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Director: DrC. Marta Bonilla Vichot
Email: mbon@upr.edu.cu

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*Incidence of **Hevea brasiliensis** on the chemical properties of the soil in the Colombian Amazon*

*Incidencia de **Hevea brasiliensis** sobre las propiedades químicas del suelo en la Amazonia colombiana*

*Incidência de **Hevea brasiliensis** nas propriedades químicas do solo da Amazônia colombiana*

Gelber Rosas-Patiño[1], Jader Muñoz-Ramos[2], Verenice Sánchez-Castillo[3]*

[1] University of the Amazon, Florencia, Caquetá, Colombia

[2] Universidad del Tolima, Ibagué, Tolima, Faculty of Forestry Engineering, Colombia

[3] University of the Amazon, Faculty of Engineering, Florencia, Caquetá, Colombia

[*] Corresponding author: g.rosas@udla.edu.co

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SUMMARY

The cultivation of *Hevea brasiliensis* (rubber) is promoted as a productive and ecological alternative, especially in agroforestry systems, although research is still required to address its impact on soil chemical conditions. This study aimed evaluate the possible effects of five types of land use on the chemical properties of horizons A and B in soils of the Colombian Amazon: agroforestry system of *H. brasiliensis* with timber and fruit trees, agroforestry system of *H. brasiliensis* associated with stubble, *H. brasiliensis* monoculture, secondary forest as positive control and native grass as negative control. The conditions of pH, exchangeable aluminum, organic carbon, potassium, phosphorus, calcium, magnesium, base saturation and cationic exchange capacity were evaluated. Similarities in soil chemical properties were found between secondary forest, agroforestry systems with fruit trees and agroforestry systems associated with stubble. The *H. brasiliensis* monoculture did not present significant differences with the native pasture. The pH was the only variable affected by soil use, while the percentage of organic carbon and the contents of phosphorus, calcium, magnesium and potassium changed depending on the A and B horizons, demonstrating that the variability of the chemical fertility of the clay soils of the Amazon are more related to the characteristics of their horizons than to the type of land use.

Keywords: rubber tree, lomerío soils, agroforestry system, acid soils.

RESUMEN

El cultivo de *Hevea brasiliensis,* caucho, se promueve como alternativa productiva y ecológica, especialmente en sistemas agroforestales, que aborden su impacto en las condiciones químicas del suelo. Este estudio tuvo como objetivo evaluar los posibles efectos de cinco tipos de uso del suelo sobre las propiedades químicas de los horizontes A y B en suelos de la Amazonia colombiana: sistema agroforestal de *H. brasiliensis* con maderables y frutales, sistema agroforestal de *H. brasiliensis* asociado a rastrojo, monocultivo de *H. brasiliensis*, bosque secundario como control positivo y pastura nativa como control negativo. Se evaluaron las condiciones de pH, aluminio intercambiable, carbono orgánico, potasio, fósforo, calcio, magnesio, saturación de bases y capacidad de intercambio catiónico. Se encontraron similitudes en las propiedades químicas del suelo entre el bosque secundario, sistema agroforestal con frutales y sistema agroforestal con rastrojo. El monocultivo de *H. brasiliensis* no presentó diferencias significativas con la pastura nativa. El pH fue la única variable afectada por el uso del suelo, mientras que el porcentaje de carbono orgánico y los contenidos de fósforo, calcio, magnesio y potasio cambiaron en función de los horizontes A y B, demostrando que la variabilidad de la fertilidad química de los suelos arcillosos de la Amazonia está más relacionada con las características propias de sus horizontes que con el tipo de uso del suelo.

Palabras clave: árbol de caucho, suelos de lomerío, sistema agroforestal, suelos ácidos.

