Impacts of artificial reservoirs on floristic diversity and plant functional traits in dry forests after 15 years

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Abstract

Dams are of paramount importance to a wide variety of human services and many of their environmental problems are known; however, there are few studies in the world addressing the impacts on the native vegetation previously distant from water bodies which became close to the lakeshore created by a dam. Thus, this paper aims to analyze the responses of a dry forest to a dam after 15 years. For this, 20 random samples of 40 trees were made, 10 close to the lakeshore and 10 distant from it, by applying the central square point method. Close to the dam, we found higher values regarding basal area, number of trees, number of evergreen trees, and zoochoric syndrome, but there were lower values of Shannon's diversity index. Therefore, the impacts of the dam after 15 years caused several changes to the tree community. The greater basal area close to the dam suggests that water deficit during the dry season was decreased and plants have thicker trunks. On the other hand, this sector had much more zoochoric syndrome and a larger number of evergreen trees than plots which are distant from water, suggesting changes with regard to the community's ecological functions. Furthermore, structural floristic data shows that the sector close to the dam is less similar to other deciduous forests within the same geographical region than the sector distant from water, thus providing evidence of the impacts of dams on the tree community.

Keywords: phytosociology, dam impacts, dispersal, deciduousness.

Impactos de um reservatório artificial sobre a diversidade florística e traços funcionais de espécies arbóreas de uma Floresta Estacional Decidual após 15 anos do represamento

Resumo

Barragens são de suma importância para uma ampla variedade de serviços humanos e muitos de seus problemas ambientais já são conhecidos. No entanto, existem poucos estudos no mundo abordando os impactos sobre a vegetação nativa anteriormente distante de corpos d'água, que após a barragem se aproximou do lago criado. Assim, este trabalho tem como objetivo analisar as respostas de uma floresta seca as margens da represa formada por uma barragem após 15 anos. Para isso, 20 amostras aleatórias de 40 árvores foram feitas, sendo 10 perto da margem do lago e 10 distante dele, através da aplicação do método de ponto central. Perto da barragem, encontramos valores mais elevados em relação à área basal, densidade, número de árvores perenifólias e zoocórica, mas houve menores valores de índice de diversidade de Shannon. Portanto, os impactos da barragem depois de 15 anos causou várias mudanças na comunidade de árvores. A maior área basal perto da barragem sugere que o déficit hídrico durante a estação seca foi diminuído, o que aumenta o crescimento em área basal das espécies. Por outro lado, este setor apresentou maior número de indivíduos zoocóricos e número maior de árvores perenifólias do que as parcelas que estão distantes da água, sugerindo mudanças no que diz respeito às funções ecológicas da comunidade. Além disso, os dados florísticos estruturais mostram que o setor perto da barragem é menos similar a outras florestas estacionais deciduais dentro de uma mesma região geográfica que o setor distante da água, proporcionando, assim, evidências dos impactos das barragens sobre a comunidade arbórea.

Palavras-chave: fitossociologia, impactos de barragens, síndrome de dispersão, deciduidade.

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1. Introduction

Historically, dams have facilitated human life; at first, with regard to farming, transportation, and domestic services and, currently, they are built to generate hydroelectric power (Evans et al., 2009). This kind of power is regarded as a clean and cheap alternative, accounting for 16% of the worldwide electricity generation in 2005 (Evans et al., 2009). Nowadays, at least 45,000 dams > 15 m high obstruct 60% of the fresh water flowing into the oceans (Nilsson et al., 2005).

In fact, dams are of paramount importance to a wide variety of human services. However, despite the "clean and cheap" idea attributed to them, many of their environmental problems are known (Nilsson and Berggren, 2000). Due to storage of water, natural habitat becomes fragmented (Nilsson et al., 2005), killing many elements of the flora. The decomposition of dead plants releases organic matter and depletes oxygen in water, and it also emits greenhouse gases (Giles, 2006). Notwithstanding, the impacts of a dam are not limited to the flooded area. The native vegetation previously distant from water bodies which became close to the lakeshore created by a dam represents long-term consequences, because this new "riparian vegetation" is completely distinct from an original riparian environment with regard to species and characteristics.

For instance, original riparian vegetation has species adapted to water saturation and species adapted to patches with water deficit (Bertrand et al., 2012). These environments are associated to many ecological functions, such as terrestrial-aquatic linkage of habitats, and they provide animals, such as birds and seed-dispersing mammals, with resources (Gundersen et al., 2010) and refuge (Palmer and Bennett, 2006), thus playing a key role in diversity maintenance.

