Chapter 9

Biogeographical Areas of Hispaniola (Dominican Republic, Republic of Haiti)

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Additional information is available at the end of the chapter

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Abstract

The island of Hispaniola is located between parallels 17 and 19 N and forms part of the Greater Antilles group in the Caribbean region. It covers an area of 76,484 km^2 and has the highest altitudes in the whole Caribbean region. The island consists of two countries: the Dominican Republic and the Republic of Haiti. The flora of both countries has been studied in depth by Liogier and several authors from the Dr. Rafael Ma. Moscoso National Botanical Garden in Santo Domingo; this has enabled us to examine the distribution of 1582 endemic species in 19 areas and several important endemic habitats for conservation: *Lepotogono buchii-Leptochloopsietum virgatae; Crotono astrophori-Leptochloopsietum virgatae; Melocacto pedenalensi-Leptochloopsietum virgatae* and *Solano microphylli-Leptochloopsietum virgatae* pine forests on serpentine belonging to the association *Leptogono buchii-Pinetum occidentalis* and high-mountain pine forests: *Dendropemom phycnophylli-Pinetum occidentalis* and *Cocotrino scopari-Pinetum occidentalis*. Some dry forest communities are of interest, including *Chrysophyllo oliviformi-Sideroxyletum salicifolii* and *Zamio debilis-Metopietum toxiferi*. Based on the floristic analysis and the vegetation study, a biogeographical typology for the island, in which we propose 19 biogeographical areas (BA) has been established.

Keywords: Caribbean, Hispaniola, biogeography, territory, area, flora and vegetation

1. Introduction

The geological history underlying the formation of the island of Hispaniola [1], the great differences in altitude and the wide range of substrates, have all led to the existence of 2050 endemic species distributed across a wide variability of habitats with an endemic nature that must be highlighted for the purposes of conservation. Therefore, in previous works, we started our study with a biogeographic proposal for the Spanish island [2].

We therefore begin our study for a biogeographical proposal for the island of Hispaniola with the general description by Takhtajan [3] on floristic regions in the world, and the work of Rivas Martínez et al. [4] on North and Central America, which establishes the rank of sector for the island of Hispaniola, and includes it within the Neotropical-Austro-American kingdom, the Caribbean-Mesoamerican region and the province of the Antilles. The studies by Borhidi [7] on the island of Cuba [5, 6] all recognise clear differences between the Greater Antilles (Cuba, Hispaniola, Jamaica and Puerto Rico) and the Lesser Antilles, based—among other considerations—fundamentally on the high biodiversity and distribution of species in the *Orchidaceae* family. Together with the existing local studies on the island of Hispaniola [8, 9] and our own recent fieldwork, we can establish a biogeographical typology based on the elemental biogeographical unit or tesela, defined as a variable area—either continuous or discontinuous—with a homogeneous geomorphological and ecological character giving rise to a single type of potential vegetation.

The island of Hispaniola with a territorial extension of 76,486 km^2 is divided between Doninican Republic and Republic of Haiti, it is an island very much studied from the floristic point of view, with very few studies of vegetation, with few studies like the one by Borhidi [7].

The importance of the study is due to the high diversity of endemic species and habitats that are of interest for conservation, with species and habitats subject to high human pressure, despite being a hot spot for the Caribbean.

In general, the island is dominated by areas very antropizadas, especially Haiti, where the human pressure is excessive; while in the Dominican Republic, anthropogenic action is somewhat lower, with areas dedicated to livestock and agriculture. However, there are two large well preserved landscape units: the rainforests of the mountains and the dry sub-deciduous forests.

2. Methodology

We conduct a botanical study from a biogeographical approach; as notwithstanding the numerous botanical and floristic works of investigation by researchers such as Urban, Ekman, Cicero, Donald Dungan, Marcano Fondeur, Jürgen Hoppe, Liogier, Zanoni, Hager, May, Borhidi, Megía, Jiménez, R. García, A. Veloz and others, very few studies have been undertaken from the perspective of phytogeography and vegetation science. Recent works have taken a floristic and physiognomic rather than a phytosociological approach [4, 8–18, 20, 21]; studies using a phytosociological methodology include Refs. [22–31]. The authorship of the species is mentioned only once in the text and is taken from Ref. [36].

The different types of habitats present on the island of Hispaniola are studied. For this purpose, we have performed over 300 years of phytosociological sampling as per Ref. [32]. At the same time, we do a floristic study on the distribution of 1500 endemisms. In order to explain the distribution of the different plant communities, a bibliographical and field-based study was carried out on existing geological materials, and a bioclimatic study of ombrotipos and thermotypes is presented in refs. [4, 33–35].

3. Results

The island's geological origin, the bioclimatic analysis with thermotypes ranging from the infratropical to the supratropical, with semiarid to hyperhumid ombrotypes, the origin of the flora as a result of migratory routes and the past isolation of the various sierras and mountains, all account for the large number of endemic species and habitats. The island has 1284 genera, of which 31 are endemic to Hispaniola: *Zombia, Leptogonum, Arcoa, Neobuchia, Fuertesia, Sarcopilea, Salcedoa, Eupatorina, Vegaea, Coeloneurum, Theophrasta, Haitia, Stevensia, Samuelssonia, Hottea, Tortuella* and *Anacaona*, among others. Several of the endemic genera are monotypes and have a restricted area, such as *Vegaea pungens* Urb., *Zephyranthes ciceroana* M. Mejía & R. García, *Gautheria domingensis* Urb., *M. domingensis, Omphalea ekmanii* Alain, *Gonocalyx tetrapterus* A. Liogier, *Goetzea ekmanii, Reinhardtia paiewonskiana* R.W. Read, T. Zanoni & M. Mejía, *Pseudophoenix ekmanii* Burret and *Salcedoa mirabaliarum* F. Jiménez & L. Katinas; or else local endemic species such as *Pinguicula casabitoana, Fuertesia domingensis* Urb., *Pereskia quisqueyana, M. jimenezii* Alain and *Salvia montecristina.*

There are a total of 5800 species according to [36], a figure that was subsequently extended by [37] to 6000 vascular species distributed in 1284 genera, with an estimated 2050 endemic species. Our study characterises the various biogeographical territories based on 1582 endemic species distributed in 19 areas (A1–A19), together with their own vegetation catenas, which we in turn break down into two subprovinces: the Central subprovince and the Caribbean-Atlantic subprovince, both clearly separate due to differences in their geological, bioclimatic, floristic and vegetation origin.

The province is characterised by a large number of endemic species, of which 114 belong to the family *Melastomataceae* [24]. The presence of a high number of endemic species with a widespread distribution on the island causes the application of Pearson's index to result in a low relation between areas A12 and A16 (r = 1.25), due to their different geological and floristic nature; between A16 and A13 (r = 1.17); and between A12 and A13 (r = 1.23). In this last case, the low relation between the two areas derives from the difference in the number of endemics. Although both zones have calcareous substrates, A13 has suffered greater human impact. A16 and A17 are highly separated, which is unsurprising as the Massif du Nord (A17) is a prolongation of the Central Cordillera range (A16). The frequent presence of calcareous islands and the intense human pressure in A17 is a further reason for their separation, with A17 acquiring a greater similarity with A15 (northwest Haiti).

The Jaccard analysis reveals that areas A12 and A16 have a distance of 0.9, representing a coincidence of only 10% and differences of 90%; this is also the case between A16 and A17, as this analysis corroborates that A17 has greater similarity with A15. The results of Pearson's analysis for areas A12 and A13 are similar to those obtained with the Jaccard analysis [24].

4. Analysis of biogeographical territories (sectors) and areas (districts) (BT, BA)

The Central Cordillera is characterised by a predominance of siliceous materials and a tropical rainy and tropical pluviseasonal macrobioclimate on the summits, occasionally tropical xeric at the base. All this has led to the development of a particular endemic flora with 451 different endemic species and vegetation units [11]. This biogeographical territory (BT) contains a single area, A16, Central-Eastern, occupying the Central Cordillera (Dominican Republic), and dominated by siliceous materials with slight inclusions of serpentines in the easternmost area, representing the transition to the Yamasense biogeographical unit. The thermotype ranges between the infra and supratropical, and the dominant ombrotype is humid-hyperhumid. The penetration of the trade winds causes the presence of both broadleaf rainforest and cloud forest towards the mid-mountain, with a dominance of species from the genera *Prestoea, Magnolia, Didymopanax, Cyathea*; while the high-mountain areas beyond the reach of the trade winds are home to *Pinus occidentalis*, a forest belonging to the endemic habitat *Dendropemon phycnophylli–Pinetum occidentalis* Cano, Veloz & Cano-Ortiz 2011, alternating with hemicryptophytic communities of *Danthonia domingensis* **Figure 1**.

In previous works, we proposed the following biogeographical territories (BT) (biogeographical sectors) for the Caribbean-Atlantic subprovince: 2.1. Bahoruco-Hottense (A12, A13); 2.2. Neiba-Matheux-North-western (A14, A15, A17 and A19); 2.3. Azua- San Juán-.Hoya

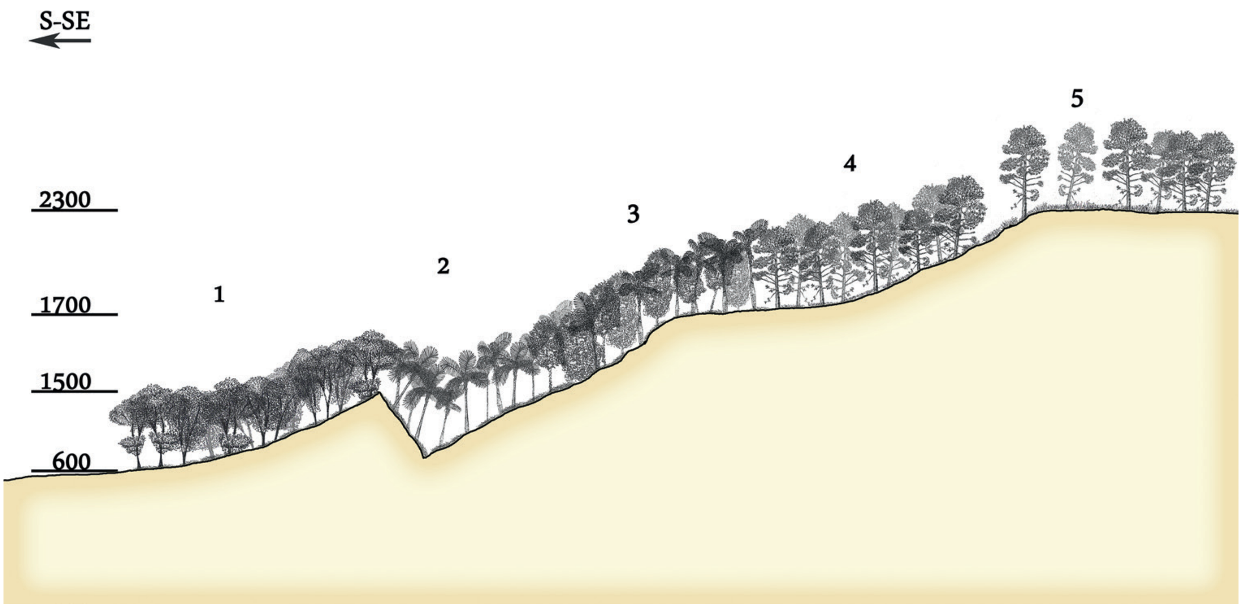

Figure 1. Vegetation catena of the Central Cordillera 1. Subhumid broadleaf forest. 2. Sierran palm forest. Community of *Prestoea montana* and *Cyateas* (palms). 3. Community of 'palo de viento' *Didymopanax tremulus* and isolated individuals of *Prestoea montana*. 4. *Pinus occidentalis* pine forest belonging to the association *Dendropemon phycnophylli–Pinetum occidentalis*. 5. Hemicryptophytic high-mountain grassland of *D. domingensis* among the cleared pine forest of *Pinus occidentalis.*

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Enriquillo-Port au Prince-Artiobonite-Gonaivës (A9, A10, A11 and A18); 2.4. Caribbean-Cibense (A3, A7 and A8); 2.5. Northern (A1, A2, A4, A5 and A6) [24].

