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Article

## Aprovechamiento forestal y diversidad arbórea en seis ejidos de Quintana Roo

### Timber forestry and tree diversity at six *ejidos* in Quintana Roo

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#### Resumen

El aprovechamiento forestal en el sureste de México se realiza desde la civilización Maya mediante usos tradicionales, concesiones forestales hasta la propiedad comunal. Actualmente, la mitad de los ejidos de Quintana Roo están enfocados en el aprovechamiento forestal maderable, principalmente en selvas medianas subperennifolias, el tipo de vegetación con mayor cobertura. El objetivo de este trabajo consistió en determinar la diversidad arbórea en 14 selvas del sur de la Península de Yucatán, con edades, prácticas de manejo y conservación distintas: seis en ejidos forestales del estado de Quintana Roo y ocho en otros sitios. Se analizaron 10 parcelas de 500 m<sup>2</sup> por sitio, en las que las especies arbóreas fueron identificadas taxonómicamente y se midió el diámetro a la altura del pecho en ejemplares desde los 7.5 cm hasta 1.30 m sobre el suelo. Se determinó una riqueza de 156 especies de árboles con abundancia, dominancia e importancia relativas contrastante entre sitios. Se realizó, para los 14 sitios, un análisis de similitud de *Bray Curtis*, que se conformó por tres grupos: el primero por un sitio en la Reserva de la Biósfera de Calakmul sin uso, el segundo por seis sin uso, desde 7 hasta 50 años y el tercero por seis ejidos forestales. La riqueza, abundancia y similitud entre ellos probablemente se asocian a la ubicación geográfica y a la edad de recuperación tanto de disturbios antrópicos como naturales. Se sugiere incorporar dichas características ecológicas como indicadores en los planes de aprovechamiento forestal, acotados ambiental y socioeconómicamente.

**Palabras clave:** Abundancia, composición, disturbio, dominancia, silvicultura, similitud.

#### Abstract

Timber forestry in southern Mexico is a common practice since Mayan civilization, through traditional uses, forest concessions and up to communal land tenure. Currently, half of *Quintana Roo*'s *ejidos* are focused on timber forestry use, mainly on middle evergreen subtropical forests, the greatest kind of vegetation cover. This aim of this study was to determine forestry diversity in 14 forests in the south of *Yucatán* Peninsula with different age, management and conservation practices: six forestry sites in *Quintana Roo* and eight in other places. 10 plots of 500 m<sup>2</sup> per site were analyzed, in which the tree species were taxonomically identified and the diameter at height was measured in specimens from 7.5 cm to 1.30 m above the ground. A richness of 156 tree species with relative abundance, dominance and importance was determined, contrasting between sites. A similarity analysis was carried out for the 14 sites by the Bray Curtis method, which was made up of three groups: the first by site of the *Calakmul* Biosphere Reserve without use, the second by six sites without use, from 7 to 50 years old and the third by six forest *ejidos*. The richness, abundance and similarity between them are probably associated with the geographical location and the age of recovery from anthropogenic and natural disturbances. It is suggested to incorporate these ecological characteristics as indicators in the forest use plans, limited environmentally and socioeconomically.

**Key words:** Abundance, composition, disturbance, dominance, forestry, similarity.

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## Introduction

Timber forestry in the *Yucatán* Peninsula has been made since the Mayan civilization, with a decrease in the years 800 to 1 000 A.D. or Classic Period (Turner and Sabloff, 2012; Sánchez-Sánchez *et al.*, 2015). During the colonial times, extraction focused on species such as dye stick (*Haematoxylon campechianum* L.), chewing gum (*Manilkara zapota* (L.) P.Royen), cedar (*Cedrela odorata* L.) and mahogany (*Swietenia macrophylla* King), under different schemes. These are summarized in three phases: traditional uses, concessions and community businesses (Noble and Dirzo, 1997; Galleti, 1999; Simonian, 1999; Negreros *et al.*, 2014).

