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Original article

Floristic diversity and structure of the dry forest in northern Ecuador

Diversidad florística y estructura del bosque seco en el norte del Ecuador

Diversidade florística e estrutura da floresta seca no norte do Equador

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SUMMARY

In Ecuador, dry forests constitute fragile ecosystems and show different states of deterioration, which affects their floristic composition. The objective of the research was to determine the floristic composition and structure of the dry forest (BmMn01) and the probable uses of the most abundant species in the "El Rosal" community. The area is located at coordinates 0.60'24'' north latitude and 78.14'75'' west longitude. Tree, shrub and

herbaceous strata were determined. For the tree stratum, five plots of 10 * 50 m were established, where individuals ≥10 cm DAP were recorded. In each of them, three subplots of 5 * 5 m were formed for the shrub layer and 3 subplots of 1 * 1 m for the herbaceous layer. The Shannon and Pielow indices and the use value of the species were determined. The floristic composition is made up of 19 families, 37 genera and 40 species. Two were classified as tree species, 16 shrubs and the rest herbaceous. The vertical structure of the tree layer was represented by *Bursera graveolens;* subarboreal by *Vachellia macracantha*, the shrubby *Croton menthodorus* and the herbaceous was uniform. The most abundant species was *Croton menthodorus* and the dominant one was *Vachellia macracantha.* The Shannon index was 3.08, which indicates medium diversity, while Pielow with 0.84 reveals a behavior of high diversity. The value of use in the community shows *Bursera graveolens, Vachellia macracantha, Opuntia pubescens* and *Sida cordifolia* as the most representative species.

Keywords: Horizontal and vertical structure, diversity Indices, use value.

RESUMEN

En Ecuador, los bosques secos constituyen ecosistemas frágiles y muestran diferentes estados de deterioro, lo que afecta su composición florística. El objetivo de la investigación fue determinar la composición florística y estructura del bosque seco (BmMn01) y los usos probables de las especies de mayor abundancia en la comunidad ""El Rosal"". El área está ubicada en las coordenadas 0.60´24´´ de latitud norte y 78.14´75´´ de longitud oeste. Se determinó los estratos arbóreos, arbustivos y herbáceos. Para el estrato arbóreo se establecieron cinco parcelas de 10 * 50 m, donde se registraron individuos ≥10 cm de DAP. En cada una de ellas se formaron tres subparcelas de 5 * 5 m para el estrato arbustivo y 3 subparcelas de 1 * 1 m para el herbáceo. Se determinaron los índices de Shannon, Pielow y el valor de uso de las especies. La composición florística está conformada por 19 familias, 37 géneros y 40 especies. Dos se catalogaron como especies arbóreas, 16 arbustivas y las restantes herbáceas. La estructura vertical del estrato arbóreo estuvo representada por *Bursera graveolens*; subarbóreo por *Vachellia macracantha*, el arbustivo por *Croton menthodorus* y el herbáceo se mostró uniforme. La especie más abundante fue *Croton menthodorus y* la

dominante fue *Vachellia macracantha.* El índice de Shannon fue 3,08 que indica diversidad media, mientras Pielow con 0,84 revela un comportamiento de alta diversidad. El valor de uso en la comunidad muestra a *Bursera graveolens*, *Vachellia macracantha, Opuntia pubescens* y *Sida cordifolia* como especies de mayor representatividad.

Palabras clave: Estructura horizontal y vertical; Índices de Diversidad; Valor de uso.

