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### TREE COMMUNITY COMPOSITION AND ABOVEGROUND BIOMASS IN A SECONDARY ATLANTIC FOREST, SERRA DO MAR STATE PARK, SÃO PAULO, BRAZIL

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Flux tower  
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**ABSTRACT:** Projects involving floristic-phytosociological surveys are becoming increasingly frequent and is a very important tool to access the biodiversity, status of succession and biomass and carbon storage, guiding conservation and management strategies. These studies are particularly important in Atlantic Forest, which is considered a hotspot in terms of biodiversity, endemism and impacts. São Paulo State lost more than 80% of original forest and, nowadays, remains only isolated patches with a variety stage of succession and history of use. The aim of this study was to characterize the structure, composition and biomass of the woody plant community in a Montane Ombrophilous Dense Forest, Serra do Mar State Park. All trees with DBH  $\geq$  4.8 cm were sampled in 1 ha plot area, totaling 1,704 individuals belonging to 38 botanical families and 143 species. The highest species richness was found in the Myrtaceae and Lauraceae families, and the greatest value of abundance and Importance (IV) was observed in the Arecaceae and Euphorbiaceae. The Shannon index ( $H'$ ) was 3.7 nats.ind.<sup>-1</sup> and the Pielou's evenness index (J) 0.7, characterizing a very diverse community with heterogeneous distribution of individuals by species. The aboveground biomass was 166.3 Mg·ha<sup>-1</sup>, similar to others studies in Atlantic forests. The forest composition, biomass and the history of land use indicate a middle secondary stage of regeneration, but evolving to a more mature condition.

### COMPOSIÇÃO DA COMUNIDADE ARBÓREA E BIOMASSA AÉREA EM UMA FLORESTA ATLÂNTICA SECUNDÁRIA, PARQUE ESTADUAL DA SERRA DO MAR, SÃO PAULO, BRAZIL

**RESUMO:** Trabalhos envolvendo levantamentos florístico-fitosociológicos são cada vez mais frequentes e são uma ferramenta importante para acessar a biodiversidade, estágio de sucessão e acúmulo de biomassa e carbono, norteando estratégias de conservação e manejo. Esses estudos são particularmente importantes para a Mata Atlântica, considerada um hotspot em função da biodiversidade, endemismo e impactos. O Estado de São Paulo perdeu mais de 80% de sua floresta original e, atualmente, existem somente fragmentos isolados, com diferentes estágios de sucessão e histórico de uso. O objetivo desse estudo foi caracterizar a vegetação, a estrutura e a biomassa de um componente arbóreo localizado em Floresta Ombrófila Densa Montana, Parque Estadual da Serra do Mar. Foram amostrados indivíduos com DAP  $\geq$  4,8 cm em 1 ha, totalizando 1.704 indivíduos pertencentes a 38 famílias botânicas e 143 espécies. A maior riqueza de espécies foi encontrada nas famílias Myrtaceae e Lauraceae e a maior abundância e Valor de Importância (VI) em Arecaceae e Euphorbiaceae. O índice de Shannon ( $H'$ ) foi de 3,7 nats.ind.<sup>-1</sup> e a equabilidade de Pielou (J) 0,7, indicando que a comunidade da área é bastante diversa, contudo a distribuição dos indivíduos pelas espécies não é homogênea. A biomassa aérea foi de 166,3 Mg·ha<sup>-1</sup>, semelhante ao encontrado em outros estudos. A composição da floresta, biomassa e o histórico de exploração da área demonstraram que a fisionomia estudada apresenta-se em estágio secundário médio de regeneração avançando para uma condição mais tardia.

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## INTRODUCTION

The Brazilian Atlantic Forest (AF) is the second largest tropical moist forest of South America, covering, initially, ca. 1.450 million km<sup>2</sup> (17%) of the country (JOLY et al., 2014) and approximately 80% of the São Paulo State (JOLY et al., 1999). The Atlantic Forest is considered the oldest Brazilian forest (RIZZINI, 1997), characterized by its high biodiversity and endemism and a hotspot for biodiversity conservation (MYERS et al., 2000), due land use change dating back to European's settlement (RIBEIRO et al., 2009). According to Malhi et al. (2014), many human-modified tropical forest landscapes are complex and highly heterogeneous and must be better understood in order to develop efficient strategies for conservation.

In São Paulo State, only 15.3% of original forest cover remains (SOSMA/INPE, 2013). The majority of these remnants are found in the mountainous region of southeast near the shore, where is also located the largest Conservation Unit of the Atlantic Forest, the Serra do Mar State Park (GALINDO-LEAL; CÂMARA, 2005). Nowadays, Atlantic Forest is mainly composed of isolated patches of small forests fragments, surrounded by pastures, agricultural fields and urbanization, and only few larger fragments remains (RIBEIRO et al., 2009). Hobbs et al. (2009) highlighted that the effect of human activities in the forest and the surrounds could promote the development of new ecosystems which differ in composition and/or function from present and past systems, especially as a consequence of changing species distributions and environmental alteration. In the last three decades, many studies have been devoted to Atlantic forest, firstly focused in fauna and flora's diversity and, more recently, focusing on the functionality of the forest and carbon stock (VIEIRA et al., 2008, JOLY et al., 2014).

The Brazilian Atlantic Forest comprises five main forest physiognomies – Dense Ombrophilous, Open Ombrophilous, Mixed Ombrophilous, Seasonal Semideciduous and Seasonal Deciduous Forests (JOLY et al., 2014). According to IBGE (2012), the dominant vegetation in the state of São Paulo is classified as Ombrophilous Dense Forest and its subdivisions based on altimetry. The one which covers the Serra do Mar and the Atlantic Plateau, with altitudes between 500 and 1,500 m, is classified as Montane Ombrophilous Dense Forest (Dm) and is partially protected by the Serra do Mar State Park (SMSP). This forest formation, composition, and functionality is strongly influenced by environmental conditions, especially rainfall, temperature

and the frequency of fog (ALVES et al., 2010; VIEIRA et al., 2011). The hillsides of Serra do Mar act as a moisture barrier against the sea breeze, which combined with the cold fronts and the South Atlantic Convergence Zone, resulting in an increase in precipitation rates, known as orographic rain (OLIVEIRA-FILHO; FONTES, 2000).

High altitudes environments, with colder and moister climates, tend to have lower temperatures and formation of mists and fog (BRUIJNZEEL; VENEKLAAS, 1998). Furthermore, these environmental conditions lead to the accumulation of large quantities of organic matter (SOETHE et al., 2008). In general, montane forests have higher density of individuals, lower diversity of species and families and, vascular and avascular epiphytic, compared with other tropical forests at lower altitudes (HAMILTON et al., 1995; LIEBERMAN et al., 1996). Alves et al. (2010) found an increase of aboveground biomass along of altitudinal gradient in the Ombrophilous Dense Atlantic Forest, as well as litter accumulation and carbon and nitrogen stocks, both above and below ground (VIEIRA et al., 2011). In the montane forests, the environmental conditions are imposed by higher altitude belts and their species could be more sensitive to current changes in the global climate, suggesting an evidence of biodiversity loss a near future (SILVA; TABARELLI, 2000).

