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# Phytosociology a Humid Forest of the Chapada of Araripe, Crato, CE, Brazil

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**Abstract**

The Chapada of Araripe is an exceptional landscape in the Caatinga, a seasonally dry tropical forest of northeastern Brazil, as it shelters several vegetation types, such as Carrasco, Cerrado, Cerradão and Humid Forest, different from the biome in which it is inserted. The first three phytophysiognomies mentioned above are already relatively well documented. However, studies of the Humid Forest of the Chapada of Araripe are still incipient. In this context, the objective of this work was to contribute to the knowledge of the composition and structural organization of the flora of a wetland area of the Chapada of Araripe, Crato-CE. The research was developed from April 2014 to February 2016 and all individuals with CAP ≥ 15 cm were sampled. The botanical material was collected in 100 plots (100 m × 10 m), between coordinates 7º14′36″S, 7º15′23.5″S and 39º28′50″W, 39º29′30.8″W at an elevation between 904 m and 963 m, at the top of the Chapada of Araripe, Crato-CE. The testimonial material was deposited in the Herbarium Caririense Dárdano de Andrade-Lima of the Regional University of Cariri. We sampled 3,067 individuals distributed in 59 species. The total basal area was 43,278 $m^2$ and the density was 3,067 per hectare. The families Fabaceae, Myrtaceae, Rubiaceae, Lauraceae and Chrysobalanceae presented greater specific richness. The species *Ocotea nitida* (Meisn.) Rower, *Protium heptaphyllum* (Aubl.) Marchand, *Licania* sp. and *Cordiera myrciiflora* (K. Schum.) C. H. Press. & Delprete were the most important to the community due to the high IVI for the sampled area. The first occurrence of the genus *Helicostylis* for Ceará was recorded. The Humid Forest of Chapada of Araripe presents floristic elements from the Amazon Region, Cerrado and species of Atlantic Forest Domain.

**Keywords:** Araripe National Forest, floristics, phytosociology

## 1. Introduction

The semi-arid domain prevails in the Brazilian northeast covering more than 750,000 $km^2$ (AB'SABER, 1977). This value represents approximately half of the territory of this region with an area of 1,542,248 $km^2$ (IBGE (Instituto Brasileiro de Geografia e estatística), 2012). This domain presents variations in its degree of aridity due to the edaphoclimatic differences related to factors such as distance from the coast, altitude, relief, chemical composition and soil depth, slope and position of the slope in relation to the windward and leeward, in high altitude areas (Andrade-Lima, 1981; Nimer, 1989). In high altitude areas there are naturally differentiated vegetation formations (enclaves) that are naturally established and in equilibrium with the environment (Cavalcante, 2001, 2005).

The maintenance of "islands" of Humid Forests of the Northeast of Brazil, is associated with the occurrence of plateaus between 500 and 1,100 m of altitude, facing the sea, such as Borborema, Chapada of Araripe, Chapada of Ibiapaba and Serra of Baturité (Nascimento, Rodal, & Silva, 2012). In these localities, orographic rainfall guarantees precipitation levels above the Northeastern average of 240-900 mm/year. Allied climatic conditions and relief of the plateaus, massifs and mountains provide a "hidden precipitation" with intense nocturnal condensation which favors the existence of rainforest vegetation in the semi-arid region (Andrade & Lins, 1965; Nascimento et al., 2012).

Cavalcante (2005) counted 20 stretches of “wetlands” or Brejos de Altitude in the Brazilian Northeast, distributed in the states of Ceará, Rio Grande do Norte, Paraíba and Pernambuco. In Ceará are located the largest stretches of Humid Forest of Brazilian Northeast, similar to those found in Serra de Baturité, Chapada of Ibiapaba and Chapada of Araripe (Pereira, 2009).

The Humid Forest of the Chapada of Araripe is conditioned by the local combination of nebular moisture with rainwater and fluvial waters according to Tabarelli, Melo, and Lira (2006). Initially, this phyto-physiognomy was classified by Andrade-Lima (1966) as the Pluvial-Nebular Tropical Sub-Perenifolia Forest, belonging to the Atlantic Forest Domain. In more recent studies Loiola et al. (2015), and Moro, Macedo, Moura-Fé, Castro, and Costa (2015) correlate the Araripe Rainforest with the Evergreen Seasonal Forest, influenced by the Amazonian Domain.

Studies of floristic composition and phytosociological aspects of the Chapada of Araripe were performed for the physiognomies of Cerrado and Cerradão (Costa, Araújo, & Lima-Verde, 2004; Alencar, Barros, & Silva, 2007).

In view of the above, the objective of this study was to contribute to the knowledge of the Phytosociology of the Humid Rainforest of Chapada of Araripe and to associate its organizational structure with other Humid Tropical Forests of Brazil, particularly in the Brazilian Northeast.

## 2. Materials and Methods

### *2.1 Area of Study*

The Chapada of Araripe occupies a central position in the Brazilian Northeast, covering part of the states of Ceará, Pernambuco and Piauí. The present work was carried out in a Wetland area (Figure 1) between the coordinates 7º14′36″S, 7º15′23.5″S and 39º28′50″W, 39º29′30.8″W, altitude between 904 m and 963 m, at the immediate top of the Chapada of Araripe, Crato-CE, from April 2014 to November 2015.

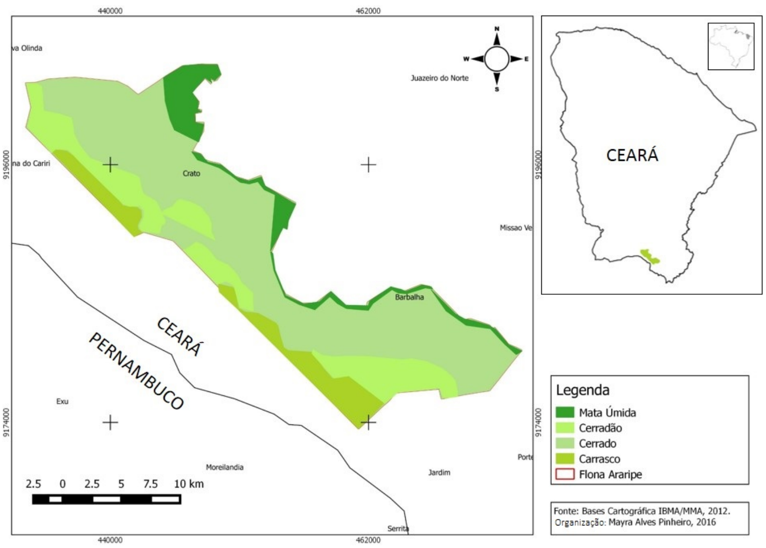


Figure 1. Location of the Chapada of Araripe, CE, Brazil

According to the classification of Koppen, the climate prevails in the Aw climate-rainy tropical climate, with average monthly precipitation of 1,033 mm (ICMbio- Instituto Chico Mendes de Conservação da Biodiversidade, 2006). The soil type was Red-Yellow Latosol deep and permeable to rain infiltration with an average monthly temperature of 24 ºC (FUNCEME - Fundação Cearense de Meteorologia e Recursos Hídricos, 2013).

