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Original article

Structure and tree composition on the tropical dry forest in Sancán valley, Manabí, Ecuador

Estructura y composición arbórea del bosque seco tropical en el valle Sancán, Manabí, Ecuador

Estrutura e composição arborea da floresta seca tropical no vale Sancán, Manabí, Ecuador

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ABSTRACT

The management of the tropical dry forest requires knowledge of its dynamics and structure. In order to generate information on a remnant of the dry forest in the Sancán Valley, the floristic and structural composition of a remnant forest was evaluated. With an area of 1 000 m^2, six sampling plots were established. The species, the diameter (D1.30) and the height of all individuals greater than 5 cm were registered. Diversity and its structure were characterized through the Shannon index, Simpson's reciprocal, theecological importance value index of each species and the structure by diameter class. 236 individuals belonging to 21 species of 20 genera and 14 families were recorded. The families with the highest number of species were: Fabaceae,Capparaceae, Euphorbiaceae and Malvaceae among the most ecologically important species were: *Ceiba trichistandra*, *Bursera graveolens* and *Geoffroea spinosa* . Diversity was high and

similar in all plots. The diameter classes reflect an inverted "J" characteristic of heterogeneous forests. The species found are representative of the tropical dry forest with anthropic intervention of selective use.

Keywords: Diversity; dry forest horizontal structure; Diametric structure.

RESUMEN

El manejo del bosque seco tropical requiere del conocimiento de su dinámica y estructura. Con el propósito de generar información sobre un remanente del bosque seco en el valle Sancán se evaluó la composición florística y estructural un remanente boscoso. Se establecieron seis parcelas de muestreo con una superficie de 1 000 m^2 y se registraron las especies, el diámetro ($D_{1,30}$) y la altura de todos los individuos mayores de 5 cm. Se caracterizó la diversidad y su estructura a través del índice de Shannon, recíproco de Simpson, el índice de valor de importancia ecológica de cada especie y la estructura por clase diamétrica. Se registraron 236 individuos que pertenecen a 21 especies de 20 géneros y 14 familias. Las familias con mayor número de especies fueron: Fabaceae, Capparaceae, Euphorbiaceae y Malvaceae; entre las especies de mayor importancia ecológica estuvieron: *Ceiba trichistandra*, *Bursera graveolens* y *Geoffroea spinosa*. La diversidad fue alta y similar en todas las parcelas. Las clases diamétricas reflejan una "J" invertida característica de un bosque heterogéneo. Las especies encontradas son representativas del bosque seco tropical con intervención antrópica de uso selectivo.

Palabras clave: Diversidad; Bosque seco Estructura horizontal; Estructura diamétrica.

RESUMO

A floresta tropical seca é uma formação vegetai que requere maior conhecimento de sua dinâmica e estrutura para a gestão e conservação. Com o proposito de gerar informação sobre um resquício da floresta seca no area Sancán, evalua-se a composição florística e estrutura de este resquício boscoso. Foram estabelecidas seis parcelas de amostragem com uma área de 1 000 m^2 (20 × 50 m); o diâmetro ($D_{1,30}$) e a altura de todos os indivíduos e" 5 cm foram registados. Composição florística, índice de Shannon y Simpson, abundância, frequência, dominância e índice de valor de importância foram determinados; e estrutura de diâmetro foi também calculado. Registraron-se 236 individuos que pertenecem a 21 espécies dentro de 20 géneros em 14 famílias. As famílias com maior número de espécies foram: Fabaceae, Capparaceae, Euphorbiaceae y Malvaceae; em as espécies de maior importância ecológica são: *Ceiba trichistandra*, *Bursera graveolens* y *Geoffroea spinosa*. De acordo com o índice de Shannon, a diversidade é alta (3,83). As classes de diâmetro refletem um "J" invertido característico da recuperação das florestas. As espécies encontradas som representativas da floresta tropical seca com intervenção antrópica do uso seletivo.

Palavras-chave: Diversidade; Floresta seca; Estrutura horizontal; Estruturadiamétrica.

