

Short-term soil chemistry changes in a fire-free land use system for smallholdings in Brazilian Amazon

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Abstract

The aim of this study was to evaluate short-term effects of a low input fire-free system for land use by smallholders in Brazilian Amazon. Changes in soil pH, organic matter and extractable nutrients were evaluated during the first and second cropping periods after lime and three fertilizer level application while using corn intercropped with rice and cowpea. During the first cropping period, lime application combined with fertilization resulted in higher soil pH in comparison with no lime and no fertilization treatments. In the second cropping period, larger value for soil pH was only observed if lime was combined with the higher fertilizer level. No lime application resulted in the decrease of soil pH, mainly when plants received fertilizer. Differences for soil organic matter were only observed during the second cropping period and the combination between liming and fertilization increased organic matter content. Both soil calcium and magnesium contents increased due to the association between liming and fertilization, while soil P was slightly increased because of fertilization. With the use of lime and the specific fertilizer levels, the soil chemistry of the fire-free land system did improve, indicating that the proposed system is suitable for smallholders in the Brazilian Amazon.

Key Words

Alternative to slash-and-burn, lime, fertilizers, mulch, smallholders

Introduction

The slash-and-burn technique is a main cause of land degradation and deforestation in many tropical countries, just like the Brazilian Amazon. It is the main technique for smallholder land use system. This agricultural pattern is characterized by cycles of cutting and burning fallow vegetation for site preparation, a cropping phase of approximately four years and a fallow stage with native vegetation reclaiming the site. Fallow vegetation has different advantages in the context of small-scale farming and management of agricultural landscapes to reclaim burned areas (Sommer 2000; Denich *et al.* 2005). Some studies document positive correlations between fallow length and subsequent crops yield (Swamy and Ramakrishnan 1988; Silva-Forsberg and Fearnside 1997; Kato *et al.* 1999; Bruun *et al.* 2006). The growth of the human population is increasing pressures on limited agricultural land, resulting in short fallow periods (Vielhauer *et al.* 2000; Denich *et al.* 2005; Sanchez *et al.* 2005). When fallow length is short, site reclaim by native vegetation is not reached, increasing the risk of soil degradation. Fire use for land preparation results in the biomass burning that releases nutrients and may impoverish soil (Davidson *et al.* 2004), but if fallow vegetation is not burned it can be a source of biomass for the management of soil organic matter to improve its physical, chemical and biological soil properties (Denich *et al.* 2005).

As a fire-free alternative is to avoid nutrient losses, a system of mechanically chopping the fallow vegetation converting it to mulch was evaluated (Kato *et al.* 1999; Sommer *et al.* 2004; Denich *et al.* 2005). The mulch layer protects the soil, conserves moisture, suppresses weed growth, and supplies the soil with organic matter and plant nutrients (Thurston 1997). In the first cropping period, immediately following land preparation, nutrients are not readily available and the slowly decomposing woody mulch does not provide nutrients as readily as do the ashes of burned vegetation (Denich *et al.* 2005). In the second cropping period the mulch material from the initial fallow period is almost completely decomposed and the nutrients released into the topsoil are available to the second planting (Denich *et al.* 2005). However, nutrients that are removed when crops are harvest need to be replaced, emphasizing the observation of Denich *et al.* (2005) that fertilization is essential to obtain acceptable yields under fire-free land preparation and justifying fertilization not only in the first cropping period. The objective of this study was to evaluate liming and fertilization rates in a fire-free land preparation system adopted at Roraima state, Brazilian Amazon. Effects of no liming, liming, and low fertilizer doses on soil chemical attributes were evaluated during the first and second cropping period after slash-and-mulch fallow vegetation.

Methods

Site description

This research was conducted at the Embrapa Roraima experimental field station, which is located in the municipality of Mucajai (60°58'W; 2°23'N) in the Brazilian state of Roraima. The climate is tropical rainy, with dry period from December to March, and annual precipitation of 1900 -2000 mm. The soil properties of the top 0.2m of the experimental site are: pH (H₂O) 5.5, soil organic matter 3.2%, available P (Mehlich extract) 0.68 mg/kg, effective CEC 3.5 cmol_c/kg, K 0.06 cmol_c/kg, Ca 1.0 cmol_c/kg and Mg 0.4 cmol_c/kg.

Site preparation

A 4-year-old fallow area was prepared for planting during the beginning of the rainy season of 2006. Fallow vegetation was cut and mulched using a chopper attached to a forestry tractor.

