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Original Article

Fire effects on Atlantic Forest sites from a composition, structure and functional perspective

Efeitos do fogo na Mata Atlântica por meio de uma abordagem de composição, estrutura e funcional

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Abstract

Recently, some portions of the Atlantic Forest biome have been suffering an increase in forest fires, possibly changing its vegetation cover, composition, structure and functioning. Understanding these changes is critical to evaluate the present and future response of tropical forests to fire. Thus, the purpose of our study was to evaluate how diversity, structure and functioning of tree communities differed between burned and unburned sites. Two unburned and two burned forest patches were selected for floristic and phytosociological surveys. Then, we calculated species richness, Shannon diversity index, tree density and basal area, Importance Value Index for trees in each site and we assessed community weighted mean of six functional traits (maximum tree height, wood density, leaf length, leaf deciduousness, shade tolerance and dispersal mode). Diversity, species richness, tree density and basal area were similar between sites. We found changes in floristic composition, but did not verified variations in functional traits. Results indicate that recovery may be fast and that pioneer and early secondary species are occupying post burned sites (nine years old). One-time anthropogenic, superficial and low intensity fires might disrupt advanced stages of succession and start again the dynamics of species substitution.

Keywords: burning, diversity, flora, functional traits, tropical rainforest.

Resumo

Recentemente, algumas regiões do bioma Mata Atlântica têm sofrido com um aumento de incêndios, possivelmente modificando sua cobertura vegetal, composição, estrutura e funcionalidade. Compreender essas mudanças é imprescindível para avaliar as respostas, no presente e futuro, das florestas tropicais ao fogo. Assim, o objetivo do nosso estudo foi avaliar como a diversidade, estrutura e funcionamento das comunidades arbóreas diferem entre áreas queimadas e não queimadas. Dois fragmentos queimados e dois fragmentos não queimados foram selecionados para os levantamentos florísticos e fitossociológicos. Depois, foram calculadas a riqueza de espécies, o Índice de diversidade de Shannon, densidade da árvore e área basal, Índice de valor de importância para as espécies em cada uma das áreas e avaliamos a média de seis características funcionais (altura máxima da árvore, densidade da madeira, comprimento da folha, deciduidade foliar, tolerância a sombra e síndrome de dispersão). Diversidade, riqueza, densidade e área basal foram similares entre as áreas analisadas. Nós encontramos mudanças na composição florística, mas não foram verificadas variações nas características funcionais. Os resultados indicam que a recuperação pode ser rápida e que espécies pioneiras e secundárias iniciais estão ocupando as áreas queimadas cerca de nove anos depois. Um único incêndio antrópico, superficial e de baixa intensidade, pode interromper estágios avançados de sucessão e iniciar a nova dinâmica de substituição de espécies.

Palavras-chave: queimadas, diversidade, flora, traços funcionais, floresta tropical.

1. Introduction

The Atlantic Forest biome is a biodiversity hotspot (Myers et al., 2000). The biome presents great diversity of habitats, among which evergreen and seasonal forests, mangroves and highland grasslands (IBGE, 2012). Due to intense deforestation and human disturbance that mostly occurred in the first half of the 19th century (Dean, 1996),

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only about 13% of Atlantic Forest biome native vegetation cover remains in Brazil (Fundação SOS Mata Atlântica, 2018). Nature reserves protect only 9% of the remaining forest (Ribeiro et al., 2009). Recently, some portions of the Atlantic Forest biome have been experiencing an increase in area burned by anthropogenic wildfires (INPE, 2021).

Every year, wildfires burn more than 400 million hectares worldwide (Andela et al., 2017) and shape the structure and diversity of all biomes (Bond and Keeley, 2005). Fires in tropical forests generally cause extensive top-kill in small trees (Hoffmann et al., 2009) and leaf-fall in larger trees, allowing increased light to the forest floor and the establishment of grasses, changing the local fire regime (Veldman and Putz, 2011). This results in lowered humidity, increased forest environment dryness, decreased tree cover, and altered species richness (Fu et al., 2013), changing likelihood of recurrent fires. Edge environments are specially more exposed to the action of strong winds, lower humidity, higher air temperatures and to fires (Magnago et al., 2015; Guedes et al., 2020). When subjected to such conditions, non-adapted species can be selectively excluded from the community, generating a drastic change in species composition of the forest environment, which may come to be dominated by few species tolerant to drought and fire conditions (Silvério et al., 2013; Brancalion et al., 2019; Sansevero et al., 2020).