INTRODUCTION

Deforestation, worldwide, is one of the processes of environmental degradation with a high negative impact on the sustainability and competitiveness of ecosystems. It generates losses of biodiversity and degradation of soils and waters. Not only changes the microclimates of the affected regions but also the climate globally. Despite the fact that deforestation has decreased in the last 25 years, forests are still being deforested worldwide (FAO 2018).

Currently, the recovery of forested areas, the reduction of logging and adequate forest management have become priority activities to restore forests, the biodiversity they harbor and the environmental services they provide, as a strategy to face the effects of climate change (Aitken *et al.*, 2008; Aguirre-Mendoza *et al.*, 2021c; Bautista-Miranda 2019).

Ecuador is a country rich in natural resources, with climatic and biological diversity such as tropical and Andean forests (Rosillo *et al*., 2020). These are considered fragile ecosystems and vulnerable to the combined effects of climate change, deforestation and degradation (Aguirre-Mendoza *et al.*, 2017). At the same time, they have the potential to help mitigate climate change, restore ecosystem functions, and provide environmental goods and services (Herzog *et al*., 2013).

Studies in this Ecuadorian formation show high floristic diversity of these forests, their great heterogeneity, differences in the current species composition due to human influence and fragmentation (Aguirre-Mendoza *et al.,* 2017; 2018).

This study was carried out with the purpose of evaluating the floristic and structural composition of the tropical dry forest of the Sancán Valley to provide elements that allow improving the management and conservation actions of the remaining dry forest.

MATERIALS AND METHODS

Study area and sampling sites

The study was carried out in the Quimis sector, Sancán valley belonging to the Jipijapa canton, located in the south of the Manabí province. It limits to the North with the La Pila parish, to the South with the Sancán community, to the East with the Cerrito la Asunción and to the West with the Membrillal parish (Figure 1). The climate is warm dry with a temperature between 21 to 37 ^{0}C and the annual rainfall average is 600 mm. The soils are clayey, on average slopes of 80 %. Lowland deciduous forest and semi-deciduous low montane and/or foot montane forest predominate in this region (Aguirre-Mendoza *et al.,* 2021c).

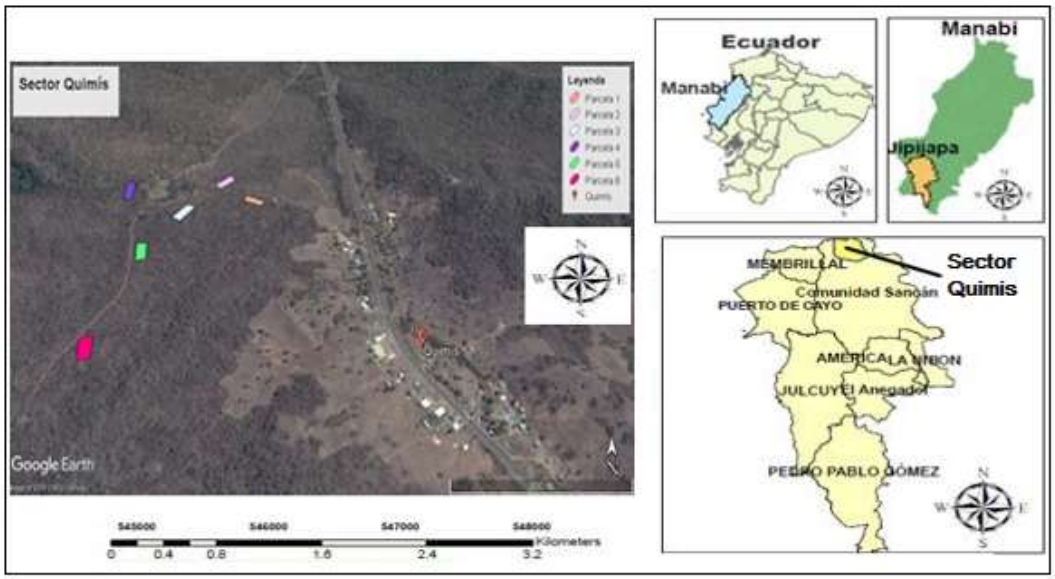

Figure 1. - Location of the plots made in the tropical dry forest, Quimis sector, Sancán valley

In the study area, six sampling plots with a surface of 1 000 m^2 (20×50 m) were established, validated by means of the species accumulation curve. For the establishment, a compass, a GPS, stakes and string were used. All individuals of tree species greater than 5 cm in diameter ($D_{1.30}$) were recorded. The species and the number of trees of each individual were identified and the total height (h) and diameter ($D_{1.30}$) were measured. The registration and collection of woody individuals followed the methodology of Phillips *et al.* (2016).

