REVISTA FLORESTA
Engenharia Florestal

ISSN 1982-4688
Edição 54
Universidade Federal do Paraná
Setor de Ciências Agrárias

ECOSYSTEM SERVICE AT RISK: EFFECT OF THE SURROUNDING AREA ON THE SEED BANK IN A PERMANENT PRESERVATION AREA

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Received for publication: 20/01/2024 – Accepted for publication: 16/10/2024

Resumo

Serviço ecossistêmico em risco: efeito da área circundante no banco de sementes em área de preservação permanente. Considerado serviço ambiental de regulação, o banco de sementes tem a capacidade de recuperar áreas degradadas sem a necessidade da intervenção humana. No entanto, esse serviço ambiental tem sido prejudicado em decorrência de atividades antrópicas, especialmente em áreas de preservação permanente (APPs). Diante disto, o objetivo deste estudo foi avaliar os impactos da área circundante sobre o serviço ambiental do banco de sementes na área de preservação permanente das nascentes do rio Apa, localizada no estado de Mato Grosso do Sul, Brasil. Para isso, foram coletas 120 amostras de solo, 60 amostras na APP e 60 na área circundante. As amostras foram cultivadas em casa de vegetação e analisadas após três meses. Foram identificadas 1.055 plântulas, 19 famílias e 48 espécies, sendo 33 na APP e 35 na área adjacente. Destas, as gramíneas representaram 78%, destacando-se Cyperaceae com 391 indivíduos (37%), Poaceae com 334 (33%) e Asteraceae com 82 (8%). Além disso, foram registradas seis espécies arbóreas, correspondendo a 12% da riqueza. Com 60 coletas em cada local, a curva de rarefação não evidenciou estabilidade na riqueza para as áreas amostradas. O estimador de riqueza *bootstrap* indicou estabilidade em 37,95 ± 2,33 na APP e 44 ± 2,75 fora da APP. Desse modo, o banco de sementes da área de preservação apresentou-se floristicamente semelhante à área de pastagem adjacente, confirmando um elevado grau de perturbação e comprometimento do serviço ambiental de regulação que deveria ser prestado pelo banco de sementes.
Palavras-chave: Mata de galeria, restauração ecológica, Serviço ambiental.

Abstract

The seed bank, considered a regulatory ecosystem service, has the potential to restore degraded areas, without the need for human intervention. However, this environmental service has been impaired by anthropogenic activities, including in permanent preservation areas (PPAs). This study investigated the impacts of the surrounding area on the environmental service of the seed bank in the Apa River headwaters PPA, in the state of Mato Grosso do Sul, Brazil. A total of 120 soil samples were collected, 60 each from the PPA and the adjacent area. The samples were cultivated in a greenhouse for three months, followed by analysis. Identification was made of 1,055 seedlings, comprising 19 families and 48 species (33 in the PPA, and 35 in the adjacent area). Of these, grasses accounted for 78%, highlighting Cyperaceae, with 391 individuals (37%), Poaceae, with 334 individuals (33%), and Asteraceae, with 82 individuals (8%). Six tree species were found, representing 12% of the species richness. With 60 samples from each location, the rarefaction curves did not indicate stability of species richness in the sampled areas. The bootstrap richness estimator provided values of 37.95 ± 2.33 for the PPA and 44 ± 2.75 for the area outside the PPA. Hence, the seed banks in the preservation area and the adjacent pasture area were floristically similar, revealing a high degree of disturbance and a compromised seed bank regulatory ecosystem service.
Keywords: Gallery forest; ecological restoration; environmental service.

INTRODUCTION

The Common International Classification of Ecosystem Services and the Millennium Ecosystem Assessment both define ecosystem services as the intrinsic capacity of an ecosystem to provide benefits to humans, either directly or indirectly (Haines-Young & Potschin, 2018). These benefits include the provision of food, wood, and regulation of water, air, soil, and climate quality. However, for these benefits to be fully realized, it is essential to preserve the environments that provide ecosystem services, ensuring that they can perform their ecological functions (Costa *et al.*, 2023). As pointed out by Hua *et al.* (2022), native forests have greater potential to provide environmental services, compared to areas that are degraded or have undergone restoration processes.

The seed bank, defined as a stock of viable seeds and other germinative structures present in the soil, continuously enriched by seed rain, has the capacity to regulate and restore the ecological conditions of ecosystems. It can also serve as an ecological indicator, reflecting the resilience of an ecosystem (Costa *et al.*, 2013; Capellesso *et al.*, 2015). The seed bank can be included among the providers of environmental services, since it can maintain environmental quality, without human intervention. This role makes the seed bank a key factor in ecosystem development and revegetation of degraded areas, aligning with the typologies previously outlined by Haines-Young & Potschin (2018).

