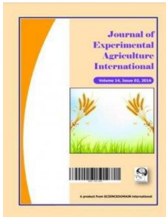

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Population Structure of *Hancornia speciosa* Gomes along the Mangabeira Trail in Sergipe, Brazil

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Authors' contributions

This work was carried out in collaboration between both authors. Author TFSNS participated of data acquisition and data analysis and interpretation and wrote the paper. Author LRNJ designed the study participated of data acquisition, wrote the paper, provided technical, logistic and material support, supervised the work, made a critical revision and correction of the manuscript for important intellectual content. Both authors read and approved the final manuscript.

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ABSTRACT

Hancornia speciosa Gomes is a Brazilian native tree. Its fruit, mangaba, has both social and economic importance and is collected by traditional people, mainly women. However, its natural habitats are being threatened by anthropic pressure. Our aim in this work was to characterize the population structure of *H. speciosa* along the Mangabeira trail at the *Reserva do Caju* (11°6'10.12" S, 37°11'4.59" W) located in Sergipe, Brazil. We sampled all mangabeira individuals in the trail and divided them into three classes of development (seedlings, juvenile and adult trees). In order to analyse their horizontal and vertical distribution, we measured the trees' diameter and height. The population structure of *H. speciosa* at the Mangabeira trail is mainly composed of seedling (46%) and juvenile (29%) individuals, which indicates a regeneration process. The diameter distribution of seedlings and adults was divided into six classes. The three lowest classes accounted for 94% of the total of trees. We also observed a typical "inverted J" pattern, with a high number of young

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plants, which is common to tropical forests. In terms of their vertical distribution, the majority of the individuals were classified under the lower stratum, which corresponded to 47% of the total population featuring 1.01-m average height. The high coefficient of variation in the lower stratum may explain the heterogeneity of the vertical structure, formed by individuals with different strategies to capture sun light and different behaviour towards resources supply. Thus, it is not possible to state that this population is in balance.

Keywords: Diameter classes; height classes; horizontal structure; mangaba; restinga; natural reserve; vertical structure; classes of development; inverted J pattern.

1. INTRODUCTION

Popularly known as mangabeira, *Hancornia speciosa* Gomes is a native tree that occurs widely in the Brazilian Cerrado biome, and locally in the coastal tablelands and coastal lowlands (sandbanks and restinga ecosystem) in north-eastern Brazil. The mangabeira is a medium-sized tree, with heights varying around 2 and 10 meters, and it produces white flowers and tasty fruits called mangaba throughout the year. It grows well in acidic and poor-nutrient soils, and tolerates long drought periods [1,2,3,4].

The name mangaba comes from the Tupi-Guarani language and means 'good for eating'. Thus, the tree's main product is a fruit of both social and economic importance [5]. Characterized by a good smell and flavour, its fruit may be used in the production of candies, syrups, jams, vinegar, juices and ice cream [6]. Mangaba is harvested by traditional people, mostly women, who are involved in all production phases, from fruit harvest to product commercialization [7,8]. However, anthropic actions, such as deforestation, constructions, shrimp farms, coconut, sugarcane, soybean and corn crops and eucalyptus plantations, have caused decreases in the mangabeira population [9].

Studies about population structure are essential for conservation plans, because they enable understanding how the population occurs and regenerates [10], especially in the case of a management plan for the 'Reserva Particular do Patrimônio Natural do Caju' (Caju Private Natural Heritage Reserve) [11]. Moreover, in order to promote sustainable fruit harvesting (Lima & Scariot, 2010) and production [12] practices, greater knowledge on the mangabeira population structure and its ecological relations is necessary.

The diameter distribution evaluates the horizontal growth behaviour in a forest, and enables inferring if the population would suffer any intervention due to a possible removal of an individual [13,14]. The forest's vertical structure characterization may indicate the plant's succession stages and conservation status. Stratification provides information on the biologic and ecologic characteristics of forest species, and may enable, for example, dividing trees into different strata, such as lower, middle and upper [8].

For this reason, the aim of this paper is to characterize the vertical and horizontal structure of the *H. speciosa* population around the Mangabeira trail at the Caju Private Natural Heritage Reserve located in Sergipe, Brazil.

