PLANT SPECIES DIVERSITY AND ECOSYSTEM FUNCTIONING IN NATIVE SAVANNAS AND GRASSLANDS OF THE PLATEAU IN THE META DEPARTMENT, COLOMBIA †

[DIVERSIDAD DE ESPECIES VEGETALES Y FUNCIÓN DE LOS ECOSISTEMAS EN SABANAS NATIVAS Y PRADERAS DE LA ALTILLANURA EN EL DEPARTAMENTO DEL META, COLOMBIA]

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SUMMARY

Background: livestock farming has been based on establishing extensive breeding systems (i.e., low density of individuals per unit area). Despite the high diversity of flora in the savanna in the Orinoco plateau of Colombia, there is still a knowledge gap in the characterization of herbaceous and shrub species and their ecosystem functions respectively. **Objective:** To identify the floristic composition in natural and managed savannas, considering some physicochemical properties of the soils in the Puerto Lopez municipality of the department of Meta. **Methodology:** The fieldwork was carried out in three plots (P1, P2 and P3) of 9000 m^2 in which the identification of different species, ecosystem functions, and vegetation cover percentage were determined. Also soil parameters were evaluated texture, pH, macroelements (N, P, K, Ca, Mg), and microelements (Mg, Zn, Fe, Cu, B). **Results:** according to the UPGMA, alpha diversity (Shannon-Weiner, Simpson) and beta similarity (Jaccard, Sørensen, Sokal and Sneath) indices showed that P1 was different regarding soil properties and dominance of Poaceae species compared to P2 and P3, the latter being very similar in their floristic composition and edaphic characteristics. **Implications:** This study could be a baseline for better use of ecosystem resources and future management decisions on cattle farms under similar conditions. **Conclusion:** Alpha diversity was lower in the P1 plot with anthropogenic disturbances compared to those with little or no intervention (P2 and P3). The highest abundance of grass species, shrubs, and even species that may indicate conditions that favor disturbance, such as fire, were found in P2 and P3.
Key words: floristic composition; shrubs; grasses; ecosystem function; acid soils.

RESUMEN

Antecedentes: La ganadería se ha basado en el establecimiento de sistemas de cría extensivos (es decir, baja densidad de individuos por unidad de superficie). A pesar de la alta diversidad de flora en la sabana del altiplano del Orinoco de Colombia, aún existe un vacío de conocimiento en la caracterización de especies herbáceas y arbustivas y sus funciones ecosistémicas respectivamente. **Objetivos:** Identificar la composición florística en sabanas naturales y manejadas, considerando algunas propiedades fisicoquímicas de los suelos del municipio Puerto López del departamento del Meta. **Metodología:** El trabajo de campo se realizó en tres parcelas (P1, P2 y P3) de 9000 m^2 en las que se determinó la identificación de diferentes especies, funciones ecosistémicas y el porcentaje de cobertura vegetal. También se evaluaron parámetros del suelo textura, pH, macroelementos (N, P, K, Ca, Mg) y microelementos (Mg, Zn, Fe, Cu, B). **Resultados:** según el análisis de la UPGMA, diversidad alfa (Shannon-Weiner, Simpson) y similaridad beta

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(Jaccard, Sørensen, Sokal y Sneath) mostró que P1 fue diferente en cuanto a propiedades del suelo y dominancia de especies de Poaceae en comparación con P2 y P3, siendo estos últimos muy similares en su composición florística y características edáficas. **Implicaciones:** Este estudio podría ser una base para un mejor uso de los recursos del ecosistema y futuras decisiones de manejo en granjas ganaderas en condiciones similares. **Conclusión:** La mayor abundancia de especies de pastos, arbustos e incluso especies que pueden indicar condiciones que favorecen la perturbación, como el fuego, se encontraron en P2 y P3.
Palabras clave: composición florística; arbustos; pastos; funciones ecosistémicas; suelos ácidos.

INTRODUCTION

The savannas of Los Llanos Orientales are located in the eastern region of Colombia. This zone of the country belongs to the watershed basin in the Orinoco region, which has an area of about 17 million hectares distributed in the departments of Meta, Casanare, Vichada, and Arauca (Colombia) (Amézquita *et al.,* 2013). Four agroecological regions comprise the Orinoco basin region: Piedmont, Flood plains, Flood plains poorly drained, and Plateau (plain and dissected) (IGAC 2004, Otero and Pérez, 2015). The plateau soils are characterized by their acidity and high aluminum and iron content. Likewise, they have low phosphorus, potassium, calcium, and magnesium concentration (low natural fertility) and exposure to rain for eight months per year (from 2000 to 3000 millimeters of rain/year) that favors leaching and weathering (IGAC 2004, Bernal *et al.,* 2013).

