SPACE-TEMPORAL DYNAMICS OF ENDEMIC TREE SPECIES IN SECONDARY FOREST IN THE ATLANTIC FOREST DOMAIN IN BRAZIL

Ana Laura da Silva Luz[2*], Maria das Graças Ferreira Reis[3], Geraldo Gonçalves dos Reis[3], Margarete Marin Lordelo Volpato[4], Jônio Pizzol Caliman[2], Cátia Cardoso da Silva[2] and Rennan Salviano Terto[2]

[1] Received on 06.01.2023 accepted for publication on 01.08.2023.
[2] Universidade Federal de Viçosa, Programa de Pós-Graduação em Ciência Florestal, Viçosa, MG - Brasil. E-mail: <ana_lauraluz@hotmail.com> , <catia.cardoso@ufv.br> , <rennan.terto@ufv.br> and <jpcaliman@gmail.com>.
[3] Universidade Federal de Viçosa, Departamento de Engenharia Florestal, Viçosa, MG - Brasil. E-mail: <mgfreis@ufv.br> and <greis@ufv.br>.
[4] Empresa de Pesquisa Agropecuária de Minas Gerais, Lavras, MG - Brasil. E-mail: <margovolpato@gmail.com>.
*Corresponding author.

ABSTRACT – Understanding the dynamics of endemic tree component species based on natural regeneration (NR) and adult trees (AT) is essential for formulating conservation strategies for protecting these species. The objective of the present study was to identify endemic species in a preserved area of secondary forest in the Atlantic Forest domain in Brazil and to evaluate their dynamics over 24 years. Based on inventories carried out from 1992 to 2016 of the NR (diameter at breast height - $dbh \leq 5$ cm) and of the AT ($dbh \geq 5$ cm) in ten sites with different characteristics (physiographic, edaphic, and successional), it was possible to, initially, identify 58 species classified as endemic to Brazil (EBR) and/or those exclusive to the Brazilian Atlantic Forest (EAF), among the 226 species in the entire survey. Subsequently, this classification was reassessed based on updated information on its occurrence, and only 38 of these species were maintained as endemic to Brazil and/or to the Atlantic Forest. Some species were recorded in the AT and NR strata, in different sites, throughout the study period, while others occurred in only one level (AT or NR), some with low abundance. Among these endemic species, eight are included in the endangered species lists, and 15 can be classified as rare, as there was only one individual in the survey. Considering the two arboreal strata it was observed that some species were abundant in the forest in all inventories and several sites, while others went throughout the study period with few individuals and, in some cases, disappeared due to mortality. These results contribute to understanding the factors that can affect the local abundance of endemic species over time, allowing the definition of conservation actions for protecting these vulnerable species, thus avoiding their extinction.

Keywords: Vulnerability of tree species; Species distribution; Forest conservation.

DINÂMICA ESPAÇO-TEMPORAL DE ESPÉCIES ARBÓREAS ENDÊMICAS EM FLORESTA SECUNDÁRIA NO DOMÍNIO DA MATA ATLÂNTICA, NO BRASIL

RESUMO – A compreensão da dinâmica das espécies endêmicas do componente arbóreo, com base na regeneração natural (RN) e nas árvores adultas (AA) é fundamental para a formulação de estratégias de conservação dessas espécies. O objetivo do presente estudo foi identificar as espécies endêmicas em uma área preservada de floresta secundária, no domínio da Mata Atlântica, no Brasil, e avaliar sua dinâmica ao longo de 24 anos. Com base em inventários realizados de 1992 a 2016 da RN (diâmetro à altura do peito - ***dap*** $\leq$ 5cm) e das AA (***dap*** $\geq$ 5 cm), em dez locais com diferentes características (fisiográficas, edáficas e sucessionais), foi possível identificar 58 espécies classificadas como endêmicas do Brasil e/ou àquelas exclusivas da Mata Atlântica brasileira, dentre as 226 espécies de todo o levantamento. Posteriormente, essa classificação foi reavaliada a partir de informações atualizadas de sua ocorrência, sendo que apenas 38 dessas espécies permaneceram como endêmicas do Brasil e/ou da Mata Atlântica. Algumas espécies foram registradas na AA e na RN, em diversos locais, em todo o período do estudo, enquanto outras ocorreram em apenas um nível (AA ou RN), inclusive

com baixa abundância. Dentre essas espécies endêmicas, oito estão incluídas em listas de espécies ameaçadas de extinção e 15 podem ser classificadas como raras (apresentaram apenas um indivíduo). Considerando os dois estratos arbóreos, foi observado que algumas espécies permaneceram na floresta em todos os inventários, enquanto outras ingressaram ao longo do período do estudo, com poucos indivíduos, inclusive com elevada mortalidade, deixando de ocorrer na área. Esses resultados contribuem para o entendimento dos fatores que podem afetar a abundância local de espécies endêmicas ao longo do tempo, permitindo a definição de ações de conservação para proteger essas espécies vulneráveis, evitando assim, a sua extinção.

Palavras-Chave: Vulnerabilidade de espécies arbóreas; Distribuição de espécies; Conservação de florestas.

1. INTRODUTION

The Atlantic Forest has geographic and climatic characteristics that result in high species richness, with a high degree of endemism (Myers et al., 2000). In Brazil, the occurrence of at least 3,922 endemic tree species is recognized, with 60% (2,357 species) occurring in the phytogeographic domain of the Atlantic Forest (Flora e Funga do Brasil, 2023).

Species endemism is related to the distribution of taxa with exclusive natural occurrence (Işik, 2011). The identification of endemic species and the understanding of distribution patterns are influenced by historical, ecological and evolutionary information about the species, supporting the assessment of the risk of extinction, recovery planning, management and monitoring of species, which allows the achievement of goals of nature conservation strategies (Işik, 2011; Gallagher et al., 2020).

Studies that assess the dynamics of endemic populations favor the understanding of the ecological mechanisms that cause species specificity, especially when considering differences in local habitat, management history and landscape context (Santos et al., 2021). In addition, more careful assessments that consider the dynamics, structure, size, fluctuations and threats of the population are more useful than superficial assessments and are essential for defining well-founded conservation strategies (Kamino et al., 2012; Kougioumoutzis et al., 2021). Most studies used to identify the endemism of a species consist of listings based on inventories carried out on a single occasion (Stehmann et al., 2009; Rocha et al., 2017; Lima et al., 2020) and, also, they do not consider population dynamics in different plant size classes (natural regeneration and adult trees).

