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Translated from the original in spanish

Effect of forest use in semi deciduous forests on the Guanahacabibes Peninsula, Cuba

Efecto del aprovechamiento forestal en bosques semideciduos en la península de Guanahacabibes, Cuba

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ABSTRACT

This work focuses on the study of the semi deciduous forest in two sectors of the Guanahacabibes Peninsula, Cuba, with different post-harvest recovery times (> 30 and 2 to 5 years), with the aim of determining its composition and structure. Five plots were delimited at random taking into account the management history, determining 13 vegetation variables which were analyzed by the normality test by Shapiro Wilk and tested the homogeneity of variance between groups with the Levene test. The treatment of five years of forest post-harvest recovery in the locality of Cabo San Antonio is characterized by having one of the highest densities in the upper arboreal stratum and in the time of selective post-harvest recovery, the richness and density of the plant formation decreases as more strata were involved in harvesting, which delayed the recovery of the forest.

Keywords: forest use; strata; Guanahacabibes Peninsula; sectors.

RESUMEN

Este trabajo se centra en el estudio del bosque semideciduo notófilo en dos sectores de la Península de Guanahacabibes, Cuba, con diferentes tiempos de recuperación posaprovechamiento forestal (>30 y de 2 a 5 años), con el objetivo de determinar su composición y estructura. Se delimitaron cinco parcelas al azar teniendo en cuenta el historial de manejo, determinándose 13 variables de vegetación, las cuales se analizaron mediante la prueba de normalidad por Shapiro Wilk y se probó la homogeneidad de varianza entre grupos con el test de Levene. El tratamiento de cinco años de recuperación posaprovechamiento forestal en la localidad del Cabo San Antonio se caracteriza por tener una de las más altas densidades en el estrato arbóreo superior y en el tiempo de recuperación postala selectiva, disminuye la riqueza y la densidad de la formación vegetal mientras mayor número de estratos fueron implicados en el aprovechamiento, lo que tardó la recuperación del bosque.

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Palabras clave: aprovechamiento forestal; estratos; Península de Guanahacabibes; sectores.

INTRODUCTION

The semi-deciduous forests, because of the environmental conditions where they are found, their position in the flat and submountainous parts of the relief, the high average annual temperatures and the relatively low accumulated rainfall, have also been categorized in consideration of the Holdridge system, within the dry forest life zone. These have been recognized as one of the most endangered ecosystems in Mesoamerica. Fernández and Sáenz, (2000)

From the perspective of natural resource management, considering integrally the aspects of production, conservation and restoration, it is important to understand the response of ecosystems to disturbances, as well as to detect change in the state of ecological systems. Since these are processes that occur at large temporal and spatial scales, the focus of long-term ecological research and continuous observation is essential. Franklin *et al.,* (2001).

A possible biological indicator that allows the identification, environmental monitoring and development of management and conservation strategies is resilience, which refers to the ability and capacity of ecosystems to absorb, buffer and resist abiotic and biotic changes that occur after disturbances of natural or anthropogenic origin Bellwood and others (2004). The work was aimed at determining the structure and composition of the semi-deciduous forest by the effect of forest exploitation in its spatial-temporal manifestation.

MATERIALS AND METHODS

The Peninsula de Guanahacabibes Biosphere Reserve is located in the westernmost tip of the island of Cuba. It is an elongated, narrow and flat territory of some 101 500 ha Herrera et al. (1987), of which 28 000 ha comprise the land area of the national park of the same name. This peninsula is formed by three sectors: Cabo de San Antonio, El Veral and Cabo Corrientes (Figure 1).