The last phase of forest concessions in *Quintana Roo* was carried out by *Maderas Industrializadas de Quintana Roo* (Miqro) parastatal company from 1954 to 1983, which focused on the use of cedar and mahogany, mainly (Negreros *et al.*, 2014; Torres-Rojo *et al.*, 2016). Miqro's experience laid the foundations for establishing infrastructure and technical personnel, as well as a forestry culture. In the 1980s, the Forest Pilot Plan (PPF, for its acronym in Spanish) was implemented, through the German Cooperation Agency and the Mexican government (Armijo *et al.*, 2010; Negreros *et al.*, 2014); this resulted in community forest inventories, community forest companies and the establishment of permanent forest areas, which subsequently consolidated regional community organizations, such as the Society of *Ejido* Producers of *Quintana Roo* and the Organization of *Ejido* Forest Producers of the *Maya* Zone (Galleti, 1999; Armijo *et al.*, 2010).

Collective tenure through agrarian communities or *ejidos* has been recognized since the Mexican Revolution before the Agrarian Law (Bray *et al.*, 2007). Communal property in Mexico is close to 80 % of forests and jungles (Galleti, 1999; Bray *et al.*, 2007) and is particularly relevant in central and southern *Quintana Roo*; the first neotropic community timber forestry harvesting center was organized there (Torres-Rojo *et al.*, 2016) and where the greatest activity of community projects is carried out (Bray *et al.*, 2007). Mainly medium-sized evergreen forests are managed, which

are the main type of vegetation in the entity (Islebe *et al.*, 2015); they register from 100 (Synnott, 2009) to 200 species in total (Negreros *et al.*, 2014).