In the present study, we sought to identify species endemic to Brazil and/or those exclusive to the Brazilian Atlantic Forest and to evaluate their dynamics based on inventories carried out over 24 years, in different environmental conditions, considering the adult trees and natural regeneration of the tree component, in a preserved secondary forest, in the Atlantic Forest domain.

2. MATERIAL AND METHODS

The study was carried out in the municipality of Viçosa, Minas Gerais (20º48'06"S and 42º51'33"W) in a preserved area of secondary Montana Seasonal Forest, in the domain of the Atlantic Forest. The area is considered the largest forest fragment in the municipality, consisting of 194 ha. Anthropogenic interventions of selective removal of wood and partial deforestation of vegetation for the implantation of agricultural crops and pastures were carried out in the area, however, it remains preserved since 1960 (Garcia et al., 2011). The region's climate is classified as CWa, with rainfall unevenly distributed throughout the year, hot rainy summers and dry winters. The average annual precipitation is 1,319 mm, with an annual average maximum and minimum temperature of 26.8 and 15.7 °C, respectively (Sanches et al., 2017).

Phytosociological studies were carried out over 24 years, between 1992 and 2016, in ten sites with differences in physiographic, edaphic (especially fertility) and successional aspects (Table 1), considering, separately, the Adult Trees (AT) and the Natural Regeneration (NR) of the tree component.

The survey of tree species in the AT, with *dbh* greater than 5 cm, in each site, was carried out in six contiguous sampling units of 10 x 20 m, in an area of 20 x 60 m, totaling 60 permanent samples units in the ten study sites, in the inventories years of 1992, 1995, 1998, 2001, 2004, 2007, 2012 and 2016. In the center of the sampling units of 10 x 20 m, inventories of the NR were carried out in plots of 1 x 20 m, considering

Table 1 – Aspect (Asp), topographic position (TP), slope (S), leaf area index (LAI), photosynthetically active radiation transmittance (t%),classification according to succession stage (Suc) and fertility (Fert) per site; average number of species (N1), average number of individuals (N2) and average Shannon-Wiener diversity index (H') from inventories, per site, in an area of secondary Montana Seasonal Forest of Atlantic Forest, in Viçosa, Minas Gerais.

***Tabela 1** – Exposição (Asp), posição topográfica (TP), declividade (S), índice de área foliar (LAI), transmitância de radiação fotossinteticamente ativa (t%), classificação de acordo com estágio de sucessão (Suc) e fertilidade (Fert) por local; número médio de espécies (N1), número médio de indivíduos (N2) e Índice médio de diversidade de Shannon-Wiener (H') dos inventários, por local, em área de Floresta Estacional Semidecidual Montana secundária da Mata Atlântica, em Viçosa, Minas Gerais.*

Site	Asp[1]	TP[1]	S (%)[1]	LAI[2]	t%[2]	Suc[3]	Fert[3]	N1	N2	H'
1	NE	UT	40	3,6	8,9	FIS	mf	27	150	2,65
2	NE	HS	21	4,5	6,0	FIS	mf	35	210	2,71
3	NE	LT	43	4,9	2,7	FIS	lf	53	250	3,31
4	NE	HS	80	3,6	9,3	FIS	lf	47	190	3,23
5	-	L	3	5,2	1,7	FAS	hf	48	269	3,15
6	SW	LT	51	5,0	1,8	FAS	af	57	293	3,32
7	SW	HS	45	5,2	1,6	FIS	lf	59	199	3,60
8	SW	HS	20	4,2	3,7	FIS	mf	50	244	3,31
9	SW	LT	14	5,1	2,8	FIS	mf	38	197	2,61
10	SW	UT	45	4,3	2,5	FIS	lf	53	212	3,23

Source: [1]Fernandes (1998), [2]Pezzopane et al. (2018) and [3]Caliman (2015). NE = northeast; SW = southwest; L = lowland; LT= lower third; HS = half slope; UT = upper third. [3]Succession stage and soil fertility levels at a depth of 0-20 cm, where: FIS = Forest in intermediate stage of succession; FAS = Forest in more advanced stage of succession, hf = high fertility, mf = medium fertility, lf = low fertility.

Fonte: [1]Fernandes (1998), [2]Pezzopane et al. (2018) e [3]Caliman (2015). NE = nordeste; SW = sudoeste; L = baixada; LT= terço inferior; HS = meia encosta; UT = terço superior. [3]Estágio de sucessão e níveis de fertilidade do solo na profundidade de 0-20 cm, em que: FIS = Floresta em estágio intermediário de sucessão; FAS = Floresta em estágio mais avançado de sucessão, hf = alta fertilidade, mf = média fertilidade, lf = baixa fertilidade.

three classes of height (*h*): plants with h greater than 3 m and *dbh* smaller than 5 cm (Class 3), plants with *h* between 1 and 3 m (Class 2) and plants with *h* lower than 1 m (Class 1). The NR inventories were carried out in the years of 1992, 1995, 2000, 2008 and 2013. The partial results of these AT and NR inventories, with all species, were published by Volpato (1994); Fernandes (1998), Silva et al. (2004), Pezzopane (2001), Pezzopane et al. (2018), Higuchi et al. (2006), Garcia et al. (2011), Souza (2015), Caliman (2015; 2019) and Caliman et al. (2020).

Endemic species were identified by two endemism criteria, based on Rocha et al. (2017): species endemic to Brazil (Flora e Funga do Brasil, 2023) and endemic to the Atlantic Forest (Stehmann et al., 2009; Lima et al., 2020). Information on the distribution of species available in the Tropics (Tropicos, 2023) was obtained in the "distribution" section, to identify the area of occurrence of the species and confirm the endemism information. Occurrence information contained in SpeciesLink (2023) was also used to complement the distribution information with constantly updated data.

After filtering the species confirmed as endemic to Brazil and/or to the Atlantic Forest, information on ecological groups (Pioneer – P; Initical Secondary – IS; Late Secondary, LS and, climax – CL) was included for each species and, abundance (number of individuals per site and year of inventory) was included for the tree component in the NR (in three classes of plant height), and in the AT, according to data obtained in inventories from 1992 to 2016, to better understand the dynamics of these species and, which helps the management decision, aiming at their conservation.

