Research Article

Population structure and spatial distribution of *Guadua weberbaueri* Pilg. in native and anthropized forests in the western Brazilian Amazon[1]

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ABSTRACT

Brazilian forestry laws do not provide specifications for the management of bamboo-dominated forests. This study aimed to characterize the bamboo population structure, its spatial distribution and the effects of shoot density on the diversity and density of dominant tree species in the southwest of the Amazon Rainforest. An inventory was carried out in forest with and without anthropogenic interference, and the height and diameter at breast height of the trees were measured, as well as the diametrical, vertical and spatial distribution of the shoots. The bamboo diametrical distribution presented an irregular behavior in the two areas under study and the vertical distribution behaved irregularly in the forest without anthropization, in an asymmetric negative way when compared to the forest that suffered anthropogenic disturbance. The bamboo spatial distribution did not show changes in its aggregate pattern between the studied environments, and its density did not present a significant correlation with the density and diversity of tree species.

KEYWORDS: Bamboo, diversity and density of tree species, primary and secondary forest.

RESUMO

Estrutura populacional e distribuição espacial de *Guadua weberbaueri* Pilg. em florestas nativas e antropizadas da Amazônia Ocidental brasileira

As leis florestais brasileiras não fornecem especificações para o manejo de florestas dominadas por bambu. Objetivou-se caracterizar a estrutura populacional de bambu, sua distribuição espacial e os efeitos da densidade de brotos na diversidade e densidade de espécies arbóreas dominantes no sudoeste da Floresta Amazônica. Realizou-se inventário em floresta com e sem interferência antrópica e mediu-se a altura e o diâmetro à altura do peito das árvores, bem como a distribuição diametral, vertical e espacial dos brotos. A distribuição diametral do bambu apresentou comportamento irregular nas duas áreas em estudo e a distribuição vertical comportou-se de forma irregular na floresta sem antropização, de forma assimétrica negativa quando comparada à floresta que sofreu perturbação antrópica. A distribuição espacial do bambu não apresentou alterações em seu padrão de agregados entre os ambientes estudados, e sua densidade não apresentou correlação significativa com a densidade e diversidade de espécies arbóreas.

PALAVRAS-CHAVE: Bambu, diversidade e densidade de espécies arbóreas, floresta primária e secundária.

INTRODUCTION

The Acre state, located in the western Amazon, Brazil, has approximately 88.1 % of its forest cover preserved (INPE 2023), and its main environments are upland *terra firme* (solid ground) and marginal lands of rivers with periodic floods. They have very distinct geomorphological, pedological and floristic characteristics (Acre 2006). As for the flora, there are ten typologies. The ones that stand out most in the landscape are dense forest, open forest with palm and bamboo, and forest with vines (Daly & Silveira 2008). For the forests with bamboo, Acre holds the largest native bamboo reserve in the world, with more than seven million hectares (Pereira & Beraldo 2007).

Bamboo is the main or secondary element of the understory of primary forests, accounting for approximately 59 % of the state's vegetation cover, with four bamboo species recorded (Ferreira 2014),

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of which *Guadua weberbaueri* Pilger has a wide distribution (Carvalho et al. 2013).

Bamboos of the *Guadua* genus have a life cycle lasting between 28 and 32 years. They are semelparous and monocarpic, meaning they reproduce only once and then die. Reproduction and death events occur synchronously within each population, but not between populations (Silveira 2005, Nelson & Bianchini 2005). After the reproduction or death of a bamboo population, there is a high probability that the neighboring population will also reproduce or die within one or two years (Torezan & Silveira 2000, Nelson et al. 2006). Thus, the sequential pattern of reproduction and death resemble a row of falling dominoes, suggesting that there is information sharing between neighboring populations, even in the absence of evident gene exchange (Carvalho 2010).

The key traits of *Guadua weberbaueri* are its rapid growth (Silvério et al. 2010) and aggressive nature in taking over the understory of native forests (Lima et al. 2012), particularly in areas that are naturally an open canopy (Calouro et al. 2010). These characteristics stem from the fact that bamboo areas create an extensive network of rhizomes underground. At the slightest hint of a clearing in the forest, these rhizomes rapidly produce numerous shoots that quickly fill the available space (Xu et al. 2017). Consequently, bamboo-dominated forests present lower tree densities (Griscom & Ashton 2003), and they may present a reduction of up to 40 % in the number of species sampled in one hectare (Ferreira 2014).