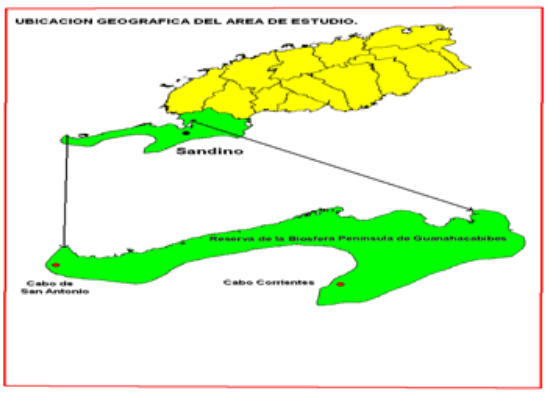

Fig. 1. Esquema de ubicación de las localidades de estudio, Cabo de San Antonio y Cabo Corrientes en la Península de Guanahacabibes.

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For the analysis of vegetation, structure and taxonomic composition, two sectors were selected for this study: Cabo San Antonio (CSA) and Cabo Corrientes (CC), in each of which two treatments were determined taking into account the time of forest exploitation of the semideciduous forest according to Ferro, (2004).
Treatment one is considered to have two to five years of post-harvest recovery and treatment two 30 years or more of post-harvest recovery (Table 1).

Tabla 1. Tratamiento por sectores.

Sectores	tratamiento 1	tratamiento 2
Cabo San Antonio	Jocuma	Catauro
Cabo Corrientes	Uvero	Cabo Corrientes

The taxonomic review of forest species was carried out according to Acevedo and Strong, (2012). In each treatment a plot of 625 m2 (25 m X 25 m) was considered as a sampling unit, 20 plots were studied (five replications for each treatment). All trees and shrubs in each plot that met the requirements were measured: ≥ 2 cm shaft diameter at 1.30 m above ground (DBH) and ≥ 2 m high.
In the plots an analysis of the structure was made according to the spatial distribution proposed by Delgado and Pérez, (2013):

(a) (Ea) Shrub stratum (2 to 4.5 m high)
(b) (Eai) Lower tree stratum (4.6 to 10 m high)
(c) (Eas) Upper tree stratum (> 10 m height), Density (Den) of each stratum and total (trees/ha), Basal area (AB) of each stratum and total of the plots, volume of each stratum and total of the plots (AB * Alt* 0.5 (m^3/ha), Average height (Alt) of each stratum and of the plots and (DBH) Average diameter at 1.30 m height from the ground. In addition, diversity (richness, frequency, abundance and dominance) was determined (Table 2).

Tabla 2. Diversidad (riqueza, frecuencia, abundancia y dominancia).

Clases diamétricas	I	II	III	IV	V	VI	VII	VIII	IX	X
Valores (cm)	2-3,5	3,6-5,1	5,2-6,7	6,8-8,3	8,4-9,9	10-11,5	11,5-13	13,1-14,6	14,7-16,2	>16,3

Importance Value Indices (IVI) were calculated for species according to their Finol equations, (1971):

IVI (Importance Value Index)

IVI=FR + DenR + DoR where:

Relative density DenR= # individuals of a species X 100

Total # individuals of all species

Relative dominance DoR= Basal area of a species X 100

Total basal area of all species

Relative frequency FR Frequency of a species X 100

Sum of all frequencies

Data analysis

For the 13 variables that were analyzed from the vegetation, their means and standard deviations were presented, their corresponding normality tests were done by Shapiro Wilk and the homogeneity of variance between groups was tested with Levene's test. None of these variables had a normal distribution, nor homogeneity of variance between groups, therefore, the non-parametric analysis of variance by Kruskall-Wallis was applied, considering as an effect the four combinations of localities and treatments: Uvero, Cabo Corrientes, Jocuma and Catauro. Then the Dunn test was carried out, to make multiple comparisons of the vegetation variables at 5 % significance (Table 1.)

The similarities between treatments, based on their species richness and densities, were determined by a cluster analysis with the Ward method, using the 1997 BDpro version 2 program.

