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# Diametric Structure of One Fragment of One Deciduous Seasonal Forest in Brazilian Savanna Eco Museum

**José Imaña-Encinas[1], Otacílio Antunes Santana[2]**

[1]Department of Forestry, University of Brasília, Brasília, Brazil
[2]Department of Biofísic and Radiobiology, Rural University of Pernambuco, Recife, Brazil
Email: jose.imana@gmail.com, otacilio.santana@gmail.com

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## Abstract

A 10 ha deciduous seasonal forest fragment (15˚45'54''S and 49˚04'03''W) found in the bioregion of the Savanna Eco Museum localized in the state of Goiás, Brazil was studied. For the phytosociological survey, 10 sample plots of 20 × 20 m were systematically located. All living trees of 5 cm *DBH* and above were measured with the plot boundaries. There were 742 individuals belonging to 83 species and 38 families. The richest families in terms of the number of species were Leguminosae, Rubiaceae, Myrtaceae, Apocynaceae and Chrisobalanaceae, which contributed 48% of the total species. The species with the highest importance value indices (*IVI*) were *Tapira quianensis* (Aubl.), *Protium heptaphyllum* (Aubl.) March., *Callisthene mayor* (Mart.), *Amaioua guianensis* (Aubl.) and *Anadenanthera macrocarpa* (Benth.) Brenan. The Shannon diversity index was 3.80 nats/individuals and the Pielou equality index was 0.86 for the total population. 549 sampled trees had *DBH* values lower than 30 cm. This indicates that this forest has a high potential for natural succession. Two *DBH* distributions were observed: the typical reverse "J", described frequently in the literature, and a nearly Gaussian distribution.

## Keywords

Native Tree Species, Diametric Distribution, Phytosociological Survey

## 1. Introduction

The geographical area of the Savanna Eco Museum is located mainly in the municipal district of Pirenópolis in the state of Goiás adjacent to the Federal District, occupying an area of 8.066 km$^2$ [1] [2], as in **Figure 1**.


**Figure 1.** Location of the Savanna Eco Museum. GO = Goiás State, DF = Federal District, MG = Minas Gerais State.

Diameter distributions are important tools in forest management planning, for both researchers and forest administrators [3] [4] [5]. It's mentioned that the diameter distribution [6] enables the interpretation of plant species population dynamics, towards consistent decisions on possible silvicultural interventions [7] [8] [9]. The Savanna Eco Museum has been idealized to contribute to the environmental conservation of the Paraná and Tocantins rivers' watershed region.

The natural vegetation of the Eco Museum area presents the plant communities of the well-defined savanna biome. The communities include typical savanna, and two other tree communities: gallery forests associated with watercourses, and the interfluve, forests which are not associated with watercourses. The deciduous woodlands occur on very steep slopes and it is deciduous during the dry season.

Floristic, phytosociological [2] [4] [7] [10] [27] and dendrometric studies can be conducted in these plant communities to provide relevant and important information and knowledge for the conservation of the remaining forests. Referring to the levels of biological diversity, from 4444 km$^2$ (total) of the Savanna Eco Museum, only the north of the Pirenópolis county has 1058 km$^2$, which is inferred as priority areas of biodiversity at level 1, equivalent to extremely high [2]. Priority areas at level 2 (high) are in the counties of Abadânia, Alexânia, and southern region of Pirenópolis, making up a total of 2484 km$^2$. At level 3 (lower) they occur in the counties of Águas Lindas de Goiás, Cocalzinho de Goiás and Santo Antônio do Descoberto, corresponding to 902 km$^2$ [2].

The aim of this study was to do a diametric survey of the tree component of one deciduous forest stand in this Savanna Eco Museum.

## 2. Materials

The study area included a fragment of the deciduous forest in the northwestern portion of the Savanna Eco Museum on the *Raio de Sol* Farm (15˚45'54"S, 49˚04'03"W, at an altitude of 810 m) covers an area of 12.5 ha. It occurs on a steep slope of 32˚ adjacent to riparian forests and a typical savanna within a permanent preservation area. The soils are shallow, well-drained and have low natural fertility. The area has the AW-type local climate according to the Köppen-Geiger climate classification [11], with two well-defined seasons: dry winter (March to June) and rainy summer (July to February), with an average annual rainfall of 1,500 mm.

