EDAPHIC AND CLIMATIC RELATION AND ITS INFLUENCE ON THE COMPOSITION FLORISTIC LOWER STRATUM IN A FLOODPLAIN FOREST, PARÁ, BRAZIL[1]

Elayne Oliveira Braga[2*] and Mário Augusto Gonçalves Jardim[3]

[1] Received on 07.12.2015 accepted for publication on 09.09.2016.
[2] Universidade Federal Rural da Amazônia, Programa de Pós-graduação em Ciências Biológicas, Belém, PA - Brasil. E-mail: <elaynebraga@museu-goeldi.br>.
[3] Ministério da Ciência, Tecnologia e Inovação, Museu Paraense Emílio Goeldi, Coordenação de Botânica, Belém, PA - Brasil. E-mail: <jardim@museu-goeldi.br>.
*Corresponding author.

ABSTRACT – This work evaluated the soil and climate influence in the floristic composition of the lower stratum in a floodplain forest in the environmental protection area of Combu Island, in Belém, Pará. From February to April (high rainy period) and from May to July (less rainy period), all individuals with height $\leq$ 1 m were sampled and identified in four plots of 20 x 20 m divided into subplots of 1 m^2. A sample of soil per plot was collected at the depth of 20 cm in the months of April and July. The relationship between floristic with edaphic and climatic conditions was evaluated by a canonical correspondence analysis (CCA). The floristic composition between the two studied periods was similar. Differently, the physico-chemical soil composition showed variation between the two periods. The CCA indicated a significant correlation between the distribution of species and edaphic factors, although most species were not influenced by soil variables, in particular the most abundant ones. Some species showed a relationship with In and fine sand, indicating the existence of preferential sites for some species.

Keywords: : High rainy period and less rainy periods; Physico-chemical composition; Generalist species.

RELAÇÃO EDAFO-CLIMÁTICA E SUA INFLUÊNCIA NA COMPOSIÇÃO FLORÍSTICA DO ESTRATO INFERIOR EM UMA FLORESTA OMBRÓFILA DENSA ALUVIAL, PARÁ, BRASIL

RESUMO – Este trabalho avaliou a relação edafo-climática e sua influência sob a composição florística do estrato inferior em uma floresta ombrófila densa aluvial localizada na Área de Proteção Ambiental, Ilha do Combu, Belém, Pará. De fevereiro a abril (período mais chuvoso) e de maio a julho (período menos chuvoso) foram amostrados e identificados todos os indivíduos com altura $\leq$ 1 m em quatro parcelas de 20 x 20 m divididas em subparcelas de 1m^2. Foi coletada uma amostra composta de solo por parcela na profundidade de 20 cm nos meses de abril e julho. Para relacionar a florística com as condições edafo-climáticas foi realizada uma análise de correspondência canônica (CCA). A composição florística dos períodos foi similar. A composição físico-química do solo apresentou variação entre os períodos. A CCA indicou correlação significativa entre a distribuição das espécies e os fatores edáficos, no entanto, a maioria das espécies não foi influenciada pelas variáveis do solo, em especial as mais abundantes. Algumas espécies apresentaram relação com o Na e areia fina, indicando a existência de sítios preferenciais para algumas espécies.

Palavras-chave: Período chuvoso e menos chuvoso; Composição físico-química; Espécies generalistas.

1. INTRODUCTION

The floodplain forest is commonly known estuary by "lowland forest" in the Amazon. According to Abreu et al. (2014), it is related to white water rivers that are under daily cycles of flooding and receding waters, represented by the tides. It presents alluvial soils, resulting from sedimentation of suspended particles from the waters of the rivers (SANTOS et al., 2004; LOPES et al., 2006). In this ecosystem, the hydrological cycle associated to sedimentation, ensures the maintenance of biodiversity and shape a dynamic environment with a mosaic of communities (WITTMANN; JUNK, 2003; FERREIRA et al., 2005; 2013).

Studies on the relationship between plants and edaphic factors indicate that species are little influenced by the concentration of soil components. It is assumed that floristic variation occur due to aleatory or biological processes related to the dispersal process and ecological relations, such as competition, herbivory and predation (FERREIRA et al., 2010; MOSQUERA; HURTADO, 2014; HIGUCHI et al., 2015).

Individuals of different forest stratum (upper and lower) may suffer from a distinct way the influence of excess water in the soil and changes in the concentration of nutrients (CARVALHO et al., 2009). Recent studies report that the height and duration of the flood associated with factors, such as topography and radiation, have influence on the floristic composition and distribution of the plants from the lower stratum of lowland forest (ASSIS; WITTMANN, 2011; MARINHO et al., 2010; 2013). However, little is known about the relationship between the species and the physical-chemical variables (LAU; JARDIM, 2014).

The understanding of floristic composition through influence of soil and climatic variable may show if there is a pattern of ecological functionality of the species and their microsites. This information can assist in strategies for sustainable forest management of this environment. This work aimed to evaluate the soil and climate influence in the floristic composition of the lower stratum in a floodplain forest in the environmental protection area of Combu Island, in Belém, Pará.

