**JAQUELINA ALVES NUNES**

# SOLOS, VEGETAÇÃO, COMPOSIÇÃO FLORÍSTICA E PADRÃO DE DISTRIBUIÇÃO DE ESPÉCIES EM FLORESTAS ESTACIONAIS DECIDUAIS DE CARAJÁS, PARÁ, AMAZÔNIA ORIENTAL

Tese apresentada à Universidade Federal de Viçosa, como parte das exigências do Programa de Pós-Graduação em Botânica, para obtenção do título de Doctor Scientiae.

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**APROVADA: 16 de agosto de 2013.**

Reinaldo Duque Brasil L. Teixeira

Rubens Manoel dos Santos

Walnir Gomes Ferreira Júnior

Guilherme Resende Corrêa

Carlos Ernesto G. Reynaud Schaefer
(Orientador)

Aos meus pais Lúcia e Antônio e a minha querida vózinha Filomena,

Dedico

"Descobri como é bom chegar quando se tem paciência. E para se chegar, onde quer que seja, aprendi que não é preciso dominar a força, mas a razão. É preciso, antes de mais nada querer."

Amyr Klink

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## SUMÁRIO

# RESUMO

NUNES, Jaquelina Alves, D.Sc. Universidade Federal de Viçosa, agosto de 2013. **Solos, Vegetação, Composição Florística e Padrão de Distribuição de Espécies em Florestas Estacionais Deciduais de Carajás, Pará, Amazônia Oriental** Orientador: Carlos Ernesto Gonçalves Reynaud Schaefer.

As florestas decíduas na Floresta Nacional de Carajás (Flona) estão submetidas às condições climaticas similares (Aw-Koppen) e incorporadas em uma matriz de vegetação distinta (Domínio Amazônico), além de um clima diferenciado em comparação com Florestas secas típicas de outras partes do Brasil. O objetivo do primeiro capítulo foi investigar o padrão de distribuição das florestas secas na Flona de Carajás através das análises de gradiente ambiental sobre a organização da comunidade de plantas, baseado nas características edáphico/topográficas. Foram feitas duas perguntas: (1) A composição e a estrutura das florestas secas são influenciadas pelas propriedades do solo? (2) Há um padrão de distribuição das espécies arbóreas em resposta ao gradiente edáfico? Foram instaladas 36 parcelas nas sequências edáfico/topográficas: Formação Arenito Águas Claras (I e II), Granito Carajás e Granito do Complexo Xingu. Indivíduos arbóreos com CAP ≥ 10 cm foram amostrados e foi realizada a coleta de amostras de solo (0-10 cm). A fim de determinar em que medida as propriedades do solo diferiram dentro e entre as quatro áreas, os dados de solos foram classificados de acordo com análises de agrupamento e ordenação. O agrupamento das parcelas expressou claramente a diferenciação entre solos estudados, indicando que estas Florestas Decíduas, ocorrem em diferentes ambientes de solos variados, em que existem claras diferenças na fertilidade e status nutricional. Em geral, os solos em todas as áreas foram ácidos e com baixo P. No entanto, houve diferenças significativas entre as propriedades do solo entre as áreas amostradas para estas e muitas outras propriedades químicas do solo. NMDS mostrou diferentes grupos floristicos altamente diferenciados e associados a cada um dos quatro grupos compõem o gradiente. Para o modelo de distribuição de espécies utilizaram-se os dados de presença-ausência das espécies mais freqüentes e abundantes e regressão logística múltipla para a construção das curvas de resposta das espécies ao gradiente edáfico. A distribuição das espécies mais freqüentes tende a obedecer a um padrão em resposta ao gradiente edáfico, sendo estas espécies mais especializadas no que diz respeito às condições locais de solo do que as outras espécies. No segundo capítulo fez-se a seguinte pergunta: considerando-se que as florestas decíduas em Carajás estão submetidas às condições climáticas semelhantes;

e que a variabilidade florística e estrutural nessas florestas decíduas depende da natureza do substrato (solos desenvolvidos de rochas cristalinas, sedimentares, e vulcânica)? O objetivo foi comparar a composição florística e estrutura de quatro florestas decíduas na Flona de Carajás. No total, 370 espécies arbóreas, 61 famílias e 195 gêneros foram registrados nas florestas amostrados. Através da análise direta do gradiente florístico-estrutural foi possível destacar a presença de espécies que caracterizam fisionomicamente, cada ambiente quanto, comunidades de plantas com populações distintas entre si dispostas ao longo do gradiente do solo. DCA resumiu a variação florística em três grupos distintos. Não se observou variação estrutural notável entre as formações florestais decíduas em Carajás. No entanto, os atributos estruturais, apresentaram maior alcance de valores comparados com que aqueles reportados para florestas secas neotropicais de outros biomas e regiões do Brasil.

# ABSTRACT

NUNES, Jaquelina Alves, D.Sc. Universidade Federal de Viçosa, August 2013. **Soil, Vegetation, Floristic Composition and Species Distribution Pattern in Deciduous Forest in Carajás, Pará, Eastern Amazon**. Adviser: Carlos Ernesto Gonçalves Reynaud Schaefer.

The dry forests of Carajás National Forest (Flona Carajás) are subject to similar climate (Aw of Koppen's) and embedded in a matrix of Amazon Rainforest, much wetter than that of typical dry forests of other parts Brazil. In the first chapter the study aimed to investigate the distribution pattern of dry forests in the Flona Carajás through analyzes of environmental gradients on the organization of the plant community, based on edaphic and topographical characteristics. Asked: (1) Are composition and structure of dry forest formations influenced by soil properties? Are composition and structure of dry forest influenced by soil properties? (2) Is there a pattern of distribution of species in response to a soil? 36 plots were installed along the soil/topographic sequences: Águas Claras Formation Sandstone (I and II), Carajás Granite and Xingu Basement Complex. Plots were allocated with all trees ≥ 10 cm at BHC sampled; soil samples (0-10 cm) were also collected. To determine the extent to which soil properties differed within and between the four areas, soil data were analysed by cluster analysis and ordination. Plot grouping clearly revealed the differentiation between soils, indicating that these dry forest formations occur in distinct environments, where there are clear differences in soil fertility and nutrient status. In general, all soils were acid and with low P amounts. However, significant differences in soil properties occurred between sampling sites, for these and many other soil properties. NMDS was used to describe patterns in plant species composition to assess its relationship with soil variables. Different groups of species, highly differentiated and associated with each of the four groups comprising the vegetation gradient, were found. To model the distribution of species, the presence-absence of the most frequent and abundant species was used, applying multiple logistic regression to construct the response curves of species along the soil gradient. The distribution of the most frequent species tends to follow a pattern in response to soil gradient, in which some species are more specialized with regard to local soil conditions than the others. In the second chapter asked: (1) Under the same climatic conditions, is the floristic and structural variability in these dry forests dependent on the nature of the substrate? The objective was to compare the floristic composition and structure of the four dry forest fragments of Carajás. In total, 370 tree species, 63 families and 193 genera were recorded in the dry forest formations sampled. Through direct analysis of the floristic-structural gradient, was possible highlight the presence of species that characterize physiognomically each environment as plant communities with distinct populations arranged themselves along the soil gradient. DCA were used to summarize the floristic variation into main floristic axis. Plots were clustered so that they formed três distinct groups, highlighting the difference between each Dry forest formation studied. There was no marked structural variation between studied dry forests formations in Carajás. However, the structural showed greater range of values compared with those reported for neotropical dry forests from other biomes and regions of Brazil.

## Introdução geral

As florestas tropicais detêm a mais rica formação vegetacional do planeta (Cain e Castro 1959; Walter 1971) e constituem as florestas mais complexas estruturalmente (Gentry 1988 e 1992; Phillips et al. 1994; Condit et al. 1994). Em cada hectare de floresta existem aproximadamente 300 espécies arbóreas (Gentry 1988). Estima-se que estejam aproximadamente 59% das espécies de plantas e animais do planeta (Embrapa 1994). O termo floresta tropical não se refere apenas às florestas úmidas, na verdade, correspondem a um mosaico de diferentes tipos de vegetação, incluindo, nas elevações médias dos trópicos, as irregulares e biogeograficamente restritas florestas nebulares tropicais e, nas terras baixas, as florestas tropicais úmidas e as florestas tropicais sazonalmente secas (Dirzo et al. 2011). Apesar de estarem incorporadas no mesmo contexto climático, podem ter variadas condições microclimáticas possibilitando que a vegetação assuma padrões diferentes, formando um verdadeiro complexo vegetacional. Toda essa complexidade na estrutura florestal da Amazônia reflete em uma riqueza que abriga cerca de 40.000 espécies de plantas (Silva e Garda 2011).

A alta diversidade de espécies, tanto em termos de número (riqueza) de espécies e regularidade de densidade (abundância), é geralmente característica das florestas tropicais úmidas (Richards 1996). Em geral, os estudos mostram que a diversidade dessas florestas é maior na Amazônia e Ásia sendo relativamente menor na África (Ribeiro et al. 1999). A floresta amazônica está totalmente inserida na zona tropical e é caracterizada por altas temperaturas, precipitação e irradiação durante todos os períodos do ano. A combinação desses fatores explica a existência da floresta úmida como fisionomia dominante nesse bioma (Figueroa e Noble 1990), no entanto, outros tipos de vegetação estão presentes, como as florestas secas neotropicais.

Durante muitos anos, o interesse científico manteve-se focado, principalmente, sobre os ecossistemas da floresta tropical úmida, enquanto a maioria dos trabalhos desconsidera, em uma escala global altamente significativa, as Florestas Secas Neotropicais (Mayle 2006; Pennington et al. 2006). A quantidade e a extensão dos habitats de florestas decíduas têm variado ao longo do tempo, especialmente em escalas de tempo do último ciclo glacial-interglacial (Pennington et al. 2006). Ao longo do Mesozóico e do Cenozóico, o desenvolvimento tectônico da América do Sul, ocasionou a expansão da crosta oceânica ao longo da cordilheira Centro Atlântica, na sua margem oriental (Latrubesse et al. 2005), assim, a evolução tectônica em conjunto com outras fatores como a mudança do nível do mar, glaciações e mudanças de temperaturas mudaram a paleogeografia do continente, conseqüentemente direcionando a evolução das paisagens e clima, assim como as mudanças na composição da flora (Posadas; Ortiz-Jaureguizar 2010). Estes fatores, conjuntamente, favoreceram o desenvolvimento progressivo do “Diagonal de Formações Abertas Secas”, da América do Sul que por sua vez teve efeitos diversos e significativos sobre a evolução e a biogeografia da biota neotropical.

Atualmente, os ecossistemas de florestas secas se encontram altamente fragmentados e com distribuição reduzida (Pennington et al. 2006; Prance 2006). Explicar a extraordinária riqueza de espécies das florestas secas, tem se tornado um grande desafio. Sabe-se que a evidência de que os presentes fragmentos de floresta seca constituem remanescentes (refúgios) de uma formação única (o arco de floresta seca do Pleistoceno) que se estendeu por essas regiões de florestas secas disjuntas durante períodos mais secos do Pleistoceno (durante o Último Máximo Glacial) (Pennington et al. 2004; Pennington 2006). No entanto, atualmente não existem evidências paleontológicas suficientes para fornecer confiabilidade a esta hipótese de um refúgio único para as florestas secas sulamericanas (Pennington et al. 2006).

As florestas secas neotropicais são encontradas do nordeste do México ao norte da Argentina e no sudeste do Brasil em áreas separadas de tamanhos variados (Linares-Palomino et al. 2011). Fisionomicamente são muito mais variáveis que florestas tropicais úmidas, variando de baixo escrube a florestas mais altas (Pennington 2009). Essas florestas estão inseridas em praticamente todos os biomas brasileiros: no Cerrado (Ferreira-Júnior e Teixeira 2009 a,b); dentro da Caatinga, onde é frequentemente denominada de “Caatinga Arbórea” (Santos et al. 2012; Andrade-Lima 1981); na Mata Atlântica (Ibraimo et al. 2004); no Pantanal, onde ocorrem sobre solos sedimentares arenosos pleistocênicos formando mosaicos vegetacionais com Cerradões, Cerrados s.s. e Campos de Murundus (Ferreira-Júnior 2009) no estado do Mato Grosso e nos Campos Sulinos (Hack et al. 2005) no estado do Rio Grande do Sul. Além disso, ocorrem em áreas de transição entre biomas como na região Norte de Minas Gerais (Duque-Brasil 2012; Arruda 2012; Arruda et al. 2013).

As Florestas Estacionais Deciduais ocorrem em áreas livres de congelamento onde a temperatura média anual é maior que 17° C e a pluviosidade é altamente sazonal (Murphy e Lugo 1986), de quatro a seis meses secos (precipitação menor que 100 mm), que por sua vez determina a fenologia distintiva das plantas e para a floresta como um todo: uma deciduidade alternando durante a estação seca, seguido de uma fisionomia perenenifólia durante a estação chuvosa (Dirzo et al. 2011).

Embora sejam muitos os fatores que podem afetar as comunidades vegetais neotropicais, nas diferentes escalas, estes são escassamente documentados, já que, detêm menor atenção da comunidade científica, dificultando análises comparativas com outras áreas (Mooney et al. 1995; Gentry 1988). De acordo com Resende et al. (2002) e Fernandes (2003) fatores hidrológicos e pedológicos são importantes para a estratificação das fisionomias da vegetação em um determinado domínio de vegetação, sob certas condições climáticas e fisiográficas. Os fatores ambientais associados aos aspectos florísticos das vegetações adjacentes propiciam uma composição de espécies peculiar, numa escala regional (Pedralli 1997). Outros estudos fornecem indicações sobre a importância relativa dos fatores de habitat topográficos na estruturação de composição de espécies locais. (Punchi-Manage et al. 2013; Peña Claros et al. 2012). Além disso, estudos apontam que o clima e o solo afetam a composição florística e variação espacial da plantas comuns (Toledo et al. 2011 a,b; 2012).

O conhecimento da biodiversidade das formações vegetais é a condição primária e fundamental para o desenvolvimento não só de investigações botânicas e ecológicas, mas, sobretudo para o estabelecimento de modelos de preservação e conservação dos ecossistemas (Morellato e Leitão Filho 1995). Diante do exposto, este estudo visa investigar o padrão de distribuição das formações vegetais das formações decíduas na FLONA de Carajás através da análise de gradientes ambientais sobre a organização das comunidades vegetais, com base em características pedológicas e geomorfológicas.

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## Chapter l

## Soil-vegetation relationships and patterns of species distribution on Dry Forests at Carajás, islands from Brazilian Eastern Amazonia


ABSTRACT

Several abiotic factors are known to affect plant communities in the Neotropics, at different scales. Pedological and hydrological factors are important for distinguish plants communities in a given area, under the same climate and landscape. Against this background, the aim of this study was to investigate the distribution pattern of dry forests in Flona Carajás by analyzing soil and geomorphological gradients, in which two questions were raised: (1) Are composition and structure of these dry forests formations influenced by soil properties? (2) Is there a pattern of distribution of species in response to a soil gradient? In order to answer them, 36 plots were installed along the soil/ topographic sequence: Águas Claras Formation Sandstone (I and II), Carajás Granite and Xingu Basement Complex. Plots were allocated with all trees ≥ 10 cm at BHC sampled; soil samples (0-10 cm) were also collected. To determine the extent to which soil properties differed within and between the four areas, soil data were analysed by cluster analysis and ordination methods (PCA). Plot grouping clearly revealed the differentiation between soils, indicating that these dry forest formations occur in distinct environments, where there are clear differences in soil fertility and nutrient status. In general, all soils were acid and with low P amounts. However, significant differences in soil properties occurred between sampling sites, for these and many other soil properties. Nonmetric multidimensional scaling (NMDS) ordination technique was used to describe patterns in plant species composition to assess its relationship with soil variables. Different groups of species, highly differentiated and associated with each of the four groups comprising the vegetation gradient, were found. To model the distribution of species, the presence-absence of the most frequent and abundant species was used, applying multiple logistic regression to construct the response curves of species along the soil gradient. The distribution of the most frequent species tends to follow a pattern in response to soil gradient, in which some species may be considered more specialized with regard to local soil conditions than others.



Keywords: Soil-Vegetation. Tropical Dry Forest. Amazon

**Relação solo-vegetação e padrão de distribuição de espécies em Floresta Seca de Carajás, Amazônia Oriental Brasileira**

RESUMO

Diversos fatores abióticos podem afetar a composição e estrutura de comunidades vegetais na região Neotropical, em diferentes escalas. Fatores hidrológicos e pedológicos são importantes para a distinção das fitofisionomias em um determinado domínio de vegetação, sob certas condições climáticas e fisiográficas. Diante disso, o objetivo desse estudo foi investigar o padrão de distribuição das florestas decíduas na Flona de Carajás através das análises de gradiente edáfico/topográfico e foram feitas duas perguntas: (1) A composição e estrutura das formações de florestas secas são influenciadas pelas propriedades do solo? (2) Há um padrão de distribuição das espécies arbóreas em resposta ao gradiente edáfico? Para isso foram instaladas 36 parcelas ao longo da sequencia edáfico/topográfica: Formação Arenito Águas Claras (I e II), Granito Carajás e Granito do Complexo Xingu. Parcelas foram alocadas, onde todos os indivíduos arbóreos com CAP $\geq$ 10 cm foram amostrados e realizou-se coleta de amostras de solo (0-10 cm). A fim de determinar em que medida as propriedades do solo diferiram dentro e entre as quatro áreas, os dados de solos foram classificados por métodos de análise de agrupamento e ordenação (PCA). O agrupamento das parcelas expressou evidente diferenciação entre solos estudados, indicando que estas florestas decíduas, ocorrem em diferentes ambientes de solos variados, em que existem claras diferenças na fertilidade e status nutricional. Em geral, os solos em todas as florestas secas foram ácidos e com baixo P. No entanto, houve diferenças significativas entre as propriedades do solo entre as áreas amostradas para estas e muitas outras propriedades químicas do solo. A ordenação NMDS foi usada para descrever padrões na composição de espécies de plantas e avaliar a sua relação com variáveis do solo. Diferentes grupos de espécies altamente diferenciados e associados com cada um dos quatro grupos vegetacionais estudados foram encontrados. Para o modelo de distribuição de espécies utilizou-se os dados de presença-ausência das espécies mais freqüentes e abundantes e regressão logística múltipla para a construção das curvas de resposta dessas espécies ao gradiente edáfico. A distribuição das espécies mais freqüentes tende a obedecer a um padrão em resposta ao gradiente edáfico, sendo que essas espécies podem ser consideradas mais especializadas no que diz respeito às condições locais de solo do que as outras espécies.

Palavras-chave: Solo-vegetação. Floresta Tropical Seca. Amazônia.

## 1. Introduction

Diverse abiotic factors may affect plant communities in the Neotropics, at different scales. According to Resende et al. (2002) and Fernandes (2003) hydrological and pedological factors are prominent for distinguish physionomies in a given vegetation domain, under certain climatic and physiographic conditions. Others studies provide indications on the relative importance of topographic habitat factors in structuring local species composition. (Punchi-Manage et al.2013). Furthermore, studies point that climate and soil affect the floristic composition and spatial variation of plant common (Toledo et al. 2011 a,b). Amongst climate variables, the role of water availability in determining tree growth can be highlighted (Wagner et al. 2012). Amazonian forests have been conceived as a dense mosaic of different forest types, each characterized by local assemblages of tree species, among which many are edaphic specialists (Gentry 1988; Tuomisto et al. 1995; Clark et al. 1998).

Relations between plant communities and abiotic factors have been previously studied, but few studies have been conduced in with dry forests. Peña Claros et al. (2012) found that soil fertility explained a larger number of forest traits in dry forest compared with moist forest. Haridasan (2000) showed that when soil and vegetation matrices are related, soil features may be selecting plants with nutrients specific requirement, for example, plants with less tolerance to high aluminum concentration or plants that demand more nitrogen.

As mentioned above, species composition in a specific region can be influenced by a number of factors. These factors are related to variations also in species distribution within given type of vegetation. Studies showed that species respond clearly to environmental gradients (Engelbrecht et al. 2007; Toledo et al. 2012; Baltzer et al. 2008), in which topography and soil are major factors affecting species distributions and community patterns at smaller scale (Harms 2001; Miyamoto et al. 2003).

Climatic and soil conditions explained most of the variation in species occurrence, challenging the general idea that most tropical tree species are habitat generalists (Toledo et al. 2012). At a regional scale, climate can be a stronger driver of species distribution (Pyke 2001; Gentry 1988) related to water availability (Balvanera et al. 2011). However, in local scale the soil variation can affect species distribution pattern. In this respect, soil characteristics or topography are strong candidates for niche partitioning in tropical forest species (Engelbrecht et al. 2007; Tuomisto 1995). Besides this, species distribution can result from limited dispersal coupled with speciation, delayed responses to climate change, or other historical effects (Hubbell 2001).

Recent environmental studies of the National Forest of Carajás - FLONA (Schaefer et al. 2009), revealed the presence of numerous fragments physiognomically classified as Deciduous Forest (DFs) in the middle of seasonal semi-deciduous forest and dense rain forest surroundings and so far unknown to science. These DFs had been previously, mistakenly interpreted as ironstone areas in satellite images. Importantly, the DFs in Carajás are embedded in a distinct vegetation matrix (Amazonian Domain) having a different climate compared with typical Seasonal (Dry) Forests from elsewhere in Brazil.

Against this background, and following the mapping of vegetation communities of the Carajás area (Schaefer et al. 2009), some questions were preliminary raised, in order to have a better understanding of vegetation distribution in the landscape of FLONA of Carajás: (1) Are the composition and structure of these DFs formations influenced by soil properties?; (2) Is there a distribution pattern of tropical woody species in response to edaphic gradients.

Hence, the aim of this study was to elucidate the distribution pattern of vegetation formations of deciduous formations in the FLONA of Carajás through the analysis of environmental gradients on the organization of plant communities, based on pedogeomorphological characteristics.

## 2. Materials and Methods

### 2.1 Study Area

The Dry Forest vegetation islands surrounded by rain forest are located in the Carajás National Forest (FLONA) conservation unit, southeastern Pará State, Brazil (Fig. 1). In order to encompass the four major sets of dry forest landscapes we used 36 plots with 400 $m^2$ each, with a total sampling area of 1.44 hectares: (1) “Águas Claras” Archean Sandstone Formation (Grão-Pará Group); (2) Mid Proterozoic Carajás Granite and The Xingu Arquean Complex, with 9 plots each.

The regional climate is humid tropical (“Aw”) type in the Köppen system; Ab’Saber 1986), with a well-defined marked dry season between May and October (average precipitation < 60 mm in the driest months), and a rainy season between November and April. Rainfall increases with altitude and lowland areas receive an average of 1500 mm/year, whereas elevated sites up to 1900 mm/year (IBAMA et al.

2003).Average monthly temperatures range between 19 and 31°C.

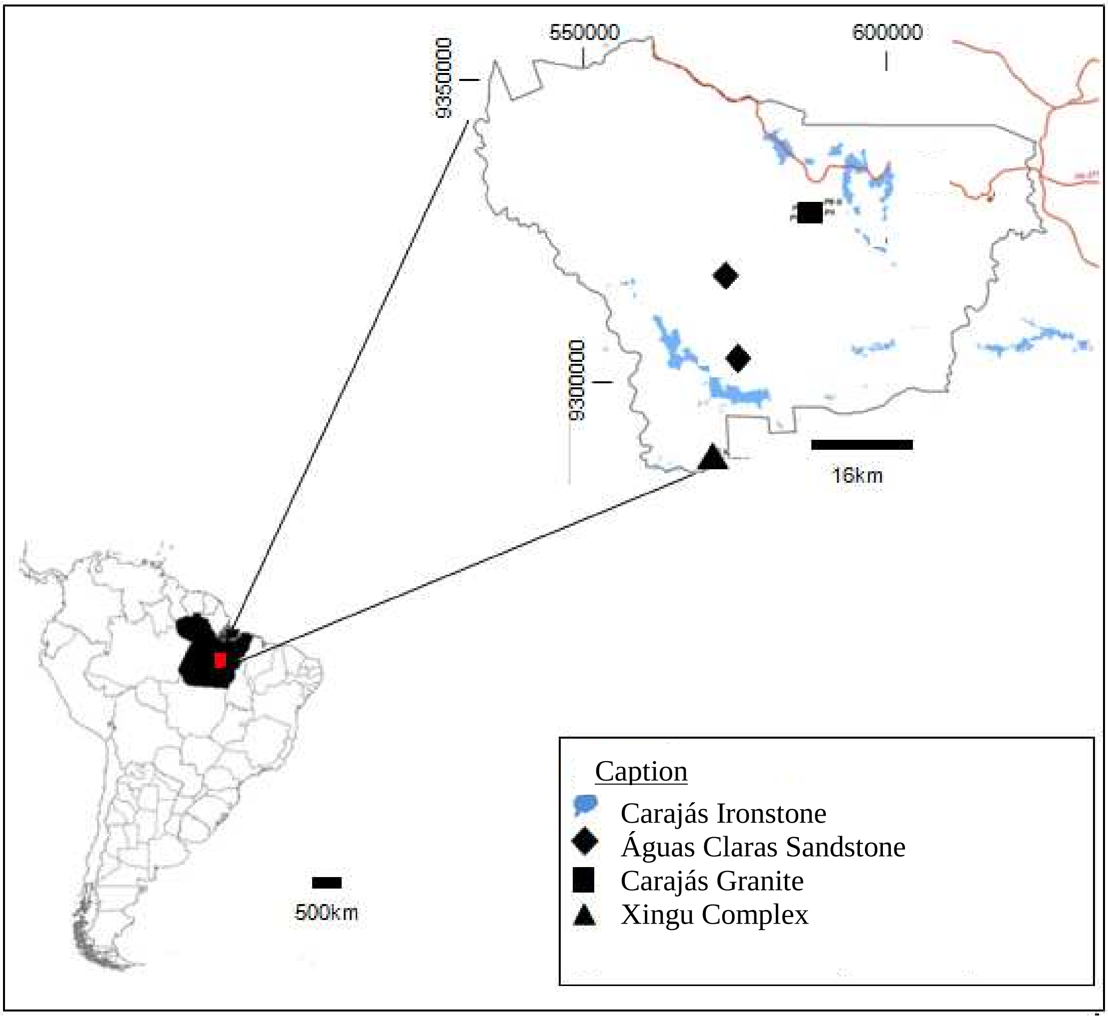


Figure 1 - Location of the Carajás National Forest, Pará, Brazil. Highlight the study area and dry forest formations on different geomorphologies, beyond the Plateau ironstone in blue.

2.2 Environmental data

Soil and vegetation were sampled in 36 replicate plots within each of the four soil-vegetation formations types.

Three replicate (0.5 L at 0 – 10 cm depth) surface samples were collected from each plot and bulked to provide one single composite sample per plot. Soil samples were air-dried and sieved (2 mm mesh), stored in glass jars and analysed by the Soil Analysis Laboratory of the Soils Department at the Federal University of Viçosa using standard procedures (Embrapa 1997). The soil variables determined included: pH; extractable P, Na, K, Fe, Zn, Mn, Cu (by Mehlich 1), exchangeable Ca, Mg and Al (extracted in KCl), % soil organic matter (TOC using the Walkley-Black method), P remaining in solution (P_Res), and derived measures such sum of bases (BS) and cation exchange capacity (CEC).

For the analysis of environmental data, an independent principal component analyses (PCA) was performed for soils. The edaphic PCA included 15 edaphic variables, where the first three axis explained, together, 76% the variation. The first axis (48%) correlated positively with variables related to soil fertility (BS, Ca, CEC, Mn and pH) and negatively to Aluminum. The second axis (16.5%) correlated positively with P_Res, Fe and negatively with TOC. Finally in the three axis (11%) correlate negatively with Cu (Table 1).

Table 1 - Correlation of soil variables with principal components I, II and III from the PCA of the 15 soil variables x 36 plots data matrix. Bolded correlations are significant at P<0.001.

| soil variables | PCA 1 | PCA 2 | PCA 3 |
|---|---|---|---|
| pH | **0.81** | -0.25 | -0.38 |
| P | 0.37 | -0.41 | 0.12 |
| K | **0.72** | -0.25 | -0.40 |
| NA | **0.67** | -0.19 | 0.49 |
| CA | **0.96** | -0.08 | -0.01 |
| MG | **0.79** | 0.49 | 0.11 |
| AL | **-0.73** | -0.06 | 0.26 |
| BS | **0.97** | 0.03 | 0.02 |
| CEC | **0.94** | 0.01 | 0.11 |
| TOC | 0.16 | **-0.70** | 0.60 |
| P_RES | 0.30 | **0.85** | -0.04 |
| ZN | **0.70** | 0.33 | 0.37 |
| FE | -0.31 | **0.68** | 0.01 |
| MN | **0.90** | 0.20 | 0.04 |
| CU | 0.22 | -0.30 | **-0.73** |

2.3.Recording of Plant Species

Considering plant species, all plots (36) of the four formations sets on different DFs landscape were sampled in FLONA of Carajás. Rare species were excluded, although they were the majority, because they with have strong habitat preference; hence, we selected 140 species with minimum occurrence of 5 individuals for this analysis. We considered two variables: occurrence based in presence/absence in the plot and the abundance (number of individual ≥ 10 cm circumference at breast height at 130 cm in each plot. First, we selected 53 species that were divided in two groups: with species density higher than 20 individuals, and lower than 19 individuals; both with frequency higher than 6 plots (16,66%).

## 2.4. Soil-Vegetation Relationship

The soil data were screened for strongly inter-correlated variables; whenever r was > 0.8 between any two variables, one was dropped from subsequent analyses. A principal components analysis (PCA) ordination was conducted using the 15 remaining soil variables to explore the dominant soil property gradients across the sampling space. The correlation matrix was used, with each soil variable standardized by standard deviation, making all variables comparable regardless of original unit of measurement (McCune and Mefford 2011). Soil variables were correlated (Pearson's correlation coefficient) with PCA component scores to identify those factors most strongly associated with each principal component.

