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# Advances in the Knowledge of the Vegetation of Hispaniola (Caribbean Central America)

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## Abstract

The vegetation types and floristic diversity in the Dominican Republic are analysed, a territory with a tropical climate and ombrotypes that range from dry to humid-hyperhumid, due to the Atlantic winds and the phenomenon known as rain shadows. The presence of high mountains and different substrates have led to a rich flora, and as a result, a high diversity of habitats, among which two large forest types are particularly notable: (1) the dry forest with 81 endemic species, of which 10 are trees, 65 shrubs, 5 climbers and 1 herbaceous species, and an absence of epiphytes and (2) the cloud forest with 19 trees, 20 shrubs, 8 climbers, 4 epiphytes, and 6 herbaceous species. In all cases, these plant communities are regarded as endemic due to their high rate of endemic species. In spite of their importance for conservation, these habitats are highly deteriorated due to deforestation for agriculture, to obtain timber, and even to add to tourism infrastructures.

**Keywords:** endemics, conservation, deterioration, diversity, forest, structure

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## 1. Introduction

The analysis of the vegetation of Hispaniola reveals different situations in terms of their state of conservation, the floristic diversity of the communities and habitat types. The process observed in the study territory resembles the reports by other authors for other countries: namely that agriculture and tourism are the primary factors affecting conservation. The island of Hispaniola has a wide floristic diversity with over 6000 endemic plants, and a high

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## 2. Materials and methods

A vegetation study was carried out on the island of Hispaniola, with particular reference to the forests in the Dominican Republic. Sixty-five ecologically and physiognomically homogeneous plots were selected, and the species present on the plots were noted and assigned a phytosociological abundance-dominance index; this index was subsequently converted to the Van der Maarel (1979) index [12]. We used our previous work as a basis for the bioclimatic and biogeographical classification of the territory [13, 14].

A statistical treatment was applied to obtain cluster and PCA. To separate the two major vegetation units (cloud forest and dry forest), we conducted a regression analysis (ANOVA) for the species *Magnolia hamorii* Howard (Maha), *Sideroxylon salicifolium* (L.) Sw. (Sisa), *Metopium toxiferum* (L.) Krug. & Urb. (Meto) and *Sideroxylon foetidissimum* Jacq. (Sifo); and a canonical correspondence analysis (CCA) between the Io (ombrothermic index) and ETP (potential evapotranspiration) of the 65 plots in the sample and the dominant species, located at altitudes below 1,200 m: *Hyeronima domingensis* Urb.(Hydo), *Magnolia hamorii* (Maha), *Magnolia pallescens* Urb. & Ekm.(Mapa) 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), a native Caribbean species of subtropical and tropical areas [15]. Outside its distribution area (Central America), this tropical plant acts as an exotic, and is a well adapted in other tropical areas such as southern China [16].

## 3. Results

The results of the ANOVA regression analysis reveal the close correlation between the species present in the forests and the potential evapotranspiration and Io index. The species in the cloud forest are closely correlated with the ombroclimatic index, and in the dry forest with potential evapotranspiration, as shown in **Figures 2** and **3** where R<sup>2</sup> always higher than 0.9.

The results of the regression analysis are Maha (*Magnolia hamorii*):  $y = 0.08585x - 1.5$ ,  $R^2 = 0.9951$ ; Sisa (*Sideroxylon salicifolium*):  $y = 0.5799x - 0.4$ ,  $R^2 = 0.9994$ ; Meto (*Metopium toxiferum*):  $y = 0.4065x - 0.5$ ,  $R^2 = 0.9979$ ; Sifo (*Sideroxylon foetidissimum*):  $y = 0.633x - 0.5$ ,  $R^2 = 0.9708$ ; highlighting the clear correlation between the abundance values for these species and the values for Io and ETP (ANOVA) (**Figure 2**).

The CCA analysis shows two groups of inventories: R1-R39, representing the dry forest and dominated by *Bursera simaruba* (L.) Sarg., *Metopium toxiferum* (L.) Krug. & Urb., *Pilosocereus polygonus* (Lam.) B. & R., *Sideroxylon foetidissimum* Jacq., *Sideroxylon salicifolium* (L.) Sw., *Prosopis juliflora* L., *Lemaireocereus 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. (**Figure 3**).

The PCA analysis of 28 dominant species produces 2 groups such as A (cloud forest) and B (dry forest) (**Figure 4**). The two groups A and B in the PCA are maintained in the cluster.

