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Floristics and phytosociology of a recovered stretch of riparian forest in the Machado river, Minas Gerais

Diego Pereira Marcelini[1], Miguel Gama Reis[2], Elenice Aparecida Fortes[3], Renon Santos Andrade[4], Walnir Gomes Ferreira Júnior[5]

[1] Instituto Federal do Sul de Minas Gerais - *Campus* Machado, Brasil. Laboratório de Botânica e Ecologia - Herbário GERAES. Graduado em Ciências Biológicas. diegomarcelini@yahoo.com.br

[2] Universidade Federal de Lavras – Programa de Pós-Graduação em Botânica Aplicada. Mestrando. miguel_greis@yahoo.com.br

[3] Universidade Estadual de Campinas – Programa de Pós-Graduação em Biologia Vegetal. Doutoranda. forteselenice@gmail.com

[4] Escola de Botânica Tropical do Jardim Botânico do Rio de Janeiro – Programa de Pós-Graduação em Botânica. Mestrando. renonandrade.ra@gmail.com

[5] Instituto Federal do Sul de Minas Gerais - *Campus* Machado, Brasil. Laboratório de Botânica e Ecologia - Herbário GERAES. Docente. walnir.ferreira@gmail.com

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Abstract

Riparian forests play an important role in maintaining environmental services and in conserving species of a genetic corridor for flora and fauna. The present study was carried out with the objective of analyzing the species composition and the horizontal structure at a recovered riparian forest with another native adjacent area in the municipality of Poço Fundo, Minas Gerais. A floristic and phytosociological survey of the arboreal sinusia was carried out in the areas. Were sampled 199 individuals and 24 species in the recovered area and 105 individuals and 23 species in the native area. Floristic similarity between areas was not verified. Shannon diversity was low in both areas. In the recovered area, there is a predominance of early species while in the native area there is a predominance of late ones. There was no floristic convergence between the two studied áreas. A structural convergence between the areas was verified 13 years after the beginning of the restoration.

Keywords: Ecological Succession. Ecological Restoration. Regeneration. Recovery of Degraded Area.

Introduction

The Atlantic Forest had it original coverage reduced to 12.4 % (SOS MATA ATLÂNTICA; INPE, 2017). The domain of its biome corresponds to the country's economic engine and it´s located close to the largest urban centers in South America. They are places with intense urbanization, industrialization and agricultural expansion which have transformed the Atlantic Forest into one of the most fragmented and threatened biomes in the world (REZENDE *et al*., 2018). Its disturbed, little-known and protected forest fragments made it possible to frame the Atlantic Forest as a biodiversity hotspot due to the richness of its biodiversity and the constant threat to which it is submitted (REZENDE *et al*., 2018).

According to Rodrigues and Gandolfi (2001), riparian forests are arboreal and shrubby communities occurring along the margins of water courses and in places subjected to temporary flooding whose importance is extreme in the physical maintenance of river margins and in interconnecting terrestrial and aquatic ecosystems as they carry out the recycling elements in waterlogged soils.

Riparian forests play an important role in species conservation acting as a genetic corridor for flora and fauna promoting the flow of species among landscape elements. It is essential to understand the relationship of different types of plants between themselves and the fauna so that the objective of riparian forests´restoring area is fulfilled (ROSOT *et al*., 2018).

The conservation value of the fragments depends on the type of present species since many are restricted to mature forests in which the maintenance of the species depends on environmental conditions found in conserved ecosystems. The isolated fragments still maintain old forests in decline with vegetation structure

resistant to fragmentation containing long-lived trees, which despite the negative impacts of habitat loss, can preserve importante parcels of the regional flora and fauna even though landscapes in tropicals countries are dominated by agriculture, often monoculture (FARAH *et al*., 2017).

Ecological restoration assists the environment in returning to a sustainable condition in which species can develop without imposing a trajectory that would faithfully reproduce specific pre-existing conditions. Restoration must be based on knowledge of the different successional stages and levels of recovery including information on degradation factors and historical conditions that would help indicate the decline or recovery of the ecosystem (MCDONALD *et al*., 2016).

Normally, in restoration projects, only a fraction of plant species is used, which represents only a small part of the biodiversity of natural ecosystems. According to Brancalion *et al.* (2015), the choice of native and typical seedlings from the region to be restored depends on several factors such as: degree of degradation of the area and its history; availability of seeds and seedlings; availability of financial resources, availability of agricultural machinery and implements that have as reference the natural process of regenerating riparian forests.

This work was carried out with the objective of analyzing the species composition and aspects of the horizontal structure of the synusia tree in a recovered area of a riparian forest with another adjacent native area, both located by the margins of Machado river in the municipality of Poço Fundo, Minas Gerais. It provided relevant information for restoration of riparian forests in the region.