Analysis of data

Floristic composition

During the collection of information in the field, botanical material was collected from all existing tree species in the sampling sites. The botanical samples of all the individuals were identified in the ECUAMZ herbarium (Amazonian Herbarium of Ecuador) of the Amazon Postgraduate Research and Conservation Center (CIPCA) of the Amazon State University. The nomenclature of scientific names follows the APG IV system.

Alpha and beta diversity indices

In order to measure the tree diversity of the forest, the Shannon-Weaver diversity index (*H'*) was estimated, which expresses the heterogeneity of a community; and the Simpson diversity index (1/D), which estimates whether a given community is made up of species with great dominance (Aguirre-Mendoza *et al.* 2021). To evaluate the beta diversity of the forest, a conglomerate of analysis was performed to detect similarities between plots. These analyzes were performed with the *BioDiversity Pro program* ver. 2.0.

Calculation of structural parameters

The ecological importance index (IVIE) of eachspecies was calculated, which relates the relative abundance (Ar), relative frequency (Fr) and relative dominance (Dr) (Manzanilla *et al*., 2020) (Table 1).

Table 1. - Equations for obtaining the structural parameters

Parameter	Formula
Absolute abundance (Aa)	Number of individuals of a species
Relative abundance (Ar %)	$Ar = \frac{\#\ de\ individuos\ de\ la\ especie}{\sum de\ Aa\ de\ todas\ las\ especies}\ x\ 100$
Relative frequency (RF %)	$Fr = \frac{Fa\ de\ la\ especie}{Fa\ de\ todas\ las\ especies}$
Relative dominance (RD%)	$Dr = \frac{Da\ de\ la\ especie}{AB\ de\ todas\ las\ especies}\ x\ 100$
Importance Value Index (IVIE)	IVI E= Ar + Fr + Dr

Diametric structure

The diameter structure of the forest was determined considering the number of individuals with $D_{1.30}$ cm ≥ 5 cm and belonging to the diameter classes established by Aguirre-Mendoza *et al.* (2017) based on determining the diameter distribution of the vegetation.

RESULTS AND DISCUSSION

The species accumulation curve indicates that the number of sampled plots was sufficient to represent the floristic richness of the forest (Figure 2).

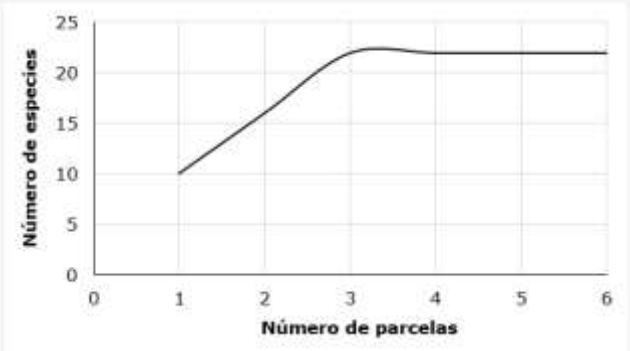

Figure 2. - Species accumulation curve in the forest of the Quimís sector, Sancán Valley

Floristic composition

In the study, 21 species, 20 genera, 14 families and a total of 236 individuals were recorded, results similar to those reported by Jiménez *et al*. (2021) who reported 31 species, 29 genera and 16 families in seven active apiaries distributed within the Quimís enclosure, and very different from what was reported by Maldonado *et al*. (2018) in a tropical montane forest that found 81 tree species.

Within the identified species, *Pithecellobium arboreum* is classified as Vulnerable (VU) and *Croton rivinifolius* Endangered (EN) according to the IUCN Red Book (IUCN, 2020), meaning it has a high risk of extinction in nature. In this sense, both species face a risk of extinction or population deterioration in the medium term.