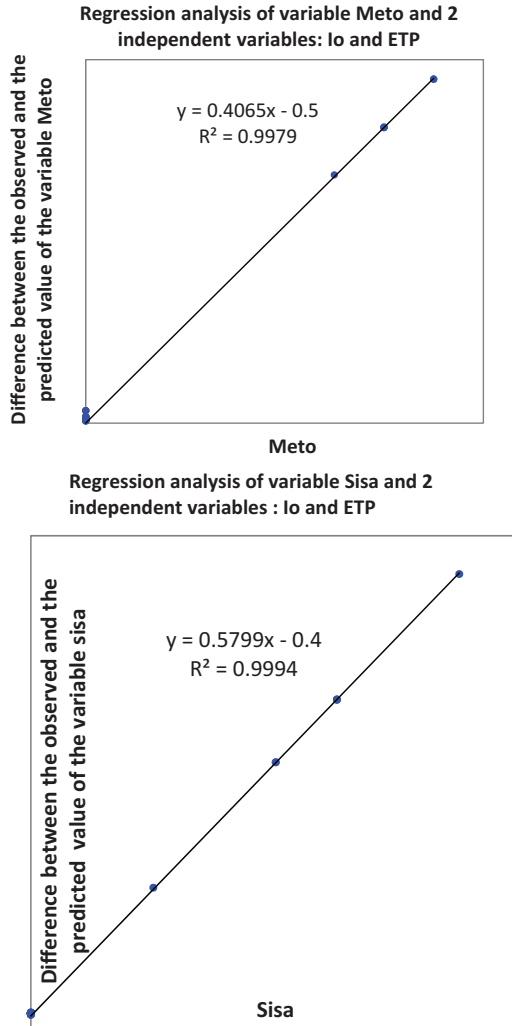


Figure 2. Regression analysis: Meto, Sisa and Io, ETP.

The forests in group B are separated into two subgroups such as G1 and G2. G1 (R1–R18) represents the communities described for the subhumid and humid territories in which the substrate takes prevalence and allows the entry of dry forest species. G2 (R19–R39) is classified into four plant communities.

Subgroup G2<sub>1</sub> includes the inventories R19–R48 taken in the Cibao Valley (Monte Cristi), in infratropical environments with a semiarid ombrotype on quaternary loans, with 17 endemic species, *Karwinskia coloneura* Urb. and *Justicia abeggii* Urb. & Ekm., exclusive to the territory. The subgroup is dominated by *Prosopis juliflora* L., *Lemaireocereus hystrix* Britt. & Rose, *Harrisia nashii* Britt. & Rose, *Consolea moniliformis* (L.) Haworth in Steud, and *Pilosocereus polygonus* (Lam.) B. & R.

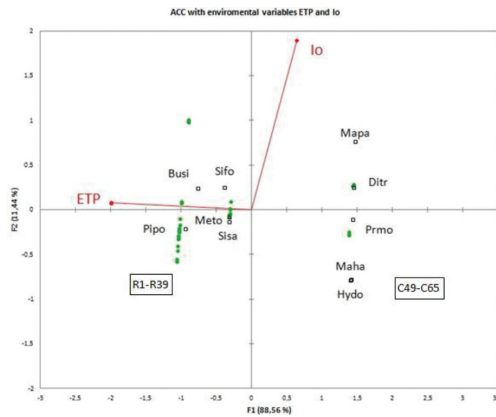


Figure 3. Canonical correspondence analysis (CCA).

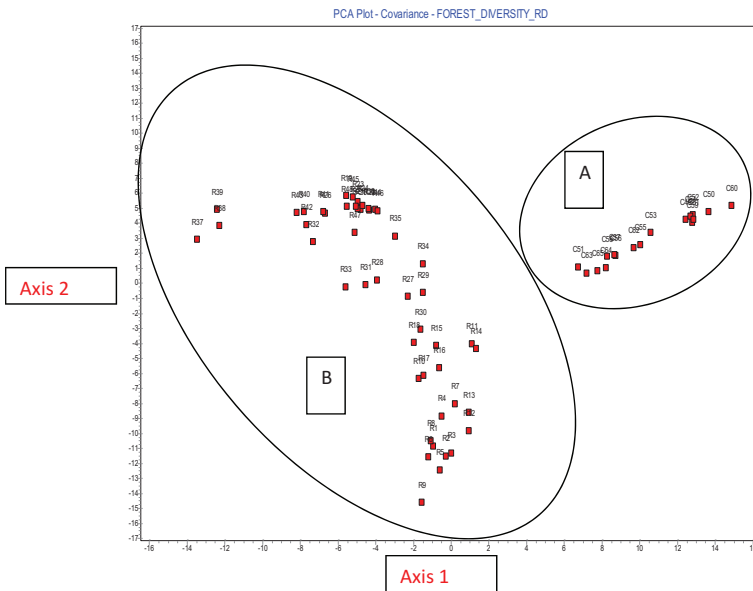
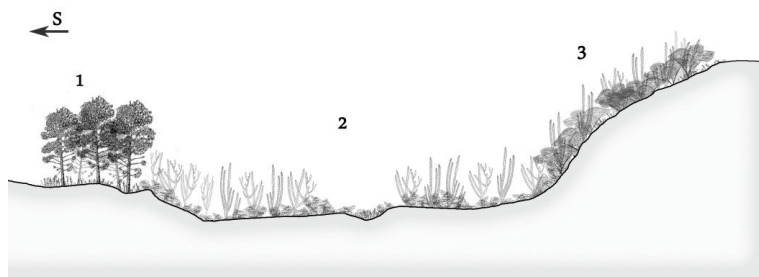


