



## Forests and Landscapes of Dominican Republic

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### Authors' contributions

This work was carried out in collaboration between all authors. Author AC-O designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript and managed literature searches. Authors CMM, JCPF, CJPG and EC managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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### ABSTRACT

**Aims:** This, in conjunction with the diversity of the substrates and the fact that the island is home to the highest mountains in the Caribbean and with a high rate of endemic species, allows them to be differentiated into three major groups –dry forest, cloud forest and the transition between dry and cloud forests. The forests in the Dominican Republic grow in a tropical climate with ombrotypes ranging from arid to humid-hyperhumid due to the moisture-laden Atlantic winds; and infra-, thermo-, meso- and supratropical thermotypes. Establish the diversity, ecology and forest types in Dominican Republic.

**Methods:** We identified all species through field surveys and comparative analyzes of how forest types, structure, diversity and ecology.

**Results:** We considered these forests to be endemic to the island of Hispaniola, as the dry forest

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presents 81 endemic species, of which 10 are trees, 65 shrubs, 5 creepers, and 1 herbaceous species; while the cloud forest has 19 trees, 20 shrubs, 8 creepers, 4 epiphytes and 6 herbaceous species.

**Conclusions:** We highlight the absence of endemic epiphytes in the dry forests, which are in a poor state of conservation and subject to greater human pressure than the cloud forest.

*Keywords:* Forests; diversity; endemics; structure; deterioration; conservation.

## 1. INTRODUCTION

Some works on vegetation published in the local journal of the Santo Domingo Botanical Garden (Moscoso) have been of assistance in this research. The influence of the rains on the forest distribution in the Dominican Republic is similar to that of south and southwest China [1]; these forests have a similar diversity and structure to those in the north of the island of Okinawa (Japan) [2] and their distribution is conditioned by climate models and human intervention. Deforestation at the hands of the local population, essentially in arid and semiarid zones, has led to the deterioration of these forests in the Dominican Republic and Haiti, similar to the situation in Ethiopia [3]. As a result the emergence of secondary plant communities with a similar structure to those found in subtropical areas of China [4]; however when deforestation occurs in the cloud forest, it gives rise to a "calimetal or fern community" of *Gleichenia bifida* (Willd.) Spreng. and *Dicranopteris flexuosa* (Schrad.) Underw., whose vigorous growth and dense coverage hinder the regeneration of the forest. The deforestation of broadleaf and mixed forest is carried out by livestock and agricultural farmers and the repercussion of fire varies depends on the environmental conditions and the type of forest [5-9]. In cases where the broadleaf (cloud) forest is burned, its dense coverage prevents the regeneration of the primary forest. We do not therefore agree with [10] that the spatial structure of the forest should be changed by frequent burning. However, if we agree with [11] as the disturbances produced by fire in the cloud forest, causing changes in the composition and structure of the forest, which for fire resistant species is replaced, such as example the species of "calimetal".

The deterioration of the forests on the island of Hispaniola is exacerbated by the Caribbean hurricanes, which have a serious impact on their structure [12]. However, the mountains on the island are still home to a number of well-conserved areas thanks to a close linear

correlation between environmental factors and forest types. In the case of well-conserved autochthonous forests and areas with secondary forests due to clearing by farmers [13], secondary forests may be better adapted to climate change than primary forests, making management of these forests fundamental to mitigating this climate change [14,15]. Therefore, there is an urgent need to enact legislative policies as has occurred in neighbouring countries such as Brazil, Costa Rica, and Guatemala [16].

## 2. METHODS 21

A study was made of the areas of dry, cloud and the transition between both forests in the Dominican Republic (Hispaniola) (Fig. 1). Ecologically and physiognomically homogeneous plots were selected and the species they contained were noted using [17]. The bioclimatic and biogeographical study was based on previous works [18,19]. To obtain the hierarchical cluster, we used the dissimilarity with Euclidean distance and Ward's agglomeration. Statistical analysis is generated automatically by the software XLSTAT and PCA with Spearman correlation. To separate the two major vegetation units (cloud forest and dry forest), we rely on the floristic composition of species *Magnolia hamorii* Howard (Maha), *Sideroxylon salicifolium* (L.) Sw. (Sisa), *Metopium toxiferum* (L.) Krug. & Urb. (Meto) and *Sideroxylon foetidissimum* Jacq. (Sifo), all species characteristic of the transitional subhumid forest between dry and cloud forest; and a canonical correspondence analysis (CCA) between the I<sub>o</sub> (ombrothermic index), ETP (potential evapotranspiration), I<sub>t</sub>/I<sub>tc</sub> (Thermicity index) and I<sub>c</sub> (Continental index) of the 65 plots in the sample and the dominant species, located at altitudes below 1,200 m: *Bursera simaruba* (L.) Sarg. (Busi), *Metopium toxiferum* (Meto), *Pilosocereus polygonus* (Lam.) B. & R. (Pipo), *Sideroxylon foetidissimum* (Sifo), *Sideroxylon salicifolium* (Sisa), *Didymopanax tremulus* Krug. & Urb. (Ditr), *Hyeronima domingensis* Urb.(Hydo), *Magnolia hamorii*

