Floresta e Ambiente 2020; 27(1): e20170570
https://doi.org/10.1590/2179-8087.057017
ISSN 2179-8087 (online)

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Floresta e Ambiente

ORIGINAL ARTICLE – Silviculture

Pedoforms Microclimate and Seasonal Forest Structure in Médio Vale do Paraíba

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Abstract

In the Rio de Janeiro State, the Atlantic Forest is restricted to small fragments, responsible for the maintenance of environmental services. These fragments occur on steep slopes dominated by concave and convex pedoforms, capable of changing the local microclimate conditions. To preserve these communities, it is necessary to determine the level of influence of these pedoforms on forests structure and species distribution. Thus, we performed a phytosociological study and installed a set of four sensors to determine the monthly mean of air temperature and relative humidity in concave and concave pedoforms. The forest structure and the microclimate averages are compared by the Levene's T-test. We observed differences between microclimatic average, importance value indexes (IVIs) and total height, indicating that microclime variations can influence the structure and composition of the tree community. However, these structure differences are punctual and insufficient to determine specific communities.

Keywords: Atlantic forest, phytosociology, environmental variables, conservation.

1. INTRODUCTION AND OBJECTIVES

In the Valley of Paraíba do Sul, a region located between the Mantiqueira Mountains at the north and the Mar Mountains at the southeast (Almeida, 1964), the Atlantic Forest was submitted to few interventions until the early 19th century (Dean, 1996), when the fertility of the soils in the region boosted the conversion of forests into coffee crops (Dean, 1996). As this region has a sloping relief where mounds, hillocks, and hills predominate with convex, concave and linear pedoforms (Silva, 2008), the removal of the forest cover led to fast soil degradation, which resulted in the decline of the coffee production in a few decades. With the collapse of the productive system, crops were gradually replaced with pastures, which hindered natural regeneration and worsened erosion in the region. Currently, it is possible to observe the silting of the surface water system, erosion of soil surface horizons, and the reduction of their productive capacity, as well as habitat fragmentation. Studies that determine the conservation status of the forest fragments in the region are essential for the establishment of actions for recovery and preservation.

In this context, phytosociological inventories are important tools as they allow the analysis, interpretation, and description of the plant community structure. They also provide knowledge on species richness and diversity (Felfili et al., 2011). In spite of their applications, most of the phytosociological studies in the region are merely descriptive (Carvalho et al., 2007; Cysneiros et al., 2015; Dan et al., 2010; Ivanauskas et al., 1999; Ivanauskas et al., 2000; Medeiros et al., 2016). Therefore, the influence of environmental variables on the dynamics of ecosystems should be further discussed, especially about the structure and floristic composition of Semideciduous Seasonal Forest arboreal communities.

Our hypotheses are that geomorphological variations, such as the different concave and convex pedoforms, have different microclimate conditions, capable of influencing the floristic composition and the structuring of the forest communities in the Paraíba do Sul Valley, being the verification of this phenomenon important for understanding ecological relations and applications of resources in future forest restoration projects.

2. MATERIALS AND METHODS

The study area is located in the municipality of Pinheiral, Rio de Janeiro State, in Médio Vale do Paraíba do Sul, Southeastern Brazil. The studied hillsides are located between the coordinates 22°33'S/44°01'W and 22°32'S/44°02'W in a fragment locally

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known as Mata do Peixoto (with 204 ha), which belongs to the Bom Sucesso Farm. The original vegetation cover is located in a transition between submontane and montane semideciduous seasonal forests (IBGE, 2013; Oliveira-Filho & Fontes, 2000). The relief of the region is wavy to strongly wavy, with altitudes varying from 360 to 720 m.a.s.l., with a predominance of steep hillsides, where linear, concave, and convex pedoforms occur (Casseti, 2005). The regional climate is classified (Köppen, 1948) as Cwa – temperate climate with dry winter and rainy summer and Am – rainy tropical climate with dry winter.

To determine the temperature (°C) and relative humidity (%) in each pedoform, four HOBO U12 Temp/RH/Light digital thermo-hygrometer sensors were installed, two apparatuses in each feature of the pedoforms, to increase local representativeness and consistent statistical data. The devices were installed in polyvinyl chloride (PVC) supports (one meter high), where they were fixed with the help of plastic clamps. In the upper portion of the structure was installed a 25 × 25 cm translucent glass slide, which protected the unit from direct rain. With the help of the HOBOware software, the devices were programmed to register the variables cited at noon every day, when the pedoforms receive solar radiation simultaneously. Data collection was performed monthly, totaling 60 monthly samples per pedoform.

For the phytosociological inventory, we selected concave and convex pedoforms. In each pedoform set, we allocated 54 plots (100 m² each), in a total of 0.54 ha sampled in each type of pedoforms, where we measured individual trees with DBH ≥ 5 cm. All samples were herborized following traditional botanical techniques (IBGE, 2013) and deposited in the Herbarium of the Department of Botany (RBR) of the Federal Rural University of Rio de Janeiro (UFRRJ). We classified the species according to their occurrence in the pedoforms as generalist (species with common occurrence in the concave and convex pedoforms) and exclusive (species that occurred only in one pedoform type). We calculated the phytosociological parameters following the form proposed by Felfili et al. (2011). All analyses were performed in Microsoft Excel (2007). We expressed floristic diversity using the Shannon index (Magurran, 2011) and evenness with the Pielou (1984) index, which we compared with results found in similar formations with acknowledged biological diversity. We analyzed the horizontal and vertical structure of each pedoform using DBH and height distribution charts. The values of total height, total basal area, and abundance of the five main species sampled and microclimate data were submitted to a normality test (Shapiro-Wilk test / R × 64 2.15.3) and homogeneity of variance test (Cochran and Bartlett / R × 64 2.15.3). According to Zar (1996), environmental variables do not usually meet the theoretical assumption due to the broad number of factors present. However, the same author affirms that T-tests are robust enough to find significant differences between treatments. Hence, we used the Levene's T-test for independent samples, at the significance level of 95%, calculated in the SPSS 21 software.