Experimental design and treatments

Four replications of the split-plot experimental design were used. Two treatments were chosen for the main plot – lime (1 t/ha) or no lime, while for the sub-plot three. Two cropping periods were considered; at the beginning of the first cropping period (FCP), during the rainy season of 2006, corn was sowed intercropped with rice and at the start of second cropping period (SCP), beginning of 2007, cowpea (*Vigna unguiculata*) was sowed. The fertilizer levels of the first cropping period (FCP) were 80-80-90-70 kg/ha (1), 50-60-50-40 kg/ha (2) and 0-0-0-0 kg/ha (3) of N, P₂O₅, K₂O and S. The fertilizer levels of the second cropping period (SCP) were 60-100-100-200 kg/ha (1), 30-50-50-70 kg/ha (2) and 0-0-0-0 kg/ha (3) of N, P₂O₅, K₂O and S. The size of each plot was 10m x 12m and the nutrient sources for seedbed fertilization were ammonia sulphate, simple superphosphate and potassium chloride. Nutrient sources for sidedressed fertilization were ammonio sulphate and potassium chloride.

Sampling and analysis

At the end of the experimental periods of both first and second cropping period (September of 2006 and 2007), all plants were harvested and soil samples were collected for the first 0.2m. Samples were used to determine soil pH (H₂O), soil organic matter, available P (Mehlich extract), Ca, Mg, and K. All evaluated parameters were analyzed statistically using Genstat package (version 11.1 VSN International Ltda). Analysis of variance ($\alpha = 0.05$) was conducted using ANOVA procedure for split-plot design. Means were separated using the least significant differences procedure.

Results

In the first cropping period, lime application resulted in higher soil pH for fertilizer levels 1 and 2, while in the second cropping period soil pH difference was only observed at the higher fertilizer level (Table 1). There were no interactions of lime application and fertilization. The pH decrease was most probably due to the acidity power of nitrogen source ammonium sulphate. Soil acidification, as a function of nitrogen fertilizer application has been verified by other authors (Mitchell and Smethurst 2004) but in higher nitrogen levels than those used in this study with low input pattern. The Brazilian Amazon soils are very weathered and characterized by low pH, low nutrient contents, and high toxic alluminium. Lime application seems to be an important way to avoid soil acidification in a fire-free land use system.

Table 1. Means of soil pH and organic matter in the first (FCP) and second cropping period (SCP).

	pH _{H2O}						Soil Organic Matter (g /kg)					
	FCP			SCP			FCP			SCP		
	1 [†]	2 [†]	3 [†]	1	2	3	1	2	3	1	2	3
L ^{††}	5.8	5.8	5.7	5.8	5.5	5.8	28.5	26.6	27.2	31.8	27.6	26.4
WL ^{††}	5.4	5.4	5.9	5.0	5.2	5.7	24.5	26.7	26.4	25.0	24.9	27.4
LSD (P=0.05)	0.4			0.5			6.9			5.9		
CV(%)	4			5			15			12		

[†] Fertilizer levels to the first period (kg/ha of N - P₂O₅ - K₂O - S): 1) 80-80-90-70; 2) 50-60-50-40; 3) 0-0-0-0. Fertilizer levels to the second period (kg/ha of N - P₂O₅ - K₂O - S): 1) 60-100-100-200; 2) 30-50-50-70; 3) 0-0-0-0. ^{††} L – liming; WL: without liming.

Management effects on soil organic matter were observed only during the second cropping period in such way that liming was associated with the larger fertilizer level that resulted in the highest soil organic matter value (Table 1). That can be explained by the improvement of crop biomass production in this treatment.

Table 2. Means of soil available P in the first (FCP) and second cropping period (SCP)

	P - Mehlich extract (mg /kg)					
	FCP			SCP		
	1 [†]	2 [†]	3 [†]	1	2	3
L ^{††}	4.1	3.0	2.9	7.1	7.1	2.6
WL ^{††}	3.6	2.8	3.5	5.4	4.9	2.3
LSD (P=0.05)		2.9		3.7		
		49		43		

[†] Fertilizer levels to the first period (kg/ha of N - P₂O₅ - K₂O - S): 1) 80-80-90-70; 2) 50-60-50-40; 3) 0-0-0-0. Fertilizer levels to the second period (kg/ha of N - P₂O₅ - K₂O - S): 1) 60-100-100-200; 2) 30-50-50-70; 3) 0-0-0-0. ^{††} L – liming; WL: without liming

