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Influence of burning and weed control on the soil fertility and vegetation cover of Brazilian Amazon pastures

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Influencia de la quema y el control de malezas sobre la fertilizad del suelo y la cobertura de vegetal de los pastizales de la Amazonía brasileña

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ABSTRACT

Keywords:
Bare soil
Fire
Forest
Soil erosion
Urochloa brizantha

In pastures it is common to use fire to control weeds, justified by the increase in soil fertility that ashes can generate. However, the benefits of this process is short-lived, and also increase the soil exposure. The permanence of weeds can contribute to the vegetation cover in areas of deficient pastures. This study aimed to evaluate the effect of prescribed burning and mowing on vegetation cover of *Urochloa brizantha (U. brizantha)* pastures and soil surface fertility in pastures located in the Brazilian Amazon. The study was conducted in Itupiranga, Pará state, Brazilian Amazon. Five pastures of *U. brizantha* cv. Marandu and a forest area were evaluated. The soil was a Ferralsol. Vegetation cover was estimated using a quadrat. Four composite soil samples were taken in each area, collected from 0–0.05 m depth. The percentage of vegetal cover of *U. brizantha*, weeds and bare soil was measured and fertility in soil samples (pH, Al^{3+}, Ca^{2+}, Mg^{2+}, K^+, Na^+, P, and H+Al) were determined. Three groups were identified in the evaluated pasture plots. Group I had the highest average percentage of bare soil (33.5%) and was associated with H+Al and P values. Group II had the highest average of *U. brizantha* cover (90%) and was associated with Ca^{2+}+Mg^{2+} and K^+. Group III had the highest average of weed cover (53.4%) and was associated with Al^{3+}. The higher percentage of *U. brizantha* in Group II was favored by the burning later. This group presented better levels of K^+, Mg^{2+} and sum of bases. The management adopting the least use of fire on the pastures, with longer time for the regeneration of forage, combined with the mechanical control of weeds, can be the best alternative for maintaining the soil cover and bringing benefits for quality surface layer of the soil.

RESUMEN

Palabras clave:
Suelo expuesto
Fuego
Bosque
Erosión del suelo
Urochloa brizantha

En los pastos es común utilizar el fuego para controlar las malas hierbas justificado por el incremento de fertilidad en el suelo que pueden generar las cenizas. Sin embargo, los beneficios de este proceso son de corta duración, además de aumentar la exposición del suelo. La permanencia de las malezas puede contribuir a la cobertura vegetal en áreas de pastos deficientes. Este estudio tuvo como objetivo evaluar el efecto de la quema prescripta y corte de malezas en la cobertura vegetal de los pastos de *U. brizantha* y en la fertilidad de la superficie del suelo en pastos ubicados en la Amazonía brasileña. El estudio se realizó en Itupiranga, estado de Pará, Amazonía brasileña. Cinco pasturas de *U. brizantha* cv. Marandu y un área de bosque fueron evaluados. El suelo era un "Latosol Rojo-Amarillo" (Ferralsols). La cobertura vegetal se estimó utilizando un cuadrante. Se tomaron cuatro muestras de suelo compuestas en cada área, recolectadas de 0–0,05 m de profundidad. Se determinó el porcentaje de cobertura vegetal de *U. brizantha*, malezas y suelo expuesto y la fertilidad en muestras de suelo (pH, Al^{3+}, Ca^{2+}, Mg^{2+}, K^+, Na^+, P y H+Al). Se identificaron tres grupos entre las parcelas de pastos evaluadas. El grupo I tuvo el porcentaje promedio más alto de suelo expuesto (33,5%) y se asoció con los valores de H+Al y P. El grupo II tuvo el promedio más alto de cobertura de *U. brizantha* (90%) y se asoció con Ca^{2+} + Mg^{2+} y K^+. El grupo III tuvo el promedio más alto de cobertura de hierbas (53,4%) y se asoció con Al^{3+}. El mayor porcentaje de *U. brizantha* en el grupo II se vio favorecido por la quema posterior. Este grupo presentó mejores niveles de K^+, Mg^{2+} y suma de bases. El manejo adoptando el menor uso del fuego en los pastos, con un mayor tiempo de regeneración de forrajes, combinado con el control mecánico de malezas, puede ser la mejor alternativa para mantener la cobertura del suelo, trayendo beneficios a la calidad química de la capa superficial del suelo.

