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Chemical attributes of soil in agroforestry systems is conditioned by the management system adopted

Atributos químicos do solo em sistemas agroflorestais é condicionada pelo sistema de gestão adotado

Los atributos químicos del suelo en los sistemas agroforestales están condicionados por el sistema de gestión adoptado

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Abstract

The aim of this study was to evaluate the influence of vegetation management on soil chemical attributes during the implementation of an agroforestry system in Pará, Brazil. Three treatments were evaluated - T1 Control (secondary vegetation - SF), T2 - Fire management system (FMS) and T3 - Management system without vegetation burning (MSWB). Soil samples were collected at 30 cm deep to analyze chemical attributes. The data were analyzed using Analysis of Variance - ANOVA, and the t-test. Treatment T2 caused the most changes in soil chemical attributes on the first analysis showing increased pH, increased levels of N, P, K, Ca, Sum of bases, CEC and percentage of base saturation, and decreased potential acidity of Al in the short term. However, in the second evaluations 48 months later, there was an inversion, in which a reduction of pH, the contents of N, P, K, Ca, Sum of bases and percentage of base saturation, as well as increased potential acidity and of the contents of Al of the soil were observed. For treatments T1 and T3, there were no substantial soil attributes changes during the first and second evaluations. Thus, soil chemical attributes were altered according to the type of management of secondary vegetation and evaluation period during the implementation of Agroforestry Systems.

Keywords: Fire; Secondary vegetation; Agroforestry systems; Vegetation burning.

Resumo

O objetivo deste estudo foi avaliar a influência do manejo da vegetação na fertilidade do solo durante a implantação de um sistema agroflorestal no Pará, Brasil. Foram avaliados três tratamentos - T1 Controle (vegetação secundária - SF), T2 - Sistema de manejo do fogo (FMS) e T3 - Sistema de manejo sem queima da vegetação (MSWB). Para análise do solo as mostras foram coletadas a uma profundidade de 30 cm durante dois períodos. Os dados foram analisados estatisticamente por meio da Análise de Variância - ANOVA e o teste t. Na primeira avaliação logo após a queima o tratamento T2 foi o que mais alterou positivamente a fertilidade do solo, apresentando aumento do pH, aumento dos níveis de N, P, K, Ca, Soma de bases, CEC e porcentagem de saturação por bases, e diminuição da acidez potencial de Al em curto prazo. Porém, nas avaliações seguintes, no período de 48 meses, ocorreu uma inversão com alterações negativas da fertilidade com diminuição do pH, dos teores de N, P, K, Ca, Soma de bases e porcentagem de saturação de bases, além de aumentar foram observadas acidez potencial e dos teores de Al do solo. Para os tratamentos T1 e T3, não houve mudanças substanciais na fertilidade do solo durante as avaliações. Assim, os atributos químicos do solo foram alterados de acordo com o tipo de manejo da vegetação secundária e o período de avaliação durante a implantação dos Sistemas Agroflorestais.

Palavras-chave: Fogo; Vegetação secundária; Sistemas agroflorestais; Queima de vegetação.

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Resumen

Este estudio tuvo como objetivo evaluar la influencia del manejo de la vegetación en la fertilidad del suelo durante la implementación de un sistema agroforestal en Pará, Brasil. Se evaluaron tres tratamientos - Control T1 (vegetación secundaria - SF), T2 - Sistema de manejo de incendios (FMS) y T3 - Sistema de manejo sin quema de vegetación (RSU). Se recolectaron muestras de suelo a una profundidad de 30 cm para el análisis de fertilidad del suelo. Los datos se analizaron estadísticamente mediante el análisis de varianza (ANOVA) y la prueba t. El tratamiento T2 causó la mayor cantidad de cambios en la fertilidad del suelo, mostrando aumento del pH, aumento de los niveles de N, P, K, Ca, Suma de bases, CIC y porcentaje de saturación de bases, y disminución de la acidez potencial del Al en el corto plazo. Sin embargo, en las siguientes evaluaciones, en el período de 48 meses, hubo una inversión, en la que se observó una reducción del pH, los contenidos de N, P, K, Ca, Suma de bases y porcentaje de saturación de bases, así como un aumento Se observó acidez potencial y del contenido de Al del suelo. Para los tratamientos T1 y T3, no hubo cambios sustanciales en la fertilidad del suelo durante las evaluaciones. Así, la fertilidad del suelo se alteró según el tipo de manejo de la vegetación secundaria durante la implementación de los Sistemas Agroforestales.

Palabras clave: Fuego; Vegetación secundaria; Sistemas agroforestales; Vegetación ardiendo.

