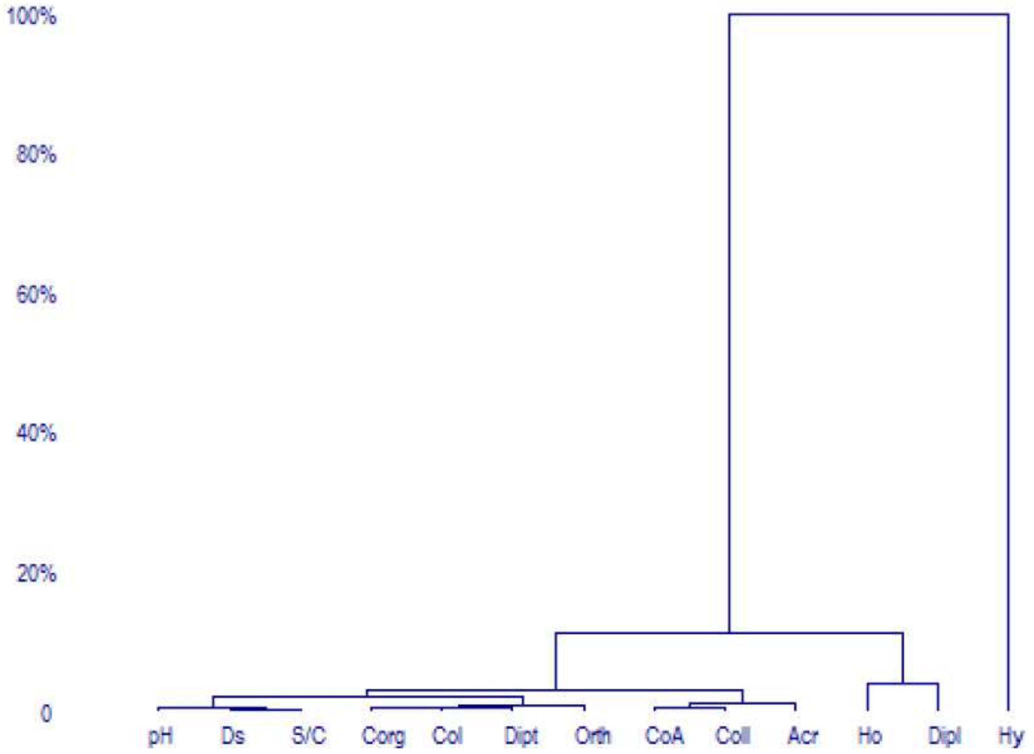


Fig. 6. Grouping between edaphic fauna of greater absolute frequency in the studied treatments, physical and chemical attributes of soil. Campo Experimental of the Tramontina Belém S/A. Corg = carbon organic; S/A = relation silt/clay, Ho = Homoptera; CoA = Coleoptera adult; dipl = Diplopoda; CoI = immature Coleoptera, Coll = Collembola; dipti = Diptera; Orth = Orthoptera; Acr = Acari; Hy = Hymenoptera.

The results showed that (I) the immature Coleoptera taxon has high similarity to the taxon Collembola and constitutes the group 1; (II) the taxon Diptera presents similarity to the taxon Orthoptera and constitute the second group. The group 2 has similarity with group 1, (III) the taxon Acari presents similarities with groups 1 and 2, constituting the third group, (IV) the taxon Coleoptera adult presents similarity to the taxon Diplopoda, constituting the group 4. (V) Groups 1, 2 and 3, have similarity to group 4. (VI) the taxon Homoptera has similarity as group 4, thus constituting the group 5. (VII) Groups 1, 2, 3, 4 and 5 they correlate with the physical attributes (Ds, relation silt/clay), but did not correlate with the chemical attributes (pH, Corg).

The taxon Hymenoptera showed that is not correlated with the physical attributes: Ds and relation silt/clay, and neither with chemical attributes: pH and Corg. Also has no similarity to other taxons analyzed. But it is possible that other edaphic variables correlate with this taxon, but these were not objects of the present study.

Ants have been widely used as biodindicadores in various types of impacts, such as recovery after mining activities, industrial pollution, agricultural practices and other land uses (Smith et al, 2009). In addition, the class Insecta, which belongs to the ant, often grouped according to trophic groups, and the availability of nutrients in the ecosystem (Leivas & Chips, 2008). They are important in below-ground processes, by altering the physical and chemical properties and the environment, its effects on plants, microorganisms and other soil organisms (Folgarait, 1998).