RESUMO

O cultivo da *Hevea brasiliensis*, a seringueira, é promovido como alternativa produtiva e ecológica, principalmente em sistemas agroflorestais, que abordam seu impacto nas condições químicas do solo. Este estudo teve como objetivo avaliar os possíveis efeitos de cinco tipos de uso da terra nas propriedades químicas dos horizontes A e B em solos da Amazônia colombiana: sistema agroflorestal de *H. brasiliensis* com árvores madeireiras e frutíferas, sistema agroflorestal de H. brasiliensis associado a restolho, monocultivo de *H. brasiliensis*, mata secundária como controle positivo e pastagem nativa como controle negativo. Foram avaliadas as condições de pH, alumínio trocável, carbono orgânico, potássio, fósforo, cálcio, magnésio, saturação por bases e capacidade de troca catiônica. Foram encontradas semelhanças nas propriedades químicas do solo entre floresta secundária, sistema agroflorestal com árvores frutíferas e sistema agroflorestal com restolho. A monocultura de H. brasiliensis não apresentou diferenças significativas com a pastagem nativa. O pH foi a única variável afetada pelo uso do solo, enquanto o percentual de carbono orgânico e os teores de fósforo, cálcio, magnésio e potássio mudaram dependendo dos horizontes A e B, demonstrando que a variabilidade da fertilidade química dos solos argilosos de na Amazônia estão mais relacionadas às características de seus horizontes do que ao tipo de uso da terra.

Palavras-chave: seringueira, solos de lomerío, sistema agroflorestal, solos ácidos.

INTRODUCTION

The chemical properties of the soil condition the nutritional processes of plants. The chemical fertility of the soil depends, among other aspects, on the pH, the content of organic matter, the presence of nutrients in solution and those adsorbed to colloids (Hailegnaw *et al.,* 2019).

In the Colombian Amazon, soils predominate with accentuated clay textures in the B horizon (Rosas *et al.*, 2016). These soils are acidic, with high aluminum content, low base saturation and limited cation exchange capacity. In addition, they have low carbon, phosphorus, potassium and magnesium contents in their mineral horizons (Rosas *et al.*, 2017), which shows agrological limitations. In this context, the availability of nutrients in productive systems, especially in agroforestry systems, depends on the cycling of organic matter that occurs in the topsoil (Celentano *et al.*, 2020).

The Amazon region in Colombia represents 42.3 % of the country's continental territory (SIAT-AC, 2022). In the last 16 years, it has lost about 5.2 % of its forest, which is replaced with pastures for cattle ranching, with a deforestation rate of 0.46 %. However, in the department of Caquetá, this rate is even higher (0.77 %) (Murad and Pearse, 2018). This deforestation is causing soil degradation and the interruption of the natural cycle of soil processes (Franco *et al.*, 2019).

Agroforestry systems (SAF) are a sustainable, integrated and diversified technological alternative (Celentano *et al.*, 2020). These contribute to soil recovery and promote the creation of a more closed nutrient cycle through deep nutrient capture, increased supply through N fixation, litter production and decomposition, as well as the increase in soil biological activity in agroforestry (Sileshi *et al.*, 2020). Particularly, in the soils of the Colombian Amazon, characterized by their low fertility (Suárez *et al.*, 2015), SAF with *H. brasiliensis* increase organic carbon in the soil and improve the nutrient balance (Joseph *et al.*, 2022).

In the Colombian Amazon region, SAF with *H. brasiliensis* (Willd. ex A.Juss.) Müll. Arg. with the purpose of rehabilitating degraded soils (Peña *et al.*, 2021). These systems are based on the guiding principle that trees in SAFs fulfill ecological functions, such as protecting the soil, improving nutrient cycling, and reducing the direct effects of sun, water, and wind (Nair *et al.*, 1985, Santana *et al..*, 2022). In addition, they contribute to increasing the cation exchange capacity and improving the availability of nitrogen, phosphorus and potassium (Suárez *et al.*, 2015). However, there is not enough clarity about the possible incidences of SAF with *H. brasiliensis* on the chemical conditions of the acidic soils of the Amazon region.

Therefore, the objective of this research was to evaluate the possible effects of five types of land use on the chemical properties of the A and B horizons in soils of the Colombian Amazon: agroforestry system of *H. brasiliensis* with timber and fruit trees, agroforestry system of *H. brasiliensis* associated with stubble, monoculture of *H. brasiliensis*, secondary forest as positive control and native pasture as negative control.

