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Artigos

Structure, floristic composition and environmental relationships of natural regeneration in a semideciduous seasonal forest

Estrutura, composição florística e relações ambientais da regeneração natural em uma floresta estacional semidecidual

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ABSTRACT

This paper aims to evaluate the floristic and structure of natural regeneration in a forest fragment located in the south of Espírito Santo State, as well as to verify the interaction between vegetation and environmental variables. The study was developed in Private Reserve of Nature Patrimony (RPPN) Cafundó, with twelve sample units (1 x 20m), where three classes based on size - Class 1 (plants between 0.1 and 1m high), Class 2 (plants between 1.1 and 3m high) and Class 3 (plants higher than 3m and less than 5cm DBH). This RPPN has a total area of 517ha, which approximately 358ha were used for allocation of experimental units. Individuals were classified according to ecological group and dispersion syndrome. Floristic diversity, equability, density and frequency of species were also calculated. Analysis of natural regeneration, floristic similarity between natural regeneration and the upper layer as well the regenerating layer interaction with environmental variables was performed through Canonical Correspondence Analysis. We found 678 individuals distributed in 73 morphospecies/species, with *Actinostemon klotzschii* and *Goniorrhachis marginata* being the most abundant. Sorensen's similarity between natural regeneration and the adult tree layer was 29%. The most dominant ecological groups were late secondary, while zoochory was the predominant dispersion syndrome among existing species. Shannon diversity index was 3.13 and equability 0.72. *Goniorrhachis marginata*, *Actinostemon klotzschii* and *Psychotria carthagenensis* species had correlation with carbon (C), phosphorus (P), declivity and canopy cover. We concluded that the natural regeneration component within studied area has a high richness and density of individuals when compared to studies developed in similar phytophysiognomies. The studied environmental variables seem to have little influence on the distribution of natural regeneration species in the RPPN, once only carbon, phosphorus, declivity and canopy cover have explained the species distribution within fragment.

Keywords: Vegetable recruitment; Environmental variables; Private protected areas; Atlantic Forest

RESUMO

O objetivo deste estudo foi descrever a florística e estrutura da regeneração natural do estrato arbustivo-arbóreo em um fragmento florestal no sul do estado do Espírito Santo, bem como verificar a interação da vegetação com algumas variáveis ambientais selecionadas. Foi desenvolvido na Reserva Particular do Patrimônio Natural (RPPN) Cafundó, em doze subparcelas de 1 x 20 m, onde foram delimitadas três classes de tamanho - classe 1 (plantas entre 0,1 e 1 m de altura), classe 2 (1,1 e 3 m de altura) e classe 3 (altura maior que 3 m e menor que 5 cm DAP). A RPPN possui uma área de 517 ha, onde 358 ha foram utilizados para alocação das unidades experimentais. Os indivíduos foram classificados quanto ao grupo ecológico e síndrome de dispersão. Foi calculado o índice de diversidade, equabilidade, densidade e frequência das espécies e a similaridade de Sorensen entre o estrato regenerante e adulto. A interação do estrato regenerante com variáveis ambientais foi realizada através da Análise de Correspondência Canônica. Foram amostrados 678 indivíduos, distribuídos em 73 espécies/morfoespécies, sendo *Actinostemon klotzschii* e *Goniorrhachis marginata* as mais abundantes. A similaridade entre regeneração e estrato arbóreo foi 29%. O grupo ecológico e a dispersão predominante, respectivamente, foram secundária tardia e zoocoria. A diversidade de Shannon (H’) foi 3,13 e equabilidade de 0,72. As espécies *Goniorrhachis marginata*, *Actinostemon klotzschii* e *Psychotria carthagenensis* tiveram correlação com carbono (C), fósforo (P), declividade e cobertura de dossel. Concluiu-se que a regeneração natural na área estudada possui elevada riqueza e densidade de indivíduos quando comparado a estudos desenvolvidos na mesma fitofisionomia. As variáveis ambientais estudadas parecem ter pouca influência na distribuição das espécies da regeneração natural, uma vez que apenas o carbono, o fósforo, a declividade e a cobertura do dossel explicaram parte da distribuição das espécies no fragmento.

Palavras-chave: Recrutamento vegetal; Variáveis ambientais; Áreas privadas protegidas; Floresta Atlântica

1 INTRODUCTION

The Atlantic Forest has experienced a fragmentation process that generated a mosaic of natural vegetation remnants, of which about 80% has an area of less than 50 ha (RIBEIRO *et al*., 2009; REZENDE *et al*., 2018)**.** Due to their small size, these fragments present low resilience and suffer numerous environmental disturbances (natural and / or anthropic) after changes in the landscape in which are inserted. Therefore, understanding the processes that influence the organization of plant communities in natural environments has been one of the main focuses of forest ecology, since it’s a key step when defining suitable forest management or restoration strategies (AGUIAR *et al*., 2017; SOBOLESKI *et al*., 2017).

Natural regeneration is considered the beginning of plant recruitment, referring to the initial stage of survival and growth of many plant species that have different forms of life and play a fundamental functional role in forest dynamics. Therefore, knowledge about the processes that influence natural regeneration enable to more efficiently access the ecosystems resilience, in addition of being an essential element for maintenance, recovery and preservation of forest fragments (CHAZDON; GUARIGUATA, 2016).