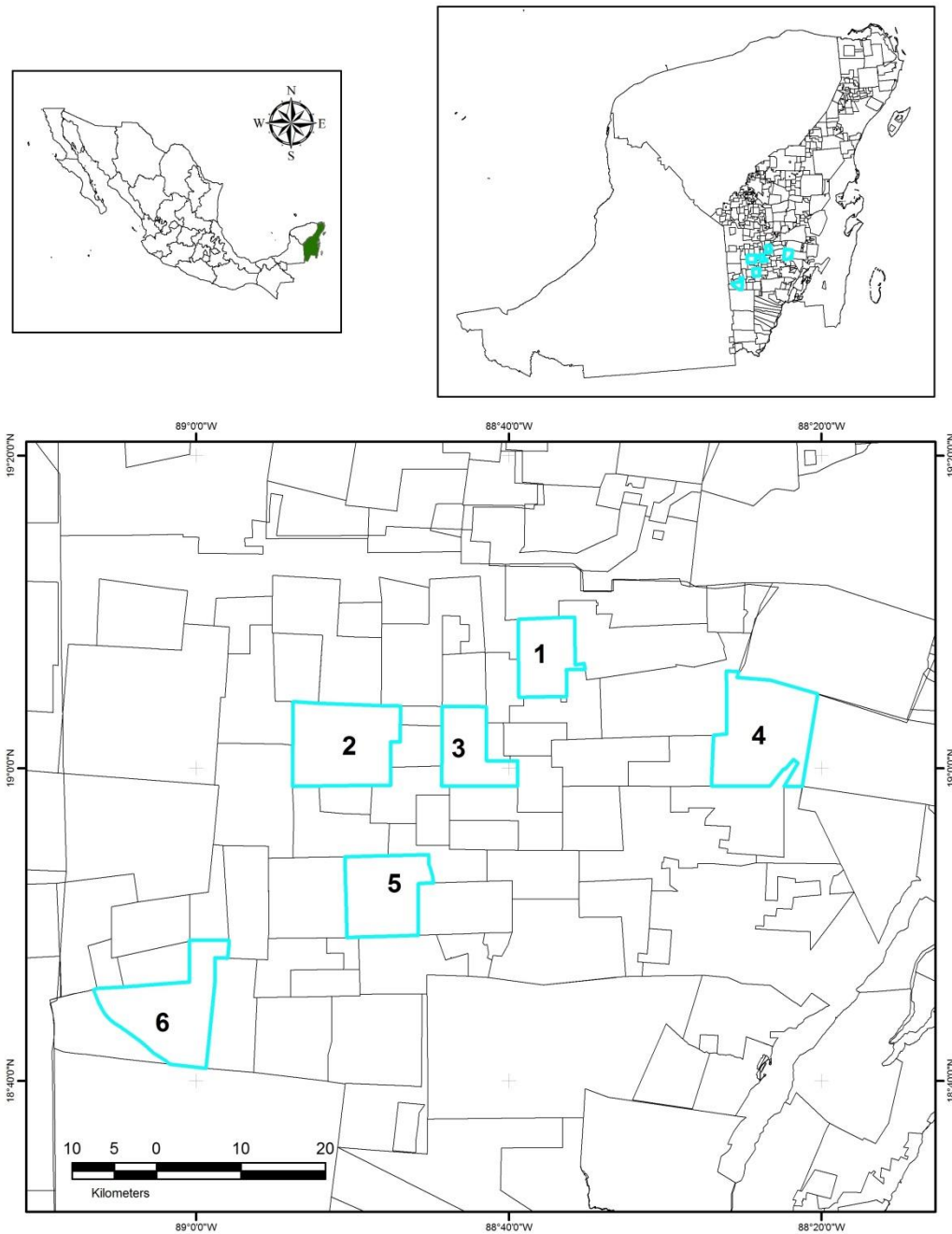
At present, timber forestry in *Quintana Roo* is practiced in 106 of its 283 *ejidos*, which together amount to 1.58 million hectares, equivalent to 54.05 % of the state's total *ejidos* and 35.41 % of the state's land area (Inegi, 2017; Registro Nacional Agrario, 2018). The selection method is used, with 25-year shifts (Snook, 1998), based on the Mexican Forest Management Method (Torres-Rojo *et al.*, 2016). Extraction focuses on 25 species (Negreros *et al.*, 2014), known as tropical commons and precious woods, which are exploited in areas designated by the *ejidatarios*, based on the General Law of Sustainable Forest Development and the authorization of the Ministry of Environment and Natural Resources (Semarnat) and the National Forest Commission (Conafor) (Semarnat-Conafor, 2014). The objective of this work was to determine the arboreal diversity of six *ejidos* under forest exploitation in *Quintana Roo* with eight other forests in the south of the *Yucatán* Peninsula under different conservation states.

## Materials and Methods

### Location

The six forest *ejidos* are located in the *Othón P. Blanco* and *Bacalar* municipalities, in the state of *Quintana Roo* (Figure 1). The information in this study comes from the databases associated with the timber and non-timber forest management programs, called Unified Timber Forestry Procedures, which were presented, submitted and validated in 2016, by six *ejidos* to the State Forestry Council of *Quintana Roo*, for authorization by the Ministry of the Environment and Natural Resources.





**Figure 1.** Location of the six forest *ejidos*: 1) *Guadalupe Victoria, Bacalar*; 2) *Otilio Montaño, Bacalar*; 3) *Francisco J. Mújica, Bacalar*; 4) *Manuel Ávila Camacho, Bacalar*; 5) *Río Escondido, Bacalar*; 6) *Othón P. Blanco, Veracruz*.

## **Plot selection**

Ten 500 m<sup>2</sup> circular plots were chosen per *ejido*, in which vegetation samplings were taken with mensuration data of the tree specimens from 7.5 cm in diameter at a height of 1.30 m, for the use of timber and non-timber forest resources, with a 283D/5m Forestry Suppliers measuring tape. The information was confirmed by the State Forestry Council of the State of *Quintana Roo*, through the Forest Management Technical Committee, in order to issue the technical opinion on the authorization process for timber forest exploitation carried out by Semarnat and Conafor.