However, the vegetation which became close to the lakeshore created by a dam is often located on hillsides (Truffer et al., 2003), without species associated to water saturation, and, then, with different species and distinct traits when compared to a typical riparian vegetation (Acker et al., 2003). Steep slope terrains reduce water infiltration into the soil, making it dry; species from these environments are adapted to reduce water loss, for instance, by losing leaves during the dry season or having fruits and seeds with low water content (Sidle et al., 2006). Thus, the impacts of a dam are not limited to the consequences of closeness to a water body to species adapted to water deficit. Will the "new riparian vegetation" play the same ecological role as that played by a typical riparian vegetation?

Changes to vegetation are critical because plants are primary producers and the basal component in most ecosystems (Loreau et al., 2001). However, most studies focus on dam impacts on grass, herbs, and shrubs and they are often conducted in temperate environments with low species diversity (Nilsson et al., 1997; Jansson et al., 2000; Nilsson and Svedmark, 2002; Mallik and Richardson, 2009), although most dams are built in tropical systems with high species diversity, with a predominance of trees (Guo et al., 2007).

Thus, this paper evaluates the upstream effects of the dam on a dry forest in the Southeast Brazilian region. This kind of forest is associated to mountainous or, at least, steep terrain, thus, it is an excellent object for studying changes to other forests undergoing a similar impact. This kind of forest have a marked dry season, therefore, many plant species lose their leaves in winter as a protective action against an excess of evapotranspiration (Murphy and Lugo, 1986) and diaspores with wing-like structures facilitate their seed dispersal (Vale et al., 2010). Both traits, often observed in dry environments, are unusual in humid environments, due to high air moisture, plant foliage hampers wind dispersal, and the excess volume of water is constant throughout the year. It is difficult to predict what happens when this kind of vegetation becomes close to a water body, such as a dam, as this represents a total change to the relationship of water to flora.

This paper aims to analyze the responses of a dry forest to the Miranda Hydroelectric Power Plant, in the Southeast Brazilian region, after 15 years. We evaluated two sectors of this forest; one is far from and the other is close to the reservoir margin, considering the environmental changes due to the dam. The main objectives of this paper were: i) identifying differences on the structure and parameters of flora, such as basal area, number of trees, richness and diversity in both sectors; and ii) investigating differences on the functional traits having leaf deciduousness and dispersal mechanism as a basis. We assumed the hypothesis that the impacts of the dam after 15 years caused several changes to dry forest structure, then, the sector close to the reservoir margin show more differences when compared to the sector distant to from it.

2. Methods

The study was carried out in a dry forest (18°54'03" S and 48°01'25" W) located at the margins of the Miranda Hydroelectric Power Plant (MHPP), in the town of Indianópolis, Minas Gerais, Brazil. The forest fragment has 35.4 ha and it is within the Araguari river basin. The MHPP was the second dam built in the Araguari river; it was completed in 1997, flooding a very large area. From then on, the study area undergoes the influence of water on the environment, totalizing 15 years until the time this study was conducted, in 2012. The tree community was evaluated in two sectors: A, 200 m far from the reservoir margin; and B, close to the reservoir margin. At the reservoir margin, the sample points were established, since it included, the tree nearest to the dam margin.

Dry forests occur in seasonal climate, with a long dry period (from 2 to 6 months). Average annual temperature is between 23 and 25°C and annual rainfall ranges from 1,160 to 1,460 mm (Alves and Rosa, 2008). It has species exhibiting functional phenology and reproductive responses adapted to dry seasonal climate, i.e. very different from species found in tropical rainforests (Miles et al., 2006). Besides, the study area is located on a rocky and shallow soil and on a steeply declined terrain. These characteristics favor water drainage and hamper soil water storage. Besides,

dry forests are regarded as endangered environments (Miles et al., 2006); nowadays, they are often impacted by dams, because they are associated to mountains and, thus, hydroelectric power generation.

Sampling was conducted by means of the central square point method (Cottam and Curtis, 1956). According to this method, each point means 4 sampled trees, those closest to the central square point. Thus, it was possible to calculate the phytosociological parameters (density, frequency, basal area, and importance value) for the different forest sectors (A and B). We randomly selected 10 points which served as the beginning for sampling in each forest sector. Starting from each point we sampled 10 central square points (totaling 40 trees) that were considered one sample. Then we repeated this proceeding 10 times in parallel to the dams margin, totalizing 10 samples in each sector (A - 200 m far from the reservoir margin; and B, close to the reservoir margin). All trees with a diameter at breast height (DBH) ≥ 5 cm were sampled. The trees were identified at the species level and the distance from the central square point was measured. The botanic material was taken to the Laboratory of Plant Ecology of Uberlândia Federal University, and the taxonomic arrangement was based on the phylogenetic position of the APG III system (Chase and Reveal, 2009).