Two transects 200 m in width and 80 m apart were systematically demarcated along the slope. In each transect five plots of 20 × 20 m (0.04 ha) were sampled at 80 m intervals along each transect, *i.e.* total coverage of 0.2 ha, with a total sample area of 0.4 ha. The data from the same plots were used for the phytosociological analysis [1].

## 3. Methods

All live trees, including the palm trees, of ≥5 cm *DBH* (diameter at breast height) were measured with an 80 cm caliper. The species were identified in the field by a tree specialist. When it was not possible, the material was dried and pressed for identification at the Brasilia University Herbarium (UB). The trees were identified to the level of species, genera and family according to the APG III system [12]. The vegetation stems diameter structure was analyzed using 2.5 cm stem diameter class intervals. Diameter class histograms were developed for the whole community and the 25 species with higher importance value index (*IVI*) [13] [14] [15], as they cumulatively contribute 70% of the *IVI*. The *IVI* was following calculated: the sum of the relative´s frequency, density and dominance divided into three.

The Liocourt quotient "*q*" to identifies if the tree component of the plant community is balanced, *i.e.* when an almost uniform "*q*" ratio occurs. It was calculated by dividing the number of individual stems of a diameter class by the number of individuals of the previous class. This calculation can also be done using basal area values, once every management system considers this dendrometric parameter [16] [17] [18] [19].

The model $Y_j = e^{\beta_0 + \beta_1 \cdot D_j}$ [20] was used to adjust the number of individual trees present in the plots per center diameter class, where: $Y_j$ estimates the number of trees per hectare; $\beta_0$ and $\beta_1$, are the equation parameters; $D_j$, the center diameter class; and e, the Napierian logarithm base, also was used the Neural Networks Method [21].

## 4. Results

All native tree species were identified (**Table 1**) and distributed in 42 families. The families [12] with the highest number of species were: Leguminosae with 11 species; Caesalpinaceae and Myrtaceae with five species each; and Rubiaceae, Melastomataceae, Apocynaceae and Annonaceae with four species each; this all representing 42% of sampling species.

**Table 1.** Floristic composition and tree parameters in a deciduous forest stand at the Savanna Eco Museum [12], species ordered by families using the *IVI* = index importance value.

| Family/species | Stems | Stems·ha$^{-1}$ | *DBH* range cm | Mean *DBH* cm | Mean Basal area m$^2$ | *IVI** |
|---|---|---|---|---|---|---|
| Anacardiaceae | (73) | | | | | |
| *Tapirira guianensis* (Aubl.) | 62 | 155 | 5.4 - 37.7 | 14.2 | 0.0991 | 27.13 (01) |
| Burseraceae | (92) | | | | | |
| *Protium heptaphyllum* (Aubl.) Marchand | 88 | 220 | 5.1 - 21.6 | 9.6 | 0.0072 | 24.24 (02) |
| Vochysiaceae | (39) | | | | | |
| *Callisthene major* (Mart.) | 23 | 57 | 6.2 - 20.2 | 12.8 | 0.0129 | 9.88 (03) |
| *Qualea dichotoma* (Mart.) Warm. | 16 | 40 | 5.3 - 16.9 | 10.6 | 0.1423 | 6.50 (15) |
| Rubiaceae | (106) | | | | | |
| *Alibertia macrophylla* K. Schum. | 22 | 55 | 5.7 - 16.6 | 8.9 | 0.0052 | 7.26 (11) |
| *Amaioua guianensis* (Aubl.) | 30 | 75 | 5.1 - 19.0 | 8.4 | 0.0055 | 9.53 (04) |
| *Guettarda viburnoides* Cham. & Schltdl. | 25 | 62 | 5.0 - 10.2 | 7.1 | 0.0039 | 6.62 (13) |
| Leguminosae | (47) | | | | | |
| *Anadenanthera macrocarpa* (Benth.) Brenan | 10 | 25 | 6.8 - 30.0 | 21.5 | 0.0362 | 8.62 (05) |
| Chrysobalanaceae | (55) | | | | | |
| *Licania octandra* (Hoff. ex Roem. & Shult.) Kuntze | 27 | 67 | 5.4 - 16.3 | 9.7 | 0.0074 | 8.38 (06) |
| Apocynaceae | (29) | | | | | |
| *Aspidosperma subincanum* (Mart.) | 20 | 50 | 5.6 - 33.0 | 10.9 | 0.0093 | 8.22 (07) |
| Malvaceae | (32) | | | | | |
| *Luehea divaricata* Mart. & Zucc. | 18 | 45 | 7.5 - 20.7 | 12.1 | 0.0114 | 7.95 (08) |
| *Tabebuia ochracea* (Cham.) Standl. | 15 | 37 | 5.7 - 19.1 | 10.2 | 0.1228 | 6.85 (12) |
| Annonaceae | (13) | | | | | |
| *Xylopia aromatica* (Lam.) Mart. | 13 | 32 | 6.3 - 21.7 | 15.6 | 0.2478 | 7.87 (09) |
| Myrtaceae | (42) | | | | | |
| *Myrcia multiflora* (Lam.) DC. | 20 | 50 | 5.2 - 12.0 | 9.2 | 0. 0064 | 7.66 (10) |
| Malpighiaceae | (23) | | | | | |
| *Byrsonima intermedia* A. Juss. | 22 | 55 | 5.1 - 17.9 | 8.1 | 0.0051 | 6.61 (14) |
| Indivíduos não identificados | (4) | 4 | 7.8 - 17.7 | 12.7 | 0.0211 | |
| … (33 families with lowest *IVI*) | | | | | | |
| Total (all species) | 742 | 1855 | | | 7.0971 | 300.00 |