In order to investigate soil properties differed within and between the four sample areas, soil data were classified using flexible beta linkage (beta = -0.25) clustering of relative euclidean distance for soil variables transformed to standard deviates (McCune and Grace 2002). A principal components analysis (PCA) ordination was conducted on the transformed soils data to explore the dominant soil property across the sampling space using PC-ORD version 6 with correction for tied ranks (McCune and Mefford 2011).

Nonmetric Multidimensional Scaling (Minchin 1987) was used to describe patterns in plant species composition and to assess their relationship to measured soil variables. NMDS is an indirect ordination procedure that has been demonstrated as particularly robust in relation to non-linearities associated with data sets that span broad environmental gradients (Minchin 1987). It is an interactive procedure that orders samples in a defined number of dimensions based on the ranked distances between sample units (McCune and Grace 2002). NMDS analyses were run for the Sorensen's (Bray-Curtis) resemblance matrices of species density relativized to plot sum (to take account of differences in total densities for plots of different size) using PC-Ord version 6 with instability criterion of 0.00001 and 249 iterations, and Monte Carlo randomization (n=249) (McCune and Mefford 2011). Soil variables were correlated with NMDS ordination axis scores and variables with significant Pearson's correlation displayed as vectors, using the biplot procedure in PC-Ord.

## 2.5 Species distribution models

For this analysis one may use data on presence-only, presence-absence or abundance. In this study, presence-absence was preferred over abundance because variation in the abundance data can be caused by a wide range of processes (competition), species traits (ecological guild, dispersal type) or sampling effects (plot position) (Toledo et al. 2012).

We used a multiple logistic regression analysis to construct species response curves to the edaphic gradient, using presence-absence data as the dependent variable. The power of a multiple logistic regression lies in the simultaneous analysis of the effect of several environmental variables (ter Braak and Looman 1986). We built a logistic model for each the most frequent species by including the three axis from the soil PCA. In this analysis we used the R program version 2.15.0.

## 3. Results

### 3.1 Soil-Vegetation Relationship

The well expressed clustering of plots showed a clear differentiation of studied soils indicating that these Dry Forest (DF) formations occur on varied, distinct, soil environments, in which clear differences on soil fertility and nutrient status exist (Fig. 2).

Over all, soils in all DF formations were acidic and with low P.  However, there were significant differences between soil properties among the sampled areas for these and many other soil chemical properties. The soils were more acidic in "Águas Claras" Sandstone Soils (AI and AII) indicating extreme leaching, and igneous rocks of Carajás Granite Soils (G) and Xingu Complex Soils (X), are less weathered, less acid and with higher available P when compared with all others sites (Table 2).

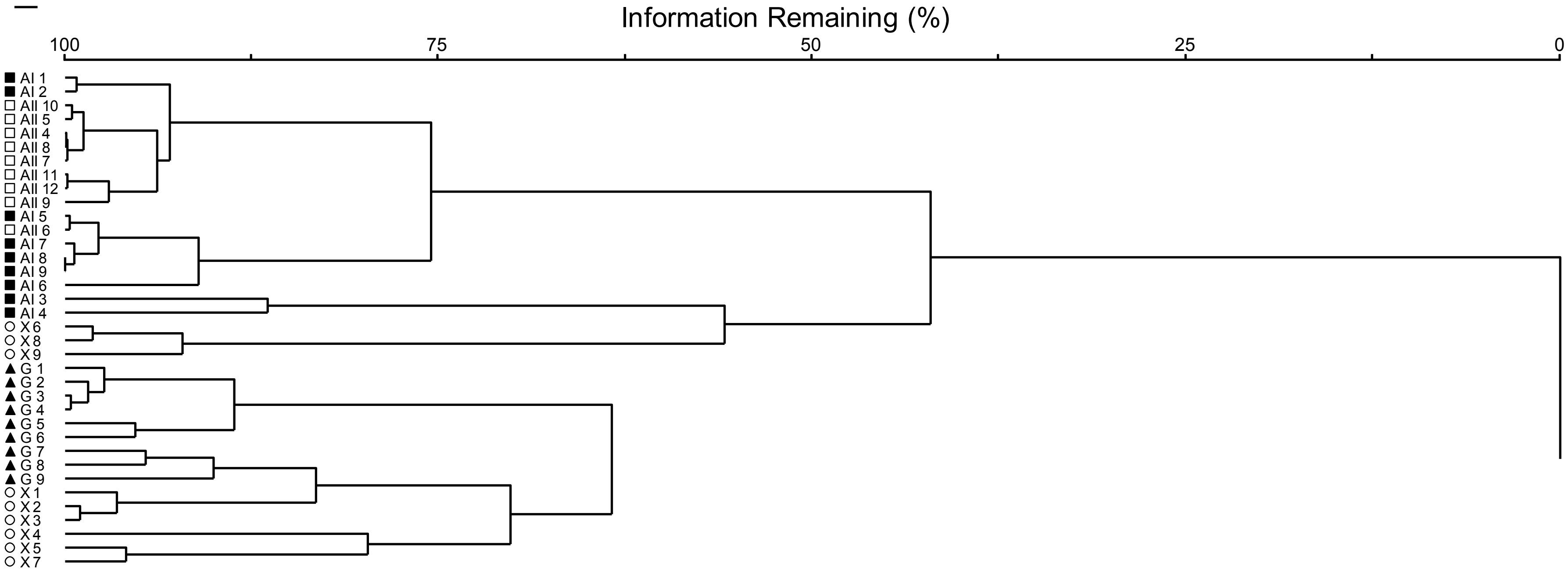


Figure 2 – Classification dendrogram of sample plots based on mean surface soil properties for samples from Águas Claras Sandstone Soils I (AI=square closed), Águas Claras Sandstone Soils II (AII=square open), Xingu Complex Soils (X= circle open) and Granite Carajás Soils (G = triangle closed) Carajás National forest, Pará State, Brazil. The classification is based on flexible beta clustering (beta = -0.25) of Relative Euclidean Distance with variables relativised to standard deviates.

Table 2 - Mean soil variable levels (±95% C.I.) for surface soils (0-10 cm) by Dry Forest, National Forest of Carajás, Pará State, Brazil. AI: Águas Claras Sandstone Soils I; AII: Águas Claras Sandstone Soils II; G: Carajás Granite Soils and X: Xingu Complex Soils. Where: BS = Total exchangeable bases; CEC =Effective Cation Exchange Capacity; TOC = Organic matter; Res-P = Residual Phosphorus.

| **Soil Variable** | **AI** | **AII** | **G** | **X** |
|---|---|---|---|---|
| pH ($H_2O$) | 3.99 ±0.23 | 4.15 ±0.27 | 5.15±0.62 | 4.86 ± 0.51 |
| P ($mg/dm^3$) | 1.82 ± 0.81 | 1.60 ±0.75 | 2.83 ±7.13 | 3.67 ± 1.69 |
| k ($mg/dm^3$) | 49.39 ±20.64 | 41 ±17.52 | 106.9±42.50 | 87.41 ± 30.68 |
| Na($mg/dm^3$) | 2.26 ± 3.58 | 1.76 ±2.25 | 4.12±2.29 | 22.98 ± 15.28 |
| Ca ($cmolc/dm^3$) | 0.39 ±0.39 | 0.28 ±0.19 | 2.78 ±2.70 | 3.56 ± 2.48 |
| Mg ($cmolc/dm^3$) | 0.69 ±0.12 | 0.72 ±0.08 | 0.52 ±0.45 | 1.07 ± 0.78 |
| $Al^{3+}$ ($cmolc/dm^3$) | 1.90±1.085 | 1.99 ±0.64 | 0.85 ±0.68 | 0.81 ± 0.77 |
| BS ($cmolc/dm^3$) | 1.21±0.51 | 1.14 ±0.30 | 3.60 ±3.17 | 4.96 ± 3.15 |
| CEC ($cmolc/dm^3$) | 3.12 ±1.05 | 3.13 ±0.66 | 4.44 ±2.67 | 5.77 ± 2.73 |
| TOC ($dag/Kg^{-1}$) | 4.16 ±3.12 | 4.24 ±2.47 | 5.94 ±2.46 | 8.85 ± 4.24 |
| P-res (mg/L) | 37.26 ±9.35 | 32.89 ±7.60 | 23.37 ±13.59 | 29.15 ± 10.17 |
| Zn ($mg/dm^3$) | 0.71 ±0.45 | 0.65 ±0.38 | 0.52 ±0.61 | 1.38 ± 0.73 |
| Fe ($mg/dm^3$) | 188.4±133.23 | 206.65 ±104.93 | 45.35±26.47 | 69.43 ± 40.18 |
| Mn ($mg/dm^3$) | 7.78 ±7.41 | 9.71 ±7.28 | 22.73 ±22.80 | 40.03 ± 27.09 |
| Cu ($mg/dm^3$) | 0.57 ±0.71 | 2.07 ±2.23 | 5.18 ±2.93 | 1.82 ± 1.40 |

Based on the PCA ordination of the screened soil variables (15 variables x 36 plots) the plots were readily separated based on soil properties, with an overall trend of greater nutrient contents associated with both igneous rock plots (Carajás Granite Soils and Xingu Complex Soils) negatively, and with nutrient-depleted Águas Claras Sandstone Soils positively in axis 1 (48% of the total variance). Conversely, the Águas Claras DF plots showed a relationship with variables such as extractable Fe and residual P. The amount of extractable Al is also higher for Águas Claras plots (Fig.3). Plots with positive scores on Axis 1 were all in Águas Claras Sandstone Soils (AI and AII) besides G1, G2 and G4 plots with soils sandstone, higher Al+ and higher extractable Fe. Axis 2 (16% of the total variance) showed Xingu Complex Soils and Granite Carajás plots two outliers of Xingu Complex Soils, with high Mn, BS and Ca, from other Granite Carajás plots. The two first PCA components was strongly correlated with nearly all of soil variables measured (Table 2), and component scores for this axis were used subsequently as a complex soil gradient for correlation with vegetation ordination results.

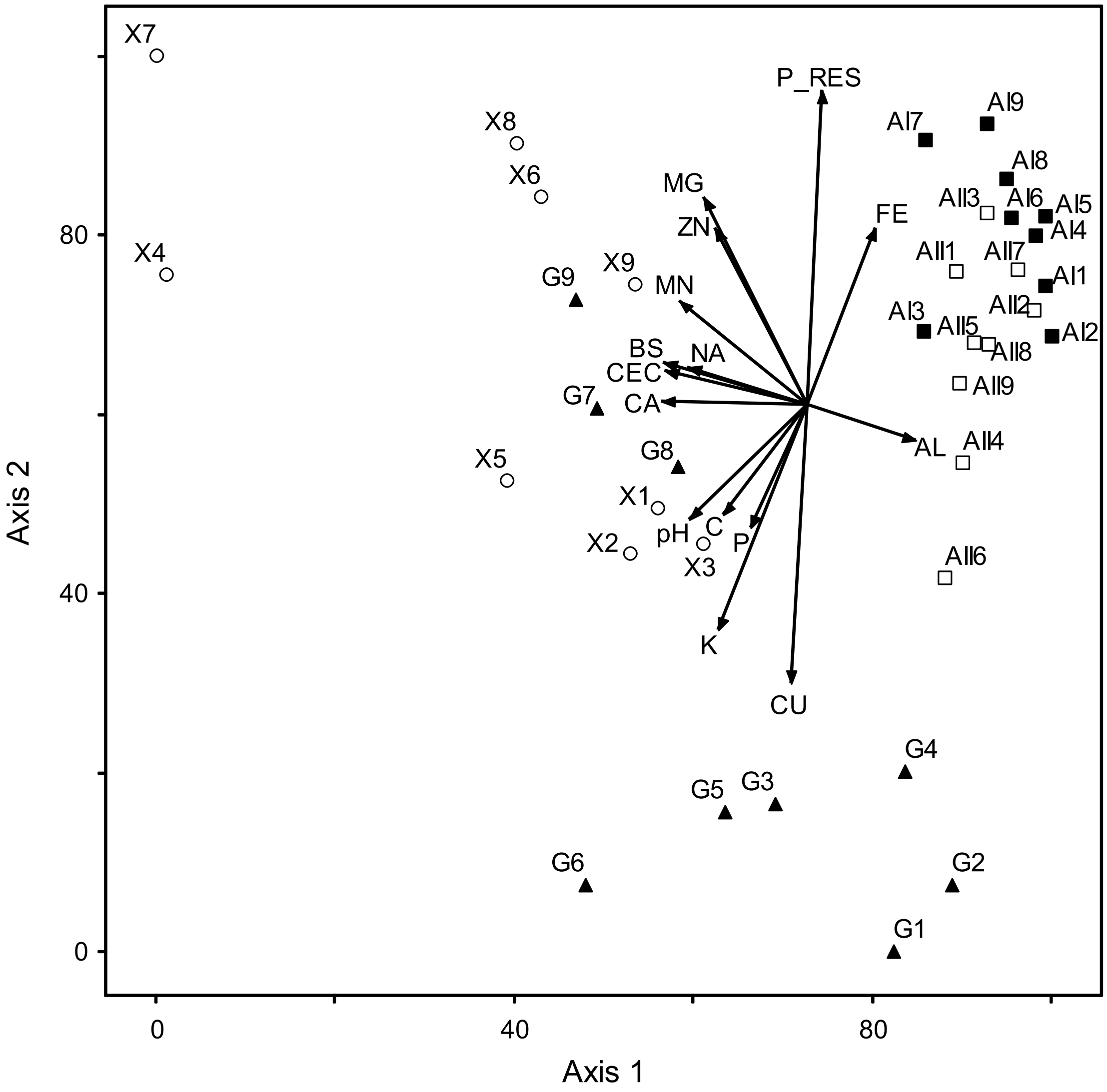


Figure 3 - Principal Components Analysis (PCA) ordination of sample plots based on surface soil chemical properties for the four lithologies types at Carajás National Forest, Pará, Brazil: Águas Claras Sandstone Soils I (AI=square closed), Águas Claras Sandstone Soils II (AII=square open), Xingu Complex Soils (X=circle open) and Granite Carajás Soils (G=triangle closed). Soil properties significantly correlated with PCA axis are overlayed as vectors (short vectors $P<0.01$, long vectors $P<0.001$). Where: BS = Total exchangeable bases; CEC = Effective Cation Exchange Capacity; TOC = Organic matter; Res-P = Residual Phosphorus.

A three dimensional NMDS solution with stress of 13.45 for the analysis of all 36 sample plots (and all 140 species) separated Águas Claras Sandstone Soils (AI) plots with high scores on axis 2 from Xingu Complex plots with low scores (Fig. 4). On axis 3 Granite Carajás Soil separated Xingu Complex plots (G) had high scores.  The NMDS ordination shows groups of species strongly differentiated and associated with each of the four DF formations which makes up the sequence. Is possible observed a gradient following from Granite Carajás Soils - Xingu Complex Soils to Águas Claras Sandstone Soils (Fig. 5).

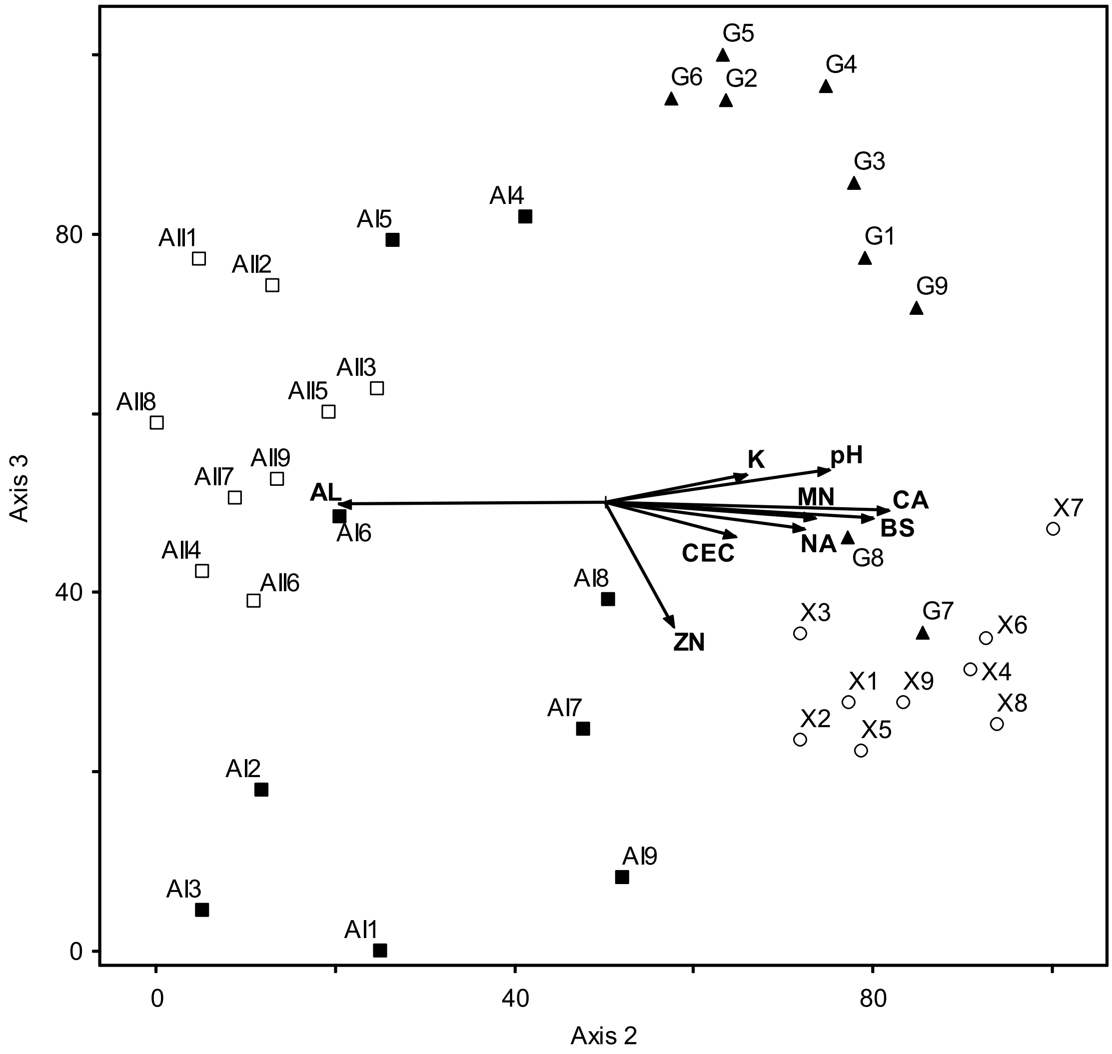


Figure 4 - Nonmetric Multidimensional Scaling (NMDS) ordination of sample plots, based on relative density of plant species for the four lithologies types at Carajás National Forest, Pará, Brazil: Águas Claras Sandstone Soils I (AI=square closed), Águas Claras Sandstone Soils II (AII=square open), Xingu Complex Soils (X=circle open) and Granite Carajás Soils (G=triangle closed). Where: BS = Total exchangeable bases; CEC = Effective Cation Exchange Capacity; S= Richness and H= diversity.

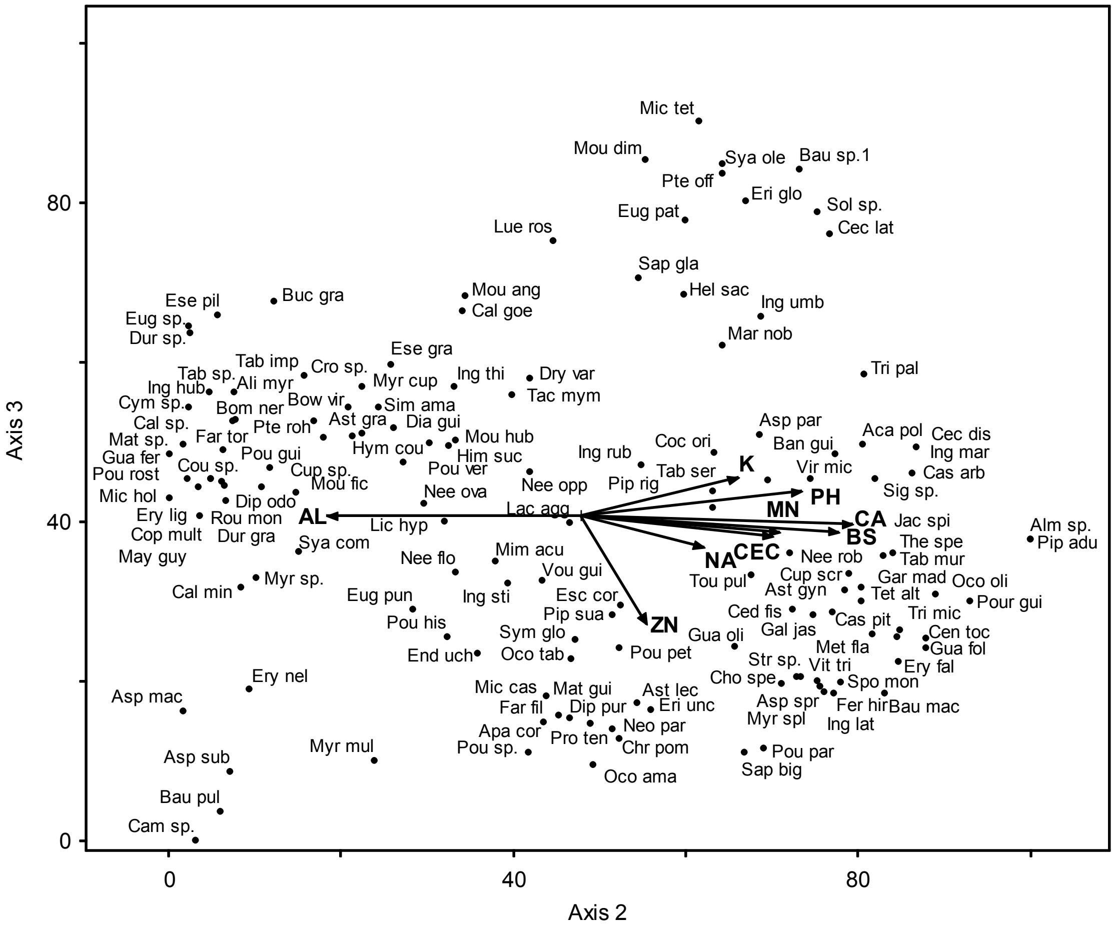


Figure 5 - Nonmetric Multidimensional Scaling (NMDS) ordination of sample plots based on relative density of plant species for the five lithhologies types at National Forest of Carajás, Pará, Brazil: Águas Claras Sandstone Soils I, Águas Claras Sandstone Soils II, Xingu Complex Soils and Granite Carajás Soils.Where: BS = Total exchangeable bases; CEC = Effective Cation Exchange Capacity. The abbreviations represented in this figure correspond to species according with Table 3 (Supplementary Material).

3.2 Species distribution models

The majority of the species studied had a relatively low frequency, with 53 species present in < 50% of the plots. Among these species, only one, Esenbeckia grandiflora (50% of the plots) occurred in half of the plots and was the most abundant species, despite of its absence in DF of the Xingu Complex Soils. Two species groups based on species distribution pattern were determined in according with combinations of frequency and abundance. The two groups had different species number; group one (species > 20 individuals) had 22 species and group two (species < 19 individuals) had 31 species.

The probability of the occurrence of a given species along the soil gradient studied was predicted for the logistic regression models. Of all species included in this analysis, 21 species responded significantly to at least one of the three scores from soil

PCA. Species showed different response curves to the three scores from soil PCA to group one (Fig. 6) and two (Fig.7). Three of types responses were identified: flat curves (no response), an increasing curve and a decreasing curve.

Of the 22 species of the first group, 10 were significantly related to at least one axis from soil PCA; furthermore, Neea floribunda had a significant relationship with axis 1 and 2 from PCA soil.  In group 2, with a total of 31 species, 11 had a significant relationship with at least one of the axis from soil PCA.

Theobroma speciosa had significant correlation with axis 1 and 2 from soil PCA. In the first group Metrodorea flavida, Aparisthimium cordatum and Neea floribunda had significative response related to PCA 1 (Fig. 6a). Margaritaria nobilis, Neea floribunda and Duroia granssabensis showed significant response to PCA2 (Fig. 6b). Finally Esenbeckia grandiflora, Sapium glandulatum and Spondias monbin had significative response to PCA 3 (Fig. 6c). From the group two the following species had significant response: Theobroma speciosa and Tetragastris altissima to PCA1 (Fig. 7a); Toulicia pulvinata, Astrocaryum ginacantum, Theobroma speciosa, Banara guianensis and Handroanthus serratifolius to PCA2 (Fig. 7b); Luehea rosea, Faramea phelipis, Casearea pitumba and Licania hypoleuca to PCA3 (Fig. 7c).

Among ten species the most frequent, seven had significant relationship with at least one of the axis from the soil PCA. The species Metrodorea flavida and Neea floribunda were significantly related to PCA 1 (Fig.8). The first one had higher probability of occurrence where there is BS, Ca, CEC and pH, and decreasing Aluminum, while the second one follows an opposite trend.

Vouarana guianensis, Neea floribunda, Margaritaria nobilis and Toulicia pulvinata were significantly related to PCA2 (Fig. 9); the first one had occurrence conditioned to increase of the TOC. N. floribunda in PCA2 occurred where extractable Fe, P-Res and TOC are higher. M. nobilis and T. pulvinata had higher probability of occurrence where P-Res and extractable Fe are higher. Finally, Esenbeckia grandiflora and Sapium glandulatum were significantly related to PCA3; distribution pattern may be seen in Figure 10.

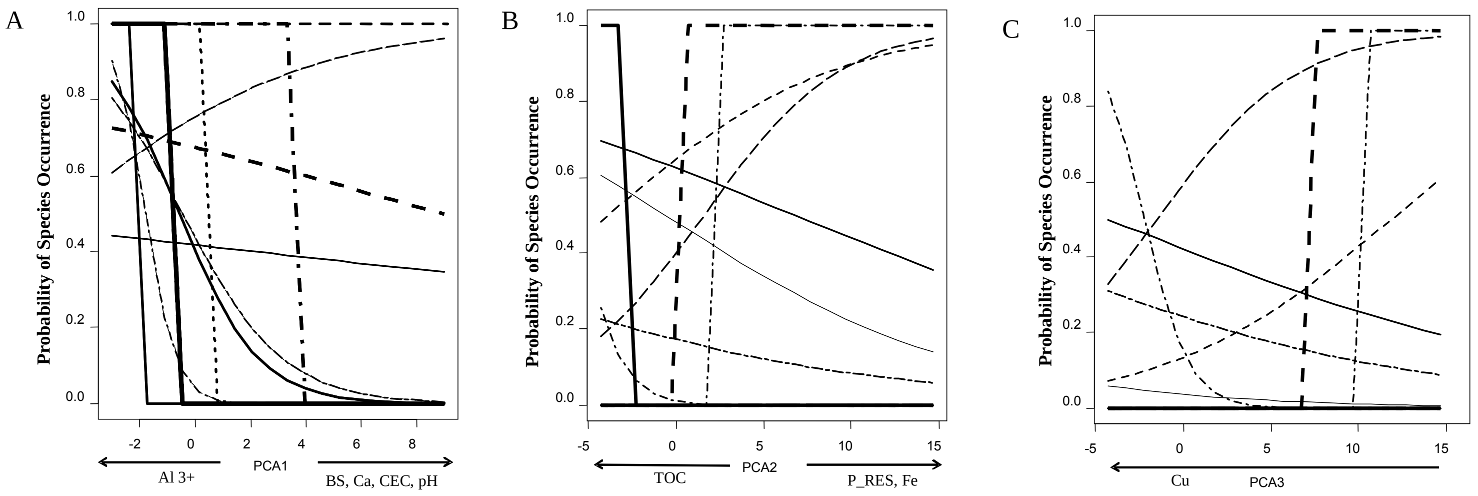


Figure 6 - Group One: The modelled probability of occurrence of each one of the 22 species in relation to (a) the soil gradient – PCA1, (b) the soil gradient – PCA2 and (c) the soil gradient – PCA3. The gradient is summarized by the principal component analysis axis. Species distribution patterns in Dry Forest, Brazilian Amazonia.

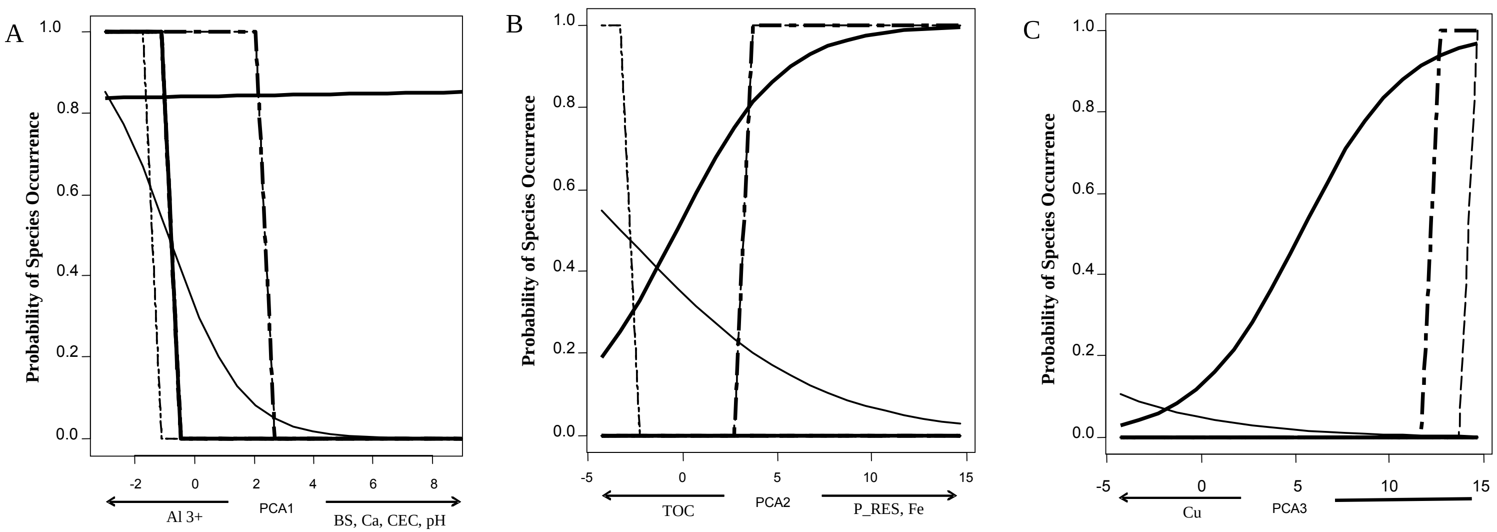


Figure 7-Group Two: The modelled probability of occurrence of each one of the 31 species in relation to (a) the soil gradient – PCA1, (b) the soil gradient – PCA2 and (c) the soil gradient – PCA3. The gradient is summarized by the principal component analysis axis. Species distribution patterns in Dry Forest, Brazilian Amazonia.