### *2.2 Phytosociological Study*

For the phytosociological study, 100 plots of 10 m × 10 m dimensions were inserted, interspersed by a space of equal size, totaling 10,000 $m^2$. Only arboreal shrub strata with a Chest Height Circumference greater or equal to 15 cm were considered (CAP ≥ 15) being disregarded bromeliads, vines and lianas.

Three to five samples were collected with flower and/or fruit of each species found in the work area. After proper herborization, the botanical material was incorporated into the collection of the Caririense Dárdano de Andrade-Lima Herbarium of the Regional University of Cariri (URCA). The identification of herbal material was performed by comparisons with previously identified specimens and an integral part of the herbarium collection and/or by specialized bibliography. The botanical families were identified according to Angiosperm Phylogeny Group (APG III - Angiosperm Phylogeny Group III, 2009). For the correct spelling of the scientific names of the species the database of the List of Species of Flora of Brazil (2014) and the database of Tropicos of the Missouri Botanical Garden (MOBOT, 2014) were consulted.

### *2.3 Parameters Analyzed*

The following parameters were analyzed:

Absolute Density and Relative Density—number of individuals in a given species estimated from the count of individuals in this area. Absolute density considers only the number of individuals of a species in a given area. The relative density considers the relation of the number of individuals of a species and the number of all the species of the area being expressed in percentage.

Absolute Dominance and Relative Dominance—degree of coverage of species as an expression of the space required by them. Absolute dominance expresses the basal space of a species in a given area. When considered, in percentage, the relation of the space occupied by the basal area of a species in relation to all the other species of the area has the relative dominance.

Absolute Frequency and Relative Frequency—probability of finding one or more individuals in a particular sample unit. The absolute frequency (FA) indicates the percentage of plots that present a particular species. The relative frequency (FR) is the ratio of FA of a given species to the sum of the FAs of all species.

Coverage Value Index (IVC)—approximate numerical representation of the percentage coverage of each species or group of species of a plant community. It can be obtained with the sum of density and relative dominance.

Index of Import Value (IVI)—value resulting from the sum of the values of relative density, relative dominance and relative frequency, thus reaching 300%.

The Index of Coverage Value (IVC) and Import Value Index (IVI) are parameters that indicate the ecological importance of a taxon (species, family, etc.) within a forest community. These indicators consider that the parameters used for their calculation portray the ecological importance of a certain species in the community, when compared to the other species in it, since relative values are used.

#### 2.3.1 Sample Adequacy and Statistical Analysis of the Parameters

Sampling sufficiency was analyzed through the graph of the collector curve and for its elaboration; the procedures proposed by Rodal, Sampaio, and Figueiredo (1992) were adopted. The Fitopac 2.1 software was used to calculate the abundance, relative frequency and absolute frequency, relative dominance and absolute dominance, diversity and aggregation indices. The software Microsoft Excel 2010 and Paleontology Analysis Statistic 2.0 (PAST 2.0) were used for statistical analysis of the data and graphical representation of the results.

#### 2.3.2 Analysis of the Diametric Class Distribution

It corresponds to the number of trees of the species per unit area and by diametric class interval (Clutter et al., 1983; Pires-O’brien & O’brien, 1995). The individuals were grouped in diametric classes. The range of class distribution was determined by the Paleontology Analysis Statistic 2.0 software (PAST 2.0). Same program used for generation of graphics.

#### 2.3.3 Diversity Indices

In the present research the indices were used:

Shannon-Weiver (H’) to estimate species richness - it measures the degree of uncertainty in predicting which species will belong to a randomly chosen individual from a sample with S species and N individuals. The lower the value of the Shannon-Weiver index, the lower the degree of uncertainty and, therefore, the sample diversity is low. Diversity tends to be higher the higher the index value (Uramoto et al., 2005). The choice of the Shannon index occurred because, according to Brower and Zar (1984), it is the diversity index most applied in ecological studies. To verify the degree of significance between the averages, the T-student test will be applied with an error acceptance of a maximum of 0.05 (5%).

Similarity indexes were used for the analysis of similarity between areas. The floristic composition of the study area was compared with other floristic surveys conducted in other Northeastern Humid Forest, Evergreen

Seasonal Forests of the State of Mato Grosso, Seasonal Forests of Maranhão and Southeastern Brazil. The comparison was made using the Similarity Index, which expresses the similarity between environments, based on the number of common species. Being a measure of correlation that varies between zero and one. The more the coefficient approaches the greater the similarity between species (Mueller-Dombois & Ellenberg, 1974). The resulting floristic similarity matrix was used for cluster analysis by the Bray-Curtis method and the generation of a dendrogram with the aid of PAST 2.0 software.

## 3. Results and Discussion

### *3.1 Phytosociology*

From plot 64 the curve of the species/area graph stabilized with 56 species (Figure 2), indicating that the studied area was sufficient for the phytosociological analysis of the vegetation of Humid Forest of the Chapada of Araripe. A total of 33 botanical families were identified covering 59 tree species.

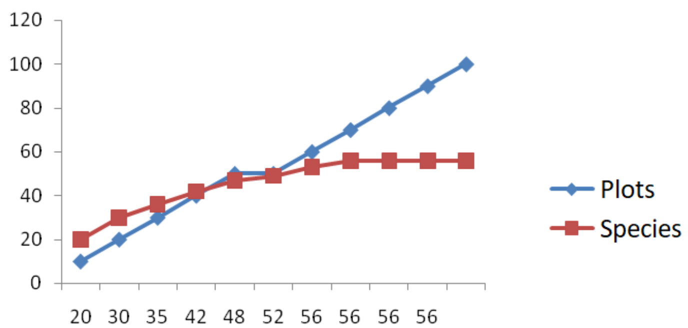


Figure 2. The curve species/area or curve of the collector sampled from a section of Humid Forest of Chapada of Araripe, Ceará, Brazil

The Shannon-Weiver diversity index (H') was 2.725. The Shannon-Weiver Index option allowed comparing the vegetation diversity index of the Wetland of Chapada of Araripe with the results found for diversity indexes of other studies in humid forests in Brazil. Such index is lower than those found by Kunz, Ivanauskas, Martins, Silva, and Stefanello (2008), Kunz, Martins, Ivanauskas, Stefanello, and Silva (2010), Kunz et al. (2014), and Ivanauskas, Monteiro, and Rodrigues (2008) for the Evergreen Seasonal Forests (between 3.07 to 3.30), located closer to the core forest area on the Parecis plateau in Mato Grosso-Brazil.