RSUMO

No Equador, as florestas secas constituem ecossistemas frágeis e apresentam diferentes estados de deterioração, o que afeta a sua composição florística. O objetivo da pesquisa foi determinar a composição e estrutura florística da floresta seca (BmMn01) e os prováveis usos das espécies mais abundantes na comunidade "El Rosal". A área está localizada nas coordenadas 0,60'24'' de latitude norte e 78,14'75'' de longitude oeste. Foram determinados os estratos arbóreo, arbustivo e herbáceo. Para o estrato arbóreo foram estabelecidas cinco parcelas de 10 x 50 m, onde foram registrados indivíduos com DAP ≥10 cm. Em cada uma delas foram formadas três subparcelas de 5 x 5 m para o estrato arbustivo e 3 subparcelas de 1 x 1 m para o estrato herbáceo. Foram determinados os índices de Shannon, Pielow e o valor de uso das espécies. A composição florística é composta por 19 famílias, 37 gêneros e 40 espécies. Duas foram classificadas como espécies arbóreas, 16 como arbustivas e as demais herbáceas. A estrutura vertical da camada arbórea foi representada por Bursera graveolens; subbarboreal por Vachellia macracantha, arbustivo por Croton menthodorus e herbáceo uniforme. A espécie mais abundante foi Croton menthodorus e a dominante foi Vachellia macracantha. O índice de Shannon foi 3,08, o que indica média diversidade, enquanto Pielow com 0,84 revela comportamento de alta diversidade. O valor de uso na comunidade mostra Bursera graveolens, Vachellia macracantha, Opuntia pubescens e Sida cordifolia como as espécies mais representativas.

Palavras-chave: Estrutura horizontal e vertical; Índices de Diversidade; Use valor.

INTRODUCTION

The necessary conservation strategies in this globalized world, with clear environmental deterioration, as well as basic and applied scientific research, require knowledge about the biological richness of different ecosystems (Schmeller *et al.,* 2018). There is an appreciable risk of loss of biological diversity due to the high destruction of natural terrestrial ecosystems, particularly forested ecosystems, requiring taxonomic and systematic research to analyze biological diversity, both before and after the transformation of those ecosystems.

Ecuador is considered one of the most megadiverse countries in the world. It has 95 plant ecosystems, resulting from the interaction of multiple factors, among which geological, biogeographical, climatic, geographical, evolutionary and ecological factors stand out (Aguirre *et al.,* 2013). The dry forests are typical of the Andean region, they represent a means of subsistence for the population since ancient times, considering that they offer: wood, fruits, resins, gums, latex, fibers among other products and as a whole contribute to maintaining the water regime, scenic beauty, protect the soil from erosion, among other services (Manchego *et al.,* 2017).

Dry forests at the national level represent fragile ecosystems and are at risk of disappearing, due to their replacement by other land uses (Aguirre 2012; Cabrera and Grosse, 2016). Its current state comes from a long history of use and deforestation from the ancient civilizations that lived in these ecosystems, until the recent conversion to other uses (Moonlight *et al.,* 2020). González et al. (2018), seven anthropogenic disturbances, being agriculture, livestock and human infrastructure the most relevant disturbances, affirm duan *et al.* (2023), that, until the beginning of the 21st century, the rate of disturbance and deforestation in these ecosystems exceeded the processes of change in land use and cover in other tropical biomes.

Ecosystems must be observed from different perspectives for their management, protection and conservation. The conservation approach for this ecosystem is that the species, both animal and plant, are subject to extreme environmental conditions as a result of low rainfall, steep slopes, and erosive processes (Muñoz, Armijos, and Erazo 2019).

The information that is necessary to generate in the studies of the vegetation of a particular forest must transcend beyond an inventory. The knowledge of the floristic composition, structure and endemism, allow to evaluate the diversity and interpret the real state of conservation of the flora of a given ecosystem, likewise, make it possible to know how forests and other types of vegetation cover work and constitute a tool to plan and execute its management (Aguirre *et al.*, 2017). Quijas *et al.* (2019) establish that there is a close, proportional link between biodiversity and the ecosystem services provided by dry forests.

From the scientific approach it is recognized by Schröder *et al.* (2021) the need to expand research on dry forests. Studies in dry forests are more abundant towards the Ecuadorian coastal zone, while for inter-Andean dry forests they are more represented in the southern Sierra compared to those carried out in the northern Sierra, the latter being scarcer. The objective of the research was to determine the floristic composition and structure of the semi-deciduous dry forest in the north of Los Valles-BmMn01 and the probable uses of the most abundant species in the "El Rosal" community.

MATERIALS AND METHODS

Study area location

The research was carried out in the semi-deciduous Forest and Shrub type dry forest of the north of the Valleys-BmMn01 (Aguirre and Medina 2013) of the "El Rosal" community, located in a transition zone between dry forest and tropical humid forest. It belongs to the La Concepción parish, Mira canton, Carchi, Ecuador. It is located at the coordinates 0.60'24" north latitude and 78.14'75" west longitude, at an altitude of 1215 meters above sea level.