1. Introduction

Agroforestry systems are multifunctional systems that can provide a wide range of economic, sociocultural, and environmental benefits regarding the use of natural resources. Among the benefits are the greater ability of agroforestry systems to synergically capture and utilize growth resources, recover degraded areas and enhance the secondary vegetation, contributing to a sustainable production REF.

In Brazil, the "Bragantina" region is mostly formed by a mosaic of secondary vegetation originated by Northeasterners, which dates back more than 400 years. The implementation of agroforestry systems in these areas has contributed to the sustainable use of the vegetation, guaranteeing ecological, economic and social benefits (Montserrat Rios, 2001).

Soil fertility and conservation play important roles for the implantation of agroforestry systems in secondary vegetation. Understanding the the implementation process and its interference in soil fertility dynamics is of great importance for the development and productivity of agroforest systems, especially regarding to soil/plant interactions (Garrity, et al., 1994).

The soil benefits under agroforestry are diverse, with emphasis on nutrient cycling, especially those of easy leaching, such as calcium (Ca), potassium (K) and sulfur (S). Through the flow of nutrients from the subsoil into the deep roots of the perennial species, there is a reduction in leaching losses through the capture of mobile nutrients by well-developed root systems of perennial species. Furthermore, nitrogen additions from biological fixation by perennial plants, maintenance of soil organic matter through litter supply below and above ground, improvement of the physical and chemical attributes of the soil as well as increased protection of the soil against erosion are also known as benefits from agroforestry (Ppaniagua, et al., 1999).

Soil fertility also depends on anthropogenic actors like vegetation management and maintenance, as well as environmental factors, which can contribute to the depletion of the physical and chemical attributes of the soil. In this sense, there is a great unexploited potential of the systems, especially related to their development in secondary vegetation areas and their interference with the transformation of the soil organic matter stock, preserving or recovering fertility and, consequently, defining the productivity of the systems (SZOTT, et al., 1991).

Considering that soil fertility is the basis for plant growth and sustainable production, it is necessary to adopt management practices that conserve and even restore degraded soils, in order to maintain productivity. The correct management of the system and its rational use to preserve its productive potential, chemical and physical properties is of fundamental importance to direct practices that conserve and improve its fertility (SALGADO, et al., 2006).

This study aimed to evaluate changes in soil attributes in agroforestry systems under two managements, with and without burning of the “leftover” vegetation, during two years. We hypothesized that initially burning can improve chemical attribute but it may not be sustained thru time.

2. Methodology

The study was conducted under field conditions in the Community of Benjamim Constant, in Bragança, state of Pará, Brazil (01°11'8.62" S and 46°40'13.47” W). The experimental area consisted of secondary vegetation, which has been established for up to 20 years.

The experimental design was entirely random, with three treatments: T1 - Control, secondary forest (SF), T2 - Fire management system (FMS) and T3 - Management system without vegetation burning (MSWB), which were distributed in nine replications.

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The preparation of the burning treatments occurred by the suppression of vegetation, by means of clear cutting, which was carried out 50 days after suppression. For the treatment without any burning, manual cutting and grinding of the understory vegetation was performed, covering the soil, maintaining the adult trees and those of economic value.

Soil samples were collected for fertility analysis every six months from the first field assessment in July 2006 until July 2010. In each treatment, 10 simple samples of 30 cm deep were randomly collected and homogenized, forming a composed sample of approximately 1 kg of soil. Then, it was placed in a plastic bag, identified and analyzed.

The following chemical analyzes were conducted according to Embrapa (1997): pH, nitrogen (N), organic matter (OM), phosphorus (P), potassium (K), sodium (Na), Calcium (Ca), exchangeable bases (Ca2+ and Mg2+), exchangeable aluminum (Al3+), potential acidity (H + Al), effective CEC (t) and percentage of base saturation (V).

The data were statistically compared using analysis of Variance - ANOVA, and the t-test at 5% probability level to calculate the difference of the means in the groups and between the groups, respectively.

3. Results and discussion

Based on the results, ANOVA showed statistical differences between the evaluated treatments, while the results of the t-test showed that the means of the three treatments are statistically different from each other, except for K and CEC (Table 1).

Table 1. Summary of Analysis of Variance (p-value) and t-test for soil fertility for each treatment (T1 – SF , T2 - FMS and T3 - MSWB).