According to their dispersal mechanism, having fruit morphology as a basis (van der Pijl, 1982), the species were classified as zoochoric (dispersal by animals), anemochoric (dispersal by wind), and autochoric (dispersal by gravity). The species were also classified, according to the fall of leaves during the dry season, as evergreen (do not lose all leaves) or deciduous (lose all leaves), based on field observation and the literature (Lopes et al., 2012).

Phytosociological parameters were calculated for each species, using the software *Fitopac 1.6* (Shepherd, 2004). We compared floristic parameters (species richness, total density, total basal area, and Shannon's diversity) to functional traits (dispersal mechanism and leaf deciduousness) by means of Student's t-test and Mann Whitney's test (non-parametric data) (Magurran, 2004).

To evaluate the β diversity in the study area, we selected other eight studies addressing dry forests (Table 1). These forests do not suffer influence of any water course. Thus, we conducted floristic comparisons between the two forest sectors (A and B) and those from other studies, in order to simulate a floristic dissimilarity test, calculated by means of the Jaccard index and Morisita-Horn similarity index (Magurran, 2004). Through the values obtained from these indexes, we performed two clusters analysis using the method of grouping the Unweighted Pair Group Method with Arithmetic Mean (UPGMA), calculated by the software *Fitopac 1.6* (Shepherd, 2004).

3. Results

We sampled 64 species in sector A (far from the reservoir margin) and 54 species in sector B (close to the reservoir margin). Shannon's diversity in sector A (3.40) was significantly higher than that in the sector B (3.20) (Table 2); otherwise, the basal area and the number of individuals were significantly lower in sector A (23.32 $m^2.ha^{-1}$ and 1,542 $ind.ha^{-1}$) than in sector B (34.43 $m^2.ha^{-1}$ and 2,672 $ind.ha^{-1}$) (Table 2).

Regarding the functional traits, we found significant differences both in the dispersal mechanism and leaf deciduousness. Sector A showed a significantly higher anemochory (41%) than sector B (23%) and lower zoochory (46% in A and 62% in B). As for the leaf deciduousness, sector A showed to be significantly more deciduous (58%) than B (39%) and, at the same time, it has less evergreen trees (42% in A and 61% in B).

In sector A, the five most representative families were Anacardiaceae (23%), Fabaceae (19%), Rhamnaceae (8%), Malvaceae (7%), and Sapindaceae (5%), representing 62% of individuals and 33% of total species (Table 3). In sector B, the five most representative families were Primulaceae (22%), Fabaceae (18%), Anacardiaceae (14%), Malvaceae (8%), and Piperaceae (7%), representing 68% of individuals and 40% of total species (Table 3). Caricaceae, Euphorbiaceae, Monimiaceae, Nyctaginaceae, and Rutaceae were found only in sector A. There were no families exclusive to sector B (Table 3).

Out of the 78 species sampled in both sectors, 24 species (31%) were exclusive to sector A and 14 (18%) were

Table 1. Structure parameters of the eight areas compared to the two sectors of this study.

Areas	Municipality	F	S	NI	BA	H'	References
A	Uberlândia	29	64	1542	23.32	3.39	Presente estudo (TL)
B	Uberlândia	24	54	2672	34.42	3.20	Presente estudo (TP)
1	Alpinópolis	24	50	1094	13.49	2.97	Fagundes et. al. 2007
2	Araguari	27	59	1082	N/Inf.	2.84	Souza et al 2007
3	Montes Claros	26	61	3293	N/Inf.	3.30	Santos et al., 2007
4	Passos	21	39	550	18.06	2.97	Fagundes et al., 2007
5	Perdizes	46	114	1771	24.14	3.74	Werneck et al., 2000
6	Santa Vitória	30	60	1225	N/Inf.	2.89	Carvalho et al., 1999
7	Uberlândia	32	64	1695	16.25	2.76	Siqueira et al., 2009
8	Uberlândia	22	46	937	14.02	2.59	Siqueira et al., 2009

F = number of families; S = richness; NI = number of individuals (ind.ha⁻¹); BA = basal area (m².ha⁻¹); H' = Shannon index.
N/Inf. = No information.

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Table 2. Comparison of floristic parameters and functional traits of the tree community* at two sectors of a dry forest in the Southeast Brazilian region.

Parameters	Sector A**	Sector B***	T	P
Richness (S)	64	54	1.03	0.32
Shannon's diversity (H')	3.39	3.20	2.06	< 0.05
Basal area (m².ha⁻¹)	23.32	34.43	2.53	< 0.05
Individuals (ind.ha⁻¹)	1,542	2,672	6.82	< 0.05
Anemochory (%)	41	23	4.18	< 0.05
Autochory (%)	13	15	0.26	0.79
Zoochory (%)	46	62	2.84	< 0.05
Deciduousness (%)	58	39	2.66	< 0.05
Evergreen trees (%)	42	61	2.65	< 0.05

T = value of Student's t-test; P = probability value of Student's t-test. *DBH ≥ 5 cm. **Distant from the reservoir margin. ***Close to the reservoir margin.