Phytosociological analysis and estimation of biomass and carbon stock of a plant community are essential for ecological study, evaluation of successional status and useful for carbon flow measurements between the forest and the atmosphere, resulting from the balance between gain through photosynthesis and loss through respiration and mortality (KEELING; PHILLIPS, 2007). Related to aboveground biomass, Melillo et al. (1993) suggested that the tropical forest has an important function on carbon exchange between atmosphere and terrestrial vegetation (36%), but there are still scarce data about the stock of carbon. Biomass and carbon stock can be calculated in a non-destructive manner by using allometric equations (CHAVE et al., 2005), which vary according to plant physiognomy. The total aboveground biomass is strongly influenced by the canopy height variation, wood density, and community plant composition, as well as successional stage of the forest, ecological interactions, climate and soil conditions (CHAVE et al., 2005; VIEIRA et al., 2008; ALVES et al., 2010).

The main aim of this study was to characterize the tree species composition and aboveground biomass of a community located in the footprint area of an Eddy covariance flux tower (KLJUN et al., 2002) in the Montane

Ombrophilous Dense Forest, in the Santa Virginia Nucleus of Serra do Mar State Park. The plot studied had suffered clearcut for charcoal production more than 40 years ago, and since then, there is no more reported disturbance. This past disturbance influenced the observed ecological and biodiversity parameters. The long term carbon and water monitoring is fundamental for a better understanding of forest functionality, especially in Tropical Forests and climate change scenarios. In this aspect, the vegetation inventory is essential to characterize the plot status of succession and carbon flux, as plants are the largest biomass component in the ecosystem (FERSTER et al., 2015).

## MATERIAL AND METHODS

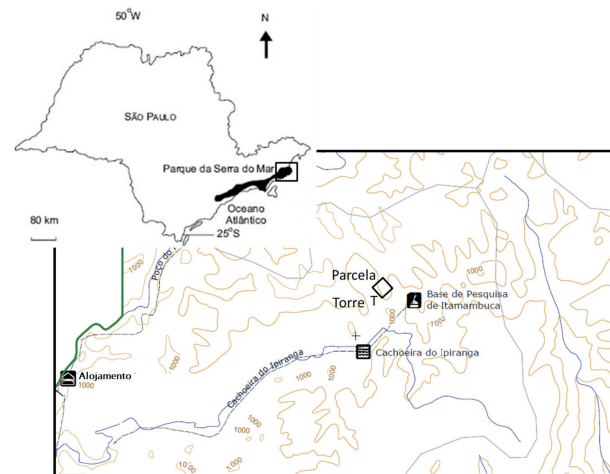
### Study area

This study was carried out in Ribeirão da Casa de Pedra watershed – Santa Virgínia Nucleus, Serra do Mar State Park – Ubatuba, SP, more specifically in the footprint area of the flux tower installed in 2007 (23°17'–23°24'S and 45°03'–45°11'W; 1,020 m of altitude; <http://www.fluxdata.org:8080/SitePages/siteInfo.aspx?BR-Afs> – Figure 1). Santa Virgínia Nucleus at Serra do Mar State Park extending over an area of 17,000 hectares and altitude range from 740 to 1,600 m (INSTITUTO FLORESTAL, 2010) is considered an important area in biological and cultural aspects. Soils in the Serra do Mar State Park are classified as Inceptisol (USDA, 1999) with approximately 60% of sand, 20% of silt and 20% of clay (Alves et al., 2010). Moreover, they are characterized by the presence of shallow soils, geologically ancient, well-drained, low pH, high phosphorus concentration and aluminum saturation compared to lower altimetric sites (SCARANIELLO et al., 2011; MARTINS, 2010).

The forest area is characterized by average litter accumulation of 7.2 Mg ha<sup>-1</sup>.yr<sup>-1</sup>, relatively well distributed along the year (AIDAR et al., unpublished data) in the surface layers of the soil, which also contains the largest nutritional reserves (VIEIRA et al., 2011). According to Köppen (1948), the regional climate can be classified as Cwa – temperate and tropical climate, with hot and wet summers, and slightly dry winters. The average minimum temperature is 10.6 °C, the maximum of 26.1 °C (MARTINS, 2010) and the average annual rainfall of 2,200 mm with the wettest months being December, January and February (SIEGLOCH; FROEHLICH; SPIES, 2012).

Veloso et al. (1991) classified the vegetation in the plot area as Montane Ombrophilous Dense Forest.

Tabarelli and Mantovani (1999) reported that as a result of land occupation and logging activities in the 1960's, the current forest vegetation is a mosaic with different successional stages (primary and secondary), pastures and Eucalyptus spp. plantations. Medeiros and Aidar (2011) found a physiognomy composed by large trees and uniform canopy covering 80% of the Ribeirão da Casa de Pedra watershed in Santa Virgínia Nucleus.



**FIGURE 1** Maps showing the location of the region (Ubatuba, SP) and study area in Santa Virgínia Nucleus – Serra do Mar State Park. The symbol (◊) indicate the sampled plot – Plot Torre (T).

### Vegetation Sampling

The phytosociological survey was performed using the plot method (MUELLER-DOMBOIS; ELLENBERG, 1974). The sampling site is located in the flux tower footprint at 1,020 m of altitude. The 100 x 100 m (1 ha) plot was divided into 25 blocks of 20 x 20 m. All living trees with stem diameter (one or multiple) at 1.30 m above the ground (DBH) ≥ 4.8 cm were included in the sample. The approximate height (from the base to the highest branch) was acquired either with a clinometer or by comparison with known height, to define the average height. The plant material was collected in the reproductive or vegetative stage (FIDALGO; BONONI, 1984) and identified by using a specialized bibliography and comparisons with specimens deposited in herbarium collections from São Paulo (“SPSF – Instituto Florestal”) and Campinas (“UEC – Universidade Estadual de Campinas”). The floristic list was prepared according to the classification system proposed in APG III (2009), and the confirmation and updating of species names and authors were accomplished by consulting the REFLOA – Flora do Brasil 2020 – LEFB database (FLORA DO BRASIL 2020, 2016). Materials with flowers, fruit, or

vegetative were incorporated into the UEC Herbarium of the University of Campinas and the codes of the incorporated exsiccates can be found on the Herbarium of the State University of Campinas (UEC) available in the speciesLink Project (CRIA, 2016).

Estimates of the vegetation aboveground biomass (AGB) were carried out to complement the characterization of the study area and it is a useful knowledge to evaluate the carbon fluxes between aboveground forest ecosystems and the atmosphere (CHAVE et al., 2005). The model chosen for moist forest stands was based on Chave et al. (2005), the same employed by Medeiros and Aidar (2011) in other plot at Serra do Mar State Park (Equation 1). The wood density values were extracted from Chave et al. (2006), when it was not available for one specific species, it was used the average of the genus or family. The allometric equations for palm trees (Equation 2) and ferns (Equation 3) were based on other authors (NASCIMENTO; LAURANCE, 2002; TIEPOLO et al., 2002, respectively). Lianas, bamboos, and epiphytes were not included. Where,  $\rho$  = wood specific density ( $\text{g}\cdot\text{cm}^{-3}$ ) (CHAVE et al. 2006, ALVES et al. 2010), DBH = diameter at 1.30 m height from the ground (cm), H = height (m), exp = exponent applied to the base, ln = natural logarithm.

$$\text{AGB} = \exp \left[ -2.977 + \ln (\rho \cdot \text{DBH}^2 \cdot H) \right] \quad [1]$$

$$\text{AGB} = \left\{ \exp[0.9285 \cdot \ln (\text{DBH}^2) + 5.7236] \cdot 1.05001 \right\} \cdot 10^{-3} \quad [2]$$

$$\text{AGB} = -4266348 \cdot \left\{ 1 - [2792284 \cdot \exp(-0.313677 \cdot H)] \right\}^{-1} \quad [3]$$

**TABLE I** List of 20 most important species, families and phytosociological parameters in Montane Ombrophilous Dense Forest, Serra do Mar State Park. NInd - Number of individuals, RelDe - Relative density, RelFr - Relative frequency, IV - Importance value, CV - Coverage value, SG. - Successional group (PI - Pioneer, ES - Early secondary, LS - Late secondary and NC - Not characterized).