RESULTS AND DISCUSSION

Characteristics of the taxonomic composition and structure of the forests in the locations studied

Means and standard deviations of 13 variables of the semi-deciduous forest in each sector and treatment studied are presented. All variables analyzed, except richness of the lower tree stratum and basal area of the upper tree stratum, were statistically significant. The Kruskall-Wallis test indicates a difference between the four effects, i.e. the combinations of localities and treatments (Table 3).

Table 3. - Means (X), standard deviations (S) and Kruskall-Wallis test results for 13 forest variables semi-deciduous in two locations and both treatments. (Ea) Shrub layer, (Eai) Lower tree layer, (Eas) Upper tree layer

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	Cabo Corrientes				Cabo San Antonio				Z	p
Variable	2 a 5 años		+30 años		2 a 5 años		+30 años			
	X	S	X	S	X	S	X	S		
Densidad Ea/ha	2627,2	493,9	2176,0	135,2	4464,0	81,58	1184,0	284,87	16,727	0,001
Densidad Eai/ha	3241,6	249,8	2323,2	170,6	1708,8	325,2	4147,2	662,25	17,057	0,001
Densidad Eas/ha	707,20	213,58	415,20	149,24	828,80	250,54	515,20	199,65	8,912	0,030
Riqueza Ea/ha	25,00	6,24	18,60	,89	11,60	1,341	12,00	1,871	16,540	0,001
Riqueza Eai/ha	21,80	2,68	22,20	2,17	20,60	2,97	24,20	2,59	4,248	0,236
Riqueza Eas/ha	12,60	2,70	10,00	3,16	17,80	1,48	14,00	5,24	8,880	0,031
Altura Ea	3,30	,14	3,54	,084	3,45	,01	3,52	,04	14,211	0,003
Altura Eai	6,62	,25	6,11	,11	7,31	,26	6,46	,33	14,051	0,003
Altura Eas	12,73	,15	13,48	,67	14,54	,78	13,78	,83	13,137	0,004
Regeneración natural	571,00	333,05	225,00	87,17	46,00	8,66	72,00	21,19	17,309	0,001
G Ea /ha	2,36	0,63	3,32	1,76	4,21	0,44	1,32	0,55	11,374	0,010
G Eai/ha	10,21	1,72	9,27	0,31	6,29	1,73	1,.27	2,81	15,229	0,002
GEAS/ha	11,98	4,39	14.70	11,50	21,96	5,39	18,30	6,74	4,771	0,189

Regeneration describes a totally different dynamic, the decrease in the filtering of sunlight by the plant cover itself hinders the development of regeneration which, having reached high values after forestry intervention, establishes the competitive phase of elimination that subsequently follows.

The five-year post-harvest recovery treatment in the town of Cabo de San Antonio is characterized by one of the highest densities in the Eas, this forest stratum has not been affected by forest harvesting for more than 40 years. The variables that resulted significant from this treatment compared to the Catauro were the density of the shrub layer, the density of the lower tree layer, basal area of the shrub layer and basal area of the lower tree layer, with the Uvero treatment the density of the lower tree layer, richness of the shrub layer, height of the upper tree layer and natural regeneration and with Cabo Corrientes, density of the upper tree layer, richness of the upper tree layer, height of the lower tree layer and natural regeneration.

The forest exploitation in this area in the lower tree stratum was destined to the production of round wood for the repair of tobacco drying houses. It is separated from the other treatments as it has the Eas with a greater development, given by a better availability of nutrients and water, for its abiotic characteristics, which decrease the tensions of the environment, and therefore it recovers faster. In this treatment, the highest average height in the Eas was recorded, due to its low density and to being affected by the felling of individuals with D1.3 between 8 and 12 cm. Natural regeneration is higher because functional groups of late stabilizers of the ecosystem are involved. In addition, among the characteristics of this treatment is the proximity to the wooded formation of the marsh, and although the humidity has not been measured, it must be greater due to the influence of the neighbouring ecosystem and the own characteristics previously mentioned.