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The Brazilian legal Amazon has a total area of, approximately, 5.0 million km^2, corresponding to about 60% of the Brazilian territory. In 2018, it had a cumulative deforested area corresponding to 708,301 km^2, equivalent to about 17% of the entire Brazilian Amazon forest. Approximately 13% of the area is occupied by agriculture, with an estimated area of 43,092,115 ha occupied by pasture (Miranda *et al*., 2019).

In these pastures, it is common to use fire to control weeds and to stimulate pastures regrowth, arguing the ashes can increase the soil fertility. However, about 90 days after burning, soil fertility levels begin to decrease (Santana *et al*., 2013). Thus, the benefits of this process are short-lived, increasing soil exposure to erosive processes.

The conversion of Amazon rainforest to pasture through slash and burn, affects the physical, chemical, biological and even mineralogical properties of the soil. It is aggravated by the general characteristics of the soils formed in the region, which have extreme poverty in phosphorus available (P); high acidity; high aluminum saturation (Al^{3+}); low Cation Exchange Capacity (CEC); macro and micronutrient poverty and susceptibility to compaction and erosion (Vale-Júnior *et al*., 2011).

The effect of temperature caused by burning on soil chemical properties leads to an increase in pH, CEC, in addition to calcium (Ca), magnesium (Mg), potassium (K) and phosphorus available (P). The rise in temperature increase the pH value and decrease the CEC. Regarding nutrients, if the burning temperature rises in excess, Ca, Mg, K and P decrease (Giovannini *et al*., 1990).

The exposure of the soil to extreme temperatures (>600 °C) also causes auterations in mineralogy and texture of the soil, increasing the amount of sand and a decrease in silt and, mainly, clay. Regarding mineralogy, with increasing temperature, the peaks for gibbsite in the sand fractions can gradually decrease in intensity, and disappear completely at a temperature above 600 °C (Ketterings *et al*., 2000).

In pastoral systems, the topsoil is sensitive to changes in management, mainly due to the compacting of the surface caused by heavy animals grazing in extensive systems. Also, the microbial activity of the soil and the contributions of plant material affect the dynamics of soil properties on the surface in relation to the soil in depth (Boeni *et al*., 2014).

Studies about chemical changes in the superficial layer of the soil (0-0.05 m) under forest subjected to burning, showed an increase in the values of pH, electrical conductivity, organic carbon and exchangeable bases, caused by the addition of ash from the fires (Iglesias *et al*., 1997). Alterations may also occur in fertility, in which the soil has higher concentrations of P, Mg and K, after being subjected to high temperatures; however, a decrease in the density of microfungi could occur (Copogna *et al*., 2009). Other alterations in the superficial layer (0-0.05 m) can be observed in relation to the increase of the sand fraction and decrease of the silt and clay fractions (Ketterings *et al*., 2000).

Because of the bad aspects that fire can cause in soil properties, some alternatives can be used to suppress its use, including mowing (weed cutting practice). The permanence of plants considered weeds, can contribute to the vegetation cover in areas with deficient pastures, in order to protect the soil (Campos *et al*., 2019).

Weeds can protect to the soil in degraded pastures, as the plants intercept the direct splash of rain promoting infiltration, increasing water retention and dissipating runoff (Lewis *et al*., 2013). Studies show lower losses of nutrients, such as N, P and K, in cultivation systems in presence of weeds (Lenka *et al*., 2017).

Regarding soil quality, the non-removal of weeds contributed positively to Ca and CEC. In addition, it raises the total organic carbon content by 0–0.03 m (Araujo-Junior *et al*., 2011). Therefore, manual weed control in areas with deficient pasture can be an efficient alternative for maintaining soil quality without the use of fire, which can promote deleterious changes in edaphic characteristics.