Material and methods

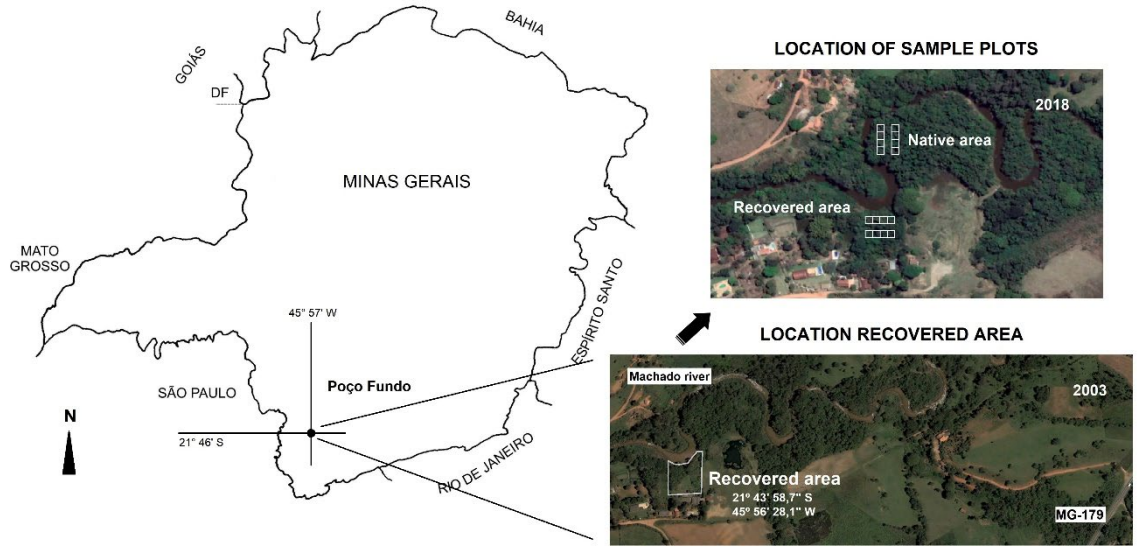
The studies were conducted in native riparian forest fragments and in a recovered riparian forest located in the municipality of Poço Fundo, southern Minas Gerais (FIGURE 1). The region is part of the Semideciduous Seasonal Forest domain within the Atlantic Forest biome (IBGE, 2004). It presents relief varying from heavily undulating to mountainous, altitude between 835 m and 1310 m. The average annual temperature in the municipality is of 20.4 °C; the maximum monthly average is of 23.2 °C; the minimum monthly average is of 17.4 °C; the average annual rainfall is of 1497 mm (CLIMATE-DATA.ORG, 2018).

The property where the recovered and native riparian forests of the present study are located was fined by the Public Ministry of Minas Gerais on December 9, 2003, pursuant to articles 5 and 6 of Law No. 7347/85, amended by article 113 of Law No. 8078 of September 11, 1990, with art. 201 and § 5 “b” of Law 8069/90.

According to the term of commitment to adjust the conduct of the Public Ministry of Minas Gerais, the owner was summoned to carry out a project approved by the State Forestry Institute aiming at the recovery of a 50 m stretch of riparian forest with 250 tree species seedlings donated by Companhia Energética de Minas Gerais (CEMIG). The seedlings were planted at a spacing of 2 m x 2 m between February and March 2004. At the end of the process, the area was fenced 30 m from the margin preventing the entry of animals.

During assessment period of the property the following native trees were identified on the site: *Inga edulis* Mart., *Croton urucurana* Baill., *Sebastiania brasiliensis* Spreng., Lauraceae not specified and *Myrciaria tenella* O. Berg. Seedlings of the following tree species were initially used in the reforestation project: *Calophyllum brasiliense* Cambess, *Schinus terebinthifolia* Raddi, *Syzygium cumini* (L.) Skeel and *Inga edulis* Mart. These species have in common their zoochoric dispersion eventhough being from different successional stages.

Figure 1. Geographical location of the recovered area and the sample plots of the present study by the margins of Machado river, Poço Fundo, MG, during the assessment period in 2003 and 2018.



Source: Prepared by the authors using Google Earth image from 2003 and 2018 (2021).

For sample collections, two (2) distinct areas of study were demarcated: i) Recovered area (21°43'58.7"S/45°56'28.1"W) and ii) Native area (21°43'51.2"S/45°56'43.4"W) close to the restored one is capable of printing floristic convergence and the source of the remaining species found there. In each of the studied areas 8 plots (MUELLER-DOMBOIS; ELLENBERG, 1974) of 10 m x 10 m were installed and distributed in two (2) lines of four plots parallel to the watercourse and spaced 3 m apart. The first four plots, from the two studied areas were positioned at a distance of 2.5 m from the margin of Machado river (FIGURE 1). This distance from the river margin was defined as a function of the dimensions of the recovered area, as no greater was spacing possible. The samplings in the two studied areas within the plots totaled 1600 m^2.

The alive and dead trees, with a minimum diameter greater than or equal to 3.18 cm at 1.30 m from the ground (DBH), were sampled and marked and numbered with metal plates. The phytosociological parameters addressed were: density, dominance and frequency, used in the composition of the importance value, described and proposed by Mueller-Dombois and Ellenberg (1974). The Shannon Diversity Index (H') (BROWER; ZAR, 1984) and the Pielou Equability Coefficient (J) (PIELOU, 1975) were calculated for each area. The phytosociological and floristic parameters described above were calculated using the FITOPAC 2 program (SHEPHERD, 2009).

