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Seasonality influence the nutrient content of litter fall in secondary forest in the Amazonian

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Secondary forest vegetation in the Bragantina area, Northeast of Pará State, is characterized by the abandonment of anthropized forests, locally known as capoeiras, in different successional stages. The current study aims to evaluate the nutrient concentrations in order to identify the treatment that have caused greater nutrient deficiency due to full and partial litter spacing well as to assess the capoeira with best nutrient cycling performance. The study area is located in 10-and-40-year-old secondary forests in Bragança County, Benjamin Constant community, Northeastern Pará State. Litter samples were collected during the dry and rainy seasons. The chemical analysis of the macro and micronutrients were further performed. The decreasing order of the herein observed nutrient concentration was N> Ca> Mg> In> K> P. By taking under consideration the 40-year-old capoeira and the treatments applied to the 10-year-old one (no thinning (NT), partial thinning (PT), and total thinning (TT)), it is possible to state that the highest concentrations in all analyzed elements showed the same descending order in micronutrient concentrations: Fe> Mn > Zn> Cu. The different-aged capoeiras within the Bragantina area showed that not all nutrients were influenced by seasonality, despite the applied thinning type, the vegetation age and the forest species.

Key words: Cycling, nutrients, amazon, Northeastern Pará, Capoeira, thinning.

INTRODUCTION

The increased land abandonment after agricultural use as well as the opening of new forest areas form a

landscape mosaic in different successional stages. It is necessary to conduct nutrient cycling studies due to the

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importance and extent of this vegetation type, since the limited nutrient availability is one of the main factors influencing the recovery dynamics of the different successional stages, after agricultural use abandonment. Kauano et al. (2012) valuated that 83% of the total area of this conservation are dominated by forests, of which 68.5% was by the Dense Ombrophilous Forest physiognomy, and 9.5% refer to secondary forests.

Forty-three percent (43%) out of the total capoeira areas in Brazil belong to Pará State and 37% of them belong to Tocantins State. The other states in order of importance are Amazonas and Rondônia (both with 7%), Roraima (3%), Acre (2%) and Amapá (1%). The total capoeira area corresponds to scale 8% of the total lands and agriculturally and 17% of the lands used in agricultural activities and forestry in the Amazon region (Costa et al., 2006). Although secondary forests are considered to be a partially degraded vegetation, it does not mean that they are unsuitable for agricultural or forestry activities, since they have social, economic and environmental values.

Plant micronutrients, which include B, Cl, Cu, Fe, Mn, Mo, Ni and Zn are required by plants at very low concentrations for proper growth and reproduction. However, despite their concentrations within the tissues and organs of plants, micronutrients have the same importance of macronutrients for their nutrition. In these low concentrations, micronutrients are key to growth and the development of plants, acting as constituents of the walls (B) and cell membranes (B, Zn), as constituents of enzymes (Fe, Mn, Cu, Ni), as enzyme activators (Mn, Zn) and photosynthesis (Fe, Cu, Mn, Cl) (Kirkby et al., 2007)

Information on the distribution and flow of nutrients in different forest compartments are obtained by studies focused on nutrients cycling within the ecosystem (Laclau et al., 2010; Viera and Schumacher, 2010). Some works involving deposition of litter and cycling of nutrients in secondary succession have been developed in the various phytophysiognomies of the Dense Ombrophilous Forest.

The total transfer of macronutrients to the soil through forest litter deposition was studied by Schumacher et al. (2008) and they found the following values: 86.14 Ca; 81.81 N; 14.42 Mg; 13.71 K; 7.16 S and 5.54 P in kg ha^{-1} and the transfer of micronutrients showed 20069.10 Mn, 3278.83 Fe, 428.30 Zn, 180.12 B, and 49.98 Cu in g ha^{-1}. Ca (among the macronutrients) and Mn (among the micronutrients) showed the highest concentrations among the nutrients that have returned to the soil through litter deposition.

Nutrients concentration in plants changes according to vegetation age, sampling time and to the interaction between nutrients and nutrient availability in the soil (Schonau, 1983). The current study evaluated seasonality (rainy and dry seasons) and vegetation age (10-and-40-year-old capoeiras) as important variables affecting nutrients concentration in the litter.

