Spatial distribution pattern and diameter structure of *Protium* Burm. f. in Iratapuru river sustainable development reserve, Amapá, Brazil

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**ABSTRACT.** The present work aims to determine the spatial distribution pattern of *Protium* Burm. f and the diametric structure of these species in a dense tropical submontane rainforest along the Sustainable Development Reserve (SDR) of the Iratapuru river. The area of study was divided into three plateau compartments called Mane Preto Sierra, Banco Grande Sierra and Alaska Sierra. In each plateau compartment it was settled a single area transect with 1,000 x 20 m, where DAP $\geq$ 10 cm of the entire *Protium* population within the transects was measured. The data was processed in the specific software Mata Nativa 2. There were inventoried *Protium tenuifolium*, *Protium alstonii*, *Protium polybotryum* subsp. *blackii* and *Protium paniculatum* var. *riedelianum*. Most individuals concentrated in smaller diametric classes, decreasing progressively to a lesser extent in larger classes. It can be concluded that the population has medium size and its vertical structure is characterized by the presence of three strata, however, its phytocenoses is defined by two clear constants: the first groups individuals of up to 15 m of height and forms the uniform and dominant stratum; the second is composed by emerging up to 35 m high and whose diameter structure shows a population in dynamic balance.

**Keywords:** Forest Amazon; occurrence; breu.

**Introduction**

Amazon Forest constitutes the primary dispersion center of *Protium* Burm. f., the main gender of Burseraceae, with its species spread over tropical and subtropical regions in South America, part of Europe, Asia and Oceania (Fine, Daly, Muñoz, Mesones, & Cameron, 2005). This gender has large distribution in South America, with a great history of use and many species adapted to each type of environment. These species are generally difficult to be identified in field and many of them are frequently reclassified, mainly for being described using untrustworthy characters (Daly, 1987).

*Protium* species, commonly known as breus, are found scattered across almost the whole State of Amapá, according to a survey conducted at the Amapá Herbarium (Hamab). The largest records of...
occurrence of these species are located at the southern end of the state. They are usually large
trees (10 to 31 m high), which present cylindrical
trunk, with buttresses or not, and exude a clear,
sticky, aromatic, volatile resin used in the varnish
industry, boat caulking and as insect repellent (Daly,
1987; Otuki, Vieira-Lima, Malheiro, Yunes, & Calixto,
2004). Moreover, in popular medicine the
Gum and resin oils of *Protium* ssp. are used for many
purposes, such as in stimulants, anti-ulcers and anti-
inflammatories (Siani et al., 1999). Its leaves are
alternate and rarely opposite, compodes and odd
pinnate and the flowers small and unisexual, off
cream, yellow green or red colour; the fruits are
drupe and more rarely capsules (Souza & Lorenzi,
2008).

The community of São Francisco do Iratapuru,
located around the Iratapuru river Sustainable
Development Reserve (SDR), live off the
sustainable exploitation of *Bertholletia excelsa* Bonpl.,
Lecythidaceae, (Brazil nut); *Copaifera duckei* Dwyer,
Fabaceae, (copaiba) and *Protium* ssp. (white breu)
(resin); besides the creation of small animals and
artisanal fishing for subsistence. They are old
residents located in the extreme south of the
conservation unit, who develop their extractive
activities within the latter, where they established
‘colocations’ that serve as exploration units. Most of
these areas are certified.

In this sense, this work aims to determine the
spatial distribution pattern of Protium species and the
diametric structure of these species in stretches of
dense tropical submontane rainforest along the
Iratapuru river Sustainable Development Reserve
(SDR), and then propose solutions for the sustainable
use and management of this natural resource.

### Material and methods

#### Area of study

The Iratapuru river SDR, which covers 806,184
hectares, was created by the Decree-Law n. 392,
from December 11th, 1997 and is located in the
Southeast region of Amapá state, covering the
cities of Laranjal do Jari, Mazagão and
Pedra Branca do Amapari, being limited by Waïapi
Indigenous Land to the North, Jari river’s course to
the West and part of Jari Ecologic Station to the
South (Figure 1) (Rabelo, 2004). It is positioned in a
region of great importance to Amapá Biodiversity
Corridor, because strategically connect
Tumucumaque National Mountain Park to Cajari
river Extractive Reserve (Pereira, Pinto Sobrinho, &
Costa Neto, 2011).

