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Maria Teresa V. N. Abdo[a], Sergio V. Valeri[b], Antonio S. Ferraudo[c], Antonio Lucio M. Martins[a], and Leandro R. Spatti[a]

[a]Polo Centro Norte-APTA (São Paulo Agency for Agribusiness), Pindorama, SP, Brazil; [b]UNESP, FCAV, Department of Vegetal Production, Jaboticabal, SP, Brazil; [c]UNESP, FCAV, Department of Exact Sciences, Jaboticabal, SP, Brazil

ABSTRACT

The occurrence of pioneer tree species inside tropical forests is usually associated with canopy openness due to disturbances. The distribution of these species under different environmental conditions, aside from light presence, can be influenced by other variables such as soil attributes, water availability, and non-arborous species presence. This work evaluates pioneer tree distribution in the Pindorama Biological Reserve, Brazil, with respect to altitude, soil attributes, and non-arborous species in 65,400-m^2 plots in two topo-sequences of semi-deciduous forest. We evaluated the physical and chemical soil attributes altitude, basal area, height, and number of individuals of tree species with diameter at breast height (DBH) ≥5 cm in a randomly chosen quadrant in each plot. Pioneer trees were characterized by the following higher occurrence species: *Acacia polyphylla, Aloysia virgata, Casearia sylvestris,* and *Croton floribundus*. Cluster analysis suggested five similar groups among sampling plots. For each group, the mean of altitude, physical and chemical soil attributes, and degree of non-arborous species infestation was calculated. Principal components analysis correlated variables with pioneer tree data. *C. floribundus* occurred at low altitudes at lower or higher fertility, *C. sylvestris* occurred in lower fertility plots, and *A. polyphylla* and *A. virgata* occurred in higher altitude plots.

Introduction

The Atlantic forest is the second largest tropical moist forest of South America after the Amazonian Forest (Oliveira-Filho & Fontes, 2000) and comprises coastal rain forests up to 300 km inland. Originally covering approximately 150 million ha, it occurs in highly heterogeneous environmental conditions (Ribeiro, Metzger, Martensen, Ponzoni, & Hirota, 2009). With a latitudinal range of approximately 29°, the Atlantic forest extends into tropical and subtropical regions in 17 states all along the Brazilian coast; rainfall is between 1000 and 3000 mm yr^{-1} and often has a short-dry period in austral winter, and temperatures range from 15 to 20°C (FAO, 2000).

Although the Atlantic forest is very fragmented and represented by a large number of small native remnants, it is estimated that there are approximately 20,000 plant species (approximately 35% of existing species in Brazil) in this biome, including several endemic and endangered species. With higher biodiversity than that of some continents (17,000 species in North America and 12,500 in Europe), the Atlantic forest is a high priority for the conservation of global biodiversity (MMA, 2016). The Atlantic forest is one of the most threatened biomes in the world, and its remnant forest fragments retain important residual flora (Higuchi et al., 2008). Such biodiversity could be explained by the broad longitudinal and altitude range of occurrence of this forest; its fauna and flora hold 1–8% of the world's total species (Ribeiro et al., 2009). For Mittermeier et al. (2003), this biome still holds great biological diversity corresponding to one of the most important biodiversity niches in the world. The diversity of tropical and equatorial rain forests is greater than that of any other vegetation type, and 25% of the plant species are represented by trees (Wright, 2002).

Native forests occupy 13.94% (3457,301 ha) of São Paulo State, Brazil and are classified as mangrove (0.6%), woody savanna (5.33%), and Atlantic forest (94.07%) (Kronka et al., 2006). The semi-deciduous tropical forest remnants occupy 2.57% of the area of the state (636,239 ha) and are distributed on the hinterland highland areas with distinct dry and wet seasons. Their flora is considered transitional between that of rain forests and savanna (Oliveira Filho & Fontes, 2000). Most natural forest fragments in the state are small due to fragmentation as a result of historical agricultural expansion and under-edge effects that interfere with tree occurrence and growth due to light incidence and colonization by invasive species (Kronka et al., 2006).