2. MATERIALS AND METHODS

The study site (Mangabeira trail) is located at the Caju Private Natural Heritage Reserve (11°6'10.12" S, 37°11'4.59" W), in Itaporanga d'Ajuda, Sergipe, Brazil (Fig. 1). It is part of the Experimental Field of Itaporanga d'Ajuda, which belongs to Empresa Brasileira de Pesquisa Agropecuária (Embrapa, the Brazilian Agricultural Research Corporation) since 1979. This experimental field has 911 ha, of which 763.37 ha are destined for the Caju Reserve (which is considered a Protected Area under the Brazilian National System of Conservation Units), which is bordered by the Vaza-Barris and Paruí rivers. The reserve is frequently used for environmental education actions aimed at students, which highlight the trail's importance, as well as for scientific researches related to biodiversity identification and conservation projects [11,15,16,17].

The region's climate is tropical savannah climate (As) according to Köppen's classification [18], and features a tropical regime with dry summer (October to March) and rainy season (April to July). Between 2000 and 2016, the annual average precipitation was 1.447 mm. The study site's soil is classified as Entisols

(Quartzipsamments), and has poor fertility. The restinga vegetation varies from forest fragments with a closed canopy to open areas with herbaceous vegetation. Brazilian restingas are characterized by a set of varied ecosystems with morphologic and climatic differences along the coast. When compared to other Brazilian ecosystems, restinga's vegetation is considered of lower abundance. However, its diversity is usually highly valued [19].

The Mangabeira trail has a total extension of 1,100 m (Fig. 1). The area is historically known as 'Mangabeira Site' due to the remarkable presence of native mangabeira individuals. To characterize the population structure, all mangabeira individuals were sampled over a five-meter area on both trail sides. The plants were divided into three life-stage classes: 1) seedlings, the plants with a height lower than 50 cm; 2) Juveniles, those with heights higher than 50 cm; and 3) Adults, those in the reproductive phase, i.e. which produce fruits. The seedlings were the only ones counted. The juveniles and adults had stems that were 30 cm in diameter at the ground level (DGL), which was measured using a tree caliper, and their height was measured using a graduated stick. The data were collected along a total area of 1.1 ha.

In order to characterize the diameter distribution of juveniles and adults, the data collected were arranged and analysed considering the following DGL statistical parameters: minimum, maximum, mean, median, mode, standard deviation, coefficient of variation, kurtosis and asymmetry. To define the diameter class ranges, we used an 88% standard deviation. Then, we calculated each diameter class' lower limit, upper limit, middle point, frequency, cumulative frequency, relative frequency and relative cumulative frequency. In addition to the frequency histogram, De Liocourt "q" quotients were obtained for the diameter classes. Thus, "q" quotients were calculated using the ratio between the number of individuals of the successive diameter classes [20], for example:

$$q1 = \frac{N_{iClass1}}{N_{iClass2}} \ldots \; q5 = \frac{N_{iClass5}}{N_{iClass6}}$$

where:

N_i = number of individuals per class.