(Maha), *Magnolia pallescens* Urb. & Ekm.(Mapa), *Prestoea montana* (Grah.) Nichol.(Prmo) and *Pinus caribaea* Morelet. This last species forms mixed stands with the cloud forest and gives the name to the vegetation class *Byrsonimo-Pinetea caribaea* Samek and Borhidi in Borhidi et al. 1979; this tropical plant acts as an exotic outside its distribution area (Central America), and is a well adapted species in other tropical areas such as southern China [20].

### 3. RESULTS AND DISCUSSION

The CCA (Fig. 2) shows two groups of inventories: -R1-R39, representing the dry forest and dominated by *Bursera simaruba*, *Metopium toxiferum* (L.) Krug. & Urb., *Pilosocereus polygonus* (Lam.) B. & R., *Sideroxylon foetidissimum* Jacq., *Sideroxylon salicifolium* (L.) Sw., *Prosopis juliflora* L., *Lemairocereus hystrix* Britt & Rose and *Acacia macracantha* H. & B. Ex Willd.; and the group C40-C65 dominated by *Didymopanax tremulus* Krug. & Urb., *Hyeronima domingensis* Urb., *Magnolia hamorii* Howard, *Magnolia pallescens* Urb. & Ekm., *Prestoea montana* (Grah.) Nichol., *Alchornea latifolia* Sw.,

*Cyathea arborea* (L.) J.E. Smith and *Cyathea furfuracea* Baker.

The PCA analysis of 28 dominant species produces two groups: A (cloud forest) and B (C subhumid forest, and D dry forest) (Fig. 3). The two groups A and C in the PCA are maintained in the cluster. The first group (A) represents the cloud forest dominated by *Magnolia hamorii* Howard, *Magnolia pallescens* Urb. & Ekm., *Prestoea montana* (Grab.) Nichol., *Didymopanax tremulus* Krug & Urb., *Alchornea latifolia* Sw., *Cyathea furfuracea* Baker, *Ormosia krugii* Urb., *Cyathea arborea* (L.) E. Smith. This forest is well represented in the central and northern mountain ranges, the Sierra de Bahoruco and the eastern range. It is characterised by a high floristic diversity and a high rate of endemics. Recently in [21] we reported that this type of forest has 23% tree species, 16.6% climbers and 21.7% epiphytes, with 45 endemic species characteristic of the cloud forest in the Los Haitises National Park. Current studies show that this type of forest has a high rate of exclusive endemic plants (northern cordillera: 44; eastern cordillera: 13; central cordillera: 278; and Bahoruco: 482 species).



Fig. 1. Environments of the study area

In the analysis of the diversity of the two forests types (dry and rain); in the dry forest there are 61 species of tree and 5 stipes, of which 10 are endemic, compared to 75 in the cloud forest and 4 stipes, of which 19 are endemic, being greater the number of epiphytic in cloud forest in the dry, with 36 species compared to 13 (Table 1). Shannom index gives values of 3,384 and 3,528 for the dry forest and cloudy respectively (Figs. 4,5,6).

The second group B constituted by the R inventories has little affinity group A consists of two subgroups C and D have a greater affinity between the two (Fig. 7).

Group C represents the subhumid transitional forest. The greater affinity with the forest is due to the presence of the species *Pilosocereus polygonus* (Lam) B. & R., *Lemairocereus hystrix*

*Britt.*, and *Leptocereus weingartianus* (Hartm.) Britt. & Rose, due to the fact that the substrates are coralline limestone with high infiltration. Recently [22,23] highlighted two types of subhumid forest in the eastern plains of the Dominican Republic with 30 endemic species and a coverage that ranges between 90-100%.

Group D represents the dry forest, dominated by species from the genera *Prosopis*, *Lemairocereus*, *Pilosocereus*, *Cylindropuntia*, *Agave* and *Bursera*. This type of forest is prevalent in the areas of Azua, Bani, San Juan, Enriquillo, Pedernales, Montecristi and the Cibao Valley. As a result of the presence of a specific local flora, there are a variety of subgroups, with a low discrimination at the cluster level at which are very valuable due to their high rate of exclusive endemics.