2. MATERIAL AND METHODS

The study was conducted in the Environmental protection area of Combu Island (APA of Combu Island) located to 7 km from the city of Belém, State of Pará, with a total area of 1.500 hectares. According to the Köppen classification, the climate is Am (hot and humid tropical type), with an average temperature of 27° C and with high precipitation in the months of February to April (1.228 mm) and low from May to July (629 mm) (AMARAL et al., 2012). The soil is Gley Humic, with little high percentage of silt and clay (JARDIM; VIEIRA, 2001). The floristic inventories occurred monthly from February to April (high rainy period) and from May to July (less rainy period) in 2015, in four plots of 20 x 20 m. In each plot were allocated 1 x 1 m subplots and performed the identification and quantification of individuals with overall height $\leq$ 1 m (MAUÉS et al., 2011). The identification of the species was made in the Museu Paraense Emílio Goeldi (MPEG). It was adopted the APG III (2009) for the classification of the Angiosperms and Smith et al. (2006) for ferns. The species names and their authors were conferred by consulting the database of the Missouri Botanical Garden (http://www.tropicos.org).

The soil samples were collected in four plots in April (high rainy period) and July (less rainy period) at the depth of 20 cm. Each collection was made up of five subsamples, one collected in center of the plot and the other four at the vertices (LAU; JARDIM, 2014). The physical and chemical composition analysis was performed in the laboratory of soil following the protocol of Embrapa (1997).

For the quantification of species diversity and ecological dominance in each period, it has been calculated the Shannon Index (H') and the Pielou Equability (J'). The horizontal structure of the community was described through relative density parameter. To evaluate the floristic similarity between periods it was elaborate an array of Bray-Curtis dissimilarity using abundance data of all species in the high rainy period and less rainy period, being expressed through Group in a dendrogram using connection method by unweighted average (UPGMA). The cofenetic correlation coefficient was used as a measure of fidelity of the original array dendrogram (OKSANEN et al., 2015).

Two matrix were elaborate: an containing the abundance of floristic species on their plots in the high rainy period and in the less rainy period, and other with the edaphic constraint variables also in the two studied periods. Among the floristic species recorded were excluded the ones with less than twenty individuals considering the two studied periods, since species with very low density adds little in terms of information and hinder interpretation of data (RODRIGUES; ARAUJO, 2013). The final analysis was conducted with 40 species.

The relationship between species and edaphic conditions was evaluated by a canonical correspondence analysis (CCA). The edaphic significant conditions were selected using the function "ordistep" member of the Vegan package. The significance of the axes and edaphic conditions was verified through the Monte Carlo permutation test from the function "anova.cca", with 999 permutations, considering $p \leq 0.05$. All analyses were performed in the software R 3.2.2 (R Foundation for Statistical Computing, 2015) through the Vegan package (OKSANEN et al., 2015).

3. RESULTS

In the high rainy period were registered 30 families, 49 genera and 63 species. Families with greater species richness were Fabaceae (12 species), Arecaceae (6), Araceae (4), and Euphorbiaceae (4). The genera with more species were: *Inga* (4) and *Desmoncus* (3). *Pariana campestris* Aubl. and *Anthurium sinuatum* Benth. ex Schott. presented higher relative density with 30.17% and 21.65%, respectively. The Shannon diversity index was 2.60 and evenness of 0.63. The species *Crudia oblonga* Benth., *Desmoncus polyacanthos* Mart., *Genipa americana* L., *Hernandia guianensis* Aubl., *Inga alata* Benoist, *Manaosella cordifolia* (DC. A.H.Gentry), *Mezilaurus mahuba* (A. Samp.) van der Werff, *Psychotria colorata* (Willd. ex Roem. & Schult.) Mull. Arg., and *Uncaria guianensis* (Aubl.) J.F. Gmel. occurred exclusively in this period, accounting for only 0.22% of the relative density of the period.

In the less rainy period were sampled 29 families, 46 genera and 59 species. Fabaceae (11 species), Araceae Arecaceae (5), and Euphorbiaceae (4) showed greater species richness among the registered families. The genera *Inga* was prevalent in number of species (3). *Pariana campestris* Aubl. and *Anthurium sinuatum* Benth. ex Schott presented higher relative density with 34.28% and 19.86%, respectively. The Shannon diversity index was 2.53 and evenness of 0.62. In this period, the exclusive species were *Dioscorea laxiflora* Mart. ex Griseb., *Doliocarpus dentatus* (Aubl.) Standl., *Ficus insipida* Willd, *Philodendron acutatum* Schott, and *Senna quinquangulata* (Rich.) H.S. Irwin & Barneby, corresponding to 0.11% of relative density only.

A total of 54 species occurred in the two studied periods. The cluster analysis showed a low spatial and temporal variation in the species abundance (Bray-Curtis Dissimilarity = 0.45). However, there is the formation of two interpretable groups, being a group formed by P1 and P3 plots in two periods and another group comprised of the P2 and P4 also plots the rainiest and less rainy period (Figure 1). The two studied periods presented variation of edaphic conditions analyzed. The natural clay, fine sand, silt, coarse sand, Al and pH (H2O) presented a higher concentration in the high rainy period. Already the N, pH (KCl), Ca, H+Al, Ca + Mg, P, MO and clay were greater in total less rainy period.

The eigenvectors of the first canonical ordination axes were low, 0.201 to the axis 1 and 0.049 axis 2. The first axis explained 45.53% and the second total variation of 11.05% data (running total = 56.58%). The significance of the relation between soil variables and species was high in both first 0.93 axes (axis 1)

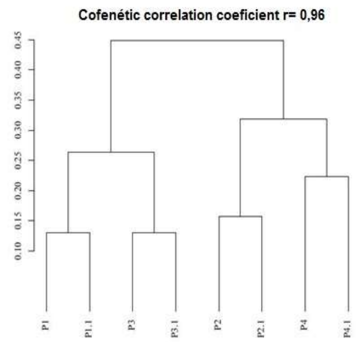

Figure 1 – Dissimilarity dendrogram based on the abundance of species, found in four plots inventoried the rainy period (P1, P2, P3 and P4) and less rainy (P1.1, P2.1, P3.1 and P4.1) in floodplain forest, Environmental Protection Area, Combu Island, Belém, Pará, Brazil. Using UPGMA method and distance Bray- Curtis. P = plot.