The botanical nomenclature followed APG III (2009). Names, synonyms, and occurrence of the species in the Rio de Janeiro State were checked in the Species List of the Flora of Brazil (Forzza, 2005).

3. RESULTS

The relative humidity was higher in concave pedoforms (12.52% higher), being January (16.35%), February (14.27%), July (15.01% higher), August (15%) and October (20.94%) the months with the highest percentage differences. The air temperature had lower mean values in concave pedoforms, with significant differences between all evaluated months and the annual average (2.9 °C), especially in December (2.49 °C) and January (4.13 °C). The significant differences between the averages of said variables in 2014 were analyzed by the Levene's T-test and are presented in Table 1.

Table 1. Temperature averages and relative air humidity in concave and convex pedoforms compared by the Levene's T-test at 95% probability, Pinheiral, RJ.

Months	Temp (°C)		SD		Cv		p-value
	CC	CV	CC	CV	CC	CV	
Jan	22.85	26.98	2.31	3.49	0.10	0.13	**0.000**
Feb	21.53	24.34	1.26	2.49	0.06	0.10	**0.001**
Mar	24.16	25.53	2.4	2.89	0.10	0.11	0.154
Apr	21.06	22.04	3.31	4.81	0.16	0.22	**0.015**
May	19.59	17.36	3.3	1.83	0.17	0.11	**0.000**
Jun	17.18	19.61	2.17	2.56	0.13	0.13	0.093
Jul	16.83	18.66	1.56	2.64	0.09	0.14	**0.000**
Aug	16.09	18.49	1.26	2.57	0.08	0.14	**0.000**
Sept	19.47	19.44	3.66	3.12	0.19	0.16	0.369

Table 1. Continued...

Months	Temp (°C)		SD		Cv		p-value
	CC	CV	CC	CV	CC	CV	
Oct	16.8	18.46	2.18	2.18	0.13	0.12	0.804
Nov	23.55	24.74	3.66	6.35	0.16	0.26	**0.000**
Dec	23.31	25.8	3.1	4.94	0.13	0.19	**0.000**
Annual average	19.41	22.31	3.69	5.25	0.19	0.24	**0.000**
Months	**AR (%)**		**SD**		**Cv**		**p-value**
	CC	**CV**	**CC**	**CV**	**CC**	**CV**	
Jan	80.18	63.83	11.52	16.84	0.14	0.26	**0.016**
Feb	90.19	75.92	6.21	13.25	0.07	0.17	**0.002**
Mar	87.9	76.59	6.49	8.57	0.07	0.11	0.205
Apr	92.28	82.02	3.82	8.31	0.04	0.10	**0.000**
May	93.15	84.32	3.85	7.42	0.04	0.09	0.079
Jun	92.94	79.3	4.79	8.34	0.05	0.11	**0.003**
Jul	87.85	83.36	7.79	9.06	0.09	0.11	0.310
Aug	84.23	80.89	11.68	13.39	0.14	0.17	0.686
Sept	84.24	71.54	1.63	3.05	0.02	0.04	**0.001**
Oct	88.21	67.27	1.37	2.88	0.02	0.04	**0.000**
Nov	68.63	64.16	2.56	2.75	0.04	0.04	0.666
Dec	82.48	75	10.79	11.33	0.13	0.15	0.770
Annual average	87.14	74.62	10.52	13.79	0.12	0.18	**0.000**

Temp: air temperature; AR: relative air humidity; SD: standard division; Cv: coefficient of variation; CC: concave pedoform; CV: convex pedoform.

In the phytosociological inventory, we recorded 1,843 individual trees (912 in concave and 931 in convex pedoforms) which were distributed in 39 families, 97 genera, and 126 species. Table 2 show the summary of phytosociological parameters for the 12 main species that occur in concave and convex pedoforms.

Table 2. Species with the highest IVI present in concave and convex pedoforms, Pinheiral, Rio de Janeiro State.

Species	Concave		Convex	
	AB	IVI	AB	IVI
Amaioua guianensis Aubl.	–		50.0	11.2
Apuleia leiocarpa (Vogel) J. F. Macbr.	131.0	32.5	88.0	21.7
Astrocaryum aculeatissimum (Schott) Burret	61.0	15.0	38.0	9.7
Astronium graveolens Jacq.	–		34.0	9.2
Brosimum guianense (Aubl.) Huber	36.0	9.7	39.0	10.6
Cupania oblongifolia Mart.	46.0	14.1	34.0	8.0
Guapira opposita (Vell.) Reitz	49.0	12.6	55.0	10.9
Jacaranda micrantha Cham.	26.0	7.5	–	
Morta	57.0	18.4	64.0	24.7
Nectandra membranacea (Sw.) Griseb.	–		19.0	6.7
Piptadenia gonoacantha (Mart.) J. F. Macbr.	17.0	12.1	27.0	15.5
Pseudopiptadenia contorta (DC.) G. P. Lewis & M. P. Lima	59.0	30.5	57.0	34.8
Senegalia polyphylla (DC.) Britton & Rose	36.0	9.5	–	
Tabernaemontana laeta Mart.	26.0	6.7	–	
Xylopia sericea A. St.-Hil.	21.0	6.8	21.0	7.9

AB: abundance; IVI: importance value index; –: This species does not occur on the pedoform.

The Shannon index was 3.81 for Mata do Peixoto, 3.63 for concave pedoforms, and 3.78 for convex pedoforms. Regarding the horizontal and vertical structure of the fragment, we found the same J-shaped data distribution pattern for DBH and height variables for both pedoforms. Figure 1 shows the distribution of individuals according to DBH and height in different pedoforms.