Savannas are a set of phytophysiognomies of open environments, in which herbaceous species dominate, accompanied by trees and shrubs that are separated and distributed over the surface of the land (San Jose *et al.,* 1998, Nepomuceno *et al.,* 2021). In South America, the savannas of northern Brazil, the Brazilian "Cerrado", "Los Llanos" of Colombia and Venezuela, and "La Gran Sabana" in Venezuela stand out (Nepomuceno *et al.,* 2021). The low soil fertility, cyclic periods of drought, and fire events allow for the prevalence of a vegetal cover dominated by the association of herbaceous and grasses with the variable presence of bushy or woody plants, which together are known by the locals as Savannas (Baruch 2005, Fidelis and Zirondi, 2021). Besides, in lowlands that allow moisture accumulation and the development of narrow and elongated streams, a gallery forest grows known as “Morichales” (Rodríguez-Qüenza *et al.,* 2019). In the livestock context, of adoption of different animal and pasture management practices is known as technification (Dos Santos *et al.*, 2021). The low level of technology in established livestock farming in savannas is free grazing, with minimum pasture management, locally known as managed savanna. The diversity of herbaceous and shrubby vegetal species and floristic composition in a physiographic region depends on several factors (i.e., Climate, relief, bird traffic, anthropic activities, and edaphoclimatic processes, unique in each area) (Dezzeo *et al.,* 2008, Higgins *et al.,* 2011, Fidelis and Zirondi, 2021).

This region has experienced changes due to agricultural development. Thus, the relief and edaphoclimatic conditions favor the establishment of extensive production systems of crops such as corn (*Zea mays* L.), soybeans (*Glycine max* L.), and sugarcane (*Saccharum officinarum* L.), even the establishment of agroforestry systems, and cattle breeding of low density per unit area (Arias-Jiménez, 2001). Cattle breeding for meat production is a long-established tradition in the Meta department, Colombia, which possesses 7.7 % of the national cattle inventory (2.164.484 animals) (Gobernación del Meta, 2021). The region is characterized by an intensive productive system, with low animal density (0.6 animal units per hectare) (Mora Marín *et al.,* 2017). The management strategies in this region have been centered on actions to increase the density of cattle per hectare and led to the introduction of African grasses of the genus *Urochloa* spp (formerly *Brachiaria* spp) (Dezzeo *et al.*, 2008, Simeão *et al.*, 2016). Due to their rusticity and plasticity, *Urochloa* species selection in tropical conditions has been made (Kato-Noguchi *et al.*, 2014). Improvement of savannas seeks an increase in weight gain in grazing animals, which has generated a loss of biodiversity of species that make up the natural vegetation cover of soils such as Oxisols (Quero-Carrillo *et al.,* 2007). This study aims to characterize the diversity and floristic composition of natural and managed savannas in the Puerto López Plateau of the Meta department in Colombia. With a view to providing elements to understand and explore the behavior of the distribution and diversity of plant species that can be found in the savannas of this region of the country, this study aims to strengthen the knowledge of the ecosystem functioning of plant species associated with physicochemical soil properties. Therefore, this information will give the farmer and extensionist an overview of the structural elements of the landscape for future decision-making.

MATERIALS AND METHODS

The floristic characterization was carried out in three plots of 150 m x 60 m (long and wide, respectively) for a total area of 9000 m^2 per plot. The plots evaluated plots were located in the hamlet of “Las Leonas” (Figure 1), which belongs to a structural plateau landscape in the Puerto López municipality, department of Meta, Colombia. Plots location and cover are described in Table 1. According to the Koppen classification, the weather is Tropical (Ami), with temperatures between 22.5 and 32.1 °C (minimum and maximum, respectively), the annual average temperature is 22.5 °C. Rainfall has a mono-modal distribution and ranges between 2600 to 3000 mm per year. Solar radiation in the area is about 2050 hours per year (Bernal *et al.,* 2013). The study was performed in December of 2022, at the beginning of the dry season.

Species identification

During the fieldwork, a free track was carried out aiming to identify taxonomically the species within each plot. In addition, a catalog of photographs and a record of the vegetative and floral morphological characteristics that are often lost (odors, colors, and presence of exudates) was compiled (IDEAM *et al.*, 2017, Lasso, 2015, Villareal *et al.,* 2004). Taxonomic identification was conducted by using "Flora of the Venezuelan Guayana." (Steyermark *et al.,* 1995), "A field guide to the families and genera of woody plants of northwest South America (Colombia, Ecuador, Peru), with supplementary notes on herbaceous taxa" (Gentry, 1993), botanical collections of the herbarium of the Universidad Nacional de Colombia, the nomenclatural types JSTOR plants (Global Plants, 2023) and the virtual database of the "Catálogo de Plantas y Líquenes de Colombia" (Bernal *et al.,* 2020). In addition, herbaceous species cover in each plot was determined by throwing a 1 x 1 m^2 PVC (Polyvinyl Chloride) pipe 27 times, aiming to determine visually the percentage cover of the different species (Mostacedo and Fredrickson, 2000). The percentage area of shrub species covered in the 9000 m^2 plot was determined by calculating the plant density per area.