Figura 1 – *Dendograma de dissimilaridade baseado na abundância das espécies, encontradas em quatro parcelas, inventariadas no período mais chuvoso (P1, P2, P3 e P4) e menos chuvoso (P1.1, P2.1, P3.1 e P4.1) na floresta ombrófila densa aluvial da Área de Proteção Ambiental, Ilha do Combu, Belém, Pará, Brasil. Usando o método UPGMA e distância de Bray-Curtis. P= parcela.*

and 0.76 (2 axis). The abundance of the species and soil variables were significantly related in the first ordination axis (p = 0.02), but not in the second axis (p = 0.28). The only soil variables correlated with the species were In and fine sand, however just as in the correlation was significant. The On was strongly negatively related with 1 shaft and fine sand positively with the 2 axis.

The ordering of the parcels in the first axis suggests that in space parcels are separated into two groups, according to their variations of edaphic conditions, being the 1 and 3 plots positioned to the left of the graph, associated with the highest content of parcels 2 and 4, and, to the right side of the chart, are related with the lowest concentration of Na and greater concentration of fine sand. However, there was no variation in species abundance among the high and less rainy period, confirming the cluster analysis (Figure 2).

The ordering of the species by the CCA suggests that the species *Manihot esculenta* Crantz, *Dichorisandra affinis* Mart., *Carapa guianensis* Aubl., *Ruellia cordifolia* Vahl, and *Costus arabicus* L. are

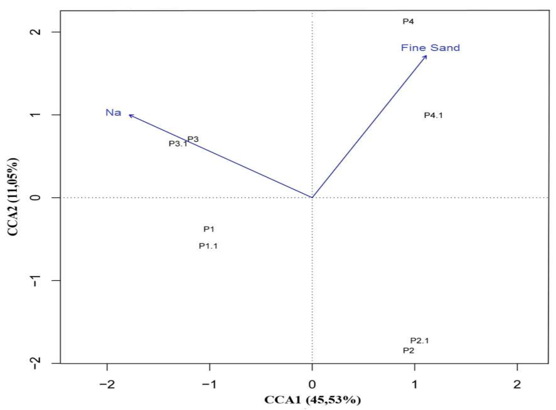

Figure 2 – Canonical correspondence analysis of four plots ordination diagram in the rainy period (P1, P2, P3 and P4) and less rainy (P1.1, P2.1, P3.1 and P4.1) in the floodplain forest, Environmental Protection Area, Combu Island, Belém, Pará, Brazil. Based on the distribution of 40 species.

***Figura 2** – Análise de correspondência canônica: diagrama de ordenação das quatro parcelas no período mais chuvoso (P1, P2, P3 e P4) e no período menos chuvoso (P1.1, P2.1, P3.1 e P4.1) na floresta ombrófila densa aluvial da Área de Proteção Ambiental, Ilha do Combu, Belém, Pará, Brasil. Baseada na distribuição de 40 espécies.*

restricted or more abundant on sites with greater availability of Sodium, independent of the period. Another group of species formed by *Syzygium malaccense* (L.) Merr. & L.M. Perry, *Memora flavida* (DC.) Bureau & k. Schum, *Machaerium ferox* (Mart. ex Benth.) Ducke, *Costus spicatus* (Jacq.) Sw., *Astrocaryum murumuru* Mart. and *Anthurium pentaphyllum* (Aubl.) G. Don, and *Inga alba* (Sw.) Willd. which tended to have higher abundance, occur exclusively in areas with lower levels of Na and greater concentration of fine sand, regardless of the period. Most species was indifferent to edaphic conditions variations (Figure 3).

4. DISCUSSION

The four families who have excelled in number of species in the two periods were well represented in other surveys which investigated the floristic composition in floodplain forest (ALMEIDA et al., 2004; ALMEIDA; JARDIM, 2011; LAU; JARDIM, 2013), evidencing the constant frequency of Fabaceae (WITTMANN et al., 2006; 2013; LUIZE et al., 2015). The Shannon index values for the high rainy period (2.60) and less rainy period (2.53) were similar and can be considered low, but it is a pattern frequently observed in estuarine lowlands (SANTOS; JARDIM, 2006).

The low diversity is a reflection of the limiting conditions imposed by the daily and periodic floods that alter the dynamics of nutrients from the soil, hindering the establishment of plants (PAROLIN et al., 2004; SILVA et al., 2015). The large number of species shared among the high and less rainy periods justifies lower dissimilarity between the periods observed floristic. The dissimilarity floristics in natural regeneration denotes temporal stability of vegetation (VENTUROLI et al., 2011).