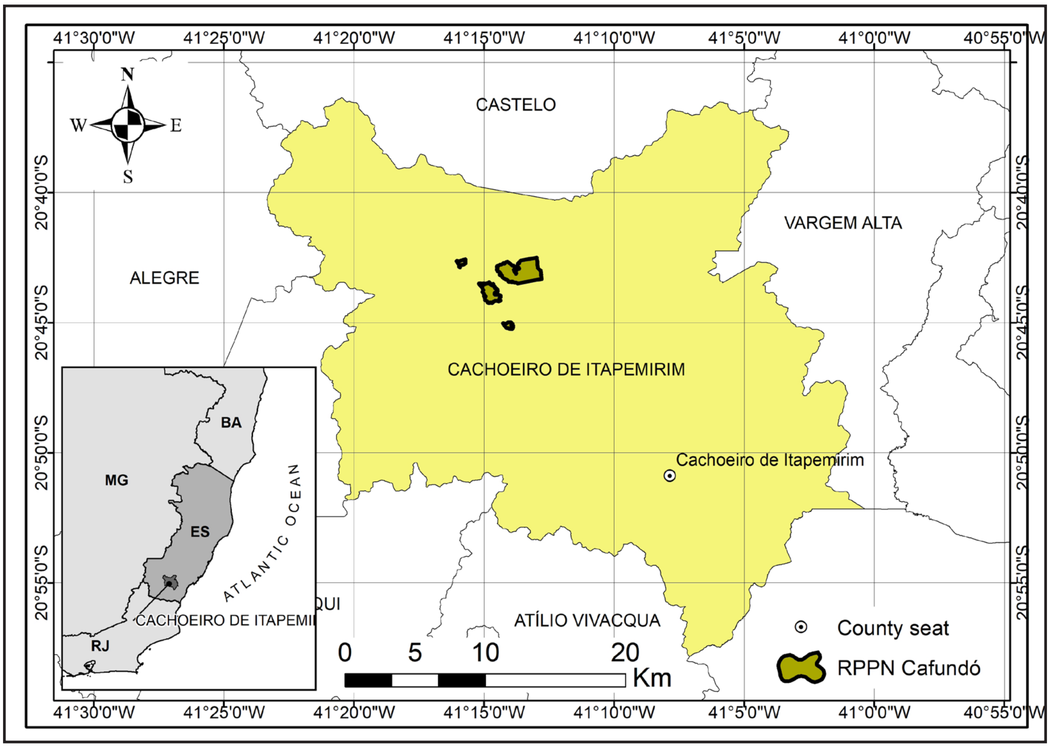
Environmental filters are fundamental in structuring the community over the succession process of tropical forests (BOUKILI; CHAZDON, 2017), affecting recruitment and species composition directly or through the interaction among different factors (DUPUY; CHAZDON, 2008). Establishment and development of new individuals through regeneration can be influenced by the opening of treefall gaps, litter accumulation, luminous incidence and nutrients (DUPUY; CHAZDON, 2008). Research that analyzes the interaction between environmental factors and plant species regeneration is still scarce in the seasonal forests of the Espírito Santo state, despite of being indispensable to provide knowledge about the behavior of populations within plant community (GARCIA *et al*., 2011), what will further provide insights and support decision making concerning actions towards environmental recovery (MARCUZZO; VIEIRA; SALIN, 2020).

Considering the importance of the natural regeneration layer to the plant community during the succession processes, and the relationships of species with environmental variables, the objectives of this study are to (1) describe the structural and floristic parameters of the natural regeneration in a Seasonal Semideciduous Forest and (2) to identify which environmental factors are correlated with the natural regeneration component itself. In order to understand what are the impacts of abiotic variations on the composition and structure of the regenerating layer, we asked: 1) Do richness and diversity vary along in the same remnant? 2) Which abiotic variables that may be affecting the species distribution in remnant?

2 MATERIALS AND METHODS

This study was carried out in Reserva Particular do Patrimônio Natural (RPPN) Cafundó (central point at 20º43' S and 41º13' W), a Protected Area in the Cachoeiro do Itapemirim municipality, south of Espírito Santo State, Brazil (Figure 1), with altimetry varying between 100 to 150 meters and inserted in a Seasonal Semideciduous Forest (IBGE, 2012). The soil of the region, by the Food and Agriculture Organization of the United Nations (FAO) system, is a very deep Typical Ferralsol (CALIMAN *et al*., 2020). According to Koppen classification system, adapted by Alvares *et al*. (2013), the climate of this region is Aw (tropical with dry season in the winter). Mean annual temperature between 12 - 18º C (minimum) and 30 - 34º C (maximum) and the mean annual rainfall is 1,293 mm, with dry season, there is less precipitation, with driest months between June and August (INSTITUTO CAPIXABA DE PESQUISA, ASSISTÊNCIA TÉCNICA E EXTENSÃO RURAL, 2019). This RPPN has a total area of 517 ha (PIROVANI; SILVA; SANTOS, 2015), from which approximately 358 ha were sampled by experimental units of this study. The matrix that surrounds the Reserve has mostly pastures for cattle farming, coffee and sugar cane plantations as its main agricultural activities.