MATERIALS AND METHODS

The research was carried out in *H. brasiliensis* (rubber) plantations, native pastures and localized secondary forests established on hilly soils within the lomerío landscape, in the rural area of the Municipalities of Belén de los Andaquíes, Florencia and El Doncello., in the department of Caquetá, Colombia. The region is characterized by having an average monthly temperature of 24.8°C, evaporation of 88.4 mm, average relative humidity of 87.1 %, average sunshine of 121 h and rainfall of 280.4 mm (IGAC, 2014).

Soil samples were collected from the following covers:

Secondary forest (Bs): forest older than 30 years, with native species, developed by rest in intervened areas; was the positive control in the investigation.

- Agroforestry system with *H. brasiliensis,* fruit trees and/or fruit trees (Saf): the agroforestry arrangements were established from *H. brasiliensis plantations* (clone FX3864) with more than 20 years of cultivation. These plantations were in the production phase and arranged in furrows of 4 m between plants and 7 m between streets. For the last three years, the rubber was fertilized annually with dolomite lime (500 g tree^{-1}) and Remital ® (500 g tree^{-1}). Between the streets were planted with *Bactris gasipaes* Kunth, *Theobroma cacao* L., *Theobroma grandiflorum* WS, *Psidium guajava* L., *Eugenia stipitata* MV, *Citrus* sp., *Borojoa patinoi* C., *Pourouma cecropiifolia* M. and *Ingas sp*. Besides, as timber species were used *Laura nobilis* L., *Cariniana pyriformis* M., *Couma macrocarpa* BR, *Trattinnickia burserifolia* M. and *Luma apiculata* DB.

- Agroforestry system with *H. brasiliensis* associated with stubble (Sar): plantation *of H. brasiliensis* (clone FX3864) with more than 20 years of establishment from native pasture, in the production phase and arranged in furrows of 4 m between plants and 7 m between streets. The producers carried out cleaning practices chete in the furrows, but it was left the streets covered with stubble where the species typical of natural regeneration in the area predominated: *Miconia* sp., *Cecropia membraneceae* T., *Piper arboreum* A., *Vismia brasiliensis* C., *Arundo donax* L., *Clidermia hirta* LD, and *Bellusia grossularoides*.

- *H. brasiliensis* in monoculture (Mhe): *H. brasiliensis* plantation (clone FX3864) with more than 20 years of establishment from native pasture, in the production phase and arranged in furrows of 4 m between plants and 7 m between streets. During the last three years it has been fertilized with dolomite lime (500 g tree $^{-1}$) and 500 g tree $^{-1}$ of Remital ®. These plantations continue to support animal load that grazes the native grass.

- Native pasture (Pna): pastures established for more than 30 years, consisting mainly of *Paspalum Notatum* F. and *Homolepis aturensis* KC, with permanent load of cattle and horses. They present levels of erosion between strong (terraces and furrows) and extremely strong (gullies and mass removal).

These pastures represent the negative control of the research, it present significant losses in soil and pasture attributes, which may indicate evident degradation processes (Dias *et al.*, 2020).

In each of the five coverages and in each horizon (A and B), every five meters away in the opposite direction to the slope, five subsamples were taken to form a composite sample of approximately 500 g. The B horizon was sampled up to 40 cm, in accordance with what was established by Cherubin *et al.* (2017), who affirm that root activity in clay soils, such as those predominant in the hills of the Amazon, is superficial due, among other factors, to compaction, which makes the absorption of nutrients in subsurface horizons difficult. The samples were sent to the soil laboratory of the Agustín Codazzi Geographic Institute (IGAC) for the respective chemical analysis (Table 1).

Table 1. - *Methods used for the determination of soil chemical variables (Zamudio et al. 2006)*

Characteristic	Method
pH	Potentiometer in 1:1 water:soil ratio.
Exchangeable aluminum (cmol kg $^{-1}$)	Extraction in KCl
Organic carbon (%)	Walkley -Black.
Potassium (cmol kg $^{-1}$)	Extraction with 1N and neutral ammonium acetate.
Available phosphorus (ppm)	Modified Bray II
Calcium (cmol kg $^{-1}$)	Extraction with 1N and neutral ammonium acetate.
Magnesium (cmol kg $^{-1}$)	Extraction with 1N and neutral ammonium acetate.
interchangeable bases (%)	Relationship of bases and aluminum.
CEC (cmol kg $^{-1}$)	Extraction with 1N and neutral ammonium acetate.