The Wetland diversity index of the Chapada of Araripe is much smaller when compared to the works of Muniz, César, and Monteiro (1994), Oliveira and Amaral (2004), carried out in stretches of Ombrophilous Forest in the Amazon region where the diversity index is above 4.0. According to Kunz et al. (2008, 2010, 2014), Ivanauskas et al. (2008), and Oliveira and Amaral (2004), the index of botanical diversity of the communities with Amazonian influence decrease with the distance from the Amazon Forest.

The diversity index of the Rainforest of the Chapada of Araripe is also lower than those found in the Atlantic Forest registered in several studies, such as Rabelo, Rodal, Lins, and Lima (2015), Joly et al. (2012), Oliveira et al. (2011), Gomes, Silva, Rodal and Silva (2009), Nascimento and Rodal (2008). These surveys indicate the Shannon-Weiver index between 3.96 and 4.48 in the different physiognomies of the Atlantic Forest closest to the coast. By statistical analysis of the H' index of other forest areas, in addition to the above, it can be verified, through the T Studant test, that there is significant statistical difference. The T-student P ($T \leq t$) bi-flow equal to 0.02543368 is lower than P (0.05) and therefore verified that there is a significant difference between the averages of the Shannon-Weaver index of Amazonian and Atlantic forests in relation to the montane and submontane forests of the Northeast, according to Tables 1 and 2.

Table 1. Comparison between H'indices of Amazon rainforest, Atlantic Forest and montane and submontane forests of the northeast

| Forest type | Authors | H' Indices | Forest type | Authors | H' Indices |
|---|---|---|---|---|---|
| FOA | Andrade et al. (2006) PB | 3 | FMSmNE | This work | 2.72 |
| FESV | Kunz et al. (2008) MT | 3.17 | FMSmNE | Nascimento & Rodal (2008) PE | 2.99 |
| FOATM | Joly, C. A. et al. (2012) RJ | 3.96 | FMSmNE | Rodal & Nascimento (2006) PE | 2.71 |
| FESV | Kunz et al. (2010a) MT | 3.51 | FMSmNE | Ferraz, Araújo, & Silva (2004) PE | 3.49 |
| FAOD | Joly, C.A. et al. (2012) RJ | 4.48 | FMSmNE | Ferraz, Rodal, & Sampaio (2003) PE | 2.92 |
| FOAT | Costa Junior et al. (2008) PE | 3.83 | FMSmNE | Tavares et al. (2000) PE | 3.6 |
| FDOAM | Dionísio et al. (2016) RR | 5.01 | FMSmNE | Costa & Araújo (2007) CE | 2.88 |

*Note.* FOA: Atlantic Ombrophylous Forest; FAOD: Atlantic Forest Ombrophilous Dense; FESV: Seasonal Forest Ever Green (Amazon); FOATM: Atlantic Rainforest Ombrophilous Forest; FOAT: Atlantic Ombrophylous Forest; FDOAM: Dense Amazonian Ombrophilous Forest.

Table 2. t-Test for H' index of Amazonian and Atlantic Forests in relation to the Forest montane and submontane of the Northeast

| Parameters | | |
|---|---|---|
| Average | 3.851428571 | 3.044285714 |
| Variance | 0.509247619 | 0.128295238 |
| Comments | 7 | 7 |
| Hypothesis of the mean difference | 0 | |
| gl | 9 | |
| Stat t | 2.674513138 | |
| P (T ≤ t) uni-caudal | 0.01271684 | |
| t critical uni-caudal | 1.833112923 | |
| P (T ≤ t) bi-caudal | 0.02543368 | |
| t bi-caudal | 2.262157158 | |

Among the factors that interfere in the wealth level of a community are, according to Mori, Silva, Lisboa, and Coradin (1989), past geological events associated with environmental heterogeneity and local disturbance levels. Muniz et al. (1994), and Oliveira and Amaral (2004) attribute this fact to the distance of the core area. While the study of Primack and Rodrigues (2001) allude to the effects of habitat fragmentation.

The Humid Rainforest of the Chapada of Araripe is far from the core area of the Evergreen Seasonal Forest of Amazonian domain in Mato Grosso and the Atlantic Forest of the coastal forests. These factors probably may justify the low Shannon-Weiver index (2,725) compared to other areas of the Amazon Forest Domain (above 4.0) and the Atlantic Forest (between 3.96 and 4.48). This argument is supported by the fact that the Humid Rainforest of the Chapada of Araripe presented the Shannon-Weiver (H') diversity index within the mean of the phytophysiognomies of the Seasonal and Outer Mountains of the Northeast of Brazil (Table 3), whose distances are similar to Flona Araripe in relation to the coast and the Amazonian domains.

Table 3. Comparison of the Shannon-Weiver diversity index of the Rainforest of the Chapada of Araripe with other Forests Mountains and Submontane of the Northeast

| **Study/Location** | **Altitude** | **Annual Precipitation** | **Nº species** | **Shannon-Weiver** |
|---|---|---|---|---|
| This work | 910-963 m | 1033 mm | 59 | 2725 |
| Nascimento & Rodal (2008), PE | 900-1,030 m | 948 | 62 | 299 |
| Rodal & Nascimento (2006), PE | 800-1,036 | 832 | 49 | 2,71 |
| Ferraz, Araújo, & Silva (2004), PE | 900 | 1066 | 53 | 349 |
| Ferraz, Rodal, & Sampaio (2003), PE | 1,100 | 1260 | 50 | 292 |
| Tavares et al. (2000), PE | 900 | 650-900 | 91 | 360 |
| Costa & Araújo (2007), CE | 900 m | 760 mm | 43 | 288 |

*Note.* The t-Test analysis: two samples in pairs for averages showed that the "stat t" 0.0316 (Table 4) is much smaller than "bi-caudal critical t" 2.4469 (t-tab) and therefore there is no significant statistical difference between the Shannon-Weaver (H') diversity index of the wet forest and the average H' of the montane and submontane forests of the northeast.