Sampling method

The extension of the area of study is eight hectares, where five plots of 10*50 m (500 m2) were located (Aguirre 2019), prior to recognizing the shape, homogeneity and distribution of the forest.

Floristic inventory

The plots were located at a minimum distance of 50 m from the forest limits. In the five 10 * 50 m plots, the arboreal component was evaluated, in each one three subplots of 5 mx 5 m (25 m²) were used for the shrub component and three subplots of 1 mx 1 m (1 m²), for the herbaceous component (Aguirre 2019).

The dasometric variable determined in the field for all plant components was the total height. The diameter at breast height (DBH) was calculated using a diameter tape in individuals ≥ 10 cm, from measuring the circumference of the stem (CAP) at 1.30 m above the ground (Rodríguez *et al.,* 2021). With the data collected, the basal area (AB) and volume (V) for the tree species were determined, based on the following equations based on the following equations $AB = 0{,}7854 * (DAP)^2$ and $V = AB * H * f$, where: *H:* total height and *F:* shape factor, 0.7 is assumed (Aguirre, 2019).

Collection of botanical samples

The fertile botanical samples were collected in duplicate in each species, they did not exceed 30 cm in length, placed in plastic bags. At the time of collection, the growth habit was identified according to Palacios (2016), taken just as the individuals were in the forest: tree, shrub, liana, grass, succulent or epiphyte. The transfer in covers reduces the risk that the samples suffer some damage when moving them to the laboratory (Palacios 2016), which were taken to the Herbarium of the Technical University of the North (Temporary Patent No. TEMP-MAATE-MCMEVS-2023- 035). The drying was carried out in the oven for botanical samples, the drying time was six hours, and every three hours it was reviewed to evaluate the state of these. Once the samples were dried, they were mounted on 29.7 x 42 cm duplex sheets, labeled according to the established file.

Identification of specimens in herbarium

The recognition at the species level was carried out with the herbarium samples that were contrasted with information from the Catalog of Vascular Plants of Ecuador. The ratification was carried out with the information of Aguirre (2019) dry forest species, for the trees, while

the shrubs and herbaceous plants, the study of flora of the Guayabillas hill (Cerón and Fiallios 2017) was used. The nomenclature of each species proceeded according to the classification proposed by Angiospermun phylogentry Group IV [APG] (2016). The spelling check of the scientific names of each species was carried out on the website The plants List of the Royal Botanic Gardens, Kew and Missouri Botanical Gardens (2013).

Floristic composition and diversity indices

The floristic composition was determined by quantifying the importance value index (IVI) of the species; this consists of the sum of the relative values of density, frequency and dominance. In diversity, the Shannon and Pielow Indices were determined (Aguirre, 2019).

Structural characterization of the forest

Four classification ranges were established according to the characteristics presented in the inventory. The strata are presented according to the following categories: herbaceous, shrubby, subarboreal and arboreal, according to the proposal of Aguirre (2019), Table 1 and its adjustment to the dry forest ecosystem.

Table 1. - Categories of strata according to Aguirre (2019) and their modification to the dry forest ecosystem

Categories modified by Aguirre (2019)	Categories adopted in the study
< 0.3 – 1.5 m: herbaceous	< 0.3 – 1.5 m: herbaceous
1.5 - 5 m: shrubby	1.5 - 3 m: shrubby
5 - 12 m: subarboreal	3.1 - 5 m: subarboreal
> 12 m: arboreal	> 5 m: arboreal

Probable uses of the species

The seven species with the greatest abundance in the study area were selected and the probable uses that they can offer were determined. The category of uses was established as follows: cultural, food, fodder, fuel, construction, sawing, toxic, environmental and medicinal (De la Torre *et al*., 2008).

The validation of the probable uses of the species was through a structured interview with a focus group of the "El Rosal" community, supported by documentary information. The selected subjects were 10 heads of family since they develop their activities in the forest or its surroundings. The guide for the technique used was framed within its objective, consisting of the utility for the families of the seven species with the greatest abundance recorded in the forest. Consented permission was obtained, which facilitated greater harmony when asking the questions.