Nutrient cycling studies are important to preserve the natural systems and their sustainability as well as to evaluate the impacts on the environment caused by nutrient losses in the litter. The ecosystem fragility may be understood as the balance between the nutrients and their quantity. It is worth highlighting the cycling efficiency. The current study aimed at evaluating the nutrients concentration, identifying the applied treatment that showed stronger nutrient deficiency due to full and partial litter removal as well as (delete) assessing the vegetation age with the best nutrient concentrations.

MATERIALS AND METHODS

The current study was conducted in Bragança County, Benjamin Constant community, east of Bragantina region and 25 km southeast from Bragança County (Rios et al., 2001) at 01°11'22" S and 46°40'41" W. Bragança County is located in a slightly wavy lowland area formed by sediments, with maximum slope of 26 m. Our area of interest was the family farmer properties, called Agricultural Units (AU), with total area 150 ha.

Two capoeiras aged 40 and 10 years were selected in the Agricultural Unit. They are approximately 400 m distant from each other and have the same history of use and the same physiographic conditions. They were derived from successive cutting and burning, planting and fallow cycles of cotton (*Gossypium hirsutum*), rice (*Oryza sativa*), beans (*Phaseolus vulgares*), tobacco (*Nicotiana tabacum*), cassava (*Manihot esculenta*) and maize (*Zea mays*) cultures.

The climate in the region is classified as Aw according to Köppen (Rocque, 1982). The mean annual temperature is 26°C, with relative humidity ranging from 80 to 91%. Annual rainfall ranges from approximately 2200 to 3000 mm. Insolation is between 2200 and 2400 h/year.

The soil in Bragantina region is predominantly dystrophic yellow latosol (DYL). It is medium textured and described as deep with advanced evolution, quite weathered, with relative concentrations of resistant clay minerals (EMBRAPA, 1999).

By considering the original cover, the predominant vegetation in Bragantina region is the Equatorial Rain Forest. Nowadays, the main original vegetation types in Bragantina region (primary dryland forest, flooded and igapó forest, dryland and mangrove fields) are very limited and sparse. The predominant landscape is featured by secondary vegetation at different ages, with different degrees of plant succession, agricultural crops and pasture areas (Vieira et al., 2007) derived from successive cutting and burning, planting and fallow cycles.

Experimental design

Six quadrangular-shaped Permanent Monitoring Plots (PMP) with 50 × 50 m (0.25 ha) dimension were systematically installed in a 40-year-old managed secondary forest. These plots were divided into twenty-five (25) 10 × 10 m subplots with no silvicultural treatment application. The experimental design in the 10-year-old capoeira was done in blocks and it was divided into plots measuring 20 × 40 m (800 m^2) each.

Thinning application in two intensities was considered to be the silvicultural treatment where treatment 0 (T0): control plot with no thinning and used as witness; treatment 1 (T1): moderate thinning intensity with partial vegetation cutting. Individuals under the canopy or those which canopy touched the selected plant were cut in order to completely release the plant; treatment 2 (T2): heavy

Table 1. Nutrient concentrations in the 10-year-old and in the 40-year-old capoeiras, Benjamin Constant community, Bragança – PA, 2009.

Capoeira	Period	Element					
		N	P	K	Ca	Mg	Na
CAP40	Rainy	16.55[a]	0.23[abc]	0.67[a]	6.57[a]	2.74[ab]	2.5[a]
	Dry	17.9[ab]	0.25[abc]	0.99[a]	6.07[a]	3.88[c]	5.29[b]
PT10	Rainy	17.64[ab]	0.25[abc]	0.48[a]	8.46[a]	1.86[a]	2.26[a]
	Dry	18.31[ab]	0.21[a]	1.47[a]	9.17[a]	2.78[ab]	5.87[b]
TT10	Rainy	16.81[a]	0.26[abc]	0.64[a]	8.39[a]	1.83[a]	2.21[a]
	Dry	19.52[b]	0.33[bc]	2.74[b]	15.75[b]	3.35[bc]	7.76[c]
NT10	Rainy	17.79[ab]	0.35[c]	0.68[a]	8.35[a]	2.15[a]	2.71[a]
	Dry	18.35[ab]	0.22[ab]	1.43[a]	10.23[a]	3.21[bc]	5.86[b]

Means followed by lowercase letters on the rows do not statistically differ from each other according to the F and Tukey tests at 5% probability. CAP: capoeira; NT: no thinning; PT: partial thinning; TT: total thinning.

thinning intensity, the entire vegetation was cut in this plot. The entire woody vegetation (height ≥ 50 cm) was cut 30 cm above the ground.