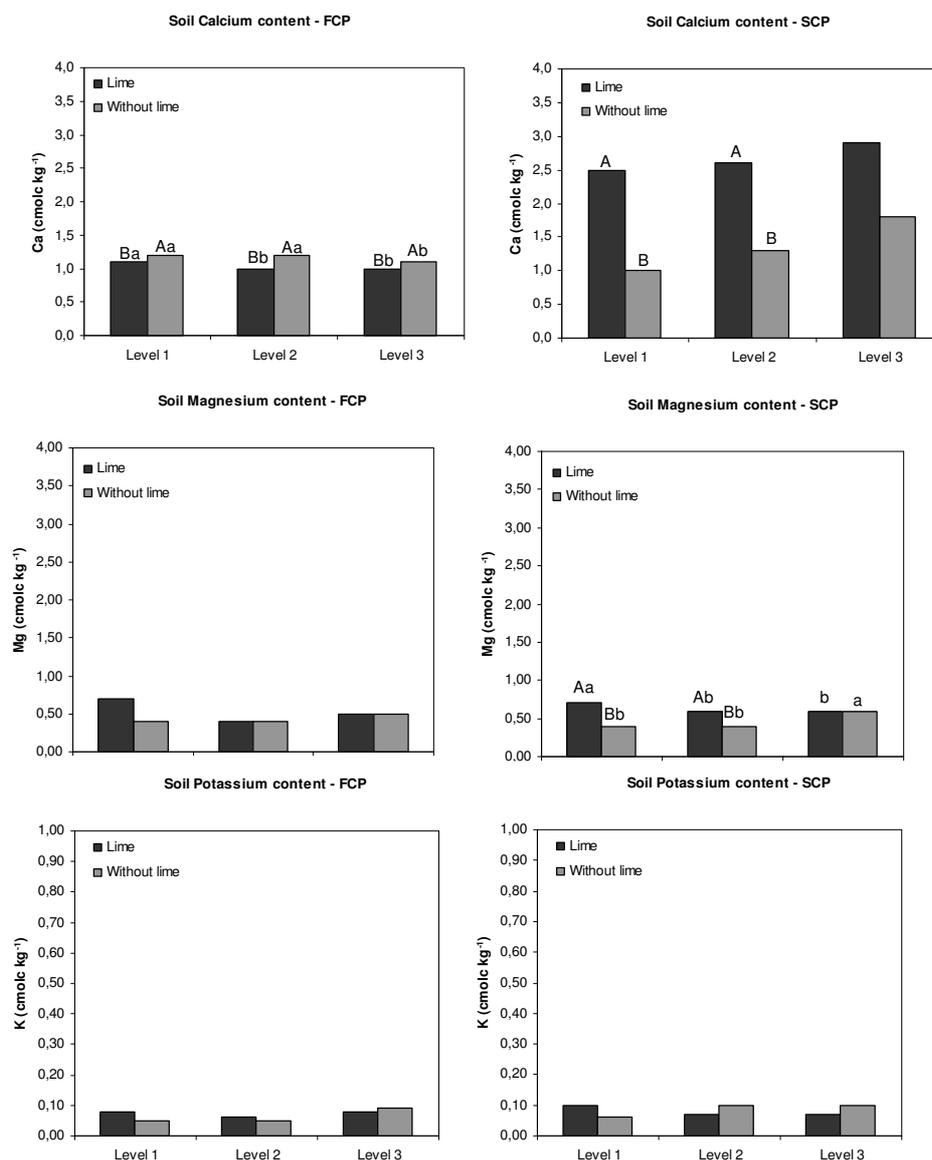


Figure 1. Means of soil calcium (Ca), magnesium (Mg) and potassium (K) in the first (FCP) and second cropping period (SCP). Fertilizer levels to the first period (kg/ha of N - P₂O₅ - K₂O - S): 1) 80-80-90-70; 2) 50-60-50-40; 3) 0-0-0-0. Fertilizer levels to the second period (kg/ha of N - P₂O₅ - K₂O - S): 1) 60-100-100-200; 2) 30-50-50-70; 3) 0-0-0-0. Different capital letters indicate significant differences within the lime treatment. Different lower case letters indicate significant differences within the fertilizer levels.

Soil phosphorus content was increased only in the second cropping period, mainly because of the fertilizer application (Table 2). Based on the Brazilian soil classification system for agricultural purposes (Sousa and Lobato 2004) for P soil content, the obtained values shifted from ‘very low’ to ‘low’ level from the first to the second cropping period.

The analysis of exchangeable bases showed higher values of calcium with no lime application during the first cropping period, whereas this situation was inverted during the second cropping period when lime application was associated with fertilization that resulted in higher calcium content compared with no lime application and no fertilization (Figure 1). Comparing fertilizer levels only, differences were observed at the first cropping period when the most elevated fertilizer level resulted in highest calcium content when using lime. When lime was not applied, calcium content was higher regardless the fertilizer application probably due to the calcium contained in the P source. Differences in the content of magnesium were only observed at the second cropping period, with highest values associated with lime application at the first and second fertilization levels (Figure 1).

Conclusion

The low input production system with lime application and fertilization is an important management tool for the avoidness of soil acidification. Moreover, it allows the increase of both soil organic matter and nutrient content, becoming the alternative fire-free system for land use feasible in Brazilian Amazon.

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