Due to the high use of fire in pasture systems in the Amazon studies of the fertility levels of these soils are necessary. In this sense, this study aimed to evaluate the effect of prescribed burning and mowing on vegetation cover of *U. brizantha* pastures and soil fertility in pastures located in the Brazilian Amazon.

MATERIALS AND METHODS

Site description

The study was conducted in Itupiranga county (05°08'20" S, 49°19'25" W), Pará state, which is part of the Brazilian Amazon. The soil is a Latossolo Vermelho-Amarelo (Embrapa, 2009), Ferralsols (FAO, 2015). The regional climate is Am in the transition to Aw (Köppen and Geiger, 1954). The region has an average annual temperature of 26.35 °C and has a dry season between May and October, and a wet season between November and April (Lisbôa, 2017).

Five pasture plots were evaluated in two contiguous farms (A and B), as well as a native (original) forest fragment between them, as reference. In the areas where the pastures were located, a previous native forest was slashed and burned for pasture formation in 1993 and was seeded with *U. brizantha* cv. Marandu. The forest in question is classified as a land-based equatorial broadleaf forest. The pastures never received any type of improvement or fertilizer and only were subjected to slash-and-burn agriculture and mowing until the year 2015 (Table 1).

Table 1. Management applied in five areas of *U. brizantha* pasture in Itupiranga county, Pará state, Brazil.

Farm	Pasture plot	Area (ha)	Number of animals per hectare (animal ha^{-1})	Management applied
A	1	6.0	1.6	Burned in 2015, and mowing
A	2	6.0	1.6	Burned in 2014, and mowing
B	3	4.0	2.0	Burned in 2010, without mowing
B	4	6.5	2.0	Burned in 2010, and mowing
B	5	7.0	2.0	Burned in 2010, and mowing

Data were collected, and analyzed in 2015 during the dry season (July). Vegetation cover (*U. brizantha*, weeds, and bare soil, %) was estimated using a quadrat (Martha-Junior *et al*., 1999), which consisted of 2.0 m^2 wooden square that contained a checkered mesh of string with 80 small squares. From each plot, 12 samples were recorded. Weeds were considered any other species than *U. brizantha*, including *Eupatorium* sp., *Cenchrus* sp., *Cynodon* sp., and *Crotalaria* sp.

Soil sampling and analysis

Soil samples were collected from 0–0.05 m under the soil surface. To cover as much as possible the entire area studied in each pasture area and in the forest area, four composite samples (obtained from three simple samples) were taken in each area (12 samples in each plot). Together with the pasture, soil samples from a natural (original) forest area that has never been altered were also collected, as a reference. In the laboratory, roots were manually removed from the soil samples before they were passed through a 2 mm sieve. The soil samples sieved were analyzed for: pH in water, in the ratio 1:2.5; Al^{3+}, Ca^{2+}, Mg^{2+} and Na^{+}, extracted with KCl at 1 mol L^{-1}, at the ratio 1:10; Al^{3+}, by titration with 0.025 mol L^{-1} NaOH; Ca^{2+} and Mg^{2+} by atomic absorption spectrophotometry; Na^{+} by flame photometry; K^{+} and P available by extraction with Mehlich-1 (HCl 0.05 mol L^{-1} + H_2SO_4 0.0125 mol L^{-1}) at the ratio 1:10; and H + Al, by Ca $(OAc)_2$ at 0.5 mol L^{-1}, adjusted pH 7.0, at the ratio 1:15, titrated with 0.0606 mol L^{-1} NaOH (Embrapa, 2011).

Statistical analysis

According to Monroe *et al.* (2016), Fontes *et al.* (2014), Rocha-Junior *et al.* (2014) and Lisbôa *et al.* (2016), the data was analyzed by ANOVA analysis. A randomized design with four replicates (four composite samples), which are considered as pseudo-replication in studies that involve data collection in the field. Each area (pastures and forest) was considered to be a fixed-effect treatment due to several sources of variation as manual control of weeds and burning.