Additionally, the extensive documents of the Unified Timber Forestry Procedures were reviewed, and their subsequent verification with the Register and History of Agrarian Nuclei and the *Diario Oficial de la Federación* (<https://phina.ran.gob.mx>). In addition, a debugging and updating of the taxonomic identities of the tree species, was carried out through The Plant List ([www.theplantlist.org](http://www.theplantlist.org)), The Global Biodiversity Information Facility ([www.gbif.org](http://www.gbif.org)) and the Herbarium of the Center of Scientific Research of *Yucatán*, A. C. ([https://www.cicy.mx/sitios/flora%20digital/indice\\_busqueda.php](https://www.cicy.mx/sitios/flora%20digital/indice_busqueda.php)) databases.

## **Floristic composition, diversity and relative importance value (VIR)**

Species richness was estimated with the taxonomic identity data, while the basimetric area per species was determined with the diameter; the Relative Importance Values (VIR, for its acronym in Spanish) were obtained by the sum of the relative abundance, frequency and basimetric area (AB), for each of the 14 sites analyzed, based on standardized formulas (Magurran, 2004) in spreadsheets.



## **Statistical analysis**

The age of the forests of the six *ejidos* was considered to be eight, taken from the time elapsed from Dean hurricane in 2007, the closest disturbance, since there are no previous reports of anthropic extraction or disturbances. The data of the analyzed plots of the six forest *ejidos* were compared to other forests in the south of the Yucatán Peninsula: *Laguna Om* and *Xhazil* with 20 and over 50 years, respectively, without use, (Macario, 2003); *Calakmul*, from 7 to 10 years and more than 20 years without use (Aguirre *et al.*, 2018) and from the *Calakmul* Biosphere Reserve: km 20 and *Ramonal*, 10 years without use. The normality test (Shapiro-Wilks) was performed at the abundance values for the 14 sites. A nonparametric test was performed using the Kruskal-Wallis test by intervals, as the normality assumptions were not met. Combinations were compared for the 14 sites using Tukey's paired tests. In addition, a Bray-Curtis similarity analysis was made and the results were presented in a dendrogram for the 14 sites, using the PAST program 3.1 version (Hammer, 2001). Statistical tests were performed with the SigmaStat 4.0 program (Systat Software, 2016).

## **Results and Discussion**

### **Floristic composition, richness and diversity of species**

For the 60 plots in the six forest *ejidos* analyzed, the total record amounted for 2 119 individuals, which belong to 93 species, 72 genera and 29 families (Table 1). The families with greatest richness were Fabaceae, Sapotaceae and Euphorbiaceae with 23, 9 and 6 % of species, respectively, and the most abundant were *Gymnanthes lucida* Sw., *Manilkara zapota* (L.) P.Royen and *Bursera simaruba* (L.) Sarg., which make up to 7.7, 6.8 y 4.9 % of the total number of individuals.