Table 4. t-Test for H' index mean in montane and submontane forests of the northeast

| Parameters | | |
|---|---|---|
| Average | 3.044285714 | 3.04 |
| Variance | 0,128295238 | 2.30084E-31 |
| Comments | 7 | 7 |
| Hypothesis of the mean difference | 0 | |
| gl | 6 | |
| Stat t | 0.031656797 | |
| P (T ≤ t) uni-caudal | 0.487886267 | |
| t critical uni-caudal | 1.943180274 | |
| P (T ≤ t) bi-caudal | 0.975772534 | |
| t bi-caudal | 2.446911846 | |

Among the botanical families presented in the Humid Rainforest of Chapada of Araripe, the species was rich in Fabaceae (11 sp.), Myrtaceae (5 sp.), Rubiaceae, Lauraceae (4 sp. Each), Chrysobalanaceae (3 sp.) and two species the families Sapindaceae, Salicaceae, Rutaceae, Melastomataceae, Bignoniaceae and Annonaceae.

Fabaceae and Myrtaceae, dominant families in number of species in the Humid Rainforest of the Chapada of Araripe (Table 5), also represent the greatest tree-specific richness in floristic surveys performed by Nascimento et al. (2012) in Pernambuco, in humid forests or brejos in the elevationof the Brejo of the Mother of God; Rodal and Nascimento (2002), in the Biological Reserve of Serra Negra, Rodal and Sales (2007), in the Wet Forest of Brejo dos Cavalos, in Caruaru, Ferraz, and Rodal (2006), in the Wet Forest of São Vicente Férrer.

Table 5. Phytosociological parameters of the families of a section of the Humid Forest of Chapada of Araripe, Ceará, Brazil

| **Families** | **NInd** | **AbsDe** | **RelDe** | **AbsFr** | **RelFr** | **AbsDo** | **RelDo** |
|---|---|---|---|---|---|---|---|
| Lauraceae | 929 | 929 | 30.29 | 100 | 11.61 | 13.08 | 30.23 |
| Fabaceae | 206 | 206 | 6.72 | 78 | 9.06 | 7.52 | 17.38 |
| Combretaceae | 15 | 15 | 0.49 | 13 | 1.51 | 4.82 | 11.14 |
| Burseraceae | 325 | 325 | 10.6 | 85 | 9.87 | 3.88 | 8.97 |
| Malpighiaceae | 82 | 82 | 2.67 | 51 | 5.92 | 3.81 | 8.8 |
| Chrysobalanaceae | 52 | 523 | 17.05 | 90 | 10.45 | 3.43 | 7.92 |
| Clusiaceae | 14 | 14 | 0.46 | 13 | 1.51 | 1.57 | 3.63 |
| Rubiaceae | 396 | 396 | 12.91 | 84 | 9.76 | 1 | 2.31 |
| Boraginaceae | 36 | 36 | 1.17 | 25 | 2.9 | 0.95 | 2.19 |
| Simaroubaceae | 17 | 17 | 0.55 | 13 | 1.51 | 0.58 | 1.35 |
| Connaraceae | 110 | 110 | 3.59 | 53 | 6.16 | 0.49 | 1.13 |
| Salicaceae | 128 | 128 | 4.17 | 58 | 6.74 | 0.46 | 1.07 |
| Annonaceae | 9 | 9 | 0.29 | 8 | 0.93 | 0.38 | 0.87 |
| Dead standing | 84 | 84 | 2.74 | 50 | 5.81 | 0.33 | 0.77 |
| Myrtaceae | 48 | 47 | 1.53 | 27 | 3.14 | 0.2 | 0.47 |
| Sapindaceae | 61 | 61 | 1.99 | 35 | 4.07 | 0,18 | 0.41 |
| Moraceae | 17 | 17 | 0.55 | 14 | 1.63 | 0,14 | 0.32 |
| Verbenaceae | 4 | 4 | 0.13 | 4 | 0.46 | 0,11 | 0.25 |
| Nyctaginaceae | 19 | 19 | 0.62 | 18 | 2.09 | 0,08 | 0.19 |
| Euphorbiaceae | 11 | 11 | 0.36 | 10 | 1.16 | 0,07 | 0.17 |
| Bignoniaceae | 9 | 9 | 0.29 | 8 | 0.93 | 0,06 | 0.14 |
| Cecropiaceae | 1 | 1 | 0.03 | 1 | 0.12 | 0,06 | 0.13 |
| Unknown 1 | 1 | 1 | 0.03 | 1 | 0.12 | 0,02 | 0.06 |
| Erythroxylaceae | 7 | 7 | 0.23 | 7 | 0.81 | 0,02 | 0.04 |
| Rutaceae | 6 | 6 | 0.2 | 6 | 0.7 | 0,02 | 0.04 |
| Unknown 2 | 3 | 3 | 0.1 | 2 | 0.23 | 0,01 | 0.02 |
| Siparunaceae | 3 | 3 | 0.1 | 3 | 0.35 | 0,01 | 0.01 |
| Proteacae | 3 | 3 | 0.1 | 3 | 0.35 | 0,01 | 0.01 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Melastomataceae | 2 | 2 | 0.07 | 2 | 0.23 | 0 | 0.01 |
| Apocynaceae | 2 | 2 | 0.06 | 2 | 0.24 | 0 | 0 |
| Styracaceae | 1 | 1 | 0.06 | 1 | 0.12 | 0 | 0 |
| Verbenaceae | 1 | 1 | 0.03 | 1 | 0.12 | 0 | 0 |
| Primulaceae | 1 | 1 | 0.03 | 1 | 0.12 | 0 | 0 |

*Note.* Nind = number of individual; AbsDe = absolute density; RelDe = relative density; AbsFr = absolute frequency; AbsFr = relative frequency; AbsDo = absolute dominance; RelDo = relative dominance.

The richness of Fabaceae and Myrtaceae was also reported in other forest areas of the Northeast, such as the studies carried out by Amorim et al. (2005), in Bahia; and in the Southeastern region of the country. These results confirm the observations of Gentry (1995) that emphasize the importance of these families in the neotropical forests.

The density obtained for the study area was 3,067 individuals $hec^{-1}$ with a total basal area of 43,278 $m^2$ $hec^{-1}$ and mean of 30.67 individuals per plot. *Ocotea nitida* (Meisn.) However stood out with 708 individuals sampled (Table 6), representing 22.78% of the total trees of the shrub-tree community of the studied area.