The analysis of the similarity between the areas was made through the agglomerative classification by UPGMA (JAMES; MCCULLOCH, 1990). The two areas were qualitatively compared (presence and absence of species), using the Sørensen similarity coefficient with the aid of MVSP© (Multi-Variate Statistical Package; Kovach Computing Services, Wales, UK) program.

The sampled species were classified as zoochoric, autochoric and anemochoric dispersion syndrome depending on the characteristics of their propagules (seeds and fruits) according to Vidal and Vidal (2007). These were also distributed into three ecological groups proposed by Gandolfi *et al*. (1995): pioneers, early secondary and late secondary.

In the diametric distributions, class intervals with increasing amplitudes were used to compensate for the strong decrease in density within the larger size classes which are typical of the negative exponential distribution, known as inverted-J (BOTREL *et al*., 2002). The collected plant materials were herborized and deposited in the GERAES Herbarium at Machado Campus of the Federal Institute of Education, Science and Technology of Southern Minas Gerais. The botanical synonyms were updated according to the website Flora do Brasil of the Botanical Garden of Rio de Janeiro (FLORA DO BRASIL, 2020). The APG IV (2016) classification system was adopted.

Results and discussion

Floristic composition and similarity

In all, 199 individuals were sampled and separated into 36 species (TABLE 1). Myrtaceae was the richest family with 9 species, followed by Euphorbiaceae, Lauraceae and Salicaceae with 4 each, Fabaceae with 3, Sapindaceae and Rutaceae with 2 each. These were the single species: Anarcadiaceae, Arecaceae, Meliaceae, Monimiaceae, Moraceae, Poligonaceae, Calophyllaceae and Solanaceae.

Study carried out by Silva *et al.* (2020) on the floristic patterns from 56 different works on riparian forests in the Atlantic Forest and Pampas reported that the families Fabaceae (55 species), Myrtaceae (52 species), Lauraceae (23 species) and Rubiaceae (20 species) were the ones that presented greater species richness in the Atlantic basin while in the Paraná-Uruguay river basin the families Myrtaceae (91 species), Fabaceae (72 species), Lauraceae (30 species) and Rubiaceae (29 species) were the most represented.

Table 1. Floristic list, successional category and dispersal syndrome of tree species found in the restored area and in the native area by the margin of Machado river´s riparian forest at a property in the municipality of Poço Fundo, Minas Gerais.

Family/Species	Popular name	NA	RA	SC	DS
ANACARDIACEAE					
Schinus terebinthifolia Raddi.	aroeira-vermelha		X	P	Zoo
ARECACEAE					
Syagrus romanzoffiana (Cham.) Glassman	jerivá		X	IS	Zoo
CALOPHYLLACEAE					
Calophyllum brasiliense Cambess.	guanandi		X	LS	Zoo
EUPHORBIACEAE					
Alchornea glandulosa Poepp. & Endl.	tamanqueiro	X	X	P	Zoo
Alchornea triplinervia (Spreng.) Müll.Arg.	pau-óleo		X	P	Zoo
Croton urucurana Baill.	sangra-d'água		X	P	Aut
Sebastiania brasiliensis Spreng.	capixava	X	X	LS	Aut
FABACEAE					
Inga edulis Mart.	ingá-cipó	X	X	IS	Zoo
Lonchocarpus cultratus (Vell.) A.M.G.Azevedo & H.C.Lima	embira-de-sapo	X		IS	Ane
Machaerium opacum Vogel	jacarandá-do-mato	X	X	IS	Ane

LAURACEAE					
Cryptocarya moschata Ness e Mart.	canela-moscada		X	LS	Zoo
Nectandra lanceolata Ness	canela-amarela		X	LS	Zoo
Ocotea corymbosa (Meisn.) Mez	canela-fedorenta	X		IS	Zoo
Ocotea lancifolia (Schott) Mez	canela-do-brejo	X		LS	Zoo
MELIACEAE					
Guarea macrophylla Vahl	saco-de-gambá	X	X	LS	Zoo
MONIMIACEAE					
Mollinedia argyrogyna Perkins	corticeira	X	X	IS	Zoo
MORACEAE					
Morus nigra L.	amora-preta		X	Ex	Zoo
MYRTACEAE					
Campomanesia guaviroba (DC.) Kiaersk.	guabiroba		X	LS	Zoo
Campomanesia reitziana D.Legrand.	guabiroba-crespa	X		IS	Zoo
Corymbia citriodora (Hook.) K.D.Hill & L.A.S.Johnson	eucalipto	X		Ex	Aut
Eugenia cerasiflora Miq.	mamoneira	X		LS	Zoo
Myrcia subcordata DC.	guamirim	X		LS	Zoo
Myrciaria sp.	-	X		NC	Zoo
Myrciaria tenella (DC.) O.Berg	cambuçí		X	IS	Zoo
Psidium guajava L.	goiabeira		X	Ex	Zoo
Syzygium cumini (L.) Skeels	jambolão		X	Ex	Zoo
POLIGONACEAE					
Triplaris americana L.	pau-formiga		X	P	Ane
RUTACEAE					
Citrus limon (L.) Osbeck	limão-cravo	X		Ex	Zoo
Zanthoxylum riedelianum Engl.	mamica-de-porca	X		P	Zoo
SALICACEAE					
Casearia decandra Jacq.	cafezeiro-do-mato	X	X	LS	Zoo
Casearia obliqua Spreng.	guaçatonga	X		LS	Zoo
Casearia sylvestris Sw.	guaçatonga	X		P	Zoo
SAPINDACEAE					
Cupania ludowigii Somner & Ferrucci	camboatá	X	X	P	Zoo
Cupania vernalis Cambess.	arco-de-peneira	X		IS	Zoo
SOLANACEAE					
Solanum sp.	-		X	NC	NC