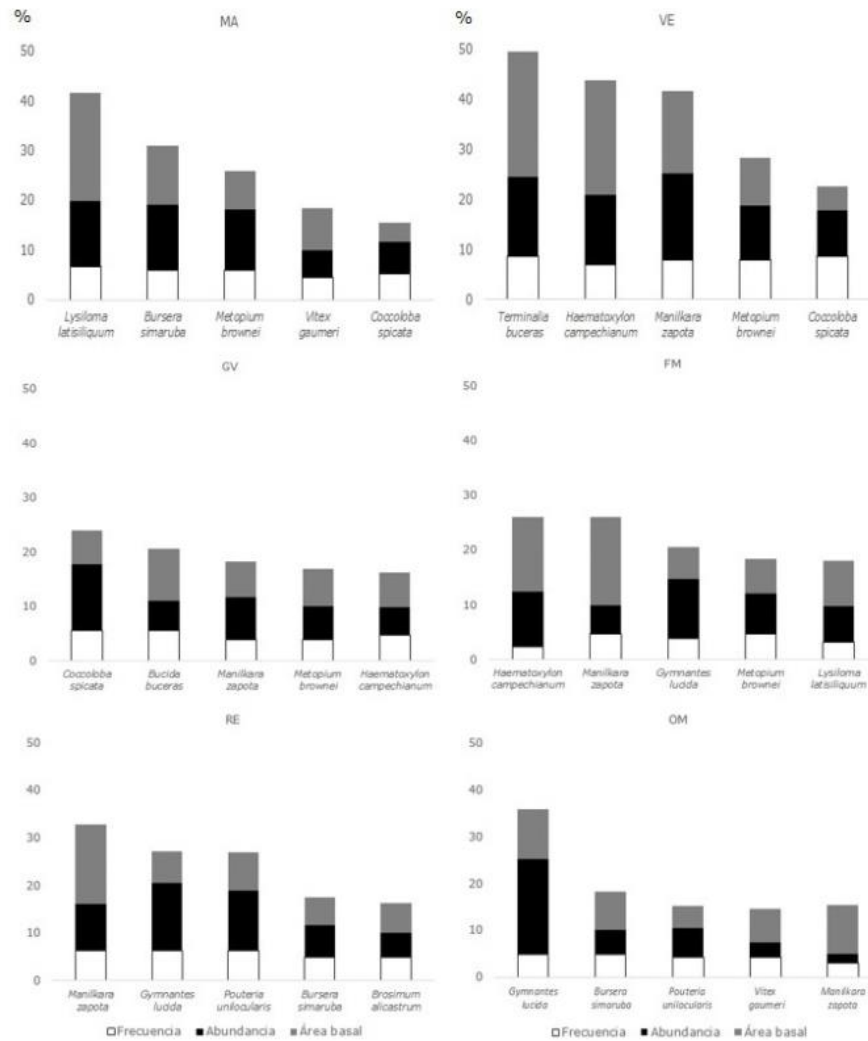
**Table 1.** *Ejido* data, structure parameters and composition of the tree species of each one of the *ejidos*.

<b>Ejido</b>	<b>MA</b>	<b>FM</b>	<b>OM</b>	<b>RE</b>	<b>VE</b>	<b>GV</b>
Total surface area (ha)	10750	5682	11002	8144	11070	5588
Number of years of the endowment of the <i>ejido</i>	49	39	43	46	35	44
Families	22	23	23	20	15	20
Genera	43	50	52	37	21	42
Species	46	60	63	40	27	51
Individuals	348	360	393	314	409	295
AB (m <sup>2</sup> )	19.86	18.06	19.27	18.64	17.11	15.16

MA = Manuel Ávila Camacho; FM = Francisco Mújica; OM = Otilio Montaña; RE = Río Escondido; VE = Veracruz; GV = Guadalupe Victoria; AB = Basimetric area.

From 93 species found in the total number of the analyzed plots of the six *ejidos*, only six out of 11 are called tropical common (in bold), that is, that they are potential harvesters; they were included between those which had a better representation based upon the Relative Importance Value (VIR): ***Lysiloma latisiliquum*** (L.) Benth, *Haematoxylon campechianum* L., *Gymnanthes lucida*, ***Manilkara zapota***, *Terminalia buceras* (L.) C. Wright, *Coccoloba spicata* Lundell, ***Bursera simaruba***, ***Metopium brownei*** (Jacq.) Urb., *Pouteria reticulata* (Engl.) Eyma, ***Vitex gaumeri*** Greenm. and ***Brosimum alicastrum*** Sw. (Figure 2). From half of the total number of individuals, four species were added to the 11 formerly mentioned in order to highlight the importance of a small number of those that are dominant in the six forest *ejidos*: *Piscidia piscipula* (L.) Sarg., *Caesalpinia gaumeri* Greenm., *Caesalpinia pulcherrima*

(L.) Sw and *Thouinia paucidentata* Radlk. From these 15 species, seven are dominant in *Francisco Mújica, Otilio Montaña, Guadalupe Victoria*; five in *Manuel Ávila Camacho, Río Escondido*; three in *Veracruz*.