The effects and interactions of the treatments were evaluated in the soil of each horizon (A and B), using a randomized complete block design, where the coverage corresponded to factor A, the horizons to factor B and the areas of study (El Doncello, Florencia and Belén de los Andaquíes) to the blocks. To statistically evaluate the effects and interactions of the treatments, an analysis of variance was performed and the means were separated using the DGC test.

The similarity between soil chemical variables was determined according to the coverage and sampling horizon through a cluster analysis. An analysis of correlations between variables was carried out using the Pearson test. Finally, a discriminant analysis was carried out to identify the soil chemical variables with the greatest statistical weight in the separation of covers and conglomerates. All statistical analyzes were run using the Infostat program (Di Rienzo *et al.,* 2018).

RESULTS AND DISCUSSION

The analysis of variance showed significant effects of the covers only on soil pH, while CO, P, Ca, Mg and K were affected by the horizon. The exchangeable aluminum content, CEC and SB of the soil were not affected by the treatments. Likewise, no interactions were evident between the factors evaluated (Table 2).

The soils of the five coverages evaluated had extremely acidic pH as a result of the source material, the high rainfall in the area and the washing of the bases (Ca, Mg, K and Na) which causes H^{+} and Al^{3+} ions to predominate (Agegnehu *et al.,* 2021). These conditions of low chemical fertility are normal for these soils in the Colombian Amazon (Rosas *et al.,* 2017), although a positive change is seen in the soil under the types of use that have received calcareous amendments and fertilizers.

Sar and Bs soils had lower pH levels; while the Mhe and Saf soils had higher pH. This may be due to the incorporation of lime dolomite and manure from grazing cattle that regulates acidity levels caused by the presence of aluminum (Rosas *et al.,* 2019; Cervantes *et al.,* 2022). On the other hand, the decomposition of leaf litter in the forest can generate low pH due to the absence of calcium in the biomass, giving rise to acidic humus (Tanikawa *et al.,* 2018). The pasture also had a higher pH value than Bs and Sar, possibly due to the contribution of bases from livestock manure. Similar results are reported by Rayne and Aula (2020) that applying bovine manure to the soil, increased the pH value and the availability of bases in the soil (Table 2).

Table 2. - *Analysis of variance between the different variables in land use under each of the horizons*