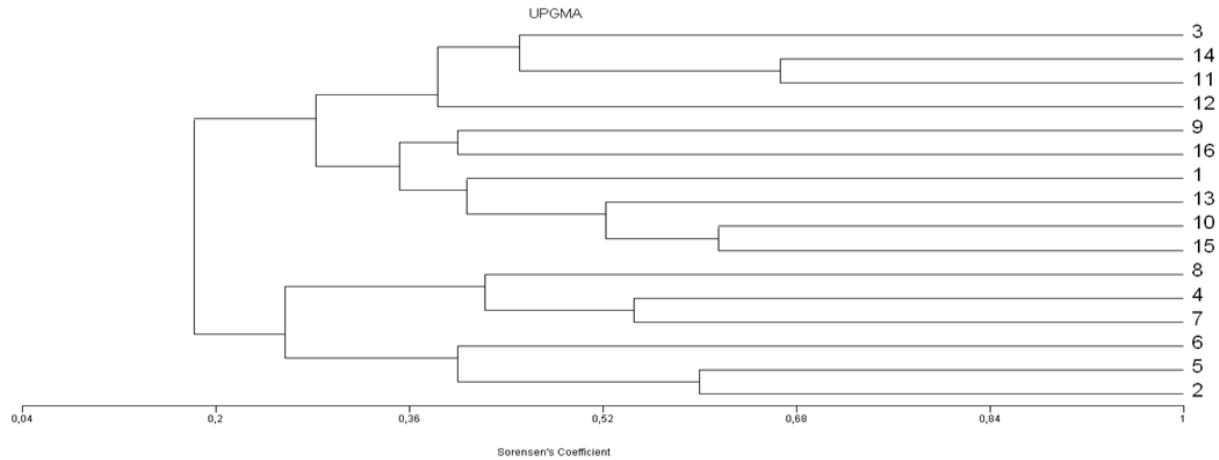
Abreviations: NA: Native Area; RA: Recovered Area; SC: Successional Category; P: Pioneer; IS: Initial secondary; LS: Late secondary; Ex: Exotic; NC: No characterization; DS: Dispersion syndrome; Zoo: Zoochoric; Aut: Autochoric; Ane: Anemochoric.

Source: Prepared by the authors (2021).

As for richness, the recovered area had 15 families and 24 species while the native area had 10 families and 23 species. Even though the species richness values were close between the areas, strong floristic similarity was not verified between them. The Sorensen coefficient obtained

was less than 0.2 (Sorensen = 0.182) in the cluster analysis performed between the block of plots from the recovered area and the native area (FIGURE 2).

Figure 2. Dendrogram of the Sorensen floristic similarity between the plots of the recovered area and the native area by the margin of Machado river´s riparian forest in a property within the municipality of Poço Fundo, Minas Gerais.



Abreviations: Plots 1 to 8: recovered area and Plots 9 to 16: native area.
Source: Prepared by the authors (2021).

The geographic proximity between the areas was not able to create greater floristic convergence. In adition is the short time of the restoration process (13 years) and the inclusion of exotic species in the planting. According to Gandolfi *et al*. (2007), restoration programs generally tend to produce physiognomic and structural convergence within diversity, within number of individuals per species by the basal area, within diameter and within height of individuals. It also shows similarity within the distribution of these individuals in the restored area when compared to the native area, and do not necessarily reach floristic convergence.

Such observation finds support in the new paradigm of ecological succession which understands that the succession process can present several possible trajectories: progressive, regressive and stationary that can produce countless future communities (MARTINS *et al*., 2012).

Phytosociological structure - Recovered area

In the recovered area, 94 individuals were sampled and classified into 15 families and 24 species (TABLE 1). The Shannon index (H') was 2.75 and the equability was 0.867. The individuals had an average diameter of 12.68 ± 9.20 cm and an average height of 6.08 ± 2.52 m and a density of 1175 individuals/ha and a basal area of 22.56 m^2 ha^{-1}.

In the recovered area, the species with the highest importance value (IV) was *Inga edulis* with 14 individuals in the sample presenting the highest relative density (RD) and high relative dominance (RDo) (TABLE 2). At the time of the survey, *I. edulis* had already been identified as a remaining specie and also had seedlings planted during the execution of the restoration project which may concequently have contributed to the results presented above.

Tabela 2. Phytosociological parameters of the species sampled from the recovered riparian forest area by the margin of Machado river within a property in the municipality of Poço Fundo, Minas Gerais.