Although species richness is important for determining conservation strategies, data on the irreplaceability of species, such as endemism of plants and birds, should be considered given how much environmental condition affects biodiversity. The species–area relationship indicates that habitat loss promotes biodiversity loss (Brooks et al., 2006). The competition between species for nutrients, water, light, and other needs limits biodiversity, as it can lead to species exclusion (Wright, 2002). Studies about this interrelation are very welcome once they can contribute to these species knowledge and preservation strategies.

According to Denslow (1987), the appearance of so many tree species in tropical rain forest results from genetic drift, habitat specialization, benign environments, or geographic isolation. Once it presents high biodiversity, it also demands many researches and studies that will guide any conservation strategy adopted.

The structure of these fragments is conditioned by the occurrence of trees from different ecological groups described by Budowsky (1965), where pioneer tree species occur in early successional stages in forests and tend to occupy areas modified by anthropogenic actions, near edges and bare places in the interior of fragments, or so-called forest gaps. Goodale, Berlyn, Gregoire, Tennakoon, and Ashton (2014) stated that since gaps were first described by Pehr Kalm in 1748, many studies have explained how this disturbance process is dynamic and complex, resulting in canopy openness that influences community and populations inside forests. The gap causes can be natural (tree falls, lightning strikes, landslides, pathogens) or anthropogenic (deliberate fire, tree cutting, pesticides, urbanization, industry, and mining) (Faria, Botelho, Mello, & Garcia, 2013), and they affect other microenvironmental conditions such as soil nutrients and moisture and biotic conditions inside the forest.

The opening of forest gaps contributes to the diversity of forest fragments, and some species depend on these conditions for regeneration (Denslow, 1987; Machado & Oliveira-Filho, 2010)

such as the group of pioneer species that is favored by these adverse conditions (Tabarelli & Montovani, 1999).

The fragmentation of forests due to anthropogenic activity such as deforestation, intensive agriculture with pesticides, and intensive soil tilling near forest remnants leads to their fragility. The probability of species survival increases with higher number of individuals of species that are secured in protected areas, far away from perturbances. This protection is inversely proportional to the distance they are from the center of the remnant they occupy and depends on the size of the remnant and the occurrence of edge effect near the edge or stochastic events inside the forest (Araújo & Williams, 2000).

Forest fragmentation may result in the extinction of some species and exposes organisms remaining in the fragment to the conditions of the surrounding areas, called the edge effect (Murcia, 1995). The edge effect causes changes in the biotic and abiotic conditions that go beyond natural intrinsic forest changes, making the area inadequate for the original ecosystem (Murcia, 1995).

According to Tabanez, Viana, and Dias (1997), edge effects influence the occurrence of tree species inside the forest up to 100 m from the edge. Canopy disturbances result in variations that can affect other micro environmental conditions such as soil nutrients and moisture and biotic conditions and can also interfere with roots, seed germination, fruit availability, and herbivores, the so-called below-ground effects (Goodale et al., 2012). The edge effect due to forest fragmentation when compared to forest interior may have similar conditions of successional forest due to the similarity of environmental conditions such as elevated light availability (Silvestrini & Santos, 2015). In these areas, the occurrence of trees and also non-arborous species is favored by the presence of light. The edge effect could explain the presence of pioneer species in some areas that gaps are not observed and no anthropogenic disturbance has been reported in the past.

The distribution patterns, survival, and reproduction of pioneer species in early successional forests that have regenerated after human disturbances are influenced by local environmental conditions, such as light, temperature, and biotic factors (Silvestrini & Santos, 2015). Pioneer species richness varies with the biome, the place, and the presence of other invasive non-arborous species that they also compete with for light, below-ground nutrients (Tilman, 1994), and water (Belsky, 1994). Specifically concerning light supply, some pioneer species may overcome shady conditions from branch extension and canopy closure and grow under some light restriction (Goodale et al., 2012).

Environmental variables such as topographical differences, precipitation, and temperature limit and interfere with tree species occurrence and should be considered in predictive modelling (Araújo & Williams, 2000). Topographical variation results in spatial variation in the chemical properties of soils derived from the same parent material (John et al., 2006); therefore, correlations between topography (slope, elevation, and convexity) and soil nutrients suggest that such physical processes are important in determining spatial variation in soil characteristics at a local scale and consequently in vegetation (John et al., 2006). According to John et al. (2006), neotropical forest plots are strongly associated with soil attributes.