In some forest fragments, these impacts can initiate the process of biotic homogenization and forest secondarization (although both phenomena are independent and happen in different ways: Nobre et al., 1991; Salazar et al., 2007; Nobre and Borma, 2009; Flores et al., 2016; Veldman and Putz, 2011; Staal et al., 2018), i. e. high proportion of species requiring undisturbed forest tend to experience intense degradation of their forest habitats, while secondary forest stands face a form of arrested succession supporting impoverished communities (Jolly et al., 2015; Mata et al., 2022). In general, it is verified higher species richness, diversity and basal area for unburned sites and lowest for recurrent burned areas in Amazon forests (Mena et al., 2020; Prestes et al., 2020).

Species response to fires has been associated with functional traits by different mechanisms, such as bark thickness, wood density and leaf area providing structural protection against fire or related to an avoidance strategy of water loss (Hoffmann et al., 2004; Hoffmann et al., 2009; Armenteras et al., 2021). In addition, in forest areas subject to fire, it would be expected to find a greater number of species with leaf deciduousness (deciduous and semideciduous species), dispersal syndromes by abiotic agents, and shadow intolerance, among other functional traits (Massi et al., 2017).

Despite the importance of the Atlantic Forest and its potential threat to fires, studies on the impacts of disturbances such as fires over these ecosystems are scarce (Guedes et al., 2020; Sansevero et al., 2020; Mata et al., 2022). Thus, the objective of our study is to contribute to filling this knowledge gap by investigating how fire shapes composition, diversity, structure and functioning of the Atlantic Forest. Here, we evaluated the extent to which diversity (richness and Shannon diversity index), structure (tree density, basal area and importance value), and functioning (community weighted mean of five vegetative and one reproductive traits) of tree communities differ between burned and unburned Atlantic Forest sites. Considering fire as an anthropogenic disturbance in humid tropical forests, we predicted that tree density, basal area, richness and diversity would be lower in the burned sites. Additionally, we predict that burned sites would be dominated by species with traits associated with small leaf length, low maximum height and wood density, shade intolerant, leaf deciduousness and abiotic dispersal. Finally, we predicted that the importance value of species of burned sites (higher for pioneer species) would differ from unburned forests (lower for pioneer species).

2. Material and Methods

2.1. Study area

The study was conducted in forest patches in Paraiba do Sul river basin, southeast Brazil (Figure 1 and Supplementary Information 1). The region is located between São Paulo and Rio de Janeiro, both Brazilian biggest cities and with a current population estimated at 2 million inhabitants along the basin (IBGE, 2017). The Paraíba do Sul river basin region has a hilly relief (between 20% to 45% slope: Embrapa, 1979), located between two large mountain ranges, the Serra da Mantiqueira and the Serra do Mar, soil is red-yellow latosol (Brasil, 1960), vegetation is Atlantic Forest biome (transition between evergreen and seasonal forests) and disjoint savanna areas (Radam Brasil, 1983), climate is classified as dry-winter subtropical (Cwa: Alvares et al., 2013), average annual temperature is 21 °C, with a relative humidity of approximately 70% (INPE, 2022), landscape is dominated by pasture, small fragments of secondary forest and silviculture (*Eucalyptus* species: Sapucci et al., 2021).

Historically, sugar cane in the 17h century, coffee in the 19th and urban-industrial expansion along the road-railway axis (1950) gave rise to an anthropogenic landscape (Dean, 1996). Years later, industrial production, especially linked to pulp and paper, and low intensity pasture took over the region land. Since then, the region has become a focus of natural regeneration of the Atlantic Forest, having its vegetation cover increased to more than 35% by 2015 (Numata et al., 2017; Silva et al., 2017). Despite that, deforestation actions, including anthropogenic fires in secondary and regenerating forests, still represent 95% of the damage caused to these environments between the years 2003 and 2021 (INPE, 2021). Furthermore, fire has negative implications for regeneration areas, for restoration projects and for the conservation of remnants (Guedes et al., 2020). We do not have information on fires that occurred in these forests, but tropical rainforests are fire-sensitive ecosystems, where fire is usually superficial and low-intensity, due to humidity, but it may cause extensive damage (Pivello et al., 2021).