Table 1. Land use and location of the three surveyed plots in the study, in the Meta department, Colombia.

Plot	Coordinates*		Height	Land Use
	North	East		
P1	474765.89	790001.32	199 m.a.s.l.	managed savanna
P2	473604.84	794732.02	188 m.a.s.l.	natural savanna
P3	473782.00	794738.06	191 m.a.s.l.	natural savanna

*Coordinate system: WGS-84 - UTM 18N EGPS: 32618, m.a.s.l: meters above the sea level.

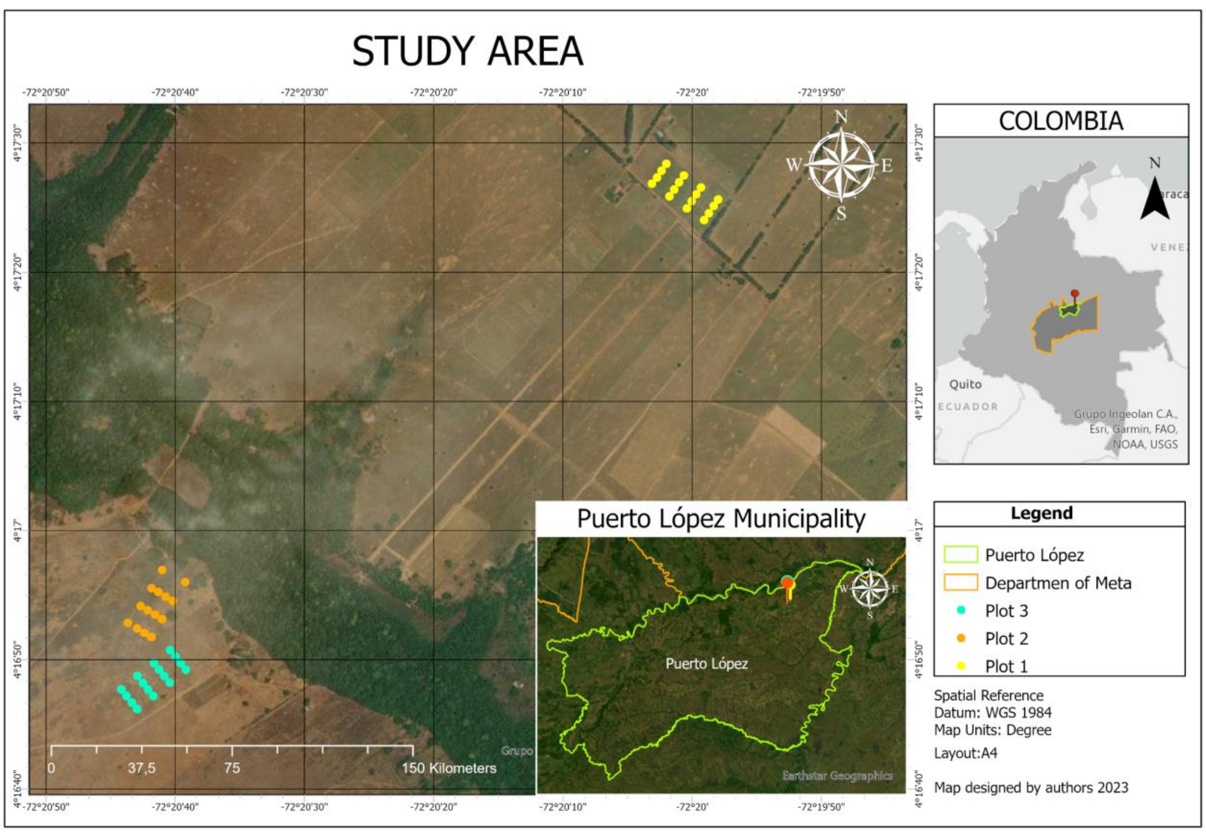

Figure 1. Location of the three surveyed plots in the study, in the Meta department, Colombia.