3. RESULTS

The general listing of species identified in inventories from 1992 to 2016 resulted in 226 species, of which 58 species are listed as endemic to Brazil (EBR) and/or to the Atlantic Forest (EAF), based on the classification of endemism presented in Flora e Funga do Brasil (2023). When analyzing species distribution information in the Tropicos (2023), it was found that 14 species are distributed in other countries: *Aniba firmula* (Nees & Mart.) Mez (Lauraceae), *Aspidosperma olivaceum* Müll.Arg., *A. parvifolium* A.DC. (Apocynaceae), *Casearia ulmifolia* Vahl ex Vent. (Salicaceae), *Carpotroche brasiliensis* (Raddi) A.Gray (Achariaceae), *Eugenia brasiliensis* Lam. (Myrtaceae), *Jacaranda macrantha* Cham., *J. puberula* Cham. (Bignoniaceae), *Pseudopiptadenia contorta* (DC.) G.P.Lewis & M.P.Lima, *Stryphnodendron polyphyllum* Mart. (Fabaceae), *Solanum argenteum* Dunal (Solanaceae), *Sorocea guilleminiana* Gaudich. (Moraceae), *Tovomita glazioviana* Engl. (Clusiaceae) and *Xylopia brasiliensis* Spreng. (Annonaceae).

Also, six species considered endemic, according to Flora e Funga do Brasil (2023), had reports of occurrence in other countries according to Species Link (2023) and were also excluded from the endemic list, namely: *Lacistema pubescens* Mart. (Lacistemataceae), *Eriotheca candolleana* (K.Schum.) A.Robyns (Malvaceae), *Miconia cinnamomifolia* (DC.) Naudin, *M. latecrenata* (DC.) Naudin (Melastomataceae), *Ouratea polygyna* Engl. (Ochnaceae) and *Picramnia glazioviana* Engl. (Picramniaceae).

Table 2 – Tree species in inventories from 1992 to 2016 (tree adults and natural regeneration), classified as Endemic to Brazil (EBR) and Endemic to the Atlantic Forest (EAF) and final classification (FC), in area of secondary Montana Seasonal Forest of the Atlantic Forest, Viçosa, Minas Gerais.

Tabela 2 *– Espécies arbóreas em inventários de 1992 a 2016 (árvores adultas e regeneração natural), classificadas como Endêmicas do Brasil (EBR) e Endêmicas da Mata Atlântica (EAF) e classificação final (FC), em área de Floresta Estacional Semidecidual Montana secundária da Mata Atlântica, Viçosa, Minas Gerais.*

Family	Cientific Name	EBR			EAF		FC
		1	2	3	4	5	
Annonaceae	*Guatteria australis* A.St.-Hil.	Y	Y	Y	N	Y	EBR
	Guatteria sellowiana Schltdl.	Y	Y	Y	N	N	EBR
Aquifoliaceae	*Ilex cerasifolia* Reissek	Y	Y	Y	N	N	EBR
Arecaceae	*Astrocaryum aculeatissimum* (Schott) Burret	Y	Y	Y	Y	N	EBR
Asteraceae	*Piptocarpha macropoda* (DC.) Baker	Y	Y	Y	N	N	EBR
Burseraceae	*Protium warmingianum* Marchand	Y	Y	Y	N	N	EBR
	Trattinnickia ferruginea Kuhlm.*	Y	-	Y	Y	Y	EBR/EAF
Chrysobalanaceae	*Hirtella hebeclada* Moric. ex DC.	Y	Y	Y	N	N	EBR
Elaeocarpaceae	*Sloanea retusa* Uittien	Y	Y	Y	Y	Y	EBR/EAF
Fabaceae	*Andira fraxinifolia* Benth.	Y	Y	Y	N	N	EBR
	Dalbergia nigra (Vell.) Allemão ex Benth.*	Y	Y	Y	Y	Y	EBR/EAF
	Melanoxylon brauna Schott*	Y	Y	Y	N	Y	EBR
	Platycyamus regnellii Benth.	Y	Y	Y	N	N	EBR
	Swartzia acutifolia Vogel	Y	Y	Y	N	Y	EBR
Hypericaceae	*Vismia martiana* Reichardt	Y	Y	Y	Y	N	EBR
Lamiaceae	*Hyptidendron asperrimum* (Spreng.) Harley	Y	Y	Y	N	N	EBR
	Vitex sellowiana Cham.	Y	Y	Y	N	N	EBR
Lauraceae	*Ocotea dispersa* (Nees & Mart.) Mez	Y	Y	Y	Y	Y	EBR/EAF
	Ocotea laxa (Nees) Mez	Y	Y	Y	Y	Y	EBR/EAF
	Ocotea odorifera (Vell.) Rohwer*	Y	Y	Y	N	Y	EBR
Lecythidaceae	*Cariniana legalis* (Mart.) Kuntze*	Y	Y	Y	Y	Y	EBR/EAF
Lythraceae	*Lafoensia glyptocarpa* Koehne*	Y	Y	Y	N	-	EBR
Melastomataceae	*Miconia cubatanensis* Hoehne	Y	Y	Y	N	N	EBR
Meliaceae	*Guarea pendula* R.S.Ramalho, A.L.Pinheiro & T.D.Penn.	Y	Y	Y	Y	Y	EBR/EAF
Moraceae	*Brosimum glaziovii* Taub.*	Y	Y	Y	Y	Y	EBR/EAF
	Ficus mexiae Standl.*	Y	Y	Y	N	-	EBR
Myrtaceae	*Eugenia cerasiflora* Miq.	Y	Y	Y	N	N	EBR
	Eugenia leptoclada O.Berg	Y	Y	Y	Y	Y	EBR/EAF
Rubiaceae	*Ladenbergia hexandra* (Pohl) Klotzsch	Y	Y	Y	N	N	EBR
	Psychotria rhytidocarpa Müll.Arg.	Y	Y	Y	N	Y	EBR
Sabiaceae	*Meliosma sellowii* Urb.	Y	Y	Y	N	N	EBR
Sapindaceae	*Matayba juglandifolia* (Cambess.) Radlk.	Y	Y	Y	N	N	EBR
Sapotaceae	*Chrysophyllum flexuosum* Mart.	Y	Y	Y	Y	N	EBR
Solanaceae	*Solanum cernuum* Vell.	Y	Y	Y	N	Y	EBR
	Solanum leucodendron Sendtn.	Y	Y	Y	Y	Y	EBR/EAF
Urticaceae	*Cecropia glaziovii* Snethl.	Y	Y	Y	Y	N	EBR
	Cecropia hololeuca Miq.	Y	Y	Y	N	Y	EBR

* Species at risk of extinction (Brazil, 2022; IUCN, 2022); [1] Flora e Funga do Brasil (2023); [2] Tropicos (2023); [3] SpeciesLink (2023), [4] Lima et al. (2020); [5] Stehmann et al. (2009); S - Yes; N - No. In the column "Final classification", we have: EBR - confirmed endemic in Brazil and occurs in several biomes; EBR/EAF - confirmed endemic to Brazil, predominates in the Atlantic Forest Biome.

