Floristic Diversity in Secondary Forest under Munduruku Indigenous Agroextractivism

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Authors’ contributions

This work was carried out in collaboration among all authors. Author PCO performed the floristic analyses and wrote the article. Author BCOQS made the exsiccat and conducted the taxonomic identification of plants. Author EG did the logistic support. All authors read and approved the final manuscript.

ABSTRACT

Aims: Knowledge is currently low about composition, richness and abundance of native plant species from secondary forests in traditional communities in the Tapajós River Basin, Western Amazon. These forests are of great importance to indigenous populations being niches of resistance to the advances of monocultures. The objective of this work was to evaluate the floristic composition of a secondary forest with typical indigenous extractive interventions.

Study Design: The secondary forest studied located in indigenous Village. This forest had 15 years of natural regeneration and was therefore an anthropized forest, where the indigenous people removed wood, fibers, oils and fruits, thus characterizing the agroextractivism on this environment and a very particular floristic composition always in evolution.

Place and Duration of Study: The research was in Santarem city, Pará state, in Ipaupixuna Village (02°32’46” S, 54°20’15” W) between June 2019 to December 2019.

Methodology: The research had a descriptive approach for floristic study, but in the same time had

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Keywords: Amazon; forest structure; Tapirira guianensis; Fabaceae.

1. INTRODUCTION

The forest biodiversity in the indigenous territories of Tapajós river Basin is not only important because of the biological or ecological approach, but essential as a locus of agroextractivism activities for survival and production of many indigenous families in remote areas of Amazon Biome. Thus, knowing the floristic richness of secondary forests exploited by these traditional peoples is important for the botanist, forest and evolutionary knowledge of these ecosystems over time under specific anthropic pressures. This interaction, indigenous and exploited forest, results in a peculiar design or structure of the forest, whose assumed characteristics reflect what they exploit, as well as the competition for light, nutrients and water among the least exploited species. According to [1], forests are indeed a cultural product of agroextractives exploitation, but the structure that these forests assume is the result of multiple ecophysiological behaviors of the species that make up such a forest, where species with greater physiological plasticity dominate the environment then outline the architecture of the forest. Micro climatic alterations in secondary forests caused by the removal of tree species of timber for the construction of indigenous houses or the making of boats among other uses, eventually generate some clearings in the forest, which are true hot spots of light and are these hot spots of light that eventually determine the species that will germinate and develop there [2], usually the most tolerant to excess light, i.e. group of pioneer species. And so successively new clearings develop and with this the structure of secondary forests begins to be drawn from the continuous change of their floristic composition and consequent forest architecture. In indigenous areas, the intact (primary) forest landscape interacts with the secondary forest clusters often forming a continuum whose function as ecological corridors is important for the uninterrupted traffic of animals important to seed dispersal and hunting as well. Thus, these secondary forest clusters always have a dual function, that of the farming and the forest, that is, the cultivation area and the harvest area in the same space. As well pointed out by [3], studying the Wajãpi indigenous groups in Amapá, there is the natural intertwining between fields (farming) and secondary forests, and it is this intertwining that characterizes the historical and cultural Amazonian agro-extractive activity. According to [4] many species derived from agroextractivism were domesticated by traditional populations, mostly indigenous, long before European colonization. Such domestication may be at the species or landscape level according to [5], although only the first type is currently accepted by modern markets. The farming fields on indigenous territory are typically planted with cassava, the main agricultural cultivation of indigenous people in the Tapajós river Basin, as well as corn, beans and some Cucurbitaceae, all domesticated plants. These agroecosystems (farming) bordering secondary forests, typically called capers, emerged from the system of cutting and burning forests, suggesting the existence of seed bank and asexual propagules still alive in these soils. These agroecosystems returns after 5 years of use with agricultural crops to be forests that regenerate over time. However, will the forest structure, function and floristic composition remain the same? Certainly, profound quantitative and qualitative changes take place so that the open and complex system [6,7] here called secondary forest, remains sustainable. In other words, the evolution of the secondary forest system, or its regeneration, changes over time due to the anthropic

Results: A high abundance was found for Tapirira guianensis Aubl followed by Buchenavia huberi Ducke and Bellucia grossularioides (L.) Triana. Fabaceae was the family of greatest quantitative expression in this 15-year-old secondary forest in indigenous landscapes followed by Arecaceae.

Conclusion: The secondary forest studied of 15 years of natural regeneration and random anthropogenic interventions by agroextractivists activities of Munduruku Indigenous people showed medium floristic richness and low floristic diversity. Interventions to enrich this secondary forest with plant species with high economic potential can bring environmental and economic benefits to these indigenous people.