2.2. Floristic and phytosociological inventory

Two unburned (U1: Caçapava and U2: Cruzeiro municipality) and two burned (B1 and B2: Caçapava municipality) forest patches were selected for floristic and phytosociological surveys, which we inventoried

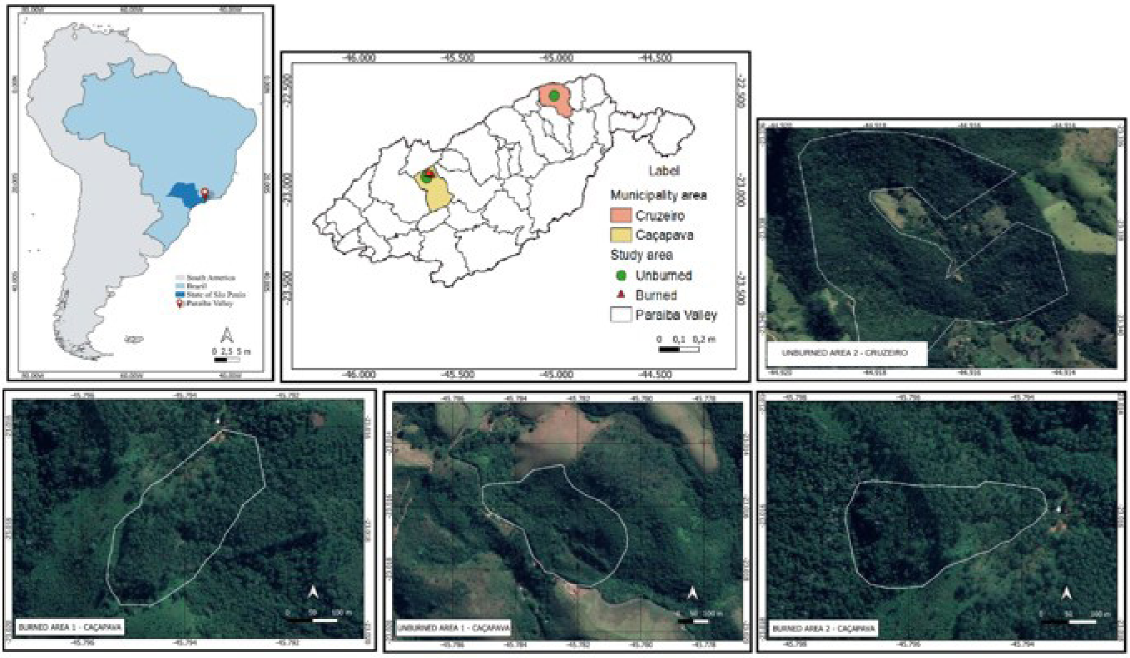

Figure 1. Paraíba do Sul river basin study site, Southeast Atlantic Forest biome, inside São Paulo state, Brazil and South America. Red and blue pins represent burned and unburned forest sites where field inventory was performed, with satellite images of each.

in the beginning of 2021 (U2 was inventoried in 2019; Figure 1 and Table S1: Silva et al., 2021). All patches were located in private properties, but U1 site was also inside a municipal protected area of sustainable use (Área de Proteção Ambiental da Serra do Palmital), covered with plateau evergreen to seasonal tropical rainforest, 20 years without disturbance; U2 was covered by evergreen to seasonal tropical rainforest, with no history of significant disturbance. B1 and B2 sites were located inside the same municipal protected area (Área de Proteção Ambiental da Serra do Palmital), covered with plateau evergreen to seasonal tropical rainforest, which burned in 2012.