Species	Family	NInd	RelDe	RelFr	IV	CV	SG
<i>Alchornea triplinervia</i> (Spreng.) Müll. Arg.	Euphorbiaceae	245	15.35	3.29	45.55	42.21	ES
<i>Euterpe edulis</i> Mart.	Arecaceae	267	16.73	3.59	32.22	28.60	ES
Cyatheaceae n.i	Cyatheaceae	117	7.33	2.84	14.61	11.70	ES
<i>Miconia cabucu</i> Hoehne	Melastomataceae	44	2.76	2.69	7.79	5.11	ES
<i>Tibouchina pulchra</i> Cogn.	Melastomataceae	23	1.44	1.79	6.91	5.12	ES
<i>Myrcia spectabilis</i> DC.	Myrtaceae	47	2.94	2.69	6.90	4.21	LS
<i>Licania hoehnei</i> Pilg.	Chrysobalanaceae	24	1.50	1.35	6.32	4.97	LS
<i>Guapira opposita</i> (Vell.) Reitz	Nyctaginaceae	35	2.19	2.39	6.20	3.81	ES
<i>Piptocarpha macropoda</i> (DC.) Baker	Asteraceae	17	1.07	1.64	5.87	4.22	PI
<i>Solanum cinnamomeum</i> Sendtn.	Solanaceae	28	1.75	1.49	5.65	4.15	PI
<i>Myrcia splendens</i> (Sw.) DC.	Myrtaceae	28	1.75	2.24	5.03	2.78	LS
<i>Schefflera angustissima</i> (Marchal) Frodin	Araliaceae	20	1.25	1.79	5.02	3.22	ES
<i>Bathysa australis</i> (A.St.-Hil.) K.Schum.	Rubiaceae	28	1.75	1.94	4.75	2.81	LS
<i>Guatteria australis</i> A. St.-Hil.	Annonaceae	27	1.69	2.24	4.45	2.21	LS
<i>Ocotea dispersa</i> (Nees and Mart.) Mez	Lauraceae	25	1.57	2.09	4.33	2.24	LS
<i>Mollinedia argyrogyna</i> Perkins	Monimiaceae	18	1.13	1.49	4.19	2.71	ES
<i>Sloanea hirsuta</i> (Schott) Planch. ex Benth.	Elaeocarpaceae	12	0.75	1.21	3.8	2.60	LS
<i>Cryptocarya mandiocana</i> Meisn.	Lauraceae	20	1.25	1.94	3.64	1.71	LS
<i>Chrysophyllum viride</i> Mart. and Eichler	Sapotaceae	5	0.31	0.75	3.49	2.74	LS
<i>Inga lanceifolia</i> Benth.	Fabaceae	20	1.25	1.79	3.43	1.64	LS

## Data Analysis

Stem density, absolute and relative dominance (Basal area), absolute and relative frequency, importance, coverage and diversity (Shannon's diversity, H'; Pielou's evenness, J) indexes were calculated using FITOPAC 2.1 software (SHEPHERD, 2010; PIELOU, 1975). Individuals were grouped by diameter and height classes to evaluate the forest structure. In addition, the species were classified into the successional groups proposed by Gandolfi et al. (1995), especially considering the survival and germination in the light, as pioneer, early secondary and late secondary. Comparisons with the literature (AIDAR et al., 2003; GOMES et al., 2011; MEDEIROS AND AIDAR, 2011; PADGURSCHI et al., 2011) were used for the species definition in each of the ecological groups.

## RESULTS AND DISCUSSION

Of a total of 1,704 trees found, 1,596 (93.7 %) were identified, 75 (4.4%) were unidentified and 33 (1.9%) correspond to standing dead individuals. The identified individual trees were distributed in 143 species belonging to 38 botanical families (Table I and 2), including 258 palms (*Euterpe edulis* – Arecaceae) and 117 ferns represented by Cyatheaceae family.

The average and maximum values of diameter were 12.8 cm and 108.2 cm, respectively. The maximum height were 35.5 m and average of 10.3 m. Stem density values (1,704 ind·ha<sup>-1</sup>) and basal area (31.9 m<sup>2</sup>·ha<sup>-1</sup>) were

**TABLE 2** List of species, families and phytosociological parameters in the Montane Ombrophilous Dense Forest, Serra do Mar State Park. NInd - Number of individuals, RelDe - Relative density, RelFr - Relative frequency, IV - Importance value, CV - Coverage value, SG. - Successional group (PI - Pioneer, ES - Early secondary, LS - Late secondary and NC - Not characterized).