*Value between brackets indicates numerical order (highest to lowest) of species by the Importance Value Index.

826 stems from 1,855 are shown in **Table 1**, the others stems were distributed in the other families. The stem diameter distribution of the individuals total showed a positive structure of the forest, like **Figure 2**, once there is a possibility of natural replacement of dead trees from higher diameter classes by the recruitment of abundant individuals from lower diameter classes.

**Figure 2** shows the diameter distribution, it is to observe that the Meyer equation has a $R^2 = 0.99$.

The highest number of species distributed in many families corroborated with other phytosociological studies carried out in the savanna region (**Table 2**). Data from absolute density (*DA*) and basal area (*G*) fit themselves close to results found in other seasonal forests. The minimum diameter was in all studies 5 cm.

According to the Liocourt quotient [16] [17] as shown in **Table 3** it is verified that the plant community studied tends to be balanced once the numeric value of the calculated ratio per diameter class presents itself in a relatively small interval "*q*" varying from 0.25 to 0.48. The calculated value varied respectively between 0.12 and 0.11 to the highest and lowest value of the calculated mean (0.36). The Liocourt quotient calculated by the diameter class (a) and basal area (b) also indicated the existence of a balance in the community studied. The low variations in the calculated index show correspondent individuals recruitment between the diameter classes due to a possible mortality tax.

**Table 2.** Tree density and basal area of some seasonal forests.

| Locality | *DA* $n \cdot ha^{-1}$ | *G* $m^2 \cdot ha^{-1}$ | Source |
|---|---|---|---|
| Itatinga, São Paulo state | 2271 | 31.93 | Ivanauskas *et al.*, 1999 [24] |
| Vale do Aço, Minas Gerais state | 1569 | 26.94 | Lopes *et al.*, 2002 [25] |
| Lavras, Minas Gerais state | 1487 | 31.03 | Souza *et al.*, 2003 [31] |
| Monte Alegre, Goiás state | 633 | 19.36 | Nascimento *et al.*, 2004 [18] |
| Lavras, Minas Gerais state | 1115 | 29.14 | Machado *et al.*, 2004 [26] |
| Lavras, Minas Gerais state | 2565 | 40.99 | Oliveira *et al.*, 2004 [27] |
| São Domingos, Goiás state | 924 | 9.92 | Silva & Scariot, 2004 [29] |
| Viçosa, Minas Gerais state | 2786 | 28.70 | Silva *et al.*, 2004 [22] |
| Bom Sucesso, Minas Gerais state | 1393 | 30.11 | Apolinário *et al.*, 2005 [23] |
| Viçosa, Minas Gerais state | 1704 | 38.45 | Campos *et al.*, 2006 [6] |
| Uberlândia, Minas Gerais state | 1268 | 42.26 | Salles & Schiavini, 2007 [28] |
| Uberaba, Minas Gerais state | 805 | 45.80 | Dias Neto *et al.*, 2009 [38] |
| Ipiaçu, Minas Gerais state | 837 | 15.15 | Gusson *et al.*, 2009 [32] |
| Ourana, Goiás state | 1647 | 15.57 | Soares *et al.*, 2015 [33] |
| Montes Claros, Goiás state | 781 | 17.62 | Soares *et al.*, 2015 [33] |
| Pirenópolis, Goiás state | 1855 | 20.08 | In this study |