7 Results of regression analysis. The parameters evaluated were: 1. Species abundance, 2. Floristic Richness; 3. Plant diversity measured by the Jentsch Mixing Coefficient; 4. Relations between Circumference & Height of trees. The size of the sampled area was 1 (one) hectare of secondary forest.

8 Among the least exploi...
interventions that are necessary on the flora and, therefore, the projection of a floristic composition becomes unpredictable every time new cycle. According to Open and Complex Systems Theory, every open system and secondary forest are one of them, as it exchanges matter and energy with its surroundings, evolves sustainable after disturbances when it alters its operating patterns to adjust to such changes. These adjustments may be modification of floristic composition and species abundance for example. Thus, the intensity of agroextractives activity over a forest can be considered as a chaos (entropy) promoting agent in the open system, so this activity becomes the great modeler of the floristic evolution of secondary forests in the Amazon. In this sense, this research had the general objective of characterize and analyses aspects of the structure and floristic composition of a secondary forest used by Munduruku indigenous peoples in the Santarém plateau under agroextractivism pressure. The specific objectives were identifying the Species abundance, Floristic Richness, Plant diversity and relations between Circumference of trees & Height of trees. The working hypothesis was that agroextractivism historically practiced by the indigenous population on forests changes over time the structure and floristic composition.

2. MATERIALS AND METHODS

2.1 Social-economic Aspects

An expressive group of the Indigenous ethnic group of Munduruku, live in a territory situated in Santarém City, Pará state/ Brazil which is formed by 4 villages - Açaizal Village, Cavada Village, Ipaupixuna village and Amparador village. These indigenous people have lived on these lands for decades and suffer from a lack of measures on the part of the Union, which transformed the territory into the epicenter of a series of rights violations, largely associated with the expansion of the soy monoculture, deforestation, destruction of sites archaeological sites, silting of streams, contamination of the air, fauna and flora by pesticides - including the death of animals - attempts at grilagem, threats and intimidation, among other problems.

2.2 Forest and Soil Aspects

The secondary forest studied located in the Ipaupixuna Village (02°32’46” S, 54°20’15” W). The forest had 15 years of natural regeneration and was therefore an anthropized forest, where the indigenous people removed wood, fibers, oils, almonds and fruits, thus characterizing the agroextractivism on this forest. The soils under the secondary forest (Capoeira) are clayey sandy loam soil with black Indian soil (TPI) patches. The analyses of soil showed pH=4.7>; pH KCL=4.4>; «Aluminums 2.7 Cmol C/Kg; Phosphor 16,79 mg/Kg and Potassium 27 mg/kg.

2.3 Parameters Evaluated

The parameters evaluated in the research site were: 1. Species abundance, which corresponds to the number of individuals (trees) / species, as well as the number of individuals (trees) / family; 2. Floristic Wealth, which corresponds to the number of species found in the sampled area (1 ha); 3. Plant diversity measured by the Jentsch Mixing Coefficient (QM), where QM = S / N, where S is number of sampled species and N is the total number of individuals (trees); 4. The relations between Circumference of trees & Height of trees. The size of the sampled area was 1 (one) hectare of secondary forest where only tree individuals with Chest Height Circumference (CHC) > 30 cm were quantified. For taxonomic identification of the plants were produced exsiccates of tree species for later comparison with exsiccates belonging to the collection of local and virtual herbaria.

2.4 Statistical Analyses

The statistical analyzes performed were Regression analyzes to verify the best mathematical model that explained the relation between circumference and plant height of the species studied through the BioEstat 5.0 program [8].

3. RESULTS AND DISCUSSION

The results showed that in the studied secondary forest of 15 years of natural regeneration with extractive anthropogenic (indigenous, in this case) and random over time interventions, a high abundance (number of trees / species) was found for Tapirira guianensis Aubl. species. followed by Buchenavia huberi Ducke and Bellucia grossularioides (L.) Triana (Fig. 1).

Thus, the predominance of T. guianensis in relation to the other species found suggests a more efficient ecophysiological behavior regarding the use of light, or water and / or soil minerals in relation to other species with low
abundance, such as *Dipteryx odorata* (Aubl.) Willd.; *Onychopetalum amazonicum* R. E. Fries or *Zygia sanguinea* (Benth.) L. Rico. Whereas prolonged periods of drought in the region gradually increase occurrences, so native tree species such as those that develop C3-type carbon fixation cycles must be practicing some strategy of tolerance to water stress to increase area colonization and consequent abundance, as *T. guianensis*. This early secondary species is tolerant to acidic, sandy and floodplain soils [9], which is the case in the study area. However, little is known about its ecophysiological behavior. Associated with the high abundance of