Species	NI	RD(%)	RF(%)	RDo (%)	IV(%)
Inga edulis Mart.	14	14,89	10	32,18	19,02
Morus nigris L.	13	13,83	12	8,5	11,44
Syzygium cumini (L.) Skeels	13	13,83	6	14,11	11,31
Schinus terebinthifolia Raddi	7	7,45	8	9,73	8,39
Sebastiania brasiliensis Spreng	5	5,32	6	6,23	5,85
Guarea macrophylla Vahl	5	5,32	8	4,11	5,81
Cryptocarya moschata Ness e Mart.	2	2,13	2	12,44	5,52
Nectandra lanceolata Ness	7	7,45	6	1,19	4,88
Syagrus romanzoffiana (Cham.) Glassman	5	5,32	4	5,15	4,82
Alchornea glandulosa Poepp. & Endl.	2	2,13	4	0,65	2,26
Árvores mortas	2	2,13	4	0,64	2,23
Croton urucurana Baill.	2	2,13	4	0,54	2,22
Casearia decandra Jacq.	2	2,13	4	0,13	2,09
Calophyllum brasiliense Cambess.	3	3,19	2	0,29	1,83
Triplaris americana L.	2	2,13	2	0,3	1,59
Alchornea triplinervia (Spreng.) Müll.Arg.	1	1,06	2	1,63	1,56
Machaerium opacum Vogel	2	2,13	2	0,58	1,48
Cupania ludowigii Somner & Ferrucci	1	1,06	2	0,91	1,32
Solanum sp.	1	1,06	2	0,26	1,11
Campomanesia guaviroba (DC.) Kiaersk	1	1,06	2	0,16	1,07
Myrciaria tenella O. Berg	1	1,06	2	0,1	1,05
Casearia arborea (Rich.) Urb.	1	1,06	2	0,06	1,04
Psidium guajava L.	1	1,06	2	0,06	1,04
Mollinedia argyrogyna Perkins	1	1,06	2	0,05	1,04

Abreviations: NI: Number of individuals; RD: Relative density; RF: Relative frequency; RDo: Relative dominance; IV: Importance value.

Source: Prepared by the authors (2021).

S. terebinthifolia, a specie introduced by the restoration project that showed good development in the area reaching a high IV, being the third specie in number of individuals and prominent values of density, frequency and relative dominance. It also demonstrated good development in the restored area. *Sebastiana brasiliensis*, *Guarea macrophylla*, *Cryptocarya moschata*, *Nectandra lanceolata* and *Syagrus romanzoffiana* are species that were present in the area and presented high IV values (TABLE 2). *S. brasiliensis* had 5 individuals and high RDo demonstrating its importance as a biomass stock besides having expressive numbers of relative density and frequency. *G. macrophylla* showed numbers similar to those of *S. brasiliensis* with the same number of individuals and density, yet presenting higher frequency and lower RDo (TABLE 2).

Among the sampled species in the restored stretch, three are exotic: *Syzygium cumini*, *Morus nigra* and *Psidium guajava*. The specie *S. cumini* is exotic and naturalized and introduced by the restoration project. The species *M. nigra* and *P. guajava* were dispersed to the recovered area

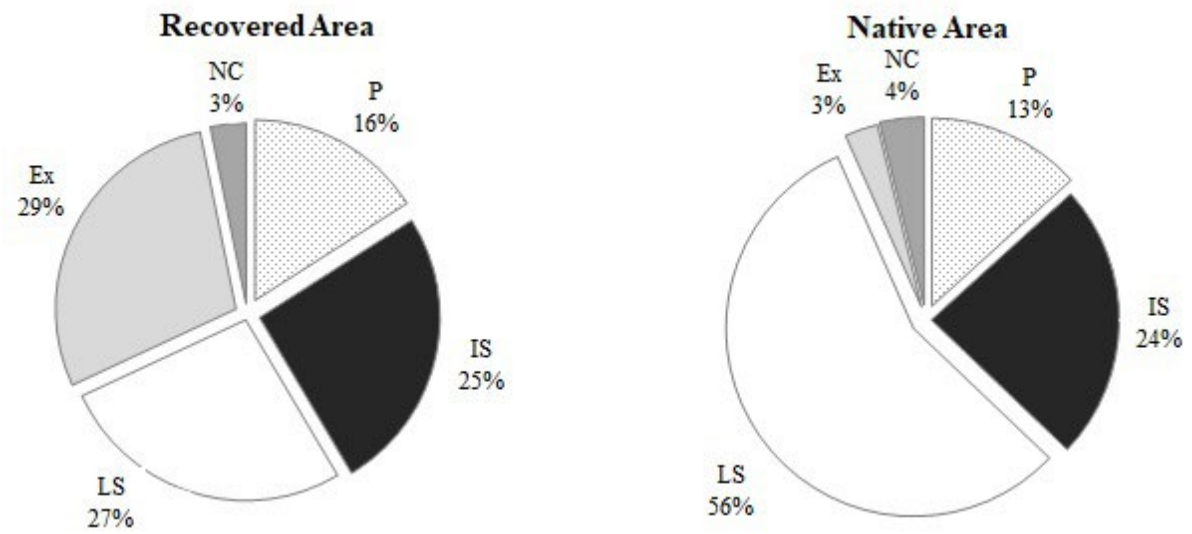
probably from existing orchards neighboring the fragment properties. Among the exotic species, *S. cumini* ranks third in IV, it is the second specie with more individuals and presents high RDo. The specie *M. nigra* ranks second in IV being the most frequent specie in the restored stretch. *P. guajava* had relatively low parameters: last place in IV, density and frequency, and second last in dominance with a single represented individual (TABLE 2).

