

# Floristics and Structure of Arboreal Components in a Restored Atlantic Forest Area

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## Research

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# Abstract

**Background:** Coffee and livestock degrade Seasonal Semideciduous Forests in the Zona da Mata region of the Atlantic Forest biome in Brazil. The floristic composition must be studied to preserve and conserve forest remnants. The objective was to evaluate the arboreal structure, characterize the seed dispersal syndrome and the ecological group of forest species of a 45-year-old restored area in Viçosa, Minas Gerais state, Brazil. The phytosociological parameters density, frequency, dominance and importance value, Shannon's diversity and Pielou's equability were evaluated considering individuals with DBH (diameter at breast height)  $\geq 5$  cm in sixteen contiguous plots (25 x 25 m).

**Results:** A total of 1,323 individuals from 109 species and 35 botanical families were registered, of which 90 were native and 15 exotic species. The importance value (VI= 11.9%) was highest for *Guarea guidonia* (Fabaceae). The Shannon's diversity ( $H'$ ) was 3.46 and the equability ( $J'$ ) was 0.74. The number of species (33%) was largest for the initial secondary successional class and the number of individuals with zoochoric dispersion syndrome for the late secondary class (38.3%). The basal area was 44.1 m<sup>2</sup> ha<sup>-1</sup> and the average height was 13 m (ranging from 2 to 32 m).

**Conclusion:** The restored Semideciduous Seasonal Forest is in an advanced successional stage with zoochoric species and a great number of late secondary species.

## 1. Background

The Atlantic Forest in Minas Gerais state, Brazil includes different formations, with a predominance of seasonal semi-deciduous forests degraded by coffee and livestock (IBGE, 2012). Forest fragmentation increases the importance of restoring these areas to conserve biodiversity and establishing representative populations of regional native flora and genetic diversity (Braga et al., 2011; Rodrigues et al., 2013; Alsherif & Fadl, 2016).

Preservation and conservation of forest remnants depends on studies on the floristic composition and ecology of plant communities (Maragon et al., 2003; Martins et al., 2018; Santos-Junior et al., 2018). Phytosociological analyzes allows to assess environmental impact for the sustainable use, conservation and restoration of the ecosystems (Durigan, 2009). The successional stages and interventions to recover a forest closer to a stage of balance are evaluated by analyzes of the floristics and structure of the arboreal component and in this study a reference area for comparison is used a lot, and whether the area is really restored or close to a natural area (Souza et al., 2015; Balestrin et al., 2019; Gardon et al., 2020). In addition, understanding the successional dynamics of a forest community in its different stages allows guiding its management (Pinto et al., 2007).

Differences between baseline conditions and the current situation of the area under restoration are used in ecological restoration to evaluate the success of the recovery and to determine the need for corrective actions (Moore et al., 1999; Gardon et al., 2020). The way to know what nature produces in the absence (or minimal) of human impacts is based on the knowledge of reference values, which are those observed

in natural landscapes and mature forests (Winter et al., 2010). Knowing the values of secondary forests and older restoration areas is important because they can serve as intermediate goals for adaptive management (Brancalion et al., 2015), allowing a better understanding of the restoration progress of areas as well as determining the period it takes to reach satisfactory values of naturalness, i.e., as close as possible to a natural ecosystem (Londe et al., 2020).

The objective was to evaluate the arboreal component and structure, characterize the seed dispersal syndrome and the ecological group of species of a 45-year-old restored area by planting in Viçosa, Minas Gerais state, Brazil.

## **2. Material And Methods**

### **2.1 Study area**

The study was carried out in a forest restored 45 years ago by planting in an area  $25 \times 400$  m (1 ha) in the "Forest of Silviculture" of the Forest Engineering Department of the Universidade Federal de Viçosa (UFV), Viçosa, Brazil the Atlantic Forest biome. The planting of native and exotic species, carried out in 1967 and 1969, formed a heterogeneous forest with 485 individuals of 57 species (32 native and 25 exotic) spaced at  $4 \times 5$  m. The area has a history of disturbance due to pasture and eucalyptus planting.

### **2.2 Sampling of tree vegetation**

The number of individuals planted or dead was evaluated in sixteen contiguous plots of  $25 \times 25$  m in 2016 per tree stratum. The circumference and height of all arboreal individuals with a diameter at breast height (DBH = 1.30 m) equal to or greater than 5 cm in the plots were measured with a tape measure and Hypsometer Forest Vertex IV, respectively.

Botanical samples (branches) of non-identified species in the field were collected to compare them with the material deposited in the VIC herbarium at the UFV, by specialists and the literature. The scientific names and authors were updated according to the Missouri Botanical Garden (2016) and families according to the Angiosperm Phylogeny Group IV system (APG IV, 2016).