Figure 4. Principal component analysis (PCA) for dry and cloud forest.

Subgroup G<sub>2</sub> includes the inventories R27–R33, 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. (Figure 5).



**Figure 5.** Profile of the vegetation of the dry forest of Cibao Valley. 1. *Leptogono buchii*-*Pinetum occidentale*. 2. *Harrisio nashii*-*Prosopidetum juliflorae*. 3. *Crotono poitaei*-*Erythroxyletum rotundifolii* [17].

Subgroup G2<sub>3</sub> (R40–R43) is located in areas of Ázua, Bani, San Juan, Enriquillo and Port au Prince (Haiti), which have a dry infratropical thermotype and are home to a spinescent forest growing on Miocene loams. In this forest, there is a predominance of *Guaiacum officinale* L., *Capparis cynophallophora* L., *Bourreria divaricata* (DC.) G. Don and *Cylindropuntia caribaea* (Britt. & Rose) Kunth; and 16 endemic plants, including particularly *Coccolobos spissa* Bailey, and *Neoabbottia paniculata* (Lam.) Britt. & Rose.

G2<sub>4</sub> contains the inventories R37–R39 taken in the dry forest between Pedernales and Barahona. The territory has a semiarid infratropical thermotype and reef limestone substrates. This forest is rich in coarse and spiny plants such as *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, *Malpigina 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 that they constitute specific endemic habitats (**Figures 6 and 7** and **Photo 1**).

The type A forest group is located in the northern areas of the great mountains; Cordillera Central, Northern, Bahoruco, Oriental, Los Haitises, all of which have an ombrotype that oscillates between the subhumid and the hyperhumid, and a thermotropical to supratropical thermotype (**Photos 2–4**).

The territory of the Dominican Republic, including some small adjacent islands, covers 48,198 km<sup>2</sup> and accounts for over two-thirds of the territory of the island of Hispaniola, located between parallels 17 and 19°N, and part of the Greater Antilles. The main aim of this chapter is to determine the forest vegetation (cloud forest), floristic diversity, and state of conservation in areas with high rainfall in the Dominican Republic. Most of the botanical studies to date are floristic in nature, and include the studies on the Sierra de Bahoruco, which highlight the substantial rainfall of up to 4000 mm and the very high rate of endemic species. Studies by various authors in the central, northern, and eastern mountain ranges containing the cloud forest [18–24], and which together with our own previous studies, form the basis of this present work [25–35]. All the above-mentioned studies focus on the knowledge of the