Table 6. Phytosociological parameters of the species found in a section of Humid Forest of Chapada of Araripe, Crato, CE, Brazil

| Species | Nind | dpNInd | AbsDe | RelDe | Nam | AbsFr | RelFr | MinAlt | MaxAlt | HCDAL Voucher |
|---|---|---|---|---|---|---|---|---|---|---|
| *Ocotea nitida* (Meisn.) Hohwer | 708 | 3.510 | 7080 | 22.97 | 100 | 100.00 | 9.40 | 4.00 | 20.00 | 10759 |
| *Licania* sp. | 442 | 6.555 | 434.0 | 14.08 | 73 | 73.00 | 6.86 | 3.00 | 20.00 | 12215 |
| *Cordiera myrciiflora* (K. Schum.) C. H. & Delprete | 383 | 3.528 | 383.0 | 12.43 | 83 | 83.00 | 7.80 | 3.00 | 6.500 | 10796 |
| *Protium heptaphyllum* March | 325 | 2.750 | 325.0 | 10.55 | 85 | 85.00 | 7.99 | 3.00 | 17.00 | 10754 |
| *Ocotea* sp. | 186 | 2.165 | 186.0 | 6.04 | 67 | 67.00 | 6.30 | 4.00 | 18.00 | 12061 |
| *Casearia javitensis* Kunth. | 119 | 1.433 | 119.0 | 3.86 | 56 | 56.00 | 5.26 | 3.00 | 12.00 | 10763 |
| *Copaifera langsdorffii* Desf. | 118 | 1.680 | 108.0 | 3.50 | 48 | 48.00 | 4.51 | 2.50 | 22.00 | 10760 |
| *Connarus detersus* Planch. | 110 | 1.508 | 110.0 | 3.57 | 53 | 53.00 | 4.98 | 3.00 | 18.00 | 12112 |
| *Byrsonima sericea* DC | 82 | 0.978 | 65.0 | 2.11 | 42 | 42.00 | 3.95 | 7.00 | 20.00 | 12108 |
| *Hirtella ciliata* Mart & Zucc. | 75 | 1.388 | 75.0 | 2.43 | 40 | 40.00 | 3.76 | 6.00 | 15.00 | 12264 |
| *Matayba guianensis* Aubl. | 61 | 1.154 | 61.0 | 1.98 | 35 | 35.00 | 3.29 | 4.00 | 15.00 | 10797 |
| *Cordia bicolor* A. DC. | 36 | 0.732 | 36.0 | 1.17 | 25 | 25.00 | 2.35 | 5.00 | 23.00 | 12039 |
| *Myrcia* sp1. | 31 | 0.624 | 29.0 | 0.94 | 21 | 21.00 | 1.97 | 6.00 | 15.00 | 10784 |
| *Ocotea* sp1. | 25 | 0.575 | 25.0 | 0.81 | 19 | 19.00 | 1.79 | 6.00 | 13.00 | 12187 |
| *Hymenaea courbaril* L. | 23 | 0.649 | 23.0 | 0.75 | 15 | 15.00 | 1.41 | 10.00 | 20.00 | 12107 |
| *Guapira cf. opposita* (Vell.) Reitz | 19 | 0.419 | 19.0 | 0.62 | 18 | 18.00 | 1.69 | 4.00 | 12.00 | 10962 |
| *Helicostylis tomentosa* (Poepp. & Endl.) Rusby | 17 | 0.473 | 17.0 | 0.55 | 14 | 14.00 | 1.32 | 5.00 | 16.00 | 10757 |
| *Simarouba amara* Aubl. | 17 | 0.493 | 17.0 | 0.55 | 13 | 1300 | 1.22 | 5.00 | 18.00 | 10798 |
| *Bowdichia virgiliodes* Kunt. | 14 | 0.349 | 14.0 | 0.45 | 14 | 14.00 | 1.32 | 12.00 | 20.00 | 12183 |
| *Buchenavia tetraphylla* (Aubl.) R. A. Roward | 14 | 0.411 | 14.0 | 0.49 | 14 | 14.00 | 1.22 | 7.00 | 20.00 | 12032 |
| *Myrcia splendens* (Sw.) DC. | 14 | 0.411 | 14.0 | 0.49 | 14 | 14.00 | 1.22 | 7.00 | 20.00 | 12165 |
| *Psidium* sp. | 14 | 0.409 | 14.0 | 0.49 | 14 | 14.00 | 1.22 | 4.00 | 6.00 | 10792 |
| Lauraceae 1 | 13 | 0.397 | 14.0 | 0.49 | 13 | 13.00 | 1.22 | 7.5 | 14.00 | 12061 |
| *Clusia nemorosa* G. Mey. | 13 | 0.367 | 13.0 | 0.42 | 12 | 12.00 | 1.13 | 7.00 | 18.00 | 10782 |
| *Dahlstedtia araripensis* (Benth.) M. J. Silva & A. M. G. Azevedo | 13 | 0.506 | 13.0 | 0.42 | 9 | 9.00 | 0.85 | 6.00 | 20.00 | 12257 |
| *Parkya platycephala* Benth. | 12 | 0.409 | 12.0 | 0.39 | 10 | 10.00 | 0.94 | 13.00 | 20.00 | 12192 |
| *Maprounea guianensis* Aubl. | 11 | 0.321 | 9.0 | 0.29 | 8 | 8.00 | 0.75 | 7.00 | 15.00 | 10797 |
| *Casearia grandiflora* Cambess. | 9 | 0.288 | 9.0 | 0.29 | 9 | 9.00 | 0.85 | 5.00 | 10.00 | 10762 |
| *Ocotea* sp2. | 9 | 0.404 | 9.0 | 0.29 | 6 | 6.00 | 0.56 | 7.00 | 14.00 | |
| *Coussarea hydrangeifolia* (Benth.) Müll. Arg. | 9 | 0.404 | 9.0 | 0.29 | 6 | 6.00 | 0.56 | 4.00 | 10.00 | 12067 |
| *Annona exsucca* DC. | 8 | 0.307 | 8.0 | 0.26 | 7 | 7.00 | 0.66 | 14.00 | 20.00 | 12060 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| *Erythroxylum* sp. | 7 | 0.256 | 7.0 | 0.23 | 7 | 7.00 | 0.66 | 5.50 | 7.00 | 10963 |
| *Machaerium acutipholium* Vogel. | 7 | 0.383 | 7.0 | 0.23 | 4 | 4.00 | 0.38 | 7.00 | 15.00 | 12164 |
| *Ocotea prolifera* (Nees e Mart.) | 7 | 0.389 | 4.0 | 0.98 | 1 | 7.00 | 0.8 | 12.00 | 14.00 | 12187 |
| *Hirtella racemosa* Lam. | 6 | 0.239 | 6.0 | 0.19 | 6 | 6.00 | 0.56 | 7.00 | 9.00 | 10755 |
| *Handro antusserratifolia* (Vahl) G. Nichols | 6 | 0.278 | 6.0 | 0.19 | 5 | 5.00 | 0.47 | 6.00 | 17.00 | 12230 |
| *Vatairea macrocarpa* (Benth.) DC | 6 | 0.278 | 6.0 | 0.19 | 5 | 5.00 | 0.47 | 10.00 | 15.00 | 12262 |
| *Myrcia* sp2. | 5 | 0.419 | 8.0 | 0.26 | 4 | 4.00 | 0.38 | 4.00 | 7.00 | 10786 |
| *Myrcia guianensis* (Aubl.) DC. | 5 | 0.350 | 3.0 | 0.83 | 1 | 5.00 | 0.6 | 4.50 | 8.00 | 12251 |
| *Vitex polygama* Cham. | 4 | 0.197 | 4.0 | 0.13 | 4 | 4.00 | 0.38 | 10.00 | 15.00 | 12265 |
| *Siparuna guianensis* Aubl. | 3 | 0.171 | 3.0 | 0.10 | 3 | 3.00 | 0.28 | 6.00 | 8.00 | 12090 |
| *Faramea nitida* Benth. | 3 | 0.223 | 3.0 | 0.10 | 2 | 2.00 | 0.19 | 3.00 | 4.00 | 12101 |
| *Zanthoxylum gardneri* Engl | 3 | 0.171 | 3.0 | 0.10 | 3 | 3.00 | 0.28 | 4.00 | 9.00 | 12163 |
| *Zanthroxylum* sp | 3 | 0.100 | 1.0 | 0.03 | 1 | 1.00 | 0.09 | 7.00 | 7.00 | 12111 |
| *Swartzia langsdorffii* Raddi | 2 | 0.141 | 2.0 | 0.06 | 2 | 2.00 | 0.19 | 7.00 | 15.00 | 12249 |
| Unidentified1 | 2 | 0.100 | 1.0 | 0.03 | 1 | 1.00 | 0.09 | 15.00 | 15.00 | 10794 |
| *Chrisophyllum marginatun* (Hook. e Arn.) Radlk. | 2 | 0.200 | 2.0 | 0.06 | 1 | 1.00 | 0.09 | 8.00 | 9.00 | 12102 |
| *Miconia ligustroides* (DC.) Naudin | 2 | 0.100 | 1.0 | 0.03 | 1 | 1.00 | 0.09 | 7.00 | 7.00 | 12087 |
| *Dimorphandra gardneriana* Tul | 2 | 0.100 | 1.0 | 0.03 | 1 | 1.00 | 0.09 | 10.00 | 10.00 | 12072 |
| *Hymenaea stilbocarpa* (Hayne) Lee et Lang | 2 | 0.100 | 1.0 | 0.03 | 1 | 1.00 | 0.09 | 20.00 | 20.00 | 12109 |
| *Cecropia pachystachya* Trécul | 1 | 0.100 | 1.0 | 0.03 | 1 | 1.00 | 0.09 | 15.00 | 15.00 | 12110 |
| *Hirtella glandulosa* Spreng. | 1 | 0.100 | 1.0 | 0.03 | 1 | 1.00 | 0.09 | 12.00 | 12.00 | 10785 |
| *Piptadenia viridiflora* (Kunth) Benth. | 1 | 0.100 | 1.0 | 0.03 | 1 | 1.00 | 0.09 | 14.00 | 14.00 | 12070 |
| *Chiococca Alba* (L.) Hitchc | 1 | 0.100 | 1.0 | 0.03 | 1 | 1.00 | 0.09 | 15.00 | 15.00 | 12094 |
| *Paramyrciaria* sp. | 1 | 0.100 | 1.0 | 0.03 | 1 | 1.00 | 0.09 | 7.00 | 7.00 | 10795 |
| *Miconia albicans* (SW) Triana | 1 | 0.100 | 1.0 | 0.03 | 1 | 1.00 | 0.09 | 8.00 | 8.00 | 12185 |
| *Himathantus drasticus* (Mart) Plumel | 1 | 0.100 | 1.0 | 0.03 | 1 | 1.00 | 0.09 | 5.00 | 5.00 | 12188 |
| *Vismia guinensis* (Aubl.) Choisy | 1 | 0.100 | 1.0 | 0.03 | 1 | 1.00 | 0.09 | 10.00 | 10.00 | 12216 |
| *Cybianthus detergens* Mart. | 1 | 0.100 | 1.0 | 0.83 | 1 | 1.00 | 0.09 | 5.00 | 5.00 | 12229 |
| *Roupala montana* Aubl. | 1 | 0.100 | 1.0 | 0.03 | 1 | 1.00 | 0.09 | 10.00 | 10.00 | 12250 |