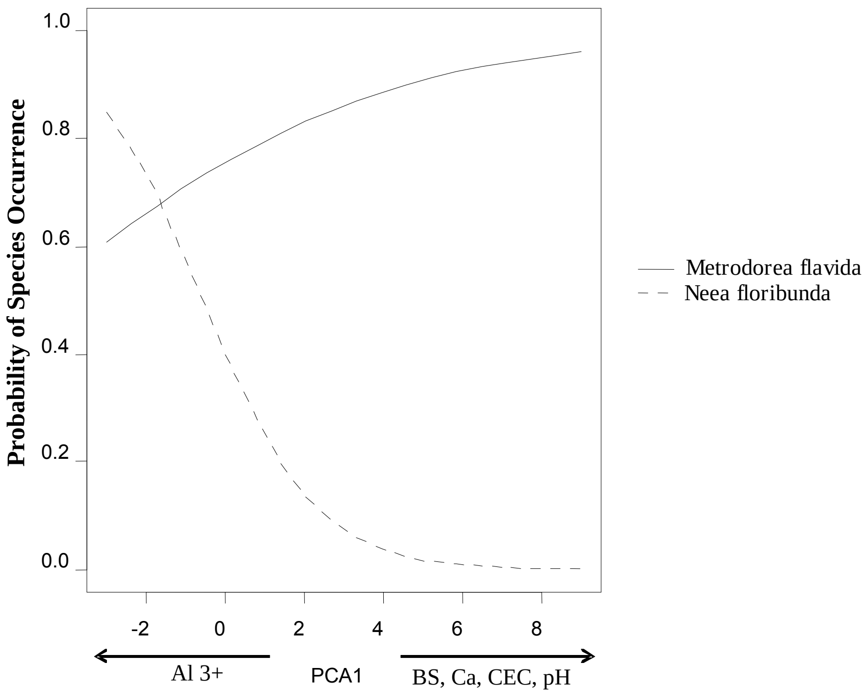


Figure 8 - Distribution patterns of two species with relationship significantive among 10 species the most frequent from PCA 1 axis at Dry Forest, Brazilian Amazonia. The gradient is summarized by the principal component analysis axis.Where: BS = Total exchangeable bases; CEC =Effective Cation Exchange Capacity.

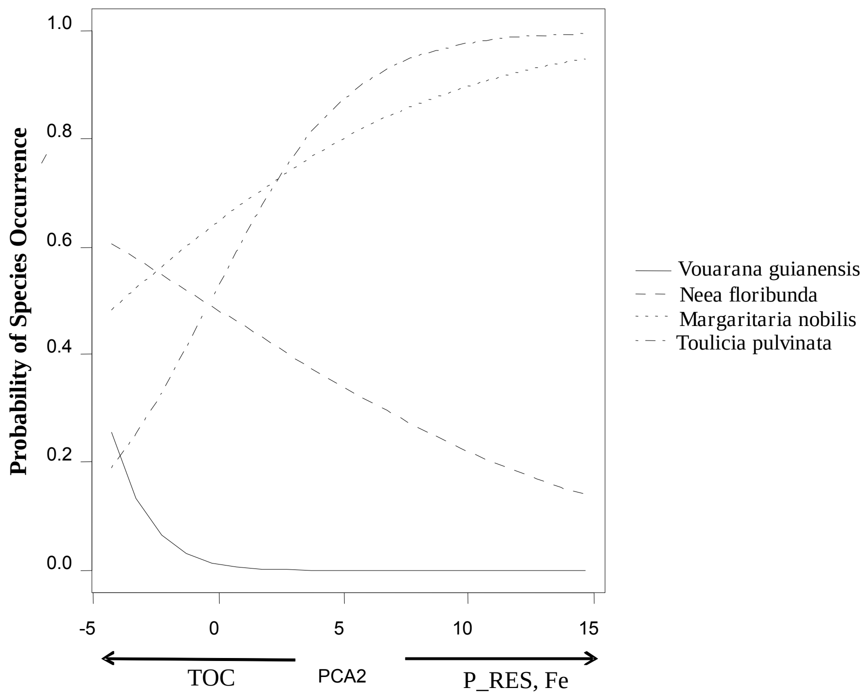


Figure 9 - Distribution patterns of four species with relationship significative among 10 species the most frequent from PCA 2 axis at Dry Forest, Brazilian Amazonia. The gradient is summarized by the principal component analysis axis.Where: TOC = Organic matter; Res_P = Residual Phosphorus.

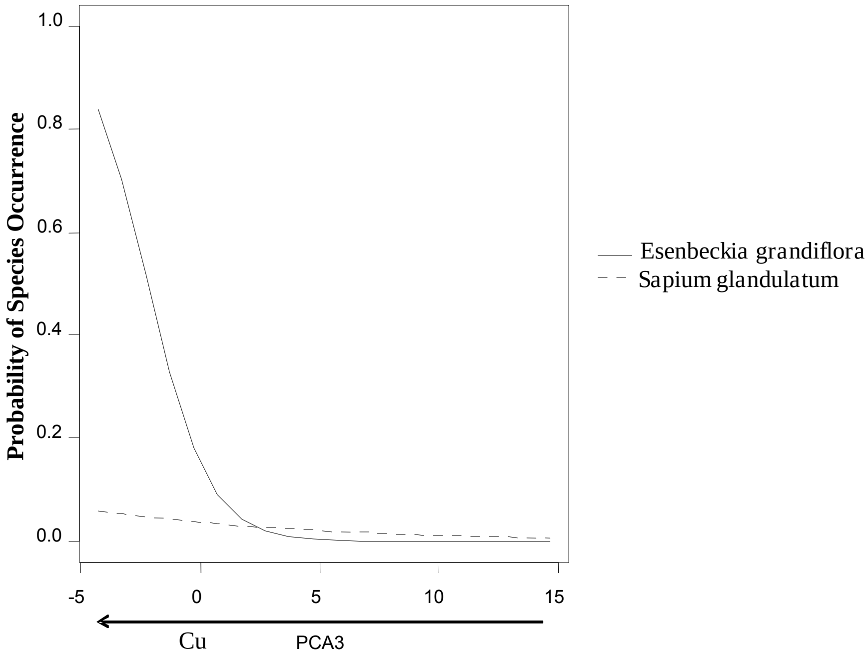


Figure 10 - Distribution patterns of two species with relationship significative among 10 species the most frequent from PCA3 axis at Dry Forest, Brazilian Amazonia. The gradient is summarized by the principal component analysis axis.

## 4. Discussion

Despite all fragments are subjected to the same climatic conditions and surrounded by rainforest, in this study, we clearly indicated that soil properties influences the existence of Dry Forest within in the Carajás National Forest. Ours results indicate that these DF formations occur on varied, distinct, soil environments, in which clear differences on soil fertility (nutrient status), chemistry do exist. In the sense, Tuomisto et al. (2003) highlight that soil variation act as an additional filter under the same climatic context; under-smalle scale. Study in dry forest ecosystems of Thailand showed that soil characteristics of the dry forest differ markedly from mixed deciduous forests. The first have soils with lower pH, cation exchange capacities and available phosphorus compared with mixed deciduous forest soils (Rundel and Boonpragob 2009).

Through PCA and cluster analysis, we found that edaphic factors play an important role in Dry Forest of Carajás, since the plots readily separated based on soil properties between each DF formation. There is an overall trend of greater nutrient contents associated with both igneous rock plots (Carajás Granite Soils and Xingu Complex Soils), illustrating that these resistant, massive rocks offer a pedoenvironment of higher fertility (Ca, Mg, K, Bases sum, micronutrients such as Mn and Zn), compared with nutrient-poor Sandstone of Águas Claras. Conversely, the Águas Claras Sandstone plots showed a positive relationship with variables such as extractable Fe, which indicates a temporary reducing conditions of these sandy soils (Magnago et al. 2012), and residual P, an indicator of low clay content, decreasing the P adsorption capacity (Leal; Veloso 1973; Tucci 1991). The TOC content had little influence on these formations, probably because all soils are basically shallow, and allow for similar biomass productivity. Available phosphorus showed higher amounts in Xingu Complex Soils and Carajás Granite Soils, areas which had less weathered soils, with, higher Na, Ca, Mg and BS than others areas studied.

Research in tropical ecosystems (e.g. Fernandes; and Sanford 1995; D0ckersmith et al. 1999) has shown that individual plants have a lasting effect on the chemical distribution of soil nutrients, contributing to the spatial heterogeneity of soil properties at mesoscale. In the case of the Carajás, the NMDS clearly indicate that the vegetation types respond to soil gradient.

Only Esenbeckia grandiflora that occurred in 50% of sampled plots could be species with lower nutrients requirement. The majority of the species registered had a relatively low frequency. Toledo et al. (2012) studied Amazon dry forest at regional scale and showed a similar pattern. In longer gradients is possible to identify specialists species along the environmental gradient, i.e., those combining a high abundance with a low frequency.

However, Pitman et al. (2001) studying the Ecuadorian Amazon forest, found that locally common species tend to have high abundance and frequency and, consequently, oligarquies of a few species is unlikely over large areas of tropical forest. However, where environmental heterogeneity is high, these presumed oligarquies-dominated areas are expected to be much smaller. Consistently, study on Colombian Amazon classified 61% species as locally rare (Duque 2004), whereas in a Bolivian dry forest the dominant species are not soil generalists, and respond clearly to local variation in soil conditions (Peña-Claros et al. 2012).

Species such as Neea floribunda and Vouarana guianensis are locally abundant in Aguas Claras Sandstone Soils, with less abundance on Granite Carajás Soils, where organic matter is intermediate (Fig 8 e 9). In the first case, greater exchangeable Al and lower nutrient status are typical, but other factors may also have a role. Sandy soils with less water-holding capacity suggest that these species are able to tolerate drier soils, or otherwise can be better competitors in such conditions. This is consistent with water availability as the main driving force for explaining species distribution (e.g. Toledo et al. 2012; Baltzer 2008).

Margaritaria nobilis and Toulicia pulvinata followed the opposite trend, with higher frequency with greater residual P and exchangeable Fe, reduce with higher organic matter. M. nobilis is particularly abundant in the Carajás Granite Soils and Xingu Complex Soils, whereas T. pulvinata had high frequency in Águas Claras Sandstone Soils, despite low density. Sapium glandulatum and Esenbeckia grandiflora were more frequent and abundant in both Águas Claras Sandstone Soils and Granite Carajás Soils, and no possible explanation could be envisaged (Fig. 10).

Although there were close associations of species distribution patterns with soil variables, most species occurred over a large part of the gradients. Our results indicate that most frequent species tend to be more specialized with regard to local soils conditions than other species studied. The model of species distribution on soil gradient indicates that species are very likely nonrandomly distributed in soil gradient.

Differential distributions of tree species related to environmental gradients were generally associated with high degree of significance and considerable variance explained by the environmental variables (Table 1). This suggests that, the total area studied (1.44 hectares), is suitable to address that question raised in the current work. Costa et al. (2005), highlight that sampling error affects more the probability of finding rare species than the recorded proportions of abundant species.

In figures 6 and 7 we can observe the contrasting distribution pattern along the soil gradient which indicates the role of soil nutrients in driving differential distribution of trees within DF in Carajás. Furthermore, it provides evidence of niche partitioning along of the soil gradient. Diverse authors have showed strong effect of edaphic heterogeneity on floristic composition and species distribution at both small and large scales (Vormisto 2002; Phillips et al. 2003; Peña-Claros et al. 2012; Arruda 2012). Studies about habitat association within a lowland Amazon landscape confirm that tree species composition respond strongly to comparatively small variations in soil, suggesting that the distributional patterns of most species segregate by landform unit even within a landscape with comparatively little apparent soil variation. These authors emphasize also that finding pervasive and deterministic habitat association among Amazon tree species does not prove pervasive physiological specialization in particular soil environments: other biological processes could contribute to the empirical patterns observed in the realized niches of these species (Phillips et al. 2003).

## 5. Conclusions

1. Under a similar conditions humid tropical climate (Aw-Koppen) and surrounded by rainforest, DF formations of Carajás occur on varied soil environments, with clear differences on soil chemistry (nutrient status).

2. Soils influence species distribution pattern in Carajás; there is a distribution pattern of tropical woody species in response to edaphic gradient, in which the most frequent species tend to be more specialized with regard to local soils conditions than other species studied.

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7. Supplementary Material

Table 3 - Total density of plant species recorded in each vegetation type at Dry Forest in Carajás National Forest, Pará State, Brazil. AI: Águas Claras Sandstone Soils I; AII: Águas Claras Sandstone Soils II; G: Carajás Granite Soils and X: Xingu Complex Soils.

| **Species** | **Abbreviation** | **AI** | **AII** | **G** | **X** |
|---|---|---|---|---|---|
| Alibertia myrciifolia Spruce ex K.Schum. | Ali myr | 2 | 10 | 3 | 0 |
| Almeidea sp. A.St.-Hil. | Alm sp. | 0 | 0 | 0 | 1 |
| Aparisthmium cordatum (A. Juss.) Baill. | Apa cor | 11 | 0 | 0 | 0 |
| Aspidosperma macrophyllum Müll. Arg. | Asp mac | 10 | 5 | 0 | 0 |
| Aspidosperma parvifolium A. DC. | Asp par | 0 | 0 | 3 | 3 |
| Aspidosperma spruceanum Benth. ex Müll. Arg. | Asp spr | 0 | 0 | 0 | 6 |
| Aspidosperma subincanum Mart. | Asp sub | 8 | 2 | 0 | 0 |
| Astronium gracile Engl. | Ast gra | 1 | 9 | 0 | 2 |
| Astrocaryum gynacanthum Mart. | Ast gyn | 3 | 0 | 6 | 3 |
| Astronium lecointei Ducke | Ast lec | 3 | 0 | 1 | 0 |
| Banara guianensis Aubl. | Ban gui | 0 | 0 | 6 | 6 |
| Bauhinia macrostachya Benth. | Bau mac | 0 | 0 | 0 | 11 |
| Bauhinia pulchella Benth. | Bau pul | 14 | 2 | 0 | 0 |
| Bauhinia sp.1 L. | Bau sp.1 | 0 | 0 | 8 | 0 |
| Bombacopsis nervosa (Uittien) A. Robyns | Bom ner | 0 | 6 | 1 | 0 |
| Bowdichia virgilioides Kunth | Bow vir | 3 | 14 | 2 | 0 |
| Buchenavia grandis Ducke | Buc gra | 0 | 8 | 1 | 0 |
| Calycolpus goetheanus (Mart. ex DC.) O.Berg | Cal goe | 0 | 3 | 3 | 0 |
| Callisthene minor Mart. | Cal min | 74 | 344 | 0 | 0 |
| Calycolpus sp.O.Berg | Cal sp. | 1 | 20 | 0 | 0 |
| Campomanesia sp Ruiz & Pav. | Cam sp. | 6 | 0 | 0 | 0 |
| Casearia arborea (Rich.) Urb. | Cas arb | 0 | 0 | 3 | 4 |
| Casearia pitumba Sleumer | Cas pit | 2 | 0 | 0 | 20 |
| Cecropia distachya Huber | Cec dis | 0 | 0 | 8 | 11 |
| Cecropia latiloba Miq. | Cec lat | 0 | 0 | 3 | 0 |
| Cedrela fissilis Vell. | Ced fis | 0 | 1 | 3 | 30 |
| Cenostigma tocantinum Ducke | Cen toc | 0 | 0 | 17 | 53 |
| Chorisia speciosa A. St.-Hil. | Cho spe | 0 | 0 | 0 | 6 |
| Chrysophyllum pomiferum (Eyma) T.D. Penn. | Chr pom | 8 | 0 | 1 | 0 |
| Cochlospermum orinocense (Kunth) Steud. | Coc ori | 0 | 1 | 3 | 3 |
| Copaifera multijuga Hayne | Cop mult | 2 | 10 | 0 | 0 |
| Coutarea sp. Aubl. | Cou sp. | 0 | 7 | 0 | 0 |
| Croton sp. | Cro sp. | 0 | 5 | 0 | 1 |
| Cupania scrobiculata Rich. | Cup scr | 2 | 0 | 5 | 3 |
| Cupania sp. L. | Cup sp. | 2 | 3 | 0 | 0 |
| Cymbopetalum Benth. | Cym sp. | 1 | 5 | 0 | 0 |
| Dialium guianense (Aubl.) Sandwith | Dia gui | 0 | 3 | 0 | 1 |
| Dipteryx odorata (Aubl.) Willd. | Dip odo | 0 | 3 | 0 | 0 |
| Diplotropis purpurea (Rich.) Amshoff | Dip pur | 4 | 2 | 1 | 15 |
| Drypetes variabilis Uittien | Dry var | 6 | 0 | 1 | 0 |

Continued...

| Species | Abbreviation | AI | AII | G | X |
|---|---|---|---|---|---|
| Duroia gransabanensis Steyerm. | Dur gra | 12 | 27 | 0 | 0 |
| Duroia sp. L.f. | Dur sp. | 0 | 6 | 0 | 0 |
| Endopleura uchi (Huber) Cuatrec. | End uch | 3 | 0 | 0 | 0 |
| Eriotheca globosa (Aubl.) A. Robyns | Eri glo | 0 | 0 | 9 | 1 |
| Erisma uncinatum Warm. | Eri unc | 4 | 0 | 0 | 0 |
| Erythrina falcata Benth. | Ery fal | 0 | 0 | 0 | 6 |
| Erythroxylum ligustrinum var. carajasense Plowman | Ery lig | 1 | 13 | 0 | 0 |
| Erythroxylum nelson-rosae Plowman | Ery nel | 15 | 17 | 0 | 2 |
| Eschweilera coriacea (DC.) S.A. Mori | Esc cor | 6 | 0 | 0 | 1 |
| Esenbeckia grandiflora Mart. | Ese gra | 88 | 230 | 92 | 0 |
| Esenbeckia pilocarpoides Kunth. | Ese pil | 0 | 13 | 0 | 0 |
| Eugenia patrisii Vahl | Eug pat | 2 | 0 | 14 | 0 |
| Eugenia punicifolia (Kunth) DC. | Eug pun | 15 | 9 | 7 | 3 |
| Eugenia sp.L. | Eug sp. | 0 | 14 | 0 | 0 |
| Faramea filipes Martius ex Benth. | Far fil | 3 | 0 | 0 | 0 |
| Faramea torquata Müll. Arg. | Far tor | 1 | 6 | 0 | 0 |
| Ferdinandusa cf. hirsuta Standl. | Fer hir | 0 | 0 | 0 | 8 |
| Galipea jasminiflora (A. St.-Hil.) Engl. | Gal jas | 0 | 2 | 2 | 19 |
| Garcinia madruno (Kunth) Hammel | Gar mad | 0 | 0 | 2 | 0 |
| Guapira ferruginea (Klotzsch ex Choisy) Lundell | Gua fer | 0 | 25 | 0 | 0 |
| Guatteria foliosa Benth. | Gua fol | 0 | 0 | 1 | 3 |
| Guatteria olivacea R.E. Fr. | Gua oli | 1 | 1 | 0 | 4 |
| Handroanthus impetiginosus (Mart. ex DC.) Mattos | Han imp | 0 | 6 | 0 | 0 |
| Handroanthus serratifolius (Vahl) S. O. Grose | Han ser | 1 | 0 | 2 | 1 |
| Helicteres sacarolha A.St.-Hil. et al. | Hel sac | 0 | 0 | 10 | 4 |
| Himatanthus sucuuba (Spruce ex Müll. Arg.) Woodson | Him suc | 4 | 4 | 0 | 1 |
| Hymenaea courbaril L. | Hym cou | 0 | 9 | 1 | 2 |
| Inga huberi Ducke | Ing hub | 1 | 2 | 0 | 0 |
| Inga lateriflora Miq. | Ing lat | 1 | 0 | 0 | 5 |
| Inga marginata Willd. | Ing mar | 0 | 0 | 9 | 5 |
| Inga rubiginosa (Rich.) DC. | Ing rub | 4 | 0 | 3 | 0 |
| Inga stipularis DC. | Ing sti | 5 | 2 | 1 | 0 |
| Inga thibaudiana DC. | Ing thi | 7 | 2 | 1 | 0 |
| Inga umbratica Poepp. & Endl. | Ing umb | 1 | 0 | 2 | 0 |
| Jacaratia spinosa (Aubl.) A. DC. | Jac spi | 0 | 0 | 4 | 13 |
| Lacistema aggregatum (P.J. Bergius) Rusby | Lac agg | 2 | 2 | 2 | 0 |
| Licania hypoleuca Benth. | Lic hyp | 4 | 8 | 3 | 0 |
| Lueheopsis rosea (Ducke) Burret | Lue ros | 1 | 13 | 26 | 0 |
| Margaritaria nobilis L. f. | Mar nob | 0 | 8 | 55 | 22 |
| Matayba guianensis Aubl. | Mat gui | 9 | 0 | 1 | 0 |
| Matayba sp. Aubl. | Mat sp. | 0 | 7 | 0 | 0 |
| Maytenus guyanensis Klotzsch ex Reissek | May guy | 0 | 6 | 0 | 0 |
| Metrodorea flavida K. Krause | Met fla | 3 | 0 | 16 | 36 |
| Micropholis casiquiarensis Aubrév. | Mic cas | 8 | 1 | 0 | 0 |
| Miconia holosericea (L.) DC. | Mic hol | 0 | 7 | 0 | 0 |
| Miconia tetraspermoides Wurdack | Mic tet | 0 | 0 | 1 | 0 |

Continued...

| Species | Abbreviation | AI | AII | G | X |
|---|---|---|---|---|---|
| Mimosa acutistipula (Mart.) Benth. | Mim acu | 1 | 9 | 0 | 6 |
| Mouriri angulicosta Morley | Mou ang | 13 | 0 | 0 | 0 |
| Mouriri dimorphandra Morley | Mou dim | 0 | 0 | 2 | 0 |
| Mouriri ficoides Morley | Mou fic | 4 | 31 | 1 | 0 |
| Mouriri huberi Cogn. | Mou hub | 11 | 5 | 2 | 0 |
| Myrcia cuprea (O. Berg) Kiaersk. | Myr cup | 59 | 17 | 0 | 0 |
| Myrcia multiflora (Lam.) DC. | Myr mul | 11 | 0 | 0 | 3 |
| Myrcia sp. DC. Ex Guill | Myr sp. | 2 | 13 | 1 | 0 |
| Myrcia splendens (Sw.) DC. | Myr spl | 0 | 0 | 0 | 1 |
| Neea floribunda Poepp. & Endl. | Nee flo | 22 | 11 | 4 | 0 |
| Neea oppositifolia Ruiz & Pav. | Nee opp | 8 | 1 | 3 | 0 |
| Neea ovalifolia Spruce ex J.A. Schmidt | Nee ova | 0 | 7 | 3 | 0 |
| Neea robusta Steyerm. | Nee rob | 0 | 2 | 4 | 5 |
| Neoraputia paraensis (Ducke) Emmerich ex Kallunki | Neo par | 2 | 0 | 0 | 0 |
| Ocotea amazonica (Meisn.) Mez | Oco ama | 3 | 0 | 0 | 0 |
| Ocotea olivacea A.C. Sm. | Oco oli | 1 | 0 | 0 | 5 |
| Ocotea tabacifolia (Meisn.) Rohwer | Oco tab | 2 | 0 | 0 | 0 |
| Piper cf. aduncum L. | Pip adu | 0 | 0 | 0 | 6 |
| Piptadenia rigida Benth. | Pip rig | 1 | 4 | 6 | 7 |
| Piptadenia suaveolens Miq. | Pip sua | 4 | 0 | 1 | 0 |
| Pourouma guianensis Aubl. | Pou gui | 0 | 6 | 0 | 0 |
| Pouteria hispida Eyma | Pou his | 6 | 2 | 0 | 0 |
| Pouteria parviflora (Benth. ex Miq.) Radlk. | Pou par | 6 | 0 | 0 | 8 |
| Pouteria petiolata T.D. Penn. | Pou pet | 6 | 0 | 1 | 0 |
| Pouteria cf. rostrata (Huber) Baehni | Pou rost | 0 | 10 | 0 | 0 |
| Pouteria sp. Aubl. | Pou sp. | 8 | 0 | 0 | 0 |
| Pouteria vernicosa T.D. Penn. | Pou ver | 13 | 45 | 18 | 16 |
| Pouteria guianensis Aubl. | Pour gui | 0 | 0 | 0 | 5 |
| Protium tenuifolium (Engl.) Engl. | Pro ten | 6 | 0 | 0 | 0 |
| Pterocarpus officinalis Jacq. | Pte off | 0 | 0 | 6 | 0 |
| Pterocarpus rohrii Vahl | Pte roh | 0 | 9 | 0 | 3 |
| Roupala montana Aubl. | Rou mon | 0 | 7 | 0 | 0 |
| Sapium biglandulosum (L.) Müll.Arg. | Sap big | 3 | 0 | 0 | 7 |
| Sapium glandulatum (Vell.) Pax | Sap gla | 6 | 31 | 115 | 0 |
| Senegalia polyphylla DC. | Sen pol | 0 | 0 | 20 | 22 |
| Sigmatanthus sp. | Sig sp. | 0 | 0 | 11 | 0 |
| Simarouba amara Aubl. | Sim ama | 0 | 6 | 1 | 0 |
| Solanaceae 1 | Sol sp. | 0 | 0 | 7 | 0 |
| Spondias mombin L. | Spo mon | 0 | 0 | 0 | 60 |
| Stryphnodendron sp Mart. | Str sp. | 0 | 0 | 0 | 35 |
| Syagrus comosa (Mart.) Mart. | Sya com | 0 | 13 | 0 | 3 |
| Syagrus oleracea (Mart.) Becc. | Sya ole | 0 | 0 | 49 | 0 |
| Symphonia globulifera L. f. | Sym glo | 3 | 0 | 0 | 0 |
| Tabernaemontana muricata Link ex Roem. & Schult. | Tab mur | 0 | 0 | 3 | 0 |
| Tabebuia sp. Gomes ex DC. | Tab sp. | 1 | 5 | 0 | 0 |

Continued...

| **Species** | **Abbreviation** | **AI** | **AII** | **G** | **X** |
|---|---|---|---|---|---|
| Tachigali myrmecophila (Ducke) Ducke | Tac mym | 0 | 1 | 1 | 0 |
| Tetragastris altissima (Aubl.) Swart | Tet alt | 0 | 0 | 7 | 5 |
| Theobroma speciosum Willd. ex Spreng. | The spe | 1 | 0 | 10 | 7 |
| Toulicia pulvinata Radlk. | Tou pul | 4 | 2 | 4 | 6 |
| Trichilia micrantha Benth. | Tri mic | 0 | 0 | 1 | 0 |
| Trichilia pallida Sw. | Tri pal | 0 | 0 | 3 | 0 |
| Virola michelii Heckel | Vir mic | 1 | 0 | 4 | 0 |
| Vitex triflora Vahl | Vit tri | 1 | 2 | 0 | 9 |
| Vouarana guianensis Aubl. | Vou gui | 13 | 6 | 4 | 1 |

## Chapter II

## Vegetation Gradient in Dry Forest at Carajás National Forest, Eastern Brazilian Amazonia

ABSTRACT

The eterogeneity in Amazonia has been attributed to the diversity of topographical, climatological, geological and edaphic conditions. The ample variation of environmental conditions appears to be one of the main key in the distribution, structure and development of vegetation. Others vegetation types are found in Amazonia, such as, Seasonally Dry Tropical Forests (DF), despite the overall humid tropical climate dominant. In this regard, considering that dry forest of Carajás is embedded in the same climate conditions; we ask if the floristic and structural variability in DFs of Carajás depends on the substrate nature (soils developed from crystalline rocks, sedimentary and volcanic). The aim of this study was to compare the floristic composition and structure of four dry forests areas present in the Carajás National Forest. Altogether 370 tree species, 61 families and 193 genera were registered along the DF formations sampled. Species richness was higher in the vegetation on Águas Claras Sandstone Soils I while the lowest in Xingu Complex Soils, with intermediate values in the Águas Claras Sandstone Soils II and Carajás Granite Soils. Through direct analysis of the floristic-structural gradient of the four DF formations along the pedogeomorphologic gradient, was possible highlight the presence of the species that characterize, physiognomically, each environment as, plant communities with distinct populations arranged themselves along the gradient of the soil. DCA were used to summarize the floristic variation into main floristic axis. Plots were clustered so that they formed three distinct groups, highlighting the difference between each Dry Forest formation studied. The Floristic Similarity showed that Águas Claras Sandstone Soil plots are closely grouped whereas the, Xingu Complex Soil had less floristic similarity between all DF studied. There was no marked structural variation between the dry forests in Carajás. However, the structural showed greater range of values compared with those reported for neotropical dry forests from elsewhere.

Keywords: Vegetation Gradient; Dry Forest, Carajás, Amazonia.