Soil Sampling

A soil-disturbed sampling was taken to determine the physical and chemical characteristics in the evaluated plots. Each sample comprised 27 subsamples and was taken at 0-20 cm depth. Furthermore, using a stainless ring of 5 x 5 cm (diameter and height) 27 undisturbed samples were taken. The 27 sampling points in each plot were taken randomly. The following parameters in the samples were determined: texture (Bouyoucos), pH in water (1:1 potentiometric), Organic Carbon (Walkley and Black), N (nitrate and ammonium, KCL 2N), P (Bray II), available K, Ca, Mg (ammonium acetate 1M pH 7), available Al (KCl 1N), Cu, Fe, Mn, Zn, B (DTPA), field capacity (FC), permanent wilting point (PWP) (Richard plates -0.33 and -15 Kp, respectively). The sample handling and analytical procedures were made according to ICONTEC (2022a, 2022b, 2022c, 2020, 2018a, 2018b, 2017, 2016, 2014, 2008, 2007). The referenced norms indicates that soil sampling is simple (one sample per plot) and detail the procedures for the analytical determination of each element or physical or chemical property analyzed in this study.

Biodiversity assessment

Using field data, the Shannon - Wiener ('H) (Sun and Ren, 2021) and Simpson (λ) (Gorelick, 2006) alpha biodiversity indices were obtained. The Jaccard (Bag *et al.*, 2019), Sørensen (Mainali *et al.*, 2022), and Sokal and Sneath (Pavoine and Ricotta, 2014) beta similarity indices were also determined. Finally, a hierarchical conglomerated analysis was performed, using the unweighted centroid clustering method (UPGMA), in which arithmetic averages are calculated to evaluate Euclidean distances between clusters (Ramírez *et al.*, 2007, Nepomuceno *et al.*, 2021).

RESULTS

In plot one (P1), eight botanical families were recorded (Table 2). P1 had the Poaceae family with higher coverage (79 %), with *Urochloa dictyoneura* as the most dominant species (Table 2). In plot (P2), 13 botanical families were found, the Poaceae family had the highest cover (53 %), *Urochloa eminii* was the most dominant species. In plot (P3), 11 botanical families were found, which was the plot with the higher number of species in this study (27 species) (Table 2).

Table 2. Inventory of plant families (herbaceous and shrubs) observed in the evaluated in the three plots in Meta department, Colombia.

id	Family	Species	Habit	Cover %	Type[1]
		Plot 1			
1	Asteraceae	*Emilia sonchifolia* L. DC.	Herb	2	Dico
2	Asteraceae	*Praxelis diffusa* Rich. Pruski	Herb	1	Dico
3	Cyperaceae	*Cyperus aggregatus* Willd. Endl.	Herb	1	Mono
4	Cyperaceae	*Rhynchospora nervosa* Vahl. Boeckeler	Herb	1	Mono
5	Dilleniaceae	*Curatella americana* L.	Shrub	5	Dico
6	Fabaceae	*Acacia mangium* Willd.	Shrub	4	Dico
7	Fabaceae	*Chamaecrista rotundifolia* Pers. Greene	Herb	1	Dico
8	Fabaceae	*Mimosa púdica* L.	Herb	3	Dico
9	Gentianaceae	*Coutoubea spicata* Aubl.	Herb	1	Dico
10	Passifloraceae	*Turnera melochia* Triana & Planch.	Herb	1	Dico
11	Poaceae	*Urochloa dictyoneura* Fig. & De Not. Veldkamp	Herb	79	Mono
12	Verbenaceae	*Stachytarpheta cayennensis* Rich. Vahl	Herb	1	Dico
		Plot 2			
1	Asteraceae	*Acanthospermum australe* Loefl. Kuntze	Herb	1	**Dico**
2	Asteraceae	*Cyanthillium cinereum* L. H.Rob.	Herb	1	**Dico**
3	Asteraceae	*Praxelis diffusa* Rich. Pruski	Herb	1	**Dico**
4	Cyperaceae	*Cyperus aggregatus* Willd. Endl.	Herb	1	**Mono**
5	Cyperaceae	*Cyperus laxus* Lam.	Herb	1	**Mono**
6	Dilleniaceae	*Curatella americana* L.	Shrub	3	**Dico**
7	Euphorbiaceae	*Croton trinitatis* Millsp.	Herb	1	**Dico**
8	Fabaceae	*Mimosa pudica* L.	Herb	3	**DIco**
9	Fabaceae	*Stylosanthes capitata* Vogel	Herb	2	**Dico**
10	Fabaceae	*Zornia diphylla* L. Pers.	Herb	1	**Dico**