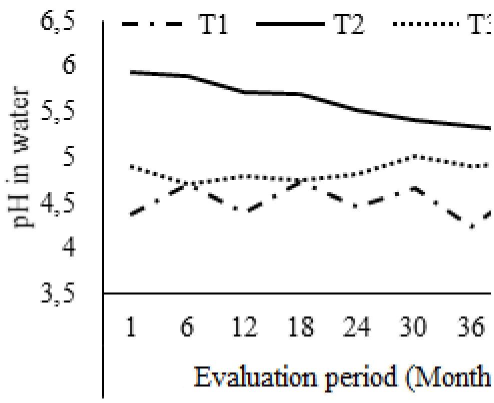
Variation source	pH	OM	N	P	K
	H_2O	g kg^{-1}	%	mg dm^{-3}	
SF mean	4.54 C	18.12 A	1.44 B	1.18 C	24.18 A
FMS mean	5.54 A	14.07 C	1.59 A	7.87 A	29.91 A
MSWB mean	4.84 B	16.87 B	1.40 B	3.23 B	23.06 A
F	53.74	45.13	4.72	51.12	1.93
p value	1.370E-09	7.370E-09	1.80E-02	2.230E-09	1.60E-01
F critical value	3.402	3.402	3.402	3.402	3.402

Variation source	Ca	Ca+Mg	H+Al	Al	CEC	V
	$cmol_c$ dm^{-3}					%
SF mean	1.13 C	1.03 B	4.69 A	1.45 A	6.06 A	19.16 B
FMS mean	3.91 A	1.80 A	3.04 B	0.76 B	6.71 A	51.25 A
MSWB mean	1.91 B	0.96 B	4.49 A	1.52 A	5.96 A	20.42 B
F	156.22	15.61	36.31	142.89	1.70	65.84
p value	1.74E-14	4.54E-05	5.51E-08	4.67E-14	2.0E-01	1.80E-10
F critical value	3.402	3.402	3.402	3.402	3.402	3.402

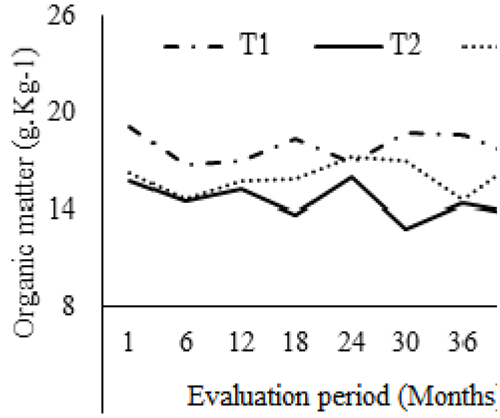
Means followed by the same letter in the columns do not differ from each other by the Tukey test at 5% probability. Source: Authors.

The highest pH was observed in Treatment FMS (up to 5.53), followed by MSWB (up to 4.84) and then SF, the control treatment (up to 4.54). The high pH value in FMS might have been due to the release of cations (Ca, Mg and K) in the form of ash during combustion, neutralizing the acidity of the soil. Treatments MSWB and SF showed significant differences in pH values, showing that the soil of SF had greater acidity in relation to the MSWB. This difference can be associated with the management practices applied at treatment MSWB, such as clearing the vegetation and incorporating the plant residues into the soil, increasing microbial activity and soil pH.

Figure 1. Values of soil pH (A) and Organic Matter (B) in T1 - Control, secondary forest, T2 - Management system with vegetation burning and T3 - Management system without vegetation burning for the implementation of the agroforestry system.



A



B

Source: Authors.

The contents of Organic Matter were higher in SF, with an average of 18.12 g kg^{-1} of soil, followed by MSWB and FMS, with averages of 16.87 and 14.07 g kg^{-1}, respectively. This higher availability in T1-SF and T3-MSWB can be attributed to the large amount of decomposing organic material. Although MSWB was managed with the clearing of the secondary vegetation, the increase in the organic layer on the soil surface did not add enough organic matter to the soil to exceed the control values. This material is probably still in the process of decomposition. In FMS, the management of the vegetation with fire caused a reduction in the organic matter content of the soil when compared with the other two treatments.

Both the pH and the levels of organic matter in the soil changed after vegetation burning, with a pH value of 5.93 in the first month and 5.04 at 48 months, which represented a reduction of 15% in FMS (Figure 1 A). On the other hand, the levels of organic matter in the soil reduced when MSWB is compared with SF and MSWB after vegetation burning.

The difference in the averages of the organic matter in MSWB with FMS was 22.35%, and FMS with MSWB was 16.6%. This represents the losses of FMS when compared with SF and MSWB (Figure 1 B). During the entire experimental period, the content of organic matter in FMS remained close to the average and always below the levels found for SF and MSWB. Treatment MSWB was the most favorable management system for maintaining soil organic matter due to the addition of crushed biomass and the maintenance of the slow decomposition process of this material, which is essential for the conservation of the chemical and physical properties of the soil, as well as the development and production of plants in soils with low natural fertility (Szott, et al., 1991). Both SF and MSWB caused highly soil acidity, which is already a characteristic of the soil under study based on the pH values obtained by Melo (2004), with a pH of 4.53 in secondary vegetation soil and by Vieira et al. (1996), with pH values of 4.48, 4.40 and 4.16 for primary forests of 20, 40 and 60 years, respectively, in the state of Pará, Brazil.