The silt was prevalent in both periods, followed by clay particles and to a lesser extent the fine sand and coarse sand. This textural soil pattern was also observed in other studies in lowland forests of the Guamá River (MATTAR et al., 2002; NOGUEIRA et al., 2004; ABREU et al., 2007) and reflects the nature of recent sedimentary mineral particles that constitute the soils of floodplain environment (GUIMARAES et al., 2013). The value of natural clay was relatively high in the rainy period, which may be related to the characteristics of clay present in the system and probably the highest content of organic matter on the surface, which contributes to the increase of the electric charges

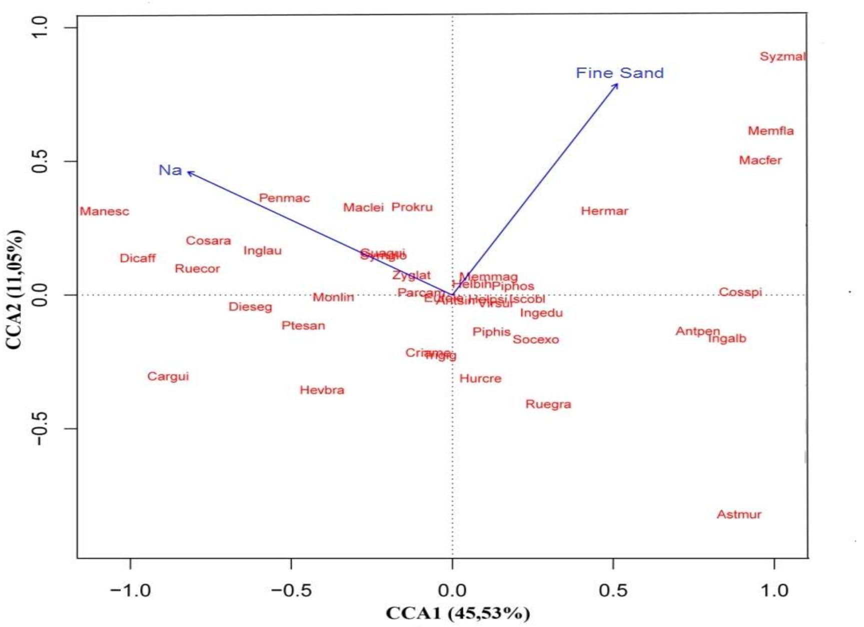

Figure 3 – Canonical correspondence analysis ordination diagram of the species based on the distribution of 40 species in four plots in the rainy season and less rainy season in floodplain Forest, Environmental Protection Area, Combu Island, Belém, Pará, Brasil. *Anthurium pentaphyllum* (Antpen), *Anthurium sinuatum* (Antsin), *Astrocaryum murumuru* (Astmur), *Carapa guianensis* (Cargui), *Costus arabicus* (Cosara), *Costus spicatus* (Cosspi), *Crinum americanum* (Criame), *Dichorisandra affinis* (Dicaff), *Dieffenbachia seguine* (Dieseg), *Euterpe oleracea* (Eutole), *Guarea guidonia* (Guagui), *Heliconia bihai* (Helbih), *Heliconia psittacorum* (Helpsi), *Herrania mariae* (Hermar), *Hevea brasiliensis* (Hevbra), *Hura crepitans* (Hurcre), *Inga alba* (Ingalb), *Inga edulis* (Ingedu), *Inga laurina* (Inglau), *Ischnosiphon obliquus* (Iscobl), *Machaerium ferox* (Macfer), *Machaerium leiophyllum* (Maclei), *Manihot esculenta* (Manesc), *Memora flavida* (Memfla), *Memora magnifica* (Memmag), *Montrichardia linifera* (Monlin), *Pariana campestris* (Parcam), *Pentaclethra macroloba* (Penmac), *Piper hispidum* Sw.(Piphis), *Piper hostmannianum* (Piphos), *Protium krukoffii* (Prokru), *Pterocarpus santalinoides* (Ptesan), *Ruellia cordifolia* (Ruecor), *Ruellia graecizans* (Ruegra), *Socratea exorrhiza* (Socexo), *Symphonia globulifera* (Symglo), *Syzygium malaccense* (Syzmal), *Trichanthera gigantea* (Trigig), *Virola surinamensis* (Virsur), *Zygia latifolia* (Zyglat).

Figura 3 *– Análise de correspondência canônica: diagrama de ordenação das espécies baseada na distribuição de 40 espécies nas quatro parcelas no período mais chuvoso e no período menos chuvoso na floresta ombrófila densa aluvial da Área de Proteção Ambiental, Ilha do Combu, Belém, Pará, Brasil.* ***Anthurium pentaphyllum*** *(Antpen),* ***Anthurium sinuatum*** *(Antsin),* ***Astrocaryum murumuru*** *(Astmur),* ***Carapa guianensis*** *(Cargui),* ***Costus arabicus*** *(Cosara),* ***Costus spicatus*** *(Cosspi),* ***Crinum americanum*** *(Criame),* ***Dichorisandra affinis*** *(Dicaff),* ***Dieffenbachia seguine*** *(Dieseg),* ***Euterpe oleracea*** *(Eutole),* ***Guarea guidonia*** *(Guagui),* ***Heliconia bihai*** *(Helbih),* ***Heliconia psittacorum*** *(Helpsi),* ***Herrania mariae*** *(Hermar),* ***Hevea brasiliensis*** *(Hevbra),* ***Hura crepitans*** *(Hurcre),* ***Inga alba*** *(Ingalb),* ***Inga edulis*** *(Ingedu),* ***Inga laurina*** *(Inglau),* ***Ischnosiphon obliquus*** *(Iscobl),* ***Machaerium ferox*** *(Macfer),* ***Machaerium leiophyllum*** *(Maclei),* ***Manihot esculenta*** *(Manesc),* ***Memora flavida*** *(Memfla),* ***Memora magnifica*** *(Memmag),* ***Montrichardia linifera*** *(Monlin),* ***Pariana campestris*** *(Parcam),* ***Pentaclethra macroloba*** *(Penmac),* ***Piper hispidum*** *Sw.(Piphis),* ***Piper hostmannianum*** *(Piphos),* ***Protium krukoffii*** *(Prokru),* ***Pterocarpus santalinoides*** *(Ptesan),* ***Ruellia cordifolia*** *(Ruecor),* ***Ruellia graecizans*** *(Ruegra),* ***Socratea exorrhiza*** *(Socexo),* ***Symphonia globulifera*** *(Symglo),* ***Syzygium malaccense*** *(Syzmal),* ***Trichanthera gigantea*** *(Trigig),* ***Virola surinamensis*** *(Virsur),* ***Zygia latifolia*** *(Zyglat).*