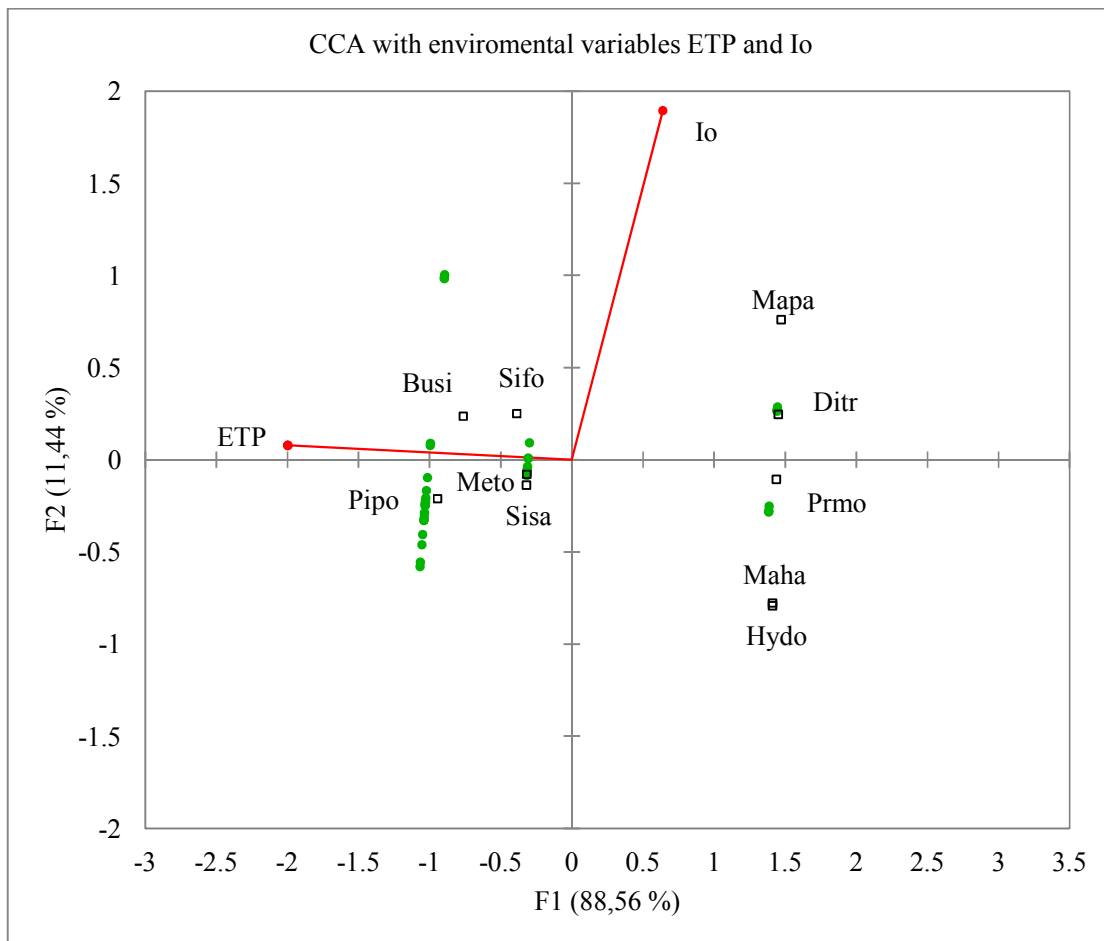
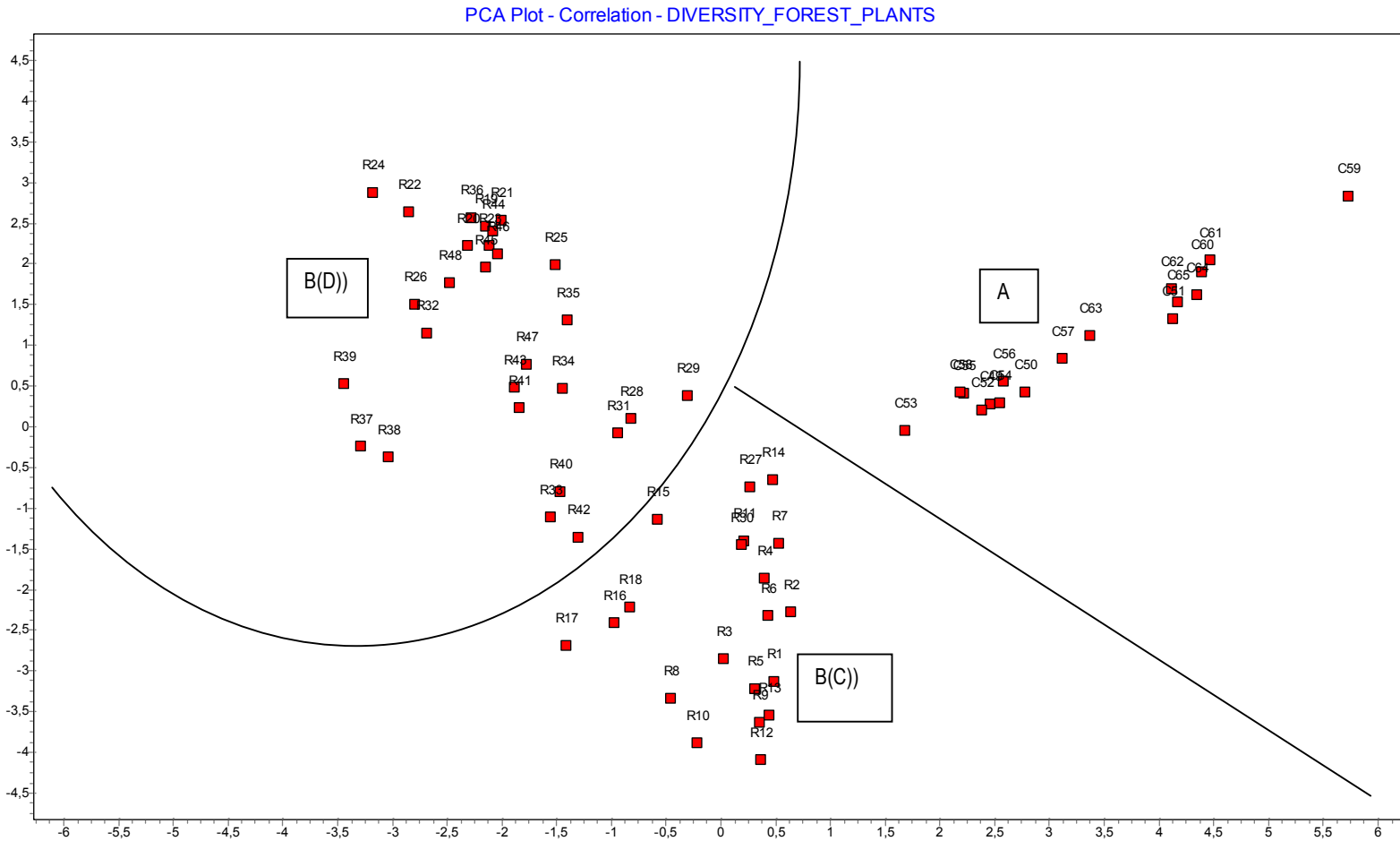