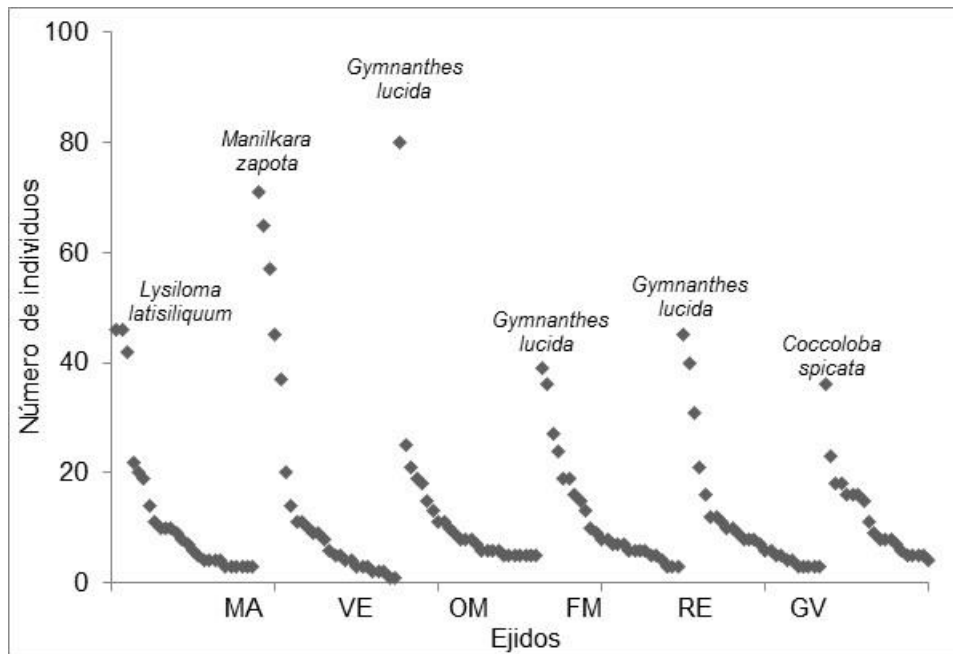
MA = *Manuel Ávila Camacho*; FM = *Francisco Mújica*; OM = *Otilio Montaña*; RE = *Río Escondido*; VE = *Veracruz*; GV = *Guadalupe Victoria*.

Frecuencia = Frequency; *Abundancia* = Abundance; *Área basal* = Basimetric area.

**Figure 2.** Relative Importance Value (VIR) for the five tree species with greater representation in the six forest *ejidos*.



The species with highest accumulated VIR for the six *ejidos* were *Manilkara zapota*, *Metopium brownei* and *Bursera simaruba*. However, when designing the abundance interval curves for each *ejido* (Ramírez-Marcial *et al.*, 2017), and with a small number of individuals, the species with greatest relative importance was *Gymnanthes lucida*, which contributed with 11, 20 and 14 % of the individuals ratio in three sites (Figure 3), with similar percentages to *Lysiloma latisiliquum*, (13 %), *Coccoloba spicata* (12 %) and *Manilkara zapota* (17 %). In contrast, from the precious species such as *Cedrela odorata*, only one individual was recorded, while *Swetenia macrophylla* had 18 in total. When analyzing and comparing the number of samples, the only one that statistically differed was Veracruz ( $p < 0.05$ ) in *Otilio Montaña*, while, based upon VIRs the statistical difference was also significant between Veracruz with *Otilio Montaña* ( $p < 0.05$ ) and *Guadalupe Victoria*, in the same magnitude ( $p < 0.05$ ).