Land use	Horizon	statistics	pH	Al (cmol kg^{-1})	CO (%)	P (ppm)	Ca (cmol kg^{-1})	Mg (cmol kg^{-1})	K (cmol kg^{-1})	SB (%)	CIC (cmol kg^{-1})
Bs	A	Media	3.63^{b}	5.27	2.57^{a}	7.9^{a}	0.23^{a}	0.15^{a}	0.17^{a}	4.40	14.77
		EE	0.07	2.47	0.66	1.32	0.06	0.04	0.04	0.60	5.11
	B	Media	3.97^{b}	4.90	0.97^{b}	3.4^{b}	0.06^{b}	0.05^{b}	0.13^{b}	3.60	12.20
		EE	0.07	2.47	0.20	1.73	0.02	0.01	0.04	1.42	5.56
Mhe	A	Media	4.33^{a}	3.10	1.8^{a}	7.6^{a}	0.7^{a}	0.42^{a}	0.22^{a}	10.73	13.67
		EE	0.15	0.57	0.12	1.45	0.25	0.18	0.06	3.76	1.45
	B	Media	4.1^{a}	5.33	0.88^{b}	2.67^{b}	0.17^{b}	0.09^{b}	0.13^{b}	3.70	11.33
		EE	0.06	1.11	0.03b	1.01	0.07	0.02	0.05	0.95	1.12
Pna	A	Media	4.27^{a}	4.10	1.83^{a}	6.37^{a}	0.67^{a}	0.32^{a}	0.23^{a}	9.00	14.60
		EE	0.03	0.82	0.13	3.31	0.22	0.19	0.03	3.40	1.76
	B	Media	4.2^{a}	5.60	0.82^{b}	1.64^{b}	0.44^{b}	0.13^{b}	0.16^{b}	5.73	13.40
		E.E.	0.06	1.47	0.09	1.06	0.12	0.06	0.03	1.19	2.17
Saf	A	Media	4.4^{a}	2.98	1.89^{a}	9.97^{a}	0.73^{a}	0.22^{a}	0.15^{a}	24.97	11.37
		EE	0.35	1.47	0.51	7.83	0.54	0.10	0.04	21.47	4.00
	B	Media	4.13^{a}	3.00	0.83^{b}	14.13^{a}	0.31^{b}	0.08^{b}	0.08^{b}	18.43	9.17
		EE	0.20	1.42	0.24	9.64	0.20	0.03	0.01	16.04	3.78
Sar	A	Media	3.93^{b}	4.07	1.87^{a}	13.4^{a}	0.23^{a}	0.19^{a}	0.16^{a}	6.23	12.70
		EE	0.03	1.23	0.43	10.04	0.11	0.08	0.03	2.83	3.65
	B	Media	3.97^{b}	5.20	0.83^{b}	1.8^{b}	0.07^{b}	0.09^{b}	0.11^{b}	2.83	12.23
		E.E.	0.03	1.76	0.06	1.21	0.02	0.04	0.02	0.66	3.80
P-valor		**US**	0,013	NS	NS	NS	NS	NS	NS	NS	NS
		H	NS	NS	<0,0001	0,0126	0,0402	0,0116	0,0129	NS	NS
		US x H	NS	NS	NS	NS	NS	NS	NS	NS	NS

Bs: Secondary Forest; Mhe: *H. brasiliensis* monoculture; Pna: Native grass; Saf: *H. brasiliensis* Agroforestry System with fruit trees; Sar: *H. brasiliensis* Agroforestry System with stubble; CO: Soil organic carbon; SB: Base saturation; CEC: Cation exchange capacity; US: Land use; H: Horizon

NS: Not significant. Means with different letter are significant differences (P > 0.05)

The differences in CO between horizons (P<0.0001) can be explained because the roots of the plants in the soils of the Amazon predominate in the surface layer of the soil (Rosas *et al.,* 2019) since, in mineral horizons, the high contents of clays and amorphous inorganic minerals hinder the translocation of organic matter to subsurface horizons (Gross and Harrison, 2019). Similarly, statistical differences were presented in the contents of P (P< 0.0126), Ca (P< 0.0402), Mg (P< 0.0116) K (P< 0.0129) because H-A organic matter is the main source of minerals in tropical soils cultivated with rubber (Zhu *et al.,* 2022); As expected, these variables presented higher values in H-A (Table 2) given that the available nutrients are usually found in a higher concentration in the A horizon than in the B (Gross and Harrison, 2019).

Although Bs presented the highest average CO because they store large amounts of CO in the leaf litter that makes up the soil litter, it was not statistically different from the covers with perennial woody plants in SAF (Table 2). The above may be due to the fact that the forest was slashed and burned to establish the rubber systems, which caused a significant increase in soil carbon (Ollinaho and Kröger, 2021).

In Saf, higher values were found than P in H-B (Table 2), the high moisture contents and temperatures of Saf favor the dynamics of P in the soil (Han *et al.,* 2020). It is likely that the increase in pH due to the addition of dolomite lime releases the phosphorus adsorbed by the iron and aluminum oxides and hydroxides of these acidic soils (Barrow and Hartemink, 2023) and is then complexed by the organic matter and absorbed by the soils. microorganisms that convert it into easily soluble organic phosphorus (Melo *et al.,* 2017; Omenda *et al.,* 2021).

In the case of K, there were higher Pna and Mhe contents (Table 2), this possibly due to the incorporation of grazing cattle manure that increases the K content in the soil, although its content decreases in the manure after two months due to its high solubility (Carpinelli *et al.,* 2020), constant grazing maintains K contributions to the soil. As expected, Ca and Mg presented higher levels in the coverages where dolomite lime was incorporated (Rosas *et al.,* 2017). However, the contents of Ca and Mg in pasture were found above those reported for Bs and Sar (Table 2) possibly due to the effect of livestock manure (Cervantes *et al.,* 2022).