of the soil, decreasing the activity of elements responsible for the aggregation and flocculation of these particles (GUIMARAES et al., 2013).

The most acidic pH in the high and less rainy periods is in accordance to Haugaasen and Peres (2006), when they found the pH of 5.01 in 20 cm of soil of lowland forest in the Rio Purus. Gonçalves et al. (2011) observed the variation of the pH of the 5.78 to 4.21 in environments with 10 m distance of tributary water, which is very similar to the values observed in this study. The increase in value of pH in soil near the Guamá river, in Belém, Pará, occurred in the high rainy period and consequently with greater precipitation (ABREU et al., 2007) and after the intense flood periods (MATTAR et al., 2002; SILVA et al., 2015). An acid soil, increasing the pH in the period of greatest rainfall was expected with the flood for the reduction of iron compounds, to the absence of oxygen, going on so the hydroxyl ion release into the soil (PONNAMPERUMA, 1972). In addition, in acid soils during the flood, the H + ions are used as receivers of electrons on the breath of anaerobic microorganisms (SILVA et al., 2015).

The concentration of Al in the high rainy period is accordance to Lima et al. (2005) that recorded higher values exchangeable aluminum in flooded soils. The increase of aluminium is related to the increased solubilization of iron and manganese compounds during the flood. Therefore, the aluminum associated with these oxides is also released, increasing their mobilization.

The highest content of sodium in the high rainy season was similar to the one established by Ferreira and Botelho (1999) and Mattar et al. (2002), who observed higher values of sodium in soil of the Amazon estuary after the flood. Despite the increasement, the sodium is not directly influenced by the flood, since it is not subject to reduction reactions, however the large amount of iron released during flooding displaces large amounts of sodium exchange sites, increasing their content in solution (FERREIRA et al., 1998; LIMA et al., 2005).

The low percentage of N and MO content on less rainy period was also observed for other soils flooded with intense nitrogen losses, mainly through denitrification and volatilization of ammonia (PONNAMPERUMA, 1972). The large amount of clay in the soil can reduce the rate of decomposition of organic matter, increasing your amount in the soil (MACHADO et al., 2014). In this study, the highest content of clay in less rainy period, probably caused an increase in MO in this same period.

The concentration of H+Al in less rainy period differed from that indicated by Machado et al. (2014), but the greatest value of Ca+Mg in this same period was similar to that observed by these authors. The value of H+Al in less rainy period in this study was similar to 6.1cmolc dm^{-3} observed by Silva et al. (2015) before the flood, and 6.57 cmolc dm^{-3} constated by Lau and Jardim (2014), also in the less rainy period. There is a trend of increased H+Al content in soils with higher content of organic matter, especially if these present acidic pH (CAMARGOS et al., 2008), proven fact in this study.

With respect to the levels of Ca and P, Abreu et al. (2007) suggested that the variation of these nutrients was not associated with any even period occurring higher values in the period of soil moisture. Acconrding to Silva et al. (2015) and Lima et al. (2005), higher values of Ca and P were observed in flooded soil, different from the present study which observed the highest content of these nutrients in the less rainy period.

The eigenvectors found in the canonical correspondence analysis can be considered low when compared with other studies (GONÇALVES et al., 2011; HIGUCHI et al., 2015) and indicate the existence of short gradients, i.e. most species is distributed throughout the environment inventoried (BOTREL et al., 2002), independent of edaphic variation in the high and less rainy periods. Despite this data variation, 56.58% were explained by the two axes of the CCA, which can be considered relatively high when compared to other studies, that in general found explanation less than 50% (CARVALHO et al., 2005; AVILA et al., 2011; RODRIGUES; ARAUJO, 2013). This result can also indicate that most species of the lower stratum, especially the more abundant, are generalists by habitat (BOTREL et al., 2002). The herbaceous *Pariana campestris* and *Anthurium sinuatum*, for example, presented a large number of individuals in all plots in both high and less rainy period, explaining some of the relationship between the bottom layer and soil variables, suggesting that there is a limitation to the occurrence of these edaphic species.

The distribution and abundance of genralist species are probably determined by stochastic order factors related to the dispersal process and ecological relations, such as competition, herbivory and predation (HIGUCHI et al., 2015). Other environmental factors were not analyzed in this study, such as the availability of light, topography and flood level. For lowland forests, studies suggest that these environmental variables, especially the flood level, are crucial in the distribution and development of adult plants and regenerating (CATTÂNIO et al., 2002; MARINHO et al., 2010; ASSIS; WITTMANN et al., 2011; LUIZE et al., 2015). In addition, species with less than twenty individuals were excluded from the analysis, which may have influenced the observed pattern.