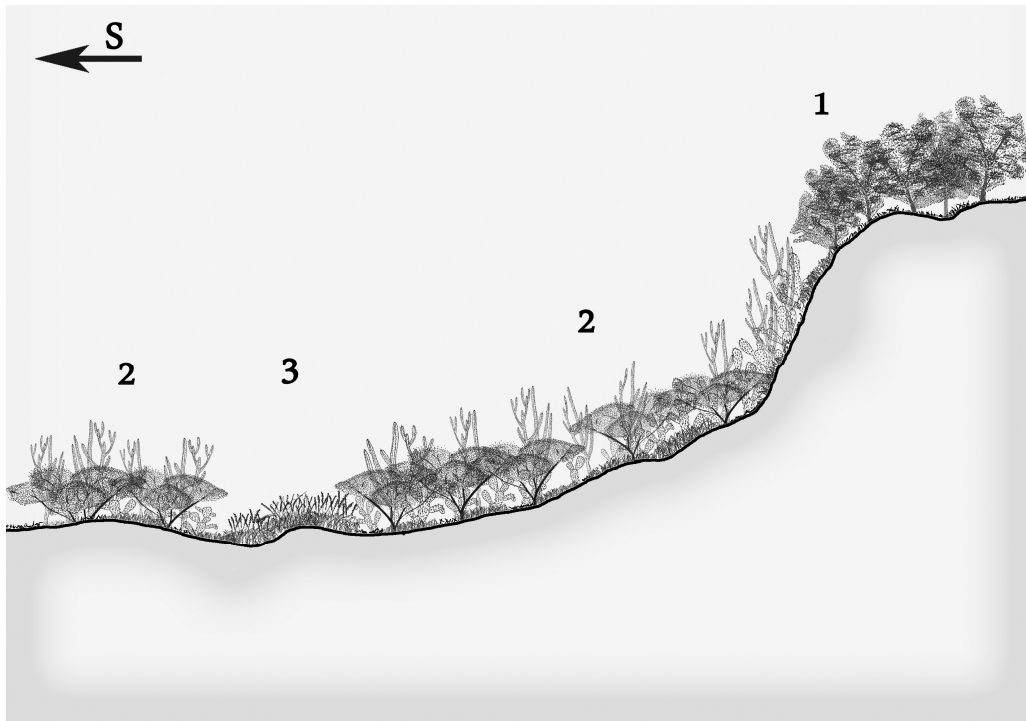
Fig. 2. Canonical correspondence analysis (CCA)