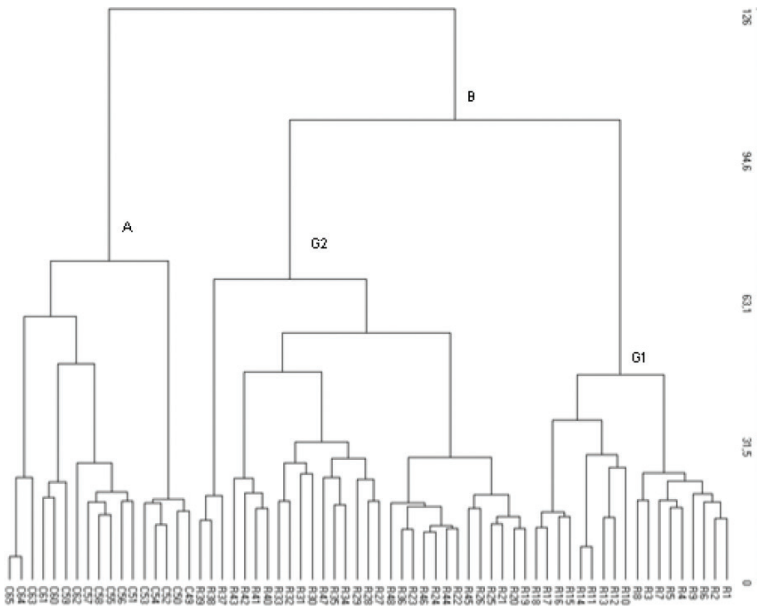


Figure 6. Cluster analysis. Diversity of forest types.

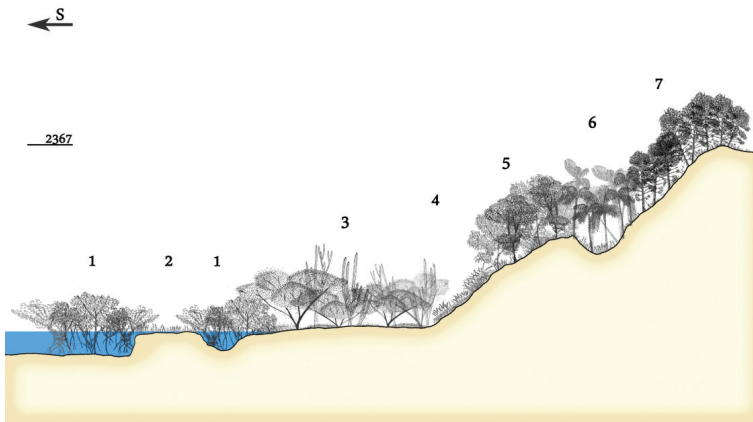


Figure 7. Profile of the vegetation of the cloud forest of Sierra Bahoruco-Barahona-Pedernales 1. *Rhabdadenia biflora-Laguncularietum racemosae* and *Lonchocarp pycnophylli-Conocarpetum erecti*. 2. Salt marshes of *Batidi-Salicornietea*. 3. *Lonchocarp pycnophylli-Cylindropundietum caribaeae*. 4. *Melocacto pedernalensis-Leptochloopsietum virgatae*. 5. Broad-leaved forest. 6. Cloud forest of *Prestoea montana* [17].

flora, with passing references to the vegetation; herein lies the interest of this work. The floristic approach is important as these are biodiversity hotspots [36], with a 33% rate of endemics compared to the total flora.



**Photo 1.** Dry forest of *Pilosocereus polygonus* (Cibao Valley, Dominican Republic).



**Photo 2.** Subtropical forests of *Pinus occidentalis* in the Cordillera Central, and the heath grass formation of *Danthonia domingensis*.



**Photo 3.** Meso and supratropical cloud forests in the Cordillera Central.

In the analysis of the diversity of the 2 forest types (dry and rain); in the dry forest, there are 61 tree species and 5 stipes, of which 10 are endemic; compared to 75 in the cloud forest and 4 stipes, of which 19 are endemic. There is more number of epiphytes in the cloud forest, with





**Photo 4.** Vegetation of Los Haitises (A6). 1. Latifoliolate mahogany forest *Swietenia mahagoni*. 2. *Ormosia krugii* and *Prestoea montana* which is enriched on the summits with *Didymopanax morototoni*.

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

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

36 species, than in the dry forest, with 13 species (**Table 1**). Shannon’s index gives values of 3384 and 3528 for the dry and cloud forest, respectively.

#### 4. Discussion and conclusions

There are areas with 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 extension toward western Haiti, including Beata Island and the Cibao Valley, Monte Cristi. These territories have a high rate of endemics, therefore, the habitats where they grow should also be considered endemic. The cloud forest, however, is always found in the mountains as a consequence of the moisture-laden winds from the Atlantic. In both cases, the forest distribution 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.