The dynamics and structure in forest remnants are influenced by edge effects associated with local topography, soil, and historical perturbations (Higuchi et al., 2008; Machado & Oliveira-Filho, 2010). The following are among other variables that also influence these processes: underground water supply (Appolinário, Oliveira-Filho, & Guilherme, 2005), light incidence, nutrient availability (John et al., 2006; Machado & Oliveira-Filho, 2010; Tanner, Vitousek, & Cuevas, 1998; Vitousek, Walker, Whiteaker, & Matson, 1993), soil

moisture (Denslow, 1987), porosity (Higuchi et al., 2008), temperature (Machado & Oliveira-Filho, 2010), and global climate change (Higuchi et al., 2008; Machado & Oliveira-Filho, 2010; Mumbi et al., 2014).

According to Vitousek et al. (1993), nutrients supply can limit plant growth and plants have different behaviors depending on the nutrient and the site age.

Although many studies have considered pioneer tree species establishment at different sites with respect to light presence and gap formation, not all take into account soil attributes and topography, which may affect this process. In this context, the evaluation of pioneer tree growth in all stages after seedling and the degree of interference of edaphic conditions are very welcome (Goodale et al., 2014).

We wanted to find out if there is relation between the occurrence of pioneer tree species in two toposequences with the soil attributes and presence of non-arborous species in the plots, which are indirectly conditioned by light presence and edge effects.

We characterized the most common pioneer tree species of the Pindorama Biological Reserve, SP, Brazil, according to topographical differences, physical and chemical soil attributes, and non-arborous species infestation to verify the hypothesis that variation in soil fertility and texture, topography and competition for resources with present non-arboreous species due and edge effects will interfere with different tree species.

Methods

The present study was carried out at the Polo Centro Norte – APTA State Research Center in the Pindorama Biological Reserve, in the municipality of Pindorama, São Paulo state, Brazil (21°13′S; 48°55′W). The study site had a total area of 144 ha of seasonal semi-deciduous forest, distributed in four forest fragment remnants of Atlantic Forest biome (Kronka, Matsukuma, & Nalon, 1993). The climate of this region is tropical and humid (Aw) according to Köppen's classification, having a dry season during austral winter and a rainy season during austral summer. Average annual rainfall is 1258 mm, and average temperature during summer is 23.8°C (January, February, and March) and during winter (June, July, and August) is 19.3°C (Lepsch & Valadares, 1976).

The remnants studied are very important due to the history of the deforestation process and because they harbor endemic species of fauna and flora. Located in an agricultural area currently dominated by sugar cane, *citrus*, and experimental fields, these fragments have no record of anthropogenic actions but are under continuous pressure from surrounding agricultural areas and edge effects due to fragmentation. There was no burning, logging, or damage in these remnants other than stochastic factors and edge effects that have influenced successional processes of trees. The evaluated area was homogeneous, and we did not observe gap formation that could differentiate any plot; therefore, all were considered as being under the same conditions.

According to Soil Taxonomy (United States, 1999), the soils studied in Polo Centro Norte are classified as Typic Kanhapludalf (Area 1) and Typic Plinthudult (Area 2) with a sandy texture surface horizon up to 1-m depth and a subsurface argillic horizon; because of differences in water infiltration, these are very susceptible to erosion.