*Note.* Nind = number of individual; AbsDe = absolute density; RelDe = relative density; AbsFr = absolute frequency; AbsFr = relative frequency; AbsDo = absolute dominance; RelDo = relative dominance.

The species most frequently were *Ocotea nitida* (100%), *Protium heptaphyllum* (85%), *Cordiera myrciifolia* (83%) and *Licania* sp. (74%). These four species presented high values of density, basal area and frequency. Species that present these parameter profiles constitute the most structurally important within the community (Lamprecht, 1990).

The species with the highest Coverage Value Index (CVI) and Import Value Index (IVI) were *Ocotea nitida*, *Licania* sp., *Protium heptaphyllum*, *Cordiera myrciiflora*, *Buchenavia tetraphyla*, *Byrsonima sericea*, *Ocotea* sp. and *Copaifera langsdorffii*.

The mean height of the subjects was 9.64 meters (Figure 3). When considered only the arboreal individuals this value reached 13.4 m. The individuals with higher mean height were *Parkia platycephala* (16.86), *Hymenaea courbaril* (16.71), *Annona exsucca* (15.75), *Bowdichia virgilioides* (15.57), *Buchevania tetraphyla* (14.8), *Cordia bicolor* (14.6), *Vatairea macocarpa* (14.2), *Machaerium acutifolium* (12.57), *Simarouba amara* (12.5) and *Byrsonina sericea* (12.45).

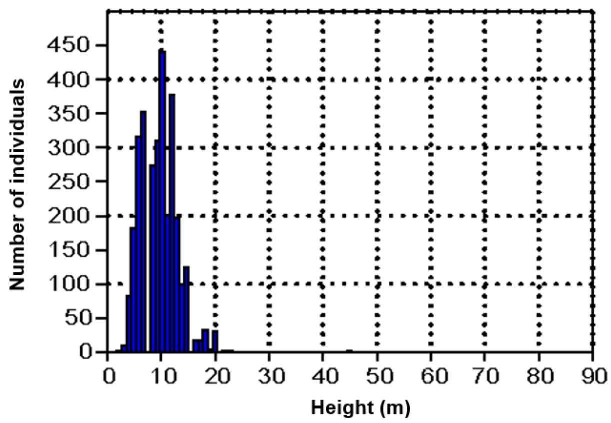


Figure 3. Graph of the distribution of number of individuals by height in the Humid Rainforest of Chapada of Araripe, Crato, Ceará, Brazil

*Bowdichia virgilioides*, *Buchevania tetraphyla* and *Simarouba amara* also stand out in the upper stratum of the montane forests or Matas Umides Serranas studied by Nascimento et al. (2012) on the plateau of Borborema, in Pernambuco.