Fig. 1. Abundance (number of trees / species) in 15-year-old secondary forest in Aldeia Ipaupixuna, Santarém, Pará, Brazil

1 - *Plathymenia foliolosa* Benth.; 2 - *Attalea speciosa* Mart. ex Spreng.; 3 - *Trattinnickia burseraefolia* (Mart.) Willd.; 4 - *Crataeva benthamii* Eichler; 5 - *Buchenavia huberi* Ducke; 6 - *Dipteryx odorata* (Aubl.) Willd.; 7 - *Onychopetalum amazonicum* R. E. Fries; 8 - *Zygia sanguinea* (Benth.) L. Rico; 9 - *Euterpe edulis* Martius; 10 - *Nectandra* sp.; 11 - *Stryphnodendron* sp.; 12 - *Bellucia grossularioides* (L.) Triana.; 13 - *Byrsonima* sp.; 14 - *Byrsonima crispa* A. Juss.; 15 - *Attalea maripa* (Aubl.) Mart.; 16 - *Ceiba pentandra* (L.) Gaertn; 17 - *Himatanthus sucuuba* (Spruce ex Müll. Arg.) Woodson.; 18 - *Tapirira guianensis* Aubl.; 19 - *Adenanthera pavonina* L.; 20 - *Lacmellea arborescens* (Müll. Arg.) Markgr

Fig. 2. Family Abundance (Number of individuals / family) in 15-year secondary forest in Aldeia Ipaupixuna, Santarém, Pará, Brazil

1 – *Anacardiaceae*; 2 – *Annonaceae*; 3 – *Apocynaceae*; 4 – *Arecaceae*; 5 – *Burseraceae*; 6 – *Capparidaceae*; 7 – *Combretaceae*; 8 – *Fabaceae*; 9 – *Lauraceae*; 10 – *Malpighiaceae*; 11 – *Malvaceae*; 12 – *Melastomataceae*
T. guianensis, popularly known as wood pigeon, it is still possible to extract tannin from the species, as well as to use it in meliponiculture. Our results are in accordance with [10], that suggested also Tatapiririca (Tapirira guianensis) as others species like Tucumá (Astrocaryum vulgare), ingá (Inga heterophylla), sapucaia (Lecythis pisonis), açai (Euterpe oleracea), matamatá-vermelho (Lecythis idatimon), and sucuuba (Himatanthus sucuuba) as a potential species to use on agroforest systems cause a great economic importance. The importance of a floristic survey far beyond botanical gain is the socioeconomic gain of research; in other words, we can now point out to the indigenous people of the Ipaupixuna Village new possibilities for economic exploitation of untapped species such as T. guianensis. Thus, the greater abundance of T. guianensis in the studied landscape ends up modeling the structure of the secondary forest and its architecture and canopy roughness as a function of its crown and branch. In this case, the modeling of the secondary forest studied is not caused by the cultural issue, since there is no exploitation of this species by the indigenous, but only ecophysiological issues are determinant for its structure. Thus, at a macro level, we can say that selective extractivism shapes secondary forests, but at a micro level, the ecophysiological behavior of the different species determines such a structure. When we now observe the results of the Abundance of families in the study area, then in descending order the following botanical families stand out as shown in Fig. 2: Fabaceae; Arecaceae; Apocynaceae and Malpighiaceae. Although 12 botanical families were observed, only these four families are the most abundant, and therefore there is a predominance in the secondary forest studied of 1/3 of the total botanical families surveyed, therefore, not equitable, since the other 2/3 of the botanical families have low abundance (1 tree / family). Fabaceae was then the family of greatest quantitative expression in this 15-year-old secondary forest or of natural regeneration in indigenous landscapes in this studied as well as observed for other authors [11,12]. Considering that Fabaceae is a family where most genera through their roots do symbiosis with nitrogen-fixing soil bacteria, then this behavior guarantees a prominence in relation to the other families that do not. Nitrogen uptake of the soil by rhizosphere where this symbiosis exists, offers a metabolic economy for plants regarding protein synthesis in relation to those species that do not make such determining the process of colonization area. This may explain, for example, the greater abundance of this botanical family, Fabaceae in the forest studied and not anthropic cultural issues as stated by [1]. Again, here the ecophysiological strategy of tree species in secondary forest vegetation ends by delineating throw quantification of botanical family abundance, the structure of the forest. Thus, this research points out the Tapirira guianensis species as a potential species quantitatively for new forms of sustainable use of it, as well as the Fabaceae family as an important family for the provision of ecosystem services, specifically related to nitrogen in soils. As for the floristic richness were found in 1 hectare of secondary forest of 15 years of age, 20 species of plants with circumference above 30 cm, that is, approximately 500 m² was 1 species. Compared to the 40 years old secondary forest studied by [14], where he found 81 species, we can say that our results are in the expected average, suggesting similar secondary forest evolution processes in the Amazon Biome. The possibility of enriching these secondary forests with species of high economic value such as cumarú, chestnut, cocoa, cupuaçu, andiroba among other species is always welcome in the management of capoeiras and increasing income of agro-extractive indigenous families, as [15] also observed in his studied about potential of secondary forest with Euterpe oleracea enrichment. Such action is not yet intensified by these traditional populations, who do so in some way through knowledge passed down from generation to generation in a non-systematic but rather random way. The enrichment of these secondary forests would increase species richness and abundance at the same time, with gains beyond the structural ones, i.e. with gains in biomass and carbon stock in indigenous landscapes. But this enrichment could be driven by economic markets. In accordance with [16], Q’eqchi’ settlement patterns during the late nineteenth and twentieth centuries were largely driven by exogenous economic activity rather than carrying capacity. In the Amazon, this same exogenous international pressure exists, specifically over Euterpe oleracea (açai). Such secondary forests enriched becoming productive over time, they can be used as territory demarcation tools, as they are economically active areas. Considering that the studied area is an area of conflict over the territory, where indigenous and soy / cattle producers discuss the limits of their lands, then this technological model of secondary capoeira enrichment could be an instrument of indigenous empowerment in these scenarios in Tapajós river Basin. Regarding the
relationships between tree circumference and tree height, Figs. 3, 5 and 6 generally point to geometric and exponential relations respectively for *Tapirira guianensis*, *Euterpe edulis* and *Himatanthus sucuuba*, which shows an increase in circumference of the exponential or geometric stem when the tree height increases, that is, secondary growth increment (circumference) as a function of surface increment (height).