The litter samples were collected during March (rainy season) and November (dry season) 2009, by using a square collector (0.25 × 0.25 m^2) placed directly on the ground and withdrawn after each collection. The litter samples were stored in paper bags while they were still in the field. Then, they were placed in the oven at 20°C for 72 h. After which they were dried and were separately ground in a Wiley mill. They were then placed in plastic vials and stored in a dry place.

Laboratory analysis

Samples were taken to the laboratory and divided into 12 groups. Each sampling group had three replications collected from each subplot. Regarding the nutrients analysis, 2 g of plant material were weighed and homogenized in order to be analyzed according to the methods by EMBRAPA (1999).

The classic Kjeldahl method was used to determine Nitrogen as described by Tedesco et al. (1985). The elements P, K, Ca, Mg, Na, Cu, Mn, Fe and Zn were determined by the samples' acid digestion, using nitric acid and perchloric acid at 180°C for 45 min in order to obtain limpid digestates. After the acid digestion and the distilled-water process, ammonium vanadate and ammonium molybdate solutions were used. Na and K readings were done by flame spectrophotometer. Ca, Mg, Cu, Mn, Fe and Zn readings were done by atomic absorption (SpectrAA 220, Varian, Palo Alto, CA, USA), according to the methodology by Embrapa (1997). These readings were carried out by directly determining the elements in the nitric-perchloric extract, using hollow-cathode lamp without interference or ionization problems.

Statistical analysis

The litter nutrient content values were subjected to the following statistical treatments in order to obtain greater representation in the result analyses: normality analysis by adhesion test (KS) at 5% significance level; variance analysis (ANOVA) with Tukey's test at 5% significance level and regression analyses were adopted to

compare the means. Multivariate data analysis was conducted using the Principal Components (PCs) technique, which used the correlation matrix among variables to form the components. The first two components, that is, those with the biggest explained variance (Hair et al., 2009) were taken under consideration for interpretation purposes. The Minitab software version 17 was used.

RESULTS AND DISCUSSION

The mean macronutrient concentrations in the 40-year-old capoeira litter regarding the N, P, and Ca elements did not show significant variations (Tukey, $p < 0.05$) among each other in the rainy and dry periods (Table 1). However, they showed different concentrations among elements. The nutrients N and Ca showed higher macronutrient concentrations (Figure 1) than the other analyzed elements. The transfer magnitude of all macronutrients showed the following order: N>Ca>Na>Mg>K>P.

The macronutrient concentrations in the 10-year-old capoeira (NT) showed the following descending order in nutrient concentration in the non-thinned capoeira: N>Ca>Na>Mg>K>P. As for the rainy and dry peridos, P alone showed the highest concentrations during the rainy season and all other elements presented the highest concentrations during the dry season. The nutrients P, Mg and N showed statistically significant difference (Tukey, $p < 0.05$), as shown in Table 1.