** Espécies em risco de extinção (Brasil, 2022; IUCN, 2022); [1] Flora e Funga do Brasil (2023); [2] Tropicos (2023); [3] SpeciesLink (2023); [4] Lima et al. (2020); [5] Stehmann et al. (2009); Y - Sim; N - Não. Na coluna "Classificação final", tem-se que: EBR - confirmada endêmica do Brasil e ocorre em vários biomas; EBR/EAF - confirmada endêmica do Brasil, predomina no Bioma Mata Atlântica.*

Table 3 – Number of individuals per site and year of inventory, of endemic species in adult trees (1992-2016), in an area of secondary Montana Seasonal Forest of the Atlantic Forest, Viçosa, Minas Gerais.
Tabela 3 *– Número de indivíduos por local e ano de inventário, das espécies endêmicas na fase adulta (1992-2016), em área de Floresta Estacional Semidecidual Montana secundária da Mata Atlântica, Viçosa, Minas Gerais.*

Scientific name (Family)	EG	Site	1992	1995	1998	2001	2004	2007	2012	2016
A. aculeatissimum (Are)	**IS**	**8**	3	3	3	4	5	5	5	5
A. fraxinifolia (Fab)	**IS**	**7**	5	5	5	4	3	3	3	3
C. glaziovii (Urt)	**P**	**1**	1	1	1	2	2	2	2	1
		9			2	2	2	2	1	1
		10	2	2						
C. hololeuca (Urt)	**P**	**2**	6	4	2	2	3	3		
		6	1							
		7	1	1	1	1	1	1	1	1
		8	1	1	1		2	2	2	2
		9		2	2	1	1			
C. flexuosum (Sap)	**LS**	**5**	2	2	2	2	3	3	3	3
		6	8	7	6	6	6	7	8	9
		7								2
C. legalis (Lec)	**LS**	**6**	7	7	8	7	8	8	7	6
D. nigra (Fab)	**IS**	**1**	1	1						
		2	1	1						
		3	13	13	13	9	8	6	5	5
		4							1	1
		7	2	2	2	2	1	1	1	1
		8	12	17	19	23	26	25	31	36
		9	1	1	2	2	4	4	7	8
E. cerasiflora (Myr)	**IS**	**3**	2	3	3	3	2	2	1	1
		4	19	27	27	24	24	24	21	21
		5	1	1	1	1	1	1	1	1
		6	2	2	1	1	1	1	2	2
		9		1	1	1	1	1		
E. leptoclada (Myr)	**IS**	**4**	2	2	2	1	1	1	1	
F. mexiae (Mor)	**LS**	**6**	1	1	1	1	1			
G. sellowiana (Ann)	**IS**	**7**	1	1	1	1	1	1	1	1
H. asperrimum (Lam)	**IS**	**8**	1	1	1	1	1	1	1	1
H. hebeclada (Chr)	**LS**	**6**	6	6	5	6	6	6	6	5
I. cerasifolia (Aqu)	**LS**	**10**						2	2	2
L. hexandra (Rub)	**LS**	**3**	11	11	11	11	12	14	16	16
		4	4	6	1	1	1	1	1	
		7	19	22	24	24	24	24	24	21
		10	10	12	10	10	9	9	9	8
M. brauna (Fab)	**LS**	**7**	1	1	1	1	1			
M. juglandifolia (Sap)	**IS**	**3**	1	1	1	1	1	1	1	1
M. sellowii (Sab)	**LS**	**5**						1	1	
O. laxa (Lau)	**LS**	**3**	1	1						
		4	1	1	1			1	1	1
		5	10	9	9	9	9	9	9	9
		6	2	3	3	4	4	5	5	5
O. odorifera (Lau)	**LS**	**3**								1
		4	3	4	4	3	3	3	3	3
		8	1	1	1	1	1	1	3	3
		10	1	2	2	2	3	4	6	7
P. macropoda (Ast)	**P**	**1**	2	3	3	5	6	6	5	5
		2	2	4	4	5	5	5	4	2
		4								1
		5			1	1	1			

Continued ...
Continua...

Table 3 ...
Tabela 3 ...

P. regnellii (Fab)	**IS**	**8**					1	1	1	1
P. warmingianum (Bur)	**LS**	**3**	1	1	1	1	1	1	1	
		4	1	1	1	1	1	2	2	2
		5	11	10	9	9	9	7	7	6
		6	1	1	1	1	1	1	1	1
S. cernuum (Sol)	**P**	**1**		2						
		9	2	2	1	1	1	1	2	2
S. leucodendron (Sol)	**P**	**2**	1	1	1	1	1	1		
		3	3	3	3	2	1	1		
		8	1	1	1	1		1	1	1
S. retusa (Ela)	**LS**	**7**	2	3	4	4	4	3	3	3
T. ferruginea (Bur)	**LS**	**4**	1	1	1	1				
V. sellowiana (Lam)	**IS**	**1**	3	3	4	4	4	3	2	2
		4	3	2	3	3	3	2	2	2
		7	1	3	3	1				
		8	8	9	9	8	5	5	4	4
		9	1	1	1					
		10	11	10	10	10	10	10	7	7

EG - Ecological Group: P - Pioneer; IS - Initial Secondary; LS - Late Secondary.
EG - Grupo Ecológico: P – Pioneira; IS - Secundária Inicial; LS - Secundária Tardia.

Among the 38 endemic species (EBR and EBR/EAF), eleven were classified as exclusive to the Atlantic Forest (Table 2). Considering all inventories in this study, 28 species occurred in the AT and 29 species occurred in the NR. The species *B. glaziovii*, *G. australis*, *G. pendula*, *L. glyptocarpa*, *M. cubatanensis*, *O. dispersa*, *P. rhytidocarpa*, *S. acutifolia* e *V. martiana* did not occur in AT, while *A. fraxinifolia*, *C. legalis*, *F. mexiae*, *H. asperrium*, *M. selowii*, *P. macropoda*, *P. warmingianum* and *S. retusa* did not occur in the NR.