*DA* = absolute density; *G* = basal area.

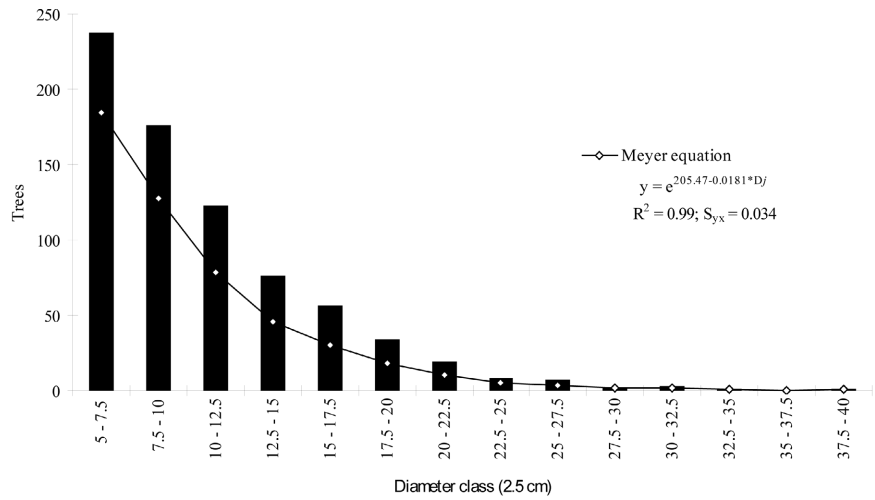


**Figure 2.** *DBH* distribution in 2.5 cm range and the adjustment of Meyer's equation.

**Table 3.** Tree distribution in 5 cm *DBH* class.

| Diameter class *cm* | *DCmp* cm | Absolute density $n_i$ | Relative density % | Average basal area $m^2 \cdot ha^{-1}$ | "*q*" (a) | "*q*" (b) |
|---|---|---|---|---|---|---|
| 5.00 - 10.00 | 7.5 | 423 | 57.0 | 0.0094 | 0.48 | 1.60 |
| 10.01 - 15.00 | 12.5 | 198 | 26.6 | 0.0151 | 0.45 | 1.56 |
| 15.01 - 20.00 | 17.5 | 90 | 12.1 | 0.0236 | 0.30 | 1.62 |
| 20.01 - 25.00 | 22.5 | 27 | 3.6 | 0.0383 | 0.30 | 1.51 |
| 25.01 - 30.00 | 27.5 | 9 | 1.2 | 0.0579 | 0.40 | 1.38 |
| 30.01 - 35.00 | 32.5 | 4 | 0.5 | 0.0799 | 0.25 | 1.39 |
| 35.01 - 40.00 | 37.5 | 1 | 0.1 | 0.1116 | - | - |
| Total | | 742 | 100 | | | |

*DCmp* = diameter class mean point. (a) = obtained by the number of individuals per class ratio. (b) = obtained by the basal area per class ratio.

## 5. Discussion

The diameter structure reveals that the arboreal community is mainly composed of small trees [34] [35]. The J-inverse pattern with 96% of the trees in the first three diameter classes indicates apparently a positive balance between recruitment and mortality until the 20 - 25 diameter class. Which would characterize the forest as self-regenerative [21] [22]. In other words, the size structure of the plant community is a result of biotic and abiotic factors [36] and a strong variation genetic [19].