**Fig. 3. Principal components analysis (PCA) for cloud (A) and B (C subhumid and D dry forest)**

**Table 1. Species diversity in the dry and cloudy forests Dominican Republic**

	Trees	Stipes	Shrubbery	Succulents	Climber	Epiphytes	Herbaceous	T. species
Dry forest	61	5	158	16	44	13	28	322
Rain forest	75	4	63	0	28	36	43	244



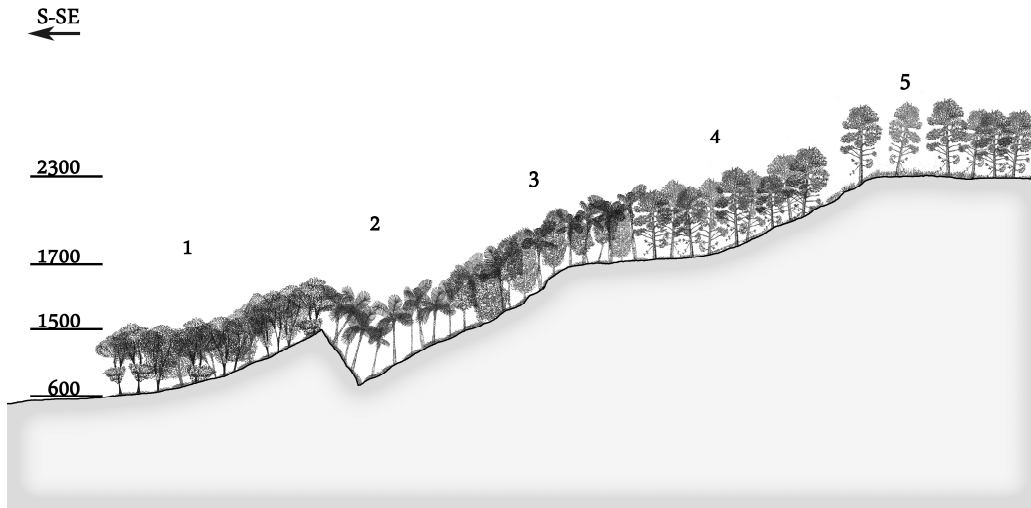
**Fig. 4.- Profile of the vegetation of the cloud forest of Sierra Bahoruco. 1.- *Rhabdadenio biflori-Laguncularietum racemosae* and *Lonchocarp pycnophylli-Conocarpetum erecti*. 2.- Salt marshes of *Batidi-Salicornietea*. 3.- *Lonchocarp pycnophylli-Cylindropundietum caribaeae*. 4.- *Melocacto pedernalensis-Leptochloopsietum virgatae*. 5.- Broad-leaved forest. 6.- Cloud forest of *Prestoea montana***

One subgroup includes the inventories taken in the Cibao Valley (Montecristi), in infratropical environments with a semiarid ombrotype on quaternary loams, with 17 endemic species, *Karwinskia coloneura* Urb. and *Justicia abeggii* Urb. & Ekm., exclusive to the territory. The subgroup is dominated by *Prosopis juliflora* L., *Lemairocereus hystrix* Britt. & Rose, *Harrisia nashii* Britt. & Rose, *Consolea moniliformis* (L.) Haworth in Steud and *Pilosocereus polygonus* (Lam.) B. & R.