The fine sand was correlated with some species, indicating that the coarser particle size fractions, even on predominantly siltic soils, have an important role in the organization of the species in the forest. This is because the soil with high content of silt and clay, although fertile, accumulates water due to poor drainage, creating conditions of hypoxia (PAROLIN, 2009). The existence of preferential niches for certain species was demonstrated by Gonçalves et al. (2011), when they noticed that the greatest abundance of thirteen species occurred in flooded forests further away from the river and with higher acidity and eleven most abundant species in an environment closer to the river and with less acidity. Lau and Jardim (2014) detected negative associations between the abundance of some species in the seed bank with the highest concentration of iron.

5. CONCLUSIONS

The floristic composition of the high and less rainy period was similar, showing that the species are adapted to constrained edaphic variations between these periods. There was physical and chemical composition variation of soil between periods. The occurrence of the species may be a consequence of a set of environmental factors. Only the edaphic variables poorly explain the distribution and abundance of species in the high and less rainy periods, being most generalist species. Aspects of autoecology flooding, topography, light intensity and the area's history are necessary to better understand the behavior of species to environmental changes.

6. ACKNOWLEDGMENTS

The authors thanks the CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) for financial support to the Project CNPQ-305667/2013-0.

7. REFERENCES

ABREU, E. M. A.; FERNANDES, A. R.; RUIVO, M. L. P. Variação temporal e vertical de atributos químicos de um gleissolo do Rio Guamá cultivado com Canaranas. **Revista Brasileira de Ciência do Solo**, v. 31, n. 2, p. 277 285, 2007.

ABREU, J.C.; GUEDES, M.C.; GUEDES, A.C.L.; BATISTA, E.M. Estrutura e distribuição espacial de andirobeiras (*Carapa* spp.) em floresta de várzea do Estuário Amazônico. **Ciência Florestal**, v.24, n.4, p.1007-1016, 2014.

ALMEIDA, A.F.; JARDIM, M.A.G. Florística e estrutura da comunidade arbórea de uma floresta de várzea na Ilha de Sororoca, Ananindeua, Pará, Brasil. **Scientia Forestalis**, v.39, n.90, p.191-198, 2011.

ALMEIDA, S.S.; AMARAL, D.D.; SILVA, A.S.L. Análise florística e estrutura de florestas de várzea no estuário amazônico. **Acta Amazonica**, v.34, n.4, p.513-524, 2004.

AMARAL, D.D.; VIEIRA, I.C.G.; SALOMÃO, R.P.; ALMEIDA, S.S.; JARDIM, M.A.G. The status of conservation of urban forests in eastern Amazonia. **Brazilian Journal of Biology**, v.72, n.2, p.257-265, 2012.

APG III. The Angiosperm Phylogeny Group. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. **Botanical Journal of the Linnean Society**, v.161, n.2, p.105-121, 2009.

ASSIS, R.L.; WITTMANN, F. Forest structure and tree species composition of the understory of two central Amazonian várzea forests of contrasting flood heights. **Flora**, v.206, n.3, p.251 260, 2011.

AVILA, A.L.; ARAUJO, M.M.; LONGHI, S.J.; GASPARIN, E. Agrupamentos florísticos na regeneração natural em remanescente de Floresta Ombrófila Mista, RS, Brasil. **Scientia Forestalis**, v.39, n.91, p.331-342, 2011.

BOTREL, R.T.; OLIVEIRA FILHO, A.T.; RODRIGUES, L.A.; CURI, N. Influência do solo e da topografia sobre as variações da composição florística e estrutura da comunidade arbóreo-arbustiva de uma floresta estacional semidecidual em Ingaí, MG. **Revista Brasileira de Botânica**, v.25, n.2, p.195 213, 2002.

CAMARGOS, V.L.; SILVA, A.F.; MEIRA NETO, J.A.A.; MARTINS, S.V. Influência de fatores edáficos sobre variações florísticas na floresta estacional semidecídua no entorno da Lagoa Carioca, Parque Estadual do Rio Doce, MG, Brasil. **Acta Botanica Brasilica**, v.22, n.1, p.75-84, 2008.

CARVALHO, J.; MARQUES, M. C. M.; RODERJAN, C. V.; BARDDAL, M.; SOUZA, S. G. A. Relações entre a distribuição das espécies de diferentes estratos e as características do solo de uma floresta aluvial no Estado do Paraná, Brasil. **Acta Botanica Brasilica**, v.23, n.1, p.1-9, 2009.

CARVALHO, D.A.; OLIVEIRA FILHO, A.T.; VILELA, E.A.; CURI, N.; van den BERG, E.; FONTES, M.A.L.; BOTEZELLI, L. Distribuição de espécies arbóreo-arbustivas ao longo de um gradiente de solos e topografia em um trecho de floresta ripária do Rio São Francisco em Três Marias, MG, Brasil. **Revista Brasileira de Botânica**, v.28, n.2, p.329 345, 2005.

CATTÂNIO, J.H.; ANDERSON, A.B.; CARVALHO, M.S. Floristic composition and topographic variation in a tidal floodplain forest in the Amazon Estuary. **Revista Brasileira de Botânica**, v.25, n.4, p.419-430, 2002.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA - EMBRAPA. **Manual de Métodos de Análises de Solo**. 2ª. ed. Rio de Janeiro: 1997. 212p.

FERREIRA, C.S.; PIEDADE, M.T.F.; WITTMANN, A.O.; FRANCO, A.C. Plant reproduction in the Central Amazonian floodplain: challenges and adaptations. **AoB Plants**, v.2010, p.1 14, 2010.