As for the multivariate data analysis using the principal components technique, it is possible to see that the principal component 1 (PC1) showed eigenvalue equals to 3.1716 in the rainy season. This value corresponds to 31.7% explained proportion of the total variation. Principal component 2 (PC2) showed eigenvalue equals to 1.7382, thus corresponding to 17.4% of the total data variation. Much of the evaluated nutrients presented positive
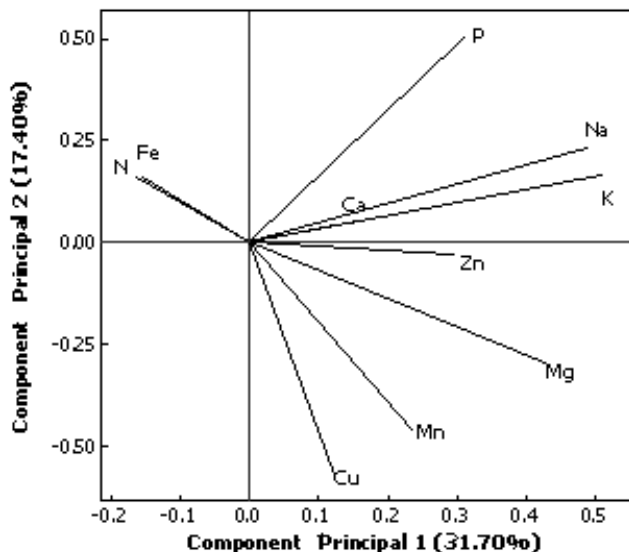
Figure 1. Variables' loads based on the principal components, in different system types. CAP: capoeira; PT: Partial thinning; TT: Total thinning; NT: no thinning, during the rainy season.
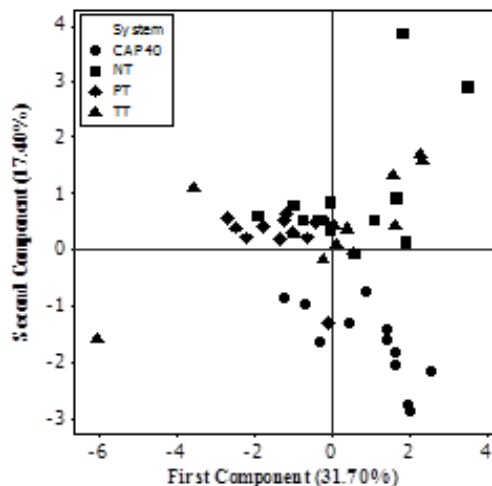

Figure 2. Variables' scores based on the principal components, in different system types. CAP: capoeira; DP: Partial thinning; DT: Total thinning; SD: no thinning, during the rainy season.

correlation with PC1, except for N and Fe (Figure 1).

Among these variables, K, Na, and Mg showed the most positive relationship with this component. Thus, by assessing the score graphic (Figure 2), one can see the association between the PC1 and the CAP40 system as well as the difference to other systems; fact that was not observed in N, K, Ca and N (rainy season) through the univariate analysis. PC2 showed bigger P representation (Figure 1). Therefore, its association with the NT10 system (Figure 2) was partially demonstrated by the univariate analysis (Tukey test), as shown in Table 1.

The principal components analysis showed different results in the dry and rainy seasons. PC1 presented eigenvalue equal to 3.2703 and it corresponded to 32.7% explained proportion of the total variation. PC2 presented eigenvalue equal to 1.4295, thus corresponding to 14.3% of the total data variation. PC1 is not represented by most of the nutrients in this analysis, but by Fe (Figure 3).

Thus, it is not possible to clearly see the distinction between systems when it comes to PC1, except for the TT10 system, which has negative correlation with this component. In fact, Fe concentration in the TT10 system litter is lower than that observed in the other systems, except for PT10, as shown by the Tukey's test (Table 2). In addition, the TT10 system also showed an overall greater nutrient availability than the other systems, thus justifying the scores disposition (Figure 4).

The 10-year-old capoeira, where the PT treatment was applied, showed the highest nutrient concentration values for N during the dry season, and the analyzed elements showed nutrient concentrations that met the following descending order: N> Ca> In> Mg> K> P. All of them showed the highest concentrations during the dry season,
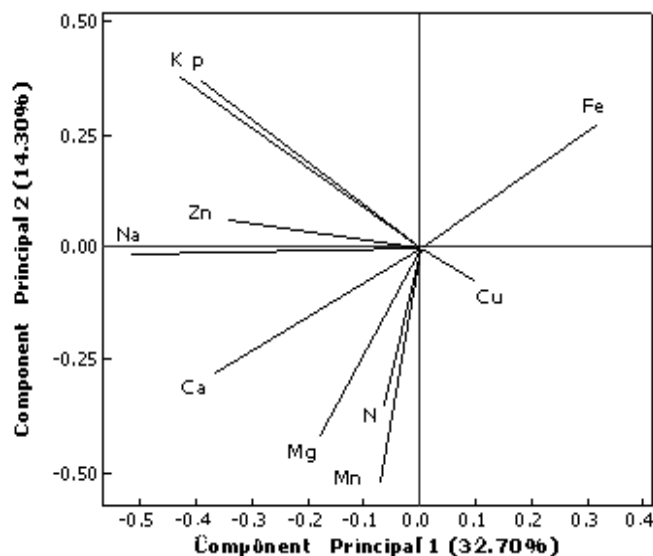

Figure 3. Variables' loads based on the principal components, in different treatment. CAP: capoeira; DP: Partial thinning; DT: Total thinning; SD: No thinning, during the dry season.

except for P, which showed higher concentrations during the rainy season.