The species *Colicodendron scabridum* and *Bursera graveolens,* according to the IUCN Red Book, are categorized as least concern (LC), that is, they are not critically endangered, similar to *Ceiba trichistandra.* The latter being the most used by the surrounding communities.

The families with the greatest diversity of species were: Fabaceae with five species, Capparaceae, Euphorbiaceae and Malvaceae with two, and the rest of the families represented by a single species (Figure 3), results similar to those reported by Aguirre *et al*. (2021a) who register: Fabaceae, Asteraceae, Malvaceae and Rubiaceae as the families with the greatest diversity of species in the dry forest of the "El Tabanco" sector, Mangahurco parish, Zapotillo, Ecuador. Likewise, Jiménez *et al*. (2021) report the families Fabaceae, Ericaceae and Malvaceae as the most diverse. According to these studies, the outstanding families in dry forests are: Fabaceae and Malvaceae.

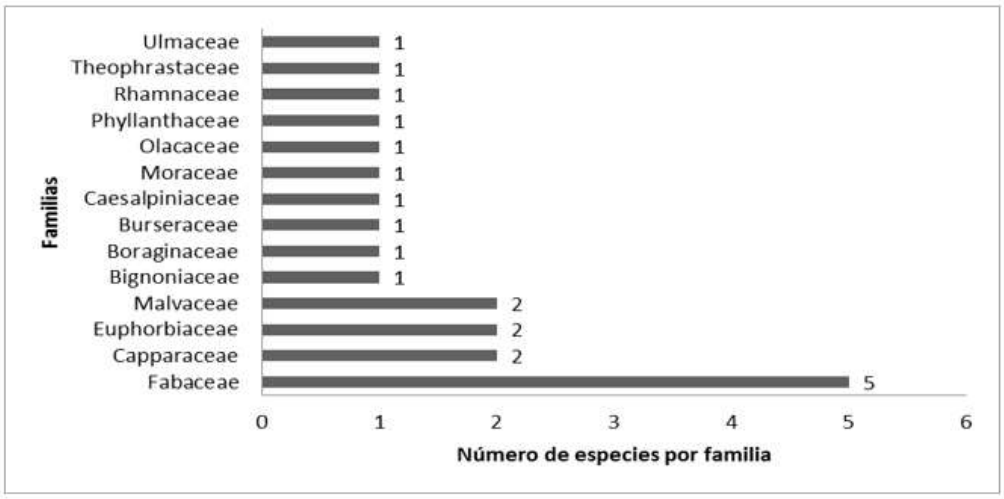

Figure 3. - Richness of tree species by family in the tropical dry forest of the Quimís sector, Sancán Valley

Structural parameters

The species with the greatest presence in the forest were *Bursera graveolens*, *Geoffroea spinosa* and *Jacquinia sprucei* , which also coincide with the most abundant. *Ceiba trichistandra*, *Jacquinia sprucei,* and *Bursera graveolens* were the most frequent species in the forest, while *Ceiba trichistandra*, *Bursera graveolens,* and *Geoffroea spinosa* were the dominant species.

The species with the highest importance value were *Ceiba trichistandra* with 33.16 %, *Bursera graveolens* with 11.46 % and *Geoffroea spinosa* with 6.99 % (Table 2), this result is similar to the one was observed by Aguirre *et al*. (2021c) who also report *Ceiba trichistandra* as an outstanding species. In the same way, Jiménez *et al*. (2019) indicate that *Ceiba trichistandra* is the most important and that it is a typical and characteristic species of the dry forests of Ecuador and Peru, compared to other dry forests in the world.

On the other hand, it was observed that among the species with the lowest IVIE are *Machaerium millei* with 0.85 % and *Croton rivinifolius and Pithecellobium excelsum* with 0.71 % each, different results from those reported by Aguirre *et al.* (2021b) indicating *Gynoxys nitida*, *Piper ecuadorense* and *Meliosma arenosa* as species with lower IVIE in the Huashapamba forest, Loja, Ecuador; to Aguirre *et al.* (2021c) in Zapotepamba where the ecologically least important species was *Melinis minutiflora*. While in the permanent plot of the dry forest in the El Tabanco sector, Mangahurco, Ecuador, the ecologically less important species are *Machaerium millei* and *Terminalia valverdae* (Aguirre *et al*., 2021a). The difference found is possibly due to the degree of anthropic intervention and maturity of the vegetation.