Adjacent soils show differing profile characteristics due to topographic influence resulting in so-called toposequences. We considered topographic and soil variations for the placement of 65 soil and vegetation characterization plots distributed throughout two toposequences (Areas 1
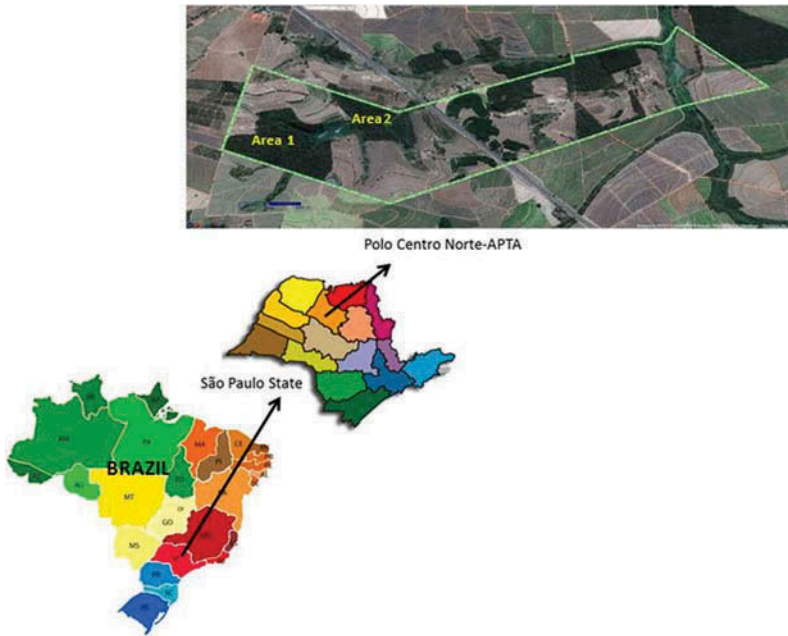
Figure 1. Polo Centro Norte, São Paulo State, Brazil, highlighted in light green and localization of surveyed areas 1 and 2 with toposequences highlighted in yellow.

and 2) (Figure 1). In each toposequence, consecutive plots of 400 m^2 (20 m × 20 m) were selected, with 43 and 22 in toposequences 1 and 2, respectively.

The degree of non-arborous vegetation infestation was evaluated in the total area of each plot (400 m^2), and 10 categories of infestation were created. They ranged from null (0) with no vegetation, to completely infested (10). The non-arborous species were not classified but were just quantified according to Valeri, Politano, Senô, and Barreto (2003).

To evaluate soil attributes and trees, a 10-m × 10-m quadrant of each plot was randomly chosen for the phytosociological survey and characterization of trees with a diameter at breast height (DBH) ≥5 cm. The area of one quadrant per plot was considered for the survey and since the species–area curve has stabilized, this sampled area proved enough data of species. If this had not happened, we would have the possibility of increasing the area of data collection in quadrants not inventoried.

The material for soil analysis was sampled in all 10 m^2 quadrants, and the distance between samples was 10–20 m.

For physical and chemical soil analysis, a composite of 20 subsamples at 0–20 cm depth was used. The samples were placed in plastic bags and brought to the "Sugar Cane Producers Association of Catanduva Region Laboratory," in Catanduva-SP, Brazil, where they were sieved and dried at 40°C. We used the following analyses and methods: particle size analysis for soil texture determination (clay and sand determinations) by sedimentation using the hydrometer method; active acidity (pH) in CaCl$_2$ (mol L^{-1}); organic matter (OM); phosphorous (P), potassium (K), calcium (Ca), and magnesium (Mg), extracted by the ion exchange

resin method; and potential acidity (H + Al) by the calcium acetate method and base saturation (V%) by calculation.

All living trees with DBH ≥ 5 cm had metal plates with plot and tree identification numbers. The DBH was measured with a caliper and the height with a wooden ruler. The basal area was calculated using the DBH values and the formula "$Ba_i = DBH^2 \times \pi/4$."

For individual trees, diameter and height were recorded, and botanical material (leaves and flowers and fruits when present) was collected for identification.

In a previous study involving these plots, 57 species from 33 families were found (Abdo, 2009). For this study, we analyzed the most abundant species and selected the pioneer species with six or more individuals in each plot. The following species met these requirements: *Acacia polyphylla* DC, *Aloysia virgata* Ruiz & Pav. A. L. Juss, *Casearia sylvestris* SW, and *Croton floribundus* Spreng. For the characterization of individuals of these species, we gave an identification number for each one, measured DBH and height and calculated the basal area as shown above.

Plots were characterized using multivariate cluster analysis of physical and chemical soil attributes and presence of non-arborous species resulting in five homogeneous within plot groups with greater difference between groups. This analysis divides data into groups or clusters that are meaningful and helpful because they capture the natural structure of the data.