These may be the possible explanations for the faunistic results of this taxons (Hymenopetera) Family Formicidae, with the highest absolute frequency (Fi) in the cropping system S1 (curauá in monocultivation) and lower absolute frequency in the cropping system S4 (paricá in monocultivation).

The order Acari has the major absolute frequency in S2 (Table 3), maybe has better adaptability to the SAF, and the physical attributes shown in Figure 5, which may also is occurring with Homoptera, Collembola and Coleoptera immature. Even in this agroforestry system, the absolute frequency of the taxon Coleoptera, Hymenoptera and the population density decreases, according to data contained in Table 4. This may be related to the increase of soil density and decrease in the silt/clay relation contained in Table 2.

With the modifications imposed by use of soil, particularly by agriculture, the fauna and the microorganisms, in different degrees of intensity, are affected by the impacts caused by agricultural practices, that may alter the composition and diversity of soil organisms.

The addition of new organic matter through the incorporation of waste or the maintenance of forest cover (using the agroforestry system, with or without burning the area) or even a diversified system (as occur in Aurora do Pará), show the importance of maintenance, incorporation and slow decomposition of organic matter on the ground.

So far, the studies show that the types of management adopted did not influence negatively the characteristics of soil and that adding of diversified organic matter in the soil, the retention and incorpration and slow decomposition of these residues led to the creation of an edaph-environment favorable to the maintaining soil quality.

The set of attributes of the soils here studied, especially those related to microbial biomass and chemistry, was adequate to indicate the quality of the substrate. However, the continuation of this kind of work, in the long term, it is necessary, in order to identify differences in biological characteristics of soil between the different management systems, especially taking into account the local climatic variation. Thus, it is necessary to intensify studies of the seasonal variation of soil attributes, the variables listed as indicators of soil quality and intensify the studies in determinated practices of management, such as the tillage and the SAF as potential in the carbon sequestration.

4. Conclusions

The result show that the types of management adopted did not influence negatively the characteristics of soil and adding organic matter to the diverse soil, retention and development and slow decomposition of these residues led to the creation of an edafoambiente of maintaining soil quality. The set of attributes of the soil studied here, especially those related to microbial biomass and chemistry, was adequate to indicate the quality of the substrate. However, the continuation of such work in the long term and different climatic conditions, it is necessary, in order to identify differences in biological characteristics under different soil management systems, especially taking into account the local climatic variation.

The Paricá (*Schizolobium amazonicum* Huber (Ducke)) is a viable native species for recuperation of disturbed areas and with detach in the wood market, nationally and internationally. Its rapid growth and adaptation to areas with low nutrient levels allow it to be optimum in agroforestry, being the second plant species used in reforestation in the Para state , and primarily designed for industry of lams rolled. Thus, it is necessary to intensify studies of the seasonal variation of soil attributes, the variables listed as indicators of soil quality and enhance studies in certain management practices such as tillage and the SAF as a potential in carbon sequestration.

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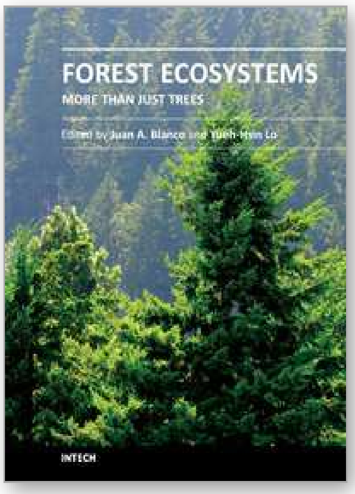

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The common idea for many people is that forests are just a collection of trees. However, they are much more than that. They are a complex, functional system of interacting and often interdependent biological, physical, and chemical components, the biological part of which has evolved to perpetuate itself. This complexity produces combinations of climate, soils, trees and plant species unique to each site, resulting in hundreds of different forest types around the world. Logically, trees are an important component for the research in forest ecosystems, but the wide variety of other life forms and abiotic components in most forests means that other elements, such as wildlife or soil nutrients, should also be the focal point in ecological studies and management plans to be carried out in forest ecosystems. In this book, the readers can find the latest research related to forest ecosystems but with a different twist. The research described here is not just on trees and is focused on the other components, structures and functions that are usually overshadowed by the focus on trees, but are equally important to maintain the diversity, function and services provided by forests. The first section of this book explores the structure and biodiversity of forest ecosystems, whereas the second section reviews the research done on ecosystem structure and functioning. The third and last section explores the issues related to forest management as an ecosystem-level activity, all of them from the perspective of the �other� parts of a forest.

How to reference

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