Table 3. Tree community* sampled in two sectors, A** and B***, of a dry forest in the Southeast Brazilian region, alphabetically arranged according to botanical families.

Family/species	RD A	RD B	RF A	RF B	RBA A	RBA B	IV (%) A	IV (%) B	DS	Dec
Anacardiaceae										
Astronium fraxinifolium Schott ex Spreng.	1.75	0.50	2.16	0.61	1.10	0.20	5.01	1.31	Ane	D
Lithraea molleoides (Vell.) Engl.	1.50	4.25	1.85	4.86	1.41	2.29	4.76	11.40	Zoo	E
Myracrodruon urundeuva Allemão	18.75	9.50	16.67	10.94	17.86	16.86	53.28	37.30	Ane	D
Tapirira guianensis Aubl.	0.75	-	0.93	-	2.08	-	3.76	-	Zoo	E
Annonaceae										
Rollinia sylvatica (A. St.-Hil.) Mart.	0.25	0.50	0.31	0.61	0.04	0.49	0.60	1.60	Zoo	E
Apocynaceae										
Aspidosperma cuspa (Kunth) S. F. Blake ex Pittier	0.75	-	0.93	-	0.77	-	2.45	-	Ane	D
Aspidosperma discolor A. DC.	-	0.25	-	0.30	-	0.03	-	0.59	Ane	D
Aspidosperma parvifolium A. DC.	0.50	-	0.62	-	1.70	-	2.82	-	Ane	D
Araliaceae										
Dendropanax cuneatus (DC.) Decne. & Planch	-	0.25	-	0.30	-	0.05	-	0.60	Zoo	E
Sciadodendron excelsum Griseb.	0.25	0.25	0.31	0.30	0.33	1.39	0.89	1.95	Zoo	D
Arecaceae										
Acrocomia aculeata (Jacq.) Lodd. ex Mart.	0.50	1.00	0.62	1.22	2.79	5.07	3.91	7.29	Zoo	E
Bignoniaceae										
Handroanthus serratifolius (Vahl) S. O. Grose	0.50	-	0.62	-	0.27	-	1.39	-	Ane	D
Tabebuia roseoalba (Ridl.) Sandwith	0.25	1.50	0.31	1.82	0.51	0.56	1.06	3.89	Ane	D
Burseraceae										
Protium heptaphyllum (Aubl.) Marchand	1.00	1.00	0.93	1.22	3.61	0.40	5.53	2.61	Zoo	E
Cannabaceae										
Celtis iguanaea (Jacq.) Sarg.	1.00	-	1.23	-	0.79	-	3.03	-	Zoo	D
Trema micrantha (L.) Blume	1.00	0.50	1.23	0.61	0.32	0.08	2.56	1.19	Zoo	E
Caricaceae										
Jacaratia spinosa (Aubl.) A. DC.	0.25	-	0.31	-	0.27	-	0.83	-	Zoo	E
Combretaceae										
Terminalia glabrescens Mart	1.50	0.75	1.85	0.91	0.77	0.46	4.12	2.12	Ane	D
Terminalia phaeocarpa Eichler	2.25	0.50	2.78	0.61	2.88	0.70	7.91	1.81	Ane	D

RD = relative density; RF = relative frequency; RBA = relative basal area; IV = importance value; DS = dispersal syndrome; Dec = deciduousness; Ane = anemochoric species; Auto = autochoric species; Zoo = zoochoric species; D = deciduous; E = evergreen. *DBH ≥ 5 cm. **Distant from the reservoir margin. ***Close to the reservoir margin.

Table 3. Continued...