![Figure 1. Location of sampled areas ('Mane Preto', 'Banco Grande' and 'Alasca') in the three field campaigns carried out in the Iratapuru River Sustainable Development Reserve (SDR).](image)
Spatial distribution and structure of Protium

Vegetation

The dominant vegetation is the Dense Ombrophilous Submontane Forest of ‘Terra Firme’ and Alluvial. The Terra Firme Forest corresponds to the highest proportion in the SDR, being remarkable for its individuals of high size and diversity of species with great economic value as Bertholletia excelsa; Copaifera duckei; Dinizia excelsa Ducke - Fabaceae (angelim), Dipterix odorata (Aubl.) Willld. - Fabaceae (cumaru) and others. The alluvial forest, better known as the flooded forest of ‘igapó’, borders the main clear watercourse formed by the Iratapuru River, with its origin in the Guinean shields. They are forests of low size, particularly Carapa guianensis Aubl. - Meliaceae (andiroba), Virola surinamensis (Role ex Rottb.) Warb. - Myristicaceae (virola), Bombax paraensis Ducke - Malvaceae (Mamorana) and Pentaclethra macroloba Willld. O. Kuntze-Fabaceae (pracaxi) (Carim et al., 2015).

Population structure

There were realized three field campaigns between 2012 and 2013. The area was divided into three compartments in North-South direction bordering Iratapuru river. The plateau areas were identified according to their local names, which are: Anani/Mane Preto Sierra (MP), 9 km away from San Francisco village on waterways and inland routes; Banco Grande Sierra (BG), 18 km away and Alaska Sierra (A), 26 km away. All of them are placed in altitudes between 200 and 300 m.

For the quantitative survey regarding the structural description of Protium population in the area, in each plateau compartment it was settled a single area transect with 1000 x 20 m (2 hectares), where there were sampled live individuals and taken height data and DBH (diameter at breast height) ≥ 10 cm. For the measurement of individuals it was used a metric tape and the total height was estimated with a 6 m rod marked in every meter. There were used wooden stakes to mark the parcels, and its limits were set with cotton strings, all of them being georeferenced with a GPS Garmin, using the UTM datum SAD`69 coordinate system.

Spatial distributions

Payandeh Index (Pi): Estimating this index, it is obtained the species’s aggregation degree through the relationship between the variance of the number of trees per parcel and the average of the number of trees (Payandeh, 1970), according Equation 1:

\[
P_i = \frac{x^2}{M_i}, \quad M_i = \frac{\sum_{j=1}^{n} n_j}{u_f}, \quad s_i^2 = \frac{\sum_{j=1}^{n} n_j^2}{u_f} - \left( \frac{\sum_{j=1}^{n} n_j}{u_f} \right)^2
\]

where:

- \(P_i\) = ‘Payandeh index’ for the i-th species;
- \(s_i^2\) = variance of the number of trees of the i-th species;
- \(M_i\) = average of the number of trees of the i-th species;

Classification. \(P_i = \) Spatial Distribution Pattern Classification of species individuals, which obeys the following scale:

- \(P_i < 1\): random distribution or no grouping;
- \(1 \leq P_i < 1.5\): tendency to grouping;
- \(P_i > 1.5\): aggregated distribution or grouped.

Species identification and characterization

The identification and morphological study were made based on photographic registry of fruit and flowering branches of these species individuals identified by the Burseraceae specialist, Dr. Douglas Daly from the New York Botanical Garden, USA, and incorporated to the Hamab in the Amápá Scientific and Technological Research Institute (Iepa). Through the vouchers (Protium altsonii Sandwith - 510; Protium polybotryum (Turez) Engl. subst. blackii (Swart) Daly - 513; Protium paniculatum var. riedelianum (Engl.) Daly - 512 and Protium tenuifolium (Engl.) Engl. - 511). The data collected in field was digitized in Excel to be processed in the specific Mata Nativa 2 software for evaluation of diametric and spatial distribution.