id	Family	Species	Habit	Cover %	Type[1]
11	Gentianaceae	*Irlbachia pratensis* Kunth L.Cobb & Maas	Herb	1	**Dico**
12	Malvaceae	*Sida linifolia* Juss.	Herb	1	**Dico**
13	Melastomataceae	*Miconia albicans* Sw. Steud.	Herb	1	**Dico**
14	Melastomataceae	*Miconia rubra* Aubl. Mabb.	Herb	1	**Dico**
15	Passifloraceae	*Turnera melochia* Triana & Planch.	Herb	1	**Dico**
16	Plantaginaceae	*Scoparia dulcis* L.	Herb	1	**Dico**
17	Poaceae	*Aristida capillacea* Lam.	Herb	2	**Mono**
18	Poaceae	*Eragrostis bahiensis* Schult.	Herb	5	**Mono**
19	Poaceae	*Panicum rudgei* Roem. & Schult.	Herb	3	**Mono**
20	Poaceae	*Paspalum conjugatum* P.J.Bergius	Herb	4	**Mono**
21	Poaceae	*Schizachyrium sanguineum* Retz. Alston	Herb	10	**Mono**
22	Poaceae	*Urochloa eminii* Mez Davidse	Herb	53	**Mono**
23	Rubiaceae	*Spermacoce capitata* Ruiz & Pav.	Herb	1	**Dico**
24	Solanaceae	*Solanum crinitum* Lam.	Shrub	1	**Dico**
		Plot 3			
1	Asteraceae	*Emilia sonchifolia* L. DC.	Herb	1	**Dico**
2	Asteraceae	*Praxelis diffusa* Rich. Pruski	Herb	1	**Dico**
3	Bignoniaceae	*Jacaranda obtusifolia* Bonpl.	Herb	1	**Dico**
4	Cyperaceae	*Rhynchospora albomarginata* Kük.	Herb	1	**Mono**
5	Cyperaceae	*Rhynchospora barbata* Vahl Kunth	Herb	3	**Mono**
6	Cyperaceae	*Rhynchospora junciformis* Kunth Boeckeler	Herb	1	**Mono**
7	Dilleniaceae	*Curatella americana* L.	Shrub	2	**Dico**
8	Fabaceae	*Crotalaria velutina* Benth.	Herb	1	**Dico**
9	Fabaceae	*Grona barbata* L. H.Ohashi & K.Ohashi	Herb	1	**Dico**
10	Fabaceae	*Mimosa pudica* L.	Herb	2	**Dico**
11	Fabaceae	*Stylosanthes capitata* Vogel	Herb	1	**Dico**
12	Fabaceae	*Zornia diphylla* L. Pers.	Herb	1	**Dico**
13	Gentianaceae	*Coutoubea spicata* Aubl.	Herb	1	**Dico**
14	Gentianaceae	*Irlbachia pratensis* Kunth L.Cobb & Maas	Herb	1	**Dico**
15	Lamiaceae	*Hyptis conferta* Pohl ex Benth.	Herb	1	**Dico**
16	Malvaceae	*Sida linifolia* Juss. ex Cav.	Herb	1	**Dico**
17	Melastomataceae	*Miconia albicans* Sw. Steud.	Herb	1	**Dico**
18	Melastomataceae	*Miconia rubra* Aubl. Mabb.	Herb	1	**Dico**
19	Melastomataceae	*Pterogastra divaricata* Bonpl. Naudin	Herb	1	**Dico**
20	Poaceae	*Andropogon bicornis* L	Herb	10	**Mono**
21	Poaceae	*Axonopus aureus* P.Beauv.	Herb	3	**Mono**
22	Poaceae	*Eragrostis bahiensis* Schult.	Herb	6	**Mono**
23	Poaceae	*Panicum rudgei* Roem. & Schult.	Herb	5	**Mono**
24	Poaceae	*Schizachyrium sanguineum* Retz. Alston	Herb	5	**Mono**
25	Poaceae	*Steinchisma laxum* Sw. Zuloaga	Herb	2	**Mono**
26	Poaceae	*Urochloa eminii* Mez Davidse	Herb	45	**Mono**
27	Rubiaceae	*Spermacoce capitata* Ruiz & Pav.	Herb	1	**Dico**

[1]Type: Mono: Monocotyledons, Dico: Dicotyledons.

The plot of the managed savanna (P1) showed the lowest number of species (12 in 8 botanical families) comparing the native savannas. P1 and P2 displayed the highest diversity of species assemblage: Fabaceae family in P1 (three species per family) and Poaceae in P2 (six species per family) (Table 2). In P3 (a native savanna), the highest number of the species observed corresponds to the Poaceae and Fabaceae families (seven and five, respectively) (Table 2). *Urochloa dictyoneura* and *Urochloa eminii* (Poaceae) exhibited the highest coverage in the three plots (from 45 to 75 %) (Table 2).