Table 2. - Structural parameters of the 10 main species of the tree component of the tropical dry forest of the Quimís sector, Sancán Valley

Species	AA	RA (%)	FA	RF (%)	GIVES	RD (%)	IVIE (%)
Ceiba trichistandra (A. Gray) Bakh.	eleven	4.66	6	10.00	13.61	84.82	33.16
Bursera graveolens (Kunth) Triana & Planch.	47	19.91	5	8.33	0.99	6.14	11.46
Geoffroea spinosa Jacq.	25	10.59	5	8.33	0.29	1.84	6.92
Jacquinia sprucei Mez.		9.75	6	10	0.10	0.62	6.79
Cynophalla mollis (Kunth) J. Presl.	19	8.05	5	8.33	0.10	0.63	5.67
Colicodendron scabridum (Kunth) Seem.	16	6.78	5	8.33	0.08	0.47	5.19
Varionia macrocephala Desv.	17	7.20	4	6.67	0.26	1.63	5.17
Tecona castanifolia (D. Don.) Melch.	18	7.63	4	6.67	0.07	0.45	4.92
Phyllanthus graveolens (Kunth) Mart.	10	4.24	4	6.67	0.08	0.49	3.80
Trema micrantha (L.) Blume.	9	3.81	3	5.00	0.06	0.40	3.06

AA: Absolute Abundance, FA: Absolute Frequency, DA: Absolute Dominance, AR: Relative Abundance, FR: Relative Frequency, DR: Relative Dominance, IVIE: Ecological Importance Value Index.

Shannon index (H) and Simpson's reciprocal (1/D)

According to the results, the diversity of species according to the Shannon index is classified as high diversity in the area of the Quimís sector, evidenced by the result obtained H=3.83. In this sense, the *Bursera graveolens* species stand out, while *Croton rivinifolius* and *Pithecellobium excelsum* present low diversity in the study area (Table 3). The results of the reciprocal of Simpson Dominance (1/D) = 0.06 and Simpson (D) =0.91 show a high expectation to make a random selection of two or more individuals of the same species in the established research area.

Similar results were reported by Aguirre-Mendoza *et al*. (2017), in the southwest of Ecuador, who reported a value of 2.51, which indicates a medium diversity. In the same way, the Simpson index showed a high dominance (S=0.93); similar to that reported by a study of the floristic composition and structure of dry forests in the province of Loja, Ecuador (Aguirre *et al*., 2013) who reported a high dominance (S = 0.89).

Table 3. - Shannon diversity index of the study species of the tropical dry forest in the Quimís sector, Sancán Valley

Species (Scientific name)	Ind by sp.	AR "PI"	Ln "PI"	PI*Ln (PI)	PI* Ln(PI)*-1
Bursera graveolens **(Kunth) Triana & Planch.**	47	0.20	-2.33	-0.46	0.46
Geoffroea spinosa **Jacq.**	25	0.11	-3.24	-0.34	0.34
Jacquinia sprucei **Mez.**		0.10	-3.36	-0.33	0.33
Cynophalla mollis **(Kunth) J. Presl.**	19	0.08	-3.63	-0.29	0.29
Tecoma castanifolia **(D. Don.) Melch.**	18	0.08	-3.71	-0.28	0.28
Varionia macrocephala **Desv.**	17	0.07	-3.80	-0.27	0.27
Colicodendron scabridum **(Kunth) Seem.**	16	0.07	-3.88	-0.26	0.26
Ceiba trichistandra **(A. Gray) Bakh.**	eleven	0.05	-4.42	-0.21	0.21
Phyllanthus graveolens **(Kunth.) Mart.**	10	0.04	-4.56	-0.19	0.19
Trema micrantha **(L.) Blume.**	9	0.04	-4.71	-0.18	0.18
Leucaena trichoides **(Jacq.) Benth.**	7	0.03	-5.08	-0.15	0.15
Jatropha curcas **L.**	6	0.03	-5.30	-0.13	0.13
Eriotheca ruizii **(K. Schum.) A. Robyns**	5	0.02	-5.56	-0.12	0.12
Senna mollissima **(Humb. & Bonpl. Ex Willd.) HS Irwin & Barnaby.**	5	0.02	-5.56	-0.12	0.12
Ziziphus thyrsiflora **Benth.**	5	0.02	-5.56	-0.12	0.12
Maclura tinctoria **(L.) Steud.**	4	0.02	-5.88	-0.10	0.10
Chionanthus _	3	0.01	-6.30	-0.08	0.08
Leucaena leucocephala **(Lam.) de Wit.**	two	0.01	-6.88	-0.06	0.06
Machaerium millei **Standl.**	two	0.01	-6.88	-0.06	0.06
Croton rivinifolius **Kunth.**	1	0.00	-7.88	-0.03	0.03
Pithecellobium excelsum **(Kunth.) Mart.**	1	0.00	-7.88	-0.03	0.03
Total	**236**	**1**	**-106.4**	**-3.83**	**3.83**