Floristic and phytosociological surveys in U1, B1 and B2 were performed using the quadrant point sampling method (Durigan, 2003), with the sampling units being distributed approximately 10 to 30 meters apart, covering the entire study area. U1 had 76 sampled quadrant points; B1, 62; and B2, 50 (forest gaps were avoided). The four individuals closest to the center of the crosshead with stem diameter ≥5 cm at breast height had their species identified and diameter measured. For data collection in U2, we randomly installed 34 plots of 25 x 4 m (100 m^2, plots were distant 100 m from each other) and we identified and measured all individuals with stem diameter ≥ 5 cm at breast height (Silva et al., 2021). Plant material was identified using botanical identification references (Lorenzi, 2016). For plant family classification, we used the Angiosperm Phylogeny Group IV (APG IV, 2016) and the Brazil Flora List (JBRJ, 2020).

2.3. Taxonomic evaluation

For each of the four sites, we calculated the following parameters: species richness, Shannon diversity index ($H' = -\sum pi.lnpi$; being $pi = ni / N$), where ni is number of individuals of a species i and N is the total number of individuals), tree density and basal area. We also determined the Importance Value Index (IVI; Kent, 2012) for trees in each site. By aggregating three important ecological parameters (abundance, dominance and frequency), this index is an indication of which species are ecologically more important in sites with and without fire.

2.4. Functional evaluation

The functional traits considered in this study are related to species strategies to cope with fire (resistance or avoidance) (Cornelissen et al., 2003; Sobral and Cianciaruso, 2012; Massi et al., 2017). These included five vegetative traits: maximum tree height, wood density, leaf length, leaf deciduousness (evergreen and deciduous) and shade tolerance (tolerant and not tolerant) and one reproductive trait: dispersal mode (biotic and abiotic). Successional status of species obtained from Barbosa et al. (2017). The information on species functional traits was obtained from data compilation (JBRJ, 2020). Finally, we calculated community weighted mean (CWM: Garnier et al., 2004) trait values, weighted by species abundance (CWM height, CWM leaf length, CWM wood density, CWM deciduousness, CWM dispersal mode, CWM shade tolerance).

2.5. Data analysis

To evaluate whether species richness, diversity, tree density and basal area (by area: m^2/ha) and CWM values of traits differed between the burned and unburned sites, we used T test. Analyzes were performed in R version 3.6.3 (R Core Team, 2019).

3. Results

3.1. Forest structure and composition

The four studied communities were characterized by distinctive plant communities as shown in Table 1 (richness of U1 and U2 were 20 and 47; while B1 and B2 were, 16 and 17). Only a few species were common to burned and unburned forest sites: *Casearia sylvestris* Sw., *Cecropia pachystachya* Trécul, *Cedrela fissilis* Vell., *Euterpe edulis* Mart., *Piptadenia gonoacantha* (Mart.) J.F.Macbr. and *Pleroma granulosum* (Desr.) D. Don. Despite that, *C. fissilis*, *E. edulis* and *P. gonoacantha* had higher IVI on unburned sites; while *C. pachystachya* and *P. granulosum* had higher IVI on burned sites (Table 1: *C. sylvestris* was found equally in burned and unburned sites). Fifty-eight species were exclusive to unburned sites (mostly late secondary species) and ten to burned ones (Table 1). *Schizolobium parahyba* (Vell.) Blake (IVI = 14.17) and *L. grandiflora* (IVI = 34.88) dominated unburned sites 1 and 2, respectively while *X. aromatica* (IVI = 34.93) and *C. pachystachya* (IVI = 14.30) dominated burned sites 1 and 2, respectively (Table 1).

3.2. Taxonomic and functional evaluation

Richness and Shannon diversity did not differ between burned and unburned sites among burned and unburned sites (Table 2 and Figures 2A and C). Tree density and Basal area were not significantly different between burned and unburned sites (Table 2 and Figures 2B and D).

Regarding the functional composition metrics for vegetative traits, species of burned sites had the same maximum height, leaf length and wood density compared to unburned sites nine years ago (Table 2 and Figures 2E to G). CWM deciduousness was higher in burned areas, representing a higher proportion of evergreen individuals in burned and a higher percentage of deciduous individuals in unburned areas (Table 2 and Figures 2H). CWM shade tolerance and CWM dispersal mode did not differ between burned and unburned communities (Table 2 and and Figures 2I and J).