The normality of the data was checked (Shapiro and Wilk, 1965). Also, a cluster analysis was conducted based on the vegetation cover data to identify groups in terms of pasture similarity. These data were subjected to analysis of variance (ANOVA) and a post hoc test (Tukey, $P<0.05$). The soil fertility data were combined based on the groups obtained by the cluster analysis and compared with the reference area (forest) by ANOVA and a post hoc test (Tukey, $P<0.05$). A principal component analysis (PCA) was performed to analyze relationships among the vegetation cover variables and soils fertility data. All the analyses were performed using R, version 3.0.1 (R Core Team, 2013).

RESULTS AND DISCUSSION

Descriptive statistics of the vegetation cover variables are presented in Table 2.The highest percentages of *U. brizantha* cover were presented in pastures of the plot 4 (90.6%) and the plot 5 (89.4%); the highest percentage of bare soil occurred in pasture of the plot 1 (40.4%) and the highest percentage of weed cover was 53.4% in pasture of the plot 3.

The vegetation cover variables were subjected to a cluster analysis based on Euclidean distances by the complete method. Three groups were identified from the plots evaluated (Figure 1): Group I consisted of pasture plots 1 and 2 (Farm A), Group II contained pasture plots 4 and 5 (Farm B), and Group III only contained pasture plot 3 (Farm B).

Table 2. Vegetation cover and bare soil percentage in five pastures in Itupiranga county, Pará state, Brazil.

Pasture plot	*U. brizantha* (%)	Bare soil (%)	Weeds (%)
1	59.4±4.5	40.4±4.5	0.2±0.6
2	55.0±9.5	26.6±7.7	18.4±7.1
3	36.8±9.8	9.8±5.3	53.4±10.8
4	90.6±1.8	6.8±1.0	2.6±1.8
5	89.4±4.0	6.0±2.6	4.6±2.3

Vegetation cover data were combined based on their clusters and subjected to an ANOVA (Table 3). Group II had the highest average *U. brizantha* cover (90%), followed by Group I (57.2%) and III (36.8%). The absence of burning after 2010, and the practice of weed control, caused the high percentage of *U. brizantha* cover in Group II. The manual control of weeds in this group favored the domination by the species *U. brizantha*. The morphological and physiological characteristics of pastures such as a fibrous root system and C4 photosynthesis make them strong competitors, resulting in an important edaphic benefit protecting the soil surface and preventing moisture loss (Morris *et al.*, 1993; Heringer and Jacques, 2002).

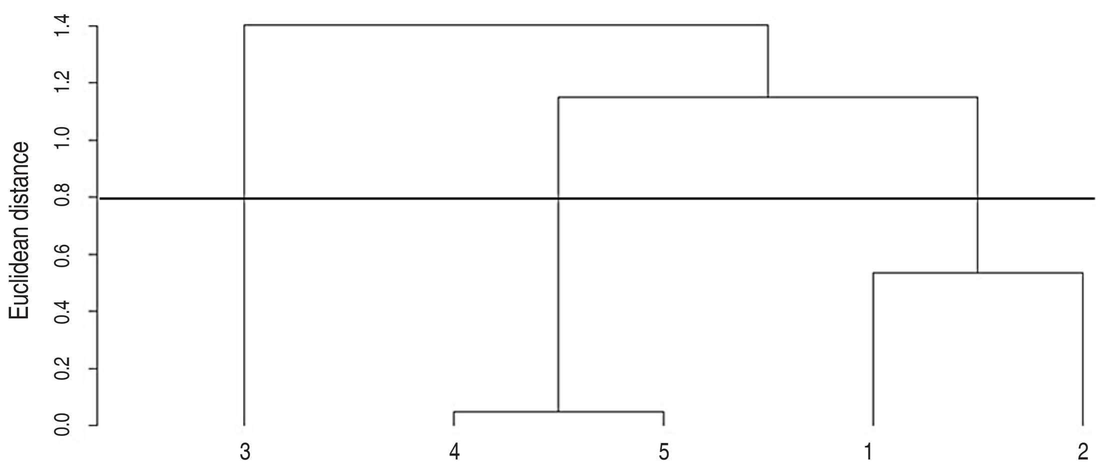

Figure 1. Cluster analysis of five *U. brizantha* pastures in Itupiranga county, Pará state, Brazil.