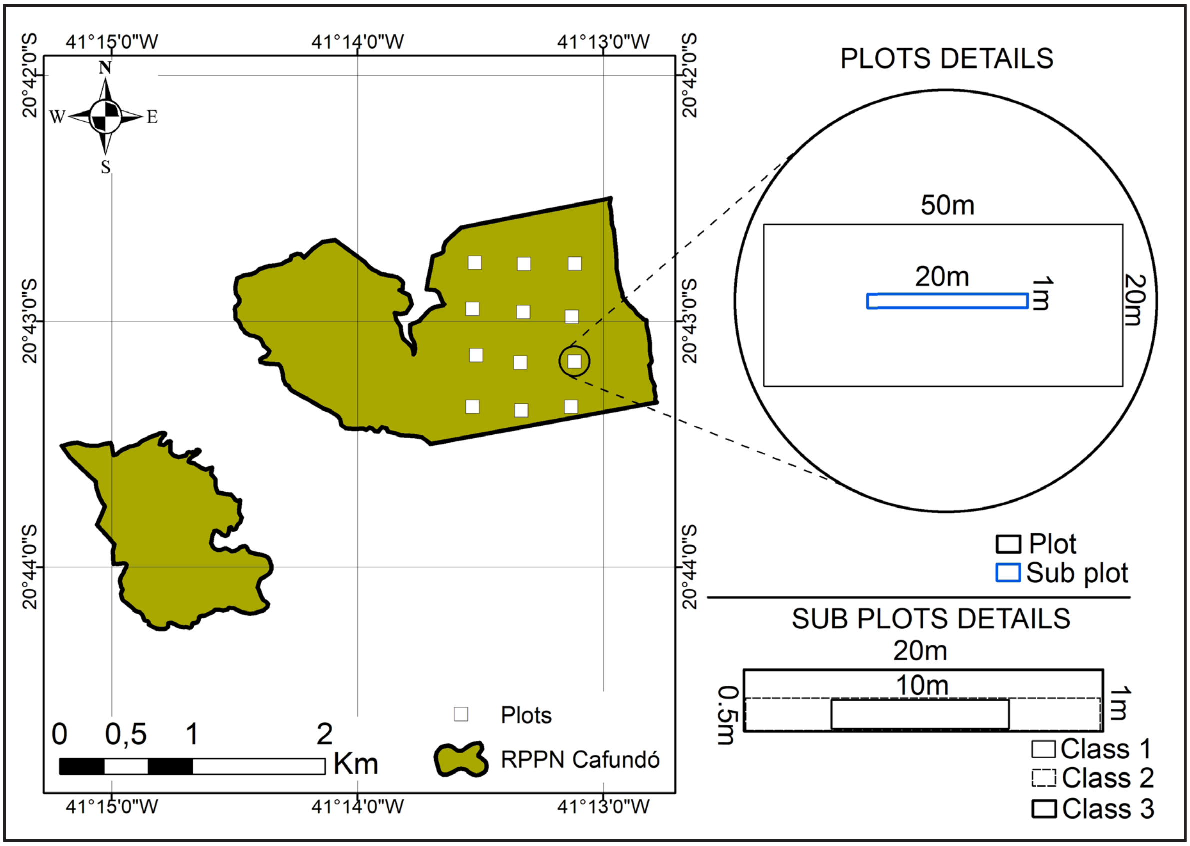
Figure 1 – Location of Cafundó RPPN in south of Espírito Santo State, Brazil



Source: Authors (2018)

From the sample units allocated in this area by Archanjo *et al*. (2012), who investigated tree structure and floristic, we have selected twelve of them to install subplots with dimensions of 1 x 20 m in order to sample natural regeneration (Figure 2). Three size classes of natural regeneration were delimited for shrub-tree individuals in these sample units (subplots). The inventory in which individuals were sampled in Class 1 was internal to Class 2, and this one internal to Class 3. The criteria for sampling and size inclusion of each class was: Class 1 - plants between 0.1 and 1 m high in 0.5 x 10 m plots (5 m²); Class 2 - plants between 1.1 and 3 m high in 0.5 x 20 m plots (10 m²); Class 3 - plants higher than 3 m and less than 5 cm DBH in 1 x 20 m plots (20 m²).

Figure 2 – Spatial distribution of sample units used for sampling shrub-tree layer, showing Class 1 (plants between 0.1 and 1 m high), Class 2 (plants between 1.1 and 3 m high) and Class 3 (plants higher than 3 m and less than 5 cm DBH)



Source: Authors (2018)

Species identification was carried out by consulting scientific botanical collections deposited in herbariums and, when necessary, sent to taxonomic specialists. Collections of botanical material were carried out for all species recorded in the study and voucher specimens were deposited in the VIES and CAP herbarium (acronym according to Thiers – continuously updated), of the Federal University of Espírito Santo. Families were classified according to Angiosperm Phylogeny Group IV (2016) and accepted names, synonymy, and authors were confirmed by reference to Flora do Brasil 2020 (JARDIM BOTÂNICO DO RIO DE JANEIRO, 2020).