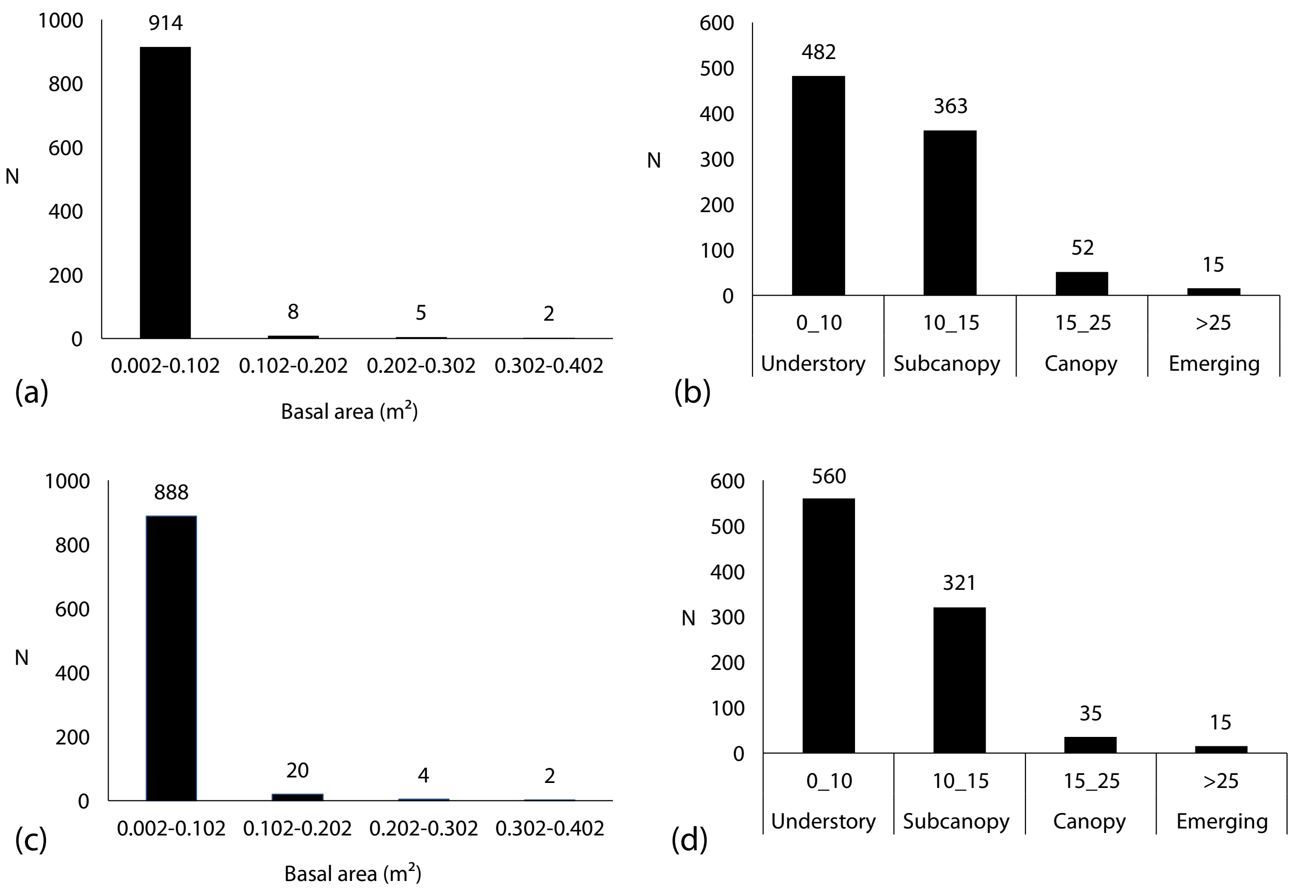

Figure 1. (a) Distribution of individual trees in concave pedoforms according to DBH classes, (b) Distribution of individuals present in concave pedoforms into different forest stratal; (c) Distribution of individuals present in convex pedoforms according to DBH classes, (d) Distribution of individuals present in convex pedoforms into the different forest strata, in Pinheiral, Rio de Janeiro State, Southeastern Brazil.

N: number of individuals.

When we compared the structural averages, the Levene's T-test did not show significant differences between the average values of the horizontal structure (basal area and DBH). However, the vertical structure (total height) showed different averages between pedoforms (Table 3).

Table 3. Mean of basal area and total height of the main species present in concave and concave pedoforms, compared to the Levene's T-test at 95% probability, Pinheiral, State of Rio de Janeiro.

	Média de DAP (cm)	**SD**	**CV**	**p-value**
Concave	12.82	7.92	0.61	0.399
Convex	12.72	8.67	0.68	
	Média de G (m²)	**SD**	**CV**	**p-value**
Concave	0.301	0.135	0.44	0.683
Convex	0.323	0.137	0.42	
	Média de HT (m)	**SD**	**CV**	**p-value**
Concave	10.22	5.39	0.52	**0.040**
Convex	9.34	5.05	0.54	

DBH: diameter at breast height; G: basal area; TH: total height; SD: standard deviation; CV: coefficient of variation.

The average values of basal area, total height, and the abundance of the main generalist species suggest punctual differences as shown in Table 4.

The analysis of floristic composition showed the occurrence of 94 species in concave pedoforms, of which 26 (20.6%) were exclusive and 102 species in convex pedoforms, of which 36 (28.6%) were exclusive. A total of 64 (50.08%) species occurred simultaneously in both pedoforms (generalists), distributed in 27 families. Fabaceae, Sapindaceae, Myrtaceae, Euphorbiaceae, Lauraceae, Annonaceae, Apocynaceae, Moraceae, Verbenaceae, Rubiaceae, and Peraceae concentrated 64.06% of the generalist species. We found a total of 55 genera; Cupania, Matayba, Casearia, Ocotea, Pera, Machaerium, and Trichilia concentrated 23.43% of the species, whereas the remaining 48 genera comprised other 47 species. The species with the largest number of individuals were Apuleia leiocarpa, *Pseudopiptadenia contorta*, *Guapira opposita*, *Amaioua guianensis*, *Brosimum guianense*, *Astrocaryum aculeatissimum*, *Cupania oblongifolia*, and *Astronium graveolens*, which concentrated 44.66% of the total individuals. Other 55 species were represented by 727 or 55.34% of individuals.