Forests dominated by bamboo are often attributed to anthropogenic causes (Carvalho et al. 2013). However, Oliver & Poncy (2009) discarded this theory, since they describe the *Guadua* genus as neotropical endemic, which has been present in the Amazon long before any human interference.

Bamboo is one of the most important non-timber forest products globally. However, despite its significance, there is limited knowledge about its distribution, particularly in natural forests. Additionally, Brazilian forestry laws lack specific guidelines for managing bamboo-dominated forests, applying the same silvicultural system regardless of the forest type. This highlights the need for studies on this forest typology to better understand bamboo-dominated environments and assess anthropogenic impacts.

This vegetation study is a way to explain how the association of plant species and the floristic diversity of natural forests occur (Silva & Bentes-Gama 2008). Therefore, it aimed to characterize the bamboo population structure and spatial distribution, considering the effects of shoot density on the diversity and density of tree species.

MATERIAL AND METHODS

The study was conducted at the Riozinho da Liberdade extractive reserve (324,905 hectares), located in the Acre state, Brazil (Figure 1), in June 2015. The reserve is located between the 07º30'00''S and 09º00'00''S latitudes and the 71º15'00''W and 72º30'00''W longitudes, covering four municipalities: Cruzeiro do Sul, Marechal Thaumaturgo, Porto Walter and Tarauacá (Brasil 2005).

The climate of the region is characterized as tropical, hot and humid, with annual average temperature of 24 ºC (Ribeiro 1977) and annual rainfall of over 2,000 mm, with a period of drought between May and October (Acre 2006). The predominant soil in the region is the Dystrophic Red-Yellow Argisol (Embrapa 2011), which corresponds to Ultisols (USDA 2014) or Acrisols (FAO 2014).

The study was conducted in areas of open forest with palm and bamboo (OFPB) and anthropized open forest with palm and bamboo (AOFPB), each with an area of 14.5 ha, 5 km away from each other. The AOFPB had no anthropogenic intervention for approximately 30 years, and the OFPB had no history of exploration for over 60 years. As reported by the riverine community, the vegetation was cut clear in the AOFPB, and later fire was set to clean the area to establish the cassava crop (*Manihot esculenta*) for three consecutive years (slash-and-burn system). After this period, the area was abandoned and entered a natural regeneration process. There was no history of anthropogenic intervention in the OFPB.

A forest inventory was carried out in the OFPB and AOFPB using a systematic sampling process with fixed area plots (Péllico Netto & Breña 1997). In each study area, ten rectangular plots of 20 x 50 m (1,000 m²) were allocated, 100 m equidistant from each other. In each plot, the diameter at breast height (DBH; 1.30 m from the soil ground) of all trees with DBH ≥ 15 cm was measured using a diameter