### **2.3 Analysis of data**

The sampled species were divided into successional categories as pioneers (P), initial (IS) and late (LS) secondary and the in the categories of initial, medium and advanced succession (Budowski 1965, Gandolfi et al., 1995). Species without ecophysiological information and not included in any of the categories were referred as non-characterized (NC). The species were also classified as anemochoric (Ane), autochoric (Auto) or zoochoric according to their seed spread syndrome (Zoo) (van der PIJL, 1982).

The phytosociological parameters density, frequency, dominance and importance value (IV), Shannon's diversity ( $H'$ ) and Pielou's Equability ( $J'$ ) (1975) (Mueller-Dombois and Ellenberg 1974, Brower et al., 1998) were obtained with the Mata Nativa 4.02 program (CIENTEC, 2016).

## 3. Results

### 3.1 Floristic

A total of 1,323 individuals of 109 species (91 natives, 15 exotics and 3 uncharacterized) of 35 botanical families were recorded in the restored Semideciduous Seasonal Forest. According to the ecological group, 25, 34, 35 and 15 species were P, IS, LS and NC, respectively, according to their ecological group (Table 1 – supplementary material). The exclusive species of the non-planted tree strata (regenerating) represented 56% of the total species sampled, being 51 natives, six exotics and four NC (Fig. 1). The IS species occupied 42%, 34.4% and 33% of the tree strata, non-planted ones and the total planted area, respectively. The proportion of individuals of those species planted was higher for the IS species (43.7%), and the individuals of the LS class prevailed in the non-planted tree strata (38.9%) and in the total area (38.3%)(Fig. 2).

The Zoo dispersion syndrome predominated with 58 species, followed by Ane and Auto syndromes with 28 and 16 species, respectively. Sixty-two species in the area were not planted in 1967 and 1969. The number of species and individuals with Zoo dispersion syndrome and the non-planted tree strata were higher, 48.6% and 52.1 species and 58.4% and 59.6% individuals, respectively. The Ane syndrome was found for 38.0% and 32.5% of for the planted species and individuals, respectively (Fig. 3).

### 3.2 Forest structure

The H' and J' indexes of the 45-year-old restored area were 3.46 and 0.74, respectively. The importance value of the *Guarea guidonia* and *Archontophoenix cunninghamiana* 4.7 and 1.6%, respectively (Fig. 4). However, the *A. cunninghamiana* was concentrated in a few plots.

### 3.3 Vertical and horizontal stratification

The majority of individuals *G. guidonia* and *A. cunninghamiana* present in the restored forest are in diametric classes of 7.5, 12.5 and 17.5 cm in diameter (Fig. 5). The height of the trees ranged from 2 to 32 m with an average of 13 m. The height of *Archontophoenix cunninghamiana* was highest (32 m) followed by *P. gonoacantha* and *A. peregrina*, both up to 30-m height, *G. guidonia* with 28 m, *L. grandiflora* and *S. campanulata* with 27 m (Fig. 6). The basal area was 44.1 m<sup>2</sup> ha<sup>-1</sup>.

## 4. Discussion

The density of species sampled (1,323 individuals ha<sup>-1</sup>) was higher than in a 9-year-old restored area with exotic and native species in Mogi-Guaçu, State of São Paulo (809 individuals ha<sup>-1</sup>) (Colmanetti and Barbosa, 2013). The richness of species sampled was higher than those of surveys in forest remnants of the Seasonal Semideciduous Forest in the Zona da Mata region (Prado Júnior et al., 2010) and in a fragment of a Legal Reserve (Lopes et al., 2011), both in the Minas Gerais state with 73 and 86 species, respectively. The density of individuals and richness of species indicate successful restoration as found in restored areas and/or preserved fragments of Seasonal Semideciduous Forest in the same region. This

is due to the increase in the number of species over the course of secondary succession in tropical forests by partition of resources between a great number of species (Aidar et al., 2001; Rodrigues et al., 2004). This improves nutrient cycling, soil fertility and shading, following a successional facilitation model (Connell and Slatyer, 1977). The recovery of diversity in secondary forests in Zona da Mata follows that of other studies (Guariguata and Ostertag, 2001; Martin et al., 2013; Rozendaal et al., 2019), showing a similar pattern between secondary forest plots and propagation sources. In addition, the higher species richness in older secondary than in primary forests is due to the coexistence of P and LS species (Bongers et al., 2009; Huston and Smith, 1987). This indicator of tree species richness in planted areas was similar to the reference areas present in the surroundings, showing that efforts have been made so that naturally diverse areas are restored from a large set of species, which is more efficient for permanent forest restoration (Rodrigues et al., 2009; Gardon et al., 2020). However, at least 20 years may be necessary for the recovery of species richness in areas of assisted and unassisted natural regeneration. This coincides with the recovery of the richness of animal species in abandoned tropical areas, showing a strong relationship between flora and fauna (Dunn, 2004; Londe et al., 2020).