The graph drawn from the stem circumference of all shrub-arboreal individuals of the area formed a negative exponential function ("J" reverse or "J" inverted) (Figure 4).

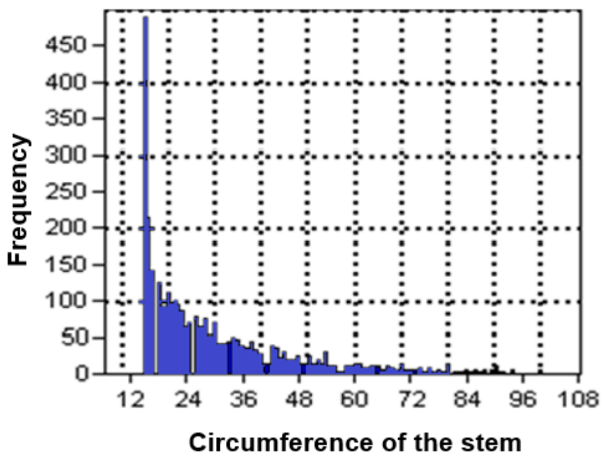


Figure 4. Class distribution of the circumference of the stems of the arboreal shrub individuals found in the Humid Rainforest of the Chapada of Araripe, Crato, Ceará, Brazil

The graph of the diameters of the eleven species with the highest importance value index was determined in the area and individually had the same pattern of distribution of inverted "J". The species analyzed showed higher numbers of individuals in the first diametric classes and, except for *Ocotea* sp1. (yellow laurel) and *Casearia javitensis*, showed a higher number of individuals in the first diametric classes, which varied according to the analyzed species, with an average of between 4 and 12 cm in diameter. The inverted "J" shape (Figure 5), as stated by Meyer (1952) and Assmann (1970), is characteristic of native forest formations. The results give evidence that the study community is persistent, stable and self-regenerating.

As for the analysis of IVI by species, *Ocotea nitida* remains more important in both the Humid Forest and the Cerradão, according to a survey carried out by Alencar et al. (2007). No longer occurring in relation to *Protium heptaphyllum*, *Licania* sp. and *Cordiera myrciiflora*, which stand out in the humid forest, but are not among the ten largest values of importance (IVI) found in the Cerrado and Cerradão phytophysiognomies of Chapada of Araripe, studied by Costa et al. (2004), and Alencar et al. (2007), respectively. According to Pitman et al. (2001), species found in different environments may present differently depending on environmental variations to which they are subject even within a small area where there may be differences in topography, soil physical and chemical characteristics and other environmental factors.

Both the Pielou equability index (J = 0.660) and the Import Value Index (IVI) give indications that the species are not well distributed. Dominance is the rate of occupation of the environment by the sampled individual and expresses the influence or contribution of taxon in the community, usually calculated in indirect values, together with the density and frequency parameters characterize the importance value index of the species for that community.The ten species with the highest IVIs represent 215.68 on a scale of 0 to 300 or 71.9% of the total IVI. *Ocotea nitida* (IVI = 58.62), *Protium heptaphyllum* (IVI = 27.68), *Licania* sp. (IVI = 27.67) and *Cordiera myrciifolia* (IVI = 22.62) together added 136.59 or 45.5% of IVI. According to Mori et al. (1989), most of the IVI of a community comprises a relatively small number of species, which shows certain uniformity in its structure and distribution. Considering what Muniz et al. (1994) asserts, this observation is valid since there are no dominant species or that stand out sharply in the Index of Importance Value, as seen in parts of the Evergreen Seasonal Forest in Gaúcha do In the North/MT, where a few species predominated in IVI (Ivanauskas et al., 2008), in the Tropical Semi-Perenifolia Rainforest (Humid Forest) in the Baturité Massif/CE (Cavalcante, Soares, & Figueiredo, 2000). Cerradão area of Chapada of Araripe (Alencar et al., 2007), among others.

In the present study a small number of species holds the highest percentage of IVI. *Ocotea nitida* (708), *Protium heptaphyllum* (325), *Licania* sp. (434) and *Cordiera myrciifolia* (383) stand out in IVI in the Humid Forest, representing together 60.02% of the total sampled individuals. The genus *Ocotea* is well represented both in Cerradões (Alencar et al., 2007) and in Perennial Seasonal Forest (Ivanauskas et al., 2008; Kunz et al., 2010; 2014). Both *Ocotea* and *Protium* (genera with the two largest IVI and IVC in the Humid Rainforest of the Chapada of Araripe) are among the main genera of the evergreen Seasonal Forests (IBGE, 2012).

The floristic analysis of the Humid Forest of Chapada of Araripe demonstrated the occurrence of Atlantic Forest, Cerrado and Amazonian Forest Region species. There are also species common to the three Formations. This finding corroborates with Rizzini (1997) regarding the phytogeography of the Brazilian flora where in the floristic composition of the humid enclaves of the Northeast can be found species of several floristic regions, such as Cerrado, Atlantic Forest and Amazon region.

The comparative analysis with the neighboring state of Pernambuco showed that 25 species are common to both federative units. In relation to the species of the Tropical Semi-Perenifolia Pluvial-Nebular Forest (or Evergreen Seasonal Forest) of the Baturité Massif listed in the works of Cavalcante et al. (2000), Cavalcante (2005), Lima-Verde, Loiola, and Freitas (2014), 12 species (*Byrsonima sericea*, *Buchenavia tetraphylla*, *Clusia nemorosa*, *Protium heptaphyllum*, *Miconia albicans*, *Simarouba amara*, *Handroanthus serratifolius*, *Guapira opposita*, *Vismia guianensis*, *Xylopia fruttacenses*, *Piptadenia viridiflora* and *Myrcia splendens*) have been found common to both forests.

The analysis of the floristic composition of the Humid Rainforest of Chapada of Araripe found that this is formed by species of wide distribution in Brazilian territory including species of the Atlantic Forest and Amazonian Forest. These results may serve as the core answers to the questions proposed by Cavalcante (2005), and Rizzini (1997) about the existence of some concrete floristic connection between the northeastern enclaves and the Amazon forest. The enclaves of Ceará represent remains of an old bridge between the Atlantic Forest and the Amazon Forest (Cavalcante, 2005). This forest cover extended throughout the coastal region and entered the mainland. The immense rainforest that comprised the mantle would have appeared in the Cretaceous Period and remained until the glaciation of Würm that culminated between 25 thousand and 17 thousand years ago. According to the same authors, the freezing of the water in the Northern Hemisphere caused the level of the sea to descend 140 m below the current one, due to the imprisonment of the water in the glaciers of the Northern Hemisphere. This contributed to reduce the circulating water in the atmosphere, as a consequence of this there were less precipitations and more droughts and expansions of deserts. Patches of tropical forests of the Northeast were conditioned to complete isolation. The vegetation adapted to the drought has spread, surrounded and isolated the forests, forming islands of humid forests of the Brazilian semiarid.