The P nutrient showed the highest and the lowest nutrient concentrations in the (NT) area during the rainy and the dry seasons, respectively. Already, K nutrient showed the highest concentration in the (TT) area during the dry season and the lowest concentration in the (NT) area during the rainy season. The Ca nutrient showed the highest concentration in the (TT) area during the dry

Table 2. Micronutrient concentrations in the 10-year-old and in the 40-year-old capoeiras, Benjamin Constant community, Bragança – PA, 2009.

Capoeira	Period	Element			
		Cu	Mn	Fe	Zn
CAP40	Rainy	26.74[b]	368.49[bcd]	1015.77[abc]	26.01[abc]
	Dry	25.22[b]	339.01[abc]	1419.61[ab]	28.47[bc]
PT10	Rainy	15.57[a]	228.73[ab]	1644.82[b]	18.1[a]
	Dry	12.94[a]	291.58[abc]	899.89[ac]	21.13[ab]
TT10	Rainy	14.39[a]	153.02[a]	1146.11[abc]	33.16[c]
	Dry	14.28[a]	484.07[cd]	481.98[c]	32.13[c]
NT10	Rainy	12.71[a]	260.48[ab]	1456.52[ab]	24.38[abc]
	Dry	13.05[a]	558.18[d]	1471.46[ab]	21.1[ab]

Means followed by lowercase letters on the rows do not statistically differ from each other according to the F and Tukey tests at 5% probability. CAP: capoeira; NT: no thinning; PT: partial thinning; TT: total thinning.
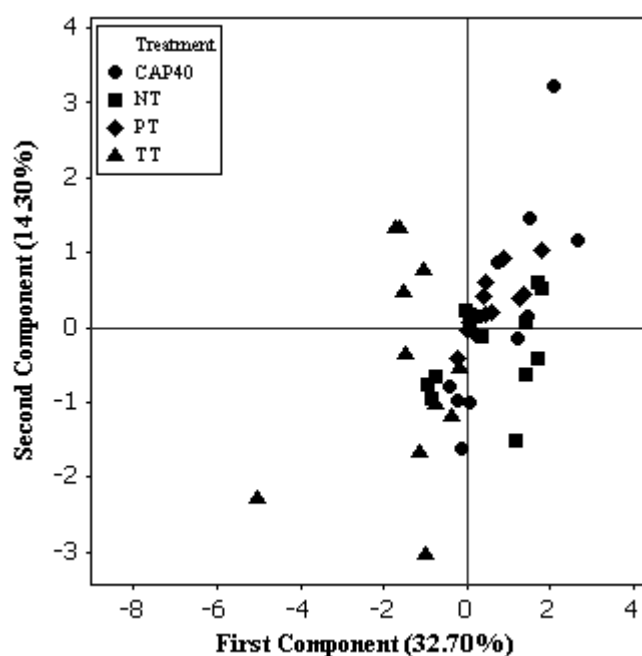

Figure 4. Variables' scores based on the principal components, in different treatment types. CAP: capoeira; DP: Partial thinning; DT: Total thinning; SD: No thinning, during the dry season.

season and the lowest concentration in the (NT) the rainy season. As for Mg, the highest and the lowest concentration values were found in the (TT) area during the dry and the rainy seasons, respectively. Na showed the highest and the lowest concentration values in the (TT) area during the dry and the rainy seasons, respectively.

Overall, the nutrient concentrations of each element in each treatment was presented in descending order as follows: N: TT>NT>PT>CAP40; P: NT>TT>CAP40>PT; K: TT>NT>PT>CAP40; Ca: TT>NT>PT>CAP40; Mg: CAP40>TT>NT>PT; Na: TT>NT>PT>CAP40; N, K, Ca and Na presented the same nutrient concentration order. The 40-year-old capoeira showed the lowest N, K, Na, and Ca concentrations, and the highest Mg concentration.