The predominance of species with the Zoo dispersion syndrome followed by Ane and Auto syndromes is important in the maintenance, spatial distribution and frequency of species (Tabarelli et al., 2002; Talora and Morellato, 2000) as found in two Semideciduous Seasonal Forest remnant with Zoo, Ane and Auto dispersion of 78%, 20%, and 2% (Lopes et al., 2011) and 68, 22 and 9%, respectively (Prado Junior et al., 2012). The predominance of species with Zoo dispersion syndrome showed the presence of dispersing animals and availability of food and shelter (Miranda Neto et al., 2012) reduction in the number of native species in the 45-year-old restored area was possibly due to the most of tree species belonged to the successional class ST, which need specific environmental conditions such as more shaded areas (Turchetto et al., 2017). The individuals planted, mostly IS species, influenced the succession and indicates that the forest is heading towards an intermediate successional stage, due to the lower percentage of P species (Silva et al., 2004). The largest number of Zoo forest species reveals plant communities in advanced stages of succession in good condition (Mazer and Wheelwright, 1993), ensuring greater protection and supply of resources for animals. High values of Zoo syndrome indicate an area closer to naturalness, confirming an advanced stage of restoration (Londe et al., 2020). This suggests that adequate proportions of this group of plants have been used in the restored area and that there are also zoochoric dispersal species in natural regeneration areas. High values for zoo-dispersal tree groups show the progression of ecological succession, the participation of local species and the attraction of fauna, contributing to the diversity of species and accelerating the regeneration of native vegetation (Wunderle, 1997).

The high values of  $H'$  and  $J'$  (3.46 and 0.74, respectively) agrees with results for other areas in Minas Gerais state with greater diversity than that of a Deciduous Forest in Montes Claros state, Minas Gerais ( $H' = 3.3$ ) (Neri et al., 2007; Santos et al., 2007) and lower than in a Semideciduous Seasonal Forest in Viçosa, Minas Gerais ( $H' = 4.25$ ) (Marangon et al., 2007). The estimated values of the  $H'$  and  $J'$  indices varies with factors such as the plot size and the inclusion criterion for the succession of vegetation and the sampling method (Higuchi et al., 2012), as well as the different degrees of naturalness of the forests

in the various study sites (Tang et al., 2020). The high  $J'$  was similar to that in a well-preserved vegetation fragment in a Seasonal Semideciduous Forest representative of the original condition in the Uberaba, Minas Gerais state ( $J' = 0.73$ ) (Dias Neto et al., 2009) and higher than that of restored areas ( $J' = 0.89$ ) (Colmanetti and Barbosa, 2013). The floristic results in the Semideciduous Seasonal Forest area were similar to the present study but factors such as succession stage, degree of disturbance and site characteristics can affect them (Gonçalves and Souza, 2014). The highest VIs of *G. guidonia* and *A. cunninghamiana* was due to the diametric distribution in the inverted J-pattern, i.e., a large number of individuals in the smaller diameter classes and that *G. Guidonia* being an LS species and well adapted to shaded environments (Lorenzi, 2002). The current intermediate-advanced succession stage of the study area allowed the propagation and development of this species, which did not occur in the initial successional stage after planting. In addition, *G. guidonia* takes longer to enter reproductive age because it is an IS (Lorenzi, 2002). *Archontophoenix cunninghamiana* is an exotic and invasive species in the understory of forest fragments or mature restored forests and this palm coexists with other native species tolerant to shade (Dislich et al., 2002; Miranda Neto et al., 2012). The presence of this species in a high-density value in a few plots makes an imbalance distribution of this species in the area. The lower number of shade-tolerant exotic species compared to that of heliophytes increases the impact of the first species threatening best-preserved environments and the conservation value (Martin et al., 2009).

The average height of arboreal individuals was greater than that of a forest fragment in good conservation stage in the Minas Gerais state (Campos et al. 2006). The average tree height greater than 12 m represents forests in advanced succession stage in the Atlantic Forest of the Minas Gerais state (CONAMA Resolution 392/2007) and its structural diversity shows a succession stage as found for primary forests. This is due to the establishment of multilayer strata at early stages of forest vegetation development, allowing the forest system to efficiently use nutrients, light, water and other resources (Danescu et al., 2016; Potzelsberger and Hasenauer, 2015). The basal area was higher than that of fragments of seasonal semi-deciduous forest in the region (Braga et al., 2011), with  $20.01 \text{ m}^2 \text{ ha}^{-1}$  and initial forest with  $23 \text{ m}^2 \text{ ha}^{-1}$  (Colmanetti and Barbosa, 2013). The increase in the basal during the succession did not reach the values found in primary forests. The presence of very large and probably centennial trees in primary forests can explain its greater variation of the basal area compared to old secondary forests (Lucas-borja et al., 2016), contributing to an increasing basal area. The basal area may indicate success in forest restoration, despite the age difference of the plantations (Braga et al., 2011; Colmanetti and Barbosa, 2013).