Due to the multivariate structure of the data, exploratory statistical techniques were used to verify similarities between plots using the physical and chemical soil attributes and infestation of non-arborous species. Hierarchic cluster analysis was based on Euclidean distances, as a measure of similarity, and Ward's method, as the linking algorithm between groups. For each group with edaphic similarity, the average of altitude, physical and chemical soil attributes, and degree of non-arborous species infestation were determined. Previous studies have applied factorial analysis for environmental and tree species variability.

We performed a factorial analysis on the physical and chemical soil characteristics of our sampling plots to determine similarity between plots; a second analysis additionally considered species abundance, height, diameter, and basal area of characterized pioneer species in plots with at least one individual. Factorial analysis is an exploratory multivariate technique that explains relationships between a set of variables with respect to a limited number of new variables that describe the covariation between the observed variables. The principal components are derived from the matrix of correlation between variables. The arrangement in plot groups of each original variable and extracted factor was tested with a general linear model, used as an analysis of variance (ANOVA). Differences between plot groups were determined using the least significant difference (LSD) multiple comparison of means test for each extracted factor. Multivariate analyses were conducted using Statistica, version 7.0, after standardization (Statistica, 2004) and ANOVA by the STAT program.

Results and discussion

Five groups emerged based on soil texture and chemical attributes and non-arborous species presence; these maximized similarities between plots within groups and differences between groups. The structure of these groups is shown in Figure 2.
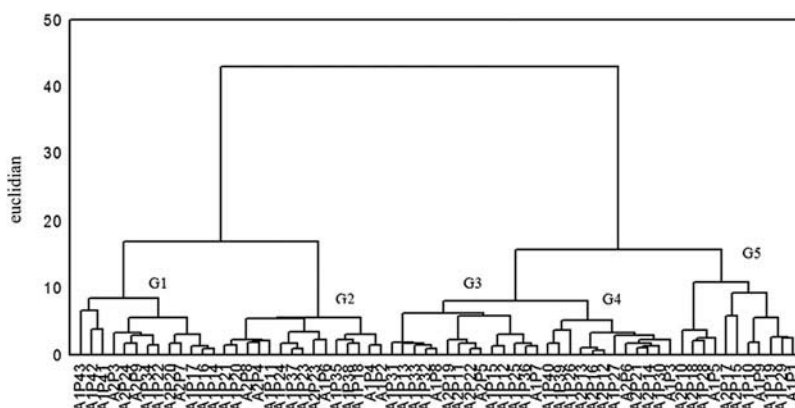
Figure 2. Structure of plot groups based on soil attributes of two semi-deciduous tropical forest toposequences in the Pindorama biological reserve, Pindorama, SP, Brazil.

Following edaphic group division, the means for altitude, physical and chemical soil attributes, and non-arborous vegetation infestation were calculated and compared using Tukey's method (Table 1).

Soil attributes of edaphic groups are shown in Figure 3.

Table 2 shows occurrence and growth characteristics of the evaluated pioneer tree species (*A. polyphylla* DC, *A. virgata* Ruiz & Pav. A. L. Juss, *C. sylvestris* SW and *C. floribundus* Spreng) for each edaphic group.

Table 3 shows the factorial analysis, ANOVA and comparison of means for the LSD test of altitude and physical and chemical soil attributes with respect to the five edaphic groups.

When evaluating the effect of topographical differences and physical and chemical soil attributes on the differentiation of the five edaphic groups, two factors account for 67% of the overall data variability. The ANOVA models indicate that altitude and soil attributes have the greatest effect on differentiating the five edaphic groups (Table 3).

The first factor, composed of altitude and soil attributes (ASF1), accounts for 46% of the data variability and was mostly driven by the following soil fertility attributes: pH, OM, Ca^{2+} Mg^{2+}, H + Al, and percentage of basis saturation (V%). The ANOVA and LSD test show that these variables were different between G1 and G2 and between these groups and the set of G3, G4, and G5. No difference was detected between G3, G4, and G5. Soil fertility of the plots, with higher percentage of basis saturation (V%) and lower acidity (pH > 6.11), decreased in the following order: G3 = G4 = G5 > G2 > G1 (Tables 1 and 3 and Figure 2). The second factor of altitude and soil attributes (ASF2) accounts for 21% of the data variability and is mostly due to the altitude and clay and sand texture of the soils (Table 3). There is a negative correlation between altitude and clay with respect to sand. The ANOVA and LSD test show that these variables also contribute to edaphic group differentiation. Higher altitude plots had more clay and less sand and decreased in the following order: G2 = G5 > G3 = G4 > G1 (Tables 1 and 3).