Ind by sp. = number of individuals per species in the six plots; AR= relative abundance; PI= proportion of the number of individuals of species *i* with respect to the total; Ln= natural logarithm.

Beta diversity

The dendrogram derived from the *Bray-Curtis similarity-dissimilarity matrix* (1957) (Figure 4) groups the study plots into three well-defined sets. In group one is plot 1, group two is made up of plots 3, 5, 4 and 6, and group three is made up of plot 2. The groupings are influenced by the number of individuals of the species with the greatest

floristic composition, due to that their abundance was very similar, despite the fact that their richness was very different between the sampling sites.

In general, the similarity of the tropical dry forest plots in the Quimís sector is more than 50 % similar, with clear heterogeneity and diverse species that develop in this area, located 200 m from the road and 300 m above sea level, influenced by anthropic activities such as: logging for firewood, carpentry and the use of non-timber products. This coincides with what was found by Vistín-Guamantaqui and Espinoza (2021) in the Evergreen Montano Alto forest of the Sangay-Ecuador National Park where they reported a similarity of species of more than 50 %, and selective logging, the extraction of firewood and other non-timber forest products, as the factors that modify the most the dynamics of the forest, as well as its structure and composition.

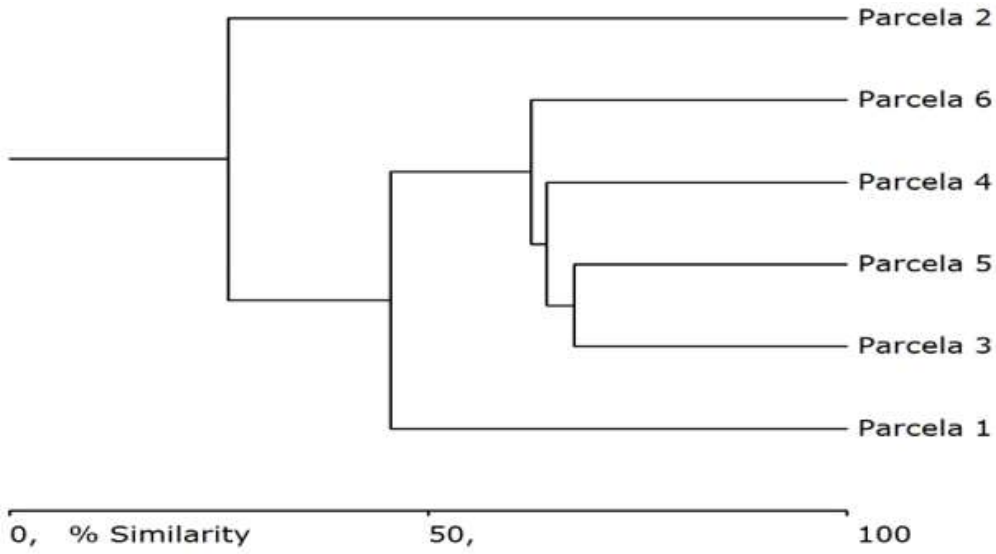

Figure 4. - Floristic similarity dendrogram obtained by cluster analysis using the Bray-Curtis similarity measure