Group I had the highest average percentage of bare soil (33.5%), followed by Groups II (6.4%) and III (9.8%). Group I had the highest average percentage of bare soil because burning between 2014 and 2015 affected vegetation cover and caused an increase in bare soil. Burning is a quite common practice among Brazilian farmers since, theoretically, it increases soil fertility by adding nutrients from ash. However, this benefit is temporary because the soils are exposed to leaching by rainfall, triggering a low soil fertility and increase aluminum saturation, which affects plant growth (Heringer and Jacques, 2002; Santana *et al.*, 2013).

Group III had the highest average weed cover (53.4%), followed by Group I (9.3%) and II (3.6%). Group III (only contained pasture plot 3) had the highest average weed cover because it received no weed control, as opposed to Santos *et al.* (2019), who considered mowing as an inefficient activity for weed control. In this study, this method proved to be effective, since Group I and Group II showed less weeds compared to Group III.

Table 3. Vegetation cover variables averages (%) in three groups of *U. brizantha* pasture in Itupiranga county, Pará state, Brazil.

Group	*U. brizantha* (%)	Bare soil (%)	Weeds (%)
I	57.2^{b}	33.5^{a}	9.3^{b}
II	90.0^{a}	6.4^{b}	3.6^{b}
III	36.8^{c}	9.8^{b}	53.4^{a}
[1]CV (%)	52.73	36.47	10.26

Different lower case letters in a column indicate a statistically significant difference (P<0.05) between the groups according to the Tukey test.
[1] Coefficient of variation.

Table 4 shows the fertility data of five pastures and forest plots in the areas studied. Soil pH varied from 3.5 to 4.0. P varied from 1.5 mg dm^{-3} (pasture 2) to 5.1 mg dm^{-3} (forest). K^+ varied from 120 mg dm^{-3} (forest) to 40 mg dm^{-3} (pasture 3 and 4). The highest value of Ca^{2+} was in forest soil (1.0 cmol$_c$ dm^{-3}), and the smallest value was in pasture 4 soil (0.1 cmol$_c$ dm^{-3}). The Mg^{2+} values varied from 0.2 cmol$_c$ dm^{-3} (pasture 4) to 0.9 cmol$_c$ dm^{-3} (forest and pasture 4). Al^{3+} was another element that presented values bellow 1.0 cmol$_c$ dm^{-3} and varied from 0.4 cmol$_c$ dm^{-3} (pasture 4) to 1.0 cmol$_c$ dm^{-3} (pasture 4). Higher values of H+Al were observed in forest soil (12.7 cmol$_c$ dm^{-3}).

Table 4. Soil fertility data of forest and pastures, in Itupiranga county, Pará state, Brazil.

	Forest	Pasture 1	Pasture 2	Pasture 3	Pasture 4	Pasture 5
pH	3.5±0.2	3.9±0.1	4.0±0.3	4.0±0.1	3.7±0.2	3.9±0.2
P	5.1±1.9	3.5±0.6	1.5±0.7	1.9±0.3	1.7±0.8	2.2±0.9
K^+	120.0±24.4	90.0±46.9	120±11.5	40.0±27.0	40.0±20.4	43.8±13.7
Na^+	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0
Ca^{2+}	1.0±0.2	0.5±0.2	0.4±0.2	0.3±0.2	0.1±0.1	0.4±0.2
Mg^{2+}	0.9±0.3	0.5±0.2	0.9±0.3	0.4±0.2	0.2±0.1	0.7±0.3
Al^{3+}	0.9±0.3	0.9±0.3	0.4±0.2	0.8±0.2	1.0±0.1	0.8±0.4
H+Al	12.7±2.1	7.7±1.4	4.2±2.1	7.0±1.0	5.9±1.6	7.3±1.5
SB	2.1±0.5	1.2±0.5	1.6±0.5	0.8±0.4	0.5±0.2	1.2±0.6