BT-2. 1. The Bahoruco-Hottense district includes two areas or districts (A12 and A13). The Sierra de Bahoruco and its continuation in the Massif de la Selle and de la Hotte in Haiti have a similar geological origin and frequently suffer the impact of Caribbean hurricanes. The ombrotype in these territories ranges from subhumid to hyperhumid, leading to a predominance of broadleaf cloud forest, sierran palm forests of *Prestoea montana*, cloud forest of *Magnolia* and *Didymopanax*, and—in the supratropical thermotype on the summits—a pine forest of *P. occidentalis*, belonging to the association *Coccotrino Scopari-Pinetum occidentalis* Cano, Veloz & Cano-Ortiz 2011. The general vegetation catena characterising this biogeographical territory is therefore conditioned whether it is a dry forest, broadleaf forest, cloud forest or high-mountain pine forest. In addition, due to its high rate of endemic species, this biogeographical territory is of interest for conservation. We are unaware of the existence of *Podocarpus aristulatus* Parl. and *Ocotea wrightii* (Meisn.) Mez in the Bahoruco-Hottense sector; and this BT thus reveals significant differences when compared with the Neiba-Matheux-North-western sector. The relation between the two areas (A12 and A13) in this BT is low, as they present a certain number of different endemic species with an r = 1.23 **Figure 2**.

BA-A12. The Bahoruco-La Selle district occupies calcareous mountain ranges with an occasionally supratropical thermotype. There is a broadleaf cloud forest of *M. hamorii* and *D. tremulus*,

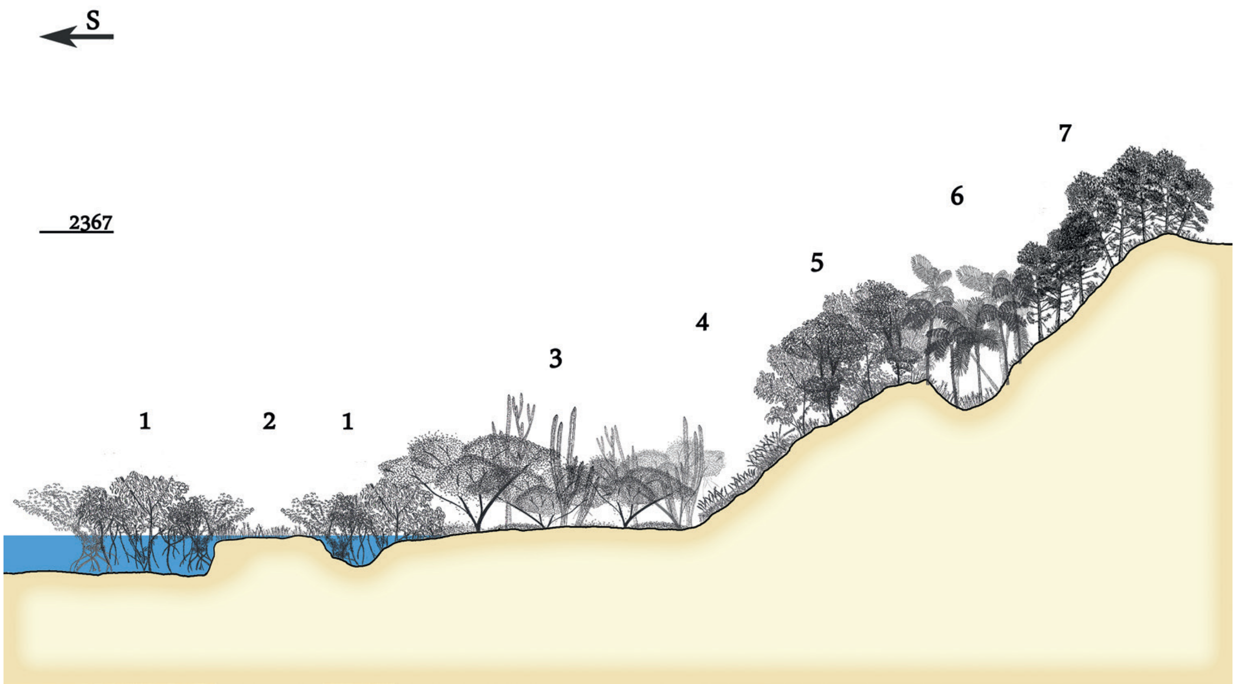

Figure 2. Vegetation catena in the Sierra de Bahoruco. 1. Mangrove forests of *Machaerio lunati-Rhizophoretum manglis*. 2. Salt marsh communities in the class *Batidi-Salicornietea*. 3. Dry forest of *Pilosocereus polygonus* and *Acacia sckleroxyla*. 4. Hemicryptophytic grassland of *Melocacto pedernalensis-Leptochloopsietum virgatae*. 5. Cloud forest of *Magnolia hamorii* and *Didymopanax tremulus*. 6. Sierran palm forest (forest of *Prestoea montana* and *Cyathea arborea*). 7. Pine forest of *Coccotrino scopari-Pinetum occidentalis*.

while on rainier sites and in gorges, there is a presence of formations of *P. montana*. This unit is home to forests of *M. hamorii* growing between 950 and 1500 m, as precipitation exceeds 2000 mm. These forests are characterised by *M. hamorii, L. bahorucanus, Mikania venosa* Alain, *C. domingensis, Rondeletia ochracea* Urb., *P. guadalupensis, H. domingensis, Arthrostylidium sarmentosum* Pilger, *Weinmannia pinnata* L., *M. ovatum, Vriesea tuercheimii, D. tremulus, Meriania involucrata* (Desr.) Naud. and *Polygala fuertesii* (Urb.) Blake. The same cloud forest at higher altitudes, where the pressure of the wind is greater, is enriched by *D. tremulus*, and on rainier sites and in moist gorges by the sierran palm forest of *P. montana*. A pine forest of *P. occidentalis* is found growing in the supratropical thermotype, with *C. scoparia, A. intermixta, N. domingensis, Eupatorium sinuatum* Lam. *var viscigerum* Urb. & Ekm., *Staurogyne repens, G. ruolphiodes var haitiensis* and *S. barahonenis*, belonging to the association *Cocotrino scopari–Pinetum occidentalis* Cano, Veloz & Cano-Ortiz 2011.

In basal zones such as the Procurrente de Barahona, Ceitillan and Pedernales, the ombrotype is semiarid and the thermotype is infratropical. There is a predominantly dry forest, with a floristic composition comprising *Lomandra hystrix, P. polygonus, Ceratocystis moniliformis, Antillesoma antillarum, Coriandria caribaea* and *Melocactus pedernalensis*, in whose clearings there is a hemicryptophytic and endemic community of *Melocaptoa pedernalensis-Leptochloopsietum virgatae* Cano, et al. [24, 25]. In coastal areas, it is worth highlighting the presence of mangrove forests of *R. mangle, L. racemosa* and *A. germinans*, enriched towards drier areas with *C. erectus*. In these territories, the mangrove forest alternates with halophilous communities of *S. portulacastrum*. This area has a high rate of endemic species, with 693 endemic plants.

BA-A13. The Hottense district is characterised by calcareous substrates whose geological origin is similar to that of La Selle and Bahoruco. It is located at the end of the southwest peninsula (Haiti), and has 171 endemic plants, but in lesser numbers than in the Bahoruco-La Selle area. However, this biogeographical unit is home to the endemic genus *Hottea*, which is distributed throughout the biogeographical units A12, A13 and A14; the highest numbers of endemic species in this genus are found in A13. This biogeographical unit has a thermotype that ranges between the infra and mesotropical, and the ombrotype is dry in the basal areas to humid on the summits of La Hotte.

BT-2.2. The Neiba-Matheux-North-western sector has four districts (A14, A15, A17 and A19). It is floristically characterised by the presence of 90 endemic species such as *Guettarda oxyphylla* Urb. and *Chionanthus dictyophyllus* (Urb.) Stearn, with its own vegetation catenas ranging from the dry to the subhumid and cloudy, with pine forests of *P. occidentalis* on the summits. Two of the areas in this biogeographical territory (A14 and A15) have a relation r = 0.93, indicating major floristic differences between both biogeographical units **Figure 3**.

BA-A14. The Neiba-Matheux district covers the calcareous mountain ranges of Neiba, Matheux and Noires with an altitude of 1793 m and a dry, subhumid-humid ombrotype and an infra, thermo and mesotropical thermotype, which is occasionally supratropical in the Massif des Montagnes Noires. It is home to a rare broadleaf forest of *P. aristulatus*, a cloud forest of *P. montana* and a forest of *D. tremulus* which is enriched with *P. aristulatus, O. wrightii, Persea krugii* Mez and *Brunellia comocladifolia* H. & B. In the highest sites in the Neiba range, it is still possible to find pine forests of *P. ocidentalis* on calcareous substrates over a limited

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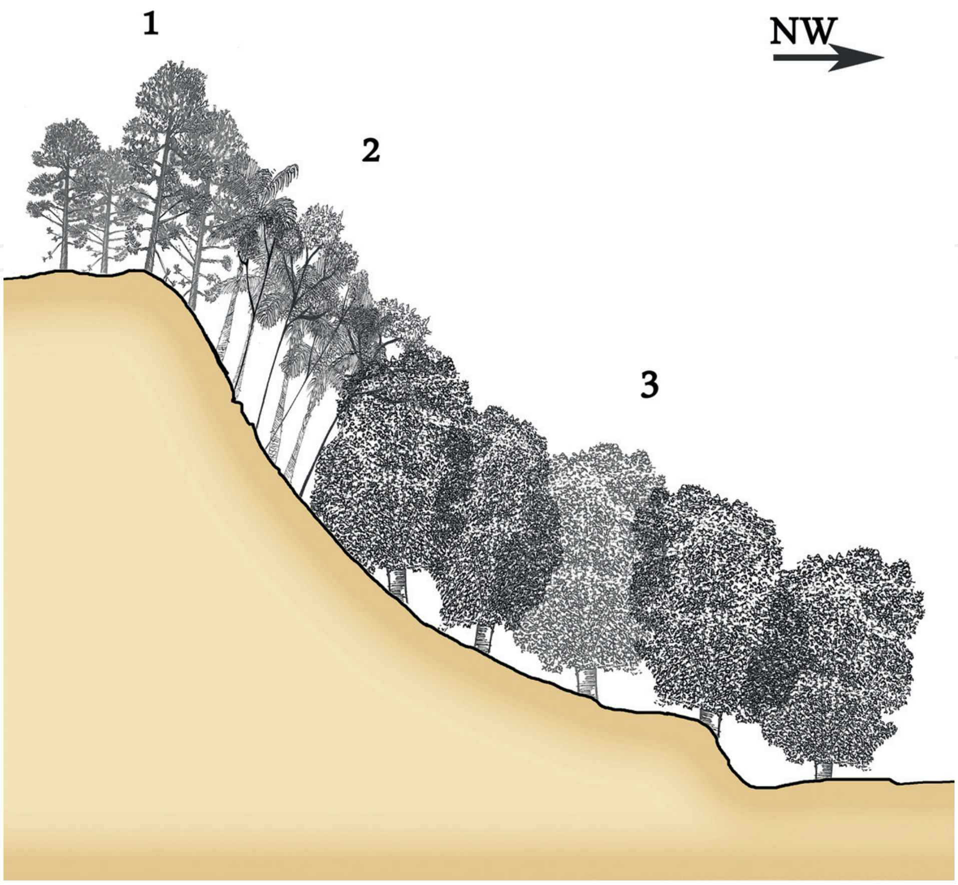

Figure 3. Vegetation catena in the Sierra de Neiba. 1. Forest of *Pinus occidentalis*. 2. Sierran palm forest of *Didymopanax tremulus* and *Podocarpus aristulatus*; 3. Broadleaf mahogany forest of *Swietenia mahagoni*.

extension. This area reveals a certain influence of the Central province due to the presence of *P. aristulatus*, which is also located near Valle Nuevo (Central Cordillera) and the absence of *M. hamorii*; the presence of the pine forest of *P. occidentalis* connects it with Bahoruco. There are 27 endemic species exclusive to this area.