Such mathematical, geometric and exponential relationships demonstrate that the physical environment (light, water and nutrients) within the secondary forest is conducive to the growth of these tree species in secondary forest, in accordance with [17]. However, for *Bellucia grossularioides*, this relationship was already more tenuous, that is, linear (Fig. 4). And finally when we see the results of Jentsch Mixing Coefficient equal a 0.078, than the floristic diversity is very low in the secondary forest studied as a result as a binomial selected agroextractivism + plant species more efficient physiologically in the use of natural resources in the indigenous landscapes. Therefore, it is concluded that an anthropic intervention to increase the floristic diversity of the environment, in this case the secondary forest, may be

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**Fig. 3. Geometric behavior between the circumference (cm) of *T. guianensis* Aubl. trees and their height (m)**

**Fig. 4. Linear behavior between the circumference (cm) of *Bellucia grossularioides* (L.) Triana trees and their height (m)**

**Fig. 5. Exponential behavior between the circumference (cm) of *Euterpe edulis* trees and their height (m) in 15-year secondary forest**

**Fig. 6. Exponential behavior between tree circumference (cm) of *Himatanthus sucuuba* and their height (m) in secondary forest of 15 years**
economically useful to these traditional peoples, which may be characterized by the enrichment of these capoeiras. It is noteworthy here that the secondary forest from its natural regeneration processes can no longer maintain high levels of floristic diversity, probably due to erosion of the reproductive propagules, seeds or roots of the site. The disappearance of these structures causes over time the erosion of certain species in the environment and almost always the predominance of another more aggressive species in the process of colonization of areas, represented here by *T. guianensis*.

4. CONCLUSION

The secondary forest studied about 15 years of natural regeneration and random anthropogenic interventions by agroextractivists activities practiced by the Munduruku Indians showed medium floristic richness and low floristic diversity. The species *T. guianensis* had the highest abundance among all species, as well as the largest abundance of botanical families were *Fabaceae* and *Arecaeae*. The studied Forest secondary is currently in the phase of secondary and primary growth of the stems, respectively circumference and plant height, intensively, given the relationships with exponential and geometric characteristics found between these parameters. The binomial selected agroextractivism and plant species more efficient physiologically with the use of natural resources in the indigenous landscapes is responsible for the low floristic diversity. Interventions to enrich this capoeira with plant species with high economic potential can bring environmental and economic benefits to the village. Finally, it emphasizes if the exacerbated predominance of *T. guianensis* over other species, signaling species with high resilience to water stress and dominance in the studied area, which clearly brings changes in the floristic composition of secondary forests.

CONSENT

All authors declare that written informed consent was obtained from the leader of indigenous people, Sir Manoel Batista da Rocha, for publication of this research.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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