Family/species	RD		RF		RBA		IV (%)		DS	Dec
	A	B	A	B	A	B	A	B		
Euphorbiaceae										
Pera glabrata (Schott) Poepp. ex Baill.	0.25	-	0.31	-	0.10	-	0.66	-	Auto	E
Fabaceae										
Acacia polyphylla DC.	0.25	1.25	0.31	1.22	0.46	0.30	1.02	2.77	Auto	D
Anadenanthera colubrina (Vell.) Brenan	2.00	4.75	2.16	4.26	8.08	8.25	12.25	17.25	Auto	D
Deguelia costata (Benth.)	9.00	2.75	5.56	2.13	3.00	0.65	17.55	5.53	Ane	E
Enterolobium contortisiliquum (Vell.) Morong	-	0.75	-	0.91	-	3.89	-	5.55	Auto	D
Inga sessilis (Vell.) Mart.	0.75	3.25	0.93	3.34	0.55	3.09	2.23	9.69	Zoo	E
Inga vera Willd.	1.00	0.50	1.23	0.61	0.56	0.81	2.80	1.92	Zoo	E
Lonchocarpus cultratus (Vell.) Az.-Tozzi & H. C. Lima	1.75	2.00	1.85	2.13	5.37	3.35	8.97	7.48	Auto	D
Machaerium hirtum (Vell). Stellfeld	-	0.50	-	0.61	-	2.79	-	3.90	Ane	D
Machaerium stipitatum (DC.) Vogel	0.25	0.50	0.31	0.61	0.12	1.85	0.68	2.96	Ane	D
Piptadenia gonoacantha (Mart.) J. F. Macbr.	2.50	1.25	3.09	1.52	2.41	1.93	8.00	4.70	Auto	D
Platypodium elegans Vogel	-	0.25	-	0.30	-	0.14	-	0.69	Ane	D
Sweetia fruticosa Spreng	-	0.25	-	0.30	-	0.15	-	0.70	Ane	D
Zollernia ilicifolia (Brongn.) Vogel	1.00	-	1.23	-	0.28	-	2.51	-	Auto	E
Lauraceae										
Endlicheria paniculata (Spreng.) J. F. Macbr.	0.50	-	0.62	-	0.66	-	1.78	-	Zoo	E
Nectandra cissiflora Nees	0.50	0.75	0.62	0.91	2.28	0.90	3.40	2.56	Zoo	E
Ocotea corymbosa (Meisn.) Mez	0.25	-	0.31	-	0.10	-	0.65	-	Zoo	E
Ocotea spixiana (Nees) Mez	-	0.50	-	0.61	-	0.16	-	1.27	Zoo	E
Lecythidaceae										
Cariniana estrellensis (Raddi) Kuntze	3.25	1.25	2.78	1.52	11.65	1.92	17.68	4.69	Ane	D
Malvaceae										
Ceiba speciosa (A. St.-Hil.) Ravenna	0.25	-	0.31	-	1.34	-	1.90	-	Ane	D
Guazuma ulmifolia Lam.	6.25	5.25	6.48	6.38	5.07	2.12	17.80	13.75	Auto	E
Luehea divaricata Mart.	0.25	2.50	0.31	2.43	0.21	0.87	0.77	5.80	Ane	D
Luehea grandiflora Mart. & Zucc.	-	0.25	-	0.30	-	0.06	-	0.62	Ane	D
Sterculia striata A. St.-Hill. & Naudin	0.25	-	0.31	-	0.38	-	0.94	-	Zoo	D
Meliaceae										
Cedrela fissilis Vell.	-	0.50	-	0.61	-	0.07	-	1.18	Ane	D
Guarea guidonia (L.) Sleumer	1.75	2.75	1.54	2.74	1.45	1.23	4.75	6.71	Zoo	E
Trichilia elegans A. Juss.	0.75	2.00	0.62	2.13	0.18	0.75	1.55	4.87	Zoo	E
Trichilia palida Sw.	-	0.50	-	0.61	-	0.20	-	1.30	Zoo	E
Monimiaceae										
Mollinedia widgrenii A. DC.	1.00	-	0.62	-	0.62	-	2.24	-	Zoo	E
Moraceae										
Ficus citrifolia Mill.	0.25	-	0.31	-	0.17	-	0.73	-	Zoo	E
Ficus trigona L. f.	0.25	0.50	0.31	0.61	0.40	0.70	0.96	1.81	Zoo	E
Maclura tinctoria (L.) Steud	-	0.25	-	0.30	-	0.05	-	0.60	Zoo	D
Myrtaceae										
Campomanesia velutina (Cambess.) O. Berg	1.00	1.00	1.23	1.22	0.32	0.43	2.55	2.65	Zoo	D
Eugenia florida DC.	0.50	0.50	0.62	0.61	0.23	0.13	1.35	1.24	Zoo	E
Myrcia splendens (Sw.) DC.	1.75	0.25	2.16	0.30	0.48	0.29	4.39	0.84	Zoo	E
Myrcia tomentosa (Aubl.) DC.	0.75	-	0.93	-	0.23	-	1.90	-	Zoo	D
Psidium guajava L.	0.25	0.25	0.31	0.30	0.04	0.04	0.60	0.59	Zoo	E

RD = relative density; RF = relative frequency; RBA = relative basal area; IV = importance value; DS = dispersal syndrome; Dec = deciduousness; Ane = anemochoric species; Auto = autochoric species; Zoo = zoochoric species; D = deciduous; E = evergreen. *DBH ≥ 5 cm. **Distant from the reservoir margin. ***Close to the reservoir margin.

Table 3. Continued...