Species	Family	NInd	RelDe	RelFr	IV	CV	SG	Voucher
<i>Alchornea triplinervia</i> (Spreng.) Müll. Arg.	Euphorbiaceae	245	15.35	3.29	45.55	42.21	ES	UEC I60360
<i>Euterpe edulis</i> Mart.	Arecaceae	267	16.73	3.59	32.22	28.60	ES	-
Cyatheaceae n.i.	Cyatheaceae	117	7.33	2.84	14.61	11.70	ES	-
<i>Miconia cabucu</i> Hoehne	Melastomataceae	44	2.76	2.69	7.79	5.11	ES	UEC I60402
<i>Tibouchina pulchra</i> Cogn.	Melastomataceae	23	1.44	1.79	6.91	5.12	ES	-
<i>Myrcia spectabilis</i> DC.	Myrtaceae	47	2.94	2.69	6.90	4.21	LS	UEC I60385
<i>Licania hoehnei</i> Pilg.	Chrysobalanaceae	24	1.50	1.35	6.32	4.97	LS	UEC I60356
<i>Guapira opposita</i> (Vell.) Reitz	Nyctaginaceae	35	2.19	2.39	6.20	3.81	ES	UEC I60414
<i>Piptocarpha macropoda</i> (DC.) Baker	Asteraceae	17	1.07	1.64	5.87	4.22	PI	UEC I60347
<i>Solanum cinnamomeum</i> Sendtn.	Solanaceae	28	1.75	1.49	5.65	4.15	PI	UEC I60448
<i>Myrcia splendens</i> (Sw.) DC.	Myrtaceae	28	1.75	2.24	5.03	2.78	LS	UEC I60383
<i>Schefflera angustissima</i> (Marchal) Frodin	Araliaceae	20	1.25	1.79	5.02	3.22	ES	UEC I60337
<i>Bathysa australis</i> (A.St.-Hil.) K.Schum.	Rubiaceae	28	1.75	1.94	4.75	2.81	LS	UEC I60429
<i>Guatteria australis</i> A. St.-Hil.	Annonaceae	27	1.69	2.24	4.45	2.21	LS	UEC I60341
<i>Ocotea dispersa</i> (Nees and Mart.) Mez	Lauraceae	25	1.57	2.09	4.33	2.24	LS	UEC I60327
<i>Mollinedia argyrogyna</i> Perkins	Monimiaceae	18	1.13	1.49	4.19	2.71	ES	UEC I60408
<i>Sloanea hirsuta</i> (Schott) Planch. ex Benth.	Elaeocarpaceae	12	0.75	1.21	3.8	2.60	LS	UEC I60358
<i>Cryptocarya mandioccana</i> Meisn.	Lauraceae	20	1.25	1.94	3.64	1.71	LS	UEC I60333
<i>Chrysophyllum viride</i> Mart. and Eichler	Sapotaceae	5	0.31	0.75	3.49	2.74	LS	UEC I60443
<i>Inga lanceifolia</i> Benth.	Fabaceae	20	1.25	1.79	3.43	1.64	LS	UEC I60317
<i>Inga marginata</i> Willd.	Fabaceae	8	0.5	0.6	3.38	2.79	ES	UEC I60320
<i>Calyptanthes strigipes</i> O. Berg	Myrtaceae	12	0.75	1.05	3.38	2.34	LS	UEC I60364
<i>Hyeronima alchorneoides</i> Allemão	Phyllanthaceae	12	0.75	1.35	3.32	1.98	ES	UEC I60421
<i>Mollinedia schottiana</i> (Spreng.) Perkins	Monimiaceae	17	1.07	1.64	3.27	1.62	LS	UEC I60407
<i>Pouteria caimito</i> (Ruiz and Pav.) Radlk.	Sapotaceae	10	0.63	1.21	3.19	1.99	LS	UEC I60442
<i>Cupania vernalis</i> Cambess.	Sapindaceae	14	0.88	1.64	3.1	1.45	ES	UEC I60438
<i>Calyptanthes lucida</i> Mart. ex DC.	Myrtaceae	16	1.00	1.05	3.03	1.99	LS	UEC I60367
<i>Cryptocarya saligna</i> Mez	Lauraceae	12	0.75	1.64	2.88	1.03	LS	UEC I60332
<i>Ocotea catharinensis</i> Mez	Lauraceae	14	0.88	1.2	2.87	1.67	LS	UEC I60325
<i>Matayba guianensis</i> Aubl.	Sapindaceae	19	1.19	1.2	2.77	1.57	LS	UEC I60440
<i>Eugenia prasina</i> O. Berg	Myrtaceae	14	0.88	0.9	2.68	1.79	LS	UEC I60370
<i>Psychotria vellosiana</i> Benth.	Rubiaceae	17	1.07	1.2	2.58	1.39	NC	UEC I60431
<i>Inga sessilis</i> (Vell.) Mart.	Fabaceae	9	0.56	0.75	2.36	1.62	ES	UEC I60319
<i>Cinnamomum</i> sp. I Schaeff.	Lauraceae	13	0.81	1.2	2.35	1.16	LS	UEC I60335
<i>Myrsine gardneriana</i> A. DC.	Primulaceae	9	0.56	1.35	2.28	0.93	ES	UEC I60423
<i>Hirtella hebeclada</i> Moric. ex DC.	Chrysobalanaceae	9	0.56	1.2	2.16	0.97	LS	UEC I60357
<i>Cordia sellowiana</i> Cham.	Boraginaceae	11	0.69	1.2	2.13	0.93	ES	UEC I60344
<i>Guapira nitida</i> (Mart. ex J.A.) Lundell	Nyctaginaceae	8	0.5	0.24	2.12	1.08	ES	UEC I60415
<i>Psychotria</i> sp. I L.	Rubiaceae	13	0.81	1.05	2.01	0.96	NC	UEC I60434
<i>Guarea macrophylla</i> Vahl	Meliaceae	8	0.5	1.05	1.92	0.87	LS	UEC I60397
<i>Allophylus petiolulatus</i> Radlk.	Sapindaceae	10	0.63	0.75	1.9	1.16	ES	UEC I60439
<i>Miconia</i> aff. <i>latecrenata</i> Triana	Melastomataceae	8	0.50	0.90	1.80	0.90	ES	UEC I60403
<i>Eugenia oblongata</i> O. Berg	Myrtaceae	7	0.44	0.90	1.75	0.85	LS	UEC I60375
<i>Myrcia guianensis</i> (Aubl.) DC.	Myrtaceae	9	0.56	0.90	1.72	0.82	LS	-
<i>Nectandra oppositifolia</i> Nees	Lauraceae	8	0.5	0.90	1.71	0.81	LS	UEC I60330
<i>Vernonanthura puberula</i> (Less.) H.Rob.	Asteraceae	4	0.25	0.45	1.59	1.14	PI	UEC I60346
<i>Myrsine leuconeura</i> Mart.	Primulaceae	8	0.5	0.75	1.58	0.83	ES	UEC I60422
<i>Casearia obliqua</i> Spreng.	Salicaceae	9	0.56	0.6	1.54	0.94	LS	UEC I60437
<i>Cedrela fissilis</i> Vell.	Meliaceae	7	0.44	0.75	1.52	0.77	ES	UEC I60396
<i>Miconia atlantica</i> Caddah & R.Goldenb.	Melastomataceae	6	0.38	0.9	1.49	0.60	ES	UEC I60404
<i>Amaioua intermedia</i> Mart. ex Schult. and Schult.f.	Rubiaceae	6	0.38	0.9	1.42	0.53	ES	UEC I60428
<i>Annona sylvatica</i> A. St.-Hil.	Annonaceae	7	0.44	0.75	1.32	0.57	ES	UEC I60340
<i>Dendropanax monogynus</i> (Vell.) Seem.	Araliaceae	2	0.13	0.30	1.23	0.93	NC	UEC I60336
<i>Cabralea canjerana</i> (Vell.) Mart.	Meliaceae	5	0.31	0.75	1.18	0.43	LS	UEC I60393
<i>Heisteria silvianii</i> Schwacke	Olacaceae	5	0.31	0.6	1.11	0.51	LS	UEC I60416
<i>Psychotria suterella</i> Müll. Arg.	Rubiaceae	7	0.44	0.6	1.11	0.51	NC	UEC I60433