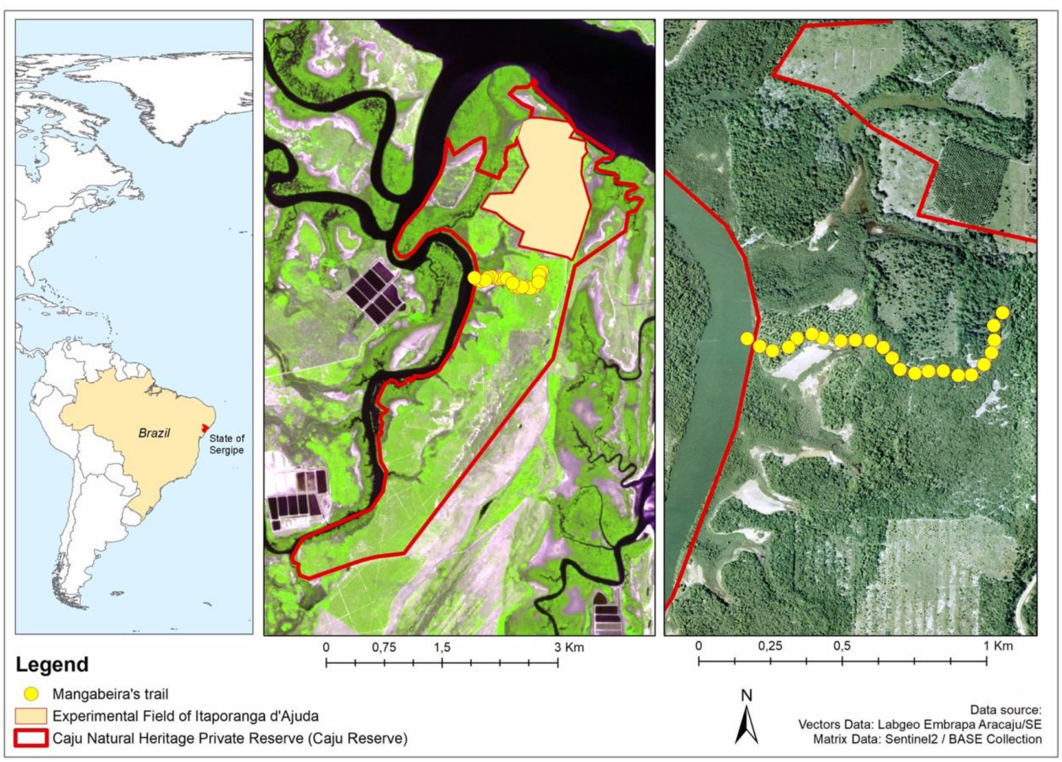

Fig. 1. Location of the Mangabeira trail at the Caju private natural heritage reserve, in Itaporanga d'Ajuda city, state of Sergipe, Brazil

Classes' heights were defined according to Lamprecht [21], who used the International Union of Forest Research Organizations' (IUFRO) classification to stratify a forest based on dominant height (H_{dom}). H_{dom} was calculated according to the Weise method, and took into account 8% of the total individuals with average height, starting with the largest diameter [22]. Thus, three classes were defined: 1) Lower stratum <1/3 H_{dom}; 2) Medium stratum >1/3 and ≤ 2/3 H_{dom}; and 3) Upper stratum > 2/3 H_{dom}. Then, we calculated the mean, standard deviation, frequency, relative frequency and coefficient of variation for each height class. All statistical analyses were performed using R [23].

3. RESULTS AND DISCUSSION

A total of 331 mangabeira individuals were sampled: 82 adults, 96 juveniles, and 153 seedlings (25, 29, and 46% respectively). The population density was of 301 individuals ha^{-1}, with 75 adults, 87 juveniles and 139 seedlings ha^{-1} (Fig. 2).

The results obtained for life stage classes (Fig. 2) and diameter classes (Fig. 3 and Tables 1 and 2) show that the population is composed mainly by young individuals. Considering only juvenile and adult individuals while studying the ecology of the mangabeira population in the Brazilian Cerrado, [24] corroborated our results, which show that the majority of the population is of juveniles (61%). In general, this pattern of young population indicates a community with a good regeneration potential, so that the presence of a large number of young individuals, when compared to adults, may be associated to a perpetuation of the studied species [25].

The diameters measured ranged from 0.2 cm (minimum DGL) to 33 cm (maximum DGL), with a mean of 7.35 cm (Table 1). The mode (0.6 cm) was smaller than the median (5.1 cm), and the median was smaller than the mean (7.35 cm). The standard deviation and coefficient of variation were 6.78 cm and 92% respectively. A high coefficient of variation of DGL values shows a very heterogeneous distribution around the collected data (Table 1), which indicates heterogeneity among the individuals studied, i.e. in different succession stages [25].

The kurtosis and asymmetry coefficient values were 0.1811 and 0.856, respectively. The kurtosis and asymmetry parameters are good statistic tools to evaluate dataset dispersion and inform the flattening and distance degree of a distribution respectively [25]. The asymmetry is negative when Mode > Median > Mean, and positive when Mode < Median < Mean. It is considered moderate when the coefficient module falls between 0.15 and 1. Otherwise, a coefficient higher than 1 implies a strong asymmetry [26]. Thus, for this study, the diameter distribution has positive and moderate asymmetry (Table 1). The kurtosis coefficient is classified as leptokurtic (exponential distribution curve) according to Crespo [27], who determines three curve types related to the kurtosis coefficient: leptokurtic, platykurtic (uniform distribution curve) and mesokurtic (binomial distribution curve).

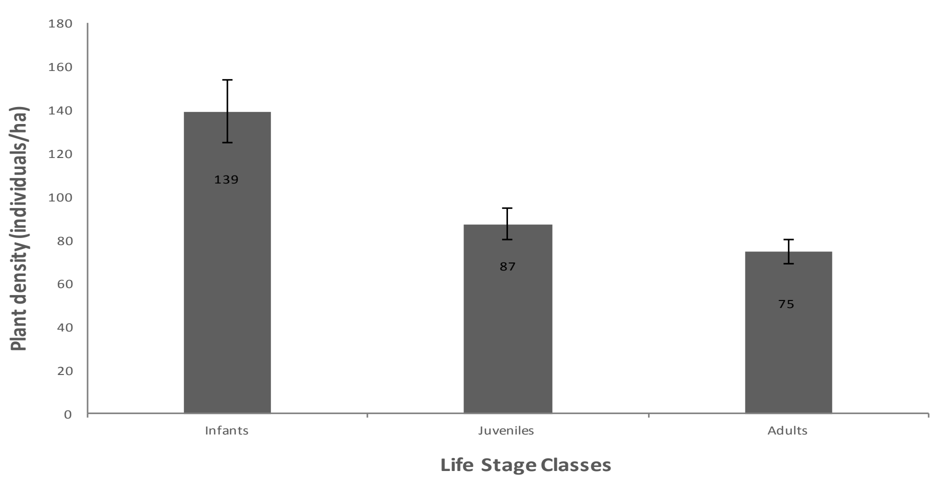

Fig. 2. Density (means and ± standard deviation) of *Hancornia speciosa* gomes in different life stage classes at the Mangabeira trail in May 2016