Family/species	RD		RF		RBA		IV (%)		DS	Dec
	A	B	A	B	A	B	A	B		
Nyctaginaceae										
Guapira venosa (Choisy) Lundell	0.25	-	0.31	-	0.16	-	0.72	-	Zoo	E
Piperaceae										
Piper aduncum L.	-	7.00	-	6.38	-	3.09	-	16.47	Zoo	E
Piper amalago L.	2.00	-	1.85	-	0.54	-	4.39	-	Zoo	E
Primulaceae										
Ardisia ambigua Mez	-	0.75	-	0.91	-	0.20	-	1.86	Zoo	E
Myrsine umbellata Mart	4.75	20.75	5.25	14.59	4.10	16.51	14.10	51.85	Zoo	E
Rhamnaceae										
Rhamnidium elaeocarpum Reissek	8.25	6.25	8.02	5.47	3.63	10.25	19.90	21.97	Zoo	D
Rubiaceae										
Alibertia edulis (L. C. Rich.) A. Rich. ex DC.	0.25	-	0.31	-	0.06	-	0.62	-	Zoo	E
Chomelia pohliana Müll.Arg	0.25	1.50	0.31	1.82	0.04	0.62	0.60	3.94	Zoo	E
Coutarea hexandra (Jacq.) K. Schum.	1.00	0.75	1.23	0.61	0.43	0.24	2.66	1.59	Ane	D
Simira sampaioana (Standl.) Steyerm.	0.25	-	0.31	-	0.12	-	0.68	-	Ane	D
Rutaceae										
Zanthoxylum riedelianum Engl.	0.50	-	0.31	-	0.13	-	0.94	-	Zoo	E
Salicaceae										
Casearia gossypiosperma Briq	1.75	0.25	1.85	0.30	0.43	0.03	4.03	0.59	Zoo	D
Casearia rupestris Eichler	1.75	-	1.54	-	1.27	-	4.56	-	Zoo	D
Casearia sylvestris Sw.	0.25	-	0.31	-	0.03	-	0.59	-	Zoo	E
Sapindaceae										
Allophylus racemosus Sw.	1.50	0.25	1.54	0.30	0.40	0.07	3.44	0.62	Zoo	E
Cupania vernalis Cambess.	-	0.25	-	0.30	-	0.03	-	0.59	Zoo	E
Dilodendron bipinnatum Radlk	3.50	1.25	3.09	1.52	2.12	0.56	8.71	3.33	Zoo	D
Matayba elaeagnoides Radlk.	0.25	0.50	0.31	0.61	0.08	0.10	0.64	1.21	Zoo	E
Sapotaceae										
Chrysophyllum gonocarpum (Mart. & Eichler) Engl.	0.50	-	0.62	-	0.39	-	1.50	-	Zoo	E
Pouteria gardneri (Mart. & Miq.) Baehni	0.25	0.50	0.31	0.61	0.63	0.14	1.19	1.25	Zoo	E
Urticaceae										
Cecropia pachystachya Trécul	0.50	2.25	0.62	2.74	0.44	2.46	1.56	7.44	Zoo	E
Urera baccifera (L.) Gaudich. ex Wedd.	1.00	-	0.93	-	0.75	-	2.67	-	Zoo	D

RD = relative density; RF = relative frequency; RBA = relative basal area; IV = importance value; DS = dispersal syndrome; Dec = deciduousness; Ane = anemochoric species; Auto = autochoric species; Zoo = zoochoric species; D = deciduous; E = evergreen. *DBH ≥ 5 cm. **Distant from the reservoir margin. ***Close to the reservoir margin.

exclusive to sector B (Table 3). The five species with the highest values in the importance value (IV) in sector A were *Myracrodruon urundeuva* (18%), *Rhamnidium elaeocarpum* (7%), *Guazuma ulmifolia* (6%), *Cariniana estrellensis* (6%), and *Deguelia costata* (6%), representing 43% of total IV (Table 3). In sector B, the five species with the highest values in the IV were *Myrsine umbellata* (17%), *Myracrodruon urundeuva* (12%), *Rhamnidium elaeocarpum* (7%), *Anadenanthera colubrina* (6%), and *Piper aduncum* (5%), representing 47% of total IV (Table 3).

Although most species were common to both forest sectors, the relative density of some species significantly differ with regard to disturbance level (Table 3). The species *Myracrodruon urundeuva* (U = 15.5, p < 0.01) and

Cariniana estrellensis (U = 25.0, p < 0.05) showed a significantly higher density in sector A. In turn, higher densities of *Myrsine umbellate* (U = 15.0, p < 0.01), *Piper aduncum* (U = 10.0, p < 0.01), *Luehea divaricata* (U = 29.0, p < 0.05), and *Cecropia pachystachya* (U = 27.0, p < 0.05) were observed in sector B.