These pH values are unsuitable for agricultural cultivation due to the immobilization of cations available to plants. The ideal pH for agricultural crops is in the range of 5.5 to 6.5, where there is greater availability of all nutrients (Fageira; Zimmerman, 1998).

According to Wells et al. (1979), depending on the original pH of the soil, the quantity and chemical composition of the ash material and the climatic conditions of the region, the pH of the burnt soil returns to values close to (or below) the levels found prior to burning, mainly due to the consumption of cations by plants and by their leaching through the soil profile.

Rheinheimer et al. (2003) also registered an increase in the pH of the topsoil after vegetation burning, with reductions in the following months of study. However, the pH of the deeper layers of the soil did not change with the burning. Ribeiro (2006) observed similar, with an increase in pH from 4.74 before burning to 5.99 after burning, showing the contribution of ash in reducing soil acidity.

As a result of the buffering capacity of the soil in the small pH variation and the type of soil, it seems that the fires do not interfere in the soil pH for a long period (Oliveira, et al., 1992). However, these variations can immediately affect the availability of some nutrients for plants, especially P, F and Cu, as they become insoluble at high and low pH. At low pH, P forms compounds insoluble with iron and at high pH, Ca compounds tend to immobilize it (Malavolta, 1985).

The levels of organic matter in treatment FMS was close to that observed by Ribeiro (2006), who found a value of 16.61 g kg^{-1} of organic matter in an agroforestry system managed without burning and 13.89 g kg^{-1} with vegetation burning. Melo (2004) also found values of OM up to 17.8 g kg^{-1} and Vieira (1996) of 13.7 g kg^{-1} in an area with a history of fires. According to Monleon & Cromack (1996), this difference from FMS to SF and MSWB can be related to the rapid acceleration of the decomposition of the material due to the fires, which causes the volatilization of nitrogen compounds and other organic compounds in the soil. Losses can vary from 20 to 80% depending on the intensity of the fire, the amount of organic matter and the climatic conditions (Covington; Sackett, 1992), corroborating with Spagnollo (2004), who registered a 36% reduction in the organic matter of the soil submitted different soil management regimes.

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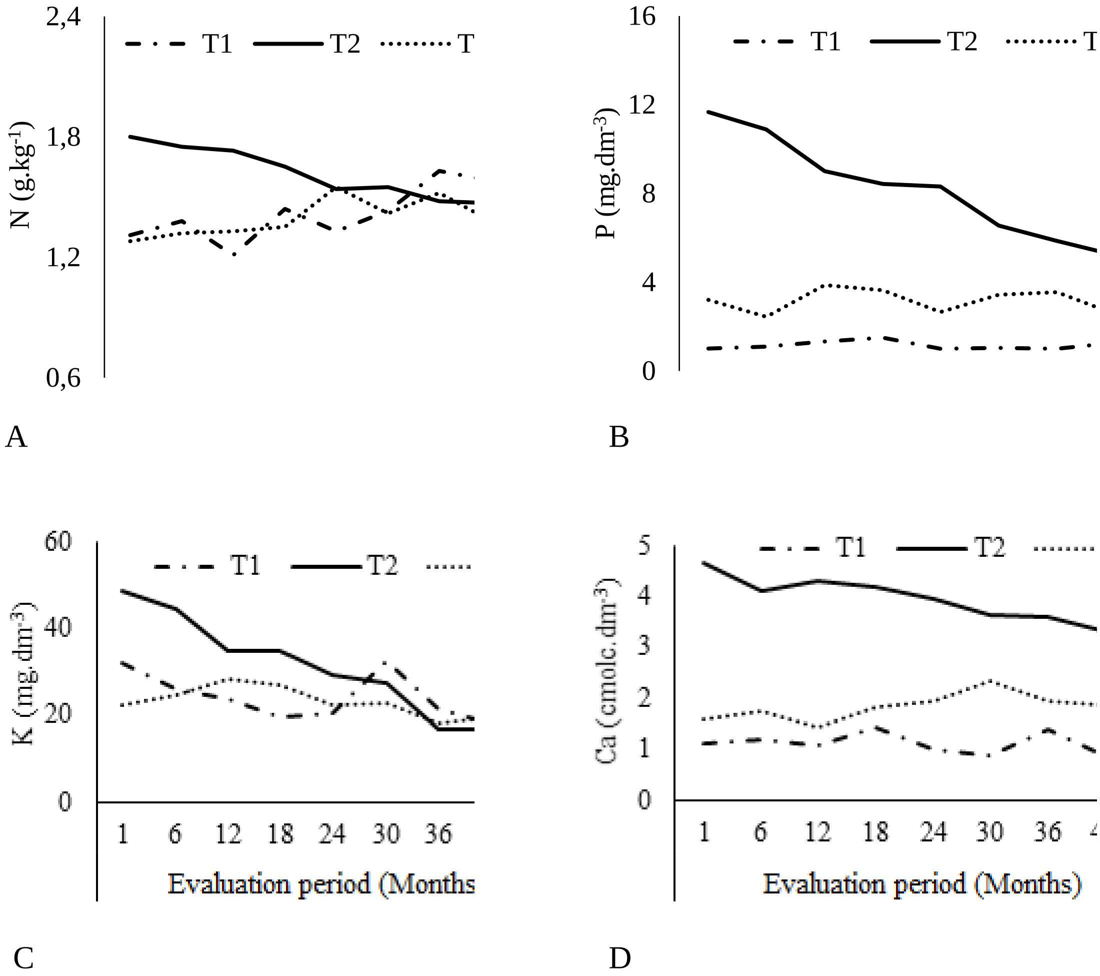
Figure 2. Values of nitrogen (A), phosphorus (B), potassium (K) and calcium (Ca), in T1 – SF - Control, secondary forest, T2 – FMS - Management system with vegetation burning and T3 – MSWB - Management system without vegetation burning for the implementation of the agroforestry system.