FERREIRA, L.V.; ALMEIDA, S.S.; AMARAL, D.D.; PAROLIN, P. Riqueza e composição de espécies da floresta de igapó e várzea da Estação Científica Ferreira Penna: Subsídios para o plano de manejo da Floresta Nacional de Caxiuanã. **Pesquisas Botânicas**, n.56, p.103-116, 2005.

FERREIRA, L.V.; CHAVES, P.P.; CUNHA, D.A.; MATOS, D.C.L.; PAROLIN, P. Variação da riqueza e composição de espécies da comunidade de plantas entre as florestas de igapós e várzeas na Estação Científica Ferreira Penna-Caxiuanã na Amazônia Oriental. **Pesquisas, Botânicas**, n.64, p.175 195, 2013.

FERREIRA, W.A.; BOTELHO, S.M. **Efeito da inundação sobre as propriedades de um gleissolo sálico sódico de várzea do Rio dos Morcegos, no município de Primavera, PA**. Belém: Embrapa; CPATU, 1999. 24p.

FERREIRA, W.A.; MODESTO JÚNIOR, M.S.; BOTELHO, S.M.; MASCARENHAS, R.E.B. **Efeito da inundação sobre as propriedades de um glei pouco húmico de várzea do Rio Guamá, nos municípios de Belém e Santa Isabel, PA**. Belém: Embrapa; CPATU, 1998. 29p.

GONÇALVES, I.S.; DIAS, H.C.T.; MARTINS, S.V.; SOUZA, A.L. Fatores edáficos e as variações florísticas de um trecho de mata ciliar do Rio Gualaxo do Norte, Mariana, MG. **Revista Árvore**, v.35, n.6, p.1235 1243, 2011.

GUIMARÃES, S.T.; LIMA, H.N.; TEXEIRA, W.G.; NEVES JUNIOR, A.F.; SILVA, F.W.R.; MACEDO, R.S.; SOUZA, K.W. Caracterização e classificação de gleissolos da várzea do Rio Solimões (Manacapuru e Iranduba), Amazonas, Brasil. **Revista Brasileira de Ciência do Solo**, v.37, n.2, p.317 326, 2013.

HAUGAASEN, T.; PERES, C.A. Floristic, edaphic and structural characteristics of flooded and unflooded forests in the lower Rio Purús region of central Amazonia, Brazil. **Acta Amazonica**, v.36, n.1, p.25 36, 2006.

HIGUCHI, P.; SILVA, A.C.; BUZZI JUNIOR, F.; NEGRINII, M.; FERREIRA, T.S.; SOUZA, S.T.; SANTOS, K.F.; VEFAGO, M.B. Fatores determinantes da regeneração natural em um fragmento de floresta com araucária no planalto catarinense. **Scientia Florestalis**, v.43, n.106, p.251 259, 2015.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE-. **Manual técnico da vegetação brasileira**. Rio de Janeiro: 2012. 271p.

JARDIM, M.A.G.; VIEIRA, I.C.G. Composição florística e estrutura de uma floresta de várzea do estuário amazônico, Ilha do Combu, Estado do Pará, Brasil. **Boletim do Museu Paraense Emílio Goeldi**, **Ciências Naturais**, v.17, n.2, p.333 354, 2001.

LAU, A.V.; JARDIM, M.A.G. Florística e estrutura da comunidade arbórea em uma floresta de várzea na Área de Proteção Ambiental, Ilha do Combu, Belém, Pará. **Biota Amazônia**, v.3, n.2, p.88 93, 2013.

LAU, A.V.; JARDIM, M.A.G. Relação entre o banco de sementes e a composição química do solo em uma floresta de várzea. **Biota Amazônia**, v.4, n.2, p.96 101, 2014.

LIMA, H.N.; MELLO, J.W.V.; SCHAEFER, C.E.G.R.; KER, J.C. Dinâmica da mobilização de elementos em solos da Amazônia submetidos à inundação. **Acta Amazonica**, v.35, n.3, p.317 330, 2005.

LOPES, E.L.N.; FERNANDES, A.R.; GRIMALDI, C.; RUIVO, M.L.P.; RODRIGUES, T.E.; SARRAZIN, M. Características químicas de um gleissolo sob diferentes sistemas de uso, nas margens do rio Guamá, Belém, Pará. **Boletim do Museu Paraense Emilio Goeldi**, v.1, n.1, p.127 137, 2006.

LUIZE, B.G.; SILVA, T.S.F.; WITTMANN, F.; ASSIS, R.L.; VENTICINQUE, E.M. Effects of the flooding gradiente on tree community diversity in várzea forests of the Purus River, Central Amazon, Brazil. **Biotropica**, v.47, n.2, p.137 142, 2015.

MACHADO, N. G.; SANCHES, L.; SILVA, L. B.; NOVAIS, J. W. Z.; AQUINO, A. M.; BIUDES, M. S.; PINTO-JUNIOR, O. B.; NOGUEIRA, J. S. Soil nutrients and vegetation structure in a neotropical seasonal wetland. **Applied Ecology and Environmental Research**, v. 13, n. 2, p. 289 305, 2014.

MAUÉS, B.A.R.; JARDIM, M.A.G.; BATISTA, F.J.; MEDEIROS, T.D.S.; QUARESMA, A.C. Composição florística e estrutura do estrato inferior da floresta de várzea na Área de Proteção Ambiental Ilha do Combu, Município de Belém, Estado do Pará. **Revista Árvore**, v.35, n.3, p.669 677, 2011.