MA = Manuel Ávila Camacho, FM = Francisco Mújica, OM = Otilio Montaña, RE = Río Escondido, VE = Veracruz, GV = Guadalupe Victoria.

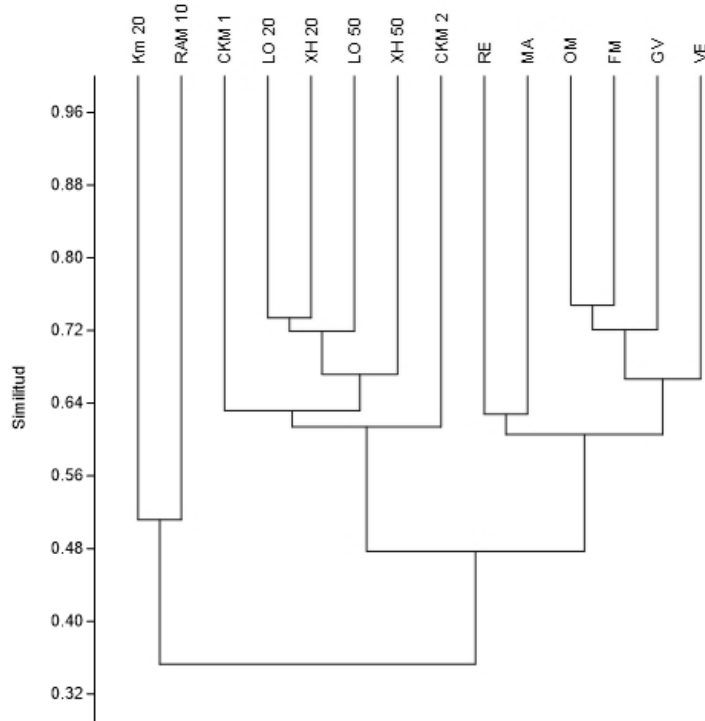
Número de individuos = Number of individuals.

**Figure 3.** Abundance interval curves of the six *ejidos*, which indicate the species with the greatest abundance for each *ejido*.

The number of species in the present study and of eight analyzed sites, was 156, from 21 (*Ramonal*) to 70 (*Xhazil* 20 years). These results are within the parameters of wealth and dominance with other forest *ejido* locations in *Quintana Roo*, where 168 species have been registered, in an interval of 93 to 117 per site, with a dominance of *Pouteria reticulata*, *Manilkara zapota* and *Bursera simarouba* (Negreros *et al.*, 2014). The sites with the greatest statistical differences were *Laguna Om* and *Xhazil*, 20 years old, compared to six and seven, respectively ( $p < 0.05$ ). On the other hand, the percentage of similarity between the 14 sites ranged from 13 % (*Veracruz* and *Ramonal*) to 75 % (*Otilio Montaña* and *Francisco Mújica*), with a general average between sites of 41 %. The sites with the least similarity were *Ramonal* (26 %) and *Km 20*, and those with the greatest similarity were *Otilio Montaña* and *Francisco Mújica* (48 %) compared to the other sites.

The similarity tree (Figure 4) shows the formation of two groups at the 0.35 value (that is, 35 % similar) which are associated with their geographic location west of the *Yucatán* Peninsula (*km 20* and *Ramonal*) with respect to the others. Two groups are formed in the middle of the similarity tree, consistent with the harvesting and incidence of hurricanes: the first, made up of sites near the *Calakmul* Biosphere Reserve and the other by the six forest *ejidos* of the state of *Quintana Roo*.