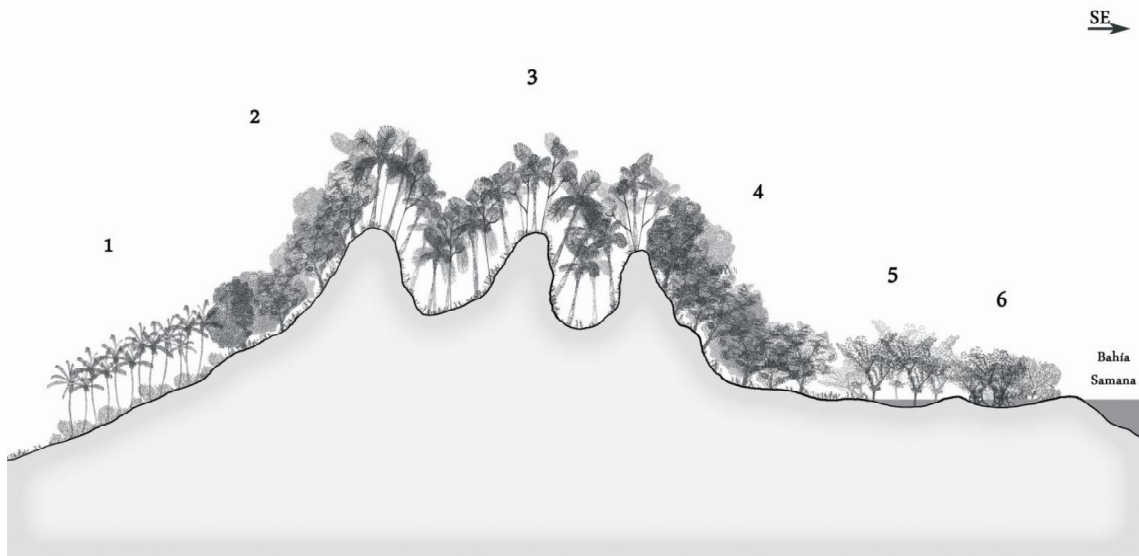
This subgroup is a community that grows in the outlying areas of the Cibao Valley in the infra and dry thermotropical thermotype. This is an intricate forest dominated by *Erythroxylum rotundifolium* Lunan and *Maytenus buxifolia* (A. Rich.) Griseb., with 36 endemic plants, of which

the following are exclusive to the territory: *Lantana leonardorum* Moldenke, *Lantana pauciflora* Urb., *Croton gonaivensis* Urb. & Ekm., *Lantana buchii* Urb., *Guettarda tortuensis* Urb. & Ekm. and *Galactia synandra* Urb. (Fig. 8).

The areas of Ázua, Bani, San Juan, Enriquillo and Port au Prince (Haiti) have a dry infratropical thermotype and are home to a spinescent forest growing on Miocene loams. In this forest there is a predominance of *Guaicum officinale* L., *Capparis cynophallophora* L., *Bourreria divaricata* (DC.) G. Don and *Cylindropuntia caribaea* (Britt. & Rose) Kunth; and 16 endemic plants, including particularly *Coccolrinax spissa* Bailey and *Neoabbottia paniculata* (Lam.) Britt. & Rose (Fig. 9).



**Fig. 5. Profile of the vegetation of the central range. 1.- Subhumid latifoliate forest. 2.- “Manacla” plantation of *Cyathea furfuracea* and *Prestoea montana*. 3.- Community of Palo de Viento *Didymopanax* and *Magnolia pallescens* with isolated elements of *Prestoea montana*. 4.- Pine forest of *Pinus occidentalis* belonging to the community of *Dendropemon phycnophyllus* Krug an urb. and *Pinus occidentalis* Sw. 5.- Hemicryptophytic high-mountain grassland of *Danthonia domingensis* between the cleared pine forests of *Pinus occidentalis***



**Fig. 6. Profile of the vegetation of the Haitises (A6).- 1.- Coconut crops. 2.- Latifoliate mahogany forest *Swietenia mahagoni*. 3.- *Ormosia krugii* and *Prestoea Montana* which is enriched on the summits witt *Didymopanax morotononi*. 4.- Latifoliate mahogany forest of *Swietenia mahagoni* similar to 2. 5.- Community *Roystonea hispaniolana* Bailey and *Pterocarpus officinalis* Jacq. 6.- Community *Machaerium lunatum* (L.f.) Ducke and *Rhizophora mangle* L**