Identified species were classified according to pioneer, early secondary and late secondary ecological groups (GANDOLFI; LEITÃO FILHO; BEZERRA, 1995; GARCIA *et al*., 2011; KUNZ; MARTINS, 2014), while their fruit/seed dispersion syndrome, zoochoric, anemochoric and autochoric, was characterized through morphological criteria, proposed by Van Der Pijl (1982).

Shannon's diversity indices (H´), Pielou's equability (J) and Sorensen's similarity coefficient (Sj_{ij}) (MAGURRAN, 2013) were used for data analysis. By estimating the species importance based on plant size classes, natural regeneration phytosociological parameters were calculated through FITOPAC 2 software (SHEPHERD, 2010). The total of phytosociological parameters of the species by size class was used to estimate natural regeneration through the sum of regeneration indices (TNR).

For the analysis of forest soil chemical and physical composition, soil samples were collected in all twelve subplots, at depths of 0 - 20 cm. Soil sampling was carried out systematically, with four collections within each subplot that were mixed to obtain a composite sample. The analysis chemical [potential acidity (H+Al), calcium (Ca), phosphorus (P), magnesium (Mg), organic matter (OM), sodium (Na), aluminum (Al), hydrogen potential (pH), potassium (K), sum of bases (SB), effective cation exchange capacity (t), cation exchange capacity at pH 7,00 (T), percentage of base saturation (V), percentage of saturation by aluminum (m) and carbon (C)] and physical analysis [fine sand (FS), coarse sand (CS), argil (Arg) and silt (S)] were performed, as well soil density and humidity according to Embrapa (2011). The collected soil was packed in plastic bags and subsequently allocated in the soil laboratory of the Department of Forestry and Wood Sciences at the Federal University of Espírito Santo for analysis.

Lemmon densitometer was used to evaluate canopy cover. Four measurements were taken at the center of each subplot in the north, south, east and west directions at 1 m from ground level in days and times nearby. Canopy cover was calculated from the average of two measurements, one in April 2015 and another in September 2015. Subplots altitude and slope were obtained from Gomes Junior *et al*. (2019), who have used the same subplots of the present study.

Three data matrices were elaborated to analyze the interaction between vegetation and environmental variables. One with abundance data, one with soil chemical variables and one with soil physical and environmental variables. Abundance values from all size classes that had at least 10 individuals in the sample constituted the first matrix. The species abundance values (a) were transformed (ln (a + 1)) to compensate possible deviations caused by high values (TER BRAAK, 1987).

Once the number of environmental variables must be less than the number of sites (TER BRAAK, 1987) and since the number of measured variables was higher than the number of subplots, it was necessary to elaborate two matrices of environmental variables in order to perform two CCA (Canonical Correspondence Analysis). Thus the second matrix included all the soil chemical variables while the third received all the soil physical variables, soil humidity and density, percentage of canopy cover and subplots slope as well elevation.

After preliminarily performing the CCA and eliminating all redundant or low correlated variables, data were processed again and the final CCA was composed only by the most representative variables that were strongly correlated with the ordering axes, which were phosphorus, carbon, slope and canopy cover. Thus, two CCA were created, one containing soil chemical variables and the other containing soil physical and environmental variables. Data were processed using CANOCO for Windows 4.5 software and the Monte Carlo permutation test to verify the correlation significance between the groups of environmental and vegetation variables (TER BRAAK, 1987).

3 RESULTS

A total of 678 individuals from the natural regeneration, distributed over 56 species and 18 morphospecies within 24 families were found in the three plant size classes. Euphorbiaceae family was the most representative in abundance, totaling 242 individuals (36%), followed by Fabaceae (13%), Rubiaceae (11%), Rutaceae (10%) and Myrtaceae (5%), totaling 75% of individuals. These families also had the highest species richness: Myrtaceae (19,2%); Fabaceae (12,3%); Rubiaceae (9,6%); Euphorbiaceae and Rutaceae (6,8%). The species with highest number of individuals were *Actinostemon klotzschii* (145), *Goniorrhachis marginata* (66), *Actinostemon verticillatus* (64), *Psychotria carthagenensis* (57), *Conchocarpus ruber* (53), *Piper klotzschianum* (28), which together represented 61% of the total (Table 1).

Table 1 – List of species from the natural regeneration layer sampled in a Submontane Semideciduous Seasonal Forest fragment, in the south of Espírito Santo State