pH: hydrogen potential; P: phosphorus (mg dm^{-3}); K: potassium (mg dm^{-3}); Na: sodium (mg dm^{-3}); Ca: calcium (cmol$_c$ dm^{-3}); Mg: magnesium (cmol$_c$ dm^{-3}); Al: aluminium (cmol$_c$ dm^{-3}); H+Al: potential acidity (cmol$_c$ dm^{-3}); SB: Sum of Basis (cmol$_c$ dm^{-3}).

The soils of all studied areas presented low levels of fertility according to Prezotti and Guarçoni (2013) classification. Soil pH values were considered low and acid. The values of Al^{3+} were medium, whereas H+Al values were high. The soils also presented low values for the sum of bases, except forest which had median values. The soil under the pastures presented low values of K^+, Ca^{2+}, and Mg^{2+}.

Zenero *et al.* (2016) found pH values in Amazon soils of 3.9, from 0 to 0.06 m of depth, which demonstrates this soil can be extremely acid. Soil pH is determined by the concentration of hydrogen ions (H^+), and it is influenced by acid (H^+, Al^{3+}, Fe^{2+}, or Fe^{3+}) and base-forming cations (Ca^{2+}, Mg^{2+}, K^+, and Na^+) in the soil. Acidic conditions occur in regions with higher amounts of precipitation. High precipitation causes leaching of base-forming cations and decreasing of soil pH. Natural acidic soils are commonly found in forest soils (McCauley *et al.*, 2017).

The action of fire on the chemical and physical properties of the soil, combined with the contribution of the nutrients present in the ash, may have contributed to the increase in pH and H+Al in the pasture areas, regarding the soil forest (original) (Giovanni *et al.*, 1990; Iglesias *et al.*, 1997; Zanero *et al.*, 2016). Regarding the Phosphorus content, the soil under forest showed better conditions in terms of Phosphorus availability for the crops, in relation to the soils under pasture (Prezotti and Guarçoni, 2013). These results are expected for Ferralsols, which present low fertility because of its source material, high weathering, removal of SiO_2, and accumulation of Al_2O_3 in its mineral phase, with a predominance of kaolinite and oxides of iron and aluminum (Araujo-Junior *et al.*, 2011).

Relating to the availability of P in soils, fire can have a great influence on the bond between P and clay minerals. Considering that the Mehlich-I extraction is based on the principle of dissolution of minerals containing P (Corrêa, 1993), studies relate to the retention of P in mineral surfaces with temperature are important. With that in mind, Ketterings *et al.* (2000) evaluated the temperature caused by fire over mineralogy and soil texture. The authors observed that the temperature by the fire influenced the clay, decreasing its quantity, mainly, by 0-5 cm, including the reduction of clay minerals such as gibbsite ($Al(OH)_3$). This mineral is important in the adsorption of P in the soil, and the decrease in that nutrient (P) is related to the decrease in the mineral ($Al(OH)_3$). Despite this, a dense canopy cover, as in the forest area, protects soil against loss of P as runoff or leaching.

The soil analysis data were combined into their respective groups and compared to each other and the forest area (Table 5). Soil pH value was smaller in forest soil (3.5) than the other pasture soils. There were no differences in Al^{3+} values between the areas. Forest soil presented the highest values for H+Al, P (5.12 mg dm^{-3}), K^+ (120 mg dm^{-3}), Ca^{2+} (0.96 cmolc dm^{-3}), Mg^{2+} (0.85 cmolc dm^{-3}), and SB (2.12 cmolc dm^{-3}).