## 5. Conclusions

The restoration of Seasonal Semideciduous Forest provided conditions to regenerating regional native species with a predominance of those with initial secondary successional zoochoric dispersion syndrome. The low frequency of pioneer species shows the progress of the restored area. Secondary forest succession is a viable and efficient strategy in fragmented environments and modified landscapes, as it increases forest coverage and the conservation of the biodiversity and ecosystem services.

# Declarations

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## Authors' contributions:

Wiane Silva, Luiz Cosimo, conducted the field measurements. Sebastião Martins, Carlos Torres, conceived the study and revised the manuscript. Wiane Silva, drafted the manuscript. Ricardo Cruz, José C. Zanuncio, revised the manuscript. The author(s) read and approved the final manuscript.

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The datasets analyzed during the current study are available from the corresponding author on reasonable request.

## Ethics approval and consent to participate:

Not applicable.

## Consent for publication:

Not applicable.

## Declaration of Competing Interest:

The authors declare that they have no know competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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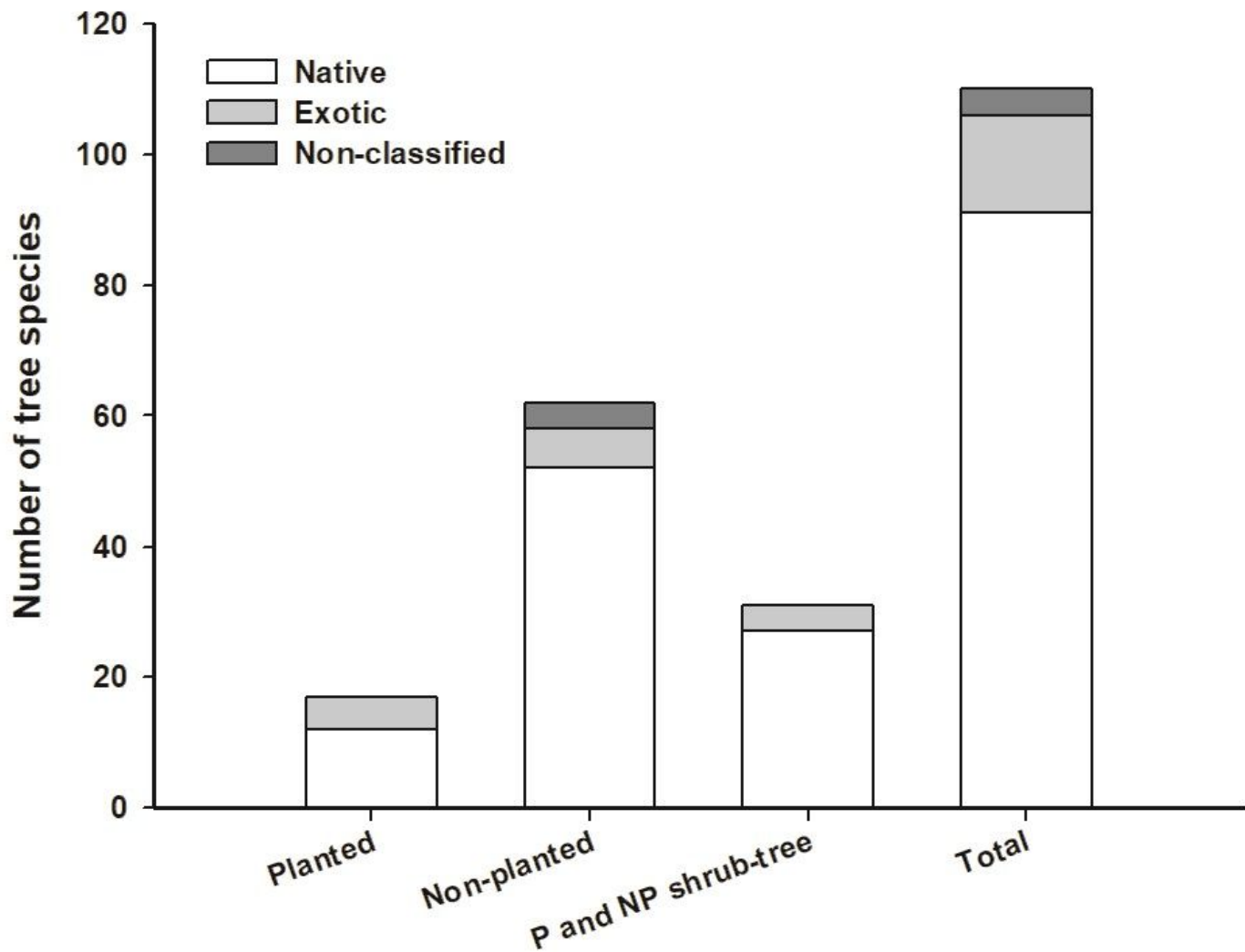
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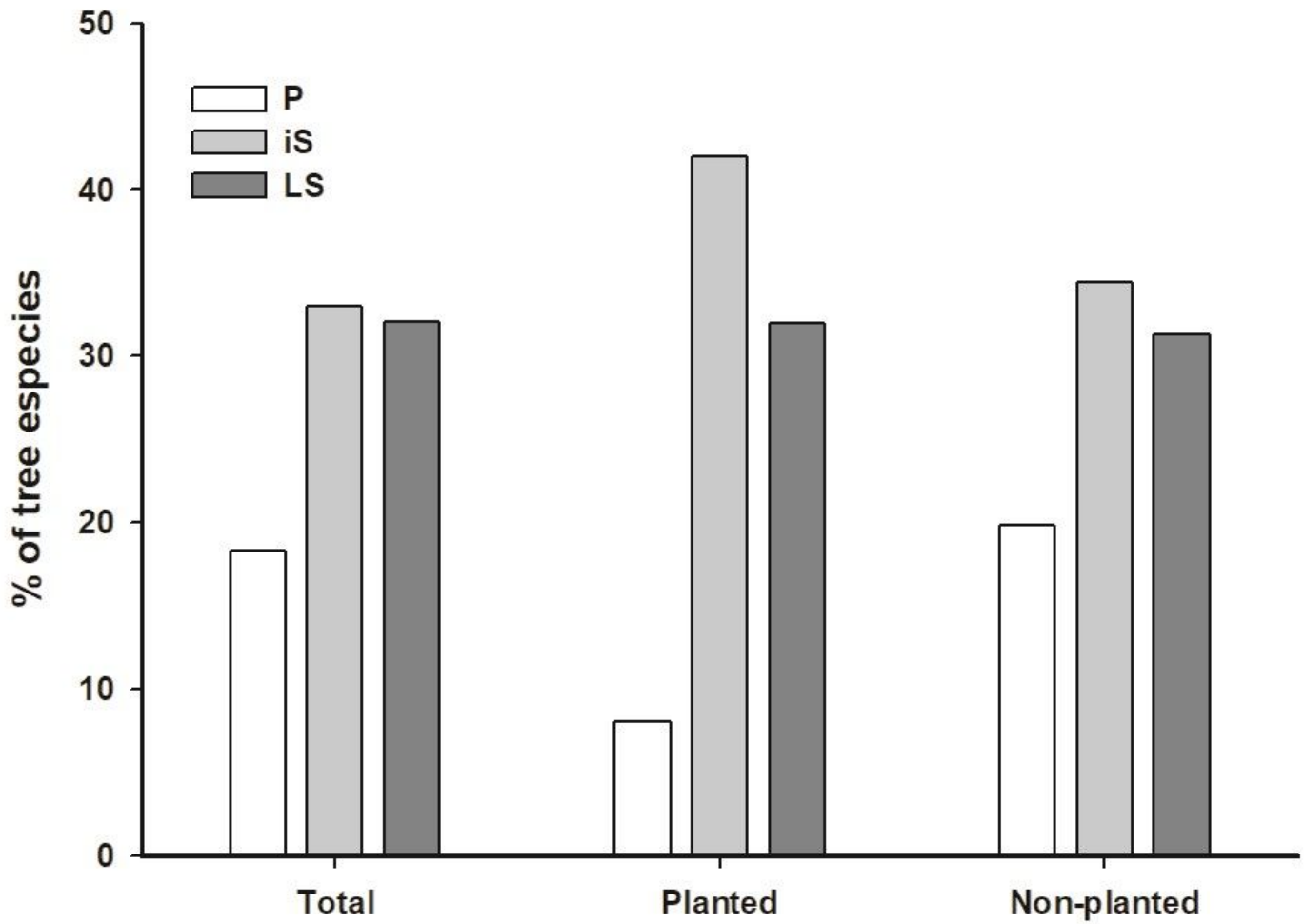
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## Figures