Family	Species	SG	DS	NRi 1	NRi 2	NRi 3	TNRi
Euphorbiaceae	*Actinostemon klotzschii* (Didr.) Pax	Ls	Au	13.1	18.9	14.9	15.7
	Actinostemon verticillatus (Klotzsch) Baill.	Ls	Au	6.1	13.4	11.1	10.2
Rutaceae	*Conchocarpus ruber (A.St.Hil.) Bruniera & Groppo*	Ls	Au	5	10.8	12.1	9.3
Fabaceae	*Goniorrhachis marginata* Taub.	Ls	Au	10.7	6.1	4.9	7.2
Euphorbiaceae	*Actinostemon concolor* (spreng.) Müll.Arg	Ls	Au	1.2	4.4	14.4	6.7
Rubiaceae	*Psychotria carthagenensis* Jacq.	Ls	Zo	10.3	2.4	0	4.2
Moraceae	*Sorocea guilleminiana* Gaudich.	Ls	Zo	2.6	7.4	2.4	4.2
Rhamnaceae	*Sarcomphalus glaziovii (Warm.) Hauenschild*	Ls	Zo	3.3	3.4	0	2.2
Burseraceae	*Protium heptaphyllum* (Aubl.) Marchand	Ls	Zo	0	4.4	1.5	2
Primulaceae	*Clavija spinosa* (Vell.) Mez	Ls	Zo	3.1	2.7	0	1.9
Celastraceae	*Monteverdia ilicifolia* (Mart. ex Reissek) Biral	Ls	Zo	1.7	1	2.4	1.7
Myrtaceae	*Eugenia supraaxillaris* Spring	Ls	Zo	0.6	1.4	2.9	1.6
	Eugenia ligustrina (Sw.) Willd.	Ls	Zo	2.7	0	1.9	1.6
Piperaceae	*Piper klotzschianum* (Kunth) C.DC.	P	Zo	4.3	0	0	1.4
Myrtaceae	*Eugenia excelsa* O. Berg	Ls	Zo	0.6	0	2.9	1.2
Meliaceae	*Trichilia casaretti* C. DC.	Ls	Zo	2.3	1	0	1.1

To be continued ...

Table 1 – Continuation

Family	Species	SG	DS	NRi 1	NRi 2	NRi 3	TNRi
Rutaceae	*Conchocarpus macrophyllus* J. C. Mikan	Ls	Au	1.2	2.1	0	1.1
	Neoraputia alba (Nees & Mart.) Emmerich ex Kallunki	Ls	Au	1.2	2.1	0	1.1
Rubiaceae	*Faramea* sp.	Nc	Zo	2	1	0	1
Malvaceae	*Pterygota brasiliensis* Allemão	Es	An	0	0	2.9	1
Rutaceae	*Esenbeckia grandiflora* Mart.	Ls	Au	0.6	0	2.4	1
Fabaceae	*Deguelia* sp.	Nc	An	1.4	0	1.5	1
	Peltogyne angustiflora Ducke	Ls	An	1.2	0	1.5	0.9
Myrtaceae	*Eugenia pisiformis* Cambess	Ls	Zo	0	1	1.5	0.8
	Eugenia platysema O.Berg	Ls	Zo	0	1	1.5	0.8
Anacardiaceae	*Astronium graveolens* Jacq.	Ls	An	0.7	0	1.5	0.7
Rubiaceae	*Posoqueria latifolia* (Rudge) Schult.	Ls	Zo	1.1	1	0	0.7
Myrtaceae	Myrtaceae sp.1	Nc	Nc	0.6	0	1.5	0.7
	Myrcia eugenioides Cambess.	Es	Zo	0	0	1.9	0.6
Salicaceae	*Casearia arborea* (Rich.) Urb.	Es	Zo	0.8	1	0	0.6
Euphorbiaceae	*Margaritaria nobilis* L.f.	P	Zo	0.8	1	0	0.6
Fabaceae	Fabaceae sp.1	Nc	Nc	1.7	0	0	0.6
	Abarema limae Iganci & M. P. Morim	Ls	Au	0.6	1	0	0.5
Myrtaceae	*Eugenia prasina* O. Berg	Ls	Zo	0.6	1	0	0.5
Rubiaceae	*Ixora brevifolia* Benth.	Ls	Zo	0	0	1.5	0.5
Annonaceae	*Annona acutiflora* Mart.	Ls	Zo	0	0	1.5	0.5
Myrtaceae	*Campomanesia guazumifolia* (Cambess.) O.Berg	Ls	Zo	0	0	1.5	0.5
Lecythidaceae	*Cariniana legalis* (Mart.) Kuntze.	Ls	An	0	0	1.5	0.5
Salicaceae	*Casearia decandra* Jacquin	Ls	Zo	0	0	1.5	0.5
Lauraceae	*Cryptocarya saligna* Mez.	Ls	Zo	0	0	1.5	0.5
Bignoniaceae	*Handroanthus ochraceus* (Cham.) Mattos	Ls	An	0	0	1.5	0.5
	Zeyheria tuberculosa (Vell.) Bureau ex Verl	Es	An	0	0	1.5	0.5
Not identified	Ni 2	Nc	Nc	1.4	0	0	0.5
Annonaceae	*Oxandra espintana* (Spruce ex Benth.) Baill.	Ls	Zo	1.4	0	0	0.5
Bignoniaceae	*Tabebuia roseoalba* (Ridley) Sandwith	Ls	An	1.2	0	0	0.4
Meliaceae	*Trichilia pallens* C. DC.	Es	Zo	1.2	0	0	0.4
Rutaceae	*Conchocarpus* sp.	Nc	Au	1.1	0	0	0.4
Bignoniaceae	Bignoniaceae sp.1	Nc	Nc	0	1	0	0.3
Myrtaceae	*Myrcia neolucida A.R.Lourenço & E.Lucas*	Ls	Zo	0	1	0	0.3
Celastraceae	*Monteverdia cestrifolia* (Reissek) Biral	Ls	Zo	0	1	0	0.3
Sapotaceae	*Chrysophyllum lucentifolium* Cronsquist	Ls	Zo	0	1	0	0.3

To be continued ...