In the Catauro area, the density values are due to a faster recovery of the plant formation, given the height of the trees and the density of the stratum. The functional response of the forest was faster because it had less abiotic tension; however, the density of the Eas is lower because the forest was directed to this stratum.

In the town of Cabo Corrientes, a different pattern is observed. Most of the variables presented higher values of density and richness in the treatment five years of post-harvest forest recovery and only five variables (shrub heights, trees of the upper and lower strata, basal area of the upper and shrub strata) presented higher values in the treatment of more than 30 years of recovery. This treatment does not show significant results compared to Catauro, in spite of having the same time of recovery after forest harvesting; however, with the treatment of Uvero the height of the shrub stratum was significant.

Different causes influence the behaviour of the density, for each ecosystem, mainly the history of Delgado management, (2012), to which they have been subjected and the different stresses to which they are exposed. The density of individuals per unit of area and, consequently, a high diversity, suggests that some species present very localized populations with very low densities (a large number of rare species); which according to another author renders these species more susceptible to the effects of fragmentation and the elimination of entire populations.

The reserve of Cabo Corrientes was cut down more than 45 years ago, taking advantage of the three layers. Logging was done using the selective method and, in many cases, in a negative way for the forest; it was done with chainsaws and axes and the environmental stresses are stronger so recovery is slower. The lower tree stratum and the shrub stratum are recovered by shoots, so the heights are lower and regeneration is greater as a result of the clearings found in the forest.

This forest, according to Delgado and Pérez, (2013), is characterized by a more open upper tree layer, given mainly by the selective and intense forest exploitation, oriented to the species of high commercial value that compose it. The floristic composition found in this locality is given, essentially, by the functional response of the ecosystem to ecological stress, coinciding with the formation of microphilic semi-deciduous forest, described by Capote and Berazaín, (1984), for the eastern zone of the country; Delgado (2012) describes it for this locality.

Cabo Corrientes has a karst soil with a higher percentage of uncovered rocky cover Delgado, (2009) and it is remarkable how natural regeneration is limited to the cavities covered by the soil, showing greater regeneration than the sector of Cabo de San Antonio. Natural regeneration is a dynamic process by which new individuals are incorporated into the breeding population.

A study conducted by Delgado *et al*., (2016) on the dynamics of regeneration in the semi-deciduous forest of the Guanahacabibes Peninsula shows the highest values of abundance in treatments with intense forest exploitation, reaching up to 80 % of the total specific wealth. The dominance of EAI was observed as shown in Table 1, similar to that detected by Delgado and Pérez, (2013), who found the highest abundance of trees in that stratum.

It is decisive in the structure of the forest formation, because the species of greater competitive capacity are present in it, classified as stabilizers of the Herrera community and others, (1988).

In Uvero Quemado, the structure and composition of this forest have been affected by harvesting methods applied for many years, mainly due to selective logging directed at the best individuals of the most important forest species.

The forests were subject to intensive use; consequently, their structure and

diversity were modified. They are currently in a successional stage of Delgado intermediate homeostasis, (2012). Many of the species have very low density in the peninsula, are opportunistic species according to the classification of Delgado *et al.,* (2015), restorative, and appear when the ecosystems have been altered.

With respect to its structure by treatments, the average specific richness was higher in the Cabo de San Antonio sector and lower towards Cabo Corrientes, which is interpreted, for the purposes of this evaluation, as a consequence of the impacts of the most intense forest extractions that have occurred in the forests of the easternmost portion of Guanahacabibes.

Forest treatments affect biodiversity by modifying the physiognomy and floristic composition of the vegetation, advancing or regressing the phases of plant succession Plana Bach, (2001).

In the first years of forest recovery, there is an increase in the growth of individuals in the EA (See Figure 2 and 3); most of the species that occupy this stratum regenerate by shoots, with more than five individuals emerging from each stump. In their recovery phase due to competition, they are eliminated, the density decreases and many go on to swell the EAI; this depends on the environmental conditions that influence the growth of individuals.