By considering the year the experiment was performed, the annual mean (2.323 mm) and the mean rainfall of the last 20 years, the mean annual rainfall (Figure 5) showed higher values in May (849.7 mm) and lower values in October and November months when there was no rain in the region. The rainfall variable showed influence on some nutrient concentrations. The highest rainfall rates in the region during the rainy season were observed in February, March, April and May. The high peak was in May, unlike the rainfall rates in the past 10 years. Since 1995, the highest rainfall value recorded in the region was 657.20 mm, and the mean recorded in May in the past 20 years was 347.6 mm.

Although rainfall favors nutrient absorption by plants, there was reduced concentration of these nutrients during the rainy season. Litter is characterized by showing bigger production during the dry season. Such period shows lower decomposition rates and nutrient concentrations. The monthly mean temperature was higher in December (27.7°C) and lower in April (25.2°C), with annual mean of 26.42°C. Thinnings change the forest microclimate by reducing the perspiration in the area and by increasing both the incidence of solar radiation inside the forest and the soil temperature; fact that favors the decomposing microorganisms.

The 10-year-old capoeira (NT) showed the following descending order in nutrient concentrations: Fe>Mn> Zn>Cu. Fe and Zn showed the highest concentrations during the rainy season. The nutrients Cu and Mn showed the highest concentrations during the dry season.
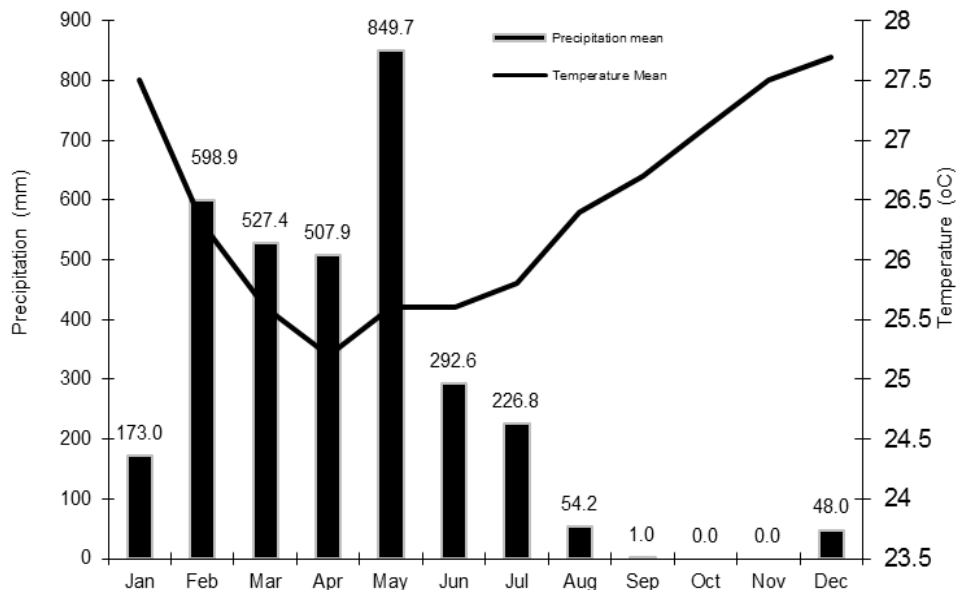
Figure 5. Annual rainfall and temperature range in Tracuateua County, 17 km distant from Bragança - PA during the experimental period, 2009.

Bianchin et al. (2016), the absence of a period with water deficit, together with the low occurrence of deciduous species in these environments, allows for greater deposition in higher precipitation and temperature, thus interfering with the concentration of nutrients.