Table 4. Averages of total height, basal area and abundance of the main species present in convex and concave pedoforms, compared with the Levene's T-test with 95% probability, Pinheiral, State of Rio de Janeiro.

***Pseudopiptadenia contorta* (angico-cabelo)**				
	Mean of G (m²)	SD	CV	p-value
Concave	0.52	0.6	0.23	0.140
Convex	0.71	0.1	0.14	
	Mean of TH (m)	SD	CV	p-value
Concave	15.44	7.82	0.50	0.094
Convex	16.16	9.39	0.58	
	Mean number of individuals	SD	CV	p-value
Concave	5.9	3.78	0.64	0.014
Convex	5.7	2.05	0.35	
***Cupania oblongifolia* (camboatá)**				
	Mean of G (m²)	SD	CV	p-value
Concave	0.144	0.009	0.06	**0.034**
Convex	0.079	0.005	0.06	
	Mean of TH (m)	SD	CV	p-value
Concave	11.32	3.22	0.28	0.903
Convex	8.26	3.08	0.37	
	Mean number of individuals	SD	CV	p-value
Concave	4.6	1.64	0.35	**0.043**
Convex	3.4	0.966	0.28	
***Apuleia leiocarpa* (garapa)**				
	Mean of g (m²)	SD	CV	p-value
Concave	0.14	0.13	0.92	0.190
Convex	0.11	0.11	0.91	
	Mean of TH (m)	SD	CV	p-value
Concave	12.82	5.24	0.40	**0.002**
Convex	9.38	3.68	0.39	
	Mean number of individuals	SD	CV	p-value
Concave	13.10	7.14	0.54	**0.001**
Convex	8.80	3.73	0.42	
***Piptadenia gonoacantha* (pau-jacaré)**				
	Mean of G (m²)	SD	CV	p-value
Concave	0.074	0.05	0.74	0.240
Convex	0.053	0.03	0.62	
	Mean of TH (m)	SD	CV	p-value

Table 4. Continued...

		Pseudopiptadenia contorta **(angico-cabelo)**		
Concave	16.29	6.87	0.42	**0.010**
Convex	13.76	3.84	0.27	
	Mean number of individuals	SD	CV	p-value
Concave	1.70	1.16	0.68	0.259
Convex	2.70	0.94	0.35	
		Astrocaryum aculeatissimum **(tucum)**		
	Mean of G (m^2)	SD	CV	p-value
Concave	0.0087	0.0028	0.32	0.559
Convex	0.0094	0.0034	0.36	
	Mean of TH (m)	SD	CV	p-value
Concave	4.87	1.16	0.23	0.761
Convex	4.11	0.924	0.22	
	Mean number of individuals	SD	CV	p-value
Concave	6.10	4.17	0.68	**0.001**
Convex	3.50	1.9	0.54	

DBH: diameter at breast height; G: basal area; TH: total height; SD: standard deviation; CV: coefficient of variation.

In the concave pedoforms, 38 botanical families occurred, among which 15 were exclusive. The families Fabaceae, Myrtaceae, Euphorbiaceae, Sapindaceae, Annonaceae, Lauraceae, Apocynaceae, Moraceae, Rubiaceae, and Malvaceae concentrated 65.87% of the species. We identified at least 73 genera in concave pedoforms. The genera Actinostemon, Cupania, Matayba, Pera, Ocotea, Pouteria, Casearia, Protium, Schefflera, Machaerium, and Trichilia concentrated 24.44% of the total species. The species with the largest number of individuals were *Apuleia leiocarpa*, *Astrocaryum aculeatissimum*, *Pseudopiptadenia contorta*, *Guapira opposita*, *Cupania oblongifolia*, *Senegalia polyphylla*, *Brosimum guianense*, *Dalbergia nigra*, *Actinostemon verticillatus*, and *Xylopia sericea*, which concentrated 57.95% of the total individuals sampled (all generalists). The 26 exclusive species are responsible for 5.65% of the total of individuals sampled.

In the convex pedoforms, 34 families occurred. The families Fabaceae, Myrtaceae, Euphorbiaceae, Sapindaceae, Annonaceae, Lauraceae, Rubiaceae, Moraceae, Verbenaceae, and Apocynaceae concentrated 67% of the species found in this pedoform. The families Fabaceae, Myrtaceae, Euphorbiaceae, Sapindaceae and Annonaceae contributed with approximately 48% of the total of species sampled. Convex pedoforms had at least 77 genera. The genera Ocotea, Machaerium, Cupania, Matayba, Xylopia, Trichilia, Alchornea, Brosimum, Annona, and Casearia concentrated 36.36% of the total species sampled. The remaining 67 genera comprised other 72 species. The species with the largest number of individuals were *Apuleia leiocarpa*, *Pseudopiptadenia contorta*, *Guapira opposita*, *Amaioua guianensis*, *Brosimum guianense*, *Astrocaryum aculeatissimum*, *Cupania oblongifolia*, *Astronium graveolens*, *Piptadenia gonoacantha*, and *Actinostemon verticillatus*, which concentrated 48.01% of the total individuals sampled. All genera cited are generalist; the 36 exclusive species (Table 1) comprise only 9% of the total individuals sampled.