Table 4 shows the factorial analysis, ANOVA and comparison of means for the LSD test of altitude and physical and chemical soil attributes, trees size variables as height, diameter, and basal area of the pioneer species evaluated with respect to the five edaphic

Table 1. General mean (GM), coefficient of variation (CV), and mean of physical and chemical attributes of the soil, clay, sand, active acidity (pH), organic matter (OM), phosphorous (P), potassium (K), calcium (Ca), and magnesium (Mg), potential acidity (H + Al), base saturation (V%), and non-arboreous species infestation (NA Infest.) for edaphic groups (G1–G5) (N = number of plots evaluated in each group), in Polo Centro Norte, Brazil.

Groups	Altitude M	Clay g kg⁻¹	Sand	P mg dm⁻³	pH CaCl₂	OM g dm⁻³	K⁺	Ca⁺	Mg²⁺ mmol_c dm⁻³	H + Al	V %	NA Infest.
CV%	3.66	10.58	4.40	26.74	4.44	15.03	86.96	16.88	21.14	16.83	4.78	41.58
GM	565.72	144.92	773.83	5.96	6.03	25.98	2.62	58.95	13.72	15.18	82.29	5.95
G1(m) N = 13	559 a	124.07 b	815.53 a	4.84 b	5.60 b	20.07 d	1.75 a	37.15 c	10.53 c	17.23 a	73.67 c	5.53 a
G2(m) N = 15	573 a	157.06 a	752.60 bc	5.06 b	5.78 b	24.13 cd	2.06 a	56.73 b	12.06 bc	17.40 a	80.20 b	5.80 a
G3(m) N = 14	569 a	142.57 a	774.21 bc	5.35 b	6.40 a	26.35 bc	2.59 a	63.21 ab	15.07 ab	12.07 b	86.82 a	5.64 a
G4(m) N = 12	556 a	148.00 a	789.08 ab	5.75 b	6.11 a	31.08 a	2.20 a	69.75 a	15.75 a	14.66ab	85.62 a	7.25 a
G5(m) N = 11	570 a	152.63 a	736.36 c	9.54 a	6.29 a	29.45 ab	3.23 a	70.54 a	15.81 a	14.27 b	85.92 a	5.63 a

Note. LSD mean multicomparisons: values followed by the same letters in each column area not significant ($p < 0.05$).
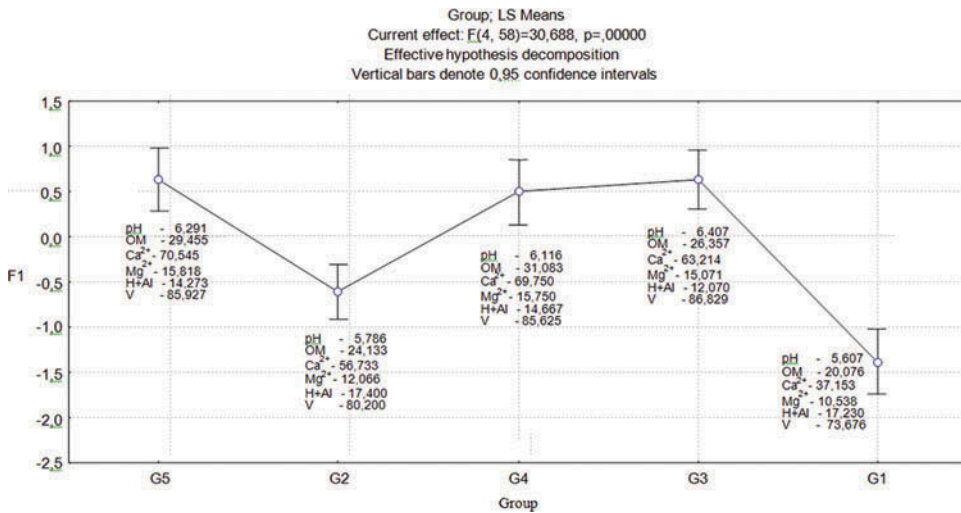
Figure 3. Soil fertility attributes of the five edaphic plot groups in the Polo Centro Norte, Brazil.