Km 20 = Km 20; RAM = *Ramonal*; CKM1 = *Calakmul 7-10 years*; LO 20 = *Laguna Om 20 years*; Xh 20 = *Xhazil 20 years*; LO 50 = *Laguna Om 50 years*; Xh 50 = *Xhazil 50 years*; CKM2 = *Calakmul 20 years*; MA = *Manuel Ávila Camacho*; FM = *Francisco Mújica*; OM = *Otilio Montaña*; RE = *Río Escondido*; VE = *Veracruz*; GV = *Guadalupe Victoria*; *Similitud* = *Similarity*

**Figure 4.** Bray-Curtis similitude dendrogram for the 14 evergreen tropical forests analyzed.

The values of abundance and relative importance among the six *ejidos*, from the time elapsed since major hurricanes such as Dean (2007) occurred, suggests that, in addition to having been affected by these natural disturbances, they have been subject to anthropogenic influences; they dominate as pioneer species, typical of early successional stages (*Lysiloma latisiliquum*), in-between such as *Coccoloba spicata* and *Gymnanthes lucida* (Mize and Negreros, 2007), to late species (*Manilkara zapota*), probably associated with the opening of natural gaps or due to

selective extraction (Dickinson *et al.*, 2000) and that they coexist with persistent dominant species (*Bursera simarouba*) and persistent non-dominant species (*Coccoloba spicata*), which can survive disturbances of different kinds (Román-Dañobeytia *et al.*, 2014).

Most of the taxa used in timber forestry are differentially light-tolerant (Vester and Calmé 2003), so the gap dynamics derived from large-scale events (hurricanes and fires), and not selective extraction, have an effect on other species in sites under logging in *Quintana Roo* (Whigham *et al.*, 1999). The differential abundance of the species, as an indicator of anthropic disturbance by forest extraction, has favored plant communities dominated by species such as *Metopium brownei* (Jacq.) Urb or *Brosimum alicastrum* Sw., due to the greater availability of light and an uneven establishment of the species, as verified in *Xhazil*, *Quintana Roo* (Macario *et al.*, 1995). This has been demonstrated by the proportion of the damage, its association with the density of wood (Vandecar *et al.*, 2011) and the history of use of the sites on different tree species, in several *ejidos* in the center of *Quintana Roo*, affected by Hurricane Dean in 2007 (McGroddy *et al.*, 2013).

According to the results of the present study, in the *Manuel Ávila Camacho ejido*, 90 km from the *Quintana Roo* coast, *Lysiloma latisiliquum* was the most abundant species with the lowest wood density. In contrast, *Gymnanthes lucida*, with a higher wood density, was dominant in three of the six *ejidos*, but is located 130 km inland from the entry site of Hurricane Dean, which affected the six *ejidos* in which it worked. Therefore, it is likely that the distance between sites associated with the distribution gradient of plant associations in the *Yucatán* Peninsula (Islebe *et al.*, 2015), the history of exploitation of *ejidos* (McGroddy *et al.*, 2013), the onslaught of anthropic or natural disturbances (de Jong, 2013; Sánchez-Sánchez *et al.*, 2015), as well as the intrinsic characteristics of tree species, operate simultaneously (Pat-Aké *et al.*, 2018) on the composition and structure of these jungles. These abundance and dominance of species, not considered profitable for commercial use, are used for firewood, medical applications and construction material, as indicated by Negreros and Mize (1993), Negreros and Hall (2000) in other forests at the center of the state of *Quintana Roo*.

## Conclusions

Based on the abundances among the 14 sites analyzed, it is proposed that this parameter be used as an indicator of the differential performance of forest species in similar plant associations, but with different use histories and as well as under uneven natural or anthropogenic disturbances. It is suggested to incorporate both wealth, as well as abundance and value of relative importance as indicative variables in timber harvesting plans, in different environmental and socioeconomic contexts.

The similarity and grouping between the analyzed forests allows to suggest that the geographical position and recovery after anthropic and natural disturbances make up the current composition of these plant associations.

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## Conflict of interests

The authors declare no conflict of interest.

## Contribution by author

Efraín Aguirre Cortés, Griselda Escalona Segura, Pedro Antonio Macario Mendoza, Jorge Leonel León Cortés, Birgit Schmook: data analysis, manuscript preparation and design of figures and tables; Luis Candelario Sánchez Pérez: analysis and processing of databases and generation of *ejido* polygons.

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