4. DISCUSSION

Empirical studies and forest succession models predict changes in abiotic conditions during the succession process (Lebrija-Trejos et al., 2010; Oliver & Larson, 1990), promoted by the development of pioneer species that favor the germination of others belonging to different ecological groups (Valiente-Banuet & Verdú, 2007).

According to the progression of this succession, the variables "temperature" and "relative humidity of the air" are changed, influencing biogeochemical processes, such as content and complexity of organic matter, degree of decomposition to microbial activity (Biasi et al., 2008; Raich et al., 2006; Wagai et al., 2008), altering the availability of nutrients that influence the development of plants.

In regions such as Médio Vale do Paraíba, where different pedoforms occur, this process can be facilitated, since the microclimatic conditions found, especially in concave pedoforms, favor the occurrence of specific environmental conditions, capable of influencing the community's ecological dynamics.

The different microclimatic pattern between pedoforms can be attributed to the shape of the feature, which in concave ones restrains the direct incidence of the winds and favors the shorter period of sunshine, besides promoting the convergence of surface waters to a central drainage line (Casseti, 2005), reducing the depth of the soils and favoring the greater proximity of the water table to the surface. Convex pedoforms promote the dispersion of water on the surface (Casseti, 2005), besides being exposed to higher solar radiation and dissecting by the action of direct winds, favoring higher temperature means and lower relative humidity.

When we analyzed the phytosociological and structural parameters of the main generalist species, we observed some differences between pedoforms, such as the significant variations between the vertical structure among pedoforms, the basal area and abundance of *Cupania oblongifolia*, the variation in the vertical structure and abundance of *Apuleia leiocarpa*, and the difference in the abundance of *Astrocaryum aculeatissimum*, being observed better establishment of their populations in concave pedoforms.

Considering the classification of those species by ecological groups (Carvalho, 2003; Lorenzi, 1998, 2002, 2009), it is possible to associate those pedoforms with differentiated microclimate conditions to promote the establishment of secondary and climax species. On the other hand, the significantly higher abundance of *Piptadenia gonoacantha*, *Brosimum guianense* and Guapira opposites in convex pedoforms suggests the microclimate conditions of those pedoforms favored the establishment of pioneer species.

Although it is probable that the existing microclimatic differences favored the occurrence of specific species and genera, in addition to populations with different behavior between pedoforms, it is worth mentioning that these variations are subtle and punctual, not being possible to determine the existence of communities of different tree species between pedoforms.

For practical purposes, knowledge about the microclimatic conditions differentiated between pedoforms and their influence on the behavior of species allows the technician, manager or owner to formulate specific conservation and preservation strategies for the Paraíba Valley forest fragments. Such strategies range from choosing appropriate species for seedling production, the ideal point of the slope for planting, or simply choosing areas with higher resilience for isolation, such as concave pedoforms.

In relation to the diversity of species, Miranda & Diógenes (1998) found for tropical forests average values of Shannon-Wiener index that vary from 1.5 to 3.5, and rarely surpass 4.5 nats. ind^{-1}. Kurtz & Araújo (2000) found for the Atlantic Forest of the Rio de Janeiro State values that vary from 1.69 to 4.4 nats. ind^{-1}, indicating that the Shannon index calculated for Mata do Peixoto (H' = 3.81), in concave (H' = 3.63) and convex pedoforms (H' = 3.78), suggests high diversity in the study area, in particular when compared with other studies carried out in semi-deciduous seasonal forests of Southeastern Brazil (Table 5).

Table 5. Shannon diversity index and Pielou evenness index calculated in different studies carried out in semi-deciduous seasonal forests of Southeastern Brazil.

Author	Local/UF	H'	J	Area (ha)	DBH
Gonzaga et al. (2008)	Tiradentes (MG)	4.23	0.87	0.9	5
Carvalho et al. (2007)	Piedade do Rio Grande (MG)	4.42	0.85	1.2	3
Carvalho et al. (2000)	Itambé do Mato Dentro (MG)	4.32	0.82	0.8	5
Silva et al. (2003)	Ibituruna (MG)	4.2	0.89	1.04	5
Botrel et al. (2002)	Ingaí (MG)	3.73	0.76	1	5
Ivanauskas et al. (2000)	Piracicaba (SP)	3	0.7	0.4	5
Ivanauskas et al. (1999)	Itatinga (SP)	3.77	0.82	0.42	5
Dan et al. (2010)	São José de Ubá (RJ)	3.87	0.86	0.2	5
Dan et al. (2010)	São José de Ubá (RJ)	3.63	0.85	0.2	5
Dan et al. (2010)	São José de Ubá (RJ)	3.84	0.91	0.2	5
Dan et al. (2010)	São José de Ubá (RJ)	3.83	0.92	0.2	5
Dan et al. (2010)	São José de Ubá (RJ)	4.6	0.87	1	5
Dan et al. (2010)	São José de Ubá (RJ)	4.35	0.88	1	5
Medeiros et al. (2016) (sob revisão)	Piraí (RJ)	3.57	0.88	0.15	5
Present study – total area	Pinheiral (RJ)	3.81	0.82	1.08	5
Present study – concave	Pinheiral (RJ)	3.63	0.79	0.54	5
Present study – convex	Pinheiral (RJ)	3.78	0.81	0.54	5

H': Shannon diversity index; J: Pielou evenness index; DBH: diameter at breast height.

Corroborating the high values of the Shannon index, the Pielou evenness index calculated for the entire fragment (J' = 0.821), and for concave (J' = 0.798) and convex pedoforms (J' = 0.817), can also be considered high. The closer this index is to one, the higher is the diversity and species abundance in the sampling units (Magurran, 1988).