BA-A15. This district is located in the northwest of the Republic of Haiti and also has a predominance of carbonated rocks. These territories are exposed to the trade winds from the Atlantic. However, as they contain no major elevations—the maximum altitude of around 840 m—the dominant ombrotype is subhumid. West-facing areas connecting with Gonaive and Hene Bay have a dry ombrotype, as this is an area of shade, and a thermotype ranging between infra and mesotropical. The floristic character is based on the presence of 59 endemic species.

BA-A17. The Central-Western district occupies the whole of the Massif du Nord in Haiti. This mountain is a prolongation of the Central Cordillera. In this case, there is also a dominance of siliceous materials with the inclusion of basic substrates; the thermotype is infra to mesotropical, and the ombrotype ranges from subhumid to humid. We collected fewer endemic species (60) in this biogeographical unit than in the Central-Eastern unit (A16), as these areas are highly altered, as is generally the case in the whole of the Republic of Haiti, which has suffered widespread deforestation throughout its history.

BA-A19. The Tortuga Island district is calcareous in nature and located in the north of Haiti, at a maximum altitude of 378 m so the trade winds only reach the highest areas. The vast majority of the territory has a dry ombrotype, occasionally becoming subhumid-humid. The relation of A19 with the nearest areas—A3 and A15—is $r = 1.02$ and $r = 0.89$. In spite of its small size, the presence of the monotypical genus *Tortuella abietifolia* Urb. & Ekman and 15 exclusive endemic species justifies its consideration as a biogeographical unit in itself.

BT-2.3. The Azua-San Juán-Hoya Enriquillo-Port au Prince-Artiobonite-Gonaivës sector (A9, A10, A11 and A18) covers all the low-lying areas in the south of the Dominican Republic and west of Haiti. These territories are differentiated from the Procurrente de Barahona as they have soft deposit materials, despite their similar infra and thermotropical thermotype and semiarid-dry ombrotype. However, in this case, there is an occasional presence of the subhumid ombrotype on the heights of the Sierra Martín García, which represents a small island surrounded by dry forest, distinguishing this area from the previous one. Although most of the territory is dominated by dry forest, there is an occasional presence of broadleaf forest on the summits of Martín García. Unlike in Bahoruco and Neiba, there are no formations of *P. occidentalis*. The dry forest in this biogeographical unit is dominated by the species *P. polygonus, L. hystrix, A. antillarum, Mimosa diplotricha* C. Wright ex Sauvalle, *Brya buxifolia* (Murr.) Urb., *N. paniculada, Thouinia domingensis* Urb. & Radlk., *Solanum microphyllum* (Lam.) G. Don., *Coccotrinax spissa* Bailey, *A. skleroxyla, Scolosanthus triacanthus* (Spreng.) DC., *C. moniliformis, M. lemairei* and *C. caribaea*. In view of the differences in flora, vegetation, geology, ombrotype and thermotype, these areas should be treated as specific biogeographical territories. In all cases, the relations between the four areas proposed have a value of *r* in Pearson's index of equal to or less than 1, as they share very few endemic species.

BA-A9. The Azua-Sán Juán-Hoya Herniquillo district is an area that extends from Bani and Azua towards the Sán Juan river valley as far as the border with Haiti, where it becomes what is known as the Central Plain in Haiti, with higher elevations. The Cordillera Central in the Sierra de Neiba is separated through the Sán Juán valley. These semiarid-dry territories border the Sierra de Neiba along the south, and extend along Lake Herniquillo to Jimani and Malpaso. From a geological point of view, there is a predominance of soft materials of a Quaternary nature with gypsum islands in the areas near Herniquillo Lake. There is a constant infra and thermotropical thermotype and a semiarid-dry ombrotype. This district has 85 endemic species, some as emblematic as *N. paniculada, M. lemairei, Acacia barahonesis* Urb. and *Zanthoxylum azuense* (Urb. & Ekm.) Jiménez, which give the territory its distinctive character. This area is characterised by the presence of habitats such as the association *Solano microphylli-Leptochloopsietum virgatae* Cano, et al. [24, 25] **Figure 4**.

BA-A10. The Central Plain district (Haiti) ascends through the area of the Sán Juán valley, past the upper stretch of the Artibonite River at altitudes of 100 m. There exists a territory with no natural vegetation that is used for agriculture (Haiti). This is the location of the Central Plain in Haiti, standing at a height of 300–400 m and separating the Massif des Montagnes Noires at 1793 m and the calcareous substrates in the siliceous Central Cordillera (Massif du Nord),

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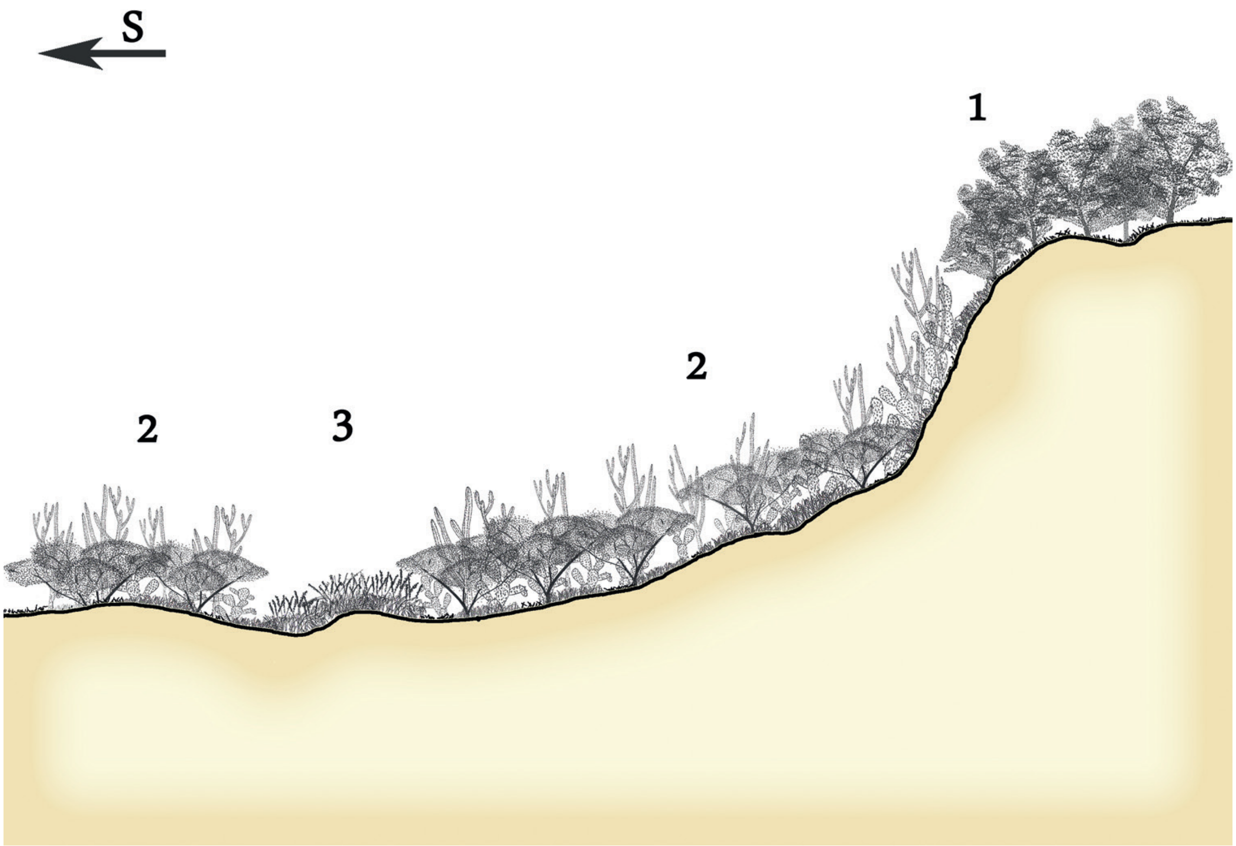

Figure 4. Vegetation catena of the Azua district. 1. Broadleaf forest of *Acacia skleroxyla* and *Coccothrinax boschiana*. 2. Dry forest of *Neoabbottio paniculatae-Guaiacetum officinalis*. 3. Hemicryptophytic community of *Solana microphylli-Leptochloopsietum virgatae.*

with maximum altitudes of 1210 m. This district (A10) has calcareous clayey substrates, a thermotropical thermotype and a dry ombrotype, and differs from the semiarid-dry forest in unit A9. This difference is evidenced in the values of Pearson's index—r = 0.91—as the Central Plain in Haiti has higher rainfall, and in its eight endemic species: *Bumelia picardae* Urb., *Carpodiptera hexaptera* Urb. & Ekm, *Dorstenia flagellifera* Urb. & Ekman, *Malpighia aquifolia* L., *Malpighia setosa* Spreng., *Phenax pauciflorus* Urb., *Plumeria paulinae* Urb. and *Thouinidium pinnatum* (Turp.) Radlk.

BA-A11. The Port au Prince-Arbiobonite-Gonaives district is past Jimini (Dominican Republic), approaching the border with Haiti and entering the plain of Port au Prince, where the materials continue to be soft and Quaternary in origin. The thermotype is infra and thermotropical, and the ombrotype is semiarid-dry due to the lack of rain, as these are areas of shadow. The Sierras de Bahoruco, La Selle and Neiba act as a barrier in the south, and those of Matheux, Noires and the Central Cordillera do the same in the northeast. The altitudes range between 0 and 100 m. These are areas with scarcely any natural vegetation as they are used for agriculture; the semiarid-dry character of the territory is prolonged the length of the northern fringe of the Massif de la Selle and de la Hotte, from Port au Prince bay to Gran Caimite, an island that is also part of this biogeographical unit. The territory extends to the southwest of the Massif de Matheux and borders these mountains before entering the Artiobonite river valley as far as the locality of Mirebalais, and northwards towards Gonaives. There are 70 endemic species in these territories, which form part of the different habitats in the dry forest in this biogeographical unit: *Catesbaea sphaerocarpa* Urb., *C. dictyophyllus, Guettarda multinervis* Urb., *Stigmaphyllon haitiense* Urb. & Ndz. and *Psychotria haitiensis* Urb.