In the AT, the sites 4 and 7 had the highest abundance of endemic species (16) (Table 3). In the site 4, *E. cerasiflora*, *O. odorifera*, *P. warmianum* and *V. selowiana* were recorded throughout the study period. Six species were sampled over 24 years at the site 7. *M. brauna* and *V. sellowiana* exhibited only one individual in the site 7, which, later on, disappeared.

Cecropia hololeuca (P), *D. nigra* (IS), *E. cerasiflora* (IS), and *V. sellowiana* (IS) stood out in the AT, occurring in more than five sites. *Cecropia hololeuca*, with one to six individuals per inventory, finished with only three individuals up to 2016. *Dalbergia nigra* occurred in seven sites, with very high abundance in sites 3, 8 and 9, with survival of 51 individuals in the last inventory. *Eugenia cerasiflora* was very abundant in all inventories in site 4 and, fifteen individuals of *V. sellowiana* remained until 2016, in four sites.

Fifteen AT species occurred in only one site, with *A. aculeatissimum*, *A. fraxinifolia*, *C. legalis*, *H. hebeclada*, *I. cerasifolia* and *S. retusa* having two to six individuals in the last inventory. These species have been recorded since 1992, except for *I. cerasifolia* (LS), which was recorded only from 2007. Eight of these species occurred in only one site with one individual, and five of these species were not recorded in 2016 (*E. leptoclada*, *F. mexiae*, *M. brauna*, *M. sellowii* and *T. ferruginea*).

In the NR (Table 4), site 7 had the highest abundance of endemics (11 species), however, only one species (L. *hexandra*, IS) was recorded in all inventories.

Twenty species that occurred in the AT were also recorded in the NR, although not always in the same site. The species that presented individuals in the NR in all inventories, in at least one site, were: *D. nigra*, *E. cerasiflora*, *E. leptoclada*, *G. pendula*, and *V. sellowiana* (IS) and, *C. flexuosum*, *L. hexandra*, *O. laxa*, *O. odorifera*, *S. acutifolia* and *T. ferruginea* (LS).

Six LS species exhibited individuals in the NR from 1995 onwards, however, only one individual of *M. brauna* was recorded in the AT between 1992 and 2004 and one individual from the NR was sampled in 2008 and 2013.

Ladenbergia hexandra, *O. laxa* and *V. sellowiana*, abundant in the AT, also occurred in several study sites,

Table 4 – Number of individuals per site, year of inventory (1992-2013) and plant size class (1-3) of endemic species in natural regeneration, in an area of secondary Montana Seasonal Forest of the Atlantic Forest, Viçosa, Minas Gerais.

Tabela 4 *– Número de indivíduos por local, ano do inventário (1992-2013) e classe de tamanho de plantas (1-3), das espécies endêmicas na regeneração natural, em área de Floresta Estacional Semidecidual Montana secundária da Mata Atlântica, Viçosa, Minas Gerais.*

Scientific name (Family)	EG	Site	Plant size class by inventory year[1]														
			1992			1995			2000			2008			2013		
			1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
A. aculeatissimum (Are)	**IS**	**8**				1			1			4			3		
B. glaziovii (Mor)	**IS**	**8**										1					
C. glaziovii (Urt)	**P**	**9**			1			1									
C. hololeuca (Urt)	**P**	**1**	1				1										
C. flexuosum (Sap)	**LS**	**5**	1			1			1							1	1
		6			1	1		1	1		1		1				1
		7					1			1		1				2	1
D. nigra (Fab)	**IS**	**1**										1					
		2							1								
		3	1														
		8	10	6	6	6	6	5	4	7	7	5	8	6	4	4	
		9	1	3	1	1	3	1	1	3	1	2	3	2	4	1	
E. cerasiflora (Myr)	**IS**	**4**	1	2	1	1	2	1	1	1	2		2	1		1	
		10										2				2	
E. leptoclada (Myr)	**IS**	**2**	1									2				2	
		3							1				1				
		6	2			1			1	1	1		1	1		1	1
		8					1			1						1	
G. australis (Ann)	**IS**	**4**										1					
		10												1			
G. pendula (Meli)	**IS**	**4**		2			2			2				2			1
		6				1			1			1			1		
G. sellowiana (Ann)	**IS**	**5**	9	8													
		7												1			
		8	11			6			4		1						
		9											1			1	
		10				1			2								
H. hebeclada (Chr)	**LS**	**7**				1	1		1	1			2			1	
I. cerasifolia (Aqu)	**LS**	**10**														1	
L. glyptocarpa (Lyt)	**LS**	**7**										1					
		10											1			1	
L. hexandra (Rub)	**LS**	**2**										4	1			2	
		3	1	1	2	1		2	1		2	2	3		1	4	
		4	1	2	2	1	1	2									
		7	1	1	3		1	3		1	2			1	2		
		8										1	1		1		
		9												1			
		10	2	1		1	1		1	1		8	3	2	8	1	2
M. brauna (Fab)	**LS**	**7**										1			1		
M. cubatanensis (Mela)	**IS**	**7**											1				
		10							1								
M. juglandifolia (Sap)	**IS**	**2**													1		
		10													1		
O. dispersa (Lau)	**IS**	**7**							1								
O. laxa (Lau)	**LS**	**4**			1			1			1						
		5		1													
		8													1		
		9	1						1								

Continued ...
Continua...

Table 4 ...
Tabela 4 ...