The presence of two groups of forests due to the humidity gradient [37] in the Dominican Republic, which varies between semiarid and hyperhumid. This classification is based on the floristic composition and less on forest structure [38]. The cloud forest in Ebony Green (Cordillera Central) has suffered frequent fires, causing an invasion of *Gleichenia bifida* and *Dicranopteris pectinata*, which prevent the germination and development of primary forest species and in turn leads to a loss of seeds and intensification in the rate of invasive species. This situation requires rapid human intervention [39] (**Photo 5**), which should be aimed at reinforcing the seed bank of species of interest to conservation in botanical gardens in the Caribbean



**Photo 5.** Deforested area in the central range invaded by *Gleichenia bifida* (Dominican Republic).



**Photo 6.** Deforestation of the dry forest in the Cibao Valley (Dominican Republic).

[40]. The rain forests on the ridges and mountain ranges of Hispaniola are rich in *Cecropia schreberiana* Miq. [41] and species of the genera *Magnolia*, *Prestoea*, *Didymopanax*, *Cyathea*; the greatest botanical diversity is found in the oldest mountains, while the younger formations are less floristically diverse [42]. The diversity of trees and epiphytes is lower in the dry forest than in the cloud forest, but there are more succulents from the Cactaceae and Agavaceae family; we found no interactions between these families and parasitic elements in the Dominican Republic as occur in Puerto Rico. This type of dry forest dominated by succulent species has a low rate of epiphytes (4%) compared to 15% for the cloud forest. Epiphytes are renowned for their abundance in dry forests: *Tillandsia recurvata* (L.) L, *Broughtonia domingensis* (Lindl.) Rolf, *Tillandsia balbisiana* Schultes, *Tillandsia usneoides* (L.) L, and *Bromelia pinguin* L.

Deforestation caused by fire or heavy machinery is causing changes in the landscape, leading to the loss of species and plant cover (**Photo 6**) in areas where there is insufficient knowledge of the flora and vegetation, despite the fact that, so far, we have described nine phytosociological classes and more than 20 associations and plant communities on the island.

Global syntaxonomical checklist of the known vegetal diversity of Hispaniola (syntaxonomical approach to Hispaniola)

Number of classes, orders, alliances and associations recognized so far. Classes: 9; Orders: 11; Alliances: 13; Associations: 29

CHRYSOBALANO-ANNONETEA GLABRAE Borhidi & Muñiz in Borhidi, Muñiz & Del-Risco 1979

Tabebuio-Bucidetalia (Lvov 1967) Borhidi & Del-Risco in Borhidi, Muñiz & Del-Risco 1979

Marcgravio rubrae-Pterocarpion officinalis Cano, Velóz, Cano-Ortiz et Esteban Ruiz 2009

1-Roystoneo hispaniolanae-Pterocarpetum officinalis Cano, Velóz, Cano-Ortiz et Esteban Ruiz 2009

BYRSONIMO-PINETEA CARIBAE Samek and Borhid in Borhidi et al. 1979

Pinetalia occidentalis-maestrensis Knapp 1964 in Borhidi et al. 1979

Ilici tuerckheimi-Pinion occidentalis Cano, Velóz et Cano-Ortiz 2011

1-Dendropemon phycnophylli-Pinetum occidentalis Cano, Velóz et Cano-Ortiz 2011

2-Cocotrinio scopari-Pinetum occidentalis Cano, Velóz et Cano-Ortiz 2011

RHIZOPHORO-AVICENNIETEA GERMINANTIS Knapp (1964) em. Borhidi & Del-Risco in Borhidi et al. 1979

Rhizophoretalia Cuatrecasas 1958

Al. Dalbergio-Rhizophorion manglis (Borhidi 1991) Cano, Cano-Ortiz, Velóz, Alatorre et Otero 2012

1-Machario lunati-Rhizophoretum manglis Cano, Cano-Ortiz & Velóz ex Cano, Cano-Ortiz, Velóz, Alatorre et Otero 2012

Avicennietalia germinantis Cuatrecasas 1958

Conocarpo-Laguncurion racemosae Cuatrecasas 1958

2-Batidi-Avicennietum germinantis Borhidi & Del-Risco & Borhidi 1991

(syn. As. Laguncurio racemosae-Avicennietum germinantis Reyes & Acosta 2003; As. Avicennietum germinantis Reyes & Acosta 2003)

3-Rhabdadenio biflorae-Laguncularietum racemosae Cano, Cano-Ortiz & Velóz ex Cano, Cano-Ortiz, Velóz, Alatorre et Otero 2012

4-Conocarpo erectae-Coccolobetum uviferae Reyes in Reyes & Acosta 2003

(syn. Conocarpetum erectae Reyes in Reyes & Acosta 2003)

5-Sthalia monospermae-Laguncularietum racemosae Cano, Cano-Ortiz & Velóz ex Cano, Cano-Ortiz, Velóz, Alatorre et Otero 2012

6-Lonchocarp pycnifolii-Conocarpetum erecti Cano, Cano-Ortiz & Velóz ex Cano, Cano-Ortiz, Velóz, Alatorre et Otero 2012