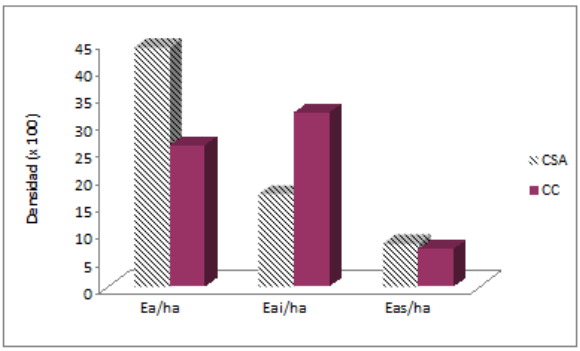

Fig. 2. Densidades de arbustos y árboles para el tratamiento de cinco años de recuperación posaprovechamiento forestal en las localidades Cabo de San Antonio (CSA) y Cabo Corrientes (CC). Ea- Estrato arbustivo, Eai- Estrato arbóreo inferior, Eas- Estrato arbóreo superior.

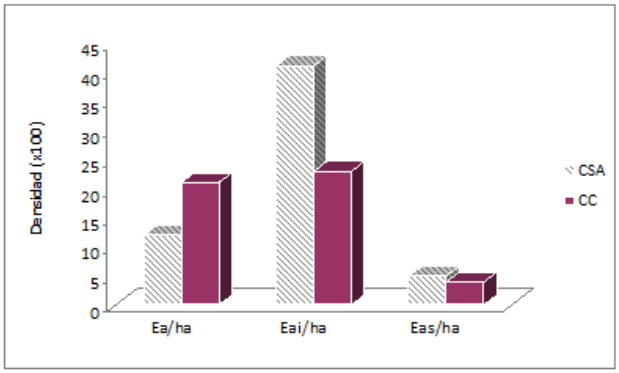

Fig. 3. Densidades de arbustos y árboles para el tratamiento de 30 años de recuperación posaprovechamiento forestal en las localidades Cabo de San Antonio (CSA) y Cabo Corrientes (CC). Ea- Estrato arbustivo, Eai- Estrato arbóreo inferior, Eas- Estrato arbóreo superior.

In the treatment of more than 30 years of post-harvest recovery, the growth of the Eai is greater, the individuals that characterize it have not reached their optimum development, do not then reach the Eas and the maximum reach will be achieved depending on the management history (type and intensity) and not on the recovery time.

In the treatment of Cabo Corrientes the highest percentage of the Importance Value Index (IVI) is in species of microphilic and sclerophytic leaves: *Heterosavia bahamensis (Britton)* Petra Hoffm, shrub species that develop in high abiotic stresses, *S. foetidissimum*, and *Savia sessiliflora (Sw.)* Willd. Species that do not appear in other ecosystems of the peninsula, such as *Erythroxylum rotundifolium Lunan*, H. *trifoliata* and P. *cuneata.*

In Uvero Quemado, one of the greatest wealth of species was obtained, 60, by its IVI, those that dominate are: *Drypetes alba* Poit., C. *gerascanthus,* S. *sessiliflora* and *Gymnanthes lucida* Sw. In this treatment the species with high forest value appear with a low value of importance index.

In the Catauro, species of economic importance abound: *C. gerascanthus*, *Metopium browneii* (Jacq.) *Calophyllum antillanum* Britton, *Terminalia chicharronia* Wright subsp. *Neglecta* (Bisse) Alwan and Stace, *Terminalia eriostachya* A. Rich. in R. de la Sagra, *Terminalia intermedia* (A. Rich.) Urb. and A. *balsamifera.*

In La Jocuma, unlike other ecosystems, the species that are most abundant are evergreens such as: S. *sessiliflora,* C. *chytraculia,* M. *browneii* and C. *diversifolia.*

The species with the highest IVI of the Jocuma treatment are characteristic of ecosystems where abiotic stresses have decreased mainly due to the greater accumulation of substrate and the thinned average height above sea level (AMSNM), (2012).