Table 1 – Conclusion

Family	Species	SG	DS	NRi 1	NRi 2	NRi 3	TNRi
Myrtaceae	*Eugenia astringens* Cambess.	Es	Zo	0	1	0	0.3
	Eugenia sp.	Nc	Zo	0	1	0	0.3
Rubiaceae	Rubiaceae sp.1	Nc	Nc	0	1	0	0.3
Siparunaceae	*Siparuna* sp.1	Nc	Zo	0	1	0	0.3
Moraceae	*Sorocea bonplandii* (Baill.) W.C.Burger *et al*.	Ls	Zo	0	1	0	0.3
Siparunaceae	*Siparuna* sp.2	Nc	Zo	0.8	0	0	0.3
Euphorbiaceae	*Croton* sp.	Nc	Au	0.7	0	0	0.2
Not identified	Ni 1	Nc	Nc	0.7	0	0	0.2
Myrtaceae	*Neomitranthes stictophylla (G.M.Barroso & Peixoto) M.C.Souza*	Ls	Zo	0.7	0	0	0.2
Rubiaceae	*Rudgea* sp.	Nc	Zo	0.7	0	0	0.2
Elaeocarpaceae	*Sloanea* sp.	Nc	Zo	0.7	0	0	0.2
Rubiaceae	*Alseis* sp.	Nc	Au	0.6	0	0	0.2
Malpighiaceae	*Byrsonima cacaophila* W.R.Anderson	Ls	Zo	0.6	0	0	0.2
Myrtaceae	*Campomanesia espiritosantensis* Landrum	Ls	Zo	0.6	0	0	0.2
Primulaceae	*Clavija* sp.	Nc	Nc	0.6	0	0	0.2
Fabaceae	*Copaifera trapezifolia* Hayne.	Ls	Zo	0.6	0	0	0.2
	Fabaceae sp.2	Nc	Nc	0.6	0	0	0.2
	Machaerium aculeatum Raddi	Es	An	0.6	0	0	0.2
	Peltophorum dubium Ducke	Es	An	0.6	0	0	0.2
Clusiaceae	*Garcinia gardneriana* (Planch. & Triana) Zappi	Ls	Zo	0.6	0	0	0.2
Meliaceae	*Trichilia hirta* L.	Ls	Zo	0.6	0	0	0.2
	Trichilia tetrapetala C.DC.	Ls	Zo	0.6	0	0	0.2
Rhamnaceae	*Sarcomphalus platyphyllus (Reissek) Hauenschild*	Ls	Zo	0.6	0	0	0.2

Source: Authors (2018)

In where: SG: Successional group; P: Pioneers; Es: Early secondary; Ls: Late secondary; DS: Dispersion syndrome; Zo: Zoochoric; An: Anemochoric; Au: Autochoric; and Nc: Not characterized. Natural Regeneration Index values (NRi) by size class (1, 2 and 3) as well Total Natural Regeneration Index (TNRi), both expressed as percentage (%) and sorted in decreasing order by TNRi.

Considering the three size classes of natural regeneration, from the 74 sampled species and morphospecies, 8 occurred in all classes, 22 in two and 44 in only one of them. Class 1 obtained the highest abundance of regenerating individuals, followed by Classes 2 and 3, respectively. From the 10 species that showed the highest values of total natural regeneration (RNT), six (*Actinostemon klotzschii*, *Actinostemon verticillatus*, *Conchocarpus ruber*, *Goniorrhachis marginata*, *Actinostemon concolor* and *Sorocea guilleminiana*) were present in all size classes with *Actinostemon klotzschii* obtaining the highest values by class. Sorensen's similarity between natural regeneration and the adult tree layer was 29%. Shannon index (H') for the natural regeneration component was 3,13 nats.ind^{-1} while Pielou's equability (J) was 0.72.

The most represented ecological groups in the three size classes were late secondary (62% of sampled species) and pioneer/initial secondary (13%). Zoochory was the predominant dispersion syndrome between species (59%), followed by autochory (16%) and anemochory (13%). The variables that didn't show redundancy in the CCA and obtained a collinearity index higher than 10 were carbon and phosphorus (Table 2) for the chemical variables and slope and canopy coverage for the physical and environment ones (Table 3).