Table 1. Variables and statistic parameters for 30-cm diameter at ground level (DGL) *Hancornia speciosa* individuals (Juveniles and adults) at the Mangabeira trail in May 2016

Statistic parameters of DGL	Results
Minimum	0.2 cm
Maximum	33 cm
Mean	7.35 cm
Median	5.1 cm
Mode	0.6 cm
Standard deviation	6.78 cm
Coefficient of variation	92%
Kurtosis	0.1811
Asymmetry	0.856

The juveniles and adults were distributed into six diameter classes with a range of 6 cm each: 1) > 0.2 ≤ 6.2; 2) > 6.2 ≤ 12.2; 3) > 12.2 ≤ 18.2; 4) > 18.2 ≤ 24.2; 5) > 24.2 ≤ 30.2; 6) > 30.2 ≤ 36.2 cm (Table 2 and Fig. 3). There is a higher relative frequency in the first class, which corresponds to more than half of the sampled population (53%) with its 95 individuals, and the middle point of this class was 3.2 cm (Table 2). We observed that 94% of the total individuals (relative cumulative frequency) were placed on three lower classes (classes 1, 2 and 3) (Table 2). The last two classes (classes 5 and 6) make 1% of the total, with a frequency of only one individual each (Table 2).

The De Liocourt "q" quotient calculated ranged from 1 (q5) to 9 (q4), with a mean of 3.46 (Fig. 3). A frequency histogram (Fig. 3) enables a visual analysis of the diameter distribution for juveniles and adults. As it may be observed, the diameters measured show a typical "inverted J" form. It happens frequently in native forests, especially tropical forests showing a higher frequency in lower classes and a lower frequency in higher classes [25,28]. However, Schaaf et al. [29] highlight the fact that low diameter classes are not always composed by younger individuals. Old trees may be thin because they might give up on increasing their resources in order to remain alive in the community. At the same time, thin trees in clearing areas may actually be young, since they are normally part of a regeneration process.

Although the mangabeira diameters show an "inverted J" pattern, this distribution may not be considered a balanced one. The De Liocourt "q" quotient, which provides information about forest balance, shows there is no constant ratio between the classes in this study (Fig. 3). Variation in "q" values over the classes show imbalance in population structure. In other words, if the "q" values are not uniform over the classes, there is a disturbance in a community [20]. It, therefore, suggests that the recruitment rate is not similar to the mortality rate. This indicates that distribution is not regular, and may suffer

Table 2. Lower limit (LL), upper limit (UL), middle point (MP), frequency (Fr), cumulative frequency (CFr), relative frequency (RFr), and relative cumulative frequency (RCFr) for six diameter classes of *Hancornia speciosa* individuals (juveniles and adults) at the Mangabeira trail in May 2016

Classes	LL	UL	MP	Fr	CFr	RFr	RCFr
	cm			individual's number		%	
1	0.2	6.2	3.2	95	95	53	53
2	6.2	12.2	9.2	39	134	22	75
3	12.2	18.2	15.5	33	167	19	94
4	18.2	24.2	28.5	9	176	5	99
5	24.2	30.2	27.2	1	177	0.5	99.5
6	30.2	36.2	33.2	1	178	0.5	100

Table 3. Classes range, height (mean and standard deviation – SD), frequency (Fr), relative frequency (RFr), and coefficient of variation (CV) for three height classes of *Hancornia speciosa* individuals (juveniles and adults) at the Mangabeira trail

Classes		Height		Fr	RFr	CV
Stratum	Range	Mean	SD			
	m				%	
Lower	0.5 – 2.4	1.01	0.46	83	47	46
Medium	2.4 – 4.8	3.71	0.73	31	17	20
Upper	4.8 – 13.5	6.49	1.46	61	36	22