In an area designated as a permanent preservation area (PPA), it is expected that the ecosystem service provided by the seed bank will maintain its integrity, given that the purpose of a PPA is to protect priority areas from anthropogenic actions and safeguard the environmental benefits present in that location (Brazil, 2012). However, this outcome has not been observed in many PPAs surrounding rivers and springs (Silva *et al.*, 2016; Lima, 2021). In Brazil, PPAs are often narrow strips of vegetation at constant risk of disturbance, because they are surrounded by extensive agricultural activities (crop and livestock production) that directly affect their structures and compositions (Zambrano *et al.*, 2019). Consequently, there are negative impacts on the ecosystem services provided by the seed bank (Tramontina & Kuplich, 2024).

Although it is widely acknowledged that it is necessary to preserve priority areas such as PPAs, together with the environmental services they provide, these environments still face major threats from anthropogenic activities in their surroundings, which generate environmental disservices (Ferraz *et al.*, 2019). Therefore, the central question to be addressed in this study was: can the environmental service provided by the seed bank in a PPA be affected by agricultural practices in the surrounding area? The hypothesis adopted was that the environmental service that should contribute to the natural recovery process of the PPA around the Apa River headwaters may be altered in its composition and structure, due to the influence of agriculture in the surrounding area. Therefore, the aim of this study was to characterize the composition of the seed bank both inside and outside the PPA, in a region strongly affected by agricultural activities.

MATERIALS AND METHODS

Study area

The study was undertaken at a permanent preservation area surrounding the headwaters of the Apa River, located in the Upper Paraguay River basin, in Ponta Porã, Mato Grosso do Sul, Brazil (22º01’55”S, 55º52’36”W). This river originates in Brazilian territory and establishes a border of over 500 km between Brazil and Paraguay, up to its confluence with the Paraguay River. According to the Köppen-Geiger climate classification, the region has an Am type climate (tropical humid or subhumid), with average annual temperature of 23 °C and average annual precipitation ranging from 1600 to 1900 mm (Alvares *et al.*, 2014). The vegetation is characteristic of Alluvial Seasonal Semideciduous Forest, within the Cerrado biome (IBGE, 2023). Since the Apa River is a transboundary river, the headwaters PPA plays a vital role in delivering ecosystem services for both Brazil and Paraguay.

Despite its importance, the PPA has been constantly impacted by anthropogenic transformations, due to nearby agricultural practices. There is the constant presence of cattle in the surrounding area, resulting in suppression of regenerating vegetation and siltation of the headwaters (Figure 1A). The predominance of activities related to crop and livestock production in the area has resulted in erosive processes caused by intensive and inappropriate land use (Figure 1B).

Figure 1. Areas within (A) and outside (B) the PPA.
Figure 1. Área interna (A) e externa (B) da APP.

The characteristics of the preservation area surrounding the Apa River headwaters made this environment ideal for the purpose of the present study, enabling the investigation and understanding of potential impacts on the environmental services of the seed bank. Since these impacts were due to nearby anthropic activities, there was a valuable opportunity to examine the interactions between human practices and ecosystem integrity, focusing on the role played by the seed bank.

Data collection and analysis

This study was conducted both within and outside the Apa River headwaters PPA. For collections within the PPA, a 400 m transect was established, where 30 soil samples were collected in the summer (PPAs) and 30 in the winter (PPAw). In the area outside the PPA, a parallel 400 m transect was established 300 m away from the preservation area, where 30 samples were collected in the summer (OPPAs) and 30 in the winter (OPPAw).

The samples were collected using a square 20 cm x 20 cm template, every 13.3 m along each transect, to a depth of 5 cm, which was the layer expected to contain the highest quantity of seeds. The samples were transported to a greenhouse with 50% shade, placed in plastic trays, and watered daily. An assessment was performed three months after the start of the experiment. The soil in the trays was then stirred and a further assessment was made after another two months in the greenhouse.

For species identification, the Angiosperm Phylogeny Group IV classification (APG *et al.*, 2016) was used, with the species names being updated based on the species list from the Flora and Funga of Brazil project and SpeciesLink. Seed bank abundance and composition were estimated based on seedling emergence, with successional classification according to the criteria of Gandolfi *et al.* (1995). The determination of species dispersal syndrome was based on Pijl (1982).

To evaluate sampling sufficiency, rarefaction curves were generated for the two sampling locations. A bootstrap estimator was also applied to calculate species richness at each site. These analyses employed R software (version 4.2.2). Species diversity was calculated using Shannon's diversity index (H', with natural logarithm base), and Pielou's evenness index (J'). The floristic similarity between the two environments, considering summer and winter, was calculated based on the emergents in the seed banks, using the Sørensen index.