RESULTS AND DISCUSSION

Floristic composition

The established growth habits show representation in all cases, where bushy and herb habits stand out, with 16 and 13 species respectively, Table 2. Two *Vachellia species* are reported. *Macracantha* and B*ursera graveolens* are in the tree category, which is typical of these dry forests in the northern highlands of Ecuador (Table 2).

Table 2. - Species registered in the dry forest of the "El Rosal" community, number of individuals and growth habit

Family	Species	No. individuals	Habit
Amaranthaceae	*Alternanthera porrigens* (Jacq.) Kuntze	5	Bush
Amaranthaceae	*Alternanthera truxillensis* kunth	6	Bush
Amaranthaceae	*Chenopodium Petiolare Kunth*	2	Grass
Asteraceae	*Agweratum sp*	2	Grass
Asteraceae	*Bidens andicola* kunth	4	Grass
Asteraceae	*kingianthus paniculatus* (Turkz .) H.Rob.	4	Bush
Asteraceae	*Onoseris hyssopifolia* kunth	3	Grass
Asteraceae	*Pappobolus imbaburensis* (Hieron.) Bread basket	6	Grass
Asteraceae	*Parthenium hysterophorus L.*	19	Grass
bignoniaceae	*Thecoma stands* (L.) Juss. former Kunth	fifteen	Bush

Boraginaceae	*Tournefortia bicolor Sw.*	4	Liana
Burseraceae	*Bursera graveolens (Kunth) Triana & Planch.*	8	Tree
Cactaceae	*Opuntia pubescens* H.L.Wendl . _ former Pfeiff.	10	Succulent
Cactaceae	*Cleistocactus sepium* (Kunth) A. Weber	eleven	Succulent
Cactaceae	*Opuntia cylindrica (Lam.) DC.*	4	Succulent
commelinaceae	*Commelina diffuse* Burm.f. _	9	Grass
Crassulaceae	*Echeveria quitensis* (Kunth) Lindl.	2	Succulent
Crassulaceae	*Bryophyllum crenatum* (Lam.) Oken	7	Succulent
cucurbitaceae	*Cucumis dipsaceus* Kuntze	1	Liana
Euphorbiaceae	*Croton menthodorus* Benth.	148	Bush
Euphorbiaceae	*Jatropha gossypiifolia* L.	eleven	Bush
Fabaceae	*Dalea coerulea* (Lf) Schinz & Thell.	2	Bush
Fabaceae	*Indigofera suffruticosa* Mill.	18	Grass
Fabaceae	*Vachellia macracantha* (Humb. & Bonpl. ex Willd.) Seigler & Ebinger	37	Tree
malvaceae	*Sida cordifolia* L.	42	Bush
malvaceae	*Byttneria ovata* The m.	Four. Five	Grass
malvaceae	*Abutilon ibarrense* kunth	3. 4	Bush
Poaceae	*Aristida adscensionis* L.	37	Grass
Poaceae	*Pappophorum papiferum* (Lam.) Kuntze	16	Grass
Poaceae	*Pennisetum clandestinum* Hochst. former Chiov.	24	Grass
Rosaceae	*Rubus adenotrichos*	23	Bush
Rutaceae	*Zanthoxylum fagara* (L.) Sarg.	51	Bush
sapindaceae	*Dodonaea viscosa* (L.) Jacq.	43	Bush
sapindaceae	*Cardiospermum halicacabum* L.	8	Liana
nightshade	*Solanum nigrescens* M. Martens & Galeotti	24	Bush
nightshade	*Capsicum rhomboideum* (Dunal) Kuntze	6	Bush
nightshade	*Lycianthes lycioides* (L.) Hassl.	2	Bush
Talinaceae	*Talinum paniculatum* (Jacq.) Gaertn.	4	Grass
verbenaceae	*Aloysia scorodonioides* (Kunth) Cham.	6	Grass
verbenaceae	*Lantana lopez-palacii Moldenke*	eleven	Bush

The flora of the dry forest of the "El Rosal" community comprises 40 species within 37 genera and 19 families. The Asteraceae family stands out with five genera and species, respectively, which represents 12.5 % of the species, surpassing the other families that show one or three in genera and species, Table 3. This is the largest family of vascular plants, represents 8 % of all the world flora and has a wide distribution in the plant ecosystems of the Rivero world (2020). It is the largest and the second most important in America, according to Ulloa *et al.* (2017). Likewise, Rivero (2020), affirms that in the Andean region of Ecuador there is a predominance of the aforementioned family, this is evidenced in its distribution that goes from the valleys to the Páramos (Table 3).