Table 5. Soil fertility data of forest soil and three pastures groups, in Itupiranga county, Pará state, Brazil.

	pH	P	K^+	Ca^{2+}	Mg^{2+}	Al^{3+}	H + Al	SB
Forest	3.5 ^{b}	5.1 ^{a}	120.0 ^{a}	0.9 ^{a}	0.8 ^{a}	0.9 ^{a}	12.6 ^{a}	2.1 ^{a}
I	3.9 ^{a}	2.7 ^{b}	65.0 ^{b}	0.4 ^{b}	0.4 ^{ab}	0.8 ^{a}	7.3 ^{b}	1.0 ^{bc}
II	3.9 ^{a}	1.8 ^{b}	81.8 ^{ab}	0.4 ^{b}	0.7 ^{a}	0.6 ^{a}	5.7 ^{b}	1.4 ^{ab}
III	3.7 ^{ab}	1.7 ^{b}	40.0 ^{b}	0.1 ^{b}	0.2 ^{b}	0.9 ^{a}	5.8 ^{b}	0.5 ^{c}
CV (%)	5.3	42.2	50.7	47.7	47.6	41.8	25.7	41.9

Different lower case letters in a column indicate a statistically significant difference (P<0.05) between the groups according to the Tukey test. pH: hydrogen potential; P: phosphorus (mg dm^{-3}); K: potassium (mg dm^{-3}); Ca: calcium (cmol$_c$ dm^{-3}); Mg: magnesium (cmol$_c$ dm^{-3}); Al: aluminium (cmol$_c$ dm^{-3}); H+Al: potential acidity (cmol$_c$ dm^{-3}); SB: Sum of Basis (cmol$_c$ dm^{-3}). CV: Coeffcient of variation (%).

As it was demonstrated in Table 5, soil pH value was higher in pastures soils, along with ash deposition, which can contribute to raising pH values, this fact may be related to the loss of the OH groups of the clays, caused by the temperature rise by burning, which contributes to the formation of oxides of various elements derived from the rupture of carbonates (Giovanni *et al.*, 1990). Also, the ashes from the fire, are mainly composed of Ca, Mg, K, Si, phosphates, and carbonates ($CaCO_3$). In spite of the short benefit of ash reported by the literature, the low solubility of this mineral allows its persistence for more than three years after the fire, keeping the pH moderately alkaline in superficial horizons, in normally acidic soils (Iglesias *et al.*, 1997).

The forest presented the highest values of macronutrients (P, K^+, Ca^{2+}, and Mg^{2+}). This fact demonstrates the important role that trees play absorbing available nutrients from lower depths and distribute it to the soil surface via litterfall. Besides, as in the forest area, it takes up available nutrients from lower depths and redistributes them to the soil surface vialitterfall, the decomposition of straw on the soil surface can increase the availability of nutrients, favoring plants(Campos et al., 2019). Kautz *et al.* (2013) explained the nutrient accumulation in the Ap horizon as a turnover and long-term accumulation of nutrients acquired from the subsoil and translocated in the shoot and root systems, predominantly as a result of litter mineralization in the Ap horizon. As the forest area has a huge diversity of tree species, they can have roots at different depths, which means greater access to nutrients compared to pasture.

As discussed before, the absence of fire after 2010 until 2015 and the practice of weed control caused a high percentage of *U. brizantha* cover in Group II, and this can benefit vegetation growth. Roots can reach high depth as in *U. brizantha*, and the high rhizosphere extension can assist them in the access to water and nutrients and provide greater shoot growth (Kautz *et al.*, 2013).

The PCA results are presented in Figure 2. Vegetation cover from the forest area was not collected. The values of Ca^{2+} and Mg^{2+} were not included in this analysis to avoid multicollinearity, instead of that, they were summed as Ca^{2+}+Mg^{2+}, for the same reason, the sum of basis was not included (Hair *et al.*, 2005).