**Gradiente vegetacional em Floresta Seca na Floresta Nacional de Carajás, Amazônia oriental Brasileira**

RESUMO

A heterogeneidade na Amazônia tem sido atribuída à diversidade de condições topográficas, climáticas, geológicas e edáficas. A ampla variação das condições ambientais parece ser a principal chave na distribuição, composição, estrutura e desenvolvimento da vegetação. Diferentes tipos de vegetação são encontrados na Amazônia, tais como, as florestas tropicais sazonalmente secas, apesar do clima tropical úmido global dominante. Considerando-se que as florestas secas em Carajás estão incorporadas nas mesmas condições climáticas; perguntamos se a variabilidade florística e estrutural nessas florestas secas dependem da natureza do substrato (solos desenvolvidos de rochas cristalinas, sedimentares, e vulcânica). O objetivo deste estudo foi comparar a composição florística e estrutura de quatro áreas de florestas decíduas presentes na Flona de Carajás. No total, 370 espécies arbóreas, 61 famílias e 193 gêneros foram registrados ao longo das formações de florestas secas amostrados. A riqueza de espécies foi maior na vegetação em solos sobre Águas Claras I, e a menor em solos do Complexo Xingu, com valores intermediários nos solos do arenito Águas Claras II e Granito Carajás. Através da análise direta do gradiente florístico-estrutural realizada a partir da distribuição dos indivíduos das espécies mais abundantes e importantes (IV) nas quatro formações estudadas ao longo do gradiente pedogeomorfológico, foi possível destacar a presença de espécies que caracterizam fisionomicamente cada ambiente quanto as comunidades de plantas com populações distintas entre si dispostas ao longo do gradiente do solo. A análise DCA foi usada para resumir a variação florística em eixos florísticos principais. As parcelas foram agrupadas formando quatro grupos distintos, destacando a diferença florística entre cada formação vegetacional estudada. A similaridade florística mostrou que as parcelas do Arenito Águas Claras estão agrupadas entre si, enquanto que as parcelas do Complexo Xingu tiveram menos semelhança florística dentre todas as áreas. Não se observou variação estrutural notável entre as florestas decíduas em Carajás. No entanto, os atributos estruturais, apresentaram maior alcance de valores comparados com que aqueles reportados para florestas secas neotropicais de outros lugares.

Palavras-chave: Gradiente Vegetacional, Florestas Secas, Carajás, Amazônia.

## 1. Introduction

The Amazon rainforest is totally inserted in the tropical zone and is characterized by high temperatures, rainfall and radiation. The combination of these factors explains the existence of rainforest as dominant in physiognomy this biome (Figueroa; Noble 1990). However, other vegetation types are also found Amazonia, such as, Seasonally Dry Tropical Forests (DF), despite the overall humid tropical climate dominant. These areas of DF are associated with local environmental factors (soils, substrates), forming a true complex vegetation in this part of Amazonia.

The variation in abundance of species in response to an environmental factor such as light, moisture or soil nutrient define an environmental gradient (Kent and Coker 1992). Changes in response to an environmental factor, such as precipitation, altitude and soil fertility, can be gradual or abrupt. However, species composition and forest structure are dependent of local landscape conditions (e.g., soil type, topography), and nearby forest types can be very different (Fajardo et al. 2005).

Heterogeneity in Amazonia has been attributed to the different topographical, climatological, geological and edaphic conditions (Bigarella and Ferreira 1985). The ample variation of environmental conditions appears to be the key main in the distribution, structure and development of vegetation (Schaeffer-Novelli and Cintrón 1993). Furthermore, the distribution of a given species within a region depends on several factors, ranging from ecological requirements to historical events, besides interactions with other species (Hutchinson 1959; ter Steege and Zagt 2002). Murphy and Lugo (1995) showed that variation in structural traits for the four DF formations, within the same climate, is largely due to differences in local soils and flooding frequency. These authors highlight that, dry forests are generally smaller in structure, simpler in composition than semi-deciduous to ombrophilous forests of a given region, but there is wide variation in most features due to differences in climate, soil, biogeography and disturbance history (Murphy and Lugo 1995).

In this context, Neotropical Forest exibit an extraordinary range of vegetation types, most probably related to both pedogeomorphologic complexity and climatic variation (Dirzo et al. 2011; Hueck 1978; Daly and Prance 1988). The mosaic of biotic and environmental conditions found within topographically complex DF likely play a fundamental role in the maintenance of the elevated species diversity found in these ecosystems (Segura et al.2003). Soil nutrients have an impact on community attributes, such as vegetation cover, tree density, biomass, species composition and competition

(Perroni-Ventura et al. 2006). Some hypotheses advanced that habitat heterogeneity controlled species richness gradients through local and regional species turnover (Shmida and Wilson 1985; Ricklefs 1987), in which the rate of species replacement increased with soil fertility (Paoli et al. 2006) and decreased with successional age (Prach 1993).

The aggregation of tropical tree species in specific soil type resource is perhaps the clearest evidence for habitat filtering (Valencia et al. 2004; Davies et al. 2005). Therefore, to determine the factors that affect the composition of a plant community changes in relation to a given factor may also yield answers to issues important to ecology, as proxies to examine patterns and develop scenarios for understanding processes at larger scales (Anderson et al. 2010). Hence, the understanding of what determines the variation in floristic composition, species distribution and vegetation structure is important (Chave 2008).

In this regard, we made the following prediction: considering that dry forest in Carajás is embedded in the same climate conditions; we ask if the floristic and structural variability in DFs in Carajás depends on the substrate nature (soils developed from crystalline rocks, sedimentary and volcanic).

The aim of this study was to compare the floristic composition and structure of four dry forests formations present in the Carajás National Forest.

## 2. Materials and Methods

### 2.1 Study Area

This study was located on dry forest islands surrounded by rain forest in the Carajás National Forest (FLONA) conservation unit, southeastern Pará State, Brazil (Fig. 1). The regional climate is tropical, hot and humid (type "Aw" in the Köppen system; Ab'Saber 1986), with a well-defined dry season between May and October (average precipitation < 60 mm in the driest months), and a rainy season between November and April. Rainfall increases with altitude, lowland areas receiving annual averages of 1500 mm and more elevated sites receiving up to 1900 mm/year (IBAMA et al. 2003). Average monthly temperatures vary between 19 and 31$^{o}$C.

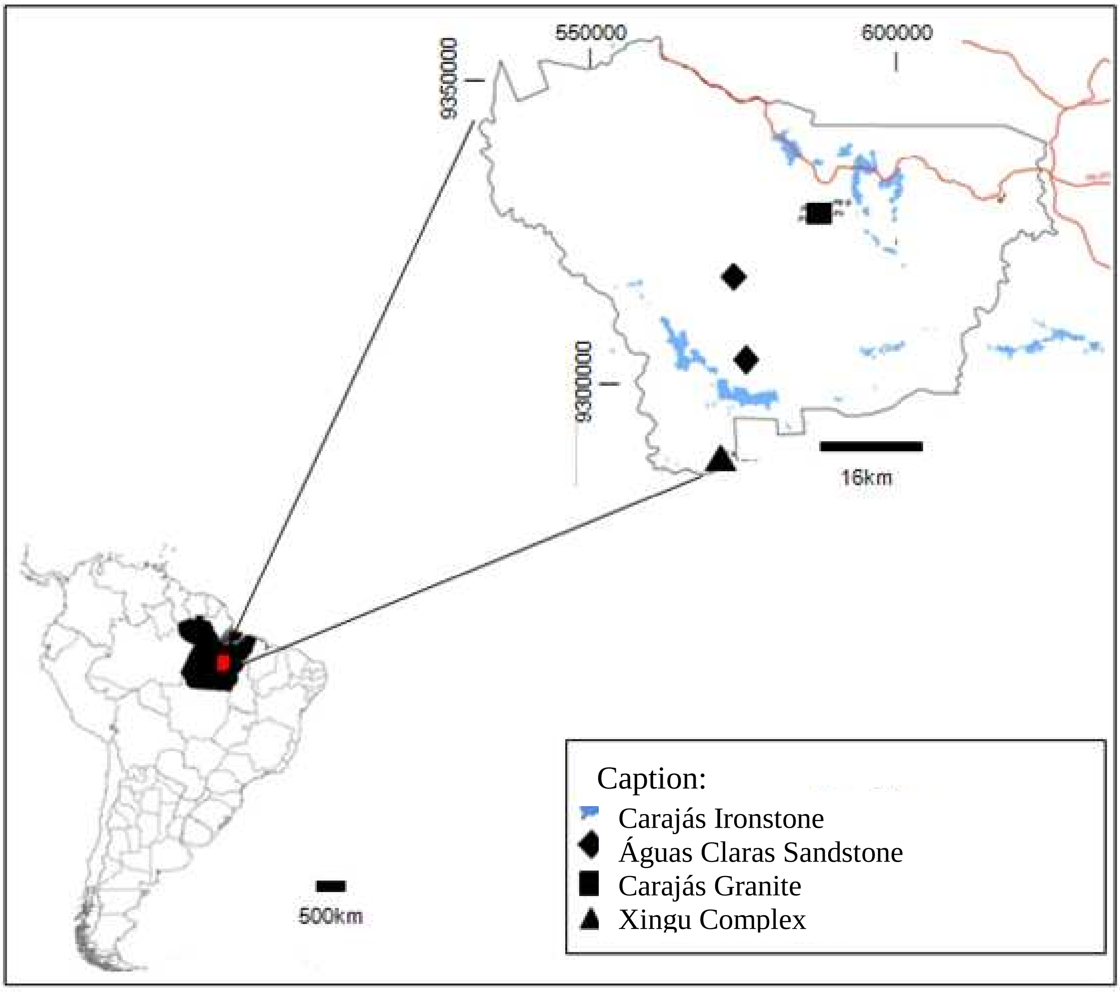


Figure 1 - Location of the Carajás National Forest, Pará, Brazil. Highlight the study area and dry forest formations on different geomorphologies, beyond the Plateau ironstone in blue.

2.2 Sampling method

In each area, transects were established in order to include the largest possible range of environments, considering vegetation, soils and geomorphology. In each transect the number of vegetation communities (physiognomically and floristically distinct) were selected for installation of the plots for vegetation studies (Mueller-Dombois; Ellemberg 1974). The four formations sum up 36 plots with 400 $m^2$ each, with a total sampling area of 1.4 ha: (1 and 2) "Águas Claras" Archean Sandstone Formation (Grão-Pará Group); (3) Carajás Mid Proterozoic Granite (G) and (4) the Xingu Archean Basement Complex (X), with 9 plots each one.

The soils in all DF formations are acidic and with low P. However, there were significant differences between soil properties among the sampled areas for these and many other soil chemical properties. The soils were more acidic in "Águas Claras" Sandstone Soils (AI and AII) indicating extreme leaching, whereas igneous rocks of

Carajás Granite Soil (G) and Xingu Complex Soil (X) are less acid and with higher available P when compared with all others sites (Table 1).

Table 1 - Mean soil variable levels (±95% C.I.) for surface soils (0-10 cm) by Dry Forest, National Forest of Carajás, Pará State, Brazil. AI: Águas Claras Sandstone Soils I; AII: Águas Claras Sandstone Soils II; G: Carajás Granite Soils and X: Xingu Complex Soils.Where: BS = Total exchangeable bases; CEC =Effective Cation Exchange Capacity; TOC = Organic matter; Res-P = Residual Phosphorus.

| **Soil Variable** | **AI** | **AII** | **G** | **X** |
|---|---|---|---|---|
| pH (H2O) | 3.99 ±0.23 | 4.15 ±0.27 | 5.15±0.62 | 4.86 ± 0.51 |
| P (mg/dm3) | 1.82 ± 0.81 | 1.60 ±0.75 | 2.83 ±7.13 | 3.67 ± 1.69 |
| k (mg/dm3) | 49.39 ±20.64 | 41 ±17.52 | 106.9±42.50 | 87.41 ± 30.68 |
| Na(mg/dm3) | 2.26 ± 3.58 | 1.76 ±2.25 | 4.12±2.29 | 22.98 ± 15.28 |
| Ca (cmolc/dm3) | 0.39 ±0.39 | 0.28 ±0.19 | 2.78 ±2.70 | 3.56 ± 2.48 |
| Mg (cmolc/dm3) | 0.69 ±0.12 | 0.72 ±0.08 | 0.52 ±0.45 | 1.07 ± 0.78 |
| Al3+ (cmolc/dm3) | 1.90±1.085 | 1.99 ±0.64 | 0.85 ±0.68 | 0.81 ± 0.77 |
| BS (cmolc/dm3) | 1.21±0.51 | 1.14 ±0.30 | 3.60 ±3.17 | 4.96 ± 3.15 |
| CEC (cmolc/dm3) | 3.12 ±1.05 | 3.13 ±0.66 | 4.44 ±2.67 | 5.77 ± 2.73 |
| OM (dag/Kg-1) | 4.16 ±3.12 | 4.24 ±2.47 | 5.94 ±2.46 | 8.85 ± 4.24 |
| P-res (mg/L) | 37.26 ±9.35 | 32.89 ±7.60 | 23.37 ±13.59 | 29.15 ± 10.17 |
| Zn (mg/dm3) | 0.71 ±0.45 | 0.65 ±0.38 | 0.52 ±0.61 | 1.38 ± 0.73 |
| Fe (mg/dm3) | 188.4±133.23 | 206.65 ±104.93 | 45.35±26.47 | 69.43 ± 40.18 |
| Mn (mg/dm3) | 7.78 ±7.41 | 9.71 ±7.28 | 22.73 ±22.80 | 40.03 ± 27.09 |
| Cu (mg/dm3) | 0.57 ±0.71 | 2.07 ±2.23 | 5.18 ±2.93 | 1.82 ± 1.40 |

## 2.3 Floristic Composition

The floristic composition was registered by phytossociological study. To organize of the floristic list we adopted the APG III system of the species classification (APG 2009). The collected species were herbalized and deposited in the collections the VIC Herbarium, Federal University of Viçosa (UFV), with duplicates deposited in the Carajás Herbarium. Species identification was based on comparisons with previously identified material of the INPA Herbarium, Carajás Herbarium and local specialists.

## 2.4 Direct analysis of the floristic-structural gradient and Detrended correspondence analysis (DCA)

The main species in each area were organized according to density, number of individuals and importance value in the 36 plots of 400 $m^2$ each which makes up the sequences. Graphs show the distribution of these species with the highest density and IV (Importance Value) along 36 plots of the proposed gradient.

DCA were used to summarize the floristic variation into main floristic axis. DCA analyses were carried out with the matrix of 36 plots and 140 species, with a minimum occurrence of 5 species, using log-transformed abundance data of each species and using detrending by 26 segments without down weighting of rare species. DCA is well suited to estimate gradient lengths because its axis are scaled in units of the mean standard deviation of species turnover (Jongman et al. 1995).

## 2.5 Phytosociology and structure

We sampled all individuals with diameter at breast height (DBH) ≥ 3.2 cm at the plots, measuring height and colleting data. Phytosociological parameters were estimated to determine the importance of each species in community composition (Newton 2007). The phytosociological parameters addressed were the usual in phytosociology: density, dominance and frequency used in the composition of the importance value (VI), as proposed by Mueller-Dombois and Ellenberg (1974).

Regarding the analysis of heterogeneity amongst the several indices to quantify the diversity of a community or ecosystem, we used the Shannon Diversity Index (H ') (Brower; Zar 1984) and the Coefficient of evenness (J) (Pielou 1975). The plant species richness observed (S), and Jackknife estimated richness were calculated for AI, AII, G and X. These richness estimators provide an estimate of the true species richness of the sampled vegetation types based on the frequency of species occurring once or twice only in the set of collected samples.The floristic and phytosociological parameters described above are calculated using the program Mata Nativa 3 (Cientec 2010).

The horizontal and vertical distribution of the four transects and their environments were analyzed from the total number of individuals per class, height and median diameter classes. The comparison of variables were carried out: total number of total individuals (N), total basal area (BA), number of species (S’) and evenness (J’) between the environments of each area.

2.6 Similarity Floristic

In order to identify and recognize different plant communities we conducted a cluster analysis enabling the assessment of floristic similarity between different environments in the pedological gradient. Quantitative data analysis was performed using the binary matrix (presence or absence) of species using Sorensen Index. A Dendrogram from this array, was produced by using flexible beta linkage (beta = -0.25), clustering of relative euclidean distance for species (McCune and Grace 2002).

Contrasted species composition of plots was obtained using a multiple response permutation procedure (MRPP), which is a nonparametric procedure for testing the hypothesis of no difference between a priori groups (Biondini et al. 1988). The a priori groups (Hereafter pedogeomorphology groups) were defined by plots that had similar environments considering vegetation, soils and geomorphology. Differences among the DF formations were evaluated with MRPP, using S0rensen distance as a distance measure, using PC-ORD version 6 (McCune and Mefford 2011).

3. Results

3.1 Floristic composition

Altogether 370 tree species and 193 genera, distributed in 2809 individual living trees were recorded and, along the DF formations sampled. Two species could not be identified (Tab. 3).

The sampled species are distributed in 61 families and 193 genera were registered; of which the higher richness was in the decreasing order: Fabaceae (60), Myrtaceae (24), Rubiaceae and Moraceae (18), Sapotaceae (17), Burseraceae and Lauraceae (16), Rutaceae (15), Sapindaceae and Apocynaceae (13), Malvaceae and Melastomataceae (12) and Anacardiaceae (10). The most representative genera were Inga (15), Pouteria (12), Protium (10), Ocotea (8), Myrcia (9), Eugenia, Mouriri, Miconia and Aspidosperma, (6) (Tab. 3).

Species richness was higher in the vegetation on Águas Claras Sandstone Soils I while the lowest in Xingu Complex Soils, with intermediate values in the Águas Claras Sandstone Soils II and Carajás Granite Soils. The same trend was observed in the number of individuals (N) and number of families (F) (Tab. 2).

When species occurrence was related to each DF formations, 250 species were found only in one area, with 120 in two or more sites. Six species had a wide distribution in all for transects: Pouteria vernicosa, Piptadenia rigida, Eugenia punicifolia, Diplotropis purpurea, Toulicia pulvinata and Vouarana guianensis (Tab.3).

3.2 Direct analysis of the floristic-structural gradient and Detrended correspondence analysis (DCA)

Through direct analysis of gradient structural-floristic shown in the graphs of distribution of individuals of the most abundant and important (IV) of the four DF formations along the pedogeomorphologic gradient (Fig. 2), we can highlight the presence of species that characterize, physiognomically, each environment as, plant communities with distinct populations arranged themselves along the gradient of the soil.

Although some species are present in various environments, their spatial distribution is concentrated in specific environments, such as Esenbeckia grandiflora, Metrodorea flavida, Cupania scrobiculata, Sapium glandulatum. While some are restricted to a determinate environment with specific environmental conditions such as Syagrus oleracea in Carajás Granite Soils, Handroanthus impetiginosus and Ficus guianensis in Águas Claras II Sandstone Soils and Spondias mombin in Xingu Complex Soils.

E. grandiflora has not occurred in Xingu Complex Soils, but was abundant in the other studied areas. Neea floribunda and Lueheopsis rosea occurred in all areas except, the Xingu Complex Soils, where the first species had greater abundance in Aguas Claras Sandstone Soils I and others two species in Carajás Granite Soils. While M. nobilis and Cedrela fissilis occured in all areas except in Aguas Claras Sandstone Soils I, both, was abundant in the Carajás Granite Soils and Xingu Complex Soils.

Floristic variation also was showed by DCA. The first two axis of abundance-based DCA ordination explained 50 percent of floristic variation. On DCA first axis (33% of explained variation), each plots sites were clustered so that three distinct groups formed, highlighting the floristic difference between each studied DF formation. On the DCA axis 2 (17% of explained variation) Águas Claras Sandsone plots were more separately to others sites. On the other hand, the plots related to Carajás Granite Soils were more closely related to the Xingu Complex Soils, due to similar floristic composition (Fig. 3). Thus the scores of plots on DCA axis 1 correlated positively with the densities of Cenostigma tocantinum, Spondias mombin and Senegalia polyphylla and negatively with the densities of Callisthene minor, Myrcia cuprea and Duroia gransabanensis. DCA axis 2 correlated positively with the densities of Callisthene minor and Erythroxylum nelson-rosae, and negatively with the densities of Neea floribunda, Myrcia cuprea and Vouarana guianensis (Tab. 3).

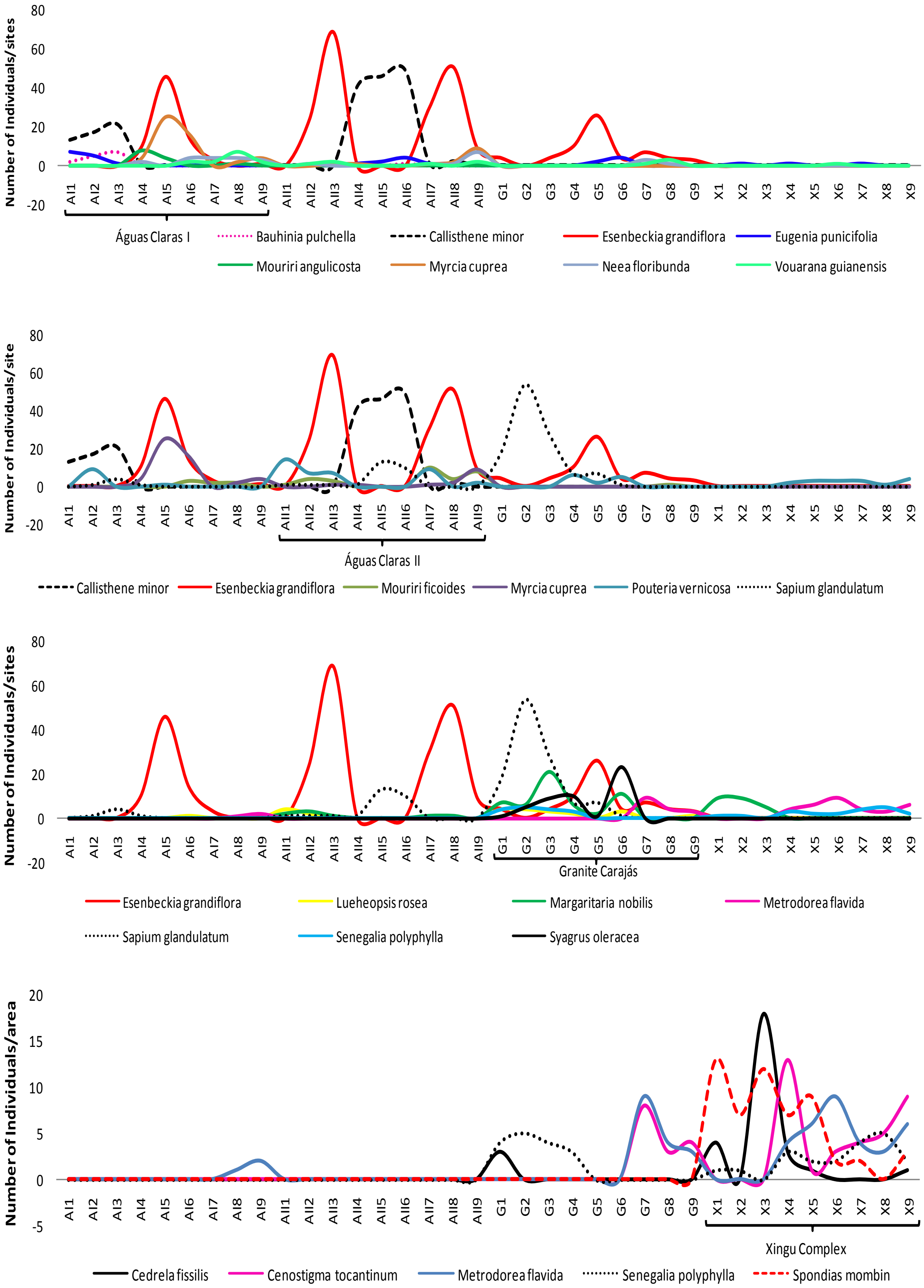


Figure 2 - Direct analysis of the floristic-structural gradient, showing the spatial distribution of the most important species of each DF formations in Carajás National Forest, Pará, Brazil. AI: Águas Claras Sandstone Soils I; AII: Águas Claras Sandstone Soils II; G: Carajás Granite Soils and X: Xingu Complex Soils.

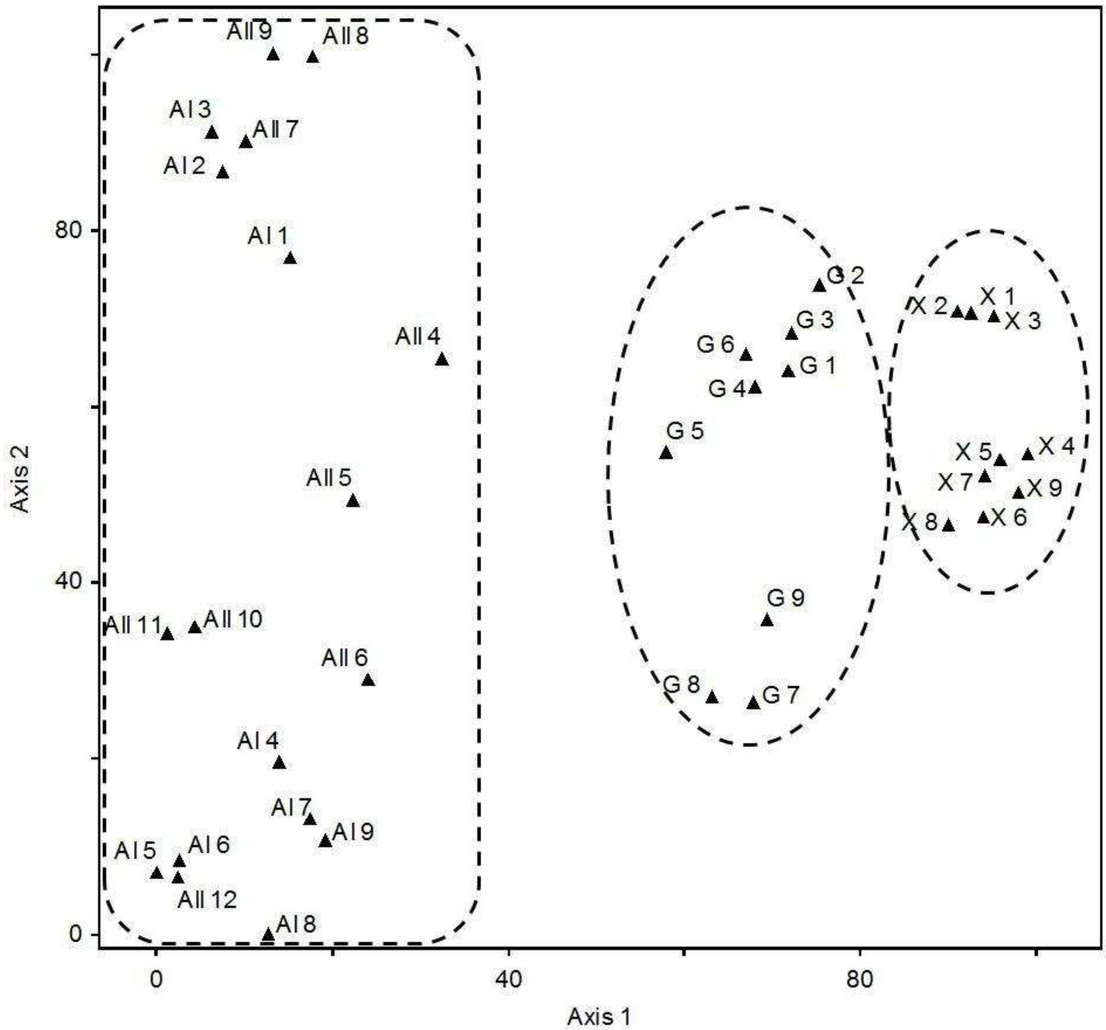


Figure 3 - Detrended Correspondence Analysis (DCA) of the dry forest formations along pedogeomorphologic gradient in the two first axis. Carajás National Forest - Pará, Brazil. AI: Águas Claras Sandstone Soils I; AII: Águas Claras Sandstone Soils II; G: Carajás Granite Soils and X: Xingu Complex Soils.

### 3.3 Vegetation structure

#### 3.3.1 Richness and diversity

Águas Claras I vegetation showed the highest species richness (154) and highest values of Shannon diversity Index (4.25) (Jackknife T (95%) = 2.31; 3.95 to 5.16) and evenness (0.84) between the communities studied. Other areas also showed considerable diversity values, ranging from 3.67 with species richness 126 in the Águas Claras II vegetation (Jackknife T (95%) = 2.31; 3.32 to 4.49) to 4.05 and richness 117 species in Xingu Complex Soil (Jackknife T (95%) =2.31; 4.01 to 4.58) and higher evenness (0.85) but the lowest species richness (117). The Carajás Granite Soil showed an intermediate value of diversity, 3.87(Jackknife T (95%) = 2.31; 3.35 to 4.93), species richness (140) and higher evenness (0.78) (Fig. 4; Tab. 2).

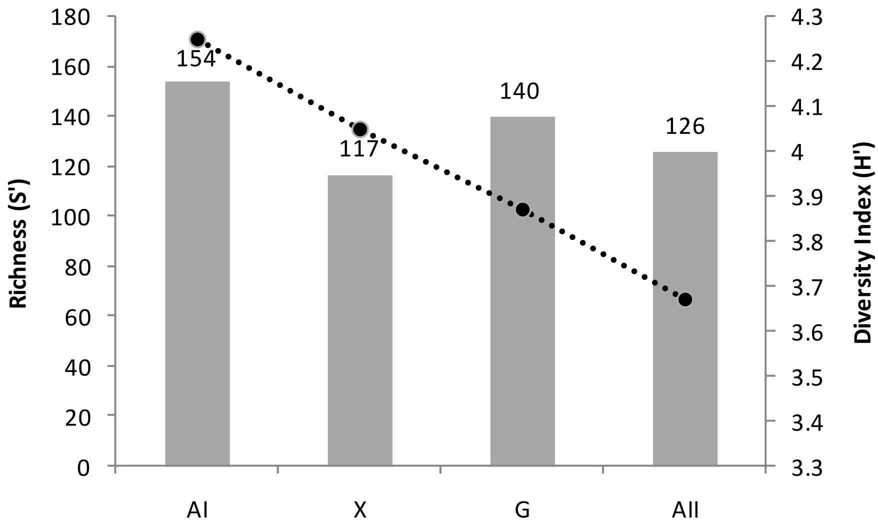


Figure 4- Richness (columns) and diversity index (dotted line) species tree communities along edaphic/topographic gradient Carajás National Forest, Pará, Brazil. AI: Águas Claras Sandstone Soils I; AII: Águas Claras Sandstone Soils II; G: Carajás Granite Soils and X: Xingu Complex Soils.