In this study the occurrence of the species *Helicostylis tomentosa* Trécule and *Guapira opposita* (Vell.) Reitz in the Chapada of Araripe was recorded for the first time. It is also the first record of the genus *Helicostylis* for the state of Ceará.

The genus *Helicostylis* in Brazil comprises six species and none of them are endemic to the country. The species *Helicostylis elegans* (J.F.Macbr.) C.C.Berg is registered in the North (PA, AM, AC) and Central-West (MT) regions, being characteristic of the Amazon Region. *Helicostylis heterotricha* Ducke is registered only in the state of Amazonas, *Helicostylis turbinata* C.C.Berg is exclusive to the Amazon Forest occurring only in the states of AM and AC, *Helicostylis* scabra (J.F.Macbr) C.C.Berg. and is restricted to the north of the country. *Helicostylis pedunculata* and *Helicostylis tomentosa* present a wider distribution than the congeners, and can be found in the Atlantic and Amazon rainforest ombrophilous forests. In the Northeast there were records of these species in Bahia, Pernambuco and Maranhão. *Helicostylis tomentosa* can be found in the areas of the Amazon Region, Atlantic Rainforest and enclaves of Humid Forest in the Caatinga domain (REFLORA, 2015; Stehmann et al., 2009).

Although Loiola et al. (2015) suggest that the vegetation of Chapada of Araripe presents similarity with the Pau Ferro Forest, located in the city of Areia, Paraíba, in this study, when the only analysis of the wetland vegetation of the Chapada of Araripe, the results indicate little similarity (0.19 or 19%) between the Humid Forest of Pau Ferro and the Humid Forest of the Chapada of Araripe.

Dendrogram of similarity through the Bray-Curtis indices (Figure 5), floristic of Northeastern Wet Rainforests, Evergreen Seasonal Forests, Cerradão/Wet Forest ecotones, and Riparian Forests revealed low similarity between the Humid Rainforest of the Chapada of Araripe and the other areas analyzed. Although it is composed mostly of species with a wide geographic distribution, the community plant organization of the Humid Forest of Chapad.

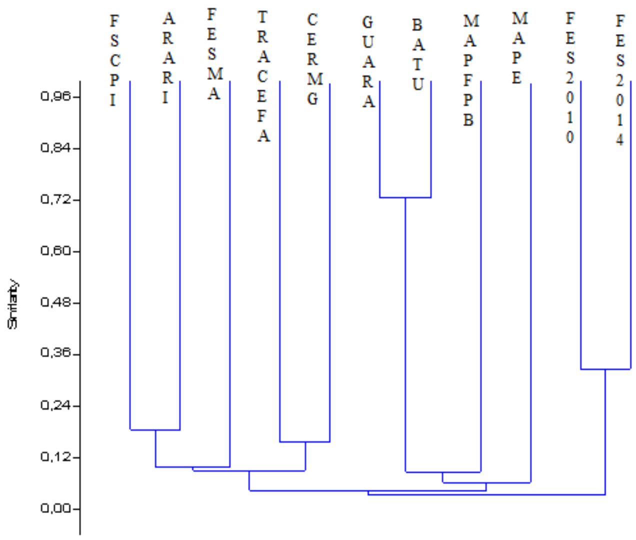


Figure 5. Floristic dendrogram of similarity between the species of the Humid Rainforest of Chapada of Araripe and other Humid Matas of Brazil determined by the Bray-curtis index

*Note*. FSCPI = Seasonal Forest in the Sete Cidades Park - PI; Arari = Rainforest of the Chapada of Araripe; FESMA = Seasonal Forest = MA; TRACEFA = Closed Transition-Amazon Forest-MT; CERMG = Seasonal Forest MG; GUARA = Guaramiranga; BATU = Baturité; MAPFPB = Atlantic Rainforest of Pau Ferro-PB; MAPE = Atlantic Forest-PE; FES = Evergreen Seasonal Forest-MT.

Among the analyzed areas, the vegetation of the Park of the Sete Cidades, in Piauí was the one that presented some similarity with the Wet Rainforest of the Chapada of Araripe. This similarity is probably related to the similar environmental conditions of both, since the two areas are surrounded by Cerrado phytophysiognomy, with species of the Atlantic Forest and the Amazonian Floristic Region, embedded in the Caatinga Domain (Matos & Felfili, 2010). In addition to the distance from the coast and the enclave condition in Caatinga, the presence of Cerrado species in both species probably favors the existence of similarity between the two areas.

In relation to the other humid forests of Ceará, the similarity index with Araripe Humid Forest is low. However, between Humid Forests of Baturité/CE and Guaramiranga/CE there is a similarity of 0.84 Bray-Curtis. These results can be explained, according to Moro et al. (2015) due to coastal distance and pedogeological characteristics. These factors directly interfere in the flora distribution (Moro et al., 2015). Guaramiranga and Baturité are approximately the same distance from the sea and share the same substratum of crystalline basement (FUNCEME, 2013; Cavalcante, 2005), while the Humid Forest of the Chapada of Araripe is more distant from the coast and on a substrate of sedimentary origin. It is also the distance from the coast that justifies the greater similarity between Matas Moidas de Baturité, Guaramiranga, both in Ceará, and the Humid Forest of Pau Ferro, in Paraíba.

The analysis performed through the Bray-Curtis index (Figure 5) suggests low similarity between the Araripe Plateau and Wet and Seasonal Forest Areas. It is observed that the species sharing is greater between the areas located in the same substrate type and exposed to similar water potential, corroborating with the studies of Moro et al. (2015), which attribute the diversity of landscapes in Ceará to the availability of water and the type of substrate that supports the flora.

## 4. Conclusion

The rainforest flora of Chapada of Araripe was composed of species occurring in the Atlantic Forest Domains, Amazonian and Cerrado Floristic Region, havinga floristic association more similar to the ciliary forest of the APA Seasonal Forest of the Sete Cidades National Park in the state of Piauí. In addition, the species *Ocotea nitida*, *Protium heptaphyllum*, *Licania* sp. and *Cordiera myrciifolia* were the most important for the area and together represented 60.02% of the total sampled individuals. Finally, the families Fabaceae, Myrtaceaae, Rubiaceae and Lauraceae presented a greater number of species richness, whereas Burseraceae, Lauraceae, Chrysobalanaceae and Rubiaceae had a major dominance in number of individuals.

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