		10		2			2			1	1		1	1				1
O. odorifera (Lau)	**LS**	**4**			2	2		2	2		2	2	1	1	1	1		
		5		2			2			1	1		1	1		1		
		7		2	1		2	1			3			3				
P. regnellii (Fab)	**IS**	**8**													2			
P. rhytidocarpa (Rub)	**LS**	**2**											1	1				2
		6										1						
		7										3	3		1	2		1
		9											1					
S. acutifolia (Fab)	**LS**	**10**	1	1		1	1		3			2			1	1		
S. cernuum (Sol)	**P**	**1**	2			1	1				1							
		2			1													
		8	1									1						
		9		1														
S. leucodendron (Sol)	**P**	**8**							1			1						
T. ferruginea (Bur)	**LS**	**4**		2			2											
		5		2	1	1	2	1	1	2	1		4			3		
V. martiana (Hyp)	**P**	**1**			1					2								
		2		2			2				1							
		4			2	1		2		1		1						
		5	1															
		7				3												
		8		1														
		9			1			1			1							
		10	1	4	1	5	3	1	3	2	1							
V. sellowiana (Lam)	**IS**	**1**							1									
		4				1			1				1					
		8	2			3			5			7			1			
		9		1		1				1			1					
		10			1		1				1	1		1				1

EG - Ecological Group: P - Pioneer; IS - Initial Secondary; LS - Late Secondary. [1]Class 1 – 0.1 m ≤ h < 1.0 m; Class 2 – 1.0 m ≥ h ≤ 3 m; Class 3 - h > 3.0 m and *dbh* < 5 cm.
EG - Grupo Ecológico: P – Pioneira; IS - Secundária Inicial; LS - Secundária Tardia. [1]Classe 1 – 0,1 m ≤ h < 1,0 m; Classe 2 – 1,0 m ≥ h ≤ 3 m; Classe 3 - h > 3,0 m e ***dap*** *< 5 cm.*

but, in the last inventory of the NR, only *L. hexandra* was abundant (21 individuals in the different plant size classes), while *O. laxa* and *V. sellowiana* had only two individuals in sites 8 and 10 (one individual in each site).

Among the abundant species in the NR, *V. martiana* occurred in eight study sites in the NR and did not occur in the AT in the first inventories and, although it occurred in several sites and years of inventory, this species ceased to occur from 2008 onwards.

Twelve species occurred in only one site in the NR. Of these species, only *A. aculeatissimum*, I. *cerasifolia* and *M. brauna* occurred in the same site of the AT, with few individuals in the NR. Eight of these species occurred in only one site, with only one individual per site inventory, and two species did not occur in the AT (*B. glaziovii* and *O. dispersa*).

Considering the mortality of endemic species until the last inventory, *E. leptoclada*, *M. brauna*, *S. cernuum* and *S. leucodendron* completely disappeared in the AT and, *C. glaziovii* and *C. hololeuca* disappeared in the NR before 2016. The situation is more critical for *B. glaziovii*, *F. mexiae*, *G. australis*, *M. cubatanensis*, *M. sellowii*, *O. dispersa* and *V. martiana*, which no longer occur in the forest at all levels (AT and NR).

4. DISCUSSION

The number of endemic species of Brazil and of the Atlantic Forest in the present study was lower than the number recorded in a study carried out in the municipality of Faria Lemos, MG (Rocha et al., 2017) and higher than that found in the Brazilian Amazon (Oliveira et al., 2017). When evaluating the

occurrence of the 58 species classified as endemic in Flora e Funga do Brasil (2023), using information obtained in Tropicos (2023) and SpeciesLink (2023), there was a reduction from 58 to 38 species actually considered endemic to Brazil. This reduction in the number of endemic species is due to the inclusion of recent information on the natural occurrence of species in other countries.

This reduction in the proportion of endemic species indicates that information on endemism should be revised, due to the increased availability of information in more recent studies. For example, the species *A. parvifolium*, *C. ulmifolia* and *P. contorta*, classified as endemic by Flora e Funga do Brasil (2023), are present in the flora of Bolivia (Jorgensen et al., 2014); *J. puberula* in the flora of Argentina (Flora Argentina, 2018) and *S. argenteum* in the flora of Panama (Monro et al., 2017). These results indicate that knowledge of species distribution is still fragmented and presents empirical information, mainly in relation to taxonomy and distribution in their areas of natural occurrence (Kougioumoutzis et al., 2021).

The contestation about the endemism of some species does not invalidate the information gathered by the consulted authors, but it shows that there is a need to expand and improve studies to identify and update information on occurrence, endemicity status and vulnerability of the species. The use of continuously updated tools (eg. SpeciesLink and Global Biodiversity Information Facility – GBIF) can facilitate this identification, provided they have complete geographic information and correct taxonomic identification (Maldonado et al., 2015).

When assessing the abundance of endemic species in the different sites, it was found that sites 4 and 7 stood out in the AT and NR. These sites have a steep slope, forest in the initial stage of succession and low fertility. There was a predominance of pioneer and initial secondary species, but there was also the emergence of late secondary species. Although with few individuals, the occurrence of LS in these sites can be partially explained by the photosynthetic plasticity and ability of these individuals to acclimatize to environments with variation in radiation availability, mainly in semideciduous forests (Martins et al., 2008; Souza et al., 2010; Pezzopane et al., 2018).

Individual mortality was recorded for most species, with a reduction in their abundance, even for those that occurred in several sites. The reduction in abundance may be related to environmental changes that have occurred over time, which may interfere on seed rain and seed and seedling bank (Campos et al., 2009; Chalermsri et al., 2020). It should be noted that there was a reduction in annual rainfall for Viçosa, MG, in some years, during the study period, mainly in the winter season, the dry season in the region (Sanches et al., 2017), which may have affected the natural regeneration

Throughout the inventories, the closure of the canopy (Pezzopane et al., 2018) allowed the appearance of late secondary species or climaxes, which are shade tolerant. Also, mortality of individuals of pioneer species, from the second inventory (1995), as occurred with the species *C. hololeuca*, *S. leucodendron* and *V. martiana*, changes light availability.With the limitation of solar radiation and the tendency for individuals of pioneer species to die, due to their short life cycle and high light requirement, space is opened allowing shade-tolerant species to develop (Goodale et al., 2012). The survival and development of these pioneer and initial secondary species was apparently dependent on the opening of natural or anthropic clearings (death or removal of large trees), to allow the regeneration of more demanding species in relation to radiation (Goodale et al., 2012; Parizotto et al., 2018).

The mortality of late secondary species (*M. brauna* and *M. sellowii*) in the last inventories suggests the existence of other barriers that affect their establishment. *Melanoxylon brauna* is classified as vulnerable due to the intense exploitation of its wood in the past (Brasil, 2022). The establishment of guidelines to favor the maintenance of this species, or others with high vulnerability, is mandatory, aiming to reduce the risk of their extinction. Seed predation and loss of viability with increased humidity, combined with the continuous and illegal exploitation of wood, even in a conservation area (Borges et al., 2015; Borges et al., 2020), highlight the difficulty of perpetuation of *M. brauna* and the need for strategies for its preservation and conservation.