The cluster analysis also showed statistical similarities between the land use typologies (Figure 1). The chemical variables presented significant differences ($P<0.0001$) between the horizons because the lomerío soils in the Amazon are acidic and the few nutrients it has are found mostly in the superficial horizons (Zhu *et al.,* 2022). In the clusters, the tendency of grouping by soil profiles was found, except for Saf where H-A and H-B were statistically similar, possibly generated by the fertilization that has been carried out in this system for three years with dolomite lime and Remital ® and by the effect of woody roots on the soil structure that facilitates the biogeochemical cycle and movement of nutrients between soil horizons (Germon *et al.,* 2020).

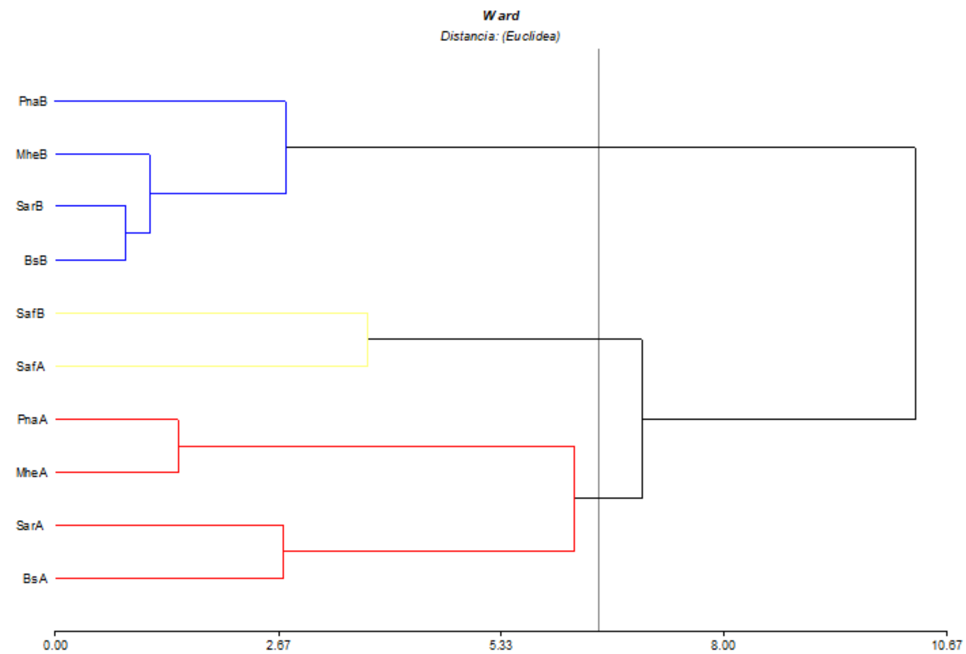

Figure 1. *- Dendrogram with land use typology focused on the chemical conditions in lomerío soils of the Amazon region. Bs: Secondary forest; Mhe: H. brasiliensis monoculture; Pna: Native grass; Saf : H. brasiliensis Agroforestry System with fruit trees; Sar: H. brasiliensis Agroforestry System with stubble; A: Horizon A; B: Horizon B.*

Correlation analysis between chemical variables

In H-A and H-B the pH was positively correlated with Ca, Mg and SB although the correlation in HB with Mg was not significant (Tables 3 and 4). This is due to the fact that by decreasing acidity (H^+ and Al^{3+}) the presence of bases increases (Hartemink and Barrow, 2023). The pH in HB was also positively correlated with P and negatively correlated with CO (Table 4). In acidic soils, increasing the pH increases the available phosphorus and improves the conditions for carbon mineralization and the formation of organo-mineral compounds (Rosas *et al.,* 2017; Buthelezi *et al.,* 2022).