The 10-year-old capoeira (NT) showed significant statistical difference (Tukey, p <0.05) in Fe and Mn, with the highest concentrations occurring during the rainy and the dry seasons, respectively. The other elements showed no significant differences. The 10-year-old capoeira (PT) showed the highest Fe concentration values during the rainy season, and the analyzed elements showed micronutrients concentration in the following descending order: Fe>Mn>Zn>Cu. The highest Fe and Cu concentrations occurred during the rainy season, and the highest Mn and Zn concentrations occurred during the dry season. The 10-year-old capoeira (PT) showed significant statistical difference (Tukey, p <0.05) in Fe, and the highest concentrations occurred during the rainy season (Table 2).

The 10-year-old capoeira (TT) showed the highest micronutrient concentration values in Fe during the dry season, and the analyzed elements showed nutrients concentration in the following decreasing order: Fe>Mn>Zn>Cu. The highest Fe and Mn concentrations occurred during the dry season and the highest Cu and Zn concentrations occurred during the rainy season. The 10-year-old capoeira (TT) showed significant statistical difference (Tukey, p <0.05) in Mn and in Zn. The highest concentrations occurred during the dry and the rainy seasons, respectively.

By taking under consideration the 40-year-old capoeira

and the treatments applied to the 10-year-old one (NT, PT, TT), it is possible to state that the overall highest concentrations of all analyzed elements showed the same descending order in nutrient concentrations: Fe>Mn>Zn>Cu. The Fe concentration was higher than that of all other analyzed elements in all the applied treatments.

By taking under consideration just the treatments applied to the 10-year-old capoeira (NT, PT, TT), it is possible to see that the highest micronutrient concentrations in Fe occurred in the (NT) system during the rainy season. The Mn showed the highest nutrient concentrations in the (NT) area during the dry season and the lowest nutrient concentrations in the (TT) area during the rainy season. The Cu showed the highest concentration in the (PT) area during the rainy season and the lowest concentration in the (NT) the rainy season. The Zn showed the highest concentration in the (TT) area during the rainy season and the lowest concentration in the (PT) area during the rainy season. Scoriza and Piña-Rodrigues (2014) found positive correlation of litter contribution with precipitation and temperature, thus interfering with the concentration of nutrients.

Results showed that N and Mg concentrations were higher in the 40-year-old capoeira both in the rainy and in the dry periods. Similar results were found by Hayashi (2006) who compared young and old capoeiras (6, 10, 30 and 40 years old). The N loss during the change in land use was described by Davidson and Martinelli (2009). These authors associated these results to change the stoichiometric balance in N and P cycling processes.

The isotopically light N in mature forest ecosystems is lost due to fractioning during nitrification and denitrification, thus leaving the enriched N behind (Amundson et al., 2003). The lower nutrient concentrations found in the 40-year-old capoeira may probably due to the longer exposure time of this litter on the ground, which leads to an advanced decomposition state, thereby showing lower nutrient contents.

The results of the two studies on N fixation in the Amazonian secondary forests are mistaken, as stated by Davidson and Martinelli (2009) who found isotopic evidence for the significant symbiotic N fixation during the first 25 years of secondary vegetation regeneration in the central Amazon region, near Manaus. On the other hand, a recent study conducted in the eastern Amazon secondary forests, in Pará State, found no significant difference in leaf N between leguminous and non-leguminous species (Davidson and Martinelli, 2009).

It was found that P concentrations in the litter decreased due to age, but K, Ca and Mg concentrations did not significantly change because of it. The seasonal variation in the mineral elements concentration in the litter appears to be strongly related to these nutrients absorption and retranslocation mechanisms.

The high Ca concentration found in the current study may be caused by the big amount of collected branches. The highest Ca content is found in the branches, and the highest Mg content is found in the leaves (Vogel, 2005). Since it has little mobility in the plant, Ca is more concentrated in lignified parts such as the branches and the bark. The highest Mg content found in the leaves was probably due to the fact that this element is part of chlorophyll (2.7% of it), thus it is more abundant in these tissues.

Studies conducted in the Amazon region found that the nutrient concentrations in plants varied greatly according to the element, the plant tissue, the soil type, the vegetation and to the family of the monitored species. In addition, they were affected by factors such as the plants' age and the leaves' physiological stage.

The total thinning area showed higher nutrient concentrations than the control plot. It might have happened due to lesser species competition for nutrients, whereas most elements concentration was stable in the 40-year-old capoeira.