According to Harper (1990), tropical forests have a higher frequency of individuals in the classes of small diameters. This behavior was also found by Guariguata et al. (1997) in Costa Rica and by Lima et al. (2013) in the Brazilian Amazon, being indicative of stability of ecological processes in tropical forests, and pointing to the existence of a "stock community" made up of different species responsible for the replacement of dead individuals (Scolforo et al., 1998). For both pedoforms were found this standard, as well as for studies by Dan et al. (2010), Gonzaga et al. (2008), Carvalho et al. (2007), Reis et al. (2007), Coraiola & Péllico Netto (2003), Silva et al. (2003), Rodrigues et al. (2003), Meira-Neto & Martins (2002), Botrel et al. (2002) in seasonal Forests of Rio de Janeiro, Minas Gerais and São Paulo.

The joint analysis of the horizontal and vertical structure of the concave pedoform points out to a dense understory, where predominate individuals with low diameter, followed by a dense subcanopy, and a continuous canopy, surpassed by a small number of emerging large-sized individuals. However, despite the structural similarity between pedoforms, we detected a small number of individuals in the canopy of convex pedoforms, which promoted a slight discontinuity of this stratum.

The low number of individuals in the canopy and the high number of individuals in the understory of convex were possibly responsible for the low average of total height and by the significant difference between pedoforms (Table 2). The cause of high density of thin individuals in the understory can be attributed to a greater luminosity promoted by the low density of individuals in the canopy (Carvalho & Nascimento, 2009; Parrotta, 1993). Such structural characteristics result from the convex edge effect due to its exposure to dry winds, higher insulation time and unfavorable microclimatic conditions (an inverse concave condition is observed).

The results of the number of individuals per species indicated a small number of species concentrated values close to 50% of the total sampled. In this context, it is worth emphasizing the predominance of the species *Apuleia leiocarpa*, *Pseudopiptadenia contorta*, and *Guapira opposita*, which showed a large number of individuals, regardless of the pedoform studied. When compared with the main studies carried out in seasonal forests in Minas Gerais and São Paulo (Botrel et al., 2002; Carvalho et al., 2007; Coraiola & Péllico Netto, 2003; Gonzaga et al., 2008; Meira-Neto & Martins, 2002; Reis et al., 2007; Rodrigues et al., 2003; Silva et al., 2003), Mata do Peixoto shows different structure and floristic composition, especially for the absence *Copaifera langsdorffii*, species cited by the authors with greater abundance in these formations. These floristic differences can be associated with the occurrence of ecotonal areas in those states between seasonal forests and Cerrado formation, because *C. langsdorfii* is typical of the latter biome.

Among the other species with high importance value in Mata do Peixoto, *Cupania oblongifolia*, *Astronium graveolens*, and *Astrocaryum aculeatissimum* stand out for their broad distribution in forests of the state, particularly in formations at the late natural regeneration stage (Borém & Oliveira-Filho, 2002; Carvalho & Nascimento, 2009; Neves & Peixoto, 2008). On the other hand, *Piptadenia gonoacantha* and *Nectandra membranacea* mostly occur in forests at early regeneration stage, but large-sized individuals were also found in communities at intermediate regeneration stage, both in dense rainforests (Cysneiros et al., 2015; Gandra et al., 2011; Guedes-Bruni et al., 2006) and semi-deciduous seasonal forests (Dan et al., 2010).

Likewise in the present study, Dan et al. (2010), Pinto Sobrinho et al. (2010), Guedes-Bruni et al. (2006) and Borém & Oliveira-Filho (2002) observed that *Pseudopiptadenia contorta* is one of the main species of the communities, evidencing its broad distribution in different forest formations in the Rio de Janeiro State. On the other hand, *Apuleia leiocarpa* shows in Mata do Peixoto a high IVI due to the large number of individuals with small basal area, a structural characteristic different from that found in other populations in the state. In their studies on dense rainforests, Cysneiros et al. (2015), Carvalho & Nascimento (2009) and Carvalho et al. (2007) pointed *A. leiocarpa* as a poorly relevant species at the lower strata of communities, as it occurs mainly in the canopy (Neves & Peixoto, 2008), and consequently has a large basal area. This structural difference for the species in Mata do Peixoto can be mainly explained by logging exploitation, which is common in seasonal forests of the Rio de Janeiro State, as most fragments of the formation are located in private areas.

5. CONCLUSIONS

The presence of species typical of ecosystems at late stage succession in concave pedoforms, as well as the largest number of pioneer and initial secondary species in convex pedoforms, indicates that, problably, the studied fragment has two different successional stages, one more incipient (convex) and another intermediate to late (concave).

This condition is result of higher annual mean relative humidity and lower temperature in concave pedoforms in relation to convex pedoforms, which may have favored the processes of resilience and the advancement of succession stages.

Despite exclusives species occurrences, differences between IVIs and Total Height of some species, the microclimate variations do not promoted significant differences in the structure and composition of tree community between pedoforms, being these differences punctual and insufficient to determine specific communities. However, they can help the development of natural regeneration.

The generalist species showed good development regardless of the pedoform, and therefore are good options for the reforestation of degraded and disturbed areas of the seasonal semideciduous forest of Rio de Janeiro. Regarding specific species, they are indicated for enrichment plantations according to their ecological group and the successional stage of the community.

The information obtained with floristic and structural analysis of the fragment contributed to the knowledge on the remains of the regional flora, as well as the amplitude of structural variations. Such information, associated with the differentiated microclimatic characteristics of each pedoform, will allow the effective application of a resource for the recovery, enrichment or preservation of seasonal semi-deciduous forests.

SUBMISSION STATUS

Received: 3 May 2017
Accepted: 9 July 2018
Associate editor: Bruno Araujo Furtado de Mendonça

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FINANCIAL SUPPORT

Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Capes).

REFERENCES

Almeida FFM. Fundamentos geológicos do relevo paulista. *Boletim do Instituto Geográfico e Geológico* 1964; 41:167-263.