The traditionally most demanded timber species are very scarce here, with very low density percentages, which gives an idea of the intensities of their extraction over many years. For example, there are S. *foetidissimum (*1.9 %), C. *odorata* (0.4 %), S. *mahagoni* (0.2 %) and species of the genus *Terminalia* (0.2 %). Other authors identify that the volume of boluses and round-ups reached a total of 71 328.4 m3 between 1987 and 1996. The analysis of the affinities between the plots measured within each sector, based on densities and species richness, shows a differentiation of the western area at the beginning of the succession after the impact of logging, with respect to the rest of the stages, which, although they include bilateral groupings, have a common trunk in the relationship tree (Figure 4).

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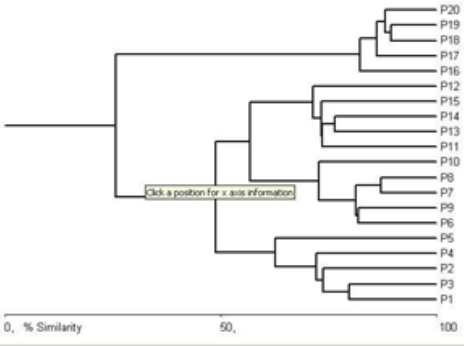

Fig. 4. Dendrograma que representa el agrupamiento de las parcelas por la similitud en riqueza de especies arbóreas y densidad. P1-5 Cabo Corrientes, P6-10 Uvero, P11-15 Catauro y P16-20 Jocuma.

The groupings obtained correspond to the cuts given according to the structure of the affinity branch. In these, the plots that mark the difference between the two sectors studied are organized, with particular distinction of the western sector in them.

Different cuts are shown to obtain a set of relationships for the whole ecosystem, which is expressed in the following groupings:

- Group 1 Plot 1 to 15 (50 % similarity).
- Group 1.1 Plots 6- 15 (55 % similarity).
- Group 2. Plots 16 to 20 (90 % similarity).

Depending on the behaviour of all these variables, a differentiation of the forest structure can be seen in its dynamics after the harvesting has taken place, where, due to the affinities between the set of plots by sectors, a more marked spatial pattern is reflected in the manifestation of the forest structure.

The complement provided by this affinity analysis ratifies that the density of individuals is the most important indicator in the evaluation of the dynamics of the recovery of the plant community impacted by forest exploitation.

Valdés and Peneque, (2008) consider that abiotic characteristics are related in greater or lesser intensity with the functioning of the forest ecosystem, conditioned by a greater or lesser tension in it. In this way, abiotic components may or may not modify the ecological functioning of the forest, causing these functional responses to be different.

Distribution of trees and shrubs by diameter classes

In the general distribution of the abundance of trees and shrubs by diameter class, it is observed that the highest values are found in classes I and II in all treatments, except in the Catauro, representing a dominance of individuals with diameters below 5.2 cm, and a tendency to decrease the number of trees as the value of the diameter class increases. Here it has been found that the greatest variability in the distribution of abundance is in Class I (2 to 5.1 cm), where 69.8 % of the total number of individuals counted is concentrated (Figure 5).