BA-A18. Gonave Island is located in the middle of Port au Prince bay, with altitudes of 702 m. It is practically devoid of natural vegetation as a result of intense human pressure. This satellite island of Hispaniola has an infra and thermotropical thermotype and a semiarid-dry ombrotype. Due to its isolation, the floristic analysis reveals the presence of 20 endemic species, of which the following are exclusive to the island: *Mouriri gonavensis* Urb. & Ekman, *Solanum aquartia* Dunal *var luxurians* (O.E. Schulz) Alain, *Dendropemon gonavensis* Urb., *Dendropemon spathulatus* Urb. & Ekman, *Galactia caimitensis* Urb. & Ekman, *Isidorea gonavensis* Aiello & Borhidi and *Pilea dispar* Urb. = (*Pilea gonavensis* Urb.). It shares some endemic species with unit A11—with a Pearson's index of $r = 0.83$—and the same type of vegetation (dry forest). We therefore include it in the same biogeographical sector.

BT-2.4. Caribbean-Cibense (A3, A7 and A8). This biogeographical territory comprises three geomorphological units that include the Eastern Coastal Plain, the Sierras de Yamasá and Prieta, and the Cibao Valley. The eastern coastal areas on the shores of the Caribbean have an altitude of less than 100 m, and are coralline in origin; in contrast, in the Cibao Valley, there is a dominance of alluvial materials, Miocene conglomerates, schists, Miocene loams, limestone hills, clays and calcareous loams. Both geomorphological units are separated by the Sierras of Yamasá and Prieta, in which there is an amalgam of substrates, as this is a crossroads between the Central Cordillera, Los Haitises, the Eastern Coastal Plain and the Cibao Valley. There are frequent serpentines, which can also be found in the province of Dabajón in the Cibao Valley, leading to the widespread presence of a dry spiny forest and a pine forest. The thermotype for this BT ranges from infra to thermotropical and the ombrotype is semiarid to subhumid; however, due to the type of substrate—serpentines and perforated coralline limestones—the territory behaves as dry. All this causes the predominance of a dry forest. This biogeographical unit has particular vegetation associations and catenas. The general vegetation catena is the dry and semi-deciduous forest of *M. toxiferum, S. mahagonii* and *C. diversifolia*. It has a large number of endemic species, distributed in the three biogeographical areas. The relation between the areas in this BT is: $r = 0.95$ for A3–A7, $r = 0.97$ for A3–A8 and $r = 1.01$ for A7–A8 **Figure 5**.

BA-A3. The Cibao Valley district is characterised by a predominance of Miocene limestone, loams and conglomerates, along with the serpentines of Dabajón. The infra and thermotropical thermotype and the semiarid-dry ombrotype have produced a dry forest flora and vegetation, and the presence of 67 endemic plants in this area. The endemic dry forest in the territory comprises a community of *L. hystrix* and *Croton astrophorus* Urb., *C. caribaea, Mammillaria prolifera* (Mill.) Haw., *Phyllostilon brassiliensis* Capan., *H. nashii, P. polygonus, B. buxifolia, Opuntia antillana* Britt. & Rose, *C. moniliformis, Lantana camara* L., *Turnera difusa* Willd. ex Schult, *Abutilon abutiloides* (Jacq.) Garcke, *O. dillenii, Malpighia cnide* K. Spreng., *C. poitaei, S. triacanthus, Erytroxylum rotundifolium* Lunam, *Croton discolor* Willd., *A. antillarum, M. lemairei,*

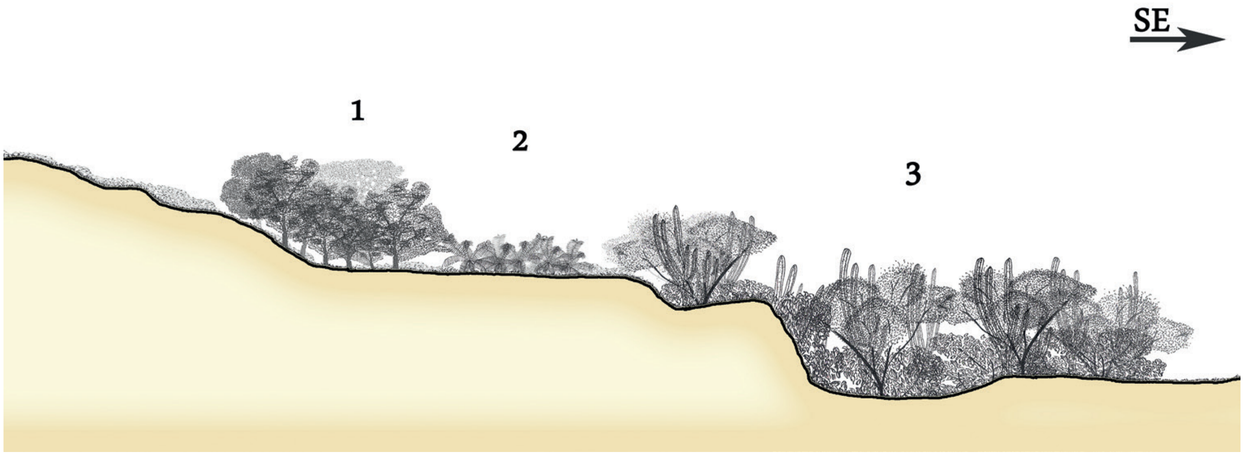

Figure 5. Vegetation catena of the Caribbean coastal unit. 1. Association *Zamio debilis-Metopietum toxiferi*. 2. Community of *Zamia debilis*. 3. Association *Chrysophyllo oliviformi-Sideroxyletum salicifolii*.

Maytenus buxifolia (A. Rich.) Griseb., *L. virgata, Phyllostilon rhamnoides* (J. Poiss.) Taub, *A. tortuosa, Caesalpinia coriaria* (Jacq.) Willd., *Caesalpinia buchii* Urb. and *Anthirea montecristina* Urb. & Ekm. [29]. Along with this dry forest it is frequent to find habitats of *Leptochloopsis virgate* and *Crotono astrophori-Leptochloopsietum virgatae* Cano, et al. [24, 25], and mangrove forests of *Rhabdadenio biflori-Laguncularietum racemosae* Cano et al. [27].

In serpenticolous territories, there is a pine forest or community of *P. occidentales, Calliandra haematomma* (Benth.) Benth., *Tabebuia berterii* (P.DC.) Britt, *Chrysophyllum. oliviforme* L., *Psychotria dolichocalix* Urb. & Ekm., *Smilax habanensis* Jacq., *Sideroxylon cubense* (Griseb.) Penn., *Miconia laevigata* (L.) DC. = (*Miconia pyramidalis* (Desr.) DC., *Croton linearis* Jacq., *Rondeletia cristi* Urb., *O. ilicifolia, Leptogonum buchii* Urb., *Guettarda pungens* Urb., *Ternstroemia peduncularis* A. DC., *Randia aculeata* L., *Byrsonima crassifolia* (L.) HBK. and *L. camara*. This is an exclusive habitat in this biogeographical unit that, along with other communities, serves to establish the differences with the other biogeographical territories: *Leptogono buchi-Pinetum occidentalis* Cano, et al. [26, 19] **Figure 6**.

The Eastern Caribbean area occupies the whole of the coastal plain overlooking the Caribbean Sea. Its coralline origin causes the substrate to be highly porous, and although the rainfall is over 800 mm, the territory acts as dry. There is a strong floristic similarity between these territories in the Cibao Valley and the areas in the southwest, and to a lesser degree between this area and that of Yamasá. There are also differences between the flora, habitats and uses of the territory and the dry areas in the southwest, as the territories on the eastern coastal plain are essentially used for the cultivation of sugarcane and coconut. These eastern plains must therefore be treated as specific biogeographical areas. There are 60 endemic species of flora, some of which have problems of conservation, as is the case of *P. quisqueyana*. In terms of vegetation, it has its own characteristic plant communities depending on the substrate. The dry forest occurs when the soil is thin and porous, but if the soil is deep, these dry phytocoenoses

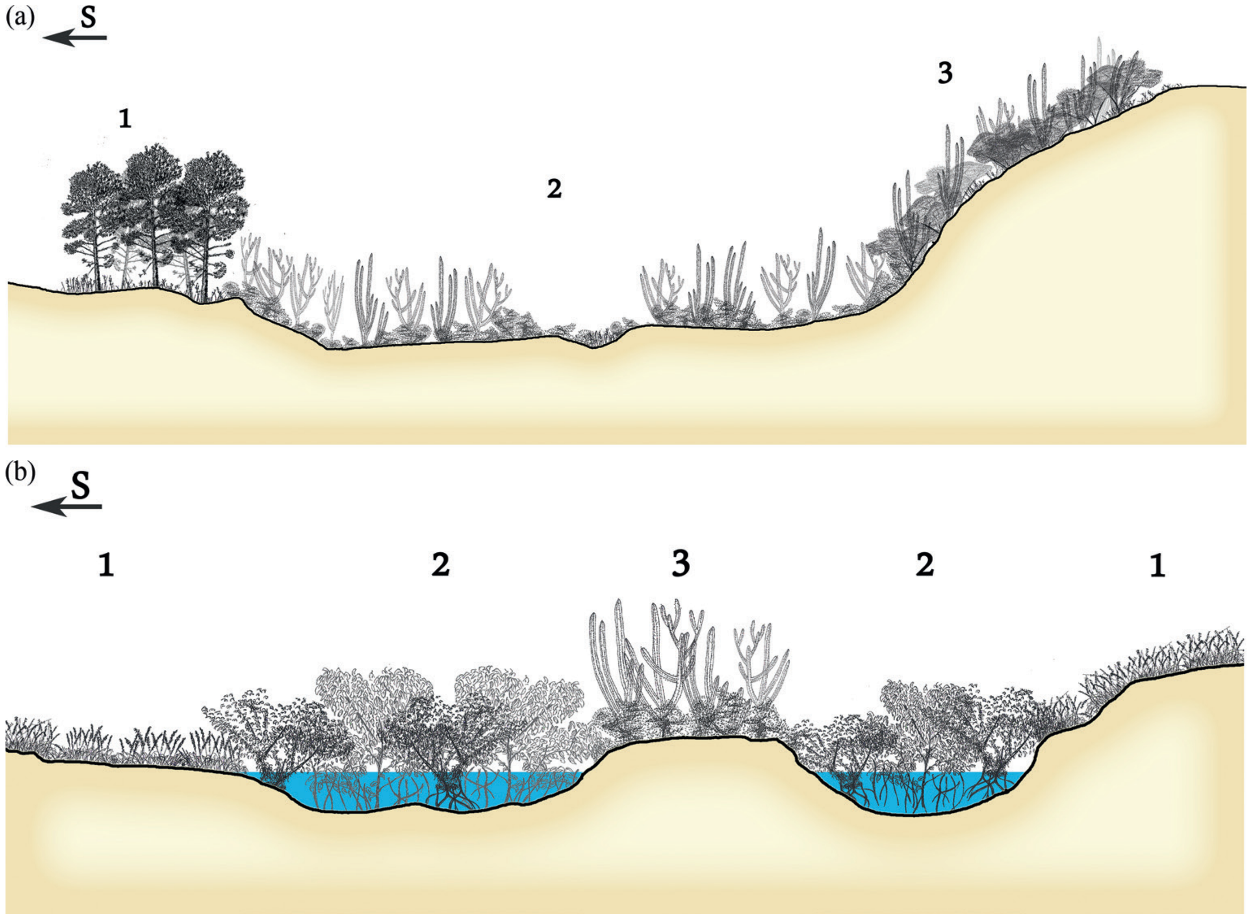

Figure 6. a. Vegetation catena of the Cibao Valley. 1. Association *Leptogono buchii-Pinetum occidentalis*. 2 and 3. Dry forest of *Harrhisio nashii-Prosopidetum juliflorae* [29]. b. Vegetation catena of the Cibao Valley. 1. Association *Crotono astrophori-Leptochloopsietum virgatae*. 2. Association *Machaerio lunati-Rhizophoretum manglis* and *Rhabdadenio biflori-Laguncularietum racemosae*. 3. Dry forest of *Harrhisio nashii-Prosopidetum juliflorae*.