Diametric structure

Figure 5 shows that the first two diameter classes group 89.83 % of the total individuals, demonstrating that the forest is made up of thin growing trees. Diameter class five (> 40 cm) is made up of six *Ceiba trichistandra individuals* , which have already reached maturity, resulting in an inverted "J"-shaped diameter distribution of the forest, a situation that is corroborated by Aguirre *et al*. (2021c), in the dry forest of Zapotepamba, Loja, Ecuador, which shows a diameter structure similar to the inverted "J" typical of dry forests; in the same way Astudillo *et al.* (2019) and Aguirre *et al*. (2021b) confirms a diameter distribution in the form of an inverted "J" that is characteristic of Andean forests, it should be noted that the community studied is self-regenerative, given the fact that there is a high concentration of individuals in the smaller classes with a marked reduction in the larger ones.

The trend of the inverted "J" curve also indicates that the plant community is developing towards more advanced stages of growth and productivity, as stated by Lamprecht (1990), where the abundant young individuals are replacing specimens that are found in the senile phase, confirmed by Aguirre-Mendoza *et al.* (2017) and Aguirre *et al.* (2018) in studies about Andean forests of southern Ecuador.

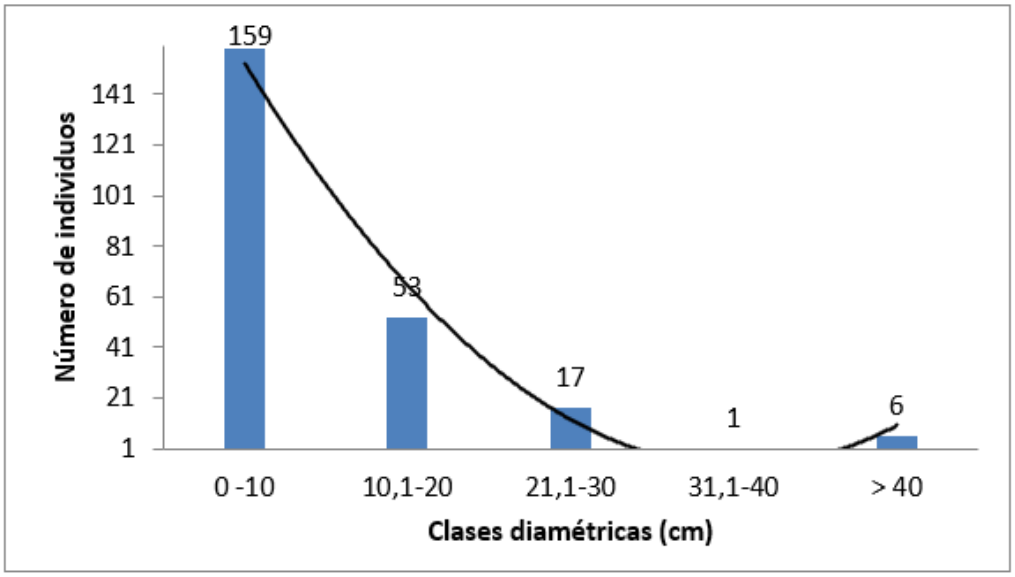

Figure 5. - Diametric structure of the tropical dry forest of Quimís, Sancán Valley

CONCLUSIONS

The floristic diversity is high, it is expressed in the presence of 21 species, 20 genera, 14 families and 236 individuals. The most diverse families were: Fabaceae, Capparaceae, Euphorbiaceae, and Malvaceae.

The ecologically important tree species were: *Ceiba trichistandra*, *Bursera graveolens* and *Geoffroea spinosa*, which suggests that it is a dry forest that preserves endemic species and characteristics of this type of ecosystem.

The first three diameter classes group the largest number of trees evaluated, which determines a diameter distribution with an inverted "J" trend, indicating that the dry forest of the Quimís sector is a forest in the process of recovery.

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Authors' contribution:
Wagner Ramírez Huila: Conception of the idea, literature search and review, instrument making, instrument application, compilation of information resulting from the instruments applied, statistic análisis, preparation of tables, graphs, and images, database preparation, general advice on the topic addressed, drafting of the original (first version), review and final version of the article, article correction, authorship coordinator, translation of terms or information obtained, review of the application of the applied bibliographic standard.

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