Table 2 – Correlation coefficients between environmental variables and the first two ordering axes found in the natural regeneration

Environmental variables	Correlation		Environmental variables	
	Axis 1	**Axis 2**	**Phosphorus**	**Carbon**
Phosphorus	0.6837	-0.0475	1.000	-
Carbon	-0.1826	0.1545	0.0387	1.000

Source: Authors (2018)

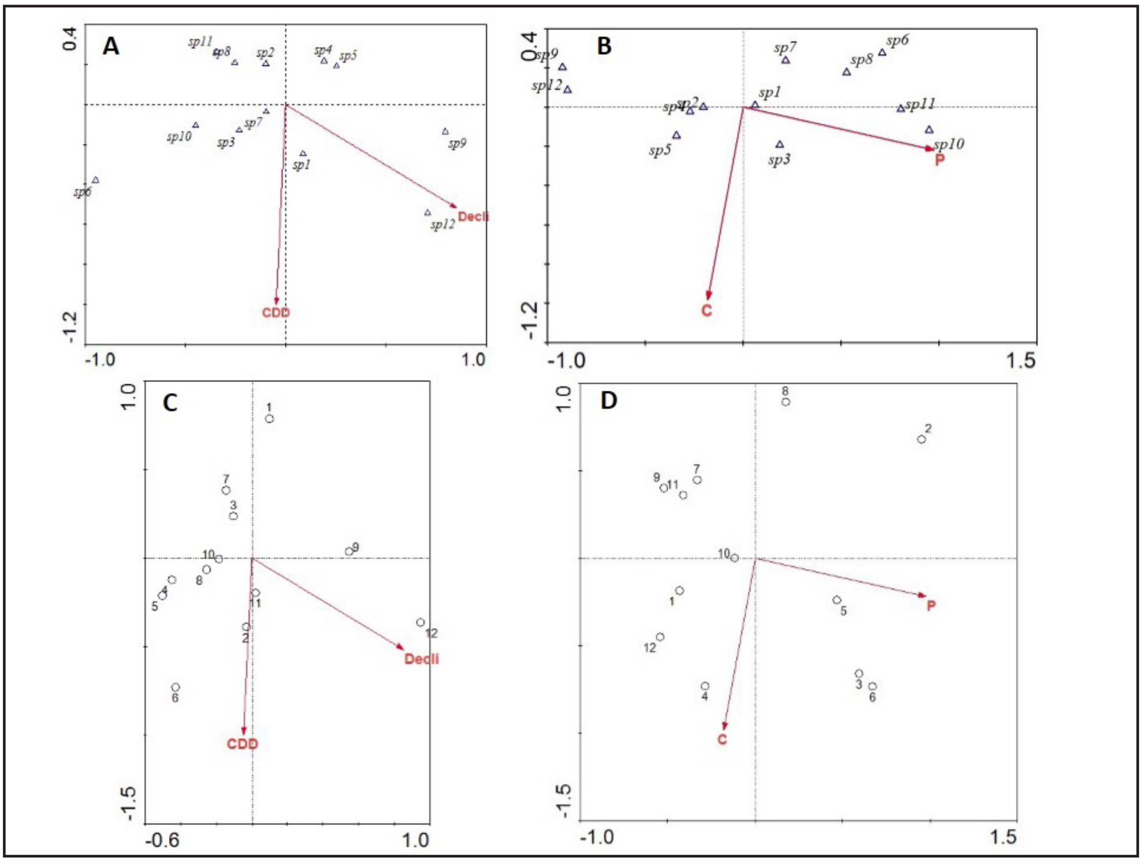
Table 3 – Correlation coefficients between the soil and environment physical variables and the first two ordering axes found in the natural regeneration

Environmental variables	Correlation		Environmental variables	
	Axis 1	**Axis 2**	**Slope**	**Canopy cover**
Slope	-0.5569	-0.1288	1.000	-
Canopy cover	-0.0150	0.1039	0.4674	1.000

Source: Authors (2018)

The physical variables of the soil and the environment that did not show redundancy in the CCA were slope and canopy cover (Figure 3). It is observed that three subplots are correlated with carbon (1, 4 and 12) and three are associated with phosphorus concentration (3, 5 and 6) (Figure 3D). Regarding species ordering, *Clavija spinosa* (sp10), *Actinostemon verticillatus* (sp.3) and *Trichilia casaretti* (sp11) demonstrated a close relationship with phosphorus increase in the soil (Figure 3B). One subplot (9 and 12) had correlation with slope, precisely because they are located close to sloping areas and seven subplots (2, 4, 5, 6, 8 and 10) had between 60 and 76% canopy cover (Figure 3C). *Monteverdia ilicifolia* (sp12) and *Sarcomphalus glaziovii* (sp9) species tended to be more abundant in places that had the highest slopes, *Goniorrhachis marginata* (sp2), *Sorocea guilleminiana* (sp8) and *Trichilia casaretti* (sp11) in flat areas (Figure 3A). Correlations between soil chemical variables and natural regeneration were 0.981 (axis 1) and 0.991 (axis 2), and between the physical variables from soil and environment were 0.941 (axis 1) and 0.948 (axis 2).

Figure 3 – Correspondence analysis (CCA), A and B – 12 most abundant species within area; C and D – subplots; B and D – chemical variables: (P) phosphorus and (C) carbon; A and C – variables canopy coverage (CDD) and slope (Decli), for natural regeneration in the study area



Source: Authors (2018)

In where: sp1: *Actinostemon klotzschii*, sp2: *Goniorrhachis marginata*, sp3: *Actinostemon verticillatus*, sp4: *Psychotria carthagenensis*, sp5: *Conchocarpus ruber*, sp6: *Piper klotzschianum*, sp7: *Actinostemon concolor*, sp8: *Sorocea guilleminiana*, sp9: *Sarcomphalus glaziovii*, sp10: *Clavija spinosa*, sp11: *Trichilia casaretti*, sp12: *Monteverdia ilicifolia.*

.