become transformed in semi-deciduous forests in transition between the dry and evergreen forest, comprising a forest of *S. mahagonii, M. toxiferum, Krugiodendron ferreum* (Vahl) Urb., *C. diversifolia, Guaiacum sanctum* L., *Thouinia trifoliata* Poit., *Z. debilis, Coccotrinax barbadensis* (Lodd ex Mart.) Sarg., *Exostema caribaeum* (Jacq.) R. & S., *Sideroxylon salicifolium* (L.) Lam., *C. oliviforme, A. bilobata* and others. On sites with more intense water runoff, there is a dry forest of *Sideroxylon foetidissimum* (Jacq.) Cron., *P. quisqueyana, P. polygonus, L. weingartianus, B. simaruba, Clusia rosea* Jacq., *S. salicifolium, Celtis trinervia* Lam., *B. buceras, Cissus oblongo-lanceolata* (Krug & Urb.) Urb., *Ficus citrifolia* P. Mill., *C. diversifolia, G. sanctum, A. skleroxyla, M. jimenezii, P. unguis-cati, C. oliviforme, K. ferreum, Guapira fragrans* (Dum. Cours.) Little and *Capparis cynophallophora* L. Forests recently diagnosed by us are *Chrysophyllo oliviformi-Sideroxyletum salicifolii* Cano & Veloz 2012 and *Zamio debilis-Metopietum toxiferi* Cano & Veloz 2012. The mangrove forests in the association *Sthalio monospermae-Laguncularietum racemosae* Cano et al. 2012 give this eastern biogeographical area its characteristic appearance.

BA-A8. The Yamasá district is a complex geomorphological unit occupying the Sierra Prieta and Yamasa ranges. It has siliceous, limestone and serpentine substrates, the last of which cause the appearance of endemic serpenticolous communities with a spiny character. This is a xerophytic high shrubland, and throughout the Quaternary era, this territory served as a route for the passage of species between the xeric areas in the Cibao Valley and the Eastern Coastal Plain and the xeric areas in the southwest. The presence of serpenticolous elements and endemic habitats in our study, such as the community of *C. haematomma, Phyllanthus nummularioides* Muell. Arg., *Caliptrogenia biflora* Alain, *Eugenia crenulata* (Sw.) Willd., *Coccotrinax argentea* (Lodd.) Sarg., *L. buchii, Coccoloba nodosa* Lindau, *Coccoloba jimenezii* Alain, *Croton impressus* Urb., *T. peduncularis, Garcinia glaucescens* Alain & M. Mejía, *Scolosanthus densiflorus* Urb., *Rondeletia berteroana* DC., *Oplonia spinosa* (Jacq.) Raf., *Eugenia dictyophylla* Urb., *Pictetia spinifolia* (Desv.) Urban and *Z. debilis*, serves as differentiating elements to establish the Yamasense area. These floristic peculiarities are related to the origin of the territory, which is why different connection forces can be established with the neighbouring territories in the various statistical studies on the rates of endemic species. Although these considerations might suggest a wide biogeographical territory, the absence of its own vegetation catenas, the fact it has a xerophytic vegetation and has served as a migratory route between the biogeographical area of the Eastern Caribbean and the Cibao Valley all lead us to propose this as a highly original biogeographical area **Figure 7**.

BT-2.5. The areas in the north of the island include five biogeographical districts (A1, A2, A4, A5 and A6) comprising the Northern Cordillera, the Samaná Pensinsula and the Eastern Cordillera, the last of which includes Los Haitises. The dominant materials are limestones or coralline rocks, although on the Atlantic coast to the north of the Northern Cordillera, there are islands of serpentines (Puerto Plata and Gaspar Hernández). Although the value of the It/Itc is mitigated by the effects of the trade winds, the thermotype continues to be infra, thermo and mesotropical; the ombrotype in this case ranges between the subhumid in the basal areas and the hyperhumid in territories more exposed to the trade winds. The macrobioclimate is tropical Caribbean-Mesoamerican Pluvial, and there are therefore no dry sites. The spiny forest occurs only in places with serpentines, as the territory acts as dry. The diversity of substrates, the bioclimate and the different dating of the areas accounts for the presence of 154 endemic species.

This territory has a predominance of ombrophilous forest with a rainy character due to the intense influence of the trade winds. This produces a dominance of a broadleaf evergreen forest with well-conserved formations of *P. montana* in Loma Diego de Ocampo, forests of *M. abbottii* to the northeast of the Northern Cordillera and, in somewhat less rainy areas, mahogany forests of *S. mahagoni* and *C. diversifolia*. In addition to the differences in flora and habitats with the rest of the territories, this biogeographical unit lacks the pine forests of *P. occidentalis*, typical of Bahoruco, Neiba and the Central province. In swampy freshwater areas, there are frequent coastal forests of *Pterocarpus officinalis* Jacq., and mangrove forests of *L. racemosa*, *A. germinans* and *Rhyzophora mangle* L., and to a lesser extent *C. erectus*. In all cases, the relation between the proposed biogeographical units has a Pearson's index of equal to or less than 1, and in some situations, the value of r is very low—$r = 0.73$ for A2–A4 and $r = 0.81$ for A4–A6—indicating a high degree of similarity between the two units **Figure 8**.

BA-A1. The Northern Cordillera district borders the Atlantic Coastal Plain to the north and the Cibao Valley to the south, and is the most recent mountain range on the whole island. There

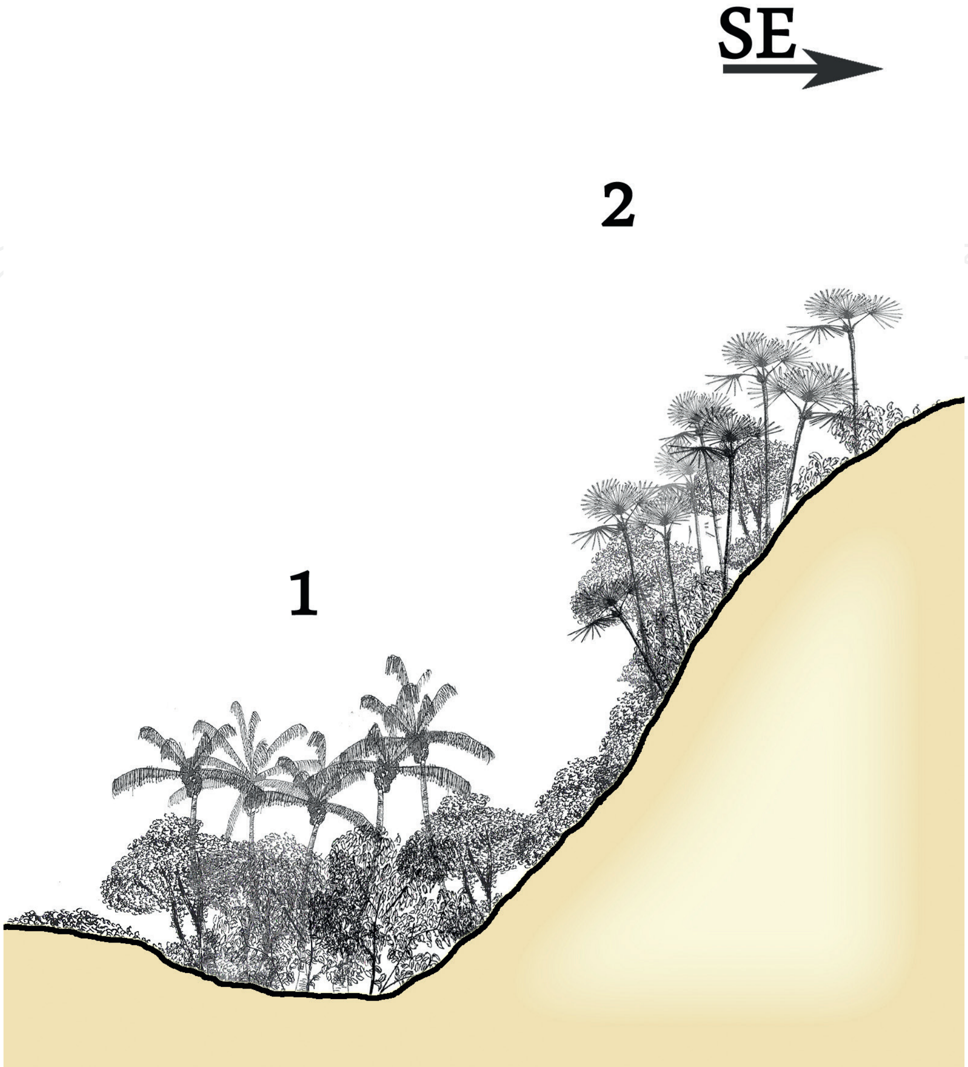

Figure 7. Vegetation catena of the Sierra de Yamasá. 1. Association *Coccotrino argentei-Tabebuietum berterii*. 2. Tangled scrubland of *Garcinio glaucescentis-Phyllanthetum numularioidis* [28].

is a predominance of limestone, schists, and volcanic and metamorphic rocks; the thermotype ranges from infra to mesotropical and the ombrotype is subhumid to hyperhumid. From the floristic point of view, we found 39 endemic species in this unit, representing one of the lowest rates on the island: *Coccotrinax boschiana* M. Mejía & R. García, *Eupatorium trichospermoides* Alain, *Gochnatia microcephala* (Griseb.) Jervis & Alain *var buchii* (Urb.) Alain, *Gonolobus domingensis* Alain, *Justicia spinosissima* Alain, *Sagraea abbottii* (Urb.) Alain, *Cytharexylum alainii* Moldelke, *Mecranium septentrionale* Stean, *Mikania platyloba* Urb. & Ekm. and others. The dominant vegetation is the sierran palm forest of *P. montana, C. racemiflora, D. tremulus, C. clusioides, Cyathea abbottii* Mason, *D. arboresus, T. occidentalis* and *O. capitatus*. On somewhat less cloudy sites and therefore at lower altitudes, there are forests of *M. abbottii*, a species that is also found in the eastern areas of the Central Cordillera and in Sierra Prieta. This species of *M. abbottii* is accompanied by *C. racemiflora, O. leucoxylon* and *S. berteriana*. The epiphyte *Vriesea ringens* (Griseb.) Harms is widespread in these forests, while remnants of mahogany forests