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Species	Family	NInd	RelDe	RelFr	IV	CV	SG	Voucher
<i>Ocotea aciphylla</i> (Nees and Mart.) Mez	Lauraceae	4	0.25	0.6	1.08	0.49	LS	UEC 160326
<i>Vernonia</i> sp.1 Schreb.	Asteraceae	4	0.25	0.45	1.07	0.62	PI	-
<i>Sloanea guianensis</i> (Aubl.) Benth.	Elaeocarpaceae	4	0.25	0.6	1.02	0.43	LS	UEC 160359
<i>Trichilia pallida</i> Sw.	Meliaceae	7	0.44	0.45	1.02	0.58	LS	UEC 160395
<i>Leandra mosenii</i> Cogn.	Melastomataceae	4	0.25	0.6	0.98	0.38	ES	-
<i>Myrceugenia myrcioides</i> (Cambess.) O. Berg	Myrtaceae	6	0.38	0.45	0.98	0.53	LS	UEC 160378
<i>Mollinedia oligantha</i> Perkins	Monimiaceae	3	0.19	0.45	0.95	0.50	NC	UEC 160406
<i>Piper cernuum</i> Vell.	Piperaceae	4	0.25	0.61	0.93	0.33	ES	UEC 160419
<i>Cordia trichoclada</i> DC.	Boraginaceae	4	0.25	0.61	0.93	0.33	ES	UEC 160343
<i>Annona dolabripetala</i> Raddi	Annonaceae	3	0.19	0.31	0.83	0.53	ES	UEC 160339
<i>Marcgravia polyantha</i> Delpino	Marcgraviaceae	5	0.31	0.31	0.81	0.51	NC	UEC 160391
<i>Marlierea silvatica</i> (O.Berg) Kiaersk.	Myrtaceae	3	0.19	0.45	0.79	0.34	LS	UEC 160376
<i>Aniba firmula</i> (Nees and Mart.) Mez	Lauraceae	4	0.25	0.45	0.78	0.33	LS	UEC 160324
<i>Daphnopsis fasciculata</i> (Meisn.) Nevlng	Thymelaeaceae	4	0.25	0.45	0.78	0.33	LS	-
<i>Citronella paniculata</i> (Mart.) R.A. Howard	Cardiopteridaceae	4	0.25	0.45	0.76	0.31	LS	UEC 160351
<i>Aureliana fasciculata</i> (Vell.) Sendtn.	Solanaceae	6	0.38	0.30	0.76	0.46	ES	UEC 160449
<i>Rudgea vellerea</i> Müll. Arg.	Rubiaceae	4	0.25	0.45	0.74	0.29	LS	UEC 160435
<i>Maytenus</i> sp.1	Celastraceae	3	0.19	0.45	0.73	0.28	LS	UEC 160353
<i>Casearia paranaensis</i> Sleumer	Salicaceae	3	0.19	0.45	0.73	0.28	LS	UEC 160436
<i>Mollinedia glabra</i> (Spreng.) Perkins	Monimiaceae	5	0.31	0.31	0.72	0.42	NC	UEC 160411
<i>Myrcia</i> sp.1	Myrtaceae	3	0.19	0.45	0.7	0.26	LS	UEC 160390
<i>Myrceugenia miersiana</i> (Gardner) D. Legrand and Kausel	Myrtaceae	3	0.19	0.45	0.68	0.23	LS	-
<i>Piptocarpha sellowii</i> (Sch. Bip.) Baker	Asteraceae	2	0.13	0.31	0.67	0.38	PI	UEC 160348
<i>Eugenia verticillata</i> (Vell.) Angely	Myrtaceae	3	0.19	0.45	0.67	0.22	LS	UEC 160374
<i>Campomanesia guaviroba</i> (DC.) Kiaersk.	Myrtaceae	3	0.19	0.31	0.55	0.25	ES	UEC 160369
<i>Ocotea glaziovii</i> Mez	Lauraceae	3	0.19	0.31	0.54	0.25	LS	UEC 160329
<i>Simira viridiflora</i> (Allemão and Saldanha) Steyerem.	Rubiaceae	3	0.19	0.31	0.54	0.24	NC	UEC 160432
<i>Mollinedia ovata</i> Ruiz and Pav.	Monimiaceae	2	0.13	0.31	0.53	0.24	NC	UEC 160412
<i>Myrcia freyreissiana</i> (O. Berg) Kiaersk.	Myrtaceae	3	0.19	0.31	0.52	0.22	LS	UEC 160388
<i>Chrysophyllum inornatum</i> Mart.	Sapotaceae	3	0.19	0.31	0.52	0.22	LS	UEC 160444
<i>Symplocos estrellensis</i> Casar.	Symplocaceae	3	0.19	0.31	0.52	0.23	ES	UEC 160451
<i>Phytolacca dioica</i> L.	Phytolaccaceae	2	0.13	0.31	0.51	0.21	NC	UEC 160426
<i>Ilex microdonta</i> Reissek	Aquifoliaceae	2	0.13	0.31	0.5	0.2	LS	UEC 160338
<i>Ocotea daphnifolia</i> (Meisn.) Mez	Lauraceae	2	0.13	0.31	0.49	0.19	LS	UEC 161508
<i>Tachigali</i> sp.1 Aubl.	Fabaceae	2	0.13	0.31	0.48	0.18	NC	UEC 160323
<i>Cryptocarya aschersoniana</i> Mez	Lauraceae	2	0.13	0.15	0.48	0.33	LS	UEC 160334
<i>Myrciaria floribunda</i> (H.West ex Willd.) O.Berg	Myrtaceae	1	0.06	0.15	0.48	0.33	LS	UEC 160381
<i>Matayba</i> sp.1 Aubl.	Sapindaceae	2	0.13	0.31	0.48	0.18	LS	UEC 161512
<i>Myrcia tijucensis</i> Kiaersk.	Myrtaceae	2	0.13	0.31	0.47	0.17	LS	UEC 160389
<i>Pouteria gardneri</i> (Mart. and Miq.) Baehni	Sapotaceae	2	0.13	0.31	0.47	0.17	LS	UEC 160445
<i>Piptocarpha axillaris</i> (Less.) Baker	Asteraceae	1	0.06	0.15	0.46	0.31	PI	UEC 160350
<i>Mollinedia engleriana</i> Perkins	Monimiaceae	2	0.13	0.31	0.46	0.16	LS	UEC 160410
<i>Mollinedia acutissima</i> Perkins	Monimiaceae	2	0.13	0.31	0.46	0.16	NC	UEC 160413
<i>Symplocos</i> sp.1 Jacq.	Symplocaceae	2	0.13	0.31	0.46	0.16	ES	UEC 160452
<i>Trichilia pallens</i> C. DC.	Meliaceae	2	0.13	0.31	0.46	0.16	LS	UEC 161510
<i>Trichilia silvatica</i> C. DC	Meliaceae	2	0.13	0.31	0.45	0.15	LS	-
<i>Maytenus</i> sp.2 Molina	Celastraceae	3	0.19	0.15	0.45	0.31	LS	UEC 160354
<i>Calyptanthes</i> sp.1 Sw.	Myrtaceae	2	0.13	0.31	0.45	0.15	LS	UEC 160366
<i>Aniba viridis</i> Mez	Lauraceae	2	0.13	0.31	0.45	0.15	LS	-
<i>Mollinedia blumenaviana</i> Perkins	Monimiaceae	2	0.13	0.31	0.44	0.14	ES	UEC 160409
<i>Stylogyne lhotzkyana</i> (A.DC.) Mez	Primulaceae	2	0.13	0.31	0.44	0.14	NC	UEC 160425
<i>Cecropia glaziovii</i> Sneathl.	Urticaceae	1	0.06	0.15	0.42	0.27	PI	-
<i>Sessea</i> sp.1 Ruiz and Pav.	Solanaceae	1	0.06	0.15	0.42	0.27	ES	UEC 160447
Myrtaceae sp.1 Juss.	Myrtaceae	1	0.06	0.15	0.41	0.26	LS	-
<i>Byrsonima ligustrifolia</i> A. Juss.	Malpighiaceae	3	0.19	0.15	0.39	0.24	ES	UEC 160392
<i>Tapiria guianensis</i> Aubl.	Anacardiaceae	1	0.06	0.15	0.37	0.22	ES	-
<i>Ardisia guianensis</i> (Aubl.) Mez	Primulaceae	1	0.06	0.15	0.34	0.19	ES	-
<i>Matayba juglandifolia</i> (Cambess.) Radlk.	Sapindaceae	2	0.13	0.15	0.32	0.17	LS	-
<i>Vernonanthura petiolaris</i> (DC.) H. Rob.	Asteraceae	1	0.06	0.15	0.28	0.13	PI	-

Continue...