These studies also suggest that the reduced competition among the remaining trees would increase the nutrient availability per plant. It would enable species regeneration and would give rise to a more diverse, nutrient-richer and more easily decomposed litter.

Regarding the total thinning, the highest concentration of all nutrients occurred during the dry season, and it showed more than 50% significant difference during this period. It did not rain in the last three collection months. Since microorganisms show slower decomposing activity during the least rainy season, the nutrients concentration in the litter was expected to show lower values. The thinning effect may have affected the number of decomposing microorganisms. The areas showing higher concentrations were: TT>NT>PT. It was found that the high concentration found during the dry season may have also affected the number of decomposing micro-organisms in K, N, Ca and in Na. The highest nutrient concentrations found in all elements during the dry season was a statistically significant aspect in all treatments, and it showed seasonal variation.

The highest Fe concentration found in the accumulated litter may be justified by its mobility, which is low (Dechen and Nachtigall, 2006). This mobility is negatively affected by several factors such as high P content, K deficiency, high Mn amount and low light intensity (Dechen and Nachtigall, 2006).

The litter contamination with soil, that is, litter sample with soil, may be considered to be a justification. Clay and soil organic matter contents also influence Fe availability. Clayey soils tend to retain Fe, and the appropriate soil organic matter levels enable better Fe use by plants due to their acidifying and reducing features, and to the ability of certain humic substances in adverse pH conditions. The Fe content in the soil is influenced by pH, since Fe increases as the acidity increases. In addition, it reaches large contents in very acidic soils with pH lower than three, and in soils rich in humic and colloid acids capable of forming soluble complexes with Fe. The second bigger micronutrient content found in the accumulated litter was Mn. It might have happened due to contamination with soil, since the Mn found in the soil comes from oxides, carbonates, silicates and sulphides. Mn oxides and sulphides are the most often found forms in the soil, and its occurrence combined with Fe is very common (Dechen and Nachtigall, 2006). It is worth emphasizng that the larger Mn content in the accumulated litter may be explained by its higher content in some species leaves.

When there is good Mn supply, the leaves accumulate high concentrations of it, as the plant grows old. A small portion of this element is translocated from the old leaves to the new growing leaves, in which the element is found in lower concentrations. However, it should be taken under consideration that the Mn concentration in the plant varies greatly among plants and species parts (Caldeira et al., 2008; Dechen and Nachtigall, 2006).

It was observed that the nutrient concentrations deposited in the litter was influenced by seasonality in some elements, since the dry period showed the highest micronutrient concentrations in most of the analyzed elements. Studies conducted in forests by Silva and Almeida (2002) and Cunha Neto et al. (2013) show that litter production is higher during the dry season. Therefore, whenever there is higher litter production during this period, it is expected to find the highest nutrients concentration during the same period. A study conducted by Brun (2010) in 35-and-55-year-old secondary forests found the same micronutrient

concentrations order in the litter that was found in the current study. However, according to Brun's (2010) study, the concentrations of all analyzed elements were higher in the oldest forest, whereas the current study found the highest micronutrient concentrations in the 10-year-old capoeira (the youngest one), except for Cu, which was higher in the 40-year-old capoeira (the oldest one). These studies differ from this study possibly possibly due to the higher accumulated biomass and also due to the significantly higher Fe and Mn contents. The quantitative storage order of nutrients in the biomass was Fe> Mn> Zn> B> Cu.

Plant physiology is another factor that may justify a particular element concentration. In this study, *Myrciaria tenella* was the predominant species in the area. This species does not need good fertile soil to develop (Carvalho et al., 2009). This is the fact that may benefit this species over other species that do not have this same feature, since each species needs a certain amount of nutrient.

Conclusions

The capoeiras with different vegetation age in the Bragantina area showed that not all nutrients were influenced by seasonality, despite the applied thinning, the vegetation age and the forest species. The oldest capoeira (40 years old) showed lower macro and micronutrient concentrations than the youngest one (10 years old). These differences may be justified by the longer abandonment time in the area and by the higher mean concentrations in the forest leaves in comparison to the other parts (branches, reproductive parts, bark) of the total litter. Besides, the vegetation management practices somehow change the balance achieved by forest ecosystems either by increasing the decomposition rate or by litter accumulation or even by its destruction.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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