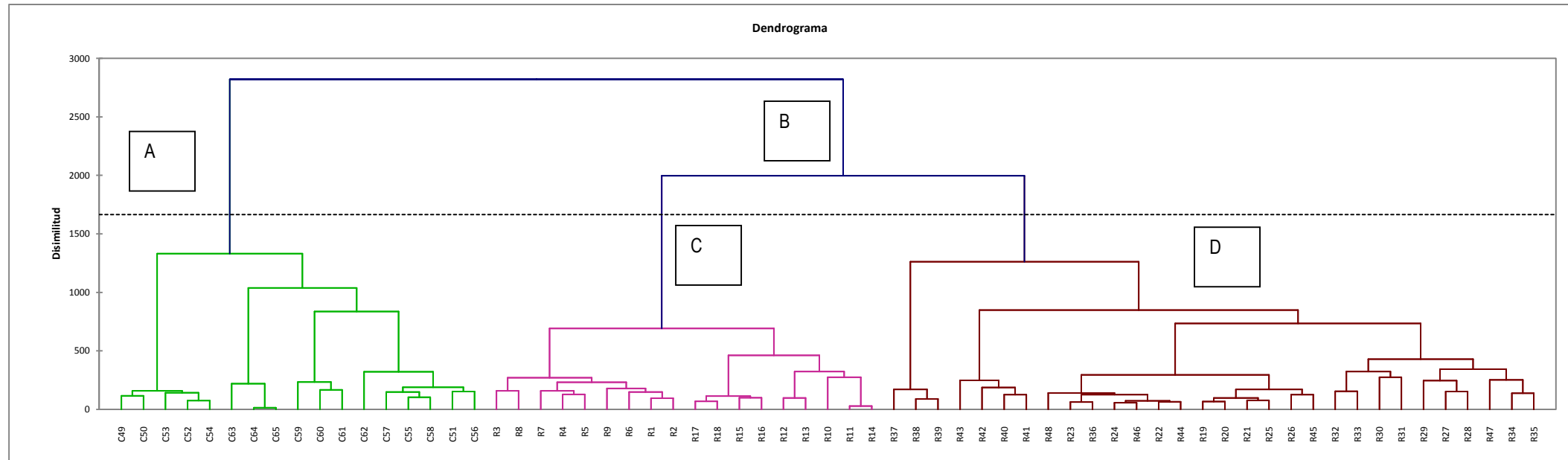
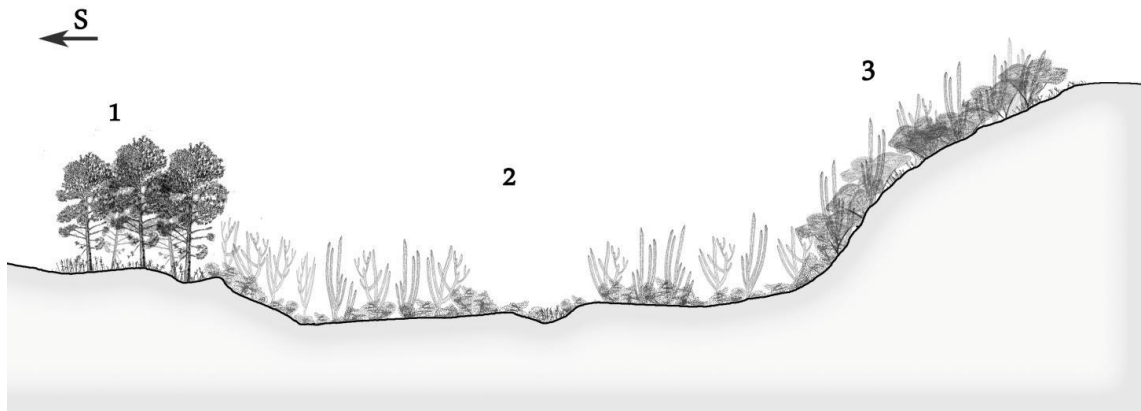
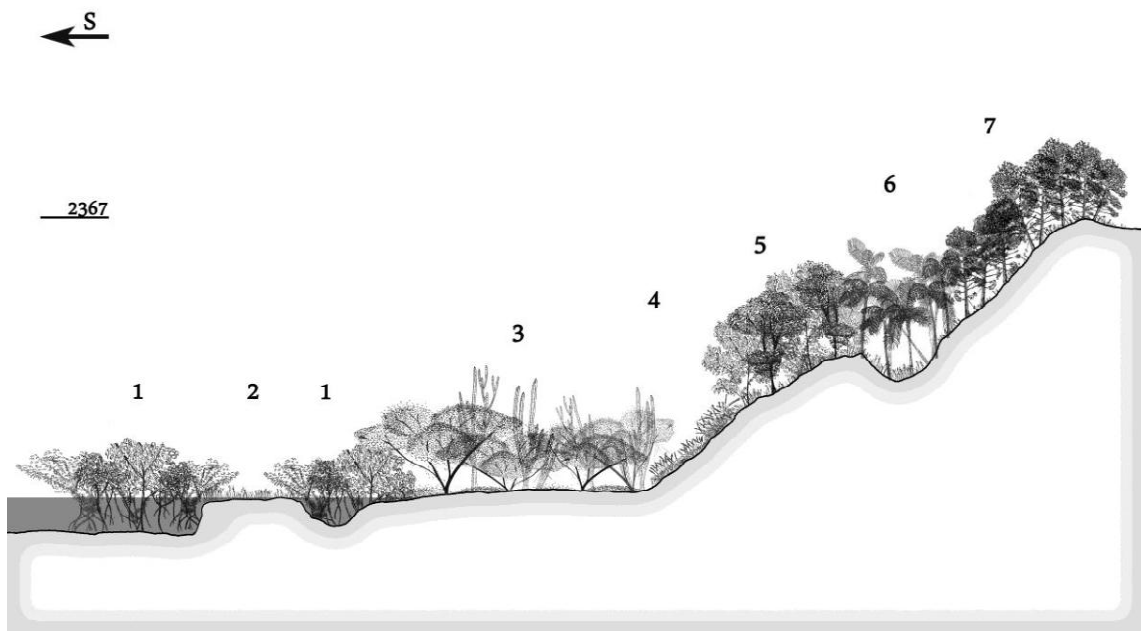