The lowest diversity was obtained in the Águas Claras II Soil, and the greatest in Águas Claras I Soil, with intermediate values in Carajás Granite Soil and Xingu Complex Soil. The comparison between values richness per plot in all for DF formations showed that Águas Claras I Soils obtained greater value, being different from the Xingu Complex Soil (Fig. 4; Tab. 2).

Dead individuals represented 4,32% of the total trees sampled. DI varied between 26 (0,88%) in Águas Claras Sandstone Soil I to 66 (2,24%) in Águas Claras Sandstone Soil II. Intermediate values are found in Carajás Granite Soils (1,2%). The Xingu Complex Soil not showed dead individuals (Tab. 2, and Supplementary Material: Tab. 4, 5, 6 and 7).

Table 2 - Floristic and structural parameters in the four transects in dry forests along edaphic/topographic sequences in Carajás National Forest, Pará, Brazil. AI: Águas Claras Sandstone Soils I; AII: Águas Claras Sandstone Soils II; G: Carajás Granite Soils and X: Xingu Complex Soils. Where: F: Family; G: Genera; N: Number of Individuals including living and trees; S': Richness; H': Index diversity; J': Evenness and DI: Number of Individuals dead trees.

| **Sites** | **F** | **G** | **N** | **S'** | **H'** | **J'** | **DI** |
|---|---|---|---|---|---|---|---|
| Águas Claras Sandstone I | 38 | 92 | 646 | 154 | 4.25 | 0.84 | 26 |
| Águas Claras Sandstone II | 41 | 89 | 931 | 126 | 3.67 | 0.76 | 66 |
| Carajás Granite Soils | 42 | 101 | 679 | 140 | 3.87 | 0.78 | 35 |
| Xingu Complex Soils | 37 | 92 | 553 | 117 | 4.05 | 0.85 | 0 |
| Total | 61 | 193 | 2809 | 370 | 4.71 | 0.80 | 127 |

3.3.2 Basal area and density

Xingu Complex Soil had lower basal area, although difference was not significant when compared with others areas. Larger individuals (for example: Anadenanthera rigida, Ficus guianensis, Bagassa guianensis, Lecythis zabucajo, Cassia leandrii and Escheweilera coriacea) were scarce and few found. These trees were distribuited on four dry forest formations studied. For this reason, BA was not varied between the studied areas (Fig. 5).

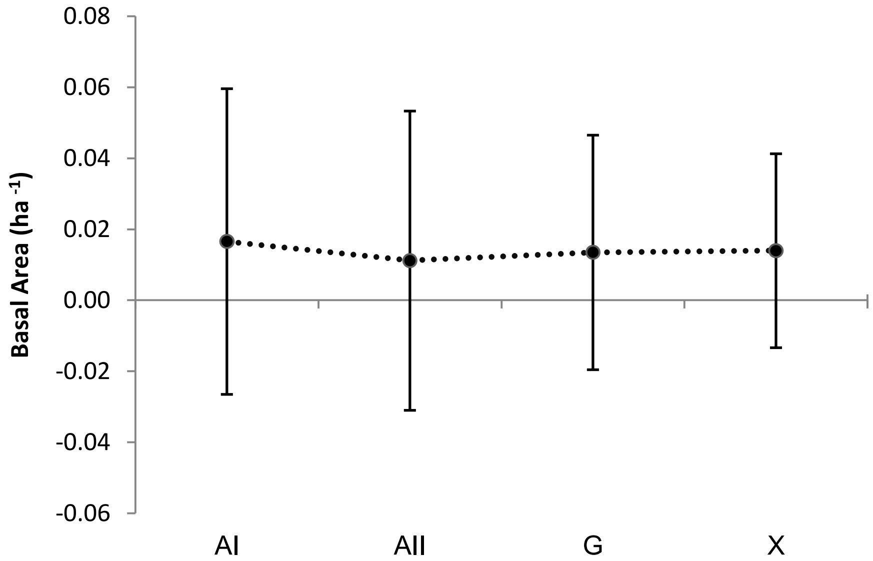


Figure 5 - Basal area in Dry Forest along edaphic/topographic gradient in the Carajás National Forest, Pará, Brazil. AI: Águas Claras Sandstone Soils I; AII: Águas Claras Sandstone Soils II; G: Carajás Granite Soils and X: Xingu Complex Soils.

The total number of individuals was higher in Águas Claras Sandstone Soils II followed by Carajás Granite Soils, with intermediate values in Águas Claras Sandstone Soil I and lower values in the Xingu Complex Soil. (Tab. 2; Fig. 6), and followed the same trend for tree density.

The estimated absolute density was higher in Águas Claras II vegetation and absolute dominance was higher in Águas Claras I, intermediate values to absolute density and absolute dominance were found in Carajás Granite and lower values were found in Xingu Complex, respectively (Tab. 4, 5, 6 and 7 - Supplementary material).

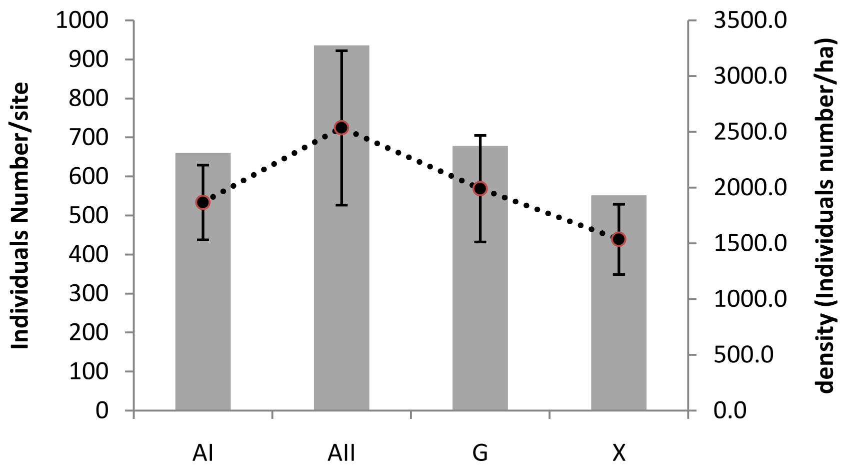


Figure 6 – Individuals number per site (columns) and Individuals per hectare (dotted line) along edaphic/topographic gradient in Carajás National Forest, Pará, Brazil AI: Águas Claras Sandstone Soils I; AII: Águas Claras Sandstone Soils II; G: Carajás Granite Soils and X: Xingu Complex Soils.

3.3.3 Height and diameter structure

Regarding the height of trees in the DF formations studied, there was little variation between areas. The Xingu Complex Soil had a maximum of 25m, while in the other areas the maximum height ranged from 40 to 45m.

Águas Claras Sandstone Soil I vegetation showed higher mean height and range values among the sites studied, whereas Águas Claras Soil II showed higher maximum height. Conversely, The Xingu Complex Soil had the highest variation in height (Fig.7).

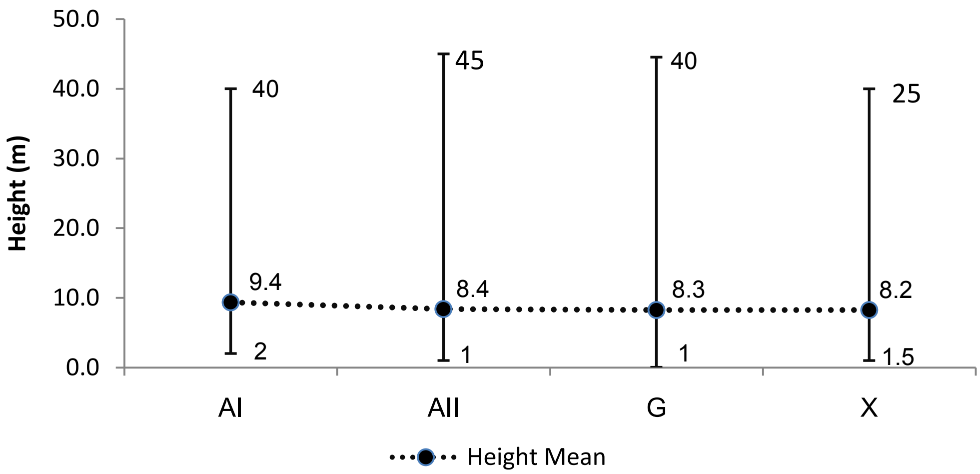


Figure 7 - Maximum, mean and minimum height of the plants communities along geomorphological gradient in Carajás National Forest, Pará, Brazil. AI: Águas Claras Sandstone Soils I; AII: Águas Claras Sandstone Soils II; G: Carajás Granite Soils and X: Xingu Complex Soils.

Considering the diameter classes of all individuals trees sampled, we can observe that, the most individuals are distributed in two diameter classes 3.2-5m and 5.1-10m, with 71.86% of the individuals (Fig. 8). Hence, there is not marked structural variation in the DF formations along edaphic/topographic gradient in Carajás.

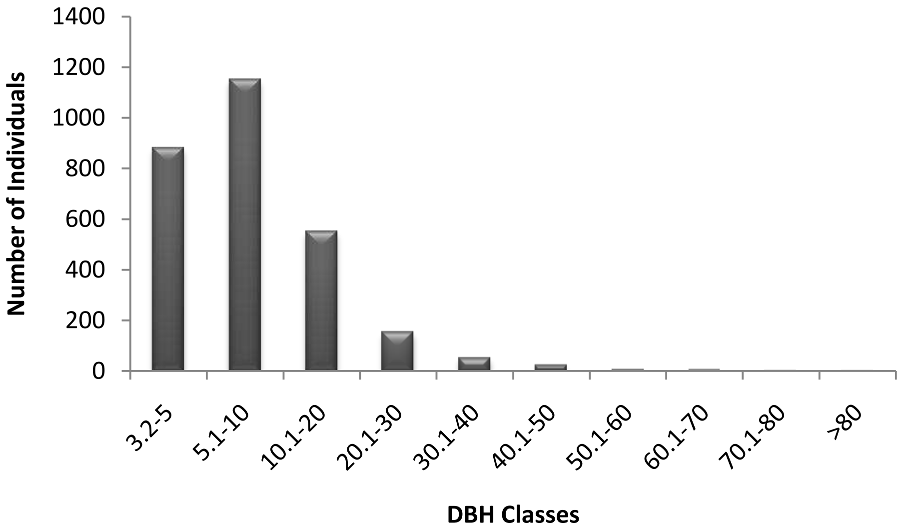


Figure 8 - Distribution of the Individuals per diameter class in the five transects along edaphic/topographic gradient in Carajás National Forest, Pará, Brazil AI: Águas Claras Sandstone Soils I; AII: Águas Claras Sandstone Soils II; B: G: Carajás Granite Soils and X: Xingu Complex Soils.

3.4. Floristic similarity

The Floristic Similarity between the DF studied shows that Águas Claras Sandstone Soil plots are closely grouped floristically whereas the, Xingu Complex Soil had less floristic similarity between all DF studied (Figure 9a and 9b). MRPP analysis showed a highly significant floristic difference between all pairs of five groups (A= 0.34, P < 0.0001, T = - 12.57). Cluster analyses indicate the separation of floristic groups according to the edaphic/topographic soils.

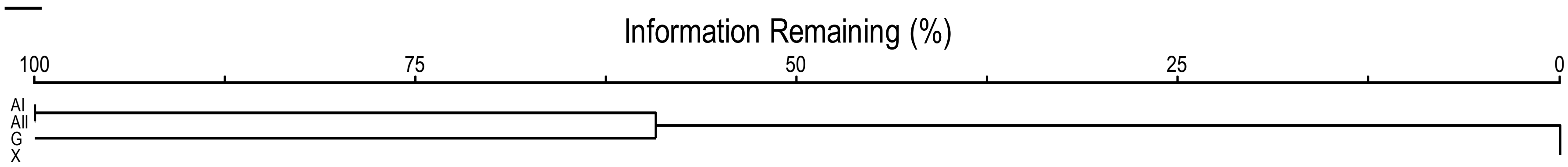

Figure 9a - Floristic similarity dendrogramalong edaphic/topographic gradient in Carajás National Forest, Pará, Brazil. AI: Águas Claras Sandstone Soils I; AII: Águas Claras Sandst one Soils II; G: Carajás Granite Soils and X: Xingu Complex Soils.

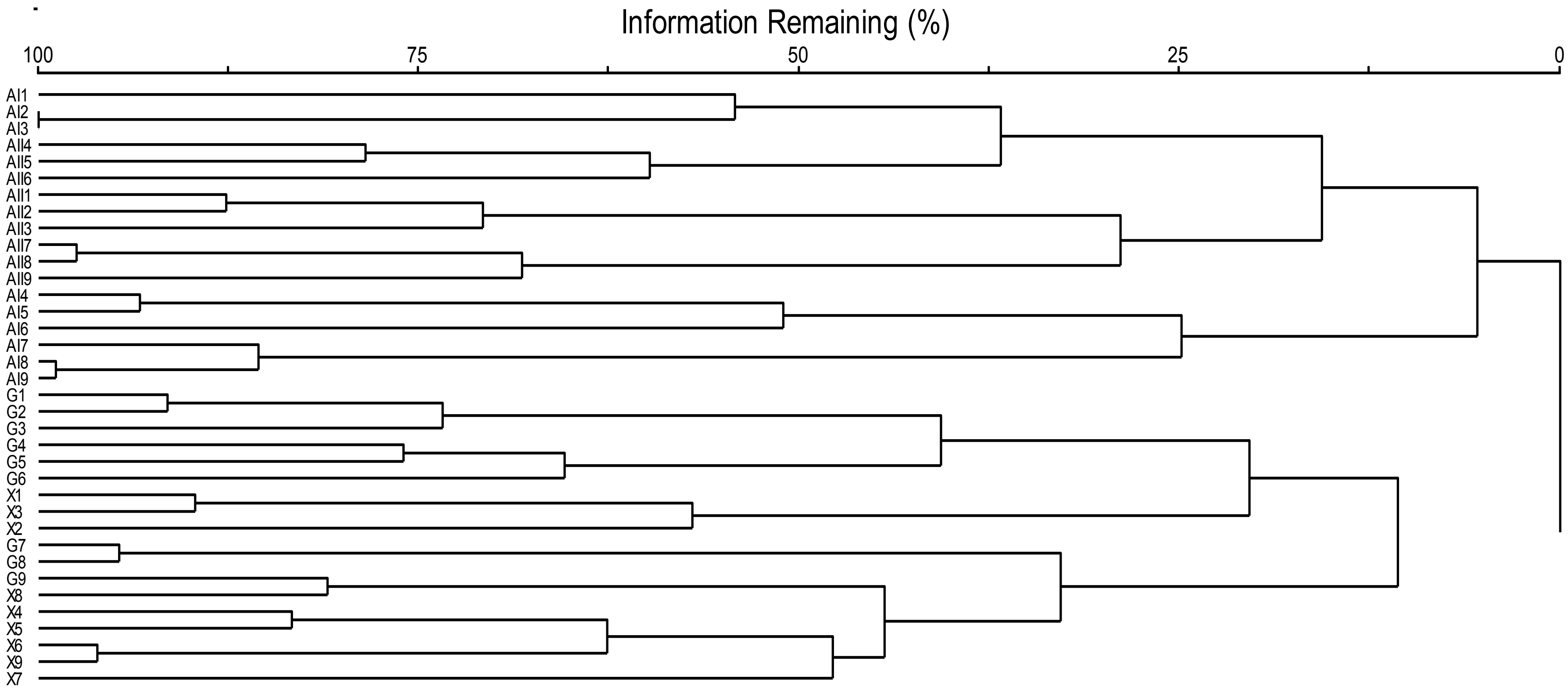


Figure 9b - Floristic similarity dendrogram of 36 plots distributedalong edaphic/topographic gradient in Carajás National Forest, Pará, Brazil. AI: Águas Claras Sandstone Soils I; AII: Águas Claras Sandstone Soils II; G: Carajás Granite Soils and X: Xingu Complex Soils.

4. Discussion

Differences in composition and physiognomic attributes under the same climatic regime highlight the significant heterogeneity that can be found in tropical dry forests within a region (Farjardo et al. 2005). In this regard, we asked if the floristic and structural heterogeneity of DF formations in Carajás affected by the nature of substrate (considering crystalline rocks, sedimentary and volcanic). Ours results indicate that, DF formations in this part of Amazonia showed marked variations in floristic composition along edaphic/topographic gradient. Overall 370 trees species were found, number that can be considered high, although the difficulties of comparison. However, certain characteristics of the floristic composition of DF formations in Carajás differ from those described for other Neotropical regions. Study in Venezuelan tropical dry forest, found 169 species, of which 91 were trees, in a total sampled area of 0,3 ha (Fajardo et al. 2005). A total of 42 woody species were recorded in dry forest in northwestern Mexico a total area of 1.2 ha (Alvarez-Yepiz et al. 2008). Gillespie et al (2000) registered 204 species in Central America in 0.1ha. Costa Rica studies registred 159 woody species (Kalacska 2004) and 135 tree species (Powers et al. 2009) both in 0.1 ha. Williams-Linera; Lorea (2009) showed 122 species for 1ha in another Mexican study. Santos et al. (2011) found 64 trees species in 0.8ha. at the Brazilian DFs in northern Minas Gerais state.

However, when species occurrence was related to each DF formation, 250 species occurred only in one area, whereas 120 occurred in two or more sites. In our study, six species were found in all DF studied. Toledo et al. (2011) reported in Bolivian Amazon, that only ten species occurred in one single floristic region and 90 occurred in two or more floristic regions in the Bolivian Amazon. There, only six species had a wide distribution in all four floristic regions studied.

The floristic of the each DF formation are peculiar, although, the Carajás Granite Soil and Xingu Complex Soil are floristically closer, with some species in common, as associated with similar nutrients status (Chapter 1). Conversely, Águas Claras Sandstone Soil I and II also shared some species, with similar trend in nutrient. All plots were clustered in away they formed distinct groups, highlighting the floristic difference in DF formations, as confirmed by DCA and floristic similarity analysis. Besides, the MRPP analysis distinguished four floristic groups according with substrate, as originally postulated. The association between plant-community arrangement on the ordination space and environmental variables projected on the diagram was similar (Chapter 1). In this concern, Rundel and Boonpragob (2009) studied DF with varied substrates, and showed that soils were shallow and relatively depleted in nutrient. According to Toledo et al. (2012) soils can be very variable and, extreme soils such as those on limestone karst, granitic outcrops and white sands can have a dramatic effect on species occurrence. In dry forest of Thailand, there are forests on Granite and Limestone with many dominant species uncommon to nearby soils (Kuchler; Sawyer 1967). Studies in dry forest associated with the Brazilian semi-arid landscape showed that forests are distributed according to a soil fertility gradient (Arruda 2012).

As expected for DF, Fabaceae, Sapotaceae and Myrtaceae were the main families, a common feature for Neotropical forest from elsewhere (Gentry 1988; Terborgh and Andresen 1998; Santos et al. 2007; ter Steege 2010). Fabaceae is commonly the richest family in Neotropical DF (Sales et al. 2004; Pennington et al. 2009; Madeira 2009; Arruda et al. 2011). The only, exception are in the Caribbean studies (Lugo et al. 2006; Gillespie 2006), in which Myrtaceae was the dominant family. Some woody families are more abundant in DF than elsewhere, and characterize this vegetation. Fabaceae was the most abundant family in terms of species and individuals in our study, representing about 13,8 percent of the total individuals. On the other hand, Rutaceae despite less abundant in terms of species, showed expressive individuals abundance (12,63%).

Despite many studies pointing to Fabaceae as the richest family in the neotropical forests (Ferreira and Prance 1998; ter Steege et al. 2006; Francez et al. 2007; Malheiros et al. 2009;), other studies (e.g. Ek and ter Steege 1998; Gentry 1990;) have shown Bombacaceae, Meliaceae and Moraceae as the richest families in Western Amazonian forests, whereas Chrysobalanaceae and Lecythidaceae are particularly rich in Guianas and east Amazonian forests. Hence, although each particular site can have a a peculiar species composition, the overall composition of neotropical forests, at family level, remains the same (Gentry 1986). Furthermore, each family can form a different group of species on different substrates in Amazonia (e.g. soils) (Muniz et al. 1994). In this sense, any useful comparison between the richness of these DF fragments and that of surrounding forests in which they are embedded would clearly need a greater research effort, using adequate sampling approach, before any conclusion could be drawn.

Plotting the distribution of the most abundant individuals and important (IV) of all five DF formations along the edaphic/topographic gradient, the same species followed the soil/geomorphology gradient. Hence, the species filtering varied according to soil. Ferreira-Júnior (2009) found similar results, when studied species a along flooding gradient in DF of Brazilian wetland Pantanal.

Overall, the structure DF formations in Carajás were not as much different as floristic composition. The mean height in all DFs formations showed to be homogeneous, except for the Xingu Complex Soil that showed the maximum height much smaller compared with the other DF. In this respect, Santos et al. (2011), mentioned that regional characteristics of climate and soil may favor increasing number of small individuals, often in blanches in aggregate forms, as seen by the low frequency of species (Tab. 4 - supplementary material). Consistently, Cólon (2011) highlighted a low floristic diversity and height, high density of small and medium sized trees, for a DF in the Caribbean. These forests occur on porous limestone substrate with shallow soils, being subjected to greater water stress and nutrient limitations than other non-calcareous dry forests under similar rainfall regimes. Murphy and Lugo (1986) reported that, generally, dry tropical forests are floristically and structurally less complex than wet tropical forests. Reflecting the overall smaller stature of dry forest, they have lower biomass compared with wet forests.

The average values of the vertical structure and basal area were higher in Águas Claras Soil I; where soils are sandstone, higher Al+ and higher extractable Fe. Study in DF at Northern Minas Gerais (Arruda et al. 2011), found similar results to BA and vertical structure in response to soil. These authors highlighted the importance of edaphic factors in the determination of a DF structure.

The estimated density and absolute dominance were 2038.88 ind.ha-1 and 27.197 $m^2$.ha-1, respectively (Tab. 4 - Supplementary material). The density found in this study was higher than the values found by Santos et al. (2011) and Peña Claros et al. 2012.

Considering all the DF formations in Carajás the Shannon diversity index was 4,71. In general, the Shannon Index obtained from empirical data falls between 1,5 and 3,5 and rarely surpasses 4 (Magurran 2004).

Plants diversity can be considered high in all DF formations studied, independently of the topography/soils. Nevertheless, there is difference between areas with greatest diversities (X and AI), and areas that had lower diversity (AII and G). In fact, The Shannon Index, structural values, tree species richness were all than the normal range of those reported for Brazilian DF from elsewhere (Nascimento et al. 2004; Ferreira-Júnior 2009; Lima et al. 2010; Arruda 2012; Duque-Brasil 2012).

A positive relationship between species diversity and basal area may be an important characteristic of the dry forest. In the Mexican dry forest, tree species diversity (alpha) increases with structural forest characteristics, such as basal area, density, canopy height and understory vegetation (Williams-Linera and Lorea 2009). Similarly, Sagar and Singh (2006) reported this relationship in the Vindhyan DF of India.

## 5. Conclusions

1. The floristic heterogeneity of DFs in Southeastern Amazonia (Carajás) influenced by soil, differences related to different substrate (igneous granite/ crystalline rocks/ sedimentary/ and volcanic).
2. We did not observe a marked structural variation of the DF formations in Carajás. However, the structural attributes showed a higher range of values compared to Neotropical dry forests from elsewhere.

6. References


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7. Material supplementary

Table 3 - List of species occurring in Dry forest in National Forest of Carajás, Pará State, Brazil. AI: Águas Claras Sandstone Soils I; AII: Águas Claras Sandstone Soils II; B: Basalt Soils; G: Carajás Granite Soils and X: Xingu Complex Soils.

| **Family** | **Species** | **AI** | **AII** | **G** | **X** |
|---|---|---|---|---|---|
| Achariaceae | Lindackeria paludosa (Benth.) Gilg | | | | x |
| Anacardiaceae | Astronium fraxinifolium Schott ex Spreng. | | | | x |
| | Astronium gracile Engl. | x | x | x | x |
| | Astronium lecointei Ducke | x | x | x | |
| | Astronium sp. | | | x | |
| | Spondias mombin L. | | | | x |
| | Tapirira cf. retusa Ducke | | | | x |
| | Tapirira guianensis Aubl. | x | x | | |
| | Tapirira sp. | | | | x |
| | Thyrsodium paraense Huber | | | | x |
| | Thyrsodium spruceanum Benth. | | x | | |
| Annonaceae | Annonaceae 1 | | x | | |
| | Cymbopetalum cf. euneurum N.A.Murray | x | | | |
| | Cymbopetalum sp. | x | x | | |
| | Duguetia cadaverica Huber | | | x | |
| | Duguetia flagellaris Huber | | | x | |
| | Duguetia stelechantha (Diels) R.E. Fr. | | | x | x |
| | Guatteria foliosa Benth. | | | x | x |
| | Guatteria olivacea R.E. Fr. | x | x | | x |
| | Rollinia insignis R.E. Fr. | | x | x | x |
| | Xylopia polyantha R.E. Fr. | | | | x |
| Apocynaceae | Aspidosperma cf. marcgravianum Woodson | | x | | |
| | Aspidosperma macrophyllum Müll. Arg. | x | x | | |
| | Aspidosperma parvifolium A. DC. | | | x | x |
| | Aspidosperma sp. | x | | | |
| | Aspidosperma spruceanum Benth. ex Müll. Arg. | | | | x |
| | Aspidosperma subincanum Mart. ex A. DC. | x | x | | |
| | Couma utilis (Mart.)Müll. Arg. | | x | | x |
| | Himatanthus sp. | | x | | |
| | Himatanthus sucuuba (Spruce ex Müll. Arg.) Woodson | x | x | | x |
| | Rauvolfia sprucei Müll. Arg. | | | x | |
| | Tabernaemontana angulata Mart. ex Müll. Arg. | | | | x |
| | Tabernaemontana muricata Link ex Roem. & Schult. | | x | x | |
| Arecaceae | Astrocaryum aculeatum G. Mey. | | | | x |
| | Astrocaryum gynacanthum Mart. | x | x | x | x |
| | Attalea maripa (Aubl.) Mart. | x | x | x | |
| | Oenocarpus distichus Mart. | x | | x | |
| | Syagrus comosa (Mart.) Mart. | | x | | x |
| | Syagrus oleracea (Mart.) Becc. | | | x | |

Continued...

| Family | Species | AI | AII | G | X |
|---|---|---|---|---|---|
| | Syagrus sp. | | x | | |
| Bignoniaceae | Jacaranda brasiliana (Lam.) Pers. | x | | | |
| | Jacaranda copaia (Aubl.) D. Don | | x | | x |
| | Handroanthus impetiginosus (Mart. ex DC.) Mattos | | x | | |
| | Handroanthus ochraceus (Cham.) Mattos | | | | x |
| | Handroanthus roseo-albus (Ridl.) Mattos | | x | | |
| | Handroanthus serratifolius (Vahl) S. O. Grose | x | | x | x |
| | Tabebuia sp. | x | x | | |
| Bixaceae | Cochlospermum orinocense (Kunth) Steud. | | x | x | x |
| Boraginaceae | Cordia exaltata Lam. | | | x | |
| | Cordia hirta I.M. Johnst. | x | | x | x |
| | Cordia naidophila I.M. Johnst. | | | | x |
| | Cordia nodosa Lam. | x | x | | |
| | Crepidospermum rhoifolium (Benth.) Triana & Planch. | | | | x |
| Burseraceae | Icica aracouchini Aubl. | x | x | | |
| | Protium apiculatum Swart | | | x | |
| | Protium cf. pilosissimum Engl. | | x | | |
| | Protium guianense (Aubl.) Marchand | | x | | |
| | Protium heptaphyllum (Aubl.) Marchand | x | x | | |
| | Protium nitidum Engl. | | | | x |
| | Protium robustum (Swart) D.M. Porter | | | x | |
| | Protium rubrum Cuatrec. | | | x | |
| | Protium spruceanum (Benth.) Engl. | x | | | |
| | Protium subserratum (Engl.) Engl. | | | x | |
| | Protium tenuifolium (Engl.) Engl. | x | x | | |
| | Tetragastris altissima (Aubl.) Swart | | x | x | x |
| | Tetragastris panamensis (Engl.) Kuntze | x | x | x | |
| | Trattinnickia burserifolia Mart. | | | x | x |
| | Trattinnickia panamensis Standl. & L.O. Williams | x | | | |
| Calophyllaceae | Calophyllum brasiliense Cambess. | x | x | | |
| Caricaceae | Jacaratia spinosa (Aubl.) A. DC. | | | x | x |
| Celastraceae | Cheiloclinium cognatum (Miers) A.C. Sm. | | | x | |
| | Maytenus guyanensis Klotzsch ex Reissek | | x | | |
| | Maytenus sp. | | x | | |
| Chrysobalanaceae | Hirtella cf. racemosa Lam. | x | | | |
| | Hirtella hispidula Miq. | x | | | |
| | Licania cf. egleri Prance | | x | | |
| | Licania hypoleuca Benth. | x | x | x | |
| | Licania sp. | | x | | |
| | Licania sprucei (Hook. f.) Fritsch | | | x | |
| Clusiaceae | Caraipa densifolia Mart. | x | x | | |
| | Clusia weddelliana Planch & Triana subs. nova | | x | | |
| | Garcinia madruno (Kunth) Hammel | | | x | |
| | Symphonia globulifera L. f. | x | x | | |
| Combretaceae | Buchenavia congesta Ducke | | x | x | |

Continued...