Table 3. - Families registered in the dry forest of the "El Rosal" community, their number of genera and species

Family	Genders	Species
Asteraceae	5	6
Cactaceae	2	3
Fabaceae	3	3
malvaceae	3	3
Poaceae	3	3
nightshade	3	3
Amaranthaceae	2	3
Crassulaceae	2	2
Euphorbiaceae	2	2
Sapindaceae	2	2
Verbenaceae	2	2
Bignoniaceae	1	1
Boraginaceae	1	1
Burseraceae	1	1
Commelinaceae	1	1
Cucurbitaceae	1	1
Rosaceae	1	1
Rutaceae	1	1
Talinaceae	1	1
Grand total	37	40

The families identified are similar in number to what was recorded by Cerón (1994) in research carried out in the parish of Ambuquí, Ecuador. This behavior is due to the similarity of climate in both ecosystems, as well as a possible analogy of the substrate, since according to Muñoz *et al.* (2023), there is strong differentiation of species composition when there is presence of different substrates, under similar climatic conditions. The number of species is greater than the 34 identified by Guerrón *et al.* (2005) in the forest of Jerusalem, Ecuador. One of the reasons for the variation, in terms of the number of registered species, is due to the difference between the altitudinal ranges established in each of the investigations, since the Jerusalem Forest is located at 2,400 meters above sea level and the study ecosystem at 1,215 meters above sea level. The dry forest of the legal community "El Rosal" is located at the limit of the dry forest area, towards a transition zone between this ecosystem and the tropical humid forest, therefore, it presents a greater number of species in relation to the dry forests with higher altitude (Villalobos 2019).

Structural characterization of the dry forest

In relation to the vertical structure, Figure 1, the species that stood out in the tree layer is *Bursera graveolens* 9 m tall, while *Vachellia macracantha* represents the subarboreal stratum. *Croton* species *menthodorus, Zanthoxylum fagara* and *Dodonaea viscosa,* were the ones that presented individuals that reached 1.5 m in height, corresponding to the shrub layer. For its part, the herbaceous stratum was made up of individuals belonging to the Asteraceae family (Figure 1).

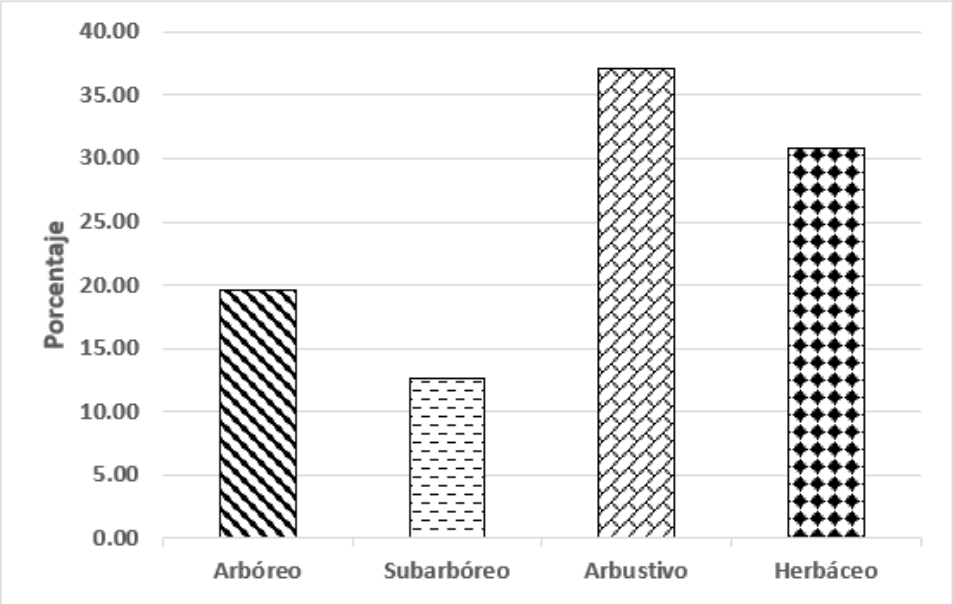

Figure. 1. - Distribution of the strata according to the growth habits of the species of the dry forest of the community "El Rosal"