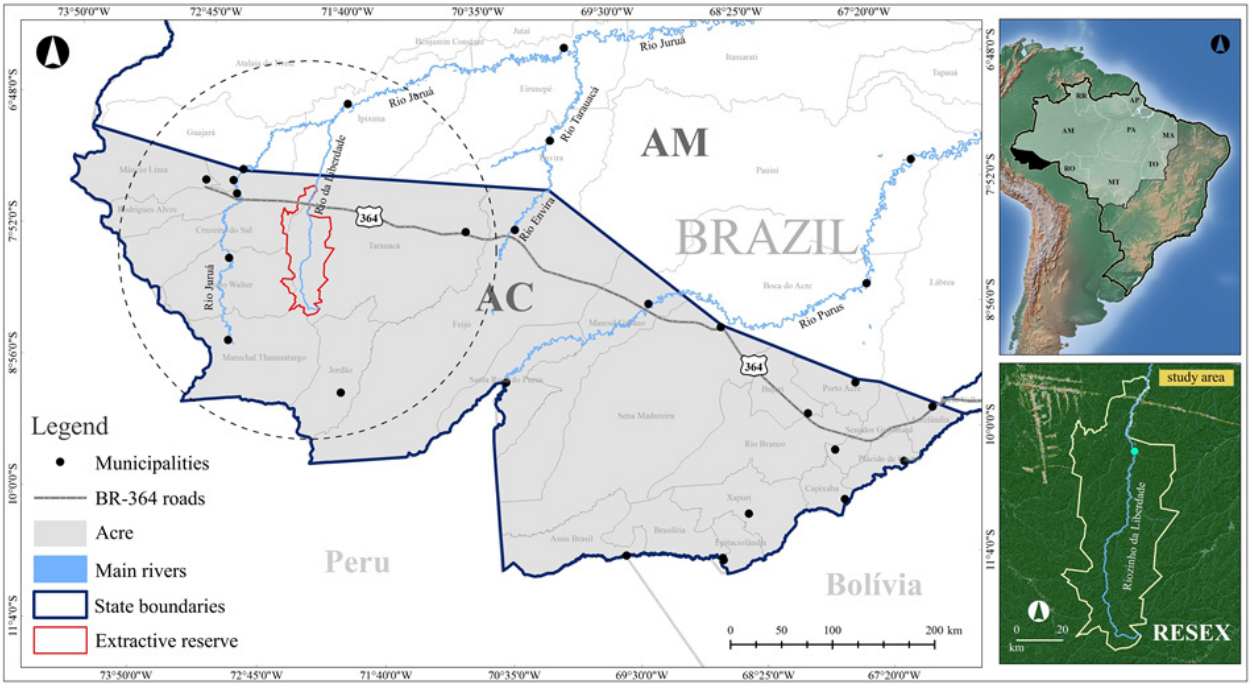

Figure 1. Location of the Riozinho da Liberdade extractive reserve (Acre state, Brazil).

tape. The diameter of all shoots within the plot was measured at 1.30 m from the soil ground. All the inventoried individuals (trees and bamboo) also had their total height measured with the aid of a 15-m telescopic pole, and individuals above 15 m were estimated visually.

The botanical identification was performed by a parataxonomist and, when possible, it was made by collecting fertile plant material, which was used for the preparation of an herbarium specimen and then sent to the Universidade Federal do Acre's herbarium. The botanical identification of *Guadua weberbaueri* was facilitated because the species, in both areas, was in the flowering phase, a rare event when considering its long vegetative phase: 29 to 32 years (Ferreira 2014).

Initially, the absolute density of bamboo shoots was determined based on the number of individuals of the species per unit area. Subsequently, the diametric and height distributions were elaborated using a class amplitude of 2 cm and 2 m, respectively. The t-test at 95 % of probability was applied to verify the significant difference in diameter and height between the study areas.

To better understand the bamboo distribution in diameter at breast height classes, the Liocourt quotient (q) was calculated for the OFPB and AOFPB (Meyer et al. 1961): $q = n_1/n_2 = n_2/n_3 = n_3/n_4 = n_{n-1}/n_n$, where n_1 is the number of individuals in the first diameter class; n_2 the number of individuals in the second diameter class; and n_n the number of individuals in the nth diameter class.

The spatial distribution patterns of the bamboo populations in the OFPB and AOFPB were evaluated using the Morisita index of dispersion (ID; Silveira Neto et al. 1976): $ID = N\{[\Sigma x^2 - (\Sigma x)]/[(\Sigma x)^2 - (\Sigma x)]\}$, where N is the total number of samples and x the number of individuals of the same species in all samples.

The ID has the advantage of being relatively independent of the mean and the number of samples, where, when ID = 1, the distribution is random; when ID > 1, the distribution is of the aggregate type; and when ID < 1, the distribution is regular (Silveira Neto et al. 1976). The significance of the ID was calculated by the chi-square test (X^2).

After confirming the data normality using the Shapiro-Wilk test, the Pearson's correlation was performed to assess the degree of relationship between bamboo culm density and i) total density of tree individuals; ii) tree species density; and iii) tree species diversity. The significance of the correlation was tested by the p-value, using the Statistica software, version 7.0 (Statsoft 2004).

RESULTS AND DISCUSSION

In the open forest with palm and bamboo (OFPB) and anthropized open forest with palm and bamboo (AOFPB) areas, 518 and 279 bamboo shoots were recorded, respectively. In both areas, the bamboo diametrical distribution presented an irregular trend, with a higher concentration of shoots in the class of 4 to 6 cm (Figure 2).

The Liocourt quotient (q) values corroborate these results, since both the OFPB and AOFPB did not show a constant q, what indicates that the *Guadua weberbaueri* does not present a J-inverted distribution. The OFPB presented a mean q of 2.50, with a variation of 0.10 to 7.24, while the AOFPB presented a mean q of 0.84, with a variation of 0.16 to 2.18. Similarly, Morales-Hidalgo & Kleinn (2006) also observed an irregular diametric distribution for the *Guadua* genus in natural forests of Colombia.