The cluster based only in the presence/absence did not results in floristic groups with similarity > 50%, suggesting a high floristic heterogeneity (Figure 1a). Otherwise, the cluster based on the number of individuals results in a group with similarity > 50%, consisting of areas 1, 2, 3, 4, 7, 8 and A (far from the reservoir) (see Figure 1b), mainly due to the high number of individuals of the trees species *Anadenanthera colubrina*, *Myracrodruon urundeuva*,
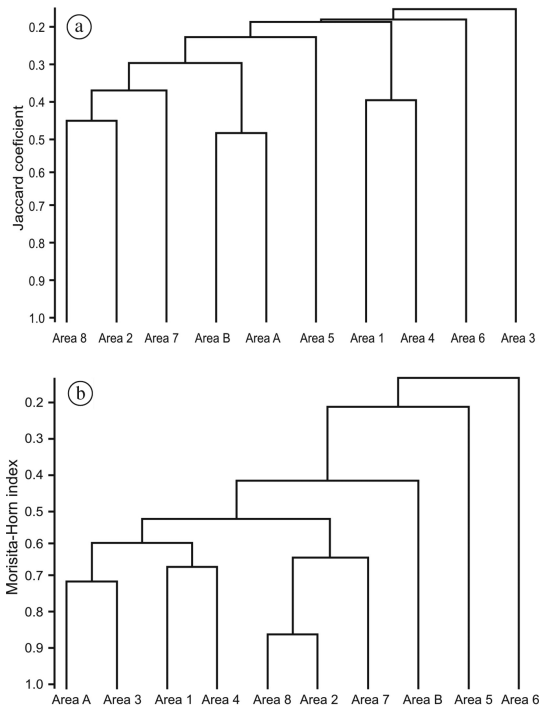
Figure 1. Similarity cluster based on presence/absence of species (a) and species abundance (b) of nine deciduous dry forests in the Southeast Brazilian region. (a) Sector distant from the reservoir margin. (b) Sector close to the reservoir margin.

Guazulma ulmifolia, and *Piptadenia gonoacantha* – all of them frequently observed in dry forests. This first group could be subdivided into two groups, one consisting of areas 1, 3, 4 and A, and the other subgroup consisting of areas 2, 7 and 8. The first group had species such as *Aralia warmingii* and many species of the genus *Trichilia*, while the second had a high abundance of *Campomanesia velutina*, *Casearia rupestris*, *Myracrodruon urundeuva*, and *Tabebuia roseoalba*. However, sector B, close to the reservoir margin, did not form a group with similarity > 50% in this cluster based on the number of individuals, perhaps due to the occurrence of species adapted to soils with a higher water supply, such as *Myrsine umbellata*, *Inga sessilis*, *Guarea guidonia*, *Piper aduncum*, and *Cecropia pachystachya*.

4. Discussion

The differences on the floristic parameters of sector A and sector B may be a consequence of the dam. The lower floristic diversity of sector B may reflect a stressful environmental condition, as low species diversity happen in disturbed environments (Connell, 1971). Water level elevation due to the dam changes the ground moisture, constituting an environmental filter; the role of an environmental filter is selecting species with similar traits able to survive and reproduce in a certain place (Sobral and Cianciaruso, 2012). In this study, the species less able to adapt to the new conditions (high soil moisture) showed

changes in their density and, in the worst scenario, they may be locally extinct (Chase, 2003). Soil influenced by the dam became saturated with water and the dry forest turned into a riparian-like forest, thus, changes in flora are expected (Gusson et al., 2011).

The influence of the number of trees and the basal area was much higher close to the dam than distant to it; this was also higher when compared to non-impacted dry forests whose results, presented in other studies, were compared to the results from this paper (Table 1). These events are probably due to the combination of two abiotic factors, higher soil moisture because of closeness to a water body and good soil nutrition, which constitutes a natural feature of these forests (Gusson et al., 2011). Drought reduces plant growth (Churkina and Running, 1998; Hinckley et al., 1979), since there is a decreased plant photosynthetic capacity (Martin et al., 1994); otherwise, soil fertility increases the plant net yield (Malhi et al., 2004; Phillips et al., 2004). Therefore, combining these factors may increase plant growth, facilitating the establishment of many trees and an increased basal area.

The higher percentage of zoochoric species in sector B when compared to sector A confirms the importance of maintaining the biotic dispersal agents in the forest, mainly in humid patches. Dispersal by animals is more common in tropical humid forests than in seasonal forests (Howe and Smallwood, 1982; Toniato and Oliveira-Filho, 2004). Therefore, the influence of the dam after 15 years showed to be able to change the predominant dispersal mechanism in patches close to the reservoir margin.