TABEBUIO-BURSERETEA Knapp (1964) Borhidi 1991

Tabebuio-Burseretalia Knapp (1964) Borhidi 1991

Leptogono buchii-Tabebuion berterii Cano, Cano-Ortiz, del Río, Velóz et Esteban Ruíz 2014

1-Cocotrino argentei-Tabebuietum berterii Cano, Cano-Ortiz, del Río, Velóz et Esteban Ruíz 2014

2-Zombio antillari-Leptogonetum buchii Cano, Cano-Ortiz, del Río, Velóz et Esteban Ruíz 2014

Calliandro haematomae-Phyllanthion nummularioidis Cano, Cano-Ortiz, del Río, Velóz et Esteban Ruíz 2014

3-Garcinio glaucescentis-Phyllanthetum numularioidis Cano, Cano-Ortiz, del Río, Velóz et Esteban Ruíz 2014

4-Tabebuio ophiolithicae-Randietum aculeati Cano, Cano-Ortiz, del Río, Velóz et Esteban Ruíz 2014

PHYLLANTHO-NEOBRACETEA VALENZUELANAE Borhidi & Muñiz in Borhidi et al. 1979

Ariadno-Phyllanthetalia Borhidi & Muniz in Borhidi et al. 1979

Tetramicro canaliculatae-Leptochloopsis virgatae Cano, Velóz et Cano-Ortiz 2010

1-Leptogono buchii-Leptochloopsietum virgatae Cano, Velóz et Cano-Ortiz 2010

Rondeletio christii-Pinion occidentalis Cano, Cano-Ortiz, del Río, Velóz et Esteban Ruíz 2014

2-Leptogono buchii-Pinetum occidentalis Cano, Veloz & Cano Ortiz 2011

COCCOTHRINACETO-PLUMERIETEA Knapp in Boirhi 1991

Lantano-Cordietalia Borhidi in Borhidi et al. 1979

Crotono poitaei-Leptochloopsis virgatae Cano, Velóz et Cano-Ortiz 2010

1-Crotono astrophori-Leptochloopsietum virgatae Cano, Velóz et Cano-Ortiz 2010

2-Melocacto pedernalensis-Leoptochloopsietum virgatae Cano, Velóz et Cano-Ortiz 2010

3-Solano microphylli-Leptochloopsietum virgatae Cano, Velóz et Cano-Ortiz 2010

Eugenio-Metopietalia toxiferi Knapp (1942) Borhidi 1991

Eugenio-Capparidion Borhidi in Borhidi et al. 1959

4-Chrysophyllo oliviformi-Sideroxyletum salicifolii Cano & Velóz 2012

5-Zamio debilis-Metopietum toxiferi Cano & Velóz 2012

6-Cocotrino gracili-Burseretum simarubae Cano, Cano-Ortiz et Velóz 2015

CERCIDI-CEREETEA Borhidi 1996

Ritterocereetalia hystricis Borhidi 1996

Harrio nashii-Acacion skleroxylae Cano, Cano-Ortiz & Velóz ex Cano-Ortiz, Musarella, Spampinato, Velóz et Cano 2015

1-Harrisio nashii-Prosopidetum juliflorae Cano, Cano-Ortiz & Velóz ex Cano-Ortiz, Musarella, Spampinato, Velóz et Cano 2015

2-Crotono poitaei-Erythroxyletum rotundifolii Cano, Cano-Ortiz & Velóz ex Cano-Ortiz, Musarella, Spampinato, Velóz et Cano 2015

3-Lonchocarp pycnophylli-Cylindropuntietum caribaeae Cano, Cano-Ortiz & Velóz ex Cano-Ortiz, Musarella, Spampinato, Velóz et Cano 2015

4-Neoabbottio paniculatae-Guaiacetum officinalis Cano, Cano-Ortiz & Velóz ex Cano-Ortiz, Musarella, Spampinato, Velóz et Cano 2015

WEINMANNIO-CYRILLETEA Knapp 1964

Weinmannio-Cyrilletalia Knapp 1964

1.-Community of Cyathea furfuracea and Prestoea motana

2.-Community of Ormosia krugii and Prestoea montana

OCOTEO-MAGNOLIETEA Borhidi and Muñiz in Borhidi et al. 1979

Ocoteo-Magnolietalia Muñiz in Borhidi et al. 1979

1.-Community of Hyeronima Montana and Magnolia pallescens

2.-Community of Hyeronima dominguensis and Magnolia hamorii

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