4 DISCUSSION

Richness and abundance of Myrtaceae and Fabaceae families have been used as important indicators for studies with regenerating layer in seasonal semideciduous forests (GARCIA *et al*., 2011). They have also stood out in Archanjo *et al*. (2012), as the richest families in the adult component of the same fragment. Myrtaceae can indicate diversity and ecological interactions (*e.g.* maintain the synchrony of flowering periods among the species) conservation degree (SMITH-RAMÍREZ; ARMESTO; FIGUEROA, 1998) while some Fabaceae species have the capacity to fix nitrogen from atmosphere and soil, presenting rapid establishment in vegetation cover (ADAMS *et al*., 2016).

Reduction in species richness throughout size classes is a structuring factor for the plant community. Higuchi *et al*. (2015) say that environmental factors that control the density of individuals in communities can act as a filter, reducing the number of species in larger classes. This reduction can be explained by the different life strategies and development capacities of the forest understory species. The species that normally occur in the three size classes of natural regeneration, are those that have the greatest potential for establishment in the forest canopy, presenting populations with permanence for longer periods in the community.

The number of species in the late secondary category shows a potential advance in forest succession in this fragment (KUNZ; MARTINS, 2014). The proportion of pioneer individuals in natural regeneration when compared to adult vegetation (ARCHANJO *et al*., 2012) was low (only 3 species). Canopy cover can act as a filter for regenerating species, making it difficult to establish seedlings of the pioneer category (HIGUCHI *et al*., 2006). The high number of zoochoric species may be related to the contribution of seed rain by the dispersing action of animals from adjacent fragments and being a protected area for biodiversity conservation. Volpato, Miranda Neto and Martins

(2018) say that this flora-fauna interaction is a fundamental process of biodiversity structuration in the Atlantic Forest.

Individuals growth in the regenerating layer may be being influenced by phosphorus, which associated with other macronutrients can promote a better development of young individuals (SANTIAGO *et al*., 2012). Despite being a macronutrient with a low content in the soil fragment (GODINHO *et al*., 2013), phosphorus was significant to explain the distribution and occurrence of the species in this study. According to Godinho *et al*. (2013) the phosphorus availability in Cafundó RPPN was significantly different over the topographic gradient, the lower portion of the fragment had a higher content than the others, which may be due to the accumulation and deposition of organic matter in the higher areas of the slope. This behavior, meets the relationship between plots with the highest correlation with phosphorus and slope, which showed a positive relationship, explaining the distribution of *Clavija spinosa* and *Trichilia casaretti* species, which have a positive correlation with phosphorus and a negative correlation with slope, as well *Sarcomphalus glaziovii* and *Monteverdia ilicifolia*, which presented an inverse correlation to the previous variables.

The clustering of many species in the diagram center can indicate a low influence of environmental variables, that in this study are canopy cover and slope. Probably *Piper klotzschianum*, *Sarcomphalus glaziovii* and *Monteverdia ilicifolia* species, that are distant from the diagram center, had greater abundance in two sample units, whose plots and species showed greater correlation with canopy cover and slope.

Piper klotzschianum and *Actinostemon klotzschii* showed high abundance in the sample units, being distributed in environments with closer canopy while *Goniorrhachis marginata* and *Psychotria carthagenensis* showed an inverse relationship with canopy coverage, being more abundant in subplots with more open canopy. Shading promoted by canopy can be a limiting factor in the establishment and juvenile phase of plant species, once reductions in light intensity can significantly affect the development of natural regeneration. However, some species may have a wide and continuous need for light as juvenile which may be the case for *Goniorrhachis marginata*, a kind of late secondary that occurred in all sample size classes and in more open places.

Some studies use multivariate analyzes to explain the spatial distribution of species abundance based on some environmental variables in order to obtain significant results from the correlation of natural regeneration (AVILA *et al*., 2011; GARCIA *et al*., 2011, VENTUROLI; FELFILI; FAGG, 2011). Studies with natural regeneration for similar phytophysiognomies have shown that the floristic richness can be altered by several factors within a same phytophysiognomy. Among them there is regeneration time, fragment size, number of seedlings present in the area, species recruitment, seed bank in the soil as well nutrients availability through cycling (KUNZ; MARTINS, 2014).

5 CONCLUSION

The studied environmental variables seem to have little influence on the distribution of natural regeneration species in the Cafundó RPPN, once only Carbon, Phosphorus, Declivity and Canopy Cover have explained the species distribution within fragment. *Goniorrhachis marginata* had its distribution correlated with these four environmental variables, followed by *Actinostemon klotzschii* and *Psychotria carthagenensis* with three of them.

However, the observed tendencies in the correlations between distribution natural regeneration species and environmental variables in this forest fragment need further studies in terms of temporal dynamics to better characterize the species in terms of their preferred habitat.

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