Anemochoric dispersal is favored in dry environments (Lima et al., 2010), because the dry diaspores can be easily carried, however, high moisture may wet the seeds, increase their weight, and make them more difficult to be carried (Talora and Morellato, 2000; Spina et al., 2001). Leaf deciduousness also facilitates wind dispersal, because less foliage means less barriers to wind (Spina et al., 2001). Therefore, many anemochoric species lose all their leaves in winter, such as *Myracrodruon urundeuva*, *Piptadenia gonoacantha*, and *Anadenanthera colubrina*, three important species found in sector A. This way, a long dry period without rainfall reduce soil moisture and it may be regarded as a significant stress factor to plants, mainly due to the evapotranspiration process; otherwise, it increases wind dispersal in deciduous plants. Anemochoric plants also can reach a high height by maximizing dispersal effectiveness, due to increased exposition to wind (Pires-O'Brien and O'Brien, 1995; Nunes et al., 2003), thus, many important species in sector A are deciduous, anemochoric, and form a canopy (except *Deguelia costata*)

However, this dispersal mechanism has disadvantages in patches close to the dam. First, because a higher water supply favors the establishment of species non-adapted to dry environments, i.e. less deciduous and more evergreen species will occur, creating barriers to dispersal (Fathi-Moghadam, 2007; Cassiani et al., 2008). Second, because water can be used by zoochoric species to produce bigger and more succulent fruits (Pinheiro and Ribeiro, 2001;

Rodrigues et al., 2010), increasing their presence in the fauna and, as a consequence, increasing the dispersal of their seeds (Gusson et al., 2011). A clear example was *Myrsine umbellata*, a zoochoric and evergreen species with low tolerance to water deficit (Silva and Dillenburg, 2007), but it dominates sector B after 15 years under the influence of the dam. Dry forest associated to mountains are usually very fertile due to the presence of basaltic rocks and there was no other environmental filter able to hinder the establishment of species typical of dry forests; then, the community close to the dam changed its physiognomy after 15 years. Previously, it was a deciduous dry forest with leaves falling in winter and predominant anemochory; now, it is a semideciduous forest with many zoochoric species. This increases the community heterogeneity, because different species are included into the community and this may be regarded as a strong impact on these forests.

The sampled species with high density in both sectors were commonly found in other forests within the same geographical region (Santos et al., 2007; Siqueira et al., 2009), except *Myrsine umbellata*. Most of them are distributed into the Brazilian dry forests, and the most frequently observed species are *Myracrodruon urundeuva* and *Anadenanthera colubrina* (Prado and Gibbs, 1993; Araújo et al., 1997; Linares-Palomino et al., 2009). Meanwhile, in all selected studies, *M. umbellata* had a limited importance, then, it is suggested that the high density of this species only in sector B is due to the dam influence. Perhaps, changes to soil moisture due to the dam favor the establishment of this species. Other study addressing *M. umbellata* on soils with high and low moisture concluded that this species has a low tolerance to hydric deficit, needing a soil with continued access to water in order to establish in warm location with high solar irradiance (Silva and Dillenburg, 2007).

The results make evident a high floristic similarity between sector A, distant from water, and other deciduous forests within the same geographical region. Sector B shows a higher richness of species adapted to high moisture on the soil, such as *Myrsine umbellata*, *Inga sessilis*, *Guarea guidonia*, *Piper aduncum*, and *Cecropia pachystachya*; the latter also indicated high moisture soils, water bodies, or superficial groundwater (Batista et al., 2008). *Guarea guidonia* and *Inga sessilis* are typical of riparian forest associated to rivers and alluvial plains and valleys, i.e. humid environments (Lorenzi, 1998).

The species showing the most significant values in sector A was *Myracrodruon urundeuva*, due to its thick individuals established before the dam was built. Meanwhile, few young individuals of this species were found close to the lakeshore, and this fact suggests that *M. urundeuva* has some problem to establish close to the reservoir. Other studies showed a high mortality and a low prevalence of seedlings, saplings, and young individuals of this species under high soil moisture conditions after the dam was built (Gusson et al., 2011).

The presence/absence did not formed coherent groups and it is possible to point out that there is a high heterogeneity in this forest. Otherwise, the structural similarity analysis divided it into sectors A and B; the first maintains a high number of species typical of dry forests and the second, after 15 years under the influence of the dam, had many species adapted to a high soil moisture condition. Thus, the regional pool of species did not change a lot, but the forest structure became very different: now, the dry forest under study is clearly more heterogeneous, with some species adapted to water saturation. Several of these species have traits commonly found in humid forests, such as zoochoric dispersal and evergreen leaves, then, it is possible to conclude that 15 years undergoing the impacts of a dam were enough to cause several changes to the forest structure, with consequences to vegetations structure, confirming the hypothesis assumed in this paper and also, is probably that the number off zoochory species will, in long-term, influence the associated fauna.

Acknowledgements

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