4. Discussion

We examined how forest structure, taxonomic diversity and functional composition, differ between the tree component of burned and unburned Atlantic Forest sites. Diversity, species richness, tree density and basal area were similar between fire regimes. We found changes in floristic composition (as shown by IVI), but not significant shifts in functional composition between fire regimes (except for leaf deciduousness). The results of field data indicates that forest recovery was very fast and that in nine years after fire functional changes are not perceived. Results might also indicate that fire intensity was not strong enough to make substantial damage.

We found 58 and 10 species exclusive to unburned and burned sites, respectively, indicating two different plant communities according to fire regime, as verified by Ribeiro et al. (2019) for savanna ecosystems. Only a few species (six) were common between burned and unburned fragments, but with dissimilar IVI. *C. pachystachya* and *T. granulosa*, which showed higher

Table 1. Family, species and Importance Value index (IVI, %) in unburned (U1 and U2) and burned (B1 and B2) forest patches in Paraíba do Sul river basin, Southeast Atlantic Forest biome, Brazil.

Family	Species	U1	U2	B1	B2
Anacardiaceae	*Schinus terebinthifolia* Raddi			1.05	2.51
Annonaceae	*Guatteria australis* A.St.-Hil.		0.71		
Apocynaceae	*Xylopia aromatica* (Lam.) Mart.			34.93	5.81
	Aspidosperma discolor var. parvifolium Müll.Arg.		0.81		
	Tabernaemontana hystrix Steud.		3.28		
Arecaceae	*Astrocaryum aculeatissimum* (Schott) Burret	2.62			
	Euterpe edulis Mart.	8.15	8.58	0.91	1.32
	Syagrus romanzoffiana (Cham.) Glassman	2.68	4.82		
Bignoniaceae	*Sparattosperma leucanthum* (Vell.) K.Schum.		8.63		
	Zeyheria tuberculosa (Vell.) Bureau ex Verl.		1.40		
Boraginaceae	*Cordia trichotoma* (Vell.) Arráb. ex Steud		1.66		
Cannabaceae	*Trema micrantha* (L.) Blume		2.35	4.2	
Dicksoniaceae	*Dicksonia sellowiana* Hook	3.75		0.89	1.53
Euphorbiaceae	*Alchornea glandulosa* Poepp. & Endl.		0.77		
	Croton floribundus Spreng.		1.71		
	Croton urucurana Baill.		1.60		
	Sapium glandulatum (Vell.) Pax		2.67		

Table 1. Continued...