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Species	Family	NInd	RelDe	RelFr	IV	CV	SG	Voucher
<i>Symplocos laxiflora</i> Benth.	Symplocaceae	1	0.06	0.15	0.26	0.11	ES	UEC 160450
<i>Terminalia januariensis</i> DC.	Combretaceae	1	0.06	0.15	0.25	0.11	NC	-
<i>Inga laurina</i> (Sw.) Willd.	Fabaceae	1	0.06	0.15	0.25	0.11	NC	UEC 160318
<i>Nectandra grandiflora</i> Nees	Lauraceae	1	0.06	0.15	0.25	0.11	LS	UEC 160331
<i>Rhodostemonodaphne macrocalyx</i> (Meisn.) Rohwer ex Madriñán	Lauraceae	1	0.06	0.15	0.24	0.09	LS	UEC 160328
<i>Eugenia brevistyla</i> D.Legrand	Myrtaceae	1	0.06	0.15	0.24	0.09	LS	UEC 160373
<i>Myrceugenia campestris</i> (DC.) D. Legrand and Kausel	Myrtaceae	1	0.06	0.15	0.24	0.09	LS	UEC 160380
<i>Sapium glandulosum</i> (L.) Morong	Euphorbiaceae	1	0.06	0.15	0.23	0.08	ES	UEC 160362
<i>Campomanesia neriiflora</i> (O. Berg) Nied.	Myrtaceae	1	0.06	0.15	0.23	0.08	LS	UEC 160368
<i>Marlierea tomentosa</i> Cambess.	Myrtaceae	1	0.06	0.15	0.23	0.08	ES	UEC 160377
<i>Guarea kunthiana</i> A. Juss.	Meliaceae	1	0.06	0.15	0.23	0.08	LS	UEC 160398
<i>Quiina glaziovii</i> Engl.	Ochnaceae	1	0.06	0.15	0.23	0.08	LS	UEC 160418
<i>Cupania oblongifolia</i> Mart.	Sapindaceae	1	0.06	0.15	0.23	0.08	LS	UEC 160441
<i>Byrsonima</i> sp.1 Rich. ex Kunth	Malpighiaceae	1	0.06	0.15	0.23	0.08	ES	UEC 161509
<i>Myrtaceae</i> sp.2 Juss.	Myrtaceae	1	0.06	0.15	0.22	0.07	LS	-
<i>Vantanea compacta</i> (Schnizl.) Cuatrec.	Humiriaceae	1	0.06	0.15	0.22	0.07	LS	UEC 160315
<i>Machaerium</i> sp.1 Pers.	Fabaceae	1	0.06	0.15	0.22	0.07	LS	UEC 160321
<i>Pterocarpus rohrii</i> Vahl	Fabaceae	1	0.06	0.15	0.22	0.07	LS	UEC 160322
<i>Salacia elliptica</i> (Mart. ex Schult.) G. Don	Celastraceae	1	0.06	0.15	0.22	0.07	ES	UEC 160355
<i>Mabea piriri</i> Aubl.	Euphorbiaceae	1	0.06	0.15	0.22	0.07	NC	UEC 160361
<i>Eugenia cuprea</i> (O.Berg) Nied.	Myrtaceae	1	0.06	0.15	0.22	0.07	LS	UEC 160372
<i>Cedrela odorata</i> L.	Meliaceae	1	0.06	0.15	0.22	0.07	ES	UEC 160394
<i>Mollinedia oligotricha</i> Perkins	Monimiaceae	1	0.06	0.15	0.22	0.07	NC	UEC 160405
<i>Quiina magallano-gomesii</i> Schwacke	Ochnaceae	1	0.06	0.15	0.22	0.07	LS	UEC 160417
<i>Myrsine umbellata</i> Mart.	Primulaceae	1	0.06	0.15	0.22	0.08	ES	UEC 160424
<i>Posoqueria latifolia</i> (Rudge) Roem. and Schult.	Rubiaceae	1	0.06	0.15	0.22	0.07	ES	UEC 160430
<i>Nectandra puberula</i> (Schott) Nees	Lauraceae	1	0.06	0.15	0.22	0.07	LS	UEC 161507
<i>Eugenia excelsa</i> O. Berg	Myrtaceae	1	0.06	0.15	0.22	0.07	LS	UEC 161511

similar to those found in other studies also developed in the area (MEDEIROS; AIDAR, 2011; ALVES et al., 2010; PADGURSCHI et al., 2011). Medeiros and Aidar (2011), in a Montane Ombrophilous Dense Forest community of with more than 35 years of regeneration, found 1,743.3 ind·ha<sup>-1</sup> and basal area of 28.5 m<sup>2</sup>·ha<sup>-1</sup>, whereas Tabarelli and Mantovani (1999) in other patch of 40-year forest at 870 m to 1.100 m obtained 2,735 ind·ha<sup>-1</sup> and 33.4 ind·ha<sup>-1</sup>. Joly et al. (2012) compared all permanent plots of the Atlantic Rainforest along an altitudinal gradient in southeastern Brazil and obtained 1,965 stems·ha<sup>-1</sup> in a mature and preserved plot at Santa Virginia Nucleus, with higher percentage of palms compared to others phytophysionomies. Lieberman et al. (1996) highlighted a positive relationship between tree density and altitude at Atlantic Forest and other tropical forests.

The Shannon diversity index  $H' = 3.7$  nats·ind.<sup>-1</sup> and the evenness index  $J' = 0.7$ , demonstrated that the community is diverse, but with uneven distribution of individuals by species, including species with a great number of individuals and species with only one representative. Other plots at Santa Virginia Nucleus, located in different areas and with distinct historical use, showed similar indexes values as found in this study (both

with  $H' = 3.6$  nats·ind.<sup>-1</sup> and  $J' = 0.7$ ) (PADGURSCHI et al., 2011; MEDEIROS; AIDAR, 2011). Padgurschi et al. (2011) compared two plots with different history of human impact within the Serra do Mar State Park regarding to the floristic composition, forest structure and aboveground biomass, and they found lower biodiversity in the plot that suffered selective logging 40 years ago in comparison to the undisturbed site ( $H' = 3.72$  nats·ind.<sup>-1</sup>,  $J' = 0.7$  and  $H' = 4.05$  nats·ind.<sup>-1</sup>,  $J' = 0.8$ , respectively; reduction in 40 tree species). Considering altitude, sites located in lower altitudes showed higher Shannon's diversity indexes (348 e 395 m altitude -  $H' = 4.5$  nats·ind.<sup>-1</sup> - ROCHELLE et al., 2011) and confirmed the hypothesis that there is a trend to the reduction in diversity with the increased altitude, since the environmental conditions imposed by higher altitudes, such as temperature reduction, frequent fog's events and high rates of precipitation, could limit the occurrence of some species and reduce the diversity indexes (TABARELLI; MANTOVANI, 1999).