Exotic species help forest recovery from degraded environments. However, they can harm the ecological development of the fragment covering the environment and smothering native species (GISP, 2005), encouraging some trophic levels to the detriment of others. Fauna modification also encourages groups of animals that feed on their fruits and this unbalances the ecological relationships in the location (ZILLER, 2007). Over time, the uncontrolled invasion of exotic species can cause loss of stability in the fragment, and then reducing functional diversity and limiting the ability to respond to environmental changes that may arise (MCCANN, 2000).

As for the succession moment, the recovered area is in the initial stage of secondary succession according to the criteria proposed by Budowski (1970), once more than 50% of the individuals is found in its canopy being characterized as of pioneer (P) and initial secondary (IS) species (FIGURE 3), and so obtaining low values of diversity and a low basal area. This doesen´t include the exotic ones.

When detailing the structural parameters, it presented an initial characteristic with more individuals belonging to this class (P and IS) (41.49 %) (FIGURE 3), with greater emphasis on the IS that presented high RF (22 %), RD (25, 52 %) and RDo (37.84 %), thus leading to a high IV (28.46 %), which are associated with pioneers (RF = 22 %, RD = 15.96 %, RDo = 14.1 % and IV = 17.35 %) thus reflecting the initial character of the recovered fragment.

Figure 3. Percentage of species individuals from different successional stages sampled in the restored and native riparian forest fragments by the margins of Machado river in a property in the municipality of Poço Fundo, Minas Gerais.



Abreviations: P: Pioneers; IS: Initial secondary; LS: Late secondaries; Ex: Exotics and NC: No characterization.
Source: Prepared by the authors (2021).

Phytosociological structure - Native area

In the native area, 105 individuals, 10 botanical families and 23 species were sampled (TABLE 2). Shannon diversity (H') was 2.53, equability was of 0.809, density was of 1312 ind/ha, mean height was of 6.5 ± 2.89 m and mean diameter was of 12.73 ± 2.91 cm, it presented a basal area of 28.85 m^2. ha^{-1}. *I. edulis* showed high density (10 individuals) and high dominance which placed themselves as the most important species in the native area (TABLE 3).

Table 3. Phytosociological parameters of the species sampled in the native area by the banks of Machado river´s riparian forest in a property within the municipality of Poço Fundo, Minas Gerais.

Species	NI	RD (%)	RF (%)	RDo (%)	IV (%)
Inga edulis Mart.	10	9,52	9,62	48,05	22,40
Sebastiania brasiliensis Spreng	16	15,24	9,62	22,73	15,86
Guarea macrophylla Vahl	24	22,86	13,46	8,06	14,79
Casearia sylvestris Sw.	11	10,48	7,69	5,4	7,86
Ocotea lancifolia (Schott) Mez.	10	9,52	5,77	1,62	5,64
Casearia arborea (Rich.) Urb.	7	6,67	7,69	2,1	5,49
Casearia obliqua Spreng.	4	3,81	3,85	1,43	3,03
Ocotea corymbosa (Meisn.) Mez.	2	1,9	3,85	3,06	2,94
Myrciaria sp.	3	2,86	3,85	1,82	2,84
Myrcia subcordata DC.	2	1,9	3,85	0,96	2,24
Machaerium opacum Vogel	2	1,9	3,85	0,26	2,00
Citrus limon (L.) Osbeck	2	1,9	3,85	0,16	1,97
Casearia decandra Jacq	2	1,9	3,85	0,14	1,96
Corymbia citriodora (Hook.) K.D.Hill & L.A.S.Johnson	1	0,95	1,92	1,46	1,44
Lonchocarpus cultratus (Vell.); A.M.G.Azevedo & H.C.Lima.	1	0,95	1,92	1,24	1,37
Campomanesia reitziana D.Legrand.	1	0,95	1,92	0,64	1,17
Alchornea glandulosa Poepp. & Endl.	1	0,95	1,92	0,42	1,10
Eugenia cerasiflora Miq.	1	0,95	1,92	0,11	1,00
Mollinedia argyrogyna Perkins	1	0,95	1,92	0,09	0,99
Cupania vernalis Cambess.	1	0,95	1,92	0,09	0,99
Zanthoxylum riedelianum Engl.	1	0,95	1,92	0,06	0,98
Cupania ludowigii Somner & Ferrucci	1	0,95	1,92	0,05	0,98
Árvores mortas	1	0,95	1,92	0,05	0,98

Abreviations: NI = Number of individuals; RD = Relative density; RF = Relative frequency; RDo = Relative dominance; IV = Importance value.

Source: Prepared by the authors (2021).