Aluminum in H-A presented a strong positive correlation with CO (Table 3), due to the ability of aluminum to form organo-mineral complexes (organic carbon-aluminum) under low pH conditions. However, in superficial horizons of tropical soils, the processes intense pedogenetics and pH changes can make these organo-mineral complexes a constant source of Al^{3+} to the soil solution (Wagai *et al.,* 2020). Aluminum also registered a strong correlation with the CEC for the two horizons (Tables 3 and 4) because in acidic soils exchangeable aluminum is the most abundant cation in the exchange zone since it contributes between 21 and 44 % of the CEC (Solly *et al.,* 2020).

CO presented a negative correlation with P and SB (Tables 3 and 4); Fonte *et al.* (2014) considers that the above may be due to the fact that in acidic soils in the Amazon, phosphorus is found mostly in organic form and not in solution.

Table 3. - *Pearson correlations between HA chemical variables in different land uses in the Colombian Amazon*

	pH	To the	CO	Q	AC	Mg	K	SB	CIC
pH	1								
Al	-0,45	1							
CO	-0,48	0.85**	1						
P	0,25	-0,46	-0.58*	1					
Ca	0,88**	-0,4	-0,5	0,5	1				
Mg	0,59*	-0,11	-0,17	0,14	0,72	1			
K	0,02	0,5	0,43	-0,37	-0,00071	0,34	1		
SB	0,79**	-0,52	-0,54*	0,6*	0,88*	0.41	-0.31	1	
CIC	-0.34	0.88**	0.86**	-0.7*	-0.45**	-0.08	0.47	-0.6	1

**Significant correlation at p<0.05; **Significant correlation at p<0.0001*

Source: *self-made*

Phosphorus was positively correlated with SB and negatively with CEC in both horizons (Tables 3 and 4), a positive relationship was also found between P and Ca in H-B. The above is normal for acidic soils (Tables 3 and 4). In these soils, the addition of bases using liming materials facilitates the desorption of P (Rosas *et al.,* 2017). The negative correlation between P and CEC may be due to the fact that P has a negative charge (it is an anion), then the increase in CIC and bases through lime applications can generate changes in soil colloids of variable charge and facilitate the leaching of P up to cause depletion of the soil's natural reserves (Getahun *et al.,* 2021; Tiehcer *et al.,* 2023).

Ca showed a positive correlation with SB and a negative correlation with CIC in both horizons, but the relationship with CIC was not significant in H-B. The addition of liming materials increases base saturation in surface horizons (Ejigu *et al.,* 2023). However, in these clay soils the translocation of these bases to subsurface horizons is limited (Antonangelo *et al.,* 2022). In these soils with high aluminum content (>3.6 cmol kg^{-1}), it is likely that the negative relationship between Ca and CEC is influenced by the saturation of exchangeable and solution aluminum (Aramburu *et al.,* 2023).

Table 4. *- Correlation analysis between the chemical variables of HB in different land uses in the Colombian Amazon*

	pH	To the	CO	Q	AC	Mg	K	SB	CIC
pH	1								
To the	-2.60E-03	1							
CO	-0,58*	0,21	1						
P	0,58*	-0,55*	-0,58*	1					
Ca	0,75*	-0,04	-0,57*	0,58*	1				
Mg	0,54	0,37	-0,27	0,2	0,56*	1			
K	0,15	0,62*	0,28	-0,27	0,26	0,55*	1		
SB	0,68*	-0,48	-0,64*	0,97**	0,69*	0,29	-0,2	1	
CIC	-0,09	0,93**	0,42	-0,6*	-0,16	0,2	0,51	-0,54*	1

*Significant correlation at p<0.05; **Significant correlation at p<0.0001.

Source: self-made

Similarities between coverage of H. brasieleinsis with the positive and negative controls

Regarding the multivariate observations in the discriminant space of the five types of coverage (Figure 2), similarities supported in the canonical axes 1 and 2 are evident between some coverages. Bs, Sar and Saf presented overlapping of their ellipsoids due to the interaction of the variable SB and CO; On the other hand, Mhe and Pna showed similarities between themselves thanks to the values of Ca and K mainly. There are contrasts between the positive control (Bs) and the negative control (Pna), while the agroforestry systems of *H. brasiliensis* (Sar and Saf) present behaviors more similar to the positive control, however, it is necessary to mention that the incorporation of bases from amendments, were determining factors in the behavior of the chemical properties of the soils.