Results and discussion

There were collected and identified four species from Protium, which were: Protium altsonii Sandwith; Protium polybotryum (Turez) Engl. subst. blackii (Swart) Daly; Protium paniculatum var. riedelianum (Engl.) Daly and Protium tenuifolium (Engl.) Engl.

There were sampled 721 live Protium individuals, from which P. tenuifolium presented the highest number of individuals, 481, distributed in all areas, with density of 80.1 ind ha⁻¹, average of 21.21 DBH, reaching the total basal area of 22.41 m²; followed by P. altsonii, with 143 individuals, registered in Mane Preto and Banco Grande complex, with density of 23.3 ind ha⁻¹ and average of 22.67 DBH, totaling a basal area of 3.84 m². Only P. polybotryum subst. Blackii, with 4 individuals, occurred in only one area, Mane Preto complex, with average of 13.85 DBH and total basal area of 0.07 m² (Table 1).
For the gender, it was registered absolute density of 121 ind ha⁻¹ and total basal area of 33.32 m², approximately. Figure 2 shows the individuals distribution in different height classes, with expressive concentration of individuals until 10 m high, reaching around 70% of the total sampled. Only 44 sampled individuals (6%) exceeded 20 m of height. It is verified that most individuals are grouped until 15 m of height, with approximately 86% of the total. Approximately 13% of individuals were positioned between 15 and 25 m of height and only nine individuals are higher than 25 m, approximately 1% of the total sampled.

The diametric distribution of the sampled population presented an inverted ‘J’ shape. Most individuals concentrated in smaller diametric classes, decreasing progressively to a lesser extent in larger classes (Figure 3), highlighting the typical pattern for mature forests in natural regeneration (Blanc, Maury-Lechon, & Pascal, 2000).

Among trees, the individual growth is usually evaluated, among other variables, mainly for the diametric increase or for the basal area, being these reliable param to indicate the state of conservation of a forest. The study of these param points the growth and the changes occurred in its composition and structure.

In general, it was registered a high density in the gender population, predominating the Protium altsonii and P. tenuifolium species. Possibly, this finding must be related to the phytophysiognomy itself and the conservation degree of the environment. Thus, the high population of the gender in the SDR can be a result of the relative absence of anthropic activities. The specialized morphology and the great competitive ability of P. tenuifolium favor its adaption to non-disturbed environments (Daly, 1987).

The constant number of trees with the same structure by class interval would be economically better. However, this is an uncommon situation in tropical forests. From a biological point of view, the structure of an uneven-aged forest tends to respond to a pattern in an inverted ‘J’ (Leuschner, 1984), typical of forests in dynamic balance, where most individuals take the first diameter classes. This is a fact that was confirmed by Carim et al. (2015), considering the same area of study.

In a general sense, the studied population can be considered to be medium-sized, with a minimum of 4 m and maximum of 35 m. In the same region, Carim et al. (2015) registered in his study a vegetation of high size with well-stratified and emergent individuals above 35 m.

The Protium species are well distributed in the forest profile. Nonetheless, they contribute differently when it comes to the number of individuals and sociological position they occupy. P. altsonii and P. tenuifolium presented individuals in all classes, being the only ones to present individuals higher than 35 m. P. paniculatum var. riedelianum registered individuals with 25 m of height. P.
polybotryum subst. blackii placed its four individuals between 5 and 11 m of height.

The diometric distribution of the sampled population presented the same pattern found in study developed with Protium pallidum Cuatrec in a Terra Firme Tropical Forest in Resex Cajari, in Amapá (Rudiger, Siani, & Veiga Junior, 2007) and in Monu, Pará State (Daly, 1987) Balanced diometric distributions, where the ability to recruit compensates mortality throughout time, is the greatest guarantee for the species existence and survival. This distribution ensures that, in the dynamic process of the forest, the species renews itself, ensuring the dynamic balance of the population (Lamprecht, 1962; Felfili, 1997).