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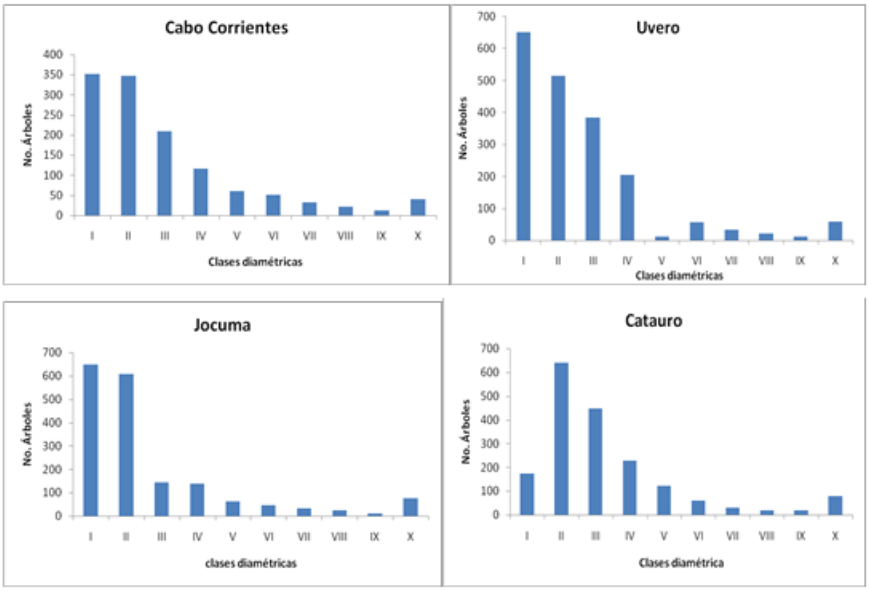

Fig. 5. Distribución del número de árboles por clases diamétricas.

The increase in individuals in the lower diameter classes (< 14.2 cm) is related to the increase that is taking place in the post-impact dynamics; the total abundance of trees and shrubs is associated with trees with moderately rough to rough bark, representing a pattern of forest architecture, which seems to be predominant in the entire ecosystem of semi-deciduous nothofagus forest.

In Cabo Corrientes, there is a close relationship between the values of the height classes and the diameter classes; however, from class 3 (> 6.7 cm), the distribution of the trees begins to decrease.
In the five-year post-harvest recovery treatments, the distribution is not uniform, the number of diameter classes is lower than that recorded in the other treatments.

Ecosystems with a high rate of forest exploitation increase the values of individuals in the shrub stratum, as reflected in Uvero and Jocuma, where the main exploitation was of round wood, mainly of bushes, for the drying of tobacco.

On the structure of the forest community with respect to the established diameter Ccases, it is confirmed that in the semideciduous forests of Guanahacabibes its impoverishment in the availability of wood resources and in its structure in general increases. Delgado and Perez, (2013), found in one hectare of sampling, that 89.5 % of the trees belonged to classes I and II (< 5 cm), our result agrees with the authors mentioned above for 2.8 ha.

In Cabo Corrientes, since the three strata were exploited before the 1960s and as a result of the high tensions and very slow recovery, the forest does not develop. Despite the fact that the Catauro has the same recovery time, harvesting was not as intense and it had a better recovery, it shows a different pattern from the rest of the localities, with a lower number of individuals in class I.

In the towns of Catauro and Cabo Corrientes, there was evidence of the effect of selective logging on the Eas, as a stratum with openings or clearings was found that had not yet been covered by the forest canopy, despite the years of logging; consequently, they have not reached their peak and

are in a phase of medium homeostasis of the succession.

Where the disturbance was more intense, trees with diameters greater than 10 cm were less abundant. It can be assumed that the disproportion between the abundances detected in the lower (I and II) and upper classes is due more to forest removals that have taken place over a long period of time than to those that have occurred recently. It can be interpreted that there are dynamic changes as time goes by in the ecological succession.
The behavior of the treatment of the Catauro, as shown in Figure 5, is given by the slow recovery of plant formation and high abiotic stresses, to which it is subjected as high rockiness and NMSA. This pattern is typical of conserved ecosystems with a late succession classified by Herrera et al., (1997), and an average to final homeostasis that coincides with that reported by Delgado and Pérez (2013), in Carabelita.

Wealth in the semi-deciduous forest with less post-harvest recovery time was lower, and the more strata were involved in harvesting the longer it took for the forest to recover. Logging modifies the diversity of the forest depending on the intensity of management and the strata that were harvested.

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