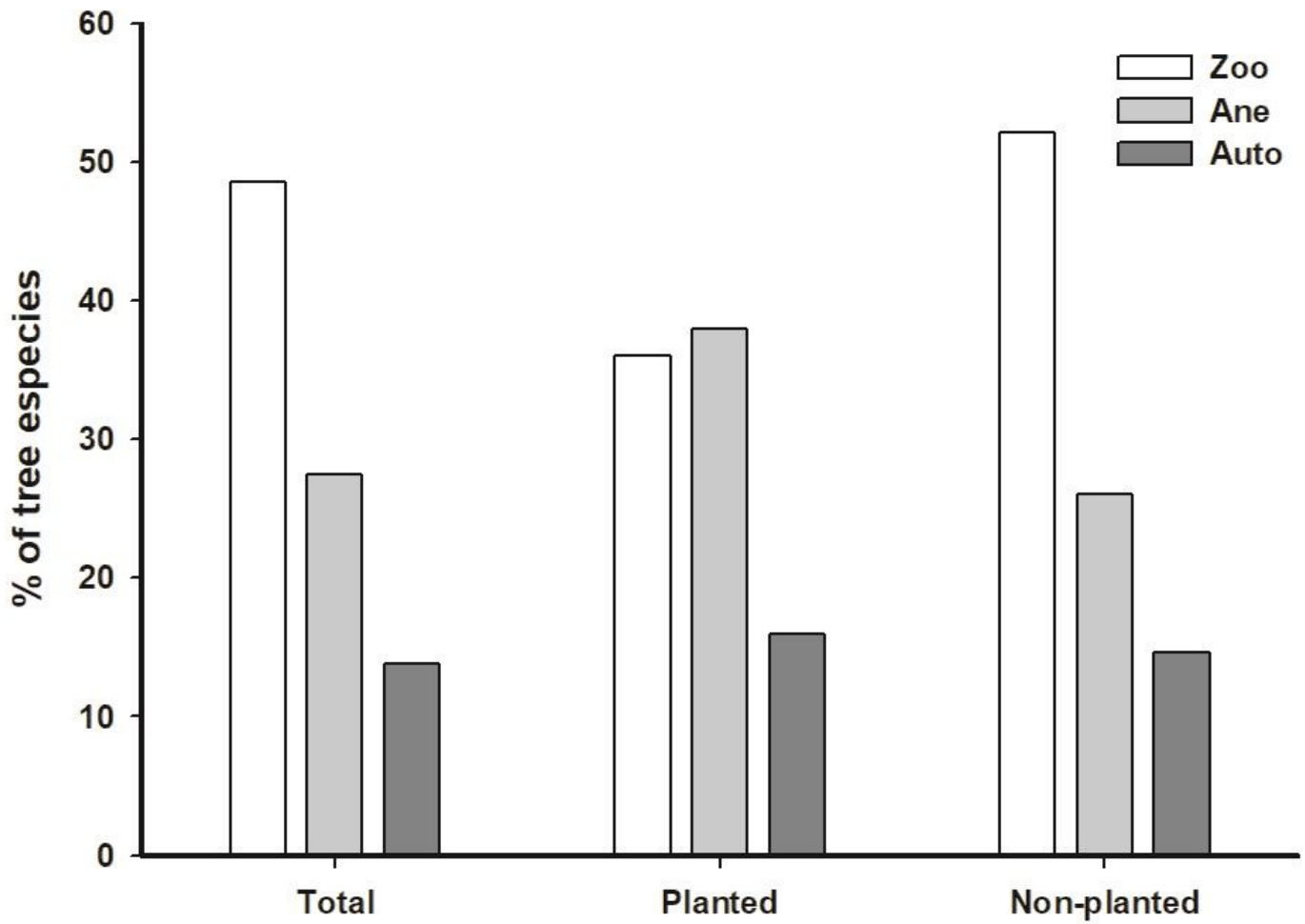
**Figure 1**

Tree species distribution in relation to the origin, being planted or non-planted tree strata in a 45-year-old restored forest in Viçosa, Minas Gerais state, Brazil. Exclusive species of planting (Planted), unplanted species in the shrub-tree strata (Non-planted), common tree species in planted and non-planted strata (P and NP shrub-tree), total area (Total).