Source: Authors.

On average, the highest contents of N were observed in FMS, with 1.59 g kg^{-1} of soil, followed by SF, with 1.44 g kg^{-1} and MSWB with 1.40 g kg^{-1} (Table 1). Treatments SF and MSWB did not show statistical differences between them. Only FMS was statistically different from the other treatments. The nitrogen content in FMS showed a reduction of 26.66% from the first to the 48th month of evaluation, with values lower than SF and MSWB from the 30th month after the management of the area (Figure 2 A).

Phosphorus was more available in T2 with 7.87 mg dm^{-3}, followed by 3.23 mg dm^{-3} in T3 and 1.18 mg dm^{-3} in T1 (Table 1). The levels of P found in SF and MSWB were low. Nevertheless, it shows the reality of most soils in the region, which present low phosphorus as a limiting factor in production, requiring the use of corrective and phosphate fertilizers to meet the needs of each culture (Smith, 2000). The results of the analyzes showed a reduction in P levels from 11.67 mg dm^{-3} in the first month of study to 4.87 mg dm^{-3} in the 48th month, corresponding to a reduction of 58.26%. Nonetheless, these values were higher than the values found in the other treatments (Figure 2 B).

The contents of K were higher in FMS with 29.91 mg dm^{-3}, followed by SF with 24.18 mg dm^{-3} and MSWB with 23.06 mg dm^{-3}. However, the data presented no statistical differences between the evaluated treatments. Nevertheless, there was a decrease in K contents from 48.79 to 14.32 mg dm^{-3} from the first to the 48th month, respectively, after burning the vegetation, corresponding to a reduction of 70.64%, with a value lower than SF and MSWB (Figure 2 C).

The highest contents of Ca were observed in the FMS treatment, with 3.91 $cmol_c$ dm^{-3}, while SF registered 1.13 and MSWB 1.91 $cmol_c$ dm^{-3}. The difference from SF to FMS was 71% and from this to MSWB, it corresponded to 51.2%. However, it was observed in the results of soil analysis that there was a reduction of 28.39% from the first to the 48th month in FMS (Figure 2 D).

According to Rheinheimer et al. (2003), N losses might be associated with their volatilization due to the increase in temperature at the soil surface. According to Debano (1991), more superficial layers of the soil are more sensitive to N losses, and are proportional to the quantity of burnt material and climatic conditions, because in places with dry soil the losses can reach 75% of the accumulated nitrogen and moist soils around 25%.

The burning of the phytomass of the aerial part might have favored the availability of nutrients, such as carbon and nitrogen, through the deposition of ashes, altering the high levels of nitrogen in the FMS treatment, which remains in the soil, being nitrified and absorbed by the plants and/or leachate. This increase in availability increases the growth of plants after fire, and gives the impression that total N is more present after a fire. However, this increase in fertility is only for the short term. Thu, any temporary increase in available nitrogen after fire is normally used by plants quickly in the first years after burning (Carballas, et al., 1993).