Protium species present high importance values in tropical forests. This is directly related to the large basal area and/or density of its individuals, influencing the management for commercial purposes, being able to be worked on individually or along with other species (Assis, Pereira, & Thomaz, 2004; Pereira, Cordeiro, & Araújo, 2004; Carim, Guimarães, & Tostes, 2013). Certainly, there seems to exist a strong tendency for the individual distribution curve to vary along South-North axis, decreasing the amount of individuals as it advances towards the upwind of Iratapuru river heading North. Anyhow, the species tend to assume different proportions along the analyzed stretch, possibly influenced by its own adaptive characteristics, what favors its large distribution and therefore its status in phytocenoses.

Abiotic factors

Possibly, factors connected to physical aspects in the SDR are influencing the Protium species distribution. Aspects related to height and lithological characteristics differences may be interfering in the adaptation of these species.

It is verified a mosaic of different lithological groups, occupying different gradients in South-North way in the SDR. In the Southern stretch of Mane Preto complex, silstone from Trombetas Formation of Silurian age is predominant. In the North flank of Banco Grand complex, it emerges shales interspersed with silstones and sandstones of Curú Formation (Devonian). In Alaska complex, located in the Northern portion of the area, sandstones from the basal portion of Trombetas formation are predominantly found.

In eastern Amazon, the substrates derive mainly from stones formed in Archean (Amazon craton), which are extremely weathered and nutrient-poor. These factors cannot be analyzed individually, certainly, the low fertility in soils is common and responds in the same way for plants communities. Therefore, other factors contribute for the predominance of determined groups, associated or not to anthropic action. Preliminary data of the soil of the Submontane Forest in Iratapuru river SDR points soils with high to medium phosphorus concentration, high organic matter content, very high acidity level and aluminum saturation, high cation exchange capacity and macro nutrients poverty.

In this sense, more detailed studies on the influence of physical and chemical factors of the soil must be considered for a more concrete answer about the operating mechanisms which influence in the distribution of Protium species and if its effects are limiting. There is an increasing evidence that the distribution of floristic communities of Amazon region is very heterogeneous and related to soil conditions (Salovaara, Thessler, Malik, & Tuomisto, 2005). The variations on the chemical composition of soils found in different analyzed plateaus indicates the low demand of Protium species regarding this characteristic. In a certain way, populations keep themselves balanced along the analyzed axis, with progressive increase in North direction.

Spatial distribution

Using the Payandeh index, it was verified that the distribution pattern to all species in the studied area tended to grouping, contrary to study developed by (Rudiger et al., 2007) in which it was considered a random distribution for P. pallidum, applying the Morisita index (MI).

Environmental differences, bio-ecological factors (predation, mortality, dispersion and birth rate) and soil and climate conditions are the main responsible for the random distribution pattern of species (Carvalho, 2002). Whereas, the grouping characteristic of the species is possibly related to its high annual seeding production, to the dispersion pattern of its species and to the absence of specific predators for them.

A plant species, although it presents a great occurrence in a determined area, its spatial distribution in different size classes can be very irregular. The grouping degree can present different values, with plants from lower size classes presenting tendency to grouping and plants from the higher size classes possibly occurring in a strongly grouped form (Carvalho, 1983).

To Kanieski et al. (2009), the spatial distribution inside the community is an important characteristic for the planning of management measures and conservation of forest formations. Anjos, Mazza,
Santos, and Delfini (2004) also confirm that the knowledge regarding the spatial distribution pattern can give information on ecology, subsidize the definition of management and/or conservation strategies, help in sampling processes or simply clarify the spatial structure of a species. In this work, it was verified that Protium species are established throughout a geomorphological gradient and lithologically different. However, it does not reflect in a limiting way for the establishment of these species to varied environmental conditions. These are species which adapt to variations, even coming to assume dominant patterns in the environment.

More profound studies on species autoecology, including its phenophases and reproductive biology and its abiotic relations must offer more profound answers on the operating mechanisms for the success of these species in tropical environments.

**Conclusion**

Protium populations present medium size and its vertical structure is characterized by the presence of three strata, however, its phytocenoses is defined by two very clear constants; the first groups individuals with 15 m high and forms the uniform and dominant stratum, the second is composed by emergent with up to 35 m of height.

The diameter structure highlights a population in dynamic balance, where the recruitment ability compensates mortality, proven by the diametric distribution curve of individuals. The Protium population is distributed by the Payandeh index tending to grouping in the Iratapuru river SDR.

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**References**


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