Seven endemic species are also classified as endangered: *B. glaziovii*, *C. legalis*, *D. nigra*, *F. mexiae*, *L. glyptocarpa*, *O. odorifera* and *T. ferruginea* (Brasil, 2022; IUCN, 2022). Most of these species showed a reduced number of individuals, in addition to their mortality in the last inventories, no longer

occurring in the study area. It should be noted that the presence of the matrix tree is of great importance, as long as it has the conditions to produce viable seeds that can germinate and/or remain in the soil seed bank until the environmental conditions, mainly humidity and radiation, are suitable for germination (Herrera & García, 2009; Schulz et al., 2018).

In addition to endemic species be considered at risk of extinction, *G. sellowiana*, *H. asperrimum*, *I. cerasifolia*, *M. juglandifolia*, *P. regnellii*, *S. cernuum* and *S. leucodendron* had few adult individuals, representing a risk for their perpetuation, indicating a warning sign for the possibility of disappearance of these species. These species can be considered rare (with one individual) (Işik, 2011) and, in the case of endemic species, it indicates a reduction in population size, which may increase their vulnerability and possibility of inclusion in lists of endangered species (Işik, 2011; Kougioumoutzis et al., 2021).

5. CONCLUSION

There is a representative number of endemic species in the study area, located in the Atlantic Forest Domain, in the Southeast region of Brazil. It should be noted that some of these species no longer occur in the area and, others are already at risk of extinction, requiring conservation management strategies, aimed at reducing the risk of disappearance.

The use of continuous inventories, mainly with the collection of data of the natural regeneration and of the adult trees of the arboreal component, together, proved to be of great relevance for a better understanding of the dynamics of endemic species in Brazil, helping to identify processes that can be determinant in the stability of these species.

These results indicate the need to define public policies for the monitoring, conservation and management of the remnants of the Atlantic Forest. For example, by connecting forest fragments through ecological corridors, the isolation of the fragments is reduced, which favors gene flow, and species regeneration, and, consequently, the survival of the endemic species.

AUTHOR CONTRIBUTIONS

Ana Laura da Silva Luz, Maria das Graças Ferreira Reis, Geraldo Gonçalves dos Reis, wrote the article and discussed the results. Margarete Marin Lordelo Volpato and Jônio Pizzol Caliman carried out the data collection. Cátia Cardoso da Silva and Rennan Salviano Terto developed with the writing of the article.

6. ACKNOWLEDGMENTS

We thank the Universidade Federal de Viçosa; the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPQ), the Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG) and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) for the research financial support and the fellowship grant.

7. REFERENCES

Borges DB, Mariano-Neto DS, Correa RX, Gaiotto FA. Changes in fine-scale spatial genetic structure related to protection status in Atlantic Rain Forest fragment. Journal for Nature Conservation, 2020;53. doi.org/10.1016/j.jnc.2019.125784

Borges EEL, Flores AV, Ataide GM, Matos ACB. Alterações fisiológicas e atividade enzimática em sementes armazenadas de *Melanoxylon brauna* Schott. Cerne, 2015;21(1):75-81. doi:10.1590/01047760201521011569

Brasil. Portaria n. 148, de 07 de junho de 2022. Atualiza o teor do ANEXO da Portaria nº 443, de 17 de dezembro de 2014 da "lista nacional oficial de espécies da flora ameaçadas de extinção" Diário Oficial [da República Federativa do Brasil] Brasília, 07 de junho de 2022.

Caliman, JP. Florística e distribuição vertical e horizontal de espécies arbóreas da Mata Atlântica, no sudeste do Brasil [dissertação]. Viçosa, Universidade Federal de Viçosa; 2015.

Caliman, JP. Estrutura diamétrica, biomassa, ingresso e mortalidade em floresta atlântica secundária ao longo de 24 anos [tese]. Viçosa: Universidade Federal de Viçosa; 2019.

Caliman JP, Reis GG, Reis MGR, Leite HG, Torres CMME, Volpato MML, et al. A.temporal and spatial variability of the diameter distribution in a secondary brazilian atlantic forest suggests site-specific management practices. Revista Árvore, 2020;44:e4406. doi:10.1590/1806-908820200000006

Campos EP, Vieira MF, Silva AF, Martins SV, Carmo FMS, Moura VM, et al. Chuva de sementes em Floresta Estacional Semidecidual em Viçosa, MG, Brasil. Acta Botanica Brasilica, 2009;23(2):451-458.

Chalermsri A, Ampornpan L, Purahong W. Seed rain, soil seed bank, and seedling emergence indicate limited potential for self-recovery in a highly disturbed, tropical, Mixed Deciduous Forest. Plants 2020;9(10):1391. https://doi.org/10.3390/plants9101391

Fernandes, HAC. Dinâmica e distribuição de espécies arbóreas em uma Floresta Secundária no Domínio da Mata Atlântica [dissertação]. Viçosa: Universidade Federal de Viçosa; 1998.

FLORA E FUNGA DO BRASIL. Flora e funga do Brasil 2023 [Internet]. Rio de Janeiro: Jardim Botânico do Rio de Janeiro, 2023. [cited 2023 jun 29] Avaiable from http://floradobrasil.jbrj.gov.br/

FLORA ARGENTINA. Flora da Argentina 2018 [Internet]. Instituto de Botánica Darwinion, 2018. [cited 2022 may 06] Available from http://buscador.floraargentina.edu.ar/

Gallagher RV, Allen S., Rivers MC, Allen AP, Butt N, Keith D, et al. Global shortfalls in extinction risk assessments for endemic flora. BioRxiv, 2020. doi: org/10.1101/2020.03.12.984559

Garcia CC, Reis MGF, Reis GG, Pezzopane JEM, Lopes HNS, Ramos DC. Regeneração natural de espécies arbóreas em fragmento de floresta estacional semidecidual Montana, no domínio da Mata Atlântica, em Viçosa, MG. Ciência Florestal, 2011; 21(4):677-688.

Goodale UM, Ashton MS, Berlyn GP, Gregoire TG, Singhakumara BMP, Tennakoon KU. Disturbance and tropical pioneer species: patterns of association across life history stages. Forest Ecology and Management, 2012; 277(1):54-66. Doi:10.1016/j.foreco.2012.04.020

Herrera JM, García D. The role of remnant trees in seed dispersal through the matrix: being alone is not always so sad. Biological Conservation, 2009; 142(1):149-158. doi:10.1016/j.biocon.2008.10.008

Higuchi P, Reis MGF, Reis GG, Pinheiro AL, Silva CT, Oliveira CHR. Composição florística da regeneração natural de espécies arbóreas ao longo de oito anos em um fragmento de floresta estacional semidecidual, em Viçosa, MG. Revista Árvore, 2006;30(6): 893-904.