As for the levels of P in FMS, they might be related to the combustion of organic matter that produced a great availability of this element on the soil surface in the form of ash, which according to Kauffman et al. (1993), favors greater development for the plants in the beginning of the rains or immobilized by the limestone substances that are present in the ash (Knoepp, et al., 2005).

The combustion of vegetation might have increased the levels of potassium and calcium in FMS through the conversion into oxides of ash rich in cations, such as K. This increase was also registered by (Grove, et al., 1986; Raison, et al., 1990; Soto; Diaz-Fierros, 1993;

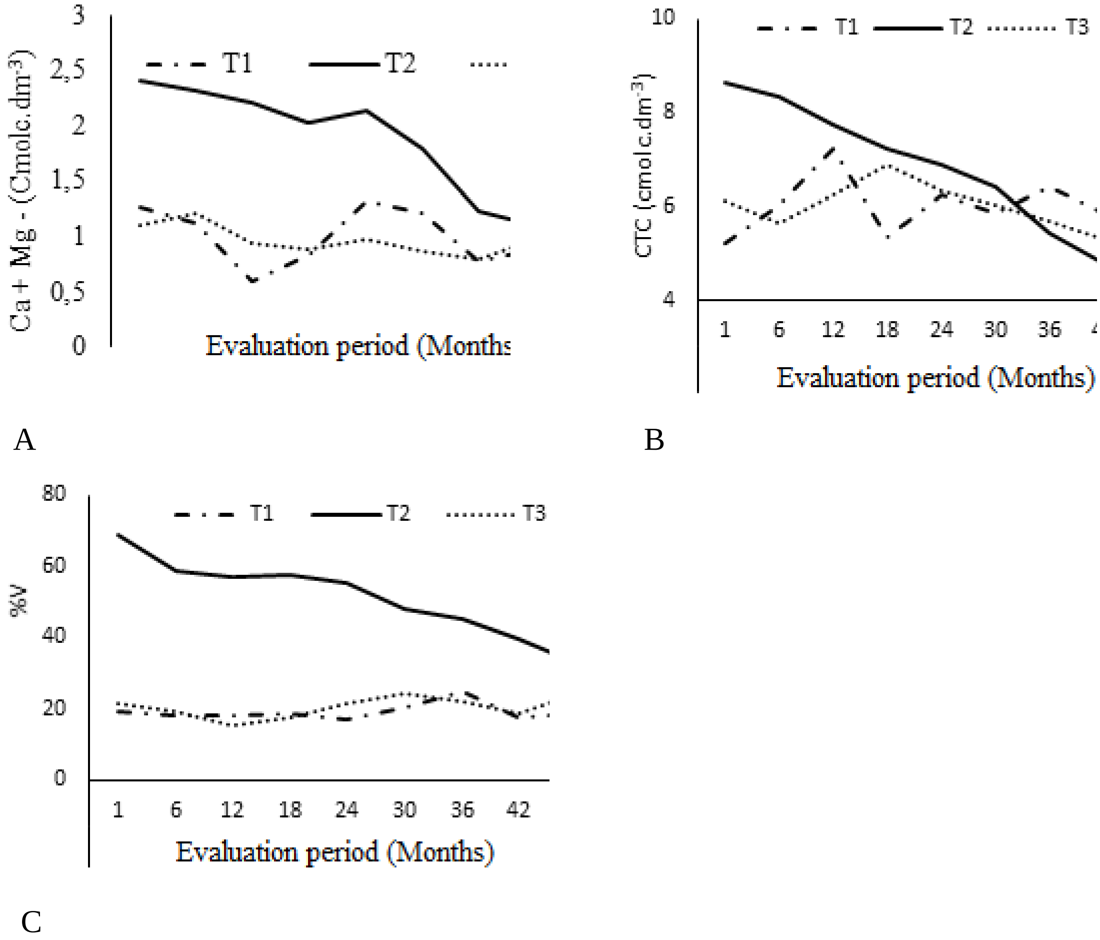
Rheinheimer, et al., 2003). According to the authors, the levels decrease sharply in some months after burning due to the rapid assimilation of this nutrient by plants in the growth phase, leaching and erosion, with values even lower before the burning, corroborating the data observed in Figures 2 C and D.

In general, all cations found in the soil, such as Ca, Mg, Na, K and ammonia (NH_4), are affected by fire (Debano, 1991) and most of them are not easily volatilized after fires, with the exception of ammonia, having its availability increased due to the accumulation of ashes due to the high concentrations of cations (Marion et al., 1991).