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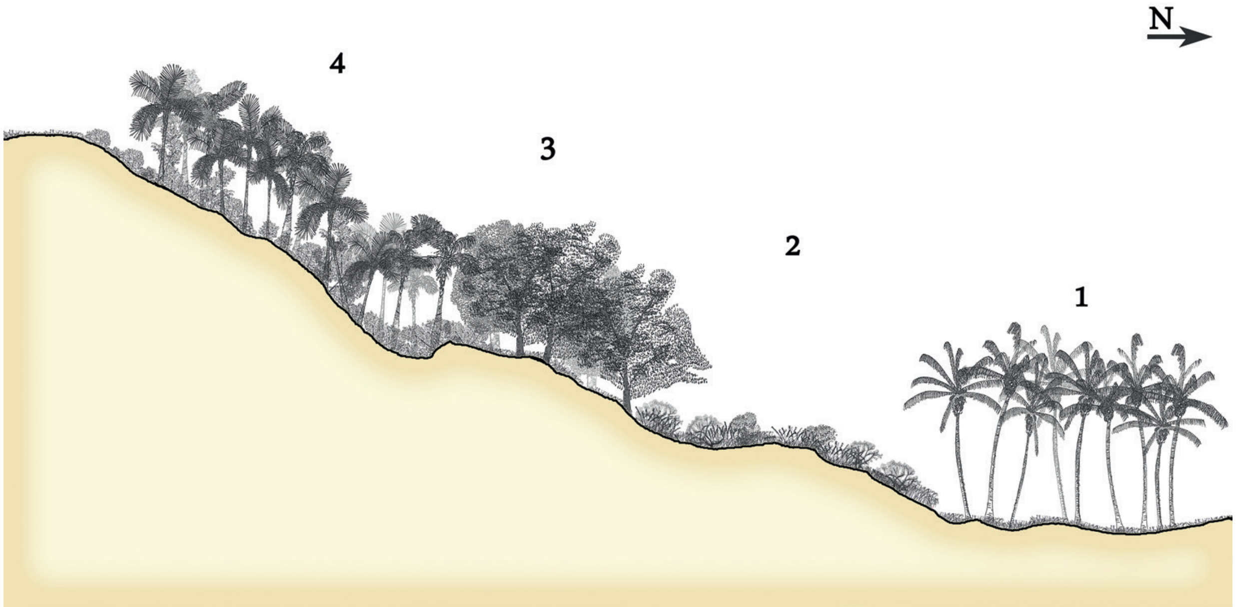

Figure 8. Vegetation catena of the Northern Cordillera. 1. Coconut cultivation. 2. Association *Leptogono buchii-Leptochloopsietum virgatae*. 3. Broadleaf mahogany forest of *Swietenia mahagoni*. 4. Sierran palm forest of *Prestoea montana*.

that have been highly altered by humans can be found in the drier areas at the foot of the mountain range. There are only small semi-deciduous copses of *S. mahagonii, C. diversifolia, Zanthoxylum martinicense* (Lam.) DC., *O. leucoxylon, Securidaca virgata* Sw., *Calophyllum calaba* L., *C. argenteum, C. oliviforme* and *G. guidonia*. In this case, the vegetation catena corresponds to a semi-deciduous mahogany forest, followed by a forest of *M. abbottii* and culminating in the more ombrophilous forest of *P. montana*.

BA-A2. The Coastal-Atlantic district is formed by small alluvial valleys of rivers with gentle gradients, with frequent marshes, isolated limestone and reef limestone. It is located to the north of the Northern Cordillera where there is a frequent presence of coconut, coffee and cocoa cultivation in addition to areas of cattle ('potreros' or pastures), so the natural vegetation is highly altered. However, there are 62 endemic species. The thermotype is infratropical and the ombrotype is subhumid and even humid, although the presence of serpentines in Puerto Plata and Gaspar Hernández causes soil xericity. We therefore include the spiny forest in the dry forest, characterised by the presence of specific plant communities such as *Zombia antillarum* (Desc. & Jacks.) Bailey and *S. cubense,* with a frequent presence in this type of forest of *L. buchii, Ouratea ilicifolia* (P.DC.) Bail., *C. sidaefolius, Eugenia maleolens* Pers. = (*Eugenia foetida* Poir.), *Jacquinia umbellata* DC., *C. jimenezii, R. aculeata, M. buxifolia, C. biflora, Vitex heptafila* A. L. Juss., *M. toxiferum, L. virgata, Cordia lima* (Desv.) R. & S., *Tabebuia polyantha* Urb. & Ekm., *C. haematomma, Diospyros caribaea* (A. DC.) Standl., *E. crenulata, C. oliviforme, C. ferrugineum, Bromelia pinguim* L., *Byrsonima spicata* (Cav.) HBK., *Poitaea galegoides* Vent., *Coccoloba pubescens* L., *Eugenia odorata* Berg and *C. linearis*. This is a tall serpentinicolous shrubland (copse) with 60–80% coverage, an average height of 3–4 m and abundant floristic diversity, located in Puerto Plata and Gaspar Hernández in infratropical subhumid-humid areas. This endemic habitat in the Coastal-Atlantic unit belongs to the association *Zombio antillari-Leptogonetum* *buchii* [28]. In the rest of the territory, the potential forest consists of *Swieteania mahagoni* and *C. diversifolia*. An important feature in this area is the presence of the Gran Estero, developed in the last 400–500 years from deposits of materials from the Northern Cordillera. This area is subject to frequent flooding, and is home to a forest of *P. officinalis* belonging to the association *Roystoneo hispaniolanae-Pterocarpetum officinalis* Cano, Veloz, Cano-Ortiz & Esteban 2009. It represents the outer edge of the mangrove forests of *R. mangle* that are typical in the broad channels and in Samaná Bay [23].

BA-A4. The Samaná Peninsula was isolated from the rest of the territory until 300–400 years ago. It constitutes a geomorphological unit dominated by karstic and limestone materials, with schists and marbles. The thermotype is infratropical and the ombrotype is subhumid-humid. The presence of escarpments (cliffs) has led to the installation of edaphoxerophilous communities that must be considered as dry forest, owing to the predominance of *P. polygonus, Z. debilis, A. antillarum, Eugenia samanensis* Alain, *B. simaruba, Capparis flexuosa* L., *Ficus velutina* H. & B. ex Willd., *E. maleolens, O. dilenii, Comocladia dodonaea* (L.) Britt., *Stigmaphyllom emarginatum* (Cav.) A. L. Juss. and *C. linearis*. This area has over 60 species of flora **Figure 9**.

BA-A5. The Eastern Cordillera is the oldest range in this biogeographical territory, and has a frequent presence of limestone, karstic landscapes, tufas, alluvial deposits and foothills. It serves as a separation from the great eastern coastal plain, with sporadic intrusions of Palaeozoic slates and basalts. The thermotype ranges from infra to mesotropical; the macrobioclimate is rainy and the ombrotype is subhumid to hyperhumid. The subhumid forest with a semi-deciduous character represents the transition between the dry and ombrophilous

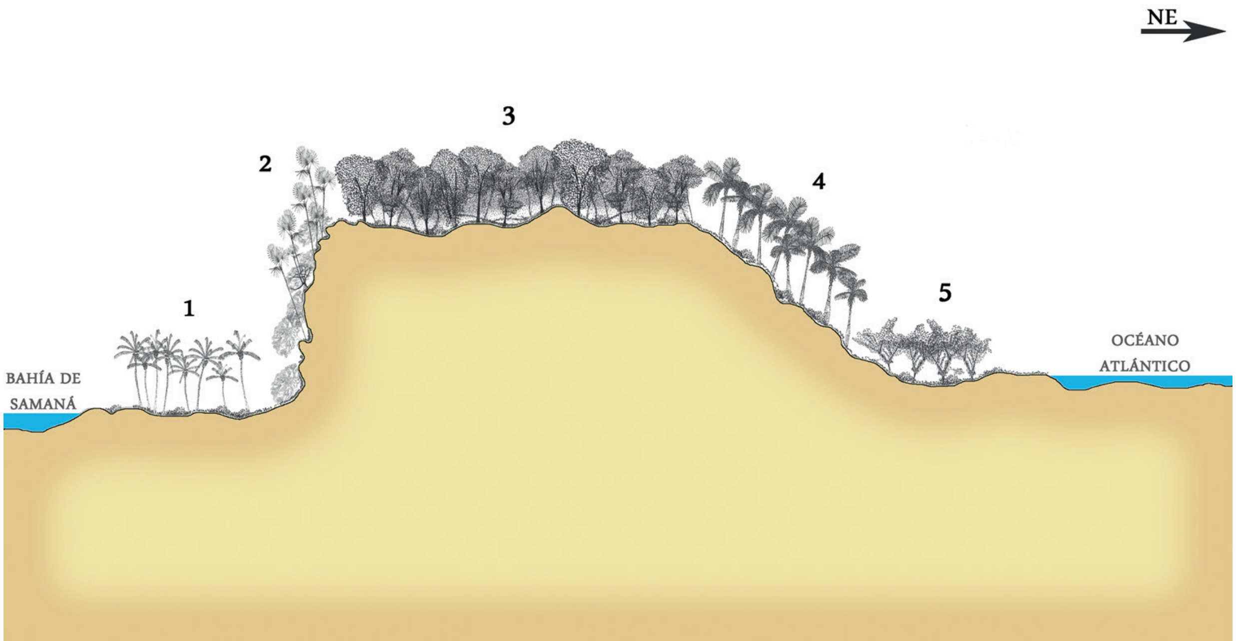

Figure 9. Vegetation catena of the Samaná Peninsula. 1. Coconut cultivation. 3. Broadleaf forest. 2. Community of *Coccothrinax gracilis* and *Bursera simaruba*. As. *Coccotrino gracili-Burseretum simarubae* [31]. 4. Cloud forest of *Prestoea montana*. 5. Forest of *Pterocarpus officinalis.* As. *Roystoneo hispaniolanae-Pterocarpetum officinalis*.

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ombrotype, where there is a predominance of *S. mahagoni, C. diversifolia* and *M. toxiferum*. These formations are found primarily in the basal areas of the Eastern Cordillera, in points of contact with the Eastern Caribbean area. However, these areas are severely altered as they are used for the cultivation of cocoa, coconut and coffee, and there is a widespread presence of the cattle enclosures known as 'potreros'. This is the reason for the low rate of endemic plants, with only eight species. Above an altitude of 600 m there is a broadleaf cloud forest with a frequent presence of *D. morototoni, Inga fagifolia* (L.) Willd., *T. occidentalis, Cyathea arborea* (L.) J. E. smith, *G. guidonia, P. montana, S. virgate* and *B. plumeriana.*

BA-A6. The rainfall in Los Haitises exceeds 2000 mm, and it is home to a vegetation with a dominance of *D. arboreus, G. guidonea, S. berteriana, P. montana* and *T. occidentalis*. We propose these territories as specific biogeographical areas due to the vegetation of the 'mogotes' (steep sided residual hills) that are typical of this territory, the high rate of endemic species—with 49 endemic plants—and the resulting diversity of habitats. Its relation with A5 gives a value of r = 0.91 and r = 0.71 with A4 (Samaná) **Figure 10**.