Table 2. Number of individuals, basal area, and height of pioneer tree species.

Groups	Acacia polyphylla	Aloysia virgate	Casearia sylvestris	Croton floribundus
Number of individuals				
G1	9	0	4	9
G2	8	8	5	1
G3	9	3	2	5
G4	2	2	1	10
G5	5	2	0	2
Diameter (cm)				
G1	21.6	0.0	9.1	18.0
G2	23.0	11.3	8.3	11.5
G3	14.8	8.8	8.8	17.5
G4	9.5	7.4	12.3	9.4
G5	16.6	12.3	0.0	22.8
Height (m)				
G1	10.9	0.0	7.9	11.3
G2	15.3	7.4	6.3	9.0
G3	10.5	6.3	6.0	11.3
G4	7.0	6.0	6.0	6.9
G5	16.4	5.5	0.0	14.0
Basal area (m^2 ha^{-1})				
G1	33.04	0.00	2.61	22.96
G2	33.34	7.93	2.69	1.03
G3	15.43	1.83	1.23	12.01
G4	1.43	0.86	1.18	6.97
G5	10.81	2.36	0.00	8.13

groups. Three factors account for 61% of the overall data variability of altitude, physical and chemical soil attributes, height, diameter, and basal area of the following pioneer tree species: *A. polyphylla, A. virgata, C. sylvestris*, and *C. floribundus* (Table 4).

The ANOVA indicates that altitude and physical and chemical soil attributes affect species variation (Table 4). The first factor, composed of soil attributes and tree growth (SGF1), accounts for 31% of data variability, and ANOVA indicates that chemical soil

Table 3. Factorial analysis, ANOVA, and mean LSD multicomparison of altitude and physical and chemical soil attributes, clay, sand, active acidity (pH), organic matter (OM), phosphorous (P), potassium (K), calcium (Ca), and magnesium (Mg), potential acidity (H + Al), base saturation (V%) (N number of observations = 65).

Factors	ASFactor 1	ASFactor 2
Altitude	−0.157075	0.624674
Clay	0.287991	0.683848
Sand	−0.144802	−0.896375
pH	0.922630	0.014964
OM	0.655940	0.277192
Ca^{2+}	0.840826	0.346372
Mg^{2+}	0.701450	−0.010131
H + Al	−0.773432	0.177557
V%	0.945190	0.195937
Expl. Var	4.100685	1.928405
Variance explained (%)	46	21
ANOVA models		
Group	**	**
Soil	*	**
Mean multicomparisons by group[a]		
G1	C	c
G2	B	c
G3	A	a
G4	A	a
G5	A	b

Note. Significance levels: *$p < 0.05$; **$p < 0.001$. ns: Not significant; LSD mean multicomparisons: values followed by the same letters in each column area not significant ($p < 0.05$).

Table 4. Factor analysis, ANOVA, and mean LSD multicomparison of altitude, physical, and chemical soil attributes, clay, sand, active acidity (pH), organic matter (OM), phosphorous (P), potassium (K), calcium (Ca), and magnesium (Mg), potential acidity (H + Al), base saturation (V%), and tree basal area, diameter at breast height, and height of *A. polyphylla, A. virgata, C. sylvestris*, and *C. floribundus* (N number of observations = 65).