These differences in amounts of soil nutrients evidenced between covers coincide with what was reported by Figueroa *et al*. (2020) who state that changes in land use alter the dynamics and content of C, N and P of the soil, with possible negative consequences for the sustainability of livestock production systems in tropical regions. For this reason, agroecosystems with rubber are an alternative for sustainable land use; in the Amazon region, the tree is an essential component in productive systems.

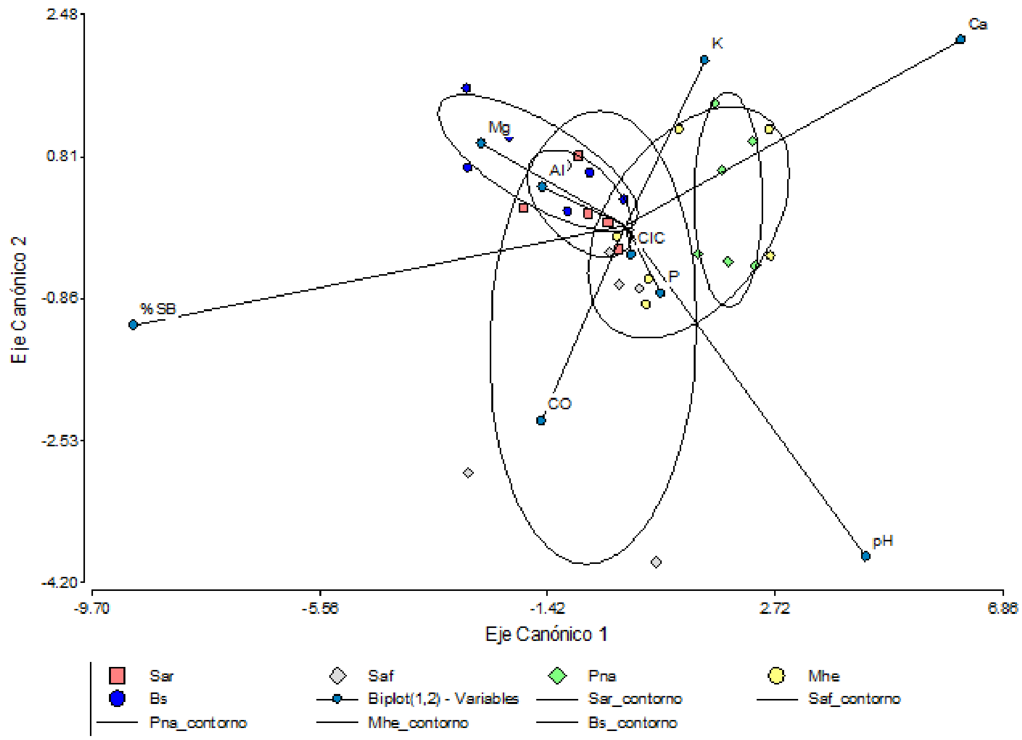

Figure 2. *- Representation of multivariate observations in five land uses, defined a priori, in the discriminant space formed by canonical axes 1 and 2 of the AD. Contours correspond to prediction ellipses.*

CONCLUSIONS

Soils under coverage of *Hevea brasiliensis* agroforestry systems show similarities in their chemical properties with the soils of the Amazon forest, while the *H. brasiliensis* monoculture presents greater similarity to degraded pasture. It is evident that the type of use has significant effects on soil pH, especially in the A horizon, due to the addition of agricultural inputs, rather than due to the action of the tree itself.

The chemical characteristics (except pH) of the soils appear not to be influenced by the presence of *H. brasiliensis* established in monoculture or agroforestry systems. In contrast, both the forest and the systems associated with stubble preserve the acidic conditions typical of Amazonian soils. These results are not conclusive, but they point to the need to carry out more in-depth studies in this field of research, especially in agroclimatic conditions of the Colombian Amazon.

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The authors declare not to have any interest conflicts.

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The authors have participated in the writing of the work and analysis of the documents.