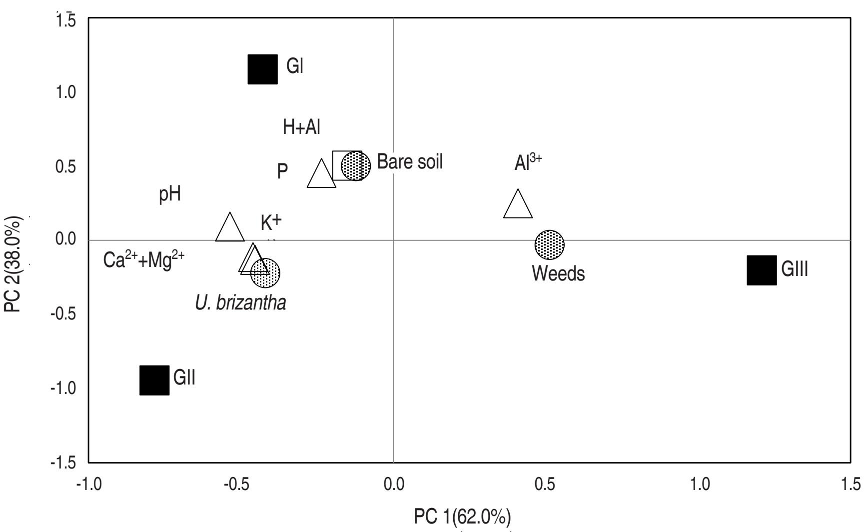

Figure 2. Principal component analysis of vegetation cover and soil fertility in *U. brizantha* pastures in Itupiranga county, Pará state, Brazil. GI: Group I; GII: Group II; GIII: Group III; P: phosphorus (mg dm^{-3}); K: potassium (mg dm^{-3}); Ca + Mg: calcium + magnesium (cmolc dm^{-3}); Al: aluminium (cmolc dm^{-3}); H+Al: potential acidity (cmolc dm^{-3}).

Principal component 1 (PC 1) explained 62.0% of the variability, and principal component 2 (PC 2) explained 38.0%. Group I, which had a high percentage of uncovered soil, was associated with the values of H+Al and P. This demonstrates that these soils have low natural fertility, which can be aggravated by burning pastures. With the most recent use of fire, 2014 and 2015, the low growth of forage in the pastures of this group indicates that, perhaps, this area has not yet recovered, with less soil coverage. In turn, the lack of cover can result in the worsening of soil quality, due to the lack of nutrient cycling, accumulation of nutrients and organic matter and leaching of nutrients. In addition, the lack of liming and soil fertilization, also aggravate the issue of acidity (Kautz *et al.*, 2013; Santos *et al.*, 2015).

Group II, where later burning occurred in 2010, there was the highest *U. brizantha* cover, and less weeds, was better related to exchangeable soil bases (Ca^{2+}+Mg^{2+}, and K^{+}). According to Crespo *et al.* (2015), an important way of nutrients entry in pasture soils is the litter. The biomass of pasture roots can contribute to the nutrients deposition in these systems; after this, nutrients return to the soil, and subsequently recycled.

PCA results for Group III had a better association for weeds and Al^{3+}. This group presented the highest aluminum values and the lowest sum of base values. Under these conditions, cultivable plants have severe restrictions on their establishment, which may decrease their presence in the area, increasing the presence of weeds. In the absence of soil correction, with the lime application, acidification causes an increase in species regarded as agricultural weeds, and a reduction in productivity (Goulding, 2016). Weed species identified in the present study are commonly found in soils with low fertility and high acidity (Gazziero *et al.,* 2006; Brighenti *et al.,* 2010; Moreira and Bragança 2011; and Costa *el al*., 2011).

CONCLUSIONS

There was similarity between the pasture areas, reducing the five pastures to three groups. The highest percentage of uncovered soil was observed in Group I, which was associated with more recent pastures burning.

The highest percentage of *U. brizantha* was observed in Group II, which was favored by the later burning, in relation to the other pastures, and with the practice of mechanical weed removal. This group had better levels of K, Mg and sum of bases.

As expected, the highest percentage of weeds was observed in Group III, where there was no control for their proliferation. This group had a greater relationship with the high levels of Al^{3+} in the area.

Adopting the least use of fire on the pastures combined with the mechanical control of weeds, can be the best alternative for maintaining the soil cover and bringing benefits for quality surface layer of the soil.

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