The *Sebastiana brasiliensis* species ranks second in IV, with high density (16 individuals) and high dominance when considering the phytosociological parameters of the restored area. *S. brasiliensis* would also be the second most important in that stretch if we removed the introduced species from the plantation in the restored area. (*S. cumini*, *S. terebinthifolia*) and invasive *M. nigra* signal structural convergence among the studied areas.

The native area presented a mature aspect following the proposed criteria by Budowski (1970), with more than 50 % of its canopy formed by individuals of late successional species (FIGURE 3). Late secondary (LS) accounted for 42.32 % RF, 56.18 % RD, 35.05 % RDo and 44.52 % IV, while P and IS totaled, respectively, 13.45 % and 32,69 % RF, 13.33 % and 23.79 % RD, 5.93 % and 55.53 % RDo and 10.91 % and 37.34 % IV. The largest domain of IS in RDo is due to the species *I. edulis* as it presented high values of this parameter with individuals with a large basal area.

In some plots a greater number of initial species was recorded characterizing environments of natural clearings caused by dead trees that opened spaces in the canopy. This effect does not denote fragment instability but only a movement between equilibrium stages once the ecosystem is not static but dynamic responding to disturbances (GUNDERSON, 2000). This sampled dynamism with the edge effect close to the river bank led to a considerable representation of species with initial characteristics. Mainly of which is reached 37.34 % IV while the P presented lower IV (10.91 %). Exotics had low IV values and few individuals (3).

Regarding long-term restoration and conservation, it seems more interesting and essential to recover the integrity and stability of ecological relationships instead of aiming for an ecosystem with the same structure as the original one. For example, bauxite mines, the fertile soil layers are lost and it is essential to use nitrogen-fixing species, exotic species or not previously existing soil layers in the site so that the soil can be recovered to contain minimal conditions to receive propagules from neighboring native areas. Thus, it is expected that restoration occurrs after recovery when considering the establishment of a successional facilitation model due to early species giving way to those that later enter the fragment (CAMPELLO, 1998).

Regarding the functional diversity role, we can say that the redundancy hypothesis recognizes that different types of ecological functionality are necessary to generate stability but the redundancy of functions resulting from the emergence of new species does not cause a proportional increase in stability (PETERSON *et al.*, 1998). The diversity-stability hypothesis differs from the redundancy hypothesis in saying that there is a linear increase in stability when the number of species increases as oppose to idiosyncrasy hypothesis which says that the ecosystem is altered with the arrival of new species allowing it to predict the direction and the size of these changes (JOHNSON *et al.*, 1996).

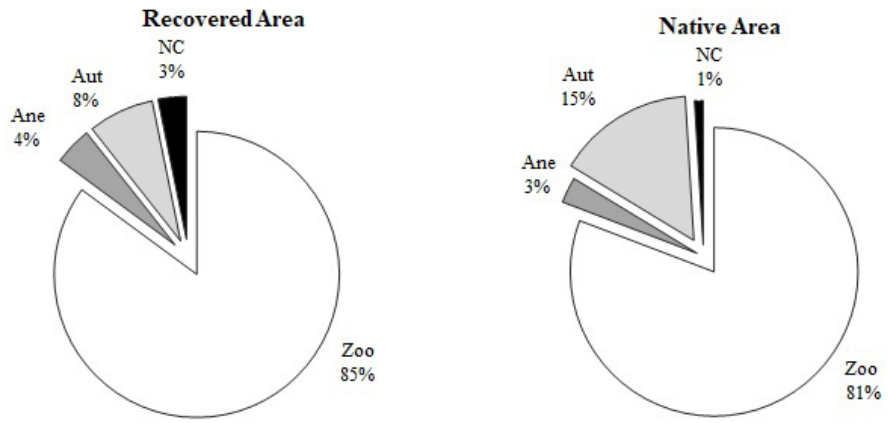
Therefore, species composition and increased diversity play an important role in stability. Either by maintaining various ecological processes through different species characteristics such as species capable of symbiotically associating themselves with mycorrhizal fungi or by increasing the probability of appearing species with similar functions that would mitigate future disturbances (MCCANN, 2000).

According to Souza and Batista (2004), species diversity depends on the proximity of the restored stretch to fragments that donate propagules (fruits and seeds) and the absence of natural barriers that prevent the arrival of propagules dispersers that occurs in the studied stretch. Consequently, it is expected that over time there will be greater similarity between the recovered fragment and the native fragment due to the geographical proximity between them.

Dispersion syndromes and diametric structure

Both areas of the present study showed a high percentage of zoochoric plants (TABLE 1; FIGURE 4). The zoochoric species accounted for 80 % RF, 85.09 % RD, 91.45 % RDo and IV was of 85.52 % in recovered area while in the

Figure 4. Percentage of individuals of species with different types of dispersion syndromes sampled by Machado river´s recovered and native riparian forest stretches within a property in the municipality of Poço Fundo, MG.



Abreviations: Zoo = Zoocoria; Ane = Anemochory; Aut = Autochory and NC = No characterization.
Source: Prepared by the authors (2021).

native area the zoochoric species accounted for 82.69 % for the same parameters, respectively, 80.92 %, 75.72 % and 79.78 %.