Angiosperm Phylogeny Group III – APG III. An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III. *Botanical Journal of the Linnean Society* 2009; 161(2): 105-121. 10.1111/j.1095-8339.2009.00996.x

Biasi C, Meyer H, Rusalimova O, Hammerle EH, Kaiser C, Baranyi C et al. Initial effects of experimental warming on carbon exchange rates, plant growth and microbial dynamics of a lichen-rich dwarf shrub tundra in Siberia. *Plant and Soil* 2008; 307(1-2): 191-205. 10.1007/s11104-008-9596-2

Borém RAT, Oliveira-Filho AT. Fitossociologia do estrato arbóreo em uma toposseqüência alterada de mata Atlântica, no município de Silva Jardim-RJ, Brasil. *Revista Árvore* 2002; 26(6): 727-742. 10.1590/S0100-67622002000600009

Botrel RT, Oliveira-Filho AT, Rodrigues L, Curi N. Influência do solo e topografia sobre as variações da composição florística e estrutura da comunidade arbóreo-arbustiva de uma floresta estacional semidecidual em Ingaí, MG-Brasil. *Revista Brasil Botânica* 2002; 25(2): 195-213. 10.1590/S0100-84042002000200008

Carvalho DA, Oliveira-Filho AT, Vilela EA, Curi N. Florística e estrutura da vegetação arbórea de um fragmento de floresta semidecidual às margens do reservatório da usina hidrelétrica Dona Rita (Itambé do Mato Dentro, MG). *Acta Botanica Brasilica* 2000; 14(1): 37-55. 10.1590/S0102-33062000000100005

Carvalho FA, Nascimento MT. Estrutura diamétrica da comunidade e das principais populações arbóreas de um remanescente de Floresta Atlântica submontana no município de Silva Jardim, RJ, Brasil. *Revista Árvore* 2009; 33(2): 327-337. 10.1590/S0100-67622009000200014

Carvalho FA, Nascimento MT, Braga JMA. Estrutura e composição florística do estrato arbóreo de um remanescente de Mata Atlântica submontana no município de Rio Bonito, RJ, Brasil (Mata Rio Vermelho). *Revista Árvore* 2007; 31(4): 717-730. 10.1590/S0100-67622007000400017

Carvalho PER. *Espécies arbóreas brasileiras*. Brasília, DF: Embrapa Informação Tecnológica; 2003.

Casseti V. *Geomorfologia* [Internet]. 2005 [cited 2013 May 2]. Available from: https://bit.ly/2ONRbMB

Coraiola M, Péllico Netto S. Análise da estrutura horizontal de uma floresta estacional semidecidual localizada no município de Cássia-MG. *Revista Acadêmica: Ciências Agrárias e Ambientais* 2003; 1(2): 11-19. 10.7213/cienciaanimal.v1i2.14898

Cysneiros VC, Mendonça-Junior JO, Gaui TD, Braz DM. Diversity, community structure and conservation status of an Atlantic forest fragment in Rio de Janeiro state, Brazil. *Biota Neotropica* 2015; 15(2): e20140132. 10.1590/1676-060320150132

Dan ML, Braga JMA, Nascimento MT. Estrutura da comunidade arbórea de fragmentos da bacia do rio São Domingos, Rio de Janeiro, Brasil. *Rodriguésia* 2010; 61(4): 749-766. 10.1590/2175-7860201061414

Dean W. *Ferro e fogo, a história e a devastação da mata atlântica brasileira*. Rio de Janeiro: Companhia das Letras; 1996.

Felfili JM, Eisenlohr PV, Fiuza MMR, Andrade LA, Meira Neto JAA. *Fitossociologia no Brasil, métodos e estudos de casos*. Viçosa, MG: Editora UFV; 2011.

Forzza RC. *Lista de espécies da flora do Brasil* [Internet]. 2005 [cited 2014 June 10]. Available from: https://bit.ly/2XAJmKX

Gandra MF, Nunes-Freitas AF, Schütte MS. Composição florística do estrato arbóreo na RPPN Porangaba em Itaguaí, estado do Rio de Janeiro, Brasil. *Floresta e Ambiente* 2011; 18(1): 87-97. 10.4322/floram.2011.026

Gonzaga APD, Oliveira-Filho AT, Machado ELM, Hargreaves P, Machado JNM. Diagnóstico florístico-estrutural do componente arbóreo da floresta da Serra de São José, Tiradentes, MG, Brasil.

Acta Botanica Brasilica 2008; 22(2): 505-520. 10.1590/S0102-33062008000200018

Guariguata MR, Chazdon RL, Denslow JS, Dupuy JM, Anderson L. Structure and floristics of secondary and old-growth forest stands in lowland Costa Rica. *Plant Ecology* 1997; 132(1): 107-120.

Guedes-Bruni RR, Silva Neto SJ, Morim MP, Mantovani W. Composição florística e estrutura de dossel em trecho de floresta ombrófila densa atlântica sobre morrote mamelonar na Reserva Biológica de Poço das Antas, Silva Jardim, Rio de Janeiro, Brasil. *Rodriguésia* 2006; 57(3): 429-442. 10.1590/2175-7860200657304

Harper JL. *Population biology of plants*. 2nd ed. London: Academic Press; 1990.

Instituto Brasileiro de Geografia e Estatística – IBGE. *Manual técnico da vegetação brasileira* [Internet]. 2nd ed. Rio de Janeiro: IBGE; 2013 [cited 2014 June 6]. Available from: https://bit.ly/2Cz2phD

Ivanauskas NM, Monteiro R, Rodrigues RR. Similaridade florística entre áreas de floresta atlântica no estado de São Paulo. *Brazilian Journal of Ecology* 2000; 1(4): 71-81.

Ivanauskas NM, Rodrigues RR, Nave AG. Fitossociologia de um trecho de Floresta Estacional Semidecidual em Itatinga, São Paulo, Brasil. *Scientia Forestalis* 1999; 56: 83-99.