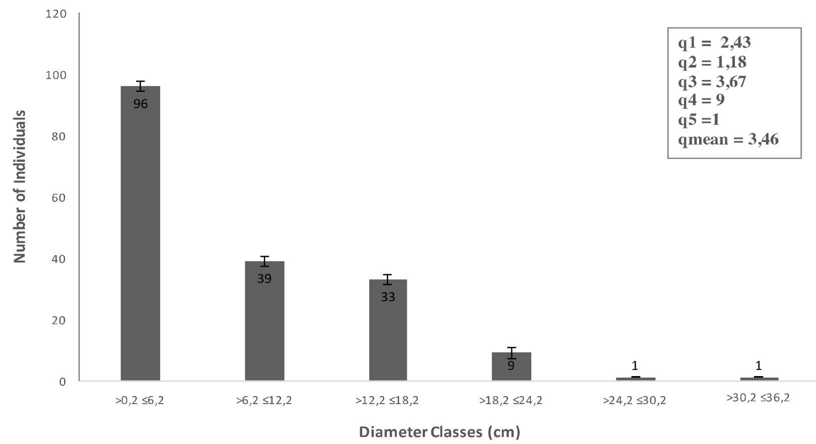

Fig. 3. Diameter classes of *Hancornia speciosa* (Juveniles and adults; number of individuals and ± standard deviation)) at the Mangabeira trail in May 2016, and De Liocourt "q" quotients between the diameter classes

anthropic pressure [30], which may be explained by the increase in harvesting intensity (probably overexploitation) promoted by some traditional communities that live around the Caju Reserve, and which is due to a reduction in the amount natural areas caused by deforestation to make way for the installation of shrimp farms and for the expansion of urban areas [11] (Fig. 1).

The dominant height calculated for the mangabeira population was 7.19 m. It enabled stratifying all individuals into three height classes according to their stratum: lower (0.5 to 2.4 m), medium (2.4 to 4.8 m), and upper (4.8 to 13.5 m) (Table 3). The majority of the trees studied (47%) were smaller than 2.4 m, and therefore classified into the lower stratum, with a 1.01 m mean height. With mean heights of 3.71 and 6.49 m, the medium and upper strata had a 17 and 36% relative frequency of individuals respectively. However, the lower stratum had a higher CV (46%) when compared to the medium (20%) and upper strata (22%).

Considering the vertical structure, it is important to distinguish at least one upper and one lower stratum to classify individuals with different strategies to capture sun light and different behaviour towards resources supply [31]. This may be explained by the heterogeneity of the vegetation structure and soil cover, or probably by the high genetic variation within the natural population [32].

This heterogeneity in the vertical structure of the mangabeira population may be essential for the maintenance of the high diversity of frugivores (especially bats and birds) in the Caju Reserve. Containing six out of 16 species, the frugivorous bats guild identified at the Caju Reserve by Rocha et al. [17] is the most abundant. The seven frugivorous bird's species registered in the Caju Reserve by Ruiz-Esparza et al. [15] encompass 7,87% of the total species, and occupy the fourth position in the trophic guild composition. The richness in frugivores (especially bats and birds) highlights the importance of sustainable practices in mangaba harvesting and in the conservation of *H. speciosa* populations at the Caju Reserve. Moreover, the bird and bat richness registered at the Caju Reserve by Rocha et al. [17] and Ruiz-Esparza et al. [15] confirms the potential importance of the area as a conservation unit in the State of Sergipe and for the restinga ecosystem.

Alongside the anthropic pressure on natural areas, which may influence the population structure of *H. speciosa*, we also observed heterogeneity in vegetation structure and soil cover along the Mangabeira trail (Fig. 1). At the study site, the vegetation structure may be associated with environmental characteristics, mainly soil attributes (humidity, porosity, structure, texture, pH, organic matter, macronutrients, cation exchange capacity and others). However, soil cover may be associated with anthropic actions, mainly burning and illegal logging. Thus, further investigation and analysis of the soil cover and spatial distribution of *H. speciosa* along the Mangabeira trail may improve the understanding about the population structure depicted in this work.

4. CONCLUSION

The population structure of *H. speciosa* at the Mangabeira trail is mainly composed of seedlings and juvenile individuals, which depicts a regeneration process. The diameter distribution of mangabeira individuals (juveniles and adults) shows an “inverted J” form, with a high number of young plants, which is common in tropical forests. Regarding the vertical structure, the high coefficient of variation in the lower stratum may explain the heterogeneity of the population structure, and indicate individuals with different strategies to capture sun light and different behaviour towards resources supply. Thus, it is not possible to affirm that this population is in balance. Considering the importance of Caju Reserve to biodiversity conservation and environment education actions, the surveillance can be improved and the local communities must be sensitized to reduce the pressure of mangaba harvesting.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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