Factors	SGFactor 1	SGFactor 2	SGFactor 3
Altitude	−0.058848	0.044408	0.820412
Clay	0.392678	−0.050797	0.633598
Sand	−0.247266	0.061369	−0.918429
pH	0.943687	−0.055886	0.005854
Organic matter	0.667975	−0.118386	0.213378
K^+	0.620416	0.101154	0.185090
Ca^{2+}	0.813107	−0.100113	0.268138
Mg^{2+}	0.716856	−0.234756	0.186871
H + Al	−0.820896	0.120754	0.105323
V%	0.916313	−0.176914	0.254163
Diameter	−0.185827	0.814851	−0.008985
Height	−0.060405	0.813625	−0.029855
Basal Area (individual)	−0.230169	0.785712	−0.024765
Expl. Var	4.955288	2.423194	2.393981
Variance explained (%)	31	15	15
ANOVA models	ns	–	–
Mean multicomparisons by groups			
Acacia polyphylla	–	A	b
Aloysia virgate	–	B	b
Casearia sylvestris	–	B	b
Croton floribundus	–	Ab	a

Note. Significance levels: ns = not significant; LSD mean multicomparisons: values followed by the same letters in each column area not significant ($p < 0.05$).

Table 5. Means for LSD test and the differentiation of number of trees (n), diameter at breast height (DBH), height (H), and basal area (BA) of *A. polyphylla* (Ac_poly), *A. virgata* (A_vir), *C. sylvestris* (C_sylv), and *Croton floribundus* (C_flor).

Species	Altitude	Clay	Sand	DBH	H	BA	n	BA ha^{-1}
Ac_poly	575	145	771	17,9	13	0.04502	33	100
A_vir	578	147	764	10,0	6	0.01155	15	13
C_sylv	573	139	782	9,1	7	0.03280	12	8
C_flor	550	136	806	14,7	10	0.03228	27	68

attributes (pH, ME, K^+, Ca^{2+} Mg^{2+}, H + Al, and percentage of saturation for bases [V%]) had no effect on growth in diameter or height of the trees.

Although fertility differs between plot groups, the range of variation is not sufficient to threaten or interfere with the development of the four species we evaluated. According to the classification of Raij, Cantarella, Quaggio, and Furlani (1997), the fertility of the soils in the plots does not limit the development of tree species of the Atlantic Forest biome with the exception of phosphorus, which was classified as low grade in Group 1.

These results agree with Machado and Oliveira-Filho (2010) who found no difference in tree growth from nutrient variation, except for pH, in three different soils including Argissols.

The second factor of soil attributes and tree variables (SGF2) accounts for 15% of the data variation. There was variation among trees in diameter, height, and basal area. *A. polyphylla* had higher growth compared to *A. virgata* and *C. sylvestris* but did not differ from *C. floribundus*. Tree growth in *A. virgata* and *C. sylvestris* was similar.

The third factor explained 15% of the data variation, and the main effects were topographical differences and clay and sand content. This factor shows a positive correlation between altitude and clay content and a negative correlation between these and sand content.

The LSD test indicates that these three variables accounted for differences in growth of *C. floribundus* when compared with the other species (Table 4). The means of tree height, basal area, and diameter at breast height of the pioneer species evaluated can be seen in Table 5.

Appolinário et al. (2005) related that dynamics of trees is influenced by ground water availability and to flood effects and that some adapted species may overcome those situations and occur preferable on humid soil. Machado and Oliveira-Filho (2010) also related that environmental variables that most strongly correlated with the variations of tree dynamics are water and light availability and mineral nutrients. Those study statements explain the presence of *C. floribundus* in humid and low-altitude soils as founded in this work and stated also by Lorenzi (2002). When considering the diameter, height, and individual basal area with respect to altitude, *C. floribundus* had better growth at lower altitude and in the sandy soils typical of groups G1 and G4. This species mainly occurred at lower altitudes, presenting a high basal area when compared with other species.

The non-arboreous species infestation didn't have significant difference between the five similarity groups of plots showing that the soil variability between the groups didn't interfere on these species.

Conclusions

The variables that contributed to data variability were soil fertility (pH, OM, Ca^{2+} Mg^{2+}, H + Al, and percentage of basis saturation [V%]), altitude, and presence of clay and sand in the soil. Soil fertility did not threaten the growth of the four pioneer tree species that we evaluated, namely *A. polyphylla*, *A. virgata*, *C. sylvestris*, and *C. floribundus*. Growth, diameter, height, and basal area varied between these species and were affected by the altitude and percentage of clay and sand in the soil. *C. floribundus* occurred in lower altitude plots. *A. polyphylla*, *A. virgata*, and *Casearia sylvestris* were mainly found in higher altitude plots with clay soil.

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