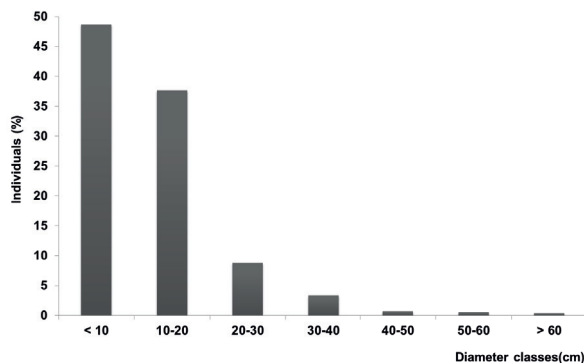
The families' dominance (basal area) in the study area, especially Arecaceae, Cyatheaceae, Fabaceae, Lauraceae, Myrtaceae and Rubiaceae were similar to the results obtained by Tabarelli and Mantovani (1999), Padgurschi et al. (2011), Medeiros and Aidar (2011) and

Joly et al. (2012). Peixoto and Gentry (1990) pointed that Myrtaceae and Lauraceae families predominate in forest formations along the entire Atlantic coast, especially under the influence of fog or in the montane forests. The sum of these families resulted in approximately 54% of the individuals present in the sampling area and influenced the importance value and coverage value results. They are often found in Atlantic Forest, especially in montane formations, along with a low number of woody vines and a high abundance of epiphytes, ferns and bamboos (JOLY et al., 2014; 2012). The presence of the Monimiaceae family with 52 individuals and nine species, confirms the hypothesis of Peixoto (1987) and Padgurschi (2010), which observed the same species in a near plot at montane Forests in Serra do Mar State Park. In fact, there are many species similarities between this study and the Padgurschi et al. (2011): Firstly, both had experienced a disruption for over 40 years ago and; secondly, both showed abundance of recognizable secondary species, like *Inga spp.*, *Miconia spp.* and *Alchornea triplinervia*.

The Arecaceae family was represented only by *Euterpe edulis*, as also found by Padgurschi et al. (2011) and Medeiros and Aidar (2011). Joly et al. (2012) highlighted the increase of palm species in higher altitudes, reaching more than 400 ind.ha<sup>-1</sup> in the Montane Ombrophilous Dense Forest, as well as Cyatheaceae species. In the studied plot, Cyatheaceae family prevailed in the lower parts of the hillside, while the Arecaceae individuals had wider distribution throughout the plot. The distribution pattern suggest that these species could be potential competitors as they both have similar architecture, form dense populations in mountainous regions and usually share similar habitats (TRYON; TRYON, 1982).

The distribution of all live trees into diameter classes showed an exponential negative or unbalanced inverted J-shaped curve, i.e., there was a predominance of young individuals in early regeneration stages and lower values of diameter and a marked decrease in the larger classes (Figure 2). The first two classes (DHB up to 20 cm) contained about 86% of the individuals sampled, followed by the classes with DHB up to 40cm with 12%, and the other classes with the remaining 2% of the total individuals. The average diameter for the entire sample was 12.8 cm, with the highest value from an *Alchornea triplinervia* (108.3 cm) individual.

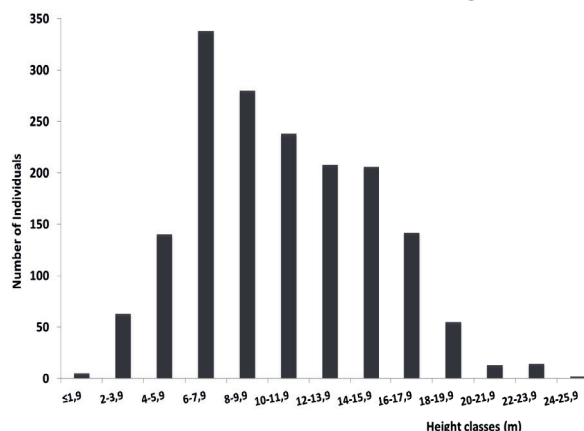
The individual distribution by height classes (Figure 3) showed low overall height with an average of 10.3 m, a result similar to other studies developed in the Atlantic Forest (OGATA; GOMES, 2006; MEDEIROS; AIDAR, 2011; JOLY et al., 2012). Most individuals (74%)



**FIGURE 2** Distribution of individuals in their respective diameter classes (in centimeters) at Santa Virgínia Nucleus.

The y-axis represents the percentage of individuals. showed heights between 6-16 m, however, less than 5% of individuals have heights between 18-26 m, similar to results of Joly et al. (2012). The taller individuals are members of the Araliaceae, Chrysobalanaceae, Elaeocarpaceae, Euphorbiaceae, Fabaceae, Lauraceae, Melastomataceae, Myrtaceae and Phyllanthaceae families. They could form an emergent canopy and are, mainly, classified as early and late secondary in the succession. Moreover, representatives of the Cyatheaceae and Arecaceae (*E. edulis*) families are typical of the understory of a forest, reaching average of 5.3 and 10.9 m high. The understanding of stem diameter and height represent the growth and, consequently, the forest structure and biomass (COOMES; ALLEN, 2007).

The environmental conditions vary along altitudinal gradients. At higher altitudes, the low-level clouds and fog formation could reduce the annual irradiance (SOUSA NETO et al., 2011). This condition, associated with the reduction of the air and soil temperature and prevalence of strong winds, could be the cause of the decrease in tree heights and the



**FIGURE 3** Distribution of individuals in size classes (height in meters) at Santa Virgínia Nucleus. The y-axis represents the number of individuals.



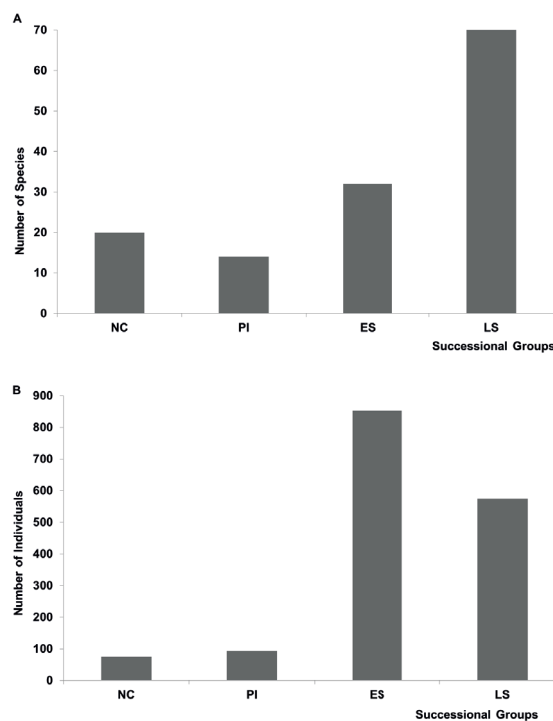
increase in diameter in montane forests (ALVES et al., 2010). Also, the distribution of light is more asymmetric in steeper terrain (ALVES et al., 2010), resulting in individuals shorter, with larger diameters instead of height, and wider crowns (ALVES; SANTOS, 2002).