Monovalent cations, such as Na and K, are present largely as chlorides and carbonates that are easily mobilized (Soto; Diaz-Fierros, 1993). Bivalent ions, such as Ca and Mg, are less mobile and commonly present as oxides and carbonates. Formation of insoluble calcium carbonate might occur, which limits the availability of P after fire. Although these available cations, monovalent and divalent, do not significantly affect the growth of plants directly, their quantity and composition determine the base saturation, which plays an important role in the control of pH regimes in the soil (Debano, et al., 1998).

The Sum of Bases (Ca + Mg) was higher in treatment FMS, with 1.80 $cmol_c$ dm^{-3}, followed by SF and MSWB with 1.03 and 0.96 $cmol_c$ dm^{-3}, respectively. Only FMS showed a statistically significant difference between the other treatments. The CEC in the treatments were close and did not show significant statistical differences. The base saturation percentage (% V) was higher in the FMS treatment with 51.25%, while SF and MSWB presented 19.16% and 20.42%, respectively. Only FMS showed a statistically significant difference from the other treatments (Table 1).

Figure 3. Values of Sum of Bases (A), Cation Exchange Capacity (B) and Base saturation (C) in T1 - Control, secondary forest, T2 - Management system with vegetation burning and T3 - Management system without vegetation burning for the implementation of the agroforestry system.



Source: Authors.

Figure 3 shows the evolution of the data regarding the sum of bases (Ca + Mg), cation exchange capacity (CEC) and bases saturation (% V) in the evaluated treatments, through the 9 periods.

Despite the difference considered in the mean of the FMS base sum in relation to the other treatments, a reduction of 2.4 $cmol_c$ dm^{-3} in the first month to 1.03 $cmol_c$ dm^{-3}in the 48th month was observed in the results of the half-yearly month analyzes, corresponding to a reduction of 57.08% (Figure 3 A). In the other treatments, the values were close to the average. However, in low amounts of those recommended for the cultivation of agricultural crops (Malavolta, et al., 1997). Similarly to other cations, this reduction might be associated with the absorption of these minerals by plants in treatments, as well as leaching and erosion. Similar results were found by (Debano, 1991; Rheinheimer, et al., 2003; Ribeiro, 2006; Kauffman, et al., 1993).

Soil CEC values also decreased after burning, in which 8.65 $cmol_c\ dm^{-3}$ was observed at the beginning of the analysis, while at the end, 4.98 $cmol_c\ dm^{-3}$ was recorded, corresponding to a reduction of 42.42 % (Figure 3 B). Ribeiro (2006) also registered a significant decrease in CEC at 160 days after burning. According to Silveira et al. (2010), the great availability of cations after the fires contributes to the increase in CEC. However, these values regress as these cations are consumed by the plants, leachate and immobilized by the potential acidity.

Although the percentage of base saturation has shown a value greater than 50% in FMS, it cannot be said that this is a eutrophic soil, since this value was masked by the high concentrations of basic cations after burning, while the values of SF and MSWB are characteristic values of the soils of the region under study (Embrapa, 1999).

The results of the semiannual analyzes showed that, right after burning, the percentage of base saturation reduced from 68.54% to 32.66%, in the 48th month (Figure 3 C), corresponding to a reduction of 52.34% in an interval of 4 years, demonstrating the effect of cations from burning and its progressive reduction over time, probably caused by losses by leaching, volatization and absorption by vegetables.

The average levels of exchangeable aluminum (Al) were higher in SF with 1.45 and MSWB with 1.52 $cmol_c\ dm^{-3}$, while in treatment FMS, 0.76 $cmol_c\ dm^{-3}$ was recorded. The result of the Analysis of Variance showed that there were statistical differences only in FMS in relation to the other treatments. The same was observed with Potential Acidity (H + Al), in which the highest values were recorded in treatments SF and MSWB with 4.69 and 4.49 $cmol_c\ dm^{-3}$, respectively, while in FMS the value of potential acidity was lower, with an average of 3.04 $cmol_c\ dm^{-3}$, which was the only treatment that showed a statistically significant difference (Table 1).