The ten most important families from the phytosociological point of view correspond to more than 60% of the area's *IVI*. The family with the highest number of individuals in the area studied was Rubiaceae and the one that dominated in terms of richness was Leguminosae with eleven species [20] [37]. In one forest in the Philippines to find the relation between the plant community's ecological suitability and the social preference, they found a strong negative relationship.

In relation to the species, the dendrometric analysis considered the top 25 *IVI* positions. It is observed that most parts of *DBH*s encounter themselves at lower diameter classes until 25 cm. The numbers in parentheses above the species' names refer to the corresponding number of individuals sampled.

Analyzing each species diameter structure, it was verified [12] that the species *Tapira guianensis*, *Protium heptaphyllum*, *Amaioua guianensis*, *Aspidosperma subincanum*, *Myrcia multiflora*, *Tabebuia ochracea*, *Guettarda pohliana*, *Guettarda virbunoides*, *Byrsonima intermedia*, *Sclerolobium paniculatum*, *Tapura amazonica*, *Curatella americana*, *Luehea divaricata*, *Licania apetala* and *Erythroxylum daphnites* presented a more regular distribution, with a tendency curve similar to the J-inverse species distribution corresponds to 60% of the 25 ones with higher *IVI*. The species that presented a completely irregular distribution were *Callisthene major*, *Anadenanthera macrocarpa*, *Xylopia aromatica*, *Astronium fraxinifolium*, *Licania octandra*, *Alibertia macrophylla*, *Qualea dichotoma*, *Salacia amygdalina*, *Emmotum nitens* and *Virola sebifera*, completing 40% of the 25 species considered. Once most part of the *DBH*s belongs to lower value diameter classes, it is assumed that the remaining trees could hardly reach high diameters possibly because of those species' inherent characteristics [32].

The diameter distribution per plot was fit by Meyer's equation [20] [34] [35]. The corresponding equation's coefficients the estimated deviation pattern ($S_{yx}$) and the coefficient of determination ($R^2$) are indicated in **Table 4**. Because of the high value of the coefficient of determination and the low value of the estimative deviation pattern the corresponding equations are fully adjusted to the existing *DBH*s in the arboreal plant community. It is observed that on the 10 plots, the diameter distribution curve shows a negative exponential tendency. It is verified the existence of a balance between high regeneration and high mortality, according to descriptions provided by [32] [36] in deciduous seasonal forests.

**Table 4.** Coefficient and statistic parameters for the Meyer's equation [20] [21].

| Plot | $\beta_0$ | $\beta_1$ | $R^2$ | $S_{yx}$ |
|---|---|---|---|---|
| 1 | 22.5640 | −0.0197 | 0.95 | 0.1751 |
| 2 | 20.3060 | −0.0188 | 0.93 | 0.1504 |
| 3 | 22.3640 | −0.0315 | 0.98 | 0.1640 |
| 4 | 19.9530 | −0.0169 | 0.97 | 0.1629 |
| 5 | 22.5420 | −0.0179 | 0.97 | 0.2024 |
| 6 | 17.1240 | −0.0130 | 0.98 | 0.2001 |
| 7 | 21.4550 | −0.0190 | 0.98 | 0.1747 |
| 8 | 19.8800 | −0.0220 | 0.95 | 0.2089 |
| 9 | 13.5820 | −0.0131 | 0.86 | 0.1979 |
| 10 | 18.0200 | −0.0203 | 0.94 | 0.1503 |

## 6. Conclusions

The *DBH* average of 10.64 cm and the average basal area of 20.08 $m^2 \cdot ha^{-1}$ are fully compatible with values found for other deciduous seasonal forests.

The diametric distribution of the 742 arboreal individuals across 7 diameter classes revealed a plant community composed mainly of small trees; 96% of them presented *DBH* less than 25 cm with a positive balance between recruitment and mortality in the first classes which characterizes it as self-regenerative.

The tree with the highest *DBH* (37.7 cm) was the species *Tapirira guianensis*.

The Liocourt quotient "*q*" showed that the arboreal plant community studied is balanced.

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## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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