Plot 1 (P1) presented the highest Simpson (**λ**) index indicating low diversity and high dominance, which is explained by the high presence of *Urochloa dictyoneura*, with 79% cover (Table 2 and Table 3). On the other hand, in P1 the lowest value for the Shannon-Weiner index (´H) is observed (Table 3), due to the low number of species found (12 species in total) compared to P2 and P3 which showed 24 and 27 species respectively (Table 2). The Jaccard, Sørensen, Sokal, and Sneath similarity indices (Table 3) were higher when comparing (P2) with (P3), indicating that the floristic composition is similar in both plots (i.e. 14 common species in the two plots) (Table 2). P3 displayed the highest number of unique species (11 species) compared to P1 and P2 (Table 2). Likewise, the similarity between P2 and P3, and their differences with P1, are confirmed by cluster analysis (UPGMA) (Figure 2).Concerning herbaceous species in the three plots were predominant. In general, dicotyledonous plants were the most abundant.

Table 3. Diversity and similarity indices for the three surveyed plots.

Indexes*	Value
Shannon-Weiner (H´) P1	0.971
Shannon-Weiner (H´) P2	2.008
Shannon-Weiner (H´) P3	2.286
Simpson (λ) P1	0.630
Simpson (λ) P2	0.300
Simpson (λ) P3	0.226
Jaccard P1 and P2	0.161
Jaccard P1 and P3	0.147
Jaccard P2 and P3	0.378
Sørensen P1 and P2	0.278
Sørensen P1 and P3	0.256
Sørensen P2 and P3	0.549
Sokal and Sneath P1 and P2	0.088
Sokal and Sneath P1 and P3	0.079
Sokal and Sneath P2 and P3	0.233

*P1: Plot 1, P2: Plot 2, P3: Plot 3.

The texture of the soils of P1 was Clay, while in P2 and P3 was Sandy Clay Loam. The plots had a pH ranging from 4.41 to 4.65. These values were classified as extremely acidic (P2, P3) and strongly acidic (P1) respectively (IGAC, 2004). The aluminum saturation in the three plots exceeds 70 %, and base saturation and phosphorus content were very low (6.00 % and 1.00 mg/kg, respectively). Organic carbon was higher in P1 (1.37 %), compared to P2 and P3, which had less than 1.00 %. Even though field capacity was higher in P1 and usable humidity was superior in P3 (13.65 %) (Table 4), total nitrogen content and field capacity in P1 was the highest (181.20 mg/kg and 27.42 %, respectively).

DISCUSSION

The results presented in this study correspond to a characterization carried out in December, which is the beginning of the dry season in the plateau (Bernal *et al.*, 2013). Poaceae and Fabaceae families predominated in all plots, covering 77 % and 7 % of the area, respectively (Table 2). One research developed on the same landscape at 35 km from this study also observed the dominance of these two families (Rippstein *et al.*, 2001). Furthermore, families such as Fabaceae, Rubiaceae, Convolvulaceae, Poaceae, Cyperaceae, Asteraceae, Lamiaceae, and Malvaceae were the most abundant in the Brazilian Caatinga biome (Nepomuceno *et al.*, 2021). From an ecological perspective, seasonality of rains, prolonged drought, and fire events are decisive factors in floristic composition architecture. Therefore, plants with physiological and morphological adaptations to these environmental conditions have advantages to predominate in these ecosystems (Dezzeo *et al.*, 2008, Coutinho *et al.*, 2019, Neves *et al.*, 2018). Although previous studies have demonstrated that the floristic composition within a biome could be highly diverse at short distances (Emilio *et al.*, 2010), P2 and P3 showed *Urochloa eminii* as the predominant species (Table 2). The grasses of this genus are originally from Africa and were introduced to Brazil in 1980 because of their adaptability to grow in complex edaphic and climatic conditions, becoming the principal grass for cattle breeding in regions such as the Plateau of Meta department (Simeão *et al.*, 2016).

The colonization capacity of *Urochloa eminii* in diverse biomes might be explained by positive or neutral interactions that show with multiple soil microorganisms, favoring its growth and giving a broad ecological niche (Wolfsdorf *et al.*, 2021). Substances with allelopathic or phytotoxic potential such us (6R,9R)-3-oxo-ionol, (6R,9S)-3-oxo-ionol, 4-ketopinoresinol were isolated from *Urochloa brizantha* species (Kato-Noguchi *et al.*, 2014), which might explain the dominance of these African grasses when introduced in the Orinoco basin. Another species with potential interaction identified in this study was *Mimosa pudica* that can develop symbiosis with alpha or beta proteobacteria that help to capture nitrogen (Ahmad *et al.*, 2012). Similar studies developed in Argentina show that plants are susceptible to the phytotoxic effects of allelopathic substances produced by other plants (Guido *et al.*, 2020).