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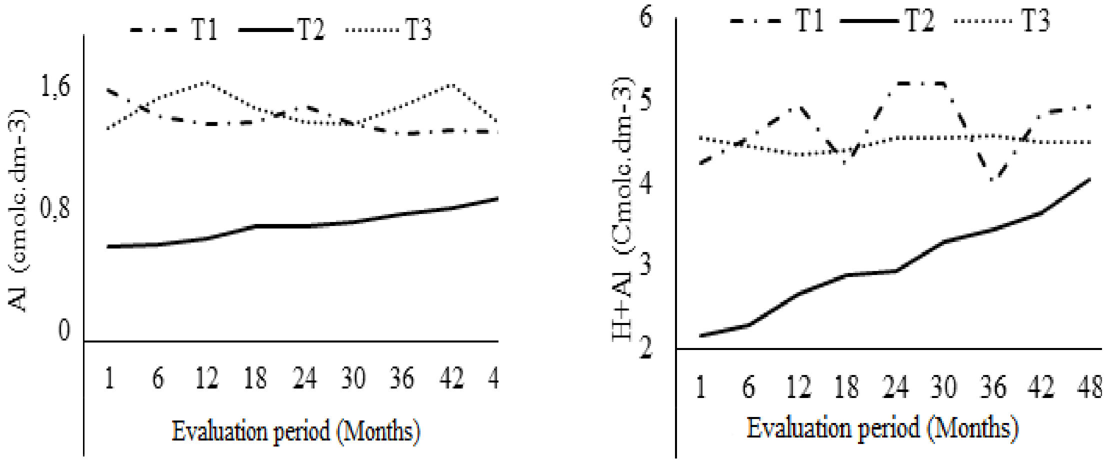
Figure 4. Values of potential acidity (A) and aluminum (B) in T1 - Control, secondary forest, T2 - Management system with vegetation burning and T3 - Management system without vegetation burning for the implementation of the agroforestry system.



A B

Source: Authors.

The low values of exchangeable aluminum are associated with the high percentage of base saturation that immobilizes exchangeable aluminum available in the soil subjected to burning of its vegetation (Silveira, et al., 2010). Although FMS had an average value of 0.76 $cmol_c$ dm^{-3}, a 49% increase in exchangeable Al values was observed from the first to the 48th month (Figure 4 A). This fact might be related to the reduction of cations in the months after the fires. Similar results were also observed by Rheinheimer et al. (2003), who found a decrease in the percentage of Al after burning and subsequent elevation after 90 days, in such a way that at the end of their study, the concentrations remained lower in the places that were burned, corroborating the data found in the present study. The high values of exchangeable Al at SF and MSWB correspond to values considered common for soils of the region, which are mostly characterized as acidic soils (Embrapa, 1999).

Although the lowest mean value of Potential Acidity (H + Al) was recorded in FMS, it was in this treatment that the greatest amplitude of the initial and final values was registered, with an increase from 2.15 to 4.04 $cmol_c$ dm^{-3}, respectively, representing a 46.78% increase (Figure 4 B). Ribeiro (2006) observed similar behavior after the fire, where approximately 2.5 $cmol_c$ dm^{-3} were recorded. In the other treatments, the values in the half-yearly evaluations were close to the averages, due to the low concentration of cations in the soil of the secondary vegetation, a characteristic common to the soils of the Amazon region that are classified as dystrophic, which limits the development and production of food crops (Smith, 2000).

The low values in the concentration of H+Al at the beginning of the evaluations are due to the large availability of cations from the ashes of the burnt material and deposited in the soil, which, in turn, reduce their availability according to the consensus of the plants that are born or re-sprout after burning, due to losses from leaching or immobilization by other chemical and/or biological components of the soil, causing the potential acidity to increase as the soil cationic potential is reduced (Debano, et al., 1998; Rheinheimer, et al., 2003).

The values of the base saturation in FMS might have favored the reduction of aluminum saturation in the same treatment, whereas in SF and MSWB treatments, the inversely proportional relationship between the percentage of base saturation and the exchangeable Al content can be observed, which is due to the increase in pH, caused by the high concentrations of basic cations (Ca and Mg) in the soil right after the fires, causing the immobilization of aluminum in the form of hydroxide (Lopes, et al., 1991).

As a general rule, the use of the vegetation cutting and burning system provides possible improvements in the soil fertility level, mainly due to increases in pH, base saturation and available P and reduction in exchangeable Al levels. However, it has also been shown that this improvement in soil fertility is of relatively short duration, which leads to the need to use fertilizers (Hernani, et al., 1999). According to Brinkmann & Nascimento (1973), despite the increases in soil fertility after burning, the return of nutrients in this way is not sufficient to guarantee activity for a long term.

4. Final Considerations

The type of management in the implementation of Agroforestry Systems changes the chemical properties of the soil through time.

The management system using vegetation burning increases soil fertility in the period one, just after burn. However, as a consequence, there is a decrease in fertility, reaching, in some cases, values lower than before the fire. The use of fire promotes a high transformation in the environment, with a very slightly increase in soil fertility after burning. Therefore, the management system without vegetation burning is the most recommended for the implantation of an agroforestry system in areas of secondary vegetation for maintaining, and even enhancing, the chemical properties of the soil.

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