Family	Species	U1	U2	B1	B2
Fabaceae	*Acacia plumosa* Mart. ex Colla			4.55	
	Albizia niopoides (Spruce ex Benth.) Burkart			5.45	3.33
	Anadenanthera colubrina (Vell.) Brenan	5.42			
	Anadenanthera peregrina (L.) Speg.		3.19		
	Bauhinia forficata Link		7.19		
	Dalbergia nigra (Vell.) Allemão ex Benth.		12.04		
	Erythrina verna Vell.		1.58		
	Inga marginata Willd.	1.02			
	Inga sessilis (Vell.) Mart.		2.66		
	Inga striata Benth.		2.03		
	Inga uruguensis Hook. & Arn.	2.36			
	Leucochloron incuriale (Vell.) Barneby & J.W.Grimes		1.72		
	Libidibia ferrea (Mart. ex Tul.) L.P.Queiroz	3.52			
	Machaerium hirtum (Vell.) Stellfeld		6.10		
	Machaerium nyctitans (Vell.) Benth.		18.21		
	Machaerium stipitatum Vogel		7.30	3.59	5.27
	Machaerium villosum Vogel	3.65			
	Paubrasilia echinata (Lam.) Gagnon. H.C.Lima & G.P.Lewis	1.53			
	Piptadenia gonoacantha (Mart.) J.F.Macbr.	5.60	26.14	3.26	3.03
	Platypodium elegans Vogel		8.41		
	Pterogyne nitens Tul.				4.81
	Senna macranthera (DC. Ex Collad.) H.S.Irwin & Barneby		1.50		
	Schizolobium parahyba (Vell.) Blake	14.17		2.83	8.31
	Aegiphila integrifolia (Jacq.) Moldenke		0.73		
	Vitex polygama Cham.		1.79		
Lauraceae	*Endlicheria paniculata* (Spreng.) J.F.Macbr.		0.94		
	Nectandra oppositifolia Nees		10.00		
	Ocotea velutina (Nees) Rohwer	6.51	1.63		
Lecythidaceae	*Cariniana estrellensis* (Raddi) Kuntze	1.90			
Malvaceae	*Apeiba tibourbou* Aubl.		1.94		
	Ceiba speciosa (A.St.-Hil.) Ravenna	7.95	1.12		
	Guazuma ulmifolia Lam.			5.00	6.70
	Luehea divaricata Mart.	4.97			
	Luehea grandiflora Mart. & Zucc.		34.88		
	Pseudobombax grandiflorum (Cav.) A.Robyns		0.99		
Melastomataceae	*Miconia cabucu* Hoehne			4.13	7.75
	Miconia cinnamomifolia (DC.) Naudin		2.43		
	Miconia sellowiana Naudin		0.71		
	Pleroma granulosum (Desr.) D. Don	4.16	5.72	7.39	12.53
	Pleroma mutabile (Vell.) Triana			2.9	2.06
Meliaceae	*Cabralea canjerana* (Vell.) Mart.		1.98		
	Cedrela fissilis Vell.	4.50	2.20	0.91	1.57
	Guarea kunthiana A.Juss.		16.14		

Table 1. Continued...

Family	Species	U1	U2	B1	B2
Moraceae	*Ficus adhatodifolia* Schott in Spreng.		0.98		
	Maclura tinctoria (L.) D.Don ex Steud.		2.52		
Myrtaceae	*Myrcia splendens* (Sw.) DC.		12.40		
	Pimenta pseudocaryophyllus (Gomes) Landrum		0.96		
	Psidium sartorianum (O.Berg) Nied.	2.71			
Phytolaccaceae	*Gallesia integrifolia* (Spreng.) Harms	1.85			
Primulaceae	*Myrsine coriacea* (Sw.) R.Br. ex Roem. & Schult.			3.40	5.70
	Myrsine gardneriana A.DC.			3.37	7.22
	Randia armata (Sw.) DC.		1.51		
Rutaceae	*Zanthoxylum rhoifolium* Lam.	2.53	3.45		1.84
Salicaceae	*Casearia decandra* Jacq.		1.39		
	Casearia sylvestris Sw.	3.30	21.98	2.03	4.41
Sapindaceae	*Cupania racemosa* (Vell.) Radlk.		1.21		
	Cupania vernalis Cambess.		6.47		
Siparunaceae	*Siparuna guianensis* Aubl.		12.48		
Cecropiaceae	*Cecropia glaziovii* Snethl.		1.19		
	Cecropia hololeuca Miq.	1.37			
	Cecropia pachystachya Trécul	3.78	2.59	9.21	14.30
Vochysiaceae	*Vochysia tucanorum* Mart.		0.67		

Table 2. Mean values and standard deviations, differences between burned and unburned sites and results of T tests and p-value of the taxonomic and structure variables and the community-weighted mean (CWM) of vegetative and reproductive traits in the four sites (two unburned and two burned).

Variables	Burned	Unburned	(B-U)/U %	T	p-value
Richness	16.5 ± 0.7	33.5 ± 19.1	-50.7	1.258	0.427
Shannon	2.6 ± 0.0	2.9 ± 0.1	-10.3	-0.122	0.919
Density	1563.4 ± 56.8	1754.1 ± 983.3	-10.9	5.689	0.108
Basal area	8.1 ± 8.9	7.3 ± 3.2	9.9	0.274	0.830
CWM height	14.9 ± 0.1	20.9 ± 3.0	-28.7	2.872	0.213
CWM leaf length	22.9 ± 3.6	16.4 ± 5.7	28.4	-1.354	0.329
CWM wood density	0.6 ± 0.0	0.6 ± 0.1	0	-0.135	0.915
CWM deciduousness	0.5 ± 0.0	0.3 ± 0.0	66.7	-6.132	**0.044**
CWM dispersal mode	0.4 ± 0.0	0.3 ± 0.1	33.3	-2.150	0.213
CWM shade tolerance	0.2 ± 0.0	0.3 ± 0.1	-33.3	3.572	0.174