Curatella americana (Dilleniaceae) is the species observed in all plots. This species is reported as characteristic of the semi-arid savannas of the ‘Caatinga’ and ‘Cerrado’ biomes of Brazil (Nepomuceno *et al.*, 2021). Moreover, this species is recognized for its importance as its presence in biomes favors the conservation of forest structure. Low altitudes and high solar radiation favor the distribution of this species (Felfili *et al.*, 1992, Dalmolin *et al.*, 2015), two common conditions in all the plots where this study was carried out. Another native species in South America (Colombia, Ecuador, and Peru) observed in this study was *Eragrostis bahiensis* (Poaceae) (Peterson and Giraldo-Cañas, 2008). This species grows mainly in sandy soils and altitudes

between 0 and 1850 m.a.s.l (Giraldo-Cañas *et al.*, 2012). In this study, *Eragrostis bahiensis* was only observed in plots (P2) and (P3) that have sandy soils.
In conditions of open habitats in which this work was carried out, it is common to observe the predominance and richness of herbs over shrubs (Nepomuceno *et al.*, 2021). The Cyperaceae family is cosmopolitan, showing high diversity in the savannas of America (tropical and subtropical) (Buddenhagen *et al.*, 2017). Several species in this family possess the C4 photosynthetic pathway, which may provide competitive advantages in adverse soil and climatic conditions compared to other species (Stock *et al.*, 2004). In this family, one tribe of importance is Rhynchosporeae, to which belong species of the genus *Rhynchospora*. In this study, were classified: *Rhynchospora albomarginata*, *Rhynchospora barbata*, *Rhynchospora junciformis*, species not reported in similar studies Nepomuceno *et al.* (2021), Ramírez *et al.*, (2007).

Table 4. Physicochemical characteristics of the soil in the three evaluated plots in the hamlet of "Las Leonas", Meta department, Colombia.

	Plots		
Parameter	**Plot 1**	**Plot 2**	**Plot 3**
Sand (%)	22.5	51.7	53.7
Silt (%)	32.9	24.5	18.4
Clay (%)	44.6	23.8	27.9
pH (1:1)	4.65	4.41	4.44
Al+H (Cmolc/Kg)	3.11	1.13	1.22
Ec[1] (dS/m)	0.05	0.05	0.07
S.O.C[2] (%)	1.372	0.611	0.914
S.O.M[3] (%)	2.37	1.05	1.58
P (mg/Kg)	0.39	1.13	0.17
CEC[4] (Cmolc/Kg)	14.117	3.747	5.606
ECEC[5] (Cmolc/Kg)	3.938	1.383	1.582
Ca (Cmolc/Kg)	0.520	0.100	0.170
Mg (Cmolc/Kg)	0.250	0.130	0.160
K (Cmolc/Kg)	0.040	0.010	0.020
Na (Cmolc/Kg)	0.020	0.010	0.010
B.S.[6] (%)	5.88	6.67	6.42
I.A.S[7] (%)	78.93	81.92	77.25
Mn (mg/Kg)	0.86	0.31	0.34
Fe (mg/Kg)	59.61	27.17	44.35
Zn (mg/Kg)	0.09	0.03	0.05
Cu (mg/Kg)	0.98	0.19	0.25
B (mg/Kg)	0.52	0.31	0.27
N-NH4 (mg/Kg)	97.44	43.42	64.94
N-NO3 (mg/Kg)	83.76	37.32	55.82
FC[8] (%)	27.42	19.54	25.22
PW[9]P (%)	18.27	8.66	11.57

[1]**Ec:** electrical conductivity; [2]**S.O.C:** Soil Organic Carbon; [3]**S.O.M:** Soil Organic Matter; [4]**CEC:** Cation exchange capacity; [5]**ECEC:** effective cation exchange capacity; [6]**B.S:** Base saturation; [7]**I.A.S:** Interchangeable aluminum percentage; [8]**FC:** Field Capacity; [9]**PWP**: Permanent Wilting Point. Plot 1: managed savanna Plot 2: natural savanna and Plot 3: natural savanna.

Some species of savanna ecosystems require fire or receive a positive stimulus from it (Fidelis and Zirondi, 2021, Pilon *et al.*, 2023). In all plots were found the following species: *Chamaecrista rotundifolia*, *Stylosanthes capitata*, *Crotalaria velutina*, *Zornia diphylla*, *Rhynchospora nervosa*, *Sida linifolia* Juss, *Miconia albicans*, *Andropogon bicornis* and *Axonopus aureus*, which favor their growth by this abiotic factor (Fidelis and Zirondi, 2021). Each plot observed displayed species that were not common between the characterized areas. In plot 1: (*Stachytarpheta cayennensis*) (Verbenaceae) and (*Jacaranda obtusifolia*) (Bignoniaceae), in plot 2: *(Croton trinitatis*) Euphorbiaceae, and in plot 3: (*Hyptis conferta*) Lamiaceae. Despite this, when comparing the characterization of the floristic composition of "Caatinga" and "Cerrado" savannas of Brazil was observed that the genus: *Croton, Jacaranda, Hyptis* and the species *Stachytarpheta cayennensis* were reported. On the contrary, in Venezuela, the floristic inventory of "La Gran Sabana" the mentioned genus was not reported (Ramírez *et al.*, 2007).