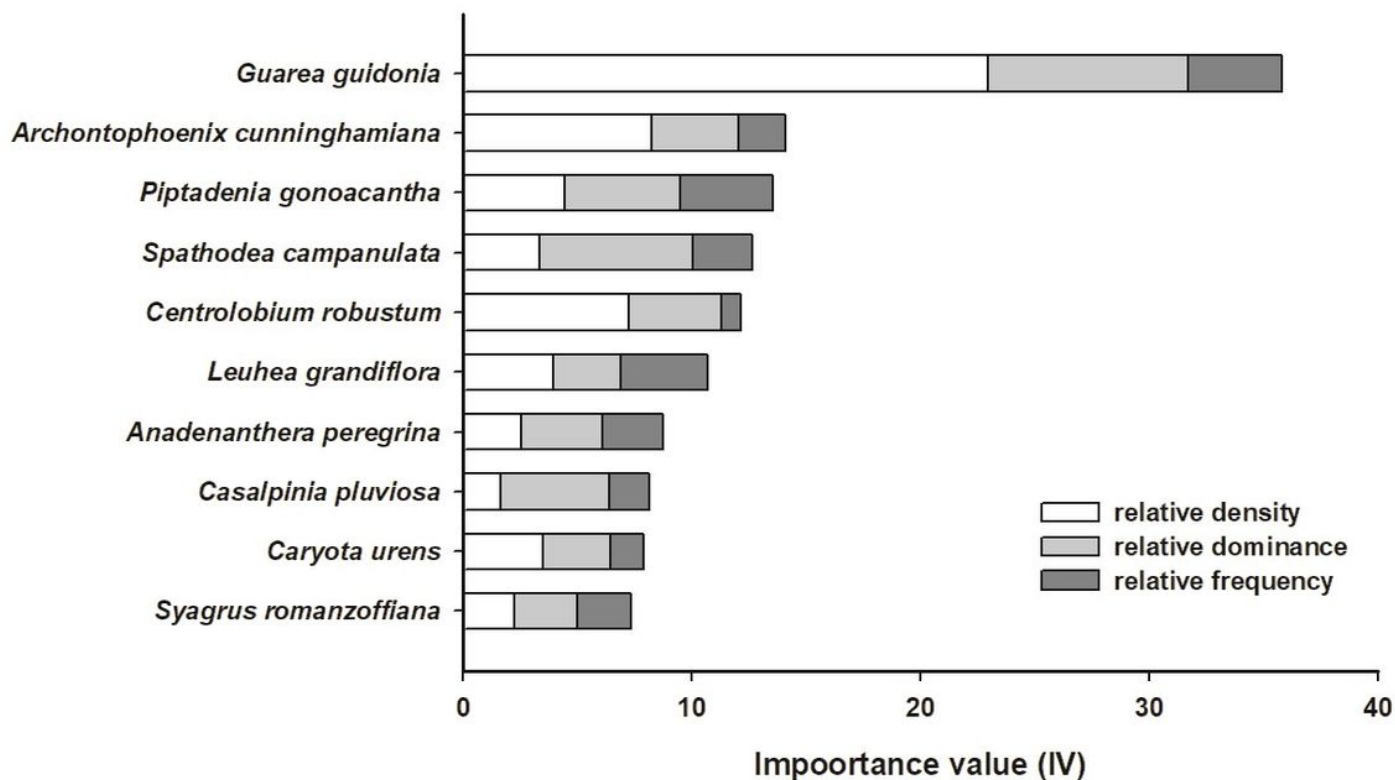
**Figure 2**

Distribution of tree species sampled (%) in the 45-year-old restored forest in Viçosa, Minas Gerais state, Brazil by successional class. P= pioneer; iS= initial secondary; LS= late secondary. Total, total tree species; Planted= planted tree species; and Non-planted, unplanted species in the shrub-tree strata.



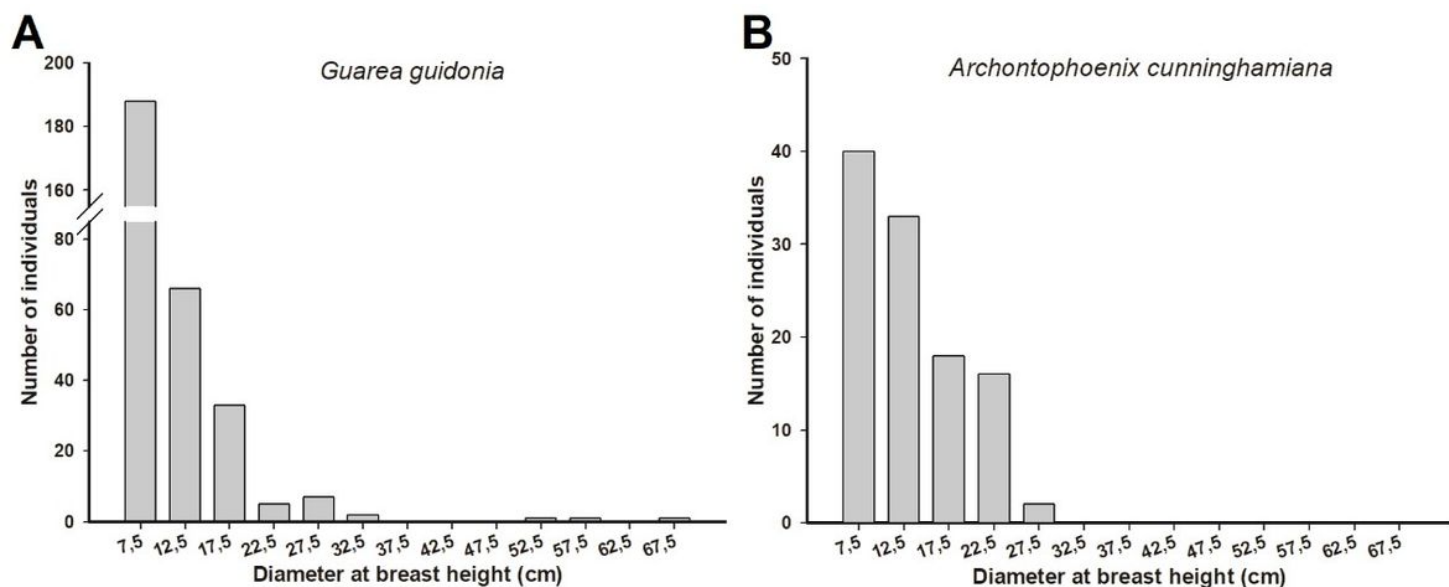
**Figure 3**

Distribution of tree species sampled (%) in the 45-year-old restored forest in Viçosa, Minas Gerais state, Brazil by dispersion syndrome. Zoo = zoochory; Ane = anemochory; Auto = autochory. Total, total tree species; Planted= planted tree species; and Non-planted, unplanted tree species in the shrub-tree strata.