Horizontal structure

The most representative species, according to abundance, in the different strata of the forest were for the arboreal and subarboreal *Vachellia macracantha* and in the shrub *Croton menthodorus,* Figure 2. The Asteraceae family was the one with the highest number of species for the herbaceous component. In this type of ecosystems, a broad representation of shrub species is observed (Aguirre 2012), considering that these species have greater ease of adaptation to extreme environmental conditions (Figure 2).

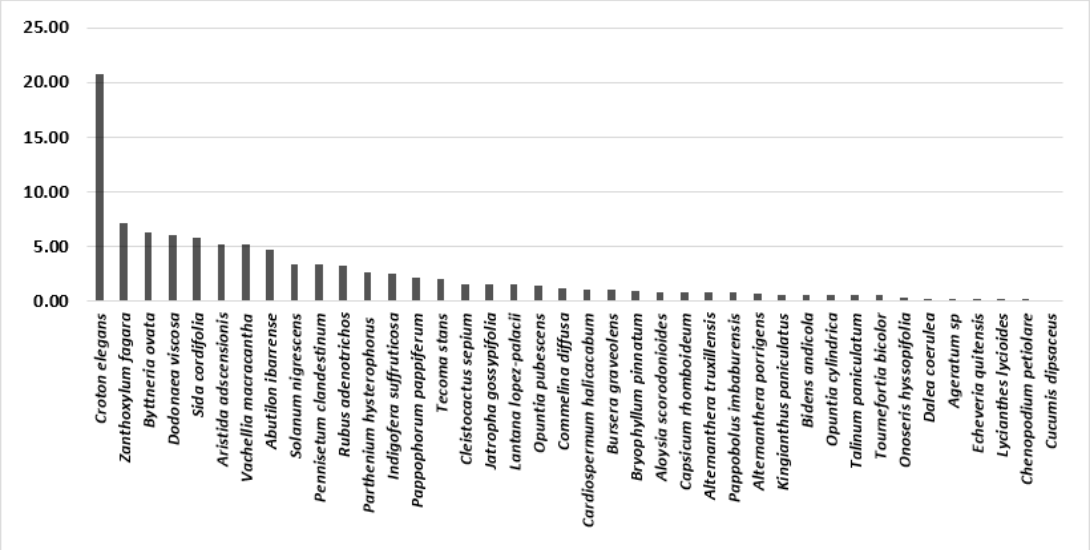

Figure. 2. - Relative abundance (%) of the species registered in the study area of the dry forest of the community "El Rosal"

The shrub layer was the one that presented the most frequency of species. Among these are *Dodonaea viscosa, Sida cordifolia and Croton menthodorus,* Figure 3. The latter was the one that was recorded the most in each of the established plots. Likewise, Albuja (2011) mentioned that this species is an indicator of inter-Andean dry forest (Figure 3).

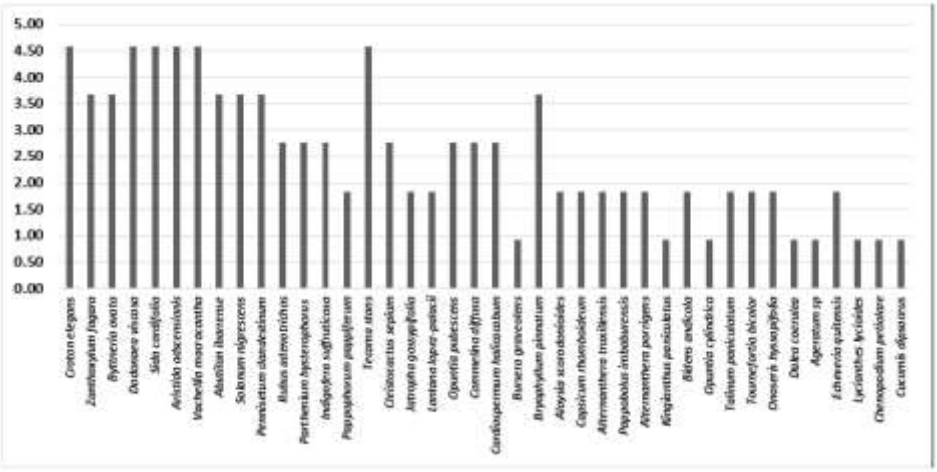

Figure. 3. - Relative frequency of the species in the study area of the dry forest of the community "El Rosal"