B = burned site; U = unburned site in Paraíba do Sul river basin, Southeast Atlantic Forest biome, Brazil. Data were averaged between the two sites per fire regime. Values in bold indicate statistical differences ($p < 0.05$) between sites.

IVI in burnt sites, are early successional species (São Paulo, 1994). On the other side *C. fissilis* and *E. edulis*, that had higher IVI on unburned sites, are late successional species. In fact, most species of the burned patches were pioneers and early secondary, while most species of unburned sites were mid to late secondary (Barbosa et al., 2017). The same results were found in burned tropical forests in the Atlantic Forest Biome in Rio de Janeiro (Sansevero et al., 2020).

We hypothesized that tree density, basal area, species richness and diversity would be lower in the burned sites compared to unburned ones. Indeed, diversity was 10% lower in burned sites, but no significant differences were found for richness, tree density and basal area. Studies have verified highest species richness, diversity and basal area for unburned sites and lowest for recurrent burned areas (Mena et al., 2020; Prestes et al., 2020). Fires generally cause high tree mortality, may locally extinguish fire-sensitive

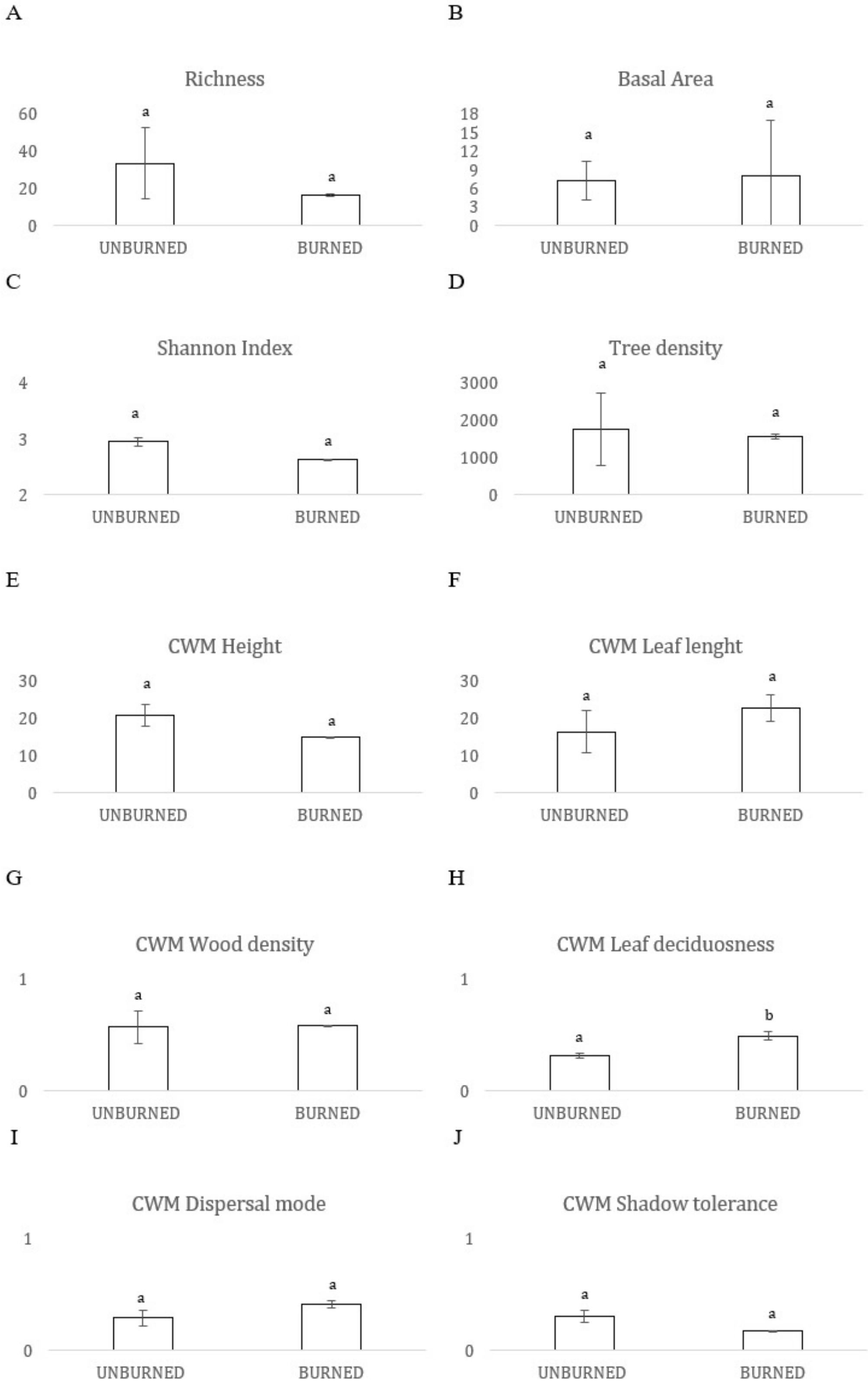

Figure 2. Average of species richness (A), basal area (B), Shannon index (C), tree density (D), CWM Height (E), CWM Leaf length (F), CWM wood density (G), CWM Leaf deciduousness (H), CWM dispersal mode (I), CWM shade tolerance (J) for tree species inventoried in burned and unburned sites in Paraíba do Sul river basin, Southeast Atlantic Forest biome, Brazil. Same letters represent no statistical difference.

species (Hoffmann and Solbrig, 2003; Leblanc et al., 2005) and cause arrested succession in communities subjected to recurrent fires. However, one-time fires, as other small-intensity disturbances in tropical forests, might disrupt advanced stages of succession and start the dynamics of species substitution (as verified for some sites in the Amazon basin: Massi et al., 2017). In addition, fire in these forests could induce sprouting of fire-resistant species trunks and roots. Genera such as *Cecropia*, *Trema*, *Croton*, *Solanum* and *Piper,* mostly pioneers, found in the present study, especially in burned sites, are known by the ability of rapidly establishing and occupying habitats in natural dynamics of regeneration (Gómez-Pompa, 1971; Whitmore, 1989). Nevertheless, this potential resilience should be evaluated with care, e.g. long-term studies, more inventoried burnt sites and evaluating pre-fire conditions of forest remnants are crucial (Andrade et al., 2020).