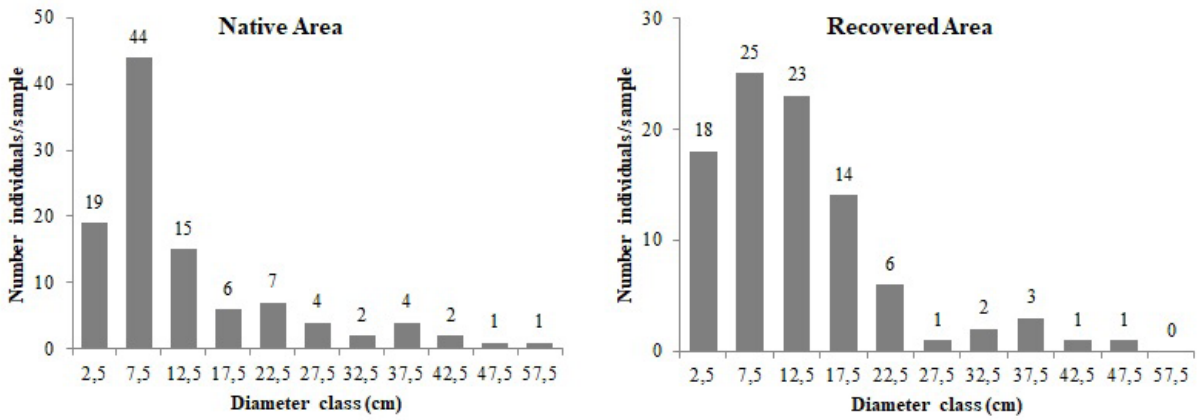
Zoochoric species tend to provide great interaction between species and improve environmental conditions promoting the colonization of plants in different successional categories (REIS; KAGEYAMA, 2003). Since these plants are attractive to fauna, they end up promoting interspecific encounters, consumer and predator nights. They play an important role in the recovery of degraded areas; in addition, they increase the diversity of species with varied ecological mechanisms in the fragment, its capacity to react to disturbances and consequently increasing their own stability. Thus, in case of extinction and addition of species, it is necessary to know their ecological mechanisms in order to cause the expected effect in the dynamics of the species in the restored stretch (MCCANN, 2000).

When analyzing the diametric structure, both the restored and the native area showed a tendency to the inverted J model (FIGURE 5). Such behavior indicates that the communities do not have problems to regenerate due to the high number of individuals in the smallest diameter classes (SILVA; NASCIMENTO, 2001).

The lower concentration of individuals in the first diametric class in the two studied areas (FIGURE 5) indicates that both are under the action of the same disturbances. These disturbances may be related to the frequent opening of trails to access the margins of Machado river and to the traffic of people and the consequent selective removal of regenerating individuals. Individuals in the initial diametric classes characterize a stock community in which there are recruits ready to re-establish the species balance even if dirtubance uccurs (SCOLFORO *et al.*, 1998).

The smaller number of individuals in the first diametric class in the two studied areas may also be related to differences in growth between plants with rapid transition from one class to another. The delay in transition in slower-growing plants or conditions such as shading of pioneer plants that would impede their transition would lead to an accumulation in the next class (SCOLFORO *et al*., 1998). It should also be considered that in riparian areas the variation in water level and floods influence the establishment of vegetation due to the conditions imposed by the environment, such as the differentiation of the floristic composition and the prevalence of larger diameter individuals (BALESTRIN *et al*., 2019).

Figure 5. Distribution of number of individuals within diametric classes in the phytosociological sampling along the stretches of recovered and native riparian forest by the margin of Machado river in a property in the municipality of Poço Fundo, Minas Gerais.



Source: Prepared by the authors (2021).

Most individuals (64.7 %) of the first diametric class are late species within the recovered area that has its canopy formed by early species. These young individuals of late species (*Guarea macrophylla*, *Casearia decandra*, *Calophyllum brasiliense*, *Sebastiania brasiliensis*, *Nectandra lanceolata*) are starting the regeneration in the area and will possibly integrate the future floristic composition in a more advanced successional moment. Among the late species, the only ones that were not sampled in the native area are *C. brasiliense* and *N. lanceolata*. *C. brasiliense* was introduced by project approved by the State Forestry Institute which aimed to recover the stretch in 2003.

The native area that has a canopy formed by late species also showed the majority of individuals of late species in the smallest diameter class (56.25 %). Such species did not evolve to reach the next class probably due to canopy openings (clearings) observed during the survey. These clearings may increase their competition with early species in the smallest diameter class. In the next class (7.5 cm), the proportion of late species rises to 70.7 % and the graph assumes the appearance of a J-inverted (FIGURE 5), with small changes and characteristics of areas with continuous regeneration.

Final considerations

The analysis diversity richness and phytosociological parameters between the analyzed areas showed no floristic convergence between the two studied areas yet structural convergence 13 years after the implementation of the restoration project.

The recovered area is in the initial stage of secondary succession (predominance of pioneer and initial secondary species), while the native area is in the medium late successional stage (predominance of late secondary species). There is a predominance of zoochoric species in both studied areas.

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