**Figure 4**

Importance value (VI) for the main species sampled in the 45-year-old restored forest in Viçosa, Minas Gerais, Brazil.



**Figure 5**

Distribution by diametric class of *Guarea guidonia* (A) and *Archontophoenix cunninghamiana* (B) individuals sampled in the 45-year-old restored forest in Viçosa, Minas Gerais, Brazil.

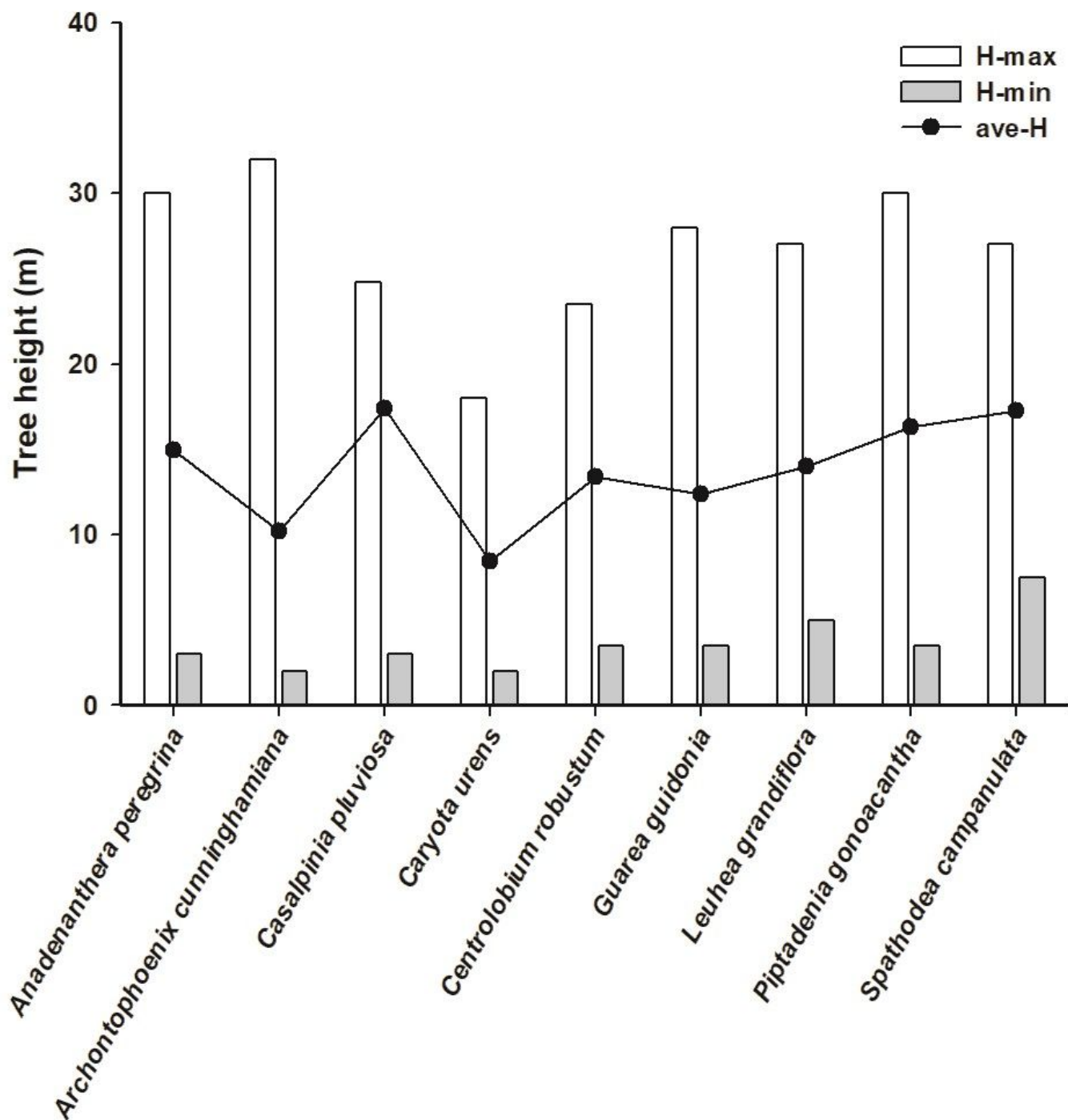


Figure 6

Vertical stratification of the nine species with the highest importance value in the 45-year-old restored forest in Viçosa, Minas Gerais state, Brazil.

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Table1Supplementary.docx](#)