Additionally, we predicted that burned sites would be dominated by species with vegetative traits associated with high light incidence (small leaf length, low maximum height and wood density and less shade tolerant species) and strategies of leaf deciduousness that represent water economy (more deciduous and semideciduous species) and with reproductive traits associated to abiotic agents to seed dispersal. Contrary to our expectations functional traits were not different according to burning influence. Nine years after fires, succession might be driving burned sites to an early secondary stage, making differences with late secondary stage studied areas (with 20 and 45 years old) subtle. The presence of more deciduous trees was also expected to be higher in burned sites, but we found the opposite, which can be explained by the fact that most evergreen species were short life cycle pioneers occupying the burnt communities.

Finally, we did not evaluate the presence of invasive species inside burned sites, but *Pteridium ssp.* was abundant in these areas. They vigorously regrow after fire and are favored by increased light (Castellani and Stubblebine, 1993). This study evaluated composition, structure and functional impacts of fire on forest patches in the Atlantic Forest biome. The Atlantic Forest is an important focus of conservation and restoration at a global level (Brancalion et al., 2019) and an understanding of the susceptibility and responses of this biome to fire, especially within the context of current fragmentation and future climate change (Scarano and Ceotto, 2015), are important for the success of its conservation and restoration efforts (Guedes et al., 2020).

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Supplementary Material

Supplementary material accompanies this paper.

Table S1. Characterization of the study areas where field inventory was performed, Paraíba do Sul river basin, Southeast Atlantic Forest biome, Brazil.

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