Köppen W. *Climatologia: con un estudio de los climas de la tierra*. México, DF: Fondo de Cultura Económica; 1948.

Kurtz BC, Araújo DSD. Composição florística e estrutura do componente arbóreo de um trecho de mata atlântica na Estação Ecológica Estadual do Paraíso, Cachoeiras de Macacu, Rio de Janeiro, Brasil. *Rodriguésia* 2000; 51(78): 69-111. 10.1590/2175-7860200051787903

Lebrija-Trejos E, Péréz-García EA, Meave JA, Bongers F, Poorter L. Functional traits and environmental filtering drive community assembly in a species-rich tropical system. *Ecology* 2010; 91(2): 386-398. 10.1890/08-1449.1

Lima JA, Gavioli ILC, Barbosa CMP, Berndt A, Gimenes FMA, Paz CCP, Cunha EA. Soybean silage and sugarcane tops silage on lamb performance. *Ciência Rural* 2013; 43(8): 1478-1484. 10.1590/S0103-84782013005000098

Lorenzi H. Árvores *brasileiras: manual de identificação e cultivo de plantas arbóreas do Brasil*. Nova Odessa: Instituto Plantarum; 1998.

Lorenzi H. Árvores *brasileiras: manual de identificação e cultivo de plantas arbóreas do Brasil*. 2nd ed. Nova Odessa: Instituto Plantarum; 2002.

Lorenzi H. Árvores brasileiras: manual de identificação e cultivo de plantas arbóreas do Brasil. 3rd ed. Nova Odessa: Instituto Plantarum; 2009.

Magurran AE. *Ecological diversity and its measurement*. Princeton: Princeton University Press; 1988.

Magurran AE. *Medindo a diversidade biológica*. Curitiba: Editora UFPR; 2011.

Medeiros AS, Pereira MG, Braz DM. Estrutura e conservação de um trecho de floresta estacional em Piraí, RJ. *Floresta e Ambiente* 2016; 23(3): 330-339. 10.1590/2179-8087.106214

Meira-Neto JAA, Martins FR. Composição florística de uma floresta estacional semidecidual montana no município de Viçosa-MG. *Revista Árvore* 2002; 26(4): 43-446. 10.1590/S0100-67622002000400006

Miranda IS, Diógenes MB. *Caracterização florística, fisionômica e estrutural da vegetação da floresta nacional do Macauã* [research report]. Rio Branco; 1998.

Neves GMS, Peixoto AL. Florística e estrutura da comunidade arbustivo-arbórea em dois remanescentes de floresta atlântica secundária – Reserva Biológica de Poço das Antas, Silva Jardim, Rio de Janeiro. *Pesquisas: Botânica* 2008; (59): 71-112.

Oliveira-Filho AT, Fontes AL. Patterns of floristic differentiation among Atlantic forests in Southeastern Brazil and the influence of climate. *Biotropica* 2000; 32(4b): 793-810. 10.1111/j.1744-7429.2000.tb00619.x

Oliver CD, Larson BC. *Forest stand dynamics*. New York: McGraw-Hill; 1990.

Parrotta JA. Secondary forest regeneration on degraded tropical lands: the role of plantations as faster ecosystems. In: Lieth H, Lohmann M, editors. *Restoration of tropical forest ecosystems*. Dordrecht: Kluwer; 1993. p. 63-73.

Pielou EC. *The interpretation of ecological data: a primer on classification and ordination*. New York: John Wiley & Sons; 1984.

Pinto Sobrinho FDA, Christo AG, Guedes-Bruni RR. Fitossociologia do componente arbóreo num remanescente de floresta ombrófila densa submontana limítrofe à Reserva Biológica do Tinguá, Rio de Janeiro. *Revista Floresta* 2010; 4(1): 111-124. 10.5380/rf.v40i1.17103

Raich JW, Russell AE, Kitayama K, Parton WJ, Vitousek PM. Temperature influences carbon accumulation in moist tropical forests. *Ecology* 2006; 87(1): 76-87. 10.1890/05-0023

Reis H, Scolforo RO, Oliveira AD, Oliveira Filho AT, Mello JM. Análise da composição florística, diversidade e similaridade de fragmentos de mata atlântica em Minas Gerais. *Cerne* 2007; 13(3): 280-290.

Rodrigues LA, Carvalho DA, Oliveira-Filho AT, Botrel RT, Silva EA. Florística e estrutura da comunidade arbórea de um fragmento florestal em Luminárias, MG. *Acta Botanica Brasilica* 2003; 17(1): 71-87. 10.1590/S0102-33062003000100006

Scolforo JRS, Pulz FA, Melo JM. Modelagem da produção, idade das florestas nativas, distribuição espacial das espécies e a análise estrutural. In: Scolforo JRS, editor. *Manejo florestal*. Lavras: UFLA; 1998. p. 189-246.

Silva CR. *Geodiversidade do Brasil: conhecer o passado, para entender o presente e prever o futuro*. Rio de Janeiro: CPRM; 2008.

Silva VF, Venturi N, Oliveira-Filho AT, Macedo RLG, Carvalho WAC, van den Berg E. Caracterização estrutural de um fragmento de floresta semidecidual no Município de Ibituruna, MG. *Cerne* 2003; 91(1): 92-106.

Valiente-Banuet A, Verdú, M. Facilitation can increase the phylogenetic diversity of plant communities. *Ecology Letters* 2007; 10(11): 1029-1036. 10.1111/j.1461-0248.2007.01100.x

Wagai R, Mayer LM, Kitayama K, Knicker H. Climate and parent material controls on organic matter storage in surface soils: a three-pool, density-separation approach. *Geoderma* 2008; 147(1-2): 23-33. 10.1016/j.geoderma.2008.07.010

Zar JH. *Biostatistic alanalysis*. 3rd ed. New Jersey: Prentice-Hall; 1996.