| Family | Species | AI | AII | G | X |
|---|---|---|---|---|---|
| | Buchenavia grandis Ducke | | x | x | |
| | Buchenavia parvifolia Ducke | x | | | |
| | Buchenavia viridiflora Ducke | | x | | |
| Connaraceae | Connarus perrottetii (DC.) Planch. | x | x | | |
| Ebenaceae | Diospyros cavalcantei Sothers | | x | x | |
| Elaeocarpaceae | Sloanea pubescens Benth. | x | | | |
| | Sloanea schomburgkii Spruce ex Benth. | x | | | |
| Erythroxylaceae | Erythroxylum ligustrinum var. carajasense Plowman | x | x | | |
| | Erythroxylum macrophyllum Cav. | x | | x | |
| | Erythroxylum nelson-rosae Plowman | x | x | | x |
| Euphorbiaceae | Aparisthmium cordatum (A. Juss.) Baill. | x | x | | |
| | Croton sp. | | x | | x |
| | Glycydendron amazonicum Ducke | x | | | x |
| | Mabea angustifolia Spruce ex Benth. | | | | |
| | Maprounea guianensis Aubl. | x | | | |
| | Sapium biglandulosum (L.) Müll.Arg. | x | | | x |
| | Sapium glandulatum (Vell.) Pax | x | x | x | |
| Fabaceae | Abarema mataybifolia (Sandwith) Barneby & J.W. Grimes | | x | x | |
| | Senegalia polyphylla (DC.) Britton | | | x | x |
| | Anadenanthera sp. | | | | x |
| | Bauhinia macrostachya Benth. | | | | x |
| | Bauhinia pulchella Benth. | x | x | | |
| | Bauhinia sp.1 | | | x | |
| | Bowdichia virgilioides Kunth | x | x | x | |
| | Cassia leandrii Ghesq. | | | | x |
| | Cenostigma sp. | | | x | x |
| | Cenostigma tocantinum Ducke | | | x | x |
| | Chamaecrista adiantifolia (Spruce ex Benth.) H.S. Irwin & Barneby | | | | x |
| | Copaifera duckei Dwyer | x | | | |
| | Copaifera martii Hayne | | | x | |
| | Copaifera multijuga Hayne | x | x | | |
| | Dialium guianense (Aubl.) Sandwith | | x | | x |
| | Dipteryx odorata (Aubl.) Willd. | | x | | |
| | Coumarouna polyphylla (Huber) Ducke | | | x | |
| | Diplotropis purpurea (Rich.) Amshoff | x | x | x | x |
| | Enterolobium contortisiliquum (Vell.) Morong | x | | | |
| | Erythrina falcata Benth. | | | | x |
| | Hymenaea courbaril L. | | x | x | x |
| | Hymenaea intermedia Ducke | x | | | |
| | Hymenaea parvifolia Huber | x | | | |
| | Inga alba (Sw.) Willd. | x | | | |
| | Inga cayennensis Sagot ex Benth. | x | x | | |
| | Inga grandiflora Wall. | | | x | |
| | Inga huberi Ducke | x | x | | |

Continued...

| Family | Species | AI | AII | G | X |
|---|---|---|---|---|---|
| | Inga lateriflora Miq. | x | | | x |
| | Inga laurina (Sw.) Willd. | x | | | |
| | Inga longiflora Spruce ex Benth. | | | | x |
| | Inga macrophylla Humb. & Bonpl. ex Willd. | | | x | x |
| | Inga marginata Willd. | | | x | x |
| | Inga panamensis Seem. | | | x | |
| | Inga paraensis Ducke | | | | x |
| | Inga rubiginosa (Rich.) DC. | x | x | x | |
| | Inga stipularis DC. | x | x | x | |
| | Inga thibaudiana DC. | x | x | x | |
| | Inga umbratica Poepp. & Endl. | x | | x | |
| | Machaerium sp. | x | | | |
| | Martiodendron sp. | | | | x |
| | Mimosa acutistipula (Mart.) Benth. | x | x | | x |
| | Ormosia paraensis Ducke | | | x | |
| | Parkia multijuga Benth. | x | | | |
| | Parkia platycephala Benth. | | x | x | |
| | Piptadenia rigida Benth. | x | x | x | x |
| | Piptadenia suaveolens Miq. | x | x | x | |
| | Platymiscium duckei Huber | | x | | x |
| | Platymiscium paraense Huber | x | | | |
| | Platymiscium sp. | x | x | | |
| | Pseudopiptadenia cf. psilostachya (DC.) G.P.Lewis & M.P.Lima | x | | | |
| | Pterocarpus officinalis Jacq. | | | x | |
| | Pterocarpus rohrii Vahl | | x | | x |
| | Pterodon emarginatus Vogel | | | x | |
| | Senna sp. | | | x | |
| | Stryphnodendron guianense (Aubl.) Benth. | x | | | |
| | Stryphnodendron racemiferum (Ducke) W.A. Rodrigues | | | x | |
| | Stryphnodendron sp. | | | | x |
| | Tachigali myrmecophila (Ducke) Ducke | | x | x | |
| Humiriaceae | Endopleura uchi (Huber) Cuatrec. | x | x | | |
| | Sacoglottis guianensis Benth. | x | x | | |
| | Sacoglottis mattogrossensis Malme | | x | | |
| Icacinaceae | Emmotum nitens (Benth.) Miers | | x | | |
| Unidentified Species | Unidentified species 1 | x | | | |
| | Unidentified species 2 | x | | | |
| Lacistemataceae | Lacistema aggregatum (P.J. Bergius) Rusby | x | x | x | |
| Lamiaceae | Vitex triflora Vahl | x | x | | x |
| Lauraceae | Aniba canelilla (Kunth) Mez | x | x | | |
| | Licaria cannella (Meisn.) Kosterm. | x | | x | |
| | Licaria guianensis Aubl. | | x | | |
| | Mezilaurus itauba (Meisn.) Taub. ex Mez | | x | | |
| | Mezilaurus sp. | | x | | |

Continued...

| Family | Species | AI | AII | G | X |
|---|---|---|---|---|---|
| | Ocotea amazonica (Meisn.) Mez | x | x | | |
| | Ocotea caudata (Nees) Mez | x | | | |
| | Ocotea longifolia Kunth | | | | x |
| | Ocotea matogrossensis Vatt. | x | | | |
| | Ocotea minor Vicent. | x | x | | |
| | Ocotea olivacea A.C. Sm. | x | | | x |
| | Ocotea tabacifolia (Meisn.) Rohwer | x | | | |
| | Rhodostemonodaphne cf. parvifolia Madriñán | | | | x |
| | Rhodostemonodaphne sp. | | x | | |
| Lecythidaceae | Eschweilera coriacea (DC.) S.A. Mori | x | | | x |
| | Eschweilera nana (O. Berg) Miers | | | | x |
| | Eschweilera pedicellata (Rich.) S.A. Mori | x | | | |
| | Eschweilera truncata A.C. Sm. | x | | | |
| | Lecythis zabucajo Aubl | | | x | |
| Malphiguiaceae | Byrsonima crispa A. Juss. | | | x | |
| | Byrsonima incarnata Sandwith | | x | x | x |
| Malvaceae | Apeiba echinata Gaertn. | | | x | |
| | Bombacopsis nervosa (Uittien) A. Robyns | | x | x | |
| | Ceiba pendrandra C.F. Gaertn. | | | | x |
| | Eriotheca globosa (Aubl.) A. Robyns | | | x | x |
| | Guazuma ulmifolia Lam. | | | x | |
| | Helicteres sacarolha A. St.-Hil., A. Juss. & Cambess. | | | x | x |
| | Lueheopsis rosea (Ducke) Burret | x | x | x | |
| | Pachira cf. faroensis (Ducke) W.S.Alverson | | | | x |
| | Pseudobombax sp. | x | | | |
| | Rhodognaphalopsis duckei A. Robyns | | x | | |
| | Sterculia excelsa Mart. | | | x | |
| | Theobroma speciosum Willd. ex Spreng. | x | | x | x |
| Melastomataceae | Miconia cuspidata Mart. ex Naudin | x | x | | |
| | Miconia holosericea (L.) DC. | | x | | |
| | Miconia sp. | | | | x |
| | Miconia sp.2 | | | | x |
| | Miconia spichigeri Wurdack | | x | | |
| | Miconia tetraspermoides Wurdack | | | x | |
| | Mouriri angulicosta Morley | x | x | | |
| | Mouriri dimorphandra Morley | | | x | |
| | Mouriri ficoides Morley | x | x | x | |
| | Mouriri grandiflora DC. | x | | | |
| | Mouriri huberi Cogn. | x | x | x | |
| | Mouriri nigra (DC.) Morley | | | x | |
| Meliaceae | Cedrela fissilis Vell. | | x | x | x |
| | Trichilia micrantha Benth. | | | x | |
| | Trichilia pallida Sw. | | | x | |
| Menispermaceae | Abuta grandifolia (Mart.) Sandwith | | x | | |
| | Abuta guianensis Eichler | | x | | |

Continued...

| Family | Species | AI | AII | G | X |
|---|---|---|---|---|---|
| Moraceae | Bagassa guianensis Aubl. | | | x | |
| | Batocarpus amazonicus (Ducke) Fosberg | | | x | |
| | Brosimum acutifolium Huber | x | | x | |
| | Brosimum cf. utile (Kunth) Oken | | x | | |
| | Brosimum longifolium Ducke | | | | x |
| | Brosimum rubescens Taub. | | x | x | |
| | Brosimum sp. | | | | x |
| | Clarisia ilicifolia (Spreng.) Lanj. & Rossberg | x | | | |
| | Clarisia racemosa Ruiz & Pav. | x | | | |
| | Ficus guianensis Desv. ex Ham. | | x | | |
| | Helicostylis tomentosa (Poepp. & Endl.) Rusby | | x | x | |
| | Helicostylis turbinata C.C. Berg | | | x | |
| | Maclura tinctoria (L.) D. Don ex Steud. | | | | x |
| | Maquira guianensis Aubl. | | | x | |
| | Maquira sclerophylla (Ducke) C.C. Berg | x | x | | |
| | Perebea mollis (Poepp. & Endl.) Huber | | | x | x |
| | Sorocea guilleminiana Gaudich. | | | | x |
| | Sorocea ilicifolia Miq. | | | x | |
| Myristicaceae | Virola calophylla (Spruce) Warb. | x | x | | |
| | Virola michelii Heckel | x | x | x | |
| | Virola sp. | x | | | |
| Myrtaceae | Calycolpus goetheanus (DC.) O. Berg | | x | x | |
| | Calycolpus sp. | x | x | | |
| | Calyptranthes crebra McVaugh. | | | x | |
| | Calyptranthes sp. | x | | | |
| | Campomanesia sp. | x | | | |
| | Eugenia cupulata Amshoff | | | x | |
| | Eugenia patrisii Vahl | x | x | x | |
| | Eugenia protenta McVaugh | x | | | |
| | Eugenia punicifolia (Kunth) DC. | x | x | x | x |
| | Eugenia tapacumensis O. Berg | | x | | |
| | Eugenia sp. | | x | | |
| | Marlierea sp. | | x | | |
| | Myrcia cuprea (O. Berg) Kiaersk. | x | x | | |
| | Myrcia fenestrata DC. | | | | x |
| | Myrcia flavescens Barb. Rodr. | x | | | |
| | Myrcia magnoliifolia DC. | | | x | |
| | Myrcia multiflora (Lam.) DC. | x | | | x |
| | Myrcia rufipila McVaugh | | x | | |
| | Myrcia splendens (Sw.) DC. | | | | x |
| | Myrcia sp. | x | x | x | |
| | Myrcia tomentosa (Aubl.) DC. | x | x | | |
| Nyctaginaceae | Guapira ferruginea (Klotzsch ex Choisy) Lundell | | x | | |
| | Neea floribunda Poepp. & Endl. | x | x | x | |
| | Neea oppositifolia Ruiz & Pav. | x | x | x | |

Continued...

| Family | Species | AI | AII | G | X |
|---|---|---|---|---|---|
| | Neea ovalifolia Spruce ex J.A. Schmidt | | x | x | |
| | Neea robusta Steyerm. | | x | x | x |
| | Neea sp. | x | | | |
| Olacaceae | Dulacia candida (Poepp.) Kuntze | | | x | |
| | Minquartia guianensis Aubl. | x | x | | |
| Opiliaceae | Agonandra brasiliensis Miers ex Benth. & Hook. f. | | | x | x |
| Peraceae | Pera sp. | | | | x |
| Phyllanthaceae | Margaritaria nobilis L. f. | | x | x | x |
| | Margaritaria sp. | | | | x |
| Piperaceae | Piper cf. aduncum L. | | | | x |
| Polygonaceae | Coccoloba sp. | | | | x |
| Proteaceae | Roupala brasiliensis Klotzsch | x | | | |
| | Roupala montana Aubl. | | x | | |
| | Roupala sp. | x | | | |
| Putranjivaceae | Drypetes variabilis Uittien | x | x | x | |
| Quiinaceae | Lacunaria jenmanii (Oliv.) Ducke | x | | | |
| Rhamnaceae | Rhamnidium sp. | | | | x |
| | Ziziphus cinnamomum Triana & Planch. | | | x | |
| | Ziziphus sp. | | | x | |
| | Prunus myrtifolia (L.) Urb. | x | | | |
| Rosaceae | Prunus sp. | | | | x |
| Rubiaceae | Alibertia claviflora K. Schum. | | | | x |
| | Alibertia myrciifolia K. Schum. | x | x | x | |
| | Amaioua sp. | | | | x |
| | Botryarrhena sp. | x | | | |
| | Chimarrhis turbinata DC. | x | | | |
| | Chomelia sp. | | x | | |
| | Chomelia tenuiflora Benth. | | | x | |
| | Coutarea sp. | | x | | |
| | Duroia gransabanensis Steyerm. | x | x | | |
| | Duroia sp. | | x | | |
| | Faramea filipes Martius ex Benth. | x | x | | |
| | Faramea torquata Müll. Arg. | x | x | | |
| | Ferdinandusa cf. hirsuta Standl. | | | | x |
| | Ferdinandusa goudotiana K. Schum. | | | x | |
| | Ixora sp. | | x | | |
| | Kutchubaea sp. | | x | | |
| | Palicourea sp. | | x | | |
| | Warszewiczia schwackei K. Schum. | | | x | |
| Rutaceae | Almeidea sp. | | | x | x |
| | Esenbeckia grandiflora Mart. | x | x | x | |
| | Esenbeckia pilocarpoides Kunth. | | x | | |
| | Galipea jasminiflora (A. St.-Hil.) Engl. | | x | x | x |
| | Galipea sp. | | x | x | x |
| | Metrodorea flavida K. Krause | x | x | x | x |

Continued...

| Family | Species | AI | AII | G | X |
|---|---|---|---|---|---|
| | Metrodorea sp. | | | | x |
| | Neoraputia paraensis (Ducke) Emmerich | x | | x | |
| | Rutaceae 1 | x | | | |
| | Rutaceae 2 | x | | | |
| | Sigmatanthus sp. | | | x | |
| | Spiranthera sp. | | x | | |
| | Zanthoxylum rhoifolium Lam. | | | x | x |
| Salicaceae | Banara guianensis Aubl. | | | x | x |
| | Casearia arborea (Rich.) Urb. | | | x | x |
| | Casearia javitensis Kunth | x | | | |
| | Casearia pitumba Sleumer | x | | | x |
| Sapindaceae | Allophylus sp. | x | | | |
| | Cupania scrobiculata Rich. | x | x | x | x |
| | Cupania sp. | x | x | | |
| | Matayba elegans Radlk. | | x | | |
| | Matayba guianensis Aubl. | x | x | x | |
| | Matayba inelegans Spruce ex Radlk. | x | | | |
| | Matayba sp. | | x | | |
| | Porocystis toulicioides Radlk. | | | x | |
| | Talisia allenii Croat | | x | | x |
| | Talisia sp. | | x | | |
| | Talisia veraluciana Guarim | | | x | |
| | Toulicia pulvinata Radlk. | x | x | x | x |
| | Vouarana guianensis Aubl. | x | x | x | x |
| | Chrysophyllum pomiferum (Eyma) T.D. Penn. | x | | x | |
| | Chrysophyllum sparsiflorum Klotzsch ex Miq. | | | x | |
| | Ecclinusa guianensis Eyma | | | x | |
| | Micropholis casiquiarensis Aubrév. | x | x | | |
| | Micropholis cylindrocarpa (Poepp. & Endl.) Pierre | | x | | |
| | Pouteria brevipes (Baker) Baehni | | | x | |
| | Pouteria caimito (Ruiz & Pav.) Radlk. | | | x | |
| | Pouteria cf. rostrata (Huber) Baehni | | x | | |
| | Pouteria fimbriata Baehni | x | | | |
| Sapotaceae | Pouteria guianensis Aubl. | | x | | |
| | Pouteria hispida Eyma | x | x | | |
| | Pouteria latianthera T.D. Penn. | | | x | |
| | Pouteria pariry (Ducke) Baehni | x | | | x |
| | Pouteria parviflora (Benth. ex Miq.) Radlk. | x | | | |
| | Pouteria petiolata T.D. Penn. | x | | x | |
| | Pouteria sp. | x | | | |
| | Pouteria vernicosa T.D. Penn. | x | x | x | x |
| Simaroubaceae | Simarouba amara Aubl. | | x | x | |
| Siparunaceae | Siparuna amazonica Mart. ex A. DC. | | | | x |
| | Siparuna guianensis Aubl. | | x | | x |
| Solanaceae | Solanum sp. | | | x | |
| | Solanaceae 1 | | x | | |

Continued...

| Family | Species | AI | AII | G | X |
|---|---|---|---|---|---|
| Styracaceae | Styrax discolor M.F. Silva | | | x | |
| Theaceae | Gordonia fruticosa (Schrad.) H. Keng | | x | | |
| Ulmaceae | Ampelocera edentula Kuhlm. | | | x | |
| Urticaceae | Cecropia distachya Huber | | | x | x |
| | Cecropia latiloba Miq. | | | x | |
| | Cecropia ulei Snethl. | | | x | |
| | Pourouma guianensis Aubl. | | | | x |
| Verbenaceae | Lippia grandis Scham | | x | | |
| Violaceae | Rinorea macrocarpa (C. Mart. ex Eichler) Kuntze | | x | | |
| Vochysiaceae | Callisthene minor Mart. | x | x | | |
| | Erisma uncinatum Warm. | x | x | | |
| | Qualea cf. rosea Aubl. | | x | | |
| | Qualea paraensis Ducke | x | | | |
| | Vochysia sp. | | x | | |

Table 4 - Structural parameters in dry forests along edaphic/topographic gradient in Carajás National Forest, Pará, Brazil. Águas Claras Sandstone Soils I; Where: N: Number of Individual; AD: Absolute Density; RD: Relative density; AF: Absolute Frequency; RF: Relative Frequency; ADo: Absolute Dominance; RDo: Relative Dominance; CV: Coverage value (%) and IV: Importance value (%).

| **Species** | **N** | **AD** | **RD** | **AF** | **RF** | **ADo** | **RDo** | **CV (%)** | **IV (%)** |
|---|---|---|---|---|---|---|---|---|---|
| Callisthene minor | 51 | 141.67 | 7.59 | 33.33 | 1.05 | 6.21 | 19.76 | 13.67 | 9.46 |
| Esenbeckia grandiflora | 73 | 202.78 | 10.86 | 55.56 | 1.74 | 0.83 | 2.65 | 6.75 | 5.08 |
| Myrcia cuprea | 50 | 138.89 | 7.44 | 55.56 | 1.74 | 0.57 | 1.82 | 4.63 | 3.67 |
| Dead Tree | 26 | 72.22 | 3.87 | 88.89 | 2.79 | 1.31 | 4.16 | 4.01 | 3.6 |
| Chrysophyllum pomiferum | 8 | 22.22 | 1.19 | 33.33 | 1.05 | 2.22 | 7.06 | 4.12 | 3.1 |
| Eschweilera coriacea | 6 | 16.67 | 0.89 | 44.44 | 1.39 | 1.92 | 6.11 | 3.5 | 2.8 |
| Neea floribunda | 17 | 47.22 | 2.53 | 55.56 | 1.74 | 0.26 | 0.82 | 1.68 | 1.7 |
| Pseudopiptadenia cf. psilostachya | 3 | 8.33 | 0.45 | 11.11 | 0.35 | 1.17 | 3.71 | 2.08 | 1.5 |
| Brosimum acutifolium | 3 | 8.33 | 0.45 | 33.33 | 1.05 | 0.89 | 2.84 | 1.65 | 1.45 |
| Mouriri angulicosta | 13 | 36.11 | 1.93 | 33.33 | 1.05 | 0.42 | 1.34 | 1.64 | 1.44 |
| Duroia gransabanensis | 12 | 33.33 | 1.79 | 55.56 | 1.74 | 0.24 | 0.77 | 1.28 | 1.43 |
| Pouteria hispida | 6 | 16.67 | 0.89 | 44.44 | 1.39 | 0.55 | 1.76 | 1.33 | 1.35 |
| Vouarana guianensis | 13 | 36.11 | 1.93 | 44.44 | 1.39 | 0.14 | 0.43 | 1.18 | 1.25 |
| Buchenavia parvifolia | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.85 | 2.71 | 1.5 | 1.23 |
| Erythroxylum nelson-rosae | 11 | 30.56 | 1.64 | 33.33 | 1.05 | 0.31 | 0.99 | 1.31 | 1.22 |
| Mouriri huberi | 11 | 30.56 | 1.64 | 55.56 | 1.74 | 0.09 | 0.28 | 0.96 | 1.22 |
| Eugenia punicifolia | 14 | 38.89 | 2.08 | 33.33 | 1.05 | 0.16 | 0.52 | 1.3 | 1.22 |
| Stryphnodendron guianense | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.95 | 3.01 | 1.58 | 1.17 |
| Pouteria vernicosa | 12 | 33.33 | 1.79 | 33.33 | 1.05 | 0.21 | 0.67 | 1.23 | 1.17 |
| Aspidosperma macrophyllum | 9 | 25.00 | 1.34 | 22.22 | 0.7 | 0.43 | 1.36 | 1.35 | 1.13 |
| Bauhinia pulchella | 14 | 38.89 | 2.08 | 33.33 | 1.05 | 0.08 | 0.25 | 1.17 | 1.13 |
| Aparisthmium cordatum | 11 | 30.56 | 1.64 | 33.33 | 1.05 | 0.16 | 0.5 | 1.07 | 1.06 |
| Micropholis casiquiarensis | 8 | 22.22 | 1.19 | 33.33 | 1.05 | 0.28 | 0.89 | 1.04 | 1.04 |
| Aspidosperma subincanum | 8 | 22.22 | 1.19 | 22.22 | 0.7 | 0.35 | 1.11 | 1.15 | 1 |
| Neea oppositifolia | 8 | 22.22 | 1.19 | 44.44 | 1.39 | 0.08 | 0.26 | 0.73 | 0.95 |
| Sacoglottis guianensis | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.73 | 2.33 | 1.24 | 0.94 |
| Pouteria sp. | 7 | 19.44 | 1.04 | 44.44 | 1.39 | 0.11 | 0.34 | 0.69 | 0.92 |
| Matayba guianensis | 9 | 25.00 | 1.34 | 33.33 | 1.05 | 0.11 | 0.34 | 0.84 | 0.91 |
| Drypetes variabilis | 6 | 16.67 | 0.89 | 44.44 | 1.39 | 0.11 | 0.36 | 0.63 | 0.88 |
| Toulicia pulvinata | 4 | 11.11 | 0.6 | 44.44 | 1.39 | 0.18 | 0.57 | 0.58 | 0.85 |
| Enterolobium contortisiliquum | 2 | 5.56 | 0.3 | 11.11 | 0.35 | 0.59 | 1.87 | 1.08 | 0.84 |
| Erisma uncinatum | 3 | 8.33 | 0.45 | 22.22 | 0.7 | 0.38 | 1.22 | 0.83 | 0.79 |
| Endopleura uchi | 3 | 8.33 | 0.45 | 22.22 | 0.7 | 0.38 | 1.2 | 0.82 | 0.78 |
| Inga thibaudiana | 7 | 19.44 | 1.04 | 33.33 | 1.05 | 0.08 | 0.24 | 0.64 | 0.78 |
| Tapirira guianensis | 4 | 11.11 | 0.6 | 33.33 | 1.05 | 0.21 | 0.67 | 0.63 | 0.77 |
| Pouteria pariry | 5 | 13.89 | 0.74 | 33.33 | 1.05 | 0.16 | 0.51 | 0.63 | 0.77 |
| Himatanthus sucuuba | 4 | 11.11 | 0.6 | 33.33 | 1.05 | 0.20 | 0.64 | 0.62 | 0.76 |
| Sapium glandulatum | 6 | 16.67 | 0.89 | 33.33 | 1.05 | 0.09 | 0.3 | 0.6 | 0.75 |
| Maquira sclerophylla | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.53 | 1.69 | 0.92 | 0.73 |

Continued...

| Species | N | AD | RD | AF | RF | ADo | RDo | CV (%) | IV (%) |
|---|---|---|---|---|---|---|---|---|---|
| Protium tenuifolium | 6 | 16.67 | 0.89 | 33.33 | 1.05 | 0.08 | 0.24 | 0.57 | 0.73 |
| Pouteria petiolata | 6 | 16.67 | 0.89 | 33.33 | 1.05 | 0.07 | 0.22 | 0.56 | 0.72 |
| Qualea paraensis | 4 | 11.11 | 0.6 | 22.22 | 0.7 | 0.27 | 0.86 | 0.73 | 0.72 |
| Prunus myrtifolia | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.50 | 1.58 | 0.87 | 0.69 |
| Campomanesia sp. | 6 | 16.67 | 0.89 | 22.22 | 0.7 | 0.15 | 0.47 | 0.68 | 0.69 |
| Clarisia racemosa | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.33 | 1.05 | 0.67 | 0.68 |
| Diplotropis purpurea | 4 | 11.11 | 0.6 | 33.33 | 1.05 | 0.10 | 0.33 | 0.46 | 0.66 |
| Sloanea schomburgkii | 2 | 5.56 | 0.3 | 11.11 | 0.35 | 0.41 | 1.32 | 0.81 | 0.66 |
| Protium spruceanum | 4 | 11.11 | 0.6 | 33.33 | 1.05 | 0.09 | 0.27 | 0.43 | 0.64 |
| Inga laurina | 5 | 13.89 | 0.74 | 33.33 | 1.05 | 0.04 | 0.12 | 0.43 | 0.63 |
| Mouriri ficoides | 4 | 11.11 | 0.6 | 22.22 | 0.7 | 0.17 | 0.53 | 0.56 | 0.61 |
| Licania hypoleuca | 4 | 11.11 | 0.6 | 33.33 | 1.05 | 0.02 | 0.07 | 0.33 | 0.57 |
| Piptadenia suaveolens | 4 | 11.11 | 0.6 | 33.33 | 1.05 | 0.02 | 0.07 | 0.33 | 0.57 |
| Sapium biglandulosum | 3 | 8.33 | 0.45 | 11.11 | 0.35 | 0.27 | 0.85 | 0.65 | 0.55 |
| Lacunaria jenmanii | 3 | 8.33 | 0.45 | 33.33 | 1.05 | 0.04 | 0.12 | 0.28 | 0.54 |
| Icica aracouchini | 4 | 11.11 | 0.6 | 22.22 | 0.7 | 0.10 | 0.32 | 0.46 | 0.54 |
| Inga alba | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.34 | 1.08 | 0.62 | 0.53 |
| Minquartia guianensis | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.18 | 0.58 | 0.44 | 0.53 |
| Virola michelii | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.32 | 1.03 | 0.59 | 0.51 |
| Inga stipularis | 5 | 13.89 | 0.74 | 22.22 | 0.7 | 0.03 | 0.08 | 0.41 | 0.51 |
| Chimarrhis turbinata | 4 | 11.11 | 0.6 | 22.22 | 0.7 | 0.04 | 0.14 | 0.37 | 0.48 |
| Ocotea minor | 3 | 8.33 | 0.45 | 22.22 | 0.7 | 0.08 | 0.26 | 0.35 | 0.47 |
| Inga rubiginosa | 4 | 11.11 | 0.6 | 22.22 | 0.7 | 0.01 | 0.04 | 0.32 | 0.44 |
| Unidentified Species 2 | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.26 | 0.83 | 0.49 | 0.44 |
| Ocotea matogrossensis | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.10 | 0.31 | 0.31 | 0.44 |
| Handroanthus sp. | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.25 | 0.81 | 0.48 | 0.43 |
| Astronium lecointei | 3 | 8.33 | 0.45 | 22.22 | 0.7 | 0.04 | 0.14 | 0.29 | 0.43 |
| Ocotea amazonica | 3 | 8.33 | 0.45 | 22.22 | 0.7 | 0.04 | 0.13 | 0.29 | 0.43 |
| Bowdichia virgilioides | 3 | 8.33 | 0.45 | 22.22 | 0.7 | 0.03 | 0.1 | 0.28 | 0.42 |
| Maprounea guianensis | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.08 | 0.25 | 0.27 | 0.41 |
| Rutaceae 3 | 3 | 8.33 | 0.45 | 22.22 | 0.7 | 0.02 | 0.08 | 0.26 | 0.41 |
| Pseudobombax sp. | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.22 | 0.7 | 0.43 | 0.4 |
| Calyptranthes sp. | 3 | 8.33 | 0.45 | 22.22 | 0.7 | 0.02 | 0.05 | 0.25 | 0.4 |
| Metrodorea flavida | 3 | 8.33 | 0.45 | 22.22 | 0.7 | 0.01 | 0.05 | 0.25 | 0.4 |
| Symphonia globulifera | 3 | 8.33 | 0.45 | 22.22 | 0.7 | 0.01 | 0.03 | 0.24 | 0.39 |
| Eugenia patrisii | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.04 | 0.14 | 0.22 | 0.38 |
| Copaifera multijuga | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.04 | 0.12 | 0.21 | 0.37 |
| Virola sp. | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.04 | 0.11 | 0.2 | 0.37 |
| Inga cayennensis | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.03 | 0.09 | 0.2 | 0.36 |
| Platymiscium sp. | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.03 | 0.09 | 0.19 | 0.36 |
| Eschweilera truncata | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.18 | 0.58 | 0.37 | 0.36 |
| Lacistema aggregatum | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.02 | 0.07 | 0.18 | 0.36 |
| Cupania scrobiculata | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.02 | 0.05 | 0.17 | 0.35 |
| Neoraputia paraensis | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.01 | 0.04 | 0.17 | 0.35 |
| Casearia pitumba | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.01 | 0.03 | 0.16 | 0.34 |

Continued...