MARINHO, T.A.S.; LOPES, A.; ASSIS, R.L.; RAMOS, S.L.F.; GOMES, L.R.P.; WITTMANN, F.; SCHÖNGART, J. Distribuição e crescimento de *Garcinia brasiliensis* Mart. e *Hevea spruceana* (Benth.) Müll. Arg. em uma floresta inundável em Manaus, Amazonas. **Ciência Florestal**, v.23, n.1, p.223 232, 2013.

MARINHO, T.A.S.; PIEDADE, M.T.F.; WITTMANN, F. Distribution and population structure of four Central Amazonian high-várzea timber species. **Wetlands Ecology and Management**, v.18, n.6, p.665 677, 2010.

MATTAR, R.M.V.C.; VIEIRA, L.S.; SILVA, G.R. Efeito da inundação sobre o pH e a disponibilidade de fóforo, sódio, ferro e manganês em um gley pouco húmico coletado na várzea do Rio Guamá, Belém (PA). **Revista de Ciências Agrárias**, n.37, p.113 121, 2002.

MOSQUERA, H.Q.; HURTADO, F.M. Diversidad florística arbórea y su relación con el suelo en un bosque pluvial tropical del Chocó Biogeográfico. **Revista Árvore**, v.38, n.6, p.1123 1132, 2014.

NOGUEIRA, E.L.S.; FERNANDES, A.R.; RUIVO, M.L.P.; RODRIGUES, T.E.; SARRAZIN, M.A. Características físicas de um gleissolo do Rio Guamá sob diferentes sistemas de uso. **Revista de Ciências Agrárias**, n.42, p.85 96, 2004.

OKSANEN, J.; BLANCHET, F.G.; KINDT, R.; LEGENDRE, P.; MINCHIN, P.R.; O'HARA, R.B.; SIMPSON, G.L.; SOLYMOS, P.; STEVENS, M.H.H.; WAGNER, H. **R package version 2.0-8.** Vegan: Community Ecology Package, 2013. [acessado em: 15 out. 2015]. Disponível em http://cran.r-project.org.

PAROLIN, P.; FERREIRA, L.V.; ALBERNAZ, A.L.K.M.; ALMEIDA, S.S. Tree species distribution in várzea forests of Brazilian Amazonia. **Folia Geobotanica**, v.39, n.4, p.371 383, 2004.

PAROLIN, P. Submerged in darkness: adaptations to prolonged submergence by woody species of the Amazonian floodplain. **Annals of Botany**, v.103, p.359 376, 2009.

PONNAMPERUMA, F.N. The Chemistry of submerged soils. **Advances in Agronomy**, v.24, p.29 96, 1972.

R FOUNDATION FOR STATISTICAL COMPUTING. Viena, Austria. 2014. [acessado em: 26 ago. 2015]. Disponível em:http:https://www.r-project.org.

RODRIGUES, R.F.; ARAÚJO, G.M. Estrutura da vegetação e características edáficas de um cerradão em solo distrófico e em solo mesotrófico no triângulo mineiro. **Bioscience Journal**, v.29, n.6, p.2013 2029, 2013.

SANTOS, S.R.M.; MIRANDA, I.S.; TOURINHO, M.M. Análise florística e estrutural de sistemas agroflorestais das várzeas do rio Juba, Cametá, Pará. **Acta Amazonica**, v.34, n.2, p.251 263, 2004.

SANTOS, G.C.; JARDIM, M.A.G. Florística e estrutura do estrato arbóreo de uma floresta de várzea no município de Santa Bárbara do Pará, Estado do Pará, Brasil. **Acta Amazonica**, v.36, n.4, p.437 446, 2006.

SILVA, G.R.; SILVA, P.A.L.; SILVA, S.B.; SILVA JUNIOR, M.L.; GAMA, M.A.P.; FERNANDES, A.R. Eletrochemical changes in Gleysol of the Amazon estuary. **Revista de Ciências Agrárias**, v.58, n.2, p.152 158, 2015.

SMITH, A.R.; PRYER, K.M.; SCHUETTPELZ, E.; KORALL, P.; SCHNEIDER, H.; WOLF, P.G. A classification for extant ferns. **Taxon**, v.55, n.3, p.703 731, 2006.

VENTUROLI, F.; FELFILI, J.M.; FAGG, C.W. Avaliação temporal da regeneração natural em uma floresta estacional semidecídua secundária, em Pirenópolis, Goiás. **Revista Árvore**, v.35, n.3, p.473 483, 2011.

WITTMANN, F.; HOUSEHOLDER, E.; PIEDADE, M.T.F.; ASSIS, R.L.; SHÖNGART, J.; PAROLIN, P.; JUNK, W.J. Habitat specifity, endemism and the neotropical distribution of Amazonian white-water floodplain trees. **Ecography**, v.36, n.6, p.690 707, 2013.

WITTMANN, F.; JUNK, W.J. Sampling communities in Amazonian white-water forests. **Journal of Biogeography**, v.30, n.10, p.1533 1544, 2003.

WITTMANN, F.; SCHÖNGART, J.; MONTERO, J.C.; THOMAS, M.; JUNK, W.J.; PIEDADE, M.T.F.; QUEIROZ, H.L.; WORBES, M. Tree species composition and diversity gradients in white-water forests across the Amazon Basin. **Journal of Biogeography**, v.33, n.8, p.1334 1347, 2006.