Vachellia macracantha dominance was manifested in Table 4, species that presented the largest basal area and volume in the forest. This behavior is due to the fact that it can develop in extreme environments, typical of dry forests, resists drought and grows in soils with few nutrients (Cueva *et al.*, 2019) (Table 4).

Table 4. - Dominance, basal area and volume of tree species present in the dry forest for the sample area

Species	individuals	Dominance (%)	basal area (m^2)	Total volume (m^3)
Vachellia macracantha	37	86	0.78	3.58
bursera graveolens	8	13	0.55	2.49

Diversity indices

The total floristic component in the study area showed the value of 3.08 for the Shannon index which, according to the ranges for this index established by Aguirre (2019), is in medium diversity. This result differs from that reported by Guerrón *et al.* (2005), in the dry forest of Jerusalem, Ecuador, which had low diversity; This variation is due to several conditions, among them the altitudinal range stands out.

Pielow equity index allows us to infer a high diversity with more homogeneous abundance (Aguirre, 2019). The value of 0.69 obtained by Valdez *et al.* (2018) is similar in the range category (> 0.67 - high diversity) but lower in 0.16. The reason for this difference would be given the richness and abundance of the species of the dry forest studied, Figure 2, which shows the *Croton menthodorus* as the most abundant (Table 5).

Table 5. - Value index of importance of the relevant species of the dry forest in the community "El Rosal"

Species	*Ar* (%)	*Dr.* (%)	*Fr* (%)	IVI
Vachellia macracantha	82.22	86.84	83.33	252.40
Bursera graveolens	17.78	13.16	16.67	47.60
TOTAL	100.00	100.00	100.00	300.00

Ar: relative abundance, Dr: relative dominance and Fr: relative frequency.

The IVI importance value index, Table 6, determined that the ecologically important species for the dry forest is *Vachellia macracantha* with a result of 252.4 and in the background *Bursera graveolens* with 47.6. This is due to the ability of this species to adapt to extreme environmental conditions and the ease of taking advantage of the resources present in the forest for its development (Paredes *et al.*, 2020).

Potential uses of the most representative species of the dry forest

The seven most abundant species of the dry forest under study, show their values in relation to the probable uses that they can offer, Table 6. The most common uses recognized by the inhabitants correspond to the categories of fodder, fuel, medicinal and environmental, standing out the medicinal use (Table 6).

Table 6. - Values of potential uses identified for the most representative species of the dry forest in "El Rosal"

Species	To the	fo	Co	Ace	tx	I	A.M	cu
V. macracantha		8	6	7			9	
B. graveolens			4	1	3	6	6	
C. methodorus						9		2
Z fagara		5				2	6	2
B. ovata						2		2
D. viscous						1	4	1
S. cordifolia		1	1			2	1	1

Al: food; Fo: fodder; Co: fuel; As: sawable; Tx: toxic; Me: medicinal; Am: environmental and Cu: cultural.

The most important species, based on the potential uses it can offer to the population, was *Vachellia macracantha* , given the multiple uses that it offers to the community members, from the cultural, environmental and productive aspects.

CONCLUSIONS

The floristic diversity in the dry forest of the "El Rosal" community is medium and with a manifestation of homogeneous equitability, where 40 species belonging to 19 families were inventoried, with the Asteraceae family being the best represented with five species.

The most dominant species recorded in the arboreal and subarboreal strata is *Vachellia macracantha*, which is also ecologically the most important.

Medicinal use is the most recognized by the residents of the "El Rosal" community and the *Vachellia species macracantha , Bursera graveolens , Sida cordifolia* and *Opuntia pubescens* are the most represented for all the categories of use.

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