| Species | N | AD | RD | AF | RF | ADo | RDo | CV (%) | IV (%) |
|---|---|---|---|---|---|---|---|---|---|
| Hirtella hispidula | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.01 | 0.03 | 0.16 | 0.34 |
| Virola calophylla | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.01 | 0.02 | 0.16 | 0.34 |
| Ocotea tabacifolia | 2 | 5.56 | 0.3 | 22.22 | 0.7 | 0.01 | 0.02 | 0.16 | 0.34 |
| Roupala sp. | 4 | 11.11 | 0.6 | 11.11 | 0.35 | 0.01 | 0.04 | 0.32 | 0.33 |
| Machaerium sp. | 2 | 5.56 | 0.3 | 11.11 | 0.35 | 0.09 | 0.28 | 0.29 | 0.31 |
| Myrcia sp. | 2 | 5.56 | 0.3 | 11.11 | 0.35 | 0.09 | 0.27 | 0.29 | 0.31 |
| Piptadenia rigida | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.13 | 0.42 | 0.28 | 0.3 |
| Astrocaryum gynacanthum | 3 | 8.33 | 0.45 | 11.11 | 0.35 | 0.01 | 0.04 | 0.24 | 0.28 |
| Faramea filipes | 3 | 8.33 | 0.45 | 11.11 | 0.35 | 0.01 | 0.03 | 0.24 | 0.27 |
| Licaria cannella | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.10 | 0.32 | 0.23 | 0.27 |
| Attalea maripa | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.09 | 0.29 | 0.22 | 0.26 |
| Parkia multijuga | 2 | 5.56 | 0.3 | 11.11 | 0.35 | 0.04 | 0.13 | 0.21 | 0.26 |
| Roupala brasiliensis | 2 | 5.56 | 0.3 | 11.11 | 0.35 | 0.04 | 0.12 | 0.21 | 0.26 |
| Oenocarpus distichus | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.08 | 0.26 | 0.21 | 0.25 |
| Myrcia tomentosa | 2 | 5.56 | 0.3 | 11.11 | 0.35 | 0.03 | 0.1 | 0.2 | 0.25 |
| Pouteria parviflora | 2 | 5.56 | 0.3 | 11.11 | 0.35 | 0.03 | 0.09 | 0.2 | 0.25 |
| Sloanea pubescens | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.07 | 0.24 | 0.19 | 0.24 |
| Jacaranda brasiliana | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.07 | 0.24 | 0.19 | 0.24 |
| Cordia nodosa | 2 | 5.56 | 0.3 | 11.11 | 0.35 | 0.02 | 0.08 | 0.19 | 0.24 |
| Miconia cuspidata | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.07 | 0.22 | 0.18 | 0.24 |
| Tetragastris panamensis | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.06 | 0.21 | 0.18 | 0.23 |
| Cupania sp. | 2 | 5.56 | 0.3 | 11.11 | 0.35 | 0.02 | 0.05 | 0.17 | 0.23 |
| Unidentified Species 1 | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.06 | 0.19 | 0.17 | 0.23 |
| Neea sp. | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.06 | 0.19 | 0.17 | 0.23 |
| Alibertia myrciifolia | 2 | 5.56 | 0.3 | 11.11 | 0.35 | 0.01 | 0.03 | 0.16 | 0.22 |
| Matayba inelegans | 2 | 5.56 | 0.3 | 11.11 | 0.35 | 0.01 | 0.02 | 0.16 | 0.22 |
| Protium heptaphyllum | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.05 | 0.17 | 0.16 | 0.22 |
| Myrcia multiflora | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.04 | 0.13 | 0.14 | 0.21 |
| Inga huberi | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.03 | 0.1 | 0.13 | 0.2 |
| Hirtella cf. racemosa | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.03 | 0.1 | 0.12 | 0.2 |
| Rutaceae 2 | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.03 | 0.09 | 0.12 | 0.19 |
| Allophyllus sp. | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.03 | 0.09 | 0.12 | 0.19 |
| Clarisia ilicifolia | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.02 | 0.07 | 0.11 | 0.19 |
| Myrtaceae 1 | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.02 | 0.06 | 0.11 | 0.19 |
| Vitex triflora | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.02 | 0.06 | 0.1 | 0.19 |
| Erythroxylum ligustrinum var. carajense | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.02 | 0.06 | 0.1 | 0.18 |
| Botryarrhena sp. | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.02 | 0.05 | 0.1 | 0.18 |
| Theobroma speciosum | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.02 | 0.05 | 0.1 | 0.18 |
| Copaifera ducke | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.04 | 0.09 | 0.18 |
| Caraipa densifolia | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.04 | 0.09 | 0.18 |
| Pouteria fimbriata | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.03 | 0.09 | 0.18 |
| Calophyllum brasiliense | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.03 | 0.09 | 0.18 |
| Myrcia flavescens | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.03 | 0.09 | 0.18 |
| Platymiscium paraense | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.03 | 0.09 | 0.18 |

Continued...

| Species | N | AD | RD | AF | RF | ADo | RDo | CV (%) | IV (%) |
|---|---|---|---|---|---|---|---|---|---|
| Mouriri grandiflora | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.03 | 0.09 | 0.18 |
| Inga umbratica | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.03 | 0.09 | 0.17 |
| Eschweilera pedicelata | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.03 | 0.09 | 0.18 |
| Ocotea caudata | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.03 | 0.09 | 0.18 |
| Casearia javitensis | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.02 | 0.08 | 0.17 |
| Trattinnickia panamensis | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.02 | 0.08 | 0.17 |
| Aspidosperma sp. | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.02 | 0.08 | 0.17 |
| Calycolpus sp. | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.02 | 0.08 | 0.17 |
| Astronium gracile | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.02 | 0.08 | 0.17 |
| Hymenaea parvifolia | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.02 | 0.08 | 0.17 |
| Aniba canelilla | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.02 | 0.08 | 0.17 |
| Connarus perrottetii | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.02 | 0.08 | 0.17 |
| Ocotea olivacea | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.01 | 0.02 | 0.08 | 0.17 |
| Guatteria olivacea | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.00 | 0.01 | 0.08 | 0.17 |
| Hymenaea intermedia | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.00 | 0.01 | 0.08 | 0.17 |
| Myrtaceae 2 | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.00 | 0.01 | 0.08 | 0.17 |
| Cymbopetalum cf. euneurum | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.00 | 0.01 | 0.08 | 0.17 |
| Mimosa acutistipula | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.00 | 0.01 | 0.08 | 0.17 |
| Rutaceae 1 | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.00 | 0.01 | 0.08 | 0.17 |
| Faramea torquata | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.00 | 0.01 | 0.08 | 0.17 |
| Lueheopsis rosea | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.00 | 0.01 | 0.08 | 0.17 |
| Erythroxylum macrophyllum | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.00 | 0.01 | 0.08 | 0.17 |
| Glycidendron amazonicum | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.00 | 0.01 | 0.08 | 0.17 |
| Cymbopetalum sp. | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.00 | 0.01 | 0.08 | 0.17 |
| Inga lateriflora | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.00 | 0.01 | 0.08 | 0.17 |
| Cordia hirta | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.00 | 0.01 | 0.08 | 0.17 |
| Handroanthus serratifolius | 1 | 2.78 | 0.15 | 11.11 | 0.35 | 0.00 | 0.01 | 0.08 | 0.17 |
| **TOTAL** | 672 | 1866.6 | 100 | 3188.89 | 100 | 31.42 | 100 | 100 | 100 |

Table 5. Structural parameters in dry forests along edaphic/topographic sequence in Águas Claras Sandstone Soils II, Carajás National Forest, Pará, Brazil. Where: N: Number of Individual; AD: Absolute Density; RD: Relative density; AF: Absolute Frequency; RF: Relative Frequency; ADo: Absolute Dominance; RDo: Relative Dominance; CV: Coverage value (%) and IV: Importance value (%).

| Species | N | AD | RD | AF | RF | ADo | RDo | CV (%) | IV (%) |
|---|---|---|---|---|---|---|---|---|---|
| Callisthene minor | 139 | 386.11 | 13.94 | 55.56 | 1.81 | 4.00 | 14.83 | 14.39 | 10.19 |
| Esenbeckia grandiflora | 183 | 508.33 | 18.36 | 55.56 | 1.81 | 1.59 | 5.9 | 12.13 | 8.69 |
| Pouteria vernicosa | 39 | 108.33 | 3.91 | 55.56 | 1.81 | 4.71 | 17.46 | 10.69 | 7.73 |
| Dead Trees | 66 | 183.33 | 6.62 | 100 | 3.25 | 0.99 | 3.66 | 5.14 | 4.51 |
| Mouriri ficoides | 30 | 83.33 | 3.01 | 66.67 | 2.17 | 0.91 | 3.39 | 3.2 | 2.85 |
| Copaifera multijuga | 9 | 25.00 | 0.9 | 55.56 | 1.81 | 0.99 | 3.68 | 2.29 | 2.13 |
| Calycolpus sp. | 20 | 55.56 | 2.01 | 88.89 | 2.89 | 0.38 | 1.41 | 1.71 | 2.1 |
| Guapira cf. ferruginea | 23 | 63.89 | 2.31 | 33.33 | 1.08 | 0.71 | 2.63 | 2.47 | 2.01 |
| Sapium glandulatum | 27 | 75.00 | 2.71 | 66.67 | 2.17 | 0.28 | 1.03 | 1.87 | 1.97 |

Continued...

| Species | N | AD | RD | AF | RF | ADo | RDo | CV (%) | IV (%) |
|---|---|---|---|---|---|---|---|---|---|
| Hymenaea courbaril | 9 | 25.00 | 0.9 | 66.67 | 2.17 | 0.68 | 2.52 | 1.71 | 1.86 |
| Ficus guianensis | 3 | 8.33 | 0.3 | 33.33 | 1.08 | 0.98 | 3.64 | 1.97 | 1.68 |
| Duroia gransabanensis | 23 | 63.89 | 2.31 | 55.56 | 1.81 | 0.24 | 0.89 | 1.6 | 1.67 |
| Handroanthus impetiginosus | 6 | 16.67 | 0.6 | 55.56 | 1.81 | 0.57 | 2.12 | 1.36 | 1.51 |
| Piptadenia rigida | 2 | 5.56 | 0.2 | 22.22 | 0.72 | 0.83 | 3.08 | 1.64 | 1.33 |
| Syagrus comosa | 13 | 36.11 | 1.3 | 55.56 | 1.81 | 0.15 | 0.54 | 0.92 | 1.22 |
| Myrcia cuprea | 14 | 38.89 | 1.4 | 55.56 | 1.81 | 0.11 | 0.39 | 0.9 | 1.2 |
| Erythroxylum nelson-rosae | 14 | 38.89 | 1.4 | 44.44 | 1.44 | 0.17 | 0.64 | 1.02 | 1.16 |
| Margaritaria nobilis | 8 | 22.22 | 0.8 | 55.56 | 1.81 | 0.23 | 0.85 | 0.83 | 1.15 |
| Neea floribunda | 10 | 27.78 | 1 | 44.44 | 1.44 | 0.24 | 0.88 | 0.94 | 1.11 |
| Pouteria cf. rostrata | 10 | 27.78 | 1 | 33.33 | 1.08 | 0.31 | 1.16 | 1.08 | 1.08 |
| Eugenia sp. | 14 | 38.89 | 1.4 | 33.33 | 1.08 | 0.18 | 0.67 | 1.04 | 1.05 |
| Pterocarpus rohrii | 9 | 25.00 | 0.9 | 22.22 | 0.72 | 0.36 | 1.35 | 1.13 | 0.99 |
| Astronium gracile | 9 | 25.00 | 0.9 | 44.44 | 1.44 | 0.17 | 0.62 | 0.76 | 0.99 |
| Eugenia punicifolia | 8 | 22.22 | 0.8 | 44.44 | 1.44 | 0.19 | 0.69 | 0.75 | 0.98 |
| Aspidosperma macrophyllum | 5 | 13.89 | 0.5 | 33.33 | 1.08 | 0.36 | 1.33 | 0.92 | 0.97 |
| Myrcia sp. | 12 | 33.33 | 1.2 | 44.44 | 1.44 | 0.07 | 0.25 | 0.73 | 0.97 |
| Vochysia sp.2 | 2 | 5.56 | 0.2 | 22.22 | 0.72 | 0.46 | 1.72 | 0.96 | 0.88 |
| Maytenus guyanensis | 6 | 16.67 | 0.6 | 44.44 | 1.44 | 0.15 | 0.54 | 0.57 | 0.86 |
| Lueheopsis rosea | 6 | 16.67 | 0.6 | 22.22 | 0.72 | 0.31 | 1.16 | 0.88 | 0.83 |
| Buchenavia grandis | 6 | 16.67 | 0.6 | 22.22 | 0.72 | 0.30 | 1.12 | 0.86 | 0.81 |
| Alibertia myrciifolia | 10 | 27.78 | 1 | 33.33 | 1.08 | 0.09 | 0.33 | 0.66 | 0.8 |
| Dipteryx odorata | 3 | 8.33 | 0.3 | 22.22 | 0.72 | 0.36 | 1.35 | 0.82 | 0.79 |
| Erythroxylum ligustrinum var. carajense | 13 | 36.11 | 1.3 | 22.22 | 0.72 | 0.08 | 0.31 | 0.81 | 0.78 |
| Vouarana guianensis | 6 | 16.67 | 0.6 | 44.44 | 1.44 | 0.05 | 0.2 | 0.4 | 0.75 |
| Roupala montana | 7 | 19.44 | 0.7 | 33.33 | 1.08 | 0.12 | 0.46 | 0.58 | 0.75 |
| Faramea torquata | 6 | 16.67 | 0.6 | 44.44 | 1.44 | 0.05 | 0.18 | 0.39 | 0.74 |
| Esenbeckia pilocarpoides | 13 | 36.11 | 1.3 | 22.22 | 0.72 | 0.04 | 0.14 | 0.72 | 0.72 |
| Miconia holosericea | 6 | 16.67 | 0.6 | 33.33 | 1.08 | 0.12 | 0.45 | 0.53 | 0.71 |
| Coutarea sp. | 6 | 16.67 | 0.6 | 33.33 | 1.08 | 0.12 | 0.44 | 0.52 | 0.71 |
| Matayba sp. | 7 | 19.44 | 0.7 | 33.33 | 1.08 | 0.08 | 0.28 | 0.49 | 0.69 |
| Duroia sp. | 5 | 13.89 | 0.5 | 33.33 | 1.08 | 0.12 | 0.43 | 0.46 | 0.67 |
| Bowdichia virgilioides | 14 | 38.89 | 1.4 | 11.11 | 0.36 | 0.06 | 0.21 | 0.81 | 0.66 |
| Licania hypoleuca | 8 | 22.22 | 0.8 | 22.22 | 0.72 | 0.12 | 0.43 | 0.62 | 0.65 |
| Himatanthus sucuuba | 4 | 11.11 | 0.4 | 22.22 | 0.72 | 0.21 | 0.78 | 0.59 | 0.63 |
| Diplotropis purpurea | 2 | 5.56 | 0.2 | 22.22 | 0.72 | 0.25 | 0.92 | 0.56 | 0.61 |
| Cymbopetalum sp. | 5 | 13.89 | 0.5 | 33.33 | 1.08 | 0.05 | 0.19 | 0.34 | 0.59 |
| Pouteria guianensis | 6 | 16.67 | 0.6 | 22.22 | 0.72 | 0.12 | 0.44 | 0.52 | 0.59 |
| Mouriri huberi | 4 | 11.11 | 0.4 | 33.33 | 1.08 | 0.06 | 0.24 | 0.32 | 0.57 |
| Bombacopsis nervosa | 6 | 16.67 | 0.6 | 22.22 | 0.72 | 0.09 | 0.33 | 0.47 | 0.55 |
| Mimosa acutistipula | 7 | 19.44 | 0.7 | 22.22 | 0.72 | 0.04 | 0.16 | 0.43 | 0.53 |
| Platymiscium sp. | 3 | 8.33 | 0.3 | 22.22 | 0.72 | 0.15 | 0.54 | 0.42 | 0.52 |
| Handroanthus sp. | 5 | 13.89 | 0.5 | 22.22 | 0.72 | 0.08 | 0.28 | 0.39 | 0.5 |

Continued...

| Species | N | AD | RD | AF | RF | ADo | RDo | CV (%) | IV (%) |
|---|---|---|---|---|---|---|---|---|---|
| Simarouba amara | 6 | 16.67 | 0.6 | 22.22 | 0.72 | 0.05 | 0.18 | 0.39 | 0.5 |
| Clusia weddelliana | 2 | 5.56 | 0.2 | 22.22 | 0.72 | 0.15 | 0.57 | 0.38 | 0.5 |
| Parkia platycephala | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.26 | 0.97 | 0.54 | 0.48 |
| Croton sp. | 5 | 13.89 | 0.5 | 22.22 | 0.72 | 0.04 | 0.14 | 0.32 | 0.46 |
| Miconia spichigeri | 4 | 11.11 | 0.4 | 22.22 | 0.72 | 0.06 | 0.21 | 0.31 | 0.45 |
| Licaria guianensis | 3 | 8.33 | 0.3 | 11.11 | 0.36 | 0.18 | 0.66 | 0.48 | 0.44 |
| Neea ovalifolia | 4 | 11.11 | 0.4 | 22.22 | 0.72 | 0.03 | 0.11 | 0.26 | 0.41 |
| Galipea sp. | 3 | 8.33 | 0.3 | 22.22 | 0.72 | 0.06 | 0.2 | 0.25 | 0.41 |
| Vitex triflora | 2 | 5.56 | 0.2 | 11.11 | 0.36 | 0.17 | 0.64 | 0.42 | 0.4 |
| Qualea cf. rosea | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.19 | 0.71 | 0.4 | 0.39 |
| Licania cf. egleri | 2 | 5.56 | 0.2 | 22.22 | 0.72 | 0.06 | 0.21 | 0.21 | 0.38 |
| Galipea jasminiflora | 2 | 5.56 | 0.2 | 11.11 | 0.36 | 0.15 | 0.56 | 0.38 | 0.37 |
| Toulicia pulvinata | 2 | 5.56 | 0.2 | 22.22 | 0.72 | 0.05 | 0.18 | 0.19 | 0.37 |
| Gordonia fruticosa | 2 | 5.56 | 0.2 | 22.22 | 0.72 | 0.05 | 0.18 | 0.19 | 0.37 |
| Abuta grandifolia | 3 | 8.33 | 0.3 | 22.22 | 0.72 | 0.02 | 0.06 | 0.18 | 0.36 |
| Calycolpus goetheanus | 3 | 8.33 | 0.3 | 22.22 | 0.72 | 0.01 | 0.05 | 0.18 | 0.36 |
| Cupania sp. | 3 | 8.33 | 0.3 | 22.22 | 0.72 | 0.01 | 0.04 | 0.17 | 0.36 |
| Myrcia rufipila | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.15 | 0.55 | 0.33 | 0.34 |
| Lacistema aggregatum | 2 | 5.56 | 0.2 | 22.22 | 0.72 | 0.02 | 0.07 | 0.14 | 0.33 |
| Siparuna guianensis | 2 | 5.56 | 0.2 | 22.22 | 0.72 | 0.01 | 0.05 | 0.13 | 0.32 |
| Pouteria hispida | 2 | 5.56 | 0.2 | 22.22 | 0.72 | 0.01 | 0.04 | 0.12 | 0.32 |
| Inga thibaudiana | 2 | 5.56 | 0.2 | 22.22 | 0.72 | 0.01 | 0.03 | 0.12 | 0.32 |
| Bauhinia pulchella | 2 | 5.56 | 0.2 | 22.22 | 0.72 | 0.01 | 0.03 | 0.11 | 0.32 |
| Connarus perrottetii | 2 | 5.56 | 0.2 | 22.22 | 0.72 | 0.01 | 0.02 | 0.11 | 0.32 |
| Abarema mataybifolia | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.13 | 0.47 | 0.29 | 0.31 |
| Rollinia insignis | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.12 | 0.45 | 0.27 | 0.3 |
| Caraipa densifolia | 4 | 11.11 | 0.4 | 11.11 | 0.36 | 0.03 | 0.11 | 0.26 | 0.29 |
| Attalea maripa | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.10 | 0.36 | 0.23 | 0.27 |
| Syagrus sp. | 3 | 8.33 | 0.3 | 11.11 | 0.36 | 0.03 | 0.11 | 0.21 | 0.26 |
| Neea robusta | 2 | 5.56 | 0.2 | 11.11 | 0.36 | 0.06 | 0.21 | 0.2 | 0.26 |
| Ixora sp. | 2 | 5.56 | 0.2 | 11.11 | 0.36 | 0.06 | 0.2 | 0.2 | 0.26 |
| Buchenavia congesta | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.07 | 0.28 | 0.19 | 0.25 |
| Dialium guianense | 3 | 8.33 | 0.3 | 11.11 | 0.36 | 0.01 | 0.04 | 0.17 | 0.23 |
| Protium guianense | 3 | 8.33 | 0.3 | 11.11 | 0.36 | 0.01 | 0.03 | 0.17 | 0.23 |
| Cedrela fissilis | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.06 | 0.21 | 0.15 | 0.22 |
| Aspidosperma subincanum | 2 | 5.56 | 0.2 | 11.11 | 0.36 | 0.03 | 0.1 | 0.15 | 0.22 |
| Inga huberi | 2 | 5.56 | 0.2 | 11.11 | 0.36 | 0.02 | 0.08 | 0.14 | 0.21 |
| Inga stipularis | 2 | 5.56 | 0.2 | 11.11 | 0.36 | 0.01 | 0.04 | 0.12 | 0.2 |
| Mezilaurus sp. | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.04 | 0.13 | 0.12 | 0.2 |
| Aniba cf. ferrea | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.03 | 0.11 | 0.1 | 0.19 |
| Tachigali myrmecophila | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.03 | 0.09 | 0.1 | 0.19 |
| Guatteria olivacea | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.02 | 0.08 | 0.09 | 0.18 |
| Talisia sp. | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.02 | 0.08 | 0.09 | 0.18 |
| Emmotum nitens | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.02 | 0.08 | 0.09 | 0.18 |
| Handroanthus roseo-albus | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.02 | 0.07 | 0.09 | 0.18 |

Continued...

| Species | N | AD | RD | AF | RF | ADo | RDo | CV (%) | IV (%) |
|---|---|---|---|---|---|---|---|---|---|
| Micropholis cylindricocarpa | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.02 | 0.07 | 0.09 | 0.18 |
| Myrcia tomentosa | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.02 | 0.07 | 0.08 | 0.18 |
| Mezilaurus itauba | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.02 | 0.07 | 0.08 | 0.18 |
| Cochlospermum orinocense | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.02 | 0.06 | 0.08 | 0.17 |
| Solanaceae 1 | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.02 | 0.06 | 0.08 | 0.17 |
| Aspidosperma cf. marcgravianum | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.02 | 0.06 | 0.08 | 0.17 |
| Kutchubaea sp. | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.01 | 0.05 | 0.07 | 0.17 |
| Rhodognaphalopsis duckei | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.01 | 0.04 | 0.07 | 0.17 |
| Chomelia sp. | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.01 | 0.03 | 0.07 | 0.16 |
| Himatanthus sp. | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.01 | 0.03 | 0.07 | 0.16 |
| Jacaranda copaia | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.01 | 0.03 | 0.07 | 0.16 |
| Inga cayennensis | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.01 | 0.03 | 0.07 | 0.16 |
| Cordia nodosa | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.01 | 0.03 | 0.07 | 0.16 |
| Neea oppositifolia | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.01 | 0.03 | 0.06 | 0.16 |
| Myrtaceae 3 | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.01 | 0.03 | 0.06 | 0.16 |
| Lippia grandis | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.01 | 0.03 | 0.06 | 0.16 |
| Annonaceae 1 | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.01 | 0.03 | 0.06 | 0.16 |
| Maytenus sp. | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.01 | 0.02 | 0.06 | 0.16 |
| Sacoglottis mattogrossensis | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.01 | 0.02 | 0.06 | 0.16 |
| Micropholis casiquiarensis | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.00 | 0.02 | 0.06 | 0.16 |
| Platymiscium duckei | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.00 | 0.01 | 0.06 | 0.16 |
| Spiranthera sp. | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.00 | 0.01 | 0.06 | 0.16 |
| Marlierea sp. | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.00 | 0.01 | 0.06 | 0.16 |
| Diospyros cavalcantei | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.00 | 0.01 | 0.06 | 0.16 |
| Licania sp. | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.00 | 0.01 | 0.06 | 0.16 |
| Matayba elegans | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.00 | 0.01 | 0.06 | 0.16 |
| Tapirira guianensis | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.00 | 0.01 | 0.06 | 0.16 |
| Buchenavia veridiflora | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.00 | 0.01 | 0.06 | 0.16 |
| Abuta guianensis | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.00 | 0.01 | 0.06 | 0.16 |
| Protium cf. pilosissimum | 1 | 2.78 | 0.1 | 11.11 | 0.36 | 0.00 | 0.01 | 0.05 | 0.16 |
| **TOTAL** | 997 | 2769.4 | 100 | 3077.7 | 100 | 26.9 | 100 | 100 | 100 |

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Table 6. Structural parameters in dry forests along edaphic/topographic sequence in Carajás Granite, Carajás National Forest, Pará, Brazil. Where: N: Number of Individual; AD: Absolute Density; RD: Relative density; AF: Absolute Frequency; RF: Relative Frequency; ADo: Absolute Dominance; RDo: Relative Dominance; CV: Coverage value (%) and IV: Importance value (%).

| Species | N | AD | RD | AF | RF | ADo | RDo | CV (%) | IV (%) |
|---|---|---|---|---|---|---|---|---|---|
| Sapium glandulatum | 115 | 319.44 | 16.11 | 66.67 | 2.33 | 2.1 | 7.28 | 11.69 | 8.57 |
| Esenbeckia grandiflora | 63 | 175.00 | 8.82 | 88.89 | 3.1 | 1.8 | 6.05 | 7.44 | 5.99 |
| Dead Tree | 35 | 97.22 | 4.9 | 88.89 | 3.1 | 2.1 | 7.25 | 6.08 | 5.08 |
| Syagrus oleracea | 49 | 136.11 | 6.86 | 66.67 | 2.33 | 1.1 | 3.76 | 5.31 | 4.32 |
| Margaritaria nobilis | 52 | 144.44 | 7.28 | 66.67 | 2.33 | 0.7 | 2.35 | 4.82 | 3.99 |

Continued...

| Species | N | AD | RD | AF | RF | ADo | RDo | CV (%) | IV (%) |
|---|---|---|---|---|---|---|---|---|---|
| Pouteria vernicosa | 15 | 41.67 | 2.1 | 44.44 | 1.55 | 1.2 | 4.03 | 3.06 | 2.56 |
| Senegalia polyphylla | 16 | 44.44 | 2.24 | 44.44 | 1.55 | 1.1 | 3.65 | 2.94 | 2.48 |
| Cenostigma tocantinum | 15 | 41.67 | 2.1 | 33.33 | 1.16 | 1.1 | 3.64 | 2.87 | 2.3 |
| Lueheopsis rosea | 17 | 47.22 | 2.38 | 66.67 | 2.33 | 0.5 | 1.57 | 1.97 | 2.09 |
| Piptadenia rigida | 6 | 16.67 | 0.84 | 33.33 | 1.16 | 1.2 | 4.23 | 2.54 | 2.08 |
| Tetragastris altissima | 7 | 19.44 | 0.98 | 33.33 | 1.16 | 1.1 | 3.89 | 2.44 | 2.01 |
| Eugenia patrisii | 14 | 38.89 | 1.96 | 44.44 | 1.55 | 0.5 | 1.83 | 1.9 | 1.78 |
| Coumarouna polyphylla | 5 | 13.89 | 0.7 | 22.22 | 0.78 | 1.1 | 3.86 | 2.28 | 1.78 |
| Cecropia distachya | 8 | 22.22 | 1.12 | 44.44 | 1.55 | 0.6 | 2.12 | 1.62 | 1.6 |
| Bagassa guianensis | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 1.1 | 3.96 | 2.05 | 1.5 |
| Metrodorea flavida | 16 | 44.44 | 2.24 | 33.33 | 1.16 | 0.3 | 0.87 | 1.56 | 1.43 |
| Jacaratia spinosa | 4 | 11.11 | 0.56 | 33.33 | 1.16 | 0.7 | 2.46 | 1.51 | 1.39 |
| Lecythis zabucajo | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.9 | 3.27 | 1.7 | 1.27 |
| Eugenia punicifolia | 6 | 16.67 | 0.84 | 22.22 | 0.78 | 0.6 | 1.93 | 1.39 | 1.18 |
| Eriotheca globosa | 8 | 22.22 | 1.12 | 44.44 | 1.55 | 0.2 | 0.59 | 0.86 | 1.09 |
| Theobroma speciosum | 10 | 27.78 | 1.4 | 33.33 | 1.16 | 0.1 | 0.48 | 0.94 | 1.01 |
| Banara guianensis | 5 | 13.89 | 0.7 | 44.44 | 1.55 | 0.2 | 0.59 | 0.65 | 0.95 |
| Sigmatanthus sp. | 8 | 22.22 | 1.12 | 33.33 | 1.16 | 0.1 | 0.43 | 0.77 | 0.9 |
| Astronium sp. | 2 | 5.56 | 0.28 | 22.22 | 0.78 | 0.5 | 1.61 | 0.95 | 0.89 |
| Protium robustum | 3 | 8.33 | 0.42 | 22.22 | 0.78 | 0.4 | 1.47 | 0.94 | 0.89 |
| Cochlospermum orinocense | 3 | 8.33 | 0.42 | 11.11 | 0.39 | 0.5 | 1.76 | 1.09 | 0.86 |
| Solanum sp. | 6 | 16.67 | 0.84 | 44.44 | 1.55 | 0.0 | 0.1 | 0.47 | 0.83 |
| Ampelocera edentula | 4 | 11.11 | 0.56 | 22.22 | 0.78 | 0.3 | 1.11 | 0.84 | 0.82 |
| Bauhinia sp.1 | 8 | 22.22 | 1.12 | 33.33 | 1.16 | 0.0 | 0.12 | 0.62 | 0.8 |
| Inga marginata | 9 | 25.00 | 1.26 | 22.22 | 0.78 | 0.1 | 0.31 | 0.78 | 0.78 |
| Trattinnickia burserifolia | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.5 | 1.69 | 0.92 | 0.74 |
| Virola michelii | 4 | 11.11 | 0.56 | 33.33 | 1.16 | 0.1 | 0.45 | 0.5 | 0.72 |
| Astrocaryum gynacanthum | 6 | 16.67 | 0.84 | 33.33 | 1.16 | 0.0 | 0.12 | 0.48 | 0.71 |
| Zizifus cinnamomum | 4 | 11.11 | 0.56 | 22.22 | 0.78 | 0.2 | 0.74 | 0.65 | 0.69 |
| Pterocarpus officinales | 4 | 11.11 | 0.56 | 33.33 | 1.16 | 0.1 | 0.33 | 0.45 | 0.69 |
| Cecropia ulei | 4 | 11.11 | 0.56 | 11.11 | 0.39 | 0.3 | 1.08 | 0.82 | 0.68 |
| Licaria cannella | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.4 | 1.43 | 0.79 | 0.65 |
| Trichilia pallida | 3 | 8.33 | 0.42 | 33.33 | 1.16 | 0.1 | 0.33 | 0.38 | 0.64 |
| Brosimum rubescens | 4 | 11.11 | 0.56 | 33.33 | 1.16 | 0.0 | 0.11 | 0.33 | 0.61 |
| Talisia veraluciana | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.4 | 1.29 | 0.71 | 0.61 |
| Tetragastris panamensis | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.4 | 1.27 | 0.7 | 0.6 |
| Calycolpus goetheanus | 3 | 8.33 | 0.42 | 33.33 | 1.16 | 0.1 | 0.21 | 0.31 | 0.6 |
| Diplotropis purpurea | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.4 | 1.21 | 0.68 | 0.58 |
| Inga panamensis | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.3 | 1.17 | 0.66 | 0.57 |
| Casearia arborea | 3 | 8.33 | 0.42 | 33.33 | 1.16 | 0.0 | 0.04 | 0.23 | 0.54 |
| Neea ovalifolia | 3 | 8.33 | 0.42 | 33.33 | 1.16 | 0.0 | 0.04 | 0.23 | 0.54 |
| Cupania scrobiculata | 5 | 13.89 | 0.7 | 22.22 | 0.78 | 0.0 | 0.15 | 0.42 | 0.54 |
| Mouriri huberi | 2 | 5.56 | 0.28 | 22.22 | 0.78 | 0.2 | 0.56 | 0.42 | 0.54 |
| Neea floribunda | 4 | 11.11 | 0.56 | 22.22 | 0.78 | 0.1 | 0.23 | 0.4 | 0.52 |