The pattern of irregular diameter distribution of the bamboo can be related to the results observed by Pereira & Beraldo (2007), who concluded that no bamboo species presents radial growth, since they already grow with their defined diameter, in which the largest diameter is near the base, decreasing with height towards the apex. Thus, the plant assumes a conical shape, and the diameter never increases with the passing of the years as in timber tree species.

Regarding the vertical distribution, the bamboo showed an irregular trend in the OFPB and an asymmetric negative shape in the AOFPB (Figure 3). Regarding the mean values of diameter

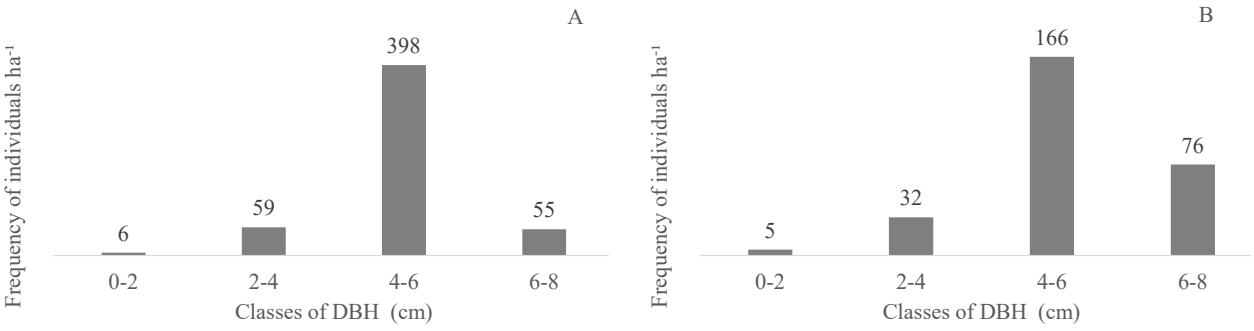

Figure 2. Diameter classes according to measurements of diameter at breast height (DBH) of bamboo shoots sampled in open forest with palm and bamboo (A) and anthropized open forest with palm and bamboo (B).

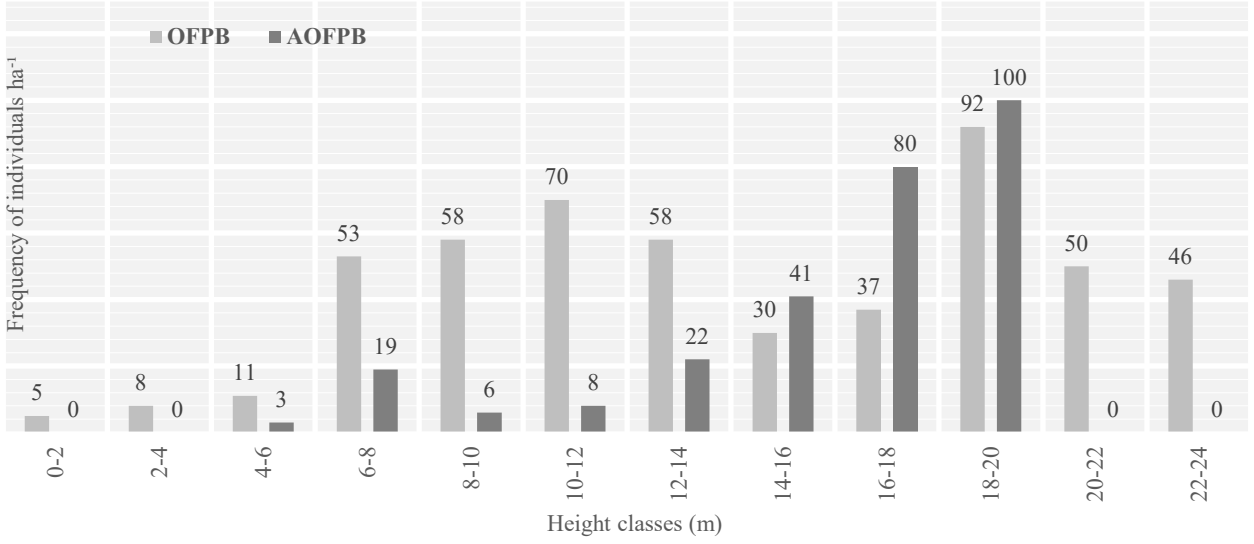

Figure 3. Vertical distribution of bamboo shoots sampled in open forest with palm and bamboo (OFPB) and anthropized open forest with palm and bamboo (AOFPB) areas.