INTERNATIONAL UNION FOR CONSERVATION OF NATURE (IUCN) [Internet]. The IUCN Red List of threatened species. Version 2022-2. Cambridge, Reino Unido: 2022. [cited 2023 april 25] Avaiable from https://www.iucnredlist.org.

Işik K. Rare and endemic species: Why are they prone to extinction? Turkish Journal of Botany, 2011;35:411-417. doi: 10.3906/bot-1012-90

Jorgensen P, Nee M, Beck S, editors. Catalago de las plantas vasculares de Bolivia. St. Louis: Missouri Botanical Press, 2014.

Kamino LHY, Siqueira MF, Sánchez-Tapia A, Stehmann JR. Reassessment of the extinction risk of endemic species in the neotropics: how can modelling tools help us? Natureza & Conservação, 2012; 10(2):191-198. doi:10.4322/natcon.2012.033

Kougioumoutzis K, Kokkoris IP, Panitsa M, Strid A, Dimopoulos P. Extinction risk assessment of the greek endemic flora. Biology, 2021; 10(3):195. doi:10.3390/biology10030195

Lima RAF, Souza VC, Siqueira MF, Teer Steege H. Defining endemism levels for biodiversity conservation: tree species in the Atlantic Forest hotspot. Biological Conservation, 2020, 252: 108825. doi:10.1016/j.biocon.2020.108825

Maldonado C, Molina CI, Zizka A, Persson C, Taylor CM, Albán J, Chilquillo E, Rønsted N, Antonelli A. Species diversity and distribution in the era of Big Data. Global Ecology and Biogeography, 2015; 24: 973-984. doi.org/10.1111/geb.12326

Martins SV, Gleriani JM, Amaral CH, Ribeiro TM. Caracterização do dossel e do estrato de regeneração natural no sub-bosque e em clareiras de uma florestal estacional semidecidual no município de Viçosa, MG. Revista Árvore, 2008;32(4):759-767. doi:10.1590/S0100-67622008000400018

Monro AK, Santamaría-Aguilar D, González F, Chacón O, Solano D, Rodríguez A et al. A first checklist to the vascular plants of La Amistad International Park (PILA), Costa Rica-Panama.

Phytotaxa, 2017; 322(1): 1–283. doi: 10.11646/phytotaxa.322.1.1

Myers N, Mittermeier RA, Mittermeier CG, Fonseca GAB, Kent J. Biodiversity hotspots for conservation priorities. Nature, 2000; 403:853-858.

Oliveira LC, Cupertino-Eisenlohr MA, Bispo RA, Silva DR, Oliveira-Filho A T, Eisenlohr PV. Composição, riqueza e categorias de ameaça das espécies arbóreas da Amazônia. Revista de Ciências Agroambientais, 2017; 15(2):223-237.

Parizotto A, Mussio CF, Ruiz EFZ, Figueiredo Filho A, Dias A N. Florística e diversidade da regeneração natural em clareiras em Floresta Ombrófila Mista. Pesquisa Florestal Brasileira, 2019;39:e201801711. doi:10.4336/2019.pfb.39e201801711

Pezzopane, JEM. Caracterização microclimática, ecofisiológica e fitossociológica em uma floresta estacional semidecidual secundária em Viçosa, MG [doutorado]. Viçosa: Universidade Federal de Viçosa; 2001.

Pezzopane JEM, Silva GF, Santos EA, Machuca MAH, Xavier TMT. Environmental conditions of the interior of the tropical forest and regeneration of tree species. African Journal of Agricultural Reserach, 2018; 13(14):718-725. doi:10.5897/AJAR2017.12214

Rocha MJR, Cupertino-Eisenlohr MA, Leoni LS, Silva AG, Nappo ME. Floristic and ecological attributes of a Seasonal Semideciduous Atlantic Forest in a key area for conservation of the Zona da Mata region of Minas Gerais State, Brazil. Hoehnea, 2017;44(1): 29-43. doi: 10.1590/2236-8906-38/2016

Sanches FO, Fialho ES, Quina RR. Evidências de mudanças climáticas em Viçosa (MG). Revista do departamento de Geografia, 2017;34:122-136. doi: 10.11606/rdg.v34i0.138581

Santos GN, Silva AC, Higuchi P, Gross A, Kilca RV, Silva MAF. et al. Dinâmica do componente arbóreo e regenerante em uma floresta nebular no Planalto Sul Catarinense. Ciência Florestal,2021;31(3):1086-1104. doi:10.5902/1980509829654

Schulz B, Durka W, Danihelka J, Eckstein RL. Differential role of a persistent seed bank for genetic variation in early vs. late successional stages. PlosOne, 2018; 13(12): e0209840. doi:10.1371/journal.pone.0209840

Silva CT, Reis G G, Reis M GF, Silva E, Chaves RA. Avaliação temporal da florística arbórea de uma floresta secundária no município de Viçosa, Minas Gerais. Revista Árvore, 2004; 28(3):429-441.

Souza, FC. Dinâmica da estrutura e do estoque de carbono da vegetação arbórea adulta em 20 anos, em floresta secundária da Mata Atlântica [doutorado]. Viçosa: Universidade Federal de Viçosa; 2015.

Souza GM, Sato AM, Ribeiro RV, Prado CHBA. Photosynthetic responses of four tropical tree species grown under gap and understorey conditions in a semi-deciduous forest. Brazilian Journal of Botany, 2010; 33(4):529-538. doi:10.1590/S0100-84042010000400002

SPECIESLINK. Rede SpeciesLink. Sistema de informação distribuído para coleções biológicas. [Internet] Centro de Referência em Informação Ambiental, 2023. [cited 2023 jun 29] Avaiable from <http://www.splink.org.br/>.

Stehmann JR, Forzza RC, Salino A, Sobral M, Costa DP, Kamino LHY, editors. Plantas da Floresta Atlântica. Rio de Janeiro: Jardim Botânico do Rio de Janeiro, 2009.

TROPICOS. Tropicos.org. [Internet] Missouri Botanical Garden, 2023. [cited 2023 jun 29] Avaiable from https://tropicos.org

Volpato, MML Regeneração natural em uma floresta secundária no domínio da Mata Atlântica: uma análise fitossociológica [dissertação]. Viçosa: Universidade Federal de Viçosa; 1994.