The alpha and beta diversity indices and the UPGMA analysis reveal that the floristic composition is similar in P2 and P3. A possible explanation for this might be the proximity between the two plots and the similarity of the physical and chemical characteristics of the soil, similar in the high sand content, low nutrient level, and usable moisture greater than 10%.

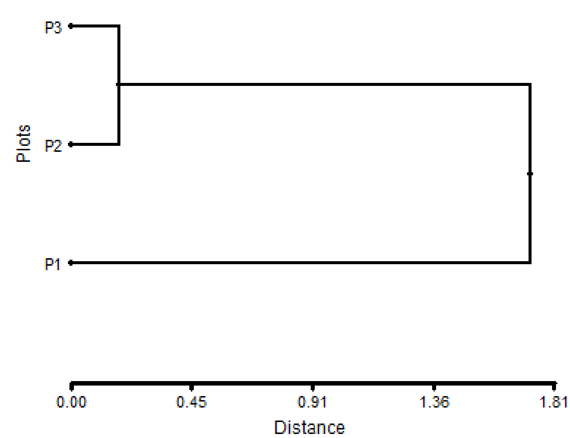

Figure 2. Cluster analysis (UPGMA) of the three assessed areas according to species cover. (P1: managed savanna, P2: natural savanna and P3: natural savanna).

The chemical and edaphic properties have a selection effect on the species, which can be found in grasslands and savanna ecosystems (Singh *et al.*, 2017). One of the most essential factors in the floristic composition is the soil available water (Verma *et al.*, 2013, Singh *et* *al.*, 2017). This study found the highest number of unique species and Shannon diversity index in P3 (Table 2 and Table 3), belonging to the area with the highest percentage of usable humidity. In fact, in savannas and grasslands, soil moisture has been shown to have an effect on seed germination, growth, and development of herbaceous and bushy plants (Singh *et al.*, 2017). The above suggests a possible effect of soil moisture as an edaphic control on species distribution in the Colombian plateau, which should be studied in detail in future research. In fragile ecosystems when nitrogen content reaches the threshold of sufficiency, aggressive species become dominant (Verma *et al.*, 2013). Therefore, P1 performed the lowest Shannon's diversity index (H') and the highest Simpson's index (λ), with the highest nitrogen content and available elements (Ca, Mg) (Table 4).

The previous findings allow us to infer that other factors of importance have influenced the families and genus distribution in the study area, in addition to soil characteristics. In all plots was observed a higher number of herbs over shrubs, similar to the studies of Ramírez *et al.* (2007), Dezzeo *et al.* (2008), Nepomuceno *et al.* (2021). The relief could be an essential factor in the distribution of plant communities in the Plateau landscape. For instance, a low relief favors the settlement of shrub communities (Rippstein *et al.*, 2001). This study was carried out in almost flat terrain. The results described in this study show that the floristic composition of the species found and soil characteristics (physical and chemical) in the plots have patterns in the landscape, particular adaptive traits, and highly complex interactions that help some species to dominate an area.

CONCLUSIONS

Knowing the floristic composition, its ecosystem function, and soil conditions (physical and chemical) will allow a better understanding of the relationship and dynamics between the essential elements of a landscape. The findings of this study show that the Poaceae family has a higher frequency and dominance in all plots. *Urochloa dictyoneura* and *U eminii* are highlighted as the predominant species. Regarding soil conditions, it was observed that P1 clay content was the highest in comparison with P2 and P3. Although the macronutrient content is higher in P1, aluminum concentration is also high compared to P2 and P3, which have less than 1.5 Cmolc/kg. The species diversity of plots with anthropogenic disturbances was lower than those with no or low intervention. The alpha diversity and beta similarity allowed us to determine that P2 and P3 have a similar floristic composition, compared with the results by performing UPGMA analysis, suggesting that these methods could complement assessing the plant species diversity. In P2 and P3 were observed more abundance of herbs and shrubs species and even species that may indicate conditions that favor disturbances for example fire (natural or induced). With this information, the farmer or agricultural technician can expand the knowledge about herb and shrub species observed in the plateau landscape, adaptation patterns according to soil and climatic characteristics. Therefore, the obtained results provide a starting point that could serve as a baseline for future decision-making regarding the management plan for establishing a pasture or other crop under similar agroecological conditions, considering the ecosystem services provided.

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Conflict of interest. Do not apply.

Compliance with ethical standards. The authors declare that there is no conflict of interest.

Data availability. All data is presented in the present paper.

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