and height, there was no significant difference between the means obtained for shoot diameter (OFPB: μ = 14 cm and σ = 2.6; AOFPB: μ = 16 cm and σ = 1.8) and height (OFPB: μ =16 cm and σ = 9.5; AOFPB: μ = 15 cm and σ = 3.7) for the forests with and without anthropogenic disturbance. This indicates that the bamboo is structurally similar in both areas, what may be associated with the bamboo plasticity, which develops well in natural forests, but also has the facility to colonize new spaces, including anthropized environments (Oliveira et al. 2013, Ferreira 2014).

The values of the Morisita index of dispersion (ID) were not non-significant by the chi-square test, with p (13.8 > 5.9) and (65.8 > 5.9), respectively for the OFPB and AOFPB.

Costa et al. (2012) also found an aggregate distribution pattern for the *Guadua weberbaueri* species in areas of mature and secondary forest (8-31 years) in the Acre state, while Silva et al. (2009) emphasized that the knowledge of the spatial distribution of species is a key factor for studies on forest ecology, being important to understand how a species uses the available resources, and how certain species reproduce and establish themselves. In the case of bamboo, which is considered an invasive species, it is important to know its spatial distribution, given its influence on the diversity and density of tree species.

However, in the present study, no significant correlation ($p < 0.05$) was found between the bamboo density and other parameters of the forest community (total density of woody individuals and diversity of species; Table 1) in the OFPB. In the AOFPB, it was not possible to perform the correlation test of bamboo density by tree species, since no tree species was frequent to the inventoried sample units (plots). Moreover, it was not possible to infer that the dominance of bamboo in the AOFPB affected the density by species, since the area that suffered anthropogenic action showed a lower density of bamboo shoots, when compared to the OFPB.

Costa et al. (2012) also did not observe a significant correlation between the density of the bamboo shoots and of the species of the research, *Apeiba* tibourbou (r = -0.01; p value = 0.95) and Ochroma *pyramidale* (r = - 0.13; p value = 0.66), what corroborates the present study, in which it was refuted that bamboo affects the density of certain woody species in environments without anthropogenic interference (OFPB). Rockwell et al. (2014) also concluded that the dominance of bamboo does not affect the diversity of woody species in forests in southwestern Amazon.

However, some studies (Griscom & Ashton 2003, Carvalho et al. 2013, Oliveira et al. 2013, Ferreira 2014) showed a decrease in the density and diversity of tree species with the increase of bamboo dominance. In addition, Oliver & Poncy (2009) also pointed out that bamboo of the *Guadua* genus has ecological importance for the maintenance of the biodiversity of ecosystems where it is inserted, since several plant and animal species are associated with it.

CONCLUSIONS

1. *Guadua weberbaueri* presents the same pattern of spatial and diameter distribution, both in a native area and in an area that suffered anthropogenic disturbance;

Table 1. Correlation between the densities of bamboo and woody individuals, species diversity and species individually.

Density correlation with bamboo	OFPB		AOFPB	
Density of woody individuals	r = 0.31	p-value = 0.60	r = 0.26	p-value = 0.50
Species richness	r = -0.63	p-value = 0.56	r = -0.89	p-value = 0.30
Correlation of the dominance of bamboo by species (OFPB)				
Euterpe precatoria Mart	r = 0.28		p value = 0.82	
Inga acreana Harms	r = -0.24		p value = 0.84	
Iriartea deltoidea Ruiz and Pav.	r = -0.55		p value = 0.63	
Pouteria macrophilla (Lam.)	r = 0.15		p value = 0.90	
Oxandra espintana (S. ex B) B.	r = 0.20		p value = 0.87	
Socratea exorrhiza exorrhiza (Mart.)	r = -0.13		p value = 0.66	

OFPB: open forest with palm and bamboo; AOFPB: anthropized open forest with palm and bamboo.

2. As for the bamboo vertical distribution, the frequency of shoots increases with increasing height classes in the environment that has undergone human interference;
3. For the two areas under study (open forest with palm and bamboo and anthropized open forest with palm and bamboo), the bamboo density did not affect the total density of individuals and the diversity of tree species.

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