Continued...

| Species | N | AD | RD | AF | RF | ADo | RDo | CV (%) | IV (%) |
|---|---|---|---|---|---|---|---|---|---|
| Buchenavia grandis | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.3 | 0.96 | 0.55 | 0.49 |
| Perebea mollis | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.3 | 0.96 | 0.55 | 0.49 |
| Toulicia pulvinata | 4 | 11.11 | 0.56 | 22.22 | 0.78 | 0.0 | 0.13 | 0.35 | 0.49 |
| Warszewiczia schwackei | 2 | 5.56 | 0.28 | 22.22 | 0.78 | 0.1 | 0.39 | 0.34 | 0.48 |
| Cecropia latiloba | 3 | 8.33 | 0.42 | 11.11 | 0.39 | 0.2 | 0.64 | 0.53 | 0.48 |
| Vouarana guianensis | 4 | 11.11 | 0.56 | 22.22 | 0.78 | 0.0 | 0.11 | 0.33 | 0.48 |
| Rauvolfia sprucei | 3 | 8.33 | 0.42 | 22.22 | 0.78 | 0.1 | 0.24 | 0.33 | 0.48 |
| Neea robusta | 4 | 11.11 | 0.56 | 22.22 | 0.78 | 0.0 | 0.08 | 0.32 | 0.47 |
| Helicteres sacarolha | 6 | 16.67 | 0.84 | 11.11 | 0.39 | 0.0 | 0.11 | 0.48 | 0.45 |
| Aspidosperma parvifolium | 3 | 8.33 | 0.42 | 11.11 | 0.39 | 0.1 | 0.51 | 0.46 | 0.44 |
| Licania hypoleuca | 3 | 8.33 | 0.42 | 22.22 | 0.78 | 0.0 | 0.05 | 0.24 | 0.42 |
| Attalea maripa | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.2 | 0.72 | 0.43 | 0.42 |
| Cheiloclinium cognatum | 3 | 8.33 | 0.42 | 22.22 | 0.78 | 0.0 | 0.05 | 0.23 | 0.41 |
| Mouriri dimorphandra | 2 | 5.56 | 0.28 | 11.11 | 0.39 | 0.2 | 0.58 | 0.43 | 0.41 |
| Neea oppositifolia | 3 | 8.33 | 0.42 | 22.22 | 0.78 | 0.0 | 0.05 | 0.23 | 0.41 |
| Alibertia myrciifolia | 3 | 8.33 | 0.42 | 22.22 | 0.78 | 0.0 | 0.04 | 0.23 | 0.41 |
| Zanthoxylum rhoifolium | 3 | 8.33 | 0.42 | 22.22 | 0.78 | 0.0 | 0.04 | 0.23 | 0.41 |
| Tabernaemontana muricata | 3 | 8.33 | 0.42 | 22.22 | 0.78 | 0.0 | 0.02 | 0.22 | 0.41 |
| Galipea jasminiflora | 2 | 5.56 | 0.28 | 22.22 | 0.78 | 0.0 | 0.06 | 0.17 | 0.37 |
| Dulacia candida | 2 | 5.56 | 0.28 | 22.22 | 0.78 | 0.0 | 0.05 | 0.16 | 0.37 |
| Bowdichia virgilioides | 2 | 5.56 | 0.28 | 22.22 | 0.78 | 0.0 | 0.04 | 0.16 | 0.36 |
| Chrysophyllum sparsiflorum | 2 | 5.56 | 0.28 | 22.22 | 0.78 | 0.0 | 0.03 | 0.16 | 0.36 |
| Handroanthus serratifolius | 2 | 5.56 | 0.28 | 22.22 | 0.78 | 0.0 | 0.03 | 0.16 | 0.36 |
| Lacistema aggregatum | 2 | 5.56 | 0.28 | 22.22 | 0.78 | 0.0 | 0.02 | 0.15 | 0.36 |
| Byrsonima incarnata | 2 | 5.56 | 0.28 | 22.22 | 0.78 | 0.0 | 0.02 | 0.15 | 0.36 |
| Garcinia madruno | 2 | 5.56 | 0.28 | 22.22 | 0.78 | 0.0 | 0.02 | 0.15 | 0.36 |
| Buchenavia congesta | 2 | 5.56 | 0.28 | 22.22 | 0.78 | 0.0 | 0.02 | 0.15 | 0.36 |
| Balfourodendron sp. | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.1 | 0.46 | 0.3 | 0.33 |
| Byrsonima crispa | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.1 | 0.45 | 0.3 | 0.33 |
| Cedrela fissilis | 3 | 8.33 | 0.42 | 11.11 | 0.39 | 0.0 | 0.11 | 0.26 | 0.3 |
| Copaifera martii | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.1 | 0.36 | 0.25 | 0.3 |
| Apeiba echinata | 2 | 5.56 | 0.28 | 11.11 | 0.39 | 0.1 | 0.22 | 0.25 | 0.29 |
| Inga rubiginosa | 3 | 8.33 | 0.42 | 11.11 | 0.39 | 0.0 | 0.07 | 0.24 | 0.29 |
| Batocarpus amazonicus | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.1 | 0.3 | 0.22 | 0.28 |
| Sterculia excelsa | 2 | 5.56 | 0.28 | 11.11 | 0.39 | 0.0 | 0.11 | 0.2 | 0.26 |
| Ziziphus sp. | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.1 | 0.24 | 0.19 | 0.26 |
| Ferdinandusa goudotiana | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.1 | 0.23 | 0.19 | 0.25 |
| Brosimum acutifolium | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.1 | 0.21 | 0.18 | 0.25 |
| Pouteria brevipes | 2 | 5.56 | 0.28 | 11.11 | 0.39 | 0.0 | 0.07 | 0.18 | 0.25 |
| Maquira guianensis | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.1 | 0.19 | 0.17 | 0.24 |
| Chomelia tenuifolia | 2 | 5.56 | 0.28 | 11.11 | 0.39 | 0.0 | 0.04 | 0.16 | 0.24 |
| Protium rubrum | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.1 | 0.18 | 0.16 | 0.24 |
| Protium subserratum | 2 | 5.56 | 0.28 | 11.11 | 0.39 | 0.0 | 0.04 | 0.16 | 0.24 |
| Inga umbratica | 2 | 5.56 | 0.28 | 11.11 | 0.39 | 0.0 | 0.03 | 0.15 | 0.23 |

Continued...

| Species | N | AD | RD | AF | RF | ADo | RDo | CV (%) | IV (%) |
|---|---|---|---|---|---|---|---|---|---|
| Pouteria latianthera | 2 | 5.56 | 0.28 | 11.11 | 0.39 | 0.0 | 0.03 | 0.15 | 0.23 |
| Oenocarpus distichus | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.16 | 0.15 | 0.23 |
| Helicostylis tomentosa | 2 | 5.56 | 0.28 | 11.11 | 0.39 | 0.0 | 0.02 | 0.15 | 0.23 |
| Eugenia cupulata | 2 | 5.56 | 0.28 | 11.11 | 0.39 | 0.0 | 0.02 | 0.15 | 0.23 |
| Simarouba amara | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.15 | 0.15 | 0.23 |
| Ormosia paraensis | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.1 | 0.12 | 0.21 |
| Stryphnodendron racemiferum | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.1 | 0.12 | 0.21 |
| Erythroxylum macrophyllum | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.1 | 0.12 | 0.21 |
| Trichilia micrantha | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.08 | 0.11 | 0.2 |
| Inga thibaudiana | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.07 | 0.11 | 0.2 |
| Parkia platycephala | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.07 | 0.1 | 0.2 |
| Diospyros cavalcantei | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.05 | 0.09 | 0.19 |
| Duguetia stelechantha | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.04 | 0.09 | 0.19 |
| Bombacopsis nervosa | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.04 | 0.09 | 0.19 |
| Styrax discolor | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.04 | 0.09 | 0.19 |
| Guazuma ulmifolia | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.04 | 0.09 | 0.19 |
| Sorocea ilicifolia | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.04 | 0.09 | 0.19 |
| Rollinia insignis | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.03 | 0.09 | 0.19 |
| Tachigali myrmecophila | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.03 | 0.09 | 0.19 |
| Senna sp. | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.03 | 0.09 | 0.19 |
| Pouteria petiolata | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.03 | 0.09 | 0.19 |
| Licania sprucei | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.03 | 0.08 | 0.19 |
| Mouriri ficoides | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.02 | 0.08 | 0.18 |
| Piptadenia suaveolens | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.02 | 0.08 | 0.18 |
| Mouriri nigra | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.02 | 0.08 | 0.18 |
| Inga stipularis | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.02 | 0.08 | 0.18 |
| Porocystis toulicioides | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.02 | 0.08 | 0.18 |
| Pterodon emarginatus | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.02 | 0.08 | 0.18 |
| Ecclinusa guianensis | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.02 | 0.08 | 0.18 |
| Cordia exaltata | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.02 | 0.08 | 0.18 |
| Matayba guianensis | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.02 | 0.08 | 0.18 |
| Astronium lecointei | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.08 | 0.18 |
| Duguetia flagellaris | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.08 | 0.18 |
| Inga grandiflora | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.08 | 0.18 |
| Galipea sp. | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.08 | 0.18 |
| Duguetia cadaverica | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.08 | 0.18 |
| Protium apiculatum | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.08 | 0.18 |
| Miconia tetraspermoides | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.08 | 0.18 |
| Abarema mataybifolia | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.08 | 0.18 |
| Pouteria caimito | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.08 | 0.18 |
| Calyptranthes crebra | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.08 | 0.18 |
| Helicostylis turbinata | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.07 | 0.18 |
| Myrcia sp. | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.07 | 0.18 |
| Guatteria foliosa | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.07 | 0.18 |

Continued...

| Species | N | AD | RD | AF | RF | ADo | RDo | CV (%) | IV (%) |
|---|---|---|---|---|---|---|---|---|---|
| Chrysophyllum pomiferum | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.07 | 0.18 |
| Hymenaea courbaril | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.07 | 0.18 |
| Myrcia magnoliifolia | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.07 | 0.18 |
| Drypetes variabilis | 1 | 2.78 | 0.14 | 11.11 | 0.39 | 0.0 | 0.01 | 0.07 | 0.18 |
| **Total** | 714 | 1983.33 | 100 | 2866.67 | 100 | 29.0 | 100 | 100 | 100 |

Table 7. Structural parameters in dry forests along edaphic/topographic sequence in Xingu Complex, Carajás National Forest, Pará, Brazil. Where: N: Number of Individual; AD: Absolute Density; RD: Relative density; AF: Absolute Frequency; RF: Relative Frequency; ADo: Absolute Dominance; RDo: Relative Dominance; CV: Coverage value (%) and IV: Importance value (%).

| Species | N | AD | RD | AF | RF | ADo | RDo | CV (%) | IV (%) |
|---|---|---|---|---|---|---|---|---|---|
| Spondias mombin | 55 | 152.78 | 9.95 | 88.89 | 3.09 | 2.75 | 12.81 | 11.38 | 8.62 |
| Jacaratia spinosa | 13 | 36.11 | 2.35 | 66.67 | 2.32 | 1.94 | 9.05 | 5.7 | 4.57 |
| Cedrela fissilis | 27 | 75.00 | 4.88 | 55.56 | 1.93 | 1.31 | 6.09 | 5.48 | 4.3 |
| Senegalia polyphylla | 20 | 55.56 | 3.62 | 88.89 | 3.09 | 1.32 | 6.15 | 4.88 | 4.29 |
| Cenostigma tocantinum | 35 | 97.22 | 6.33 | 66.67 | 2.32 | 0.84 | 3.9 | 5.11 | 4.18 |
| Metrodorea flavida | 32 | 88.89 | 5.79 | 66.67 | 2.32 | 0.36 | 1.7 | 3.74 | 3.27 |
| Cecropia distachya | 8 | 22.22 | 1.45 | 44.44 | 1.54 | 1.34 | 6.27 | 3.86 | 3.09 |
| Stryphnodendron sp. | 26 | 72.22 | 4.7 | 44.44 | 1.54 | 0.38 | 1.78 | 3.24 | 2.67 |
| Casearia pitumba | 19 | 52.78 | 3.44 | 77.78 | 2.7 | 0.12 | 0.57 | 2 | 2.24 |
| Piptadenia rigida | 7 | 19.44 | 1.27 | 44.44 | 1.54 | 0.71 | 3.31 | 2.29 | 2.04 |
| Margaritaria nobilis | 22 | 61.11 | 3.98 | 33.33 | 1.16 | 0.19 | 0.9 | 2.44 | 2.01 |
| Astronium fraxinifolium | 4 | 11.11 | 0.72 | 33.33 | 1.16 | 0.81 | 3.77 | 2.25 | 1.88 |
| Chorisia speciosa | 6 | 16.67 | 1.08 | 33.33 | 1.16 | 0.67 | 3.1 | 2.09 | 1.78 |
| Cassia leandrii | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 1.00 | 4.68 | 2.43 | 1.75 |
| Sapium biglandulosum | 7 | 19.44 | 1.27 | 44.44 | 1.54 | 0.42 | 1.94 | 1.6 | 1.58 |
| Galipea jasminiflora | 9 | 25.00 | 1.63 | 77.78 | 2.7 | 0.06 | 0.26 | 0.94 | 1.53 |
| Erythrina falcata Benth. | 6 | 16.67 | 1.08 | 44.44 | 1.54 | 0.42 | 1.95 | 1.52 | 1.53 |
| Diplotropis purpurea | 15 | 41.67 | 2.71 | 22.22 | 0.77 | 0.22 | 1.04 | 1.87 | 1.51 |
| Bauhinia macrostachya | 10 | 27.78 | 1.81 | 55.56 | 1.93 | 0.16 | 0.76 | 1.29 | 1.5 |
| Pouteria vernicosa | 10 | 27.78 | 1.81 | 44.44 | 1.54 | 0.15 | 0.7 | 1.25 | 1.35 |
| Banara guianensis | 5 | 13.89 | 0.9 | 55.56 | 1.93 | 0.19 | 0.88 | 0.89 | 1.24 |
| Pourouma guianensis | 5 | 13.89 | 0.9 | 22.22 | 0.77 | 0.40 | 1.89 | 1.39 | 1.19 |
| Maclura tinctoria | 3 | 8.33 | 0.54 | 33.33 | 1.16 | 0.33 | 1.56 | 1.05 | 1.09 |
| Vitex triflora | 6 | 16.67 | 1.08 | 55.56 | 1.93 | 0.05 | 0.21 | 0.65 | 1.08 |
| Inga lateriflora | 4 | 11.11 | 0.72 | 33.33 | 1.16 | 0.27 | 1.25 | 0.99 | 1.04 |
| Pouteria pariry | 8 | 22.22 | 1.45 | 33.33 | 1.16 | 0.11 | 0.5 | 0.97 | 1.03 |
| Inga marginata | 5 | 13.89 | 0.9 | 44.44 | 1.54 | 0.13 | 0.6 | 0.75 | 1.02 |
| Anadenanthera sp. | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.53 | 2.48 | 1.33 | 1.01 |
| Ferdinandusa cf. hirsuta | 7 | 19.44 | 1.27 | 33.33 | 1.16 | 0.09 | 0.42 | 0.84 | 0.95 |
| Inga macrophylla | 4 | 11.11 | 0.72 | 22.22 | 0.77 | 0.26 | 1.22 | 0.97 | 0.91 |
| Aspidosperma spruceanum | 5 | 13.89 | 0.9 | 22.22 | 0.77 | 0.21 | 0.99 | 0.94 | 0.89 |

Continued...

| **Species** | **N** | **AD** | **RD** | **AF** | **RF** | **ADo** | **RDo** | **CV (%)** | **IV (%)** |
|---|---|---|---|---|---|---|---|---|---|
| Ceiba pendrandra | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.45 | 2.09 | 1.14 | 0.89 |
| Tetragastris altissima | 5 | 13.89 | 0.9 | 33.33 | 1.16 | 0.13 | 0.58 | 0.74 | 0.88 |
| Toulicia pulvinata | 6 | 16.67 | 1.08 | 33.33 | 1.16 | 0.04 | 0.2 | 0.64 | 0.81 |
| Theobroma speciosum | 5 | 13.89 | 0.9 | 33.33 | 1.16 | 0.07 | 0.35 | 0.63 | 0.8 |
| Prunus sp. | 5 | 13.89 | 0.9 | 22.22 | 0.77 | 0.14 | 0.65 | 0.78 | 0.78 |
| Brosimum sp. | 4 | 11.11 | 0.72 | 33.33 | 1.16 | 0.07 | 0.32 | 0.52 | 0.73 |
| Chamaecrista adiantifolia | 3 | 8.33 | 0.54 | 33.33 | 1.16 | 0.11 | 0.5 | 0.52 | 0.73 |
| Guatteria olivacea | 4 | 11.11 | 0.72 | 33.33 | 1.16 | 0.07 | 0.31 | 0.52 | 0.73 |
| Swartzia sp. | 4 | 11.11 | 0.72 | 33.33 | 1.16 | 0.06 | 0.26 | 0.49 | 0.71 |
| Tapirira sp. | 3 | 8.33 | 0.54 | 22.22 | 0.77 | 0.15 | 0.71 | 0.63 | 0.68 |
| Eschweilera nana | 4 | 11.11 | 0.72 | 22.22 | 0.77 | 0.11 | 0.53 | 0.63 | 0.67 |
| Mimosa acutistipula | 4 | 11.11 | 0.72 | 33.33 | 1.16 | 0.03 | 0.13 | 0.43 | 0.67 |
| Cordia hirta | 3 | 8.33 | 0.54 | 33.33 | 1.16 | 0.05 | 0.25 | 0.4 | 0.65 |
| Ocotea olivacea | 4 | 11.11 | 0.72 | 33.33 | 1.16 | 0.02 | 0.07 | 0.4 | 0.65 |
| Casearia arborea | 3 | 8.33 | 0.54 | 33.33 | 1.16 | 0.02 | 0.08 | 0.31 | 0.59 |
| Eugenia punicifolia | 3 | 8.33 | 0.54 | 33.33 | 1.16 | 0.01 | 0.05 | 0.3 | 0.59 |
| Martiodendron sp. | 2 | 5.56 | 0.36 | 22.22 | 0.77 | 0.13 | 0.62 | 0.49 | 0.59 |
| Amaioua sp. | 3 | 8.33 | 0.54 | 33.33 | 1.16 | 0.01 | 0.05 | 0.29 | 0.58 |
| Neea robusta | 3 | 8.33 | 0.54 | 22.22 | 0.77 | 0.09 | 0.39 | 0.47 | 0.57 |
| Miconia sp. | 3 | 8.33 | 0.54 | 22.22 | 0.77 | 0.07 | 0.31 | 0.42 | 0.54 |
| Aspidosperma parvifolium | 3 | 8.33 | 0.54 | 22.22 | 0.77 | 0.05 | 0.25 | 0.4 | 0.52 |
| Guatteria foliosa | 3 | 8.33 | 0.54 | 22.22 | 0.77 | 0.05 | 0.24 | 0.39 | 0.52 |
| Zanthoxylum rhoifolium | 2 | 5.56 | 0.36 | 22.22 | 0.77 | 0.09 | 0.4 | 0.38 | 0.51 |
| Syagrus comosa | 3 | 8.33 | 0.54 | 22.22 | 0.77 | 0.03 | 0.16 | 0.35 | 0.49 |
| Pterocarpus rohrii | 3 | 8.33 | 0.54 | 22.22 | 0.77 | 0.03 | 0.16 | 0.35 | 0.49 |
| Tapirira cf. retusa | 2 | 5.56 | 0.36 | 22.22 | 0.77 | 0.05 | 0.25 | 0.31 | 0.46 |
| Sorocea guilleminiana | 3 | 8.33 | 0.54 | 22.22 | 0.77 | 0.01 | 0.06 | 0.3 | 0.46 |
| Brosimum longifolium | 3 | 8.33 | 0.54 | 22.22 | 0.77 | 0.01 | 0.06 | 0.3 | 0.46 |
| Cupania scrobiculata | 2 | 5.56 | 0.36 | 22.22 | 0.77 | 0.04 | 0.18 | 0.27 | 0.44 |
| Coccoloba sp. | 2 | 5.56 | 0.36 | 22.22 | 0.77 | 0.03 | 0.16 | 0.26 | 0.43 |
| Ocotea longifolia | 2 | 5.56 | 0.36 | 22.22 | 0.77 | 0.03 | 0.15 | 0.26 | 0.43 |
| Rhamnidium sp. | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.15 | 0.7 | 0.44 | 0.42 |
| Agonandra brasiliensis | 2 | 5.56 | 0.36 | 22.22 | 0.77 | 0.03 | 0.12 | 0.24 | 0.42 |
| Astronium gracile | 2 | 5.56 | 0.36 | 22.22 | 0.77 | 0.02 | 0.08 | 0.22 | 0.4 |
| Myrcia multiflora | 2 | 5.56 | 0.36 | 22.22 | 0.77 | 0.02 | 0.08 | 0.22 | 0.4 |
| Piper cf. aduncum | 3 | 8.33 | 0.54 | 11.11 | 0.39 | 0.04 | 0.17 | 0.36 | 0.37 |
| Cochlospermum orinocense | 3 | 8.33 | 0.54 | 11.11 | 0.39 | 0.03 | 0.14 | 0.34 | 0.36 |
| Duguetia stelechantha | 3 | 8.33 | 0.54 | 11.11 | 0.39 | 0.03 | 0.13 | 0.34 | 0.35 |
| Myrcia splendens | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.10 | 0.47 | 0.32 | 0.34 |
| Jacaranda copaia | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.10 | 0.45 | 0.32 | 0.34 |
| Casearia sp. | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.09 | 0.44 | 0.31 | 0.34 |
| Couma utilis | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.09 | 0.43 | 0.3 | 0.33 |
| Xylopia polyantha | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.08 | 0.36 | 0.27 | 0.31 |
| Cenostigma sp. | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.05 | 0.25 | 0.22 | 0.27 |

Continued...

| Species | N | AD | RD | AF | RF | ADo | RDo | CV (%) | IV (%) |
|---|---|---|---|---|---|---|---|---|---|
| Astrocaryum aculeatum | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.05 | 0.25 | 0.22 | 0.27 |
| Siparuna amazonica | 2 | 5.56 | 0.36 | 11.11 | 0.39 | 0.01 | 0.07 | 0.21 | 0.27 |
| Crepidospermum rhoifolium | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.05 | 0.24 | 0.21 | 0.27 |
| Siparuna guianensis | 2 | 5.56 | 0.36 | 11.11 | 0.39 | 0.01 | 0.05 | 0.2 | 0.26 |
| Margaritaria sp. | 2 | 5.56 | 0.36 | 11.11 | 0.39 | 0.01 | 0.04 | 0.2 | 0.26 |
| Erythroxylum nelson-rosae | 2 | 5.56 | 0.36 | 11.11 | 0.39 | 0.01 | 0.03 | 0.2 | 0.26 |
| Thyrsodium paraense | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.04 | 0.21 | 0.19 | 0.26 |
| Cordia naidophila | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.04 | 0.21 | 0.19 | 0.26 |
| Rollinia insignis | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.04 | 0.21 | 0.19 | 0.26 |
| Mabea angularis | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.04 | 0.18 | 0.18 | 0.25 |
| Himatanthus sucuuba | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.03 | 0.15 | 0.17 | 0.24 |
| Hymenaea courbaril | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.03 | 0.13 | 0.15 | 0.23 |
| Inga paraensis | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.02 | 0.11 | 0.15 | 0.23 |
| Platymiscium duckei | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.02 | 0.1 | 0.14 | 0.22 |
| Astrocaryum gynacanthum | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.02 | 0.1 | 0.14 | 0.22 |
| Rhodostemonodaphne cf. parvifolia | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.02 | 0.08 | 0.13 | 0.22 |
| Miconia sp.2 | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.02 | 0.07 | 0.13 | 0.21 |
| Handroanthus serratifolius | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.02 | 0.07 | 0.12 | 0.21 |
| Byrsonima incarnata | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.02 | 0.07 | 0.12 | 0.21 |
| Inga longiflora | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.02 | 0.07 | 0.12 | 0.21 |
| Eriotheca globosa | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.02 | 0.07 | 0.12 | 0.21 |
| Eschweilera coriacea | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.01 | 0.05 | 0.11 | 0.2 |
| Perebea mollis | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.01 | 0.04 | 0.11 | 0.2 |
| Trattinnickia burserifolia | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.01 | 0.04 | 0.11 | 0.2 |
| Helicteres sacarolha | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.01 | 0.03 | 0.11 | 0.2 |
| Pachira cf.faroensis | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.01 | 0.03 | 0.1 | 0.2 |
| Lindackeria paludosa | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.01 | 0.02 | 0.1 | 0.2 |
| Protium nitidum | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.00 | 0.02 | 0.1 | 0.2 |
| Galipea sp. | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.00 | 0.02 | 0.1 | 0.2 |
| Alibertia claviflora | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.00 | 0.02 | 0.1 | 0.2 |
| Myrcia fenestrata | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.00 | 0.02 | 0.1 | 0.2 |
| Vouarana guianensis | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.00 | 0.02 | 0.1 | 0.19 |
| Talisia allenii | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.00 | 0.02 | 0.1 | 0.2 |
| Metrodorea sp. | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.00 | 0.02 | 0.1 | 0.19 |
| Glycidendron amazonicum | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.00 | 0.02 | 0.1 | 0.19 |
| Rutaceae 4 | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.00 | 0.02 | 0.1 | 0.19 |
| Dialium guianense | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.00 | 0.01 | 0.1 | 0.19 |
| Croton sp. | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.00 | 0.01 | 0.1 | 0.19 |
| Pera sp. | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.00 | 0.01 | 0.1 | 0.19 |
| Tabernaemontana angulata | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.00 | 0.01 | 0.1 | 0.19 |
| Almeidea sp. | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.00 | 0.01 | 0.1 | 0.19 |
| Handroanthus ochraceus | 1 | 2.78 | 0.18 | 11.11 | 0.39 | 0.00 | 0.01 | 0.1 | 0.19 |
| **Total** | 553 | 1536.11 | 100 | 2877.78 | 100 | 21.44 | 100 | 100 | 100 |

## Conclusões Gerais

A partir dos resultados obtidos nos dois capítulos pôde-se concluir que:

1. A floresta seca na Flona de Carajás está submetida a condições similares de clima tropical úmido (Aw-Koppen) e cercada por formações florestais tropicais úmidas nas quais as propriedades do solo influenciam a ocorrêcia das formações florestais secas. Essas florestas podem ser encontradas em ambientes de solos variados, onde existem claras diferenças na química do solo (estado nutricional) e profundidade.
2. Em geral, os solos em todas as formações secas estudadas são ácidos e com baixos teores de fósforo. No entanto, houve diferenças significativas entre as propriedades do solo entre as áreas amostradas para estas e outras propriedades químicas do solo.
3. Os solos afetam os padrões de distribuição de espécies nas Florestas Secas na Flona de Carajás, evidenciando um padrão de distribuição de espécies arbóreas em resposta ao gradiente edáfico, no qual as espécies mais freqüentes tendem a ser mais especializadas no que diz respeito às condições locais de solo do que as outras espécies.
4. A heterogeneidade florística nas florestas decíduas no Sudeste da Amazônia (Carajás) variou de acordo com solos em diferentes substratos: (granito rochas ígneas cristalinas / sedimentares/e vulcânicas).
5. Não se observou variação estrutural notável das florestas secas em Carajás. No entanto, os atributos estruturais, apresentaram maior o alcance de valores comparados com que aqueles reportados para florestas secas neotropicais de outros lugares.