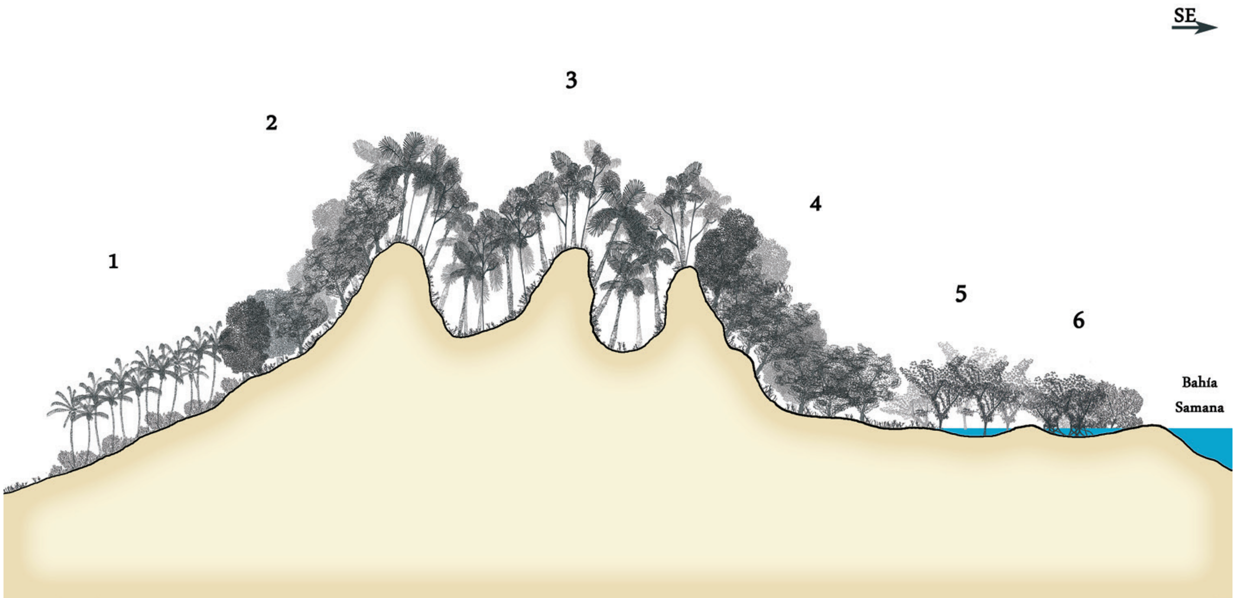

Figure 10. Vegetation catena of Los Haitises. 1. Coconut cultivation. 2. Broadleaf mahogany forest of *Swietenia mahagoni*. 3. Cloud forest of *Prestoea montana* and *Didymopanax tremulus*. 4. Broadleaf mahogany forest of *Swietenia mahagoni*. 5. Association *Roystoneo hispaniolanae-Pterocarpetum officinalis*. 6. Association *Machaerio lunati-Rhizophoretum manglis*.

5. Discussion

The island of Hispaniola is characterised by its abrupt differences in altitude—from 0 to 3175 m on Pico Duarte in the Central Cordillera—[38], the wide diversity of substrates and a pluviometric gradient that ranges from 400 to 4600 mm [35]. These three parameters, in combination with the isolation to which the various territories have been subjected, are key factors in explaining the existence of the current vegetation. For the study of this vegetation, we have established several large areas based on rainfall and temperature—dry, subhumid, humid-hyperhumid areas and high-mountain zones—as highlighted in [22, 23]. The bioclimatic analysis reveals the presence of several macrobioclimates on Hispaniola: tropical xeric, tropical pluviseasonal and tropical pluvial; all of which are reflected in different vegetation units: dry forest, subhumid broadleaf forest, cloud forest and high-mountain forest (pine forest) [35].

The dry areas have a tropical xeric macrobioclimate with a high rate of endemic species. These zones correspond closely to the study areas A3, A9 and A12 [39]. The vegetation in all the semiarid and dry areas is physiognomically very similar; it is dominated essentially by plants from the families *Agavaceae* and *Cactaceae* among others: *Lemaireocereus hystrix* (Haw.) B.&R., *Cylindropuntia caribae* (B.&R,) Kunth, *Consolea moniliformis* (L.) Haw., *Leptochloopsis virgata* (Poir.) Griseb., *Pilosocereus polygonus* (Lam.) B.& R., *Opuntia dillenii* (Fer.- Gawl) Haw., *Leptocereus weingartianus* (Hartm.) Britt. & Rose, *Acacia skleroxyla* Tuss., *Agave antillarum* Descourt. and *Pithecellobium unguis-cati* (L.) Mart. In the southwest of the island (A12), we establish two types of dry forest: first, the forest of Pedernales-Ceitillan (Procurrente de Barahona), growing on dogtooth limestone substrates. We highlight as endemic species *Melocactus pedernalensis* (Ait.) M. Mejía & R. García, *Galactia dictyophylla* Urb., *Coccoloba incrassata* Urb., *Caesalpinia domingensis* Urb. and *Guettarda stenophylla* Urb. The dry forest in area A9 with an *Io* = 2.7 has a somewhat lower rate of endemics. The most notable endemics and those which mark the difference with the dry forest of Pedernales are *Melocactus lemairei* (Monv.) Miq. *Neoabbottia paniculata* (Lam.) Britt. & Rose and *Coccotrinax spissa* Bailey. In area A3, located in the northwest of the island, there is a dry forest differentiated from the previous forests by the presence of a floristic contingent of endemic species, including *Salvia montecristina* Urb. & Ekm., *Mosiera urbaniana* Borhidi, *Croton poitaei* Urb., *Croton sidaefolius* Lam., *Guettarda tortuensis* Urb. & Ekm. and *Coccoloba buchii* Urb. The most representative plant communities in the dry areas belong to the following endemic habitats: *Lepotogono buchii-Leptochloopsietum virgatae* Cano et al. [24, 25], included in the serpentinicolous endemic alliance *Tetramicro canaliculatae-Leptochloopsion virgatae* Cano, et al. [24, 25]; *Crotono astrophori-Leptochloopsietum virgatae* Cano, et al. [24, 25], *Melocacto pedenalensi-Leptochloopsietum virgatae* Cano, et al. [24, 25], *Solano microphylli-Leptochloopsietum virgatae* Cano et al. [24, 25], included in the endemic alliance *Crotono poitaei-Leptochloopsion virgatae* Cano et al. [24, 25]; the dry forests published in Ref. [29], and the pine forests on serpentines of *Leptogono buchii-Pinetum occidentalis* Cano, Veloz & Cano-Ortiz 2011, which we include in the endemic alliance *Phyllario mummularioidi-Leptogonion buchi* Cano, Veloz, & Cano-Ortiz 2011.

Most of Hispaniola has a pluviseasonal tropical macrobioclimate and a predominantly subhumid ombrotype, with rainfall ranging from 1000 to 2000 mm and an ombrothermic index of *Io* = 3.7–4.3 (Parque Nacional del Este); *Io* = 4 (El Seibo); *Io* = 6.2 (Miches); *Io* = 5.4 (Jarabacoa) and *Io* = 5.9 (Mayaguana) (A7). The dominant vegetation in these areas is a subhumid broadleaf forest subjected to a dry season from December to April, which is why the floristic composition includes deciduous tree species due to water stress, such as *Bursera simaruba* (L.) Sarg. and *Swietenia mahagoni* (L.) Jacq., along with other species such as *Metopium toxiferum* (L.) Krug & Urb., *Krugidendron ferreum* (Vahl) Urb., *Acacia macracantha* H. & B. ex Willd., *Coccoloba diversifolia* Jacq. and *Bucida buceras* L. These formations contain important endemic elements such as the climber *Aristolochia bilobata* L. and the tree element *Melicoccus jimenezii* (Alain)

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Acev. Rodr., in addition to scrubland plants such as *Lonchocarpus neurophyllus* Benth., along with the other scrubland formations that become dominant and act as dynamic substitution stages. This is the case of *Zamia debilis* L., which coexists with the endemic species *Pereskia quisqueyana* Alain and *G. ekmanii* O.E. Schulz.

When these subhumid forests are located on perforated reef limestone, the territory acts as dry owing to the intense water losses from the soil, and present the floristic elements *P. polygonus, P. unguis-cati, L. weingartianus* and *Hylocereus undatus* (Haw.) Britt. & Rose. These formations connect with the dry forest in the southwest of the island. A similar phenomenon occurs in the rocky escarpments of Samaná, where there is a widespread frequent presence of *B. simaruba, Coccothrinax gracilis* Burret, *A. antillarum, L. weingartianum* and *O. dilleni*. These habitats tend to contain deciduous species due to water stress and correspond to the associations recently proposed by us [30]: *Chrysophyllo oliviformi-Sideroxyletum salicifolii* Cano & Veloz 2012 and *Zamio debilis-Metopietum toxiferi* Cano & Veloz 2012. In dry and subhumid areas, the serpenticolous vegetation is of great interest for conservation [28].

Humid areas have a tropical pluvial macrobioclimate, and there is therefore no dry season. Rainfall exceeds 2000 mm. These humid areas tend to be located in the mountain ranges of the Northern Cordillera, Central Cordillera, Sierra de Bahoruco, Eastern Cordillera, Los Haitises and on the Samaná Peninsula, all of which concentrate the humid rainy formations, namely broadleaf ombrophilous forests whose physiognomy varies from one place to another. In the Loma La Herradura (Eastern Cordillera), the dominant plants are *Sloanea berteriana* Choisy, *Ormosia krugii* Urb., *Didymopanax morototoni* (Aubl.) Dcne. & Planch. and *Oreopanax capitatus* (Jacq.) Dcne. & Planch. Towards the stream beds, there is a presence of the sierran palm forest of *P. montana* (Grah.) Nichol, whose associated flora are *Guarea guidonia* (L.) Sleumer, *D. morototoni, Alchornea latifolia* Sw. and *Eugenia domingensis* Berg [11].

In the Central Cordillera (A16), for example, in the Ébano Verde Science Reserve, the ombrophilous forest is dominated by species from the genus *Magnolia*, which are endemic to the island: *Magnolia pallescens* Urb. & Ekm. and *Magnolia domingensis* Urb., along with the 'palo de viento' *Didymopanax tremulus* Krug & Urb., *Ocotea leucoxylon* (Sw.) Lanessan, *Persea oblongifolia* Kopp, *Cyrilla racemiflora* L., *Cecropia schreberiana* Miq. and *Dendropanax arboreus* (L.) Decne. & Planch. This forest is home to the endemic species *Myrsine nubicola* A. Liogier, *Odontadenia polyneura* (Urb.) Woods, *Marcgravia rubra* A. Liogier, *Pinguicula casabitoana* J. Jiménez and *Tabebuia vinosa* A. Gentry. As in the Loma La Herradura, the sierran palm forest of *P. montana* can be found in the most humid gorges. When these plant communities become altered and their coverage decreases, they are quickly superseded by tropical fern or herb formations of *Dicranopteris pectinata* (Willd.) Underw. and *Gleichenia bifida* (Willd.) Spreng. [9].

In the Loma Humeadora, the cloud forest of 'palo de viento' *D. tremulus* grows at an altitude of 1100–1315 m, and this species is associated with *Clusia clusioides* (Griseb.) D'Arcy, *C. racemiflora, Ocotea foeniculacea* Mez, *Lyonia alainii* W. Judd and *P. montana*. Descending to 850–1100 m on slopes with a gradient of 45–60° but with abundant litterfall that effectively retains water, and in gorges, *P. montana* becomes dominant associated with *A. latifolia, O. leucoxylon, Bombacopsis emarginata* (A. Rich.) A. Robins., *S. berteroana, Mora abbottii* Rose & Leon., *Turpinia occidentalis* (Vent.) G. Don, *Bactris plumeriana* Mart. and *Ditta maestrensis* Borhidi [8].

In the relevés taken both in the Central Cordillera and in Sierra Bahoruco, in addition to the existence of different substrates, the broadleaf forest shows clear floristic differences, with *M. pallescens* and *M. domingensis* in the Central Cordillera and *Magnolia hamorii* Howard in the Sierra de Bahoruco. The forest of *M. hamorii* and *D. tremulus* has a large number of associated endemic species such as *Lasianthus bahorucanus* Zanoni, *Psychotria guadalupensis* (DC.) Howard, *H. domingensis* Urb. *Mecranium ovatum* Cog. (local endemic), *Vriesea tuercheimii* (Mez.) L.B. Smith, *Macrocarpaea domingensis* Urb. *Cestrum daphnoides* Griseb. *Hypolepis hispaniolica* Maxon, *Columnea domingensis* (Urb.) Wiehler and *Ilex tuerckheimii* Loes. This vegetation was included in Ref. [22] in the classes *Ocoteo-Magnolietea* Borhidi & Muñiz in Borhidi, Muñiz & Del Risco 1979 and in *Weinmannio-Cyrilletea* Knapp 1964.