According to the successional classification, the group “Not characterized (NC)” is composed of 20 species (14%), “Pioneer (PI)” by 14 species (9.8%), “Early secondary (ES)” by 32 species (22.4%) and “Late secondary (LS)” 77 species (54%) (Figure 4A). Guariguata and Ostertag (2001) assumed that forests at early stages are mainly influenced by factors that guide colonization, related to germination and sprouts. In contrast to later stages, when biotic and abiotic competitive ability and tolerance of environmental conditions among species (determined primarily by rates of species-specific growth, longevity, maximum size at maturity and the degree of shade tolerance) largely dictate patterns of species replacement over time. The level of succession also contributes to nitrogen fertilization of the soil, carbon accumulation in biomass, composition of species and stem density (KOERSELMAN; MEULEMAN, 1996). Due to the evolution in succession, gaps suitable for the light demanding species tend to be rare, decreasing the number of pioneer species (DENSLOW, 1980), while Finegan (1996) pointed that the proximity to a mature forest could improve the capacity of a secondary area to regenerate, especially because of the seed rain, remnant trees, pollinators, and dispersers.

The abundance of early secondary individuals (853 ind.) (Figure 4B), the presence of species considered typical of disturbed environments, such as *Vernonia sp.1*, *Alchornea triplinervia*, *Hyeronima alchorneoides* and *Casearia decandra*, the land use history, presence of gaps and several bamboo clumps suggest that the studied area is secondary with more than 40 years of succession (TABARELLI; MANTOVANI, 1999). However, species diversity and abundance of individuals (575) from the late secondary category suggest that the initial phase of regeneration is progressing toward the climax condition. The diversity of species from Myrtaceae and Lauraceae families indicate a progress in the succession, although the abundance of *Alchornea triplinervia* has reinforced the classification in middle secondary stage (TABARELLI; MANTOVANI, 1999). This information is highly significant to a better understanding of the community’s gas exchange potential around the flux tower (FREITAS, 2012), as secondary forests show normally high productivity and biomass accumulation pattern when compared with mature forests (BROWN; LUGO, 1990).

The inverted J-shaped standard of diameter classes is common in tropical forests with a diversity of age and composition, also found in Medeiros and Aidar (2011). It represents the age distribution of a community, since there is a direct relationship between the increase in the diameter and the age of the plant (OLIVER; LARSON, 1996). Furthermore, it indicates a self-regeneration within the community, with a predominance of recruited individuals with lower diameter values (SILVA; NASCIMENTO, 2001). The difference between the frequencies of individuals in the first and the last classes indicates that the life cycle was blocked by some past event, such as the selective cutting of larger trees (NEVES; PEIXOTO, 2008) and could reinforce the successional status of the area as middle secondary.

The calculations of the aboveground biomass using allometric models indicated that the biomass accumulated was of 166.3 Mg·ha<sup>-1</sup>, with tree species representing the greatest amount of biomass (155.6 Mg·ha<sup>-1</sup> or 93.6%), followed by the palm trees (9.2 Mg·ha<sup>-1</sup> or 5.5%) and the ferns (1.5 Mg·ha<sup>-1</sup> or 0.9%).



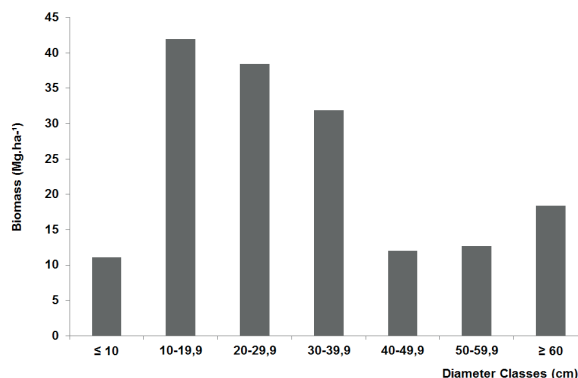
**FIGURE 4** Distribution of species and individuals in their respective successional groups at Santa Virgínia Nucleus. Figure “A” represents number of species and “B” individuals. NC - not characterized, PI - pioneers, ES - early secondary and ST - late secondary. The y-axis represents the number of species (A) e individuals (B).

The biomass at Montane Ombrophilous Dense Forest in the study of Medeiros and Aidar (2011) was similar to this study, 189.2 Mg·ha<sup>-1</sup>. The slightly higher result may be due to extrapolation errors, since the area sampled by these authors was of 0.2 ha and the result was estimated for 1 ha, unlike in the present study where exactly 1 ha of forest was surveyed. Padgurschi (2010) and Alves et al. (2010) obtained higher montane forest biomass results in mature forest, 282.6 Mg·ha<sup>-1</sup> and 271.7 Mg·ha<sup>-1</sup>, respectively. As we propose that the studied area is evolving from a logged to a late secondary forest, the aboveground biomass also has the tendency to increase with time, when species with higher values of wood density and the basal area would influence it (HOUGHTON et al., 2009).

Structure, composition, and function are the three essential attributes of forest ecosystems. Mandal and Joshi (2014) suggested that these characteristics could change in response to climate, topography, soil and disturbances. The aboveground live biomass varies widely in neotropical forests due to regional differences in the individual size, wood density, species composition, soil fertility, topography and disturbance (VIEIRA et al., 2004; CHAVE et al., 2005; MALHI et al., 2006; VIEIRA et al., 2008). The general trends for forests from high altitudes are the decline in stature and reduction in the aboveground biomass, while there is an increase in wood density (Aiba and Kitayama, 1999; Moser et al., 2007). This pattern is a result of the limiting factors acting in these forests, mainly affecting photosynthesis, transpiration and nutrient availability (AIBA; KITAYAMA, 1999; RAICH et al., 2006). However, Alves et al. (2010) found that in the Atlantic Forest, the biomass and abundance of large individuals are incremented with the increasing altitude.

Individuals with DBH  $\geq$  40 cm, even if weakly represented in the sampled area (1.6%) had influenced in the total biomass calculation - 43 Mg·ha<sup>-1</sup> or 26% of that value. In contrast, the diameters inferior to 10 cm (48.7%) had accumulated only 6.7% or 11.1 Mg·ha<sup>-1</sup> of the total biomass (Figure 5). Considering the height, those higher than 20 m (1.7% of total) had 20% of the biomass (33.8 Mg·ha<sup>-1</sup>) and those with wood density equal or higher than 0.8 g·cm<sup>3</sup> (11%) had 10.8% of the total biomass (18.02 Mg·ha<sup>-1</sup>). Medeiros and Aidar (2011) researching a plot at Montane Ombrophilous Dense Forest found that diameters of up to 13 cm comprised 60% of the individuals and 7.4% of the total biomass, similarly to the results found by Vieira et al. (2004) in

a Central Amazon forest, where trees with diameters between 10 and 29.9 cm corresponded to approximately 80% of the individuals sampled, and contributed only with 26.4 to 32.9% of the total estimated biomass.



**FIGURE 5** Distribution of aboveground biomass in the respective diameter classes at Santa Virgínia Nucleus. The y-axis represents live aboveground biomass (Mg·ha<sup>-1</sup>).

## CONCLUSIONS

The forest studied in a secondary stage of regeneration, after significant past impact more than 40 years ago. However, if we consider the little amount of pioneers species (and individuals) and the higher number of early and late secondary species (and individuals) we can conclude that the site is evolving to a more mature condition along succession and could be considered in middle stage. We can predict that aboveground biomass accumulation would increase in the future decades, especially due to the change in the composition (TABARELLI; MANTOVANI, 1999). The results will help a better understanding of the gas exchanges between atmosphere and biosphere in the area and will provide subsidies for the development a model of carbon balance in the Montane Ombrophilous Dense Atlantic Forest from southeastern Brazil.

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