Fig. 7. Cluster analysis. Diversity of forest types





**Fig. 8 . Profile of the vegetation of the dry forest of Cibao valley. 1.- *Leptogono buchii-Pinetum occidentalis*. 2.- *Harrisio nashii-Prosopidetum juliflorae* 3.- *Crotono poitaei-Erythroxyletum rotundifolii***



**Fig. 9. Profile of the vegetation of the dry forest of Azua-Bani. Broad-leaved forest. 2.- *Neoabbottio paniculatae-Guaiacetum officinali*. 3.- *Solano microphylli-Leptochloopsietum virgatae***

This group includes dry forest communities between Pedernales and Barahona. The territory has a semiarid infratropical thermotype and reef limestone substrates. This forest is rich in coarse and spiny plants: *Cylindropuntia caribaea* (Britt. & Rose) Kunth, *Cameraria linearifolia* Urb., *Bursera simaruba* (L.) Sarg. and *Agave antillarum* Descourt.; and has 24 endemics, including particularly *Melocactus pedernalensis*

M. Mejía & R. García, *Malpigia micropetala* Urb., *Thouinia domingensis* Urb. & Radlk., *Thouinidium inaequilaterum* Alain and *Lonchocarpus pycnophyllus* Urb. These samples are clearly separated from the rest due to the fact they constitute specific endemic habitats.

These forests are crucial to maintaining the biodiversity of this island –considered a

biodiversity hotspot [24], and also for preserving the relation between forest stands and the water cycle, which is of such overriding importance to society [25-27]. The state of transition between the cloud, dry and transitional forest is affected by various factors: agriculture, desforestation to obtain charcoal, in which a case in point is the mangrove. Another factor is the considerable increase in invasive species favoured by tourism and by the dispersion of fruits and seeds by birds [28,29]; a particular case is *Eichhornia crassipes* (Mart.) Solms which is very abundant in the mangrove swamps of *Laguncularia racemosa* (L.) Gaertn. in the Dominican Republic [30]. Another case of invasive species on the island is *Lonicera japonica* Thunb., a native of China which is invasive in the southern United States [31]; it was introduced in the Dominican Republic as an ornamental plant, and has now spread beyond cultivated areas –particularly in the mountains– due to a possible confusion with *Lonicera confusa* DC. This affects forest conservation. The same occurs with *Lonicera caprifolium* L., a native of Europe which has a tendency to spread beyond its cultivated areas and become naturalised. Opportunists invasive non-native species, modify the native alpha and beta diversity; with which compete for water and nutrients. It seems correct to say that the diversity of native species is reduced. However [32] concluded that non-native species diversity improve, which seems correct since most communities obtained in the degradation of ecosystems are transitional, but this affects the stability of indigenous communities in the time scale and space.

#### 4. CONCLUSION

There are areas with high dry forest plant cover in the Dominican Republic; these are located in the southwest of the island, specifically in Procurrente de Barahona, Azua-Valle de San Juan-Hoya Enriquillo and in its prolongation towards western Haiti, including Beata Island; and the Cibao Valley-Montecristi. These territories have a high rate of endemics, and as a result the habitats in which they are found should also be considered endemic. The cloud forest, however, is always located in the mountains as a consequence of the moisture-laden winds from the Atlantic. In both cases the distribution of the forest responds to the environmental factors on the island, which has a high rate of endemics owing to the island phenomenon, making it a hotspot in the Caribbean.

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#### COMPETING INTERESTS

Authors have declared that no competing interests exist.

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