The study of high-mountain areas took place in the Central Cordillera (A16), crossing the mountain from Constanza to San José de Ocoa, and in the Sierra de Bahoruco (A12). From the physiognomic point of view, the plant formations sampled between 1203 m (Sierra Bahoruco) and 2383 m (Central Cordillera) are similar, corresponding to a pine forest of *Pinus occidentalis* Sw. These are territories with lower rainfall, as the sea of clouds from the trade winds originating the broadleaf forest lies beneath. The temperature may drop to 0°C in winter. The xericity and the low temperatures in the high mountains result in the presence of a pine forest of *P. occidentalis*, which in the Central Cordillera is accompanied by endemic species, with 8–10 endemic plants per sampling unit. This is also the case in the Sierra de Bahoruco, where the pine forest has an average of 20 endemic species per sampling. The endemic character of these two mountains is caused by their former isolation.

In the Central Cordillera, these forests grow on siliceous substrates and are home to a large number of endemic species such as *I. tuerckheimii*, *Ilex fuertesiana* (Loes.) Loes. *Garrya fadyenii* Hooker, *Mikania barahonensis* Urb., *Myrica picardae* Krug & Urb., *Rubus eggersii* Rydberb., *Tetrazygia urbaniana* (Cogn. in Urb.) Croizat ex Moscoso and *Fuchsia pringsheimii* Urb.; the endemic and specific parasitic species *P. occidentalis*, *Dendropemon pycnophyllus* Krug & Urb. and *Dendropemon constantiae* Krug & Urb. are of particular importance. In the understorey of this forest, there is a high frequency of the grass *Isachne rigidifolia* (Poir.) Urb., and when the pine forest is cleared, it is substituted by a formation of single-culm grasses dominated by *D. domingensis* Hack. & Pilg., which occupies large extensions above 1800 m in the Central Cordillera.

The pine forest of *P. occidentalis* growing on limestone in the Sierra de Bahoruco has a different floristic composition, in which the endemic species *Coccothrinax scoparia* Becc., *Agave intermixta* Trel., *Senecio barahonensis* Urb., *Cestrum brevifolium* Urb., *Eupatorium gabbii* Urb., *Lyonia truncatula* Urb., *Sideroxylon repens* (Urb. & Ekm.) TD. Pennington, *Cordia selleana* Urb., *Narvalina domingensis* Cass. and *Galactia rudolphiodes* (Griseb.) Benth. & Hook. *var. haitiensis* Urb. are of particular interest, along with some other endemic herbs such as *Pilea spathulifolia* Groult, *Tetramicra ekmanii* Mansf., *Artemisia domingensis* Urb., *Gnaphalium eggersii* Urban and *Polygala crucianelloides* DC. High-mountain pine forests that have been diagnosed by us as endemic habitats of Hispaniola [26] are *Dendropemom phycnophylli-Pinetum occidentalis* Cano, Veloz & Cano-Ortiz 2011 and *Cocotrino scopari-Pinetum occidentalis* Cano, Veloz & Cano-Ortiz 2011.

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5.1. Distribution analysis of endemic species

The study of the 19 areas in Hispaniola shows a wide distribution of endemic species, but with three nuclei of particular interest due to their high rate of endemic plants, as highlighted by the comparative treatment between the total number of endemic species present in an area and the endemic species that are exclusive to this area. There are a total of 2094 endemic species in the 19 areas, of which 1162 are exclusive. The difference between 2094 − 1162 = 932, confirming the high number of endemic species distributed all over the island. The highest concentrations are found in areas A12, A16, A13 (**Table 1**), whereas the rest of the areas have a lower number of endemic species, with a slight increase in areas A4 and A9. These areas continue to be of interest as they contain endemic species that are exclusive to the territory, and even endemic genera, as occurs in A18 and A19 (**Figure 11**).

Plots	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19
1	20	15	24	36	1	12	23	2	26	1	27	482	129	11	28	278	29	8	10
2	40	61	68	127	9	45	64	7	87	9	72	699	173	29	64	440	65	20	15

1. No. of exclusive endemic taxa by area. 2. Total number of endemic taxa by area

Table 1. Comparative analysis of the total endemic species in each area with the number of endemic species exclusive to that area.

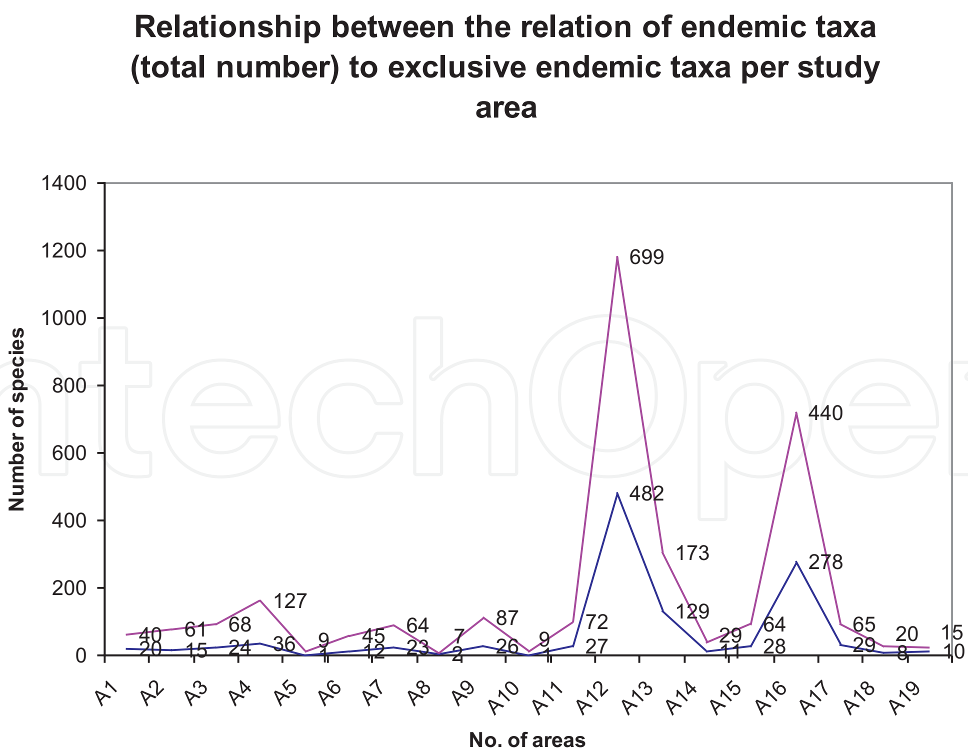

Figure 11. Ratio of total endemic species in each area to endemic species exclusive to that area.

6. Conclusions

Hispaniola has recently been elevated by us to the rank of biogeographical province [2, 22, 24], having previously been treated with the rank of biogeographical sector [4] and included in the province of the Antilles. In previous studies, we raised it to the rank of superprovince of the Central-Eastern Antilles and included Hispaniola in it, which along with a group of small neighbouring islands—Beata, Saona, Gonave and Tortuga—constitute the province of Hispaniola. In the current study, we propose a biogeographical typology with the rank of district for both countries (Dominican Republic and Republic of Haiti) in the biogeographical province of Hispaniola, in which we establish five biogeographical territories (sectors) and 19 areas (districts), in the Caribbean-Mesoamerican region. This proposal is based on geological, climatic and bioclimatic aspects and on studies of the flora and vegetation.

The high number of genera and endemic species in areas A12, A13 and A16 justifies their proposed designation as being of special interest for conservation.

Superprovince of the Central-Eastern Antilles. Province of Hispaniola. 1. **Central subprovince**. 1.1. Central BT. BA-A16. Central-Eastern. 2. **Caribbean-Atlantic subprovince**. 2.1. Bahoruco-Hottense BT. BA-A12. Bahoruco-La Selle. BA-A13. Hottense. 2.2. Neiba-Matheux-North-eastern BT. BA-A14. Neiba-Matheux. BA-A15. North-western. BA-A17. Central-Western. BA-A19. Tortuga Island. 2.3. BT Azua- San Juán-Hoya Enriquillo-Port au Prince-Artiobonite-Gonaivës. BA-A9. Azua-Sán Juán-Hoya Herniquillo. BA-A10. Central Plain. BA-A11. Port au Prince-Arbiobonite-Gonaives. BA-A18. Gonave Island. 2.4. Caribbean-Cibense BT. BA-A3. Cibao Valley. BA-A7. Eastern Caribbean. BA-A8. Yamasense. 2.5. Northern BT. BA-A1. Northern Cordillera. BA-A2. Coastal Atlantic. BA-A4. Samanense. BA-A5. Eastern. BA-A6.Haitiense **Figure 12**.

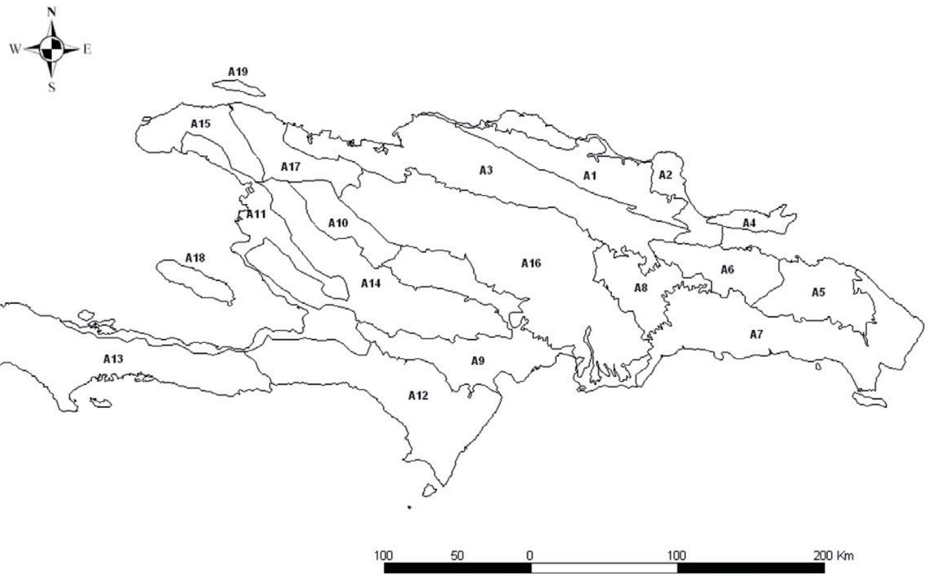

Figure 12. Map of biogeographical areas (districts) of Hispaniola. A1. Northern Cordillera. A2. Coastal-Atlantic District. A3. Cibao Valley. A4. Samanense. A5. Eastern. A6. Haitiense. A7. Eastern-Caribbean. A8. Yamasense. A9. Azua-Sán Juan-Lago Herniquillo. A10. Central Plain (Haiti). A11. Port au Prince-Ariobonite-Gonaivës. A12. Bahoruco-La Selle. A13. Hottense. A14. Neiba-Matheux. A15. Northwest Haiti. A16. Central-Eastern. A17. Central-western (Massif du Nord). A18. Gonave Island. A19 Tortuga Island.

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