RESULTS

The seed bank analysis resulted in 1,055 seedlings, belonging to 19 families and 48 species, with 33 species found within the PPA, and 35 in the outside area. Of these, 20 species were common to both areas. Six individuals were identified to the genus level, while two remained unidentified. The three families with the highest numbers of individuals were Cyperaceae, with 391 (37%), Poaceae, with 334 (33%), and Asteraceae, with 82 (8%), together representing 78% of the emergent seedlings.

Within the PPA, during the winter (PPAw), Poaceae was the most abundant family, accounting for 61.1%, with Cynodon dactylon (L.) Pers. being the most prominent species. In the summer (PPAs), 53.8% of the individuals belonged to Cyperaceae, with Cyperus aggregatus (Willd.) Endl. as the most representative species. Outside the PPA in the winter (OPPAw), Poaceae was the most abundant family (72% of the individuals), with Cynodon dactylon (L.) Pers. as the most prominent species (130 individuals). Outside the PPA in the summer (OPPAs), Poaceae was also the most abundant family (37.5%), with Urochloa decumbens (Stapf) R.D. Webster as the most representative species (Table 1).

Table 1. Seed bank species inside and outside the PPA, in winter and summer, where: (p) pioneer; (st) late secondary; (an) anemochorous; (zo) zoochorous; (au) autochorous; (hy) hydrochorous; (her) herb; (shr) shrub; (tre) climber; (arv) tree.

Tabela 1. Espécies do banco de sementes dentro e fora da APP, no inverno e verão. (p) pioneira, (st) secundária tardia. (an) anemocórica, (zo) zoocórica, (au) autocórica e (hi) hidrocórica. (erv) erva, (arb) arbusto, (tre) trepadeira e (arv) árvore.

Famílies / species	Within PPA		Outside PPA		Successional classification	Dispersal syndrome	Life form
	Winter	Summer	Winter	Summer			
Asteraceae							
Achyrocline satureioides (Lam.) DC.			2			an	her
Ageratum conyzoides L.			4		p	an	her
Bidens pilosa L.	19		1		p	zo	her
Gamochaeta americana (Mill.) Wedd.		16			p	an	her
Emilia fosbergii Nicolson	2	1	3		p	an	her
Gnaphalium spicatum Lam.		9		25	p		her
Amarantaceae							
Amaranthus L.			1				her
Aristolochiaceae							
Aristolochia esperanzae Kuntze		1		1	p		shr
Caryophyllaceae							
Drymaria cordata (L.) Willd. ex. Roem. &Schult.				3			her
Commelinaceae							
Commelina benghalensis L.	1	3			p	an	her
Commelina L.		1			p	an	her
Cyperaceae							
Cyperus aggregatus (Willd.) Endl.		101	8	31	p	an	her
Cyperus rotundus L.	4		16		p	an	her
Cyperus brevifolia (Rottb.) endl. ex Hassk.		9	3	39	p		her
Cyperus L.		1		12	p		her
Euphorbiaceae							
Euphorbia hirta L.	35		5	5	p	an	her
Croton urucurana Baill.		6			p	au	arv
Sapium haematospermum Müll.Arg.		1	1		p	zo	arv
Fabaceae							
Desmodium tortuosum (Sw.) DC.	3		1		p	zo	her
Malvaceae							
Malvastrum coromandelianum Garcke		1			p		her
Sida rhombifolia L.		1			p		arb
Sida santaremensis Mont				1	p		arb
Sida spinosa L.			1				arb
Moraceae							
Maclura tinctoria (L.) D.Don ex Steud.		1			st	zo	shr
Phyllanthaceae							
Phyllanthus tenellus Roxb.	10		4	2	p		arb
Plantaginaceae							
Scoparia L.		1	1	10	p	an	her
Poaceae							
Urochloa brizantha (Hochst. ex A.Rich.) R.D. Webster			1				her
Urochloa decumbens (Stapf) R.D. Webster		1	117	74	p	an	her
Urochloa ruziziensis (R.Germ. & Evard) Crins			1				her
Cynodon dactylon (L.) Pers.	130	24	63	7	p	an	her
Eleusine indica (L.) Gaertn.	2	4	1	2	p	an	her
Eragrostis pilosa (L.) P. Beauv.			27				her
Festuca L.			10				her
Paspalum notatum Flüggé		24			p	an	her
Raddia stolonifera R.P.Oliveira & Longhi-Wagner		12		1	p		her

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Portulacaceae							
Portulaca pilosa L.	5		28		p	zo	shr
Talinum paniculatum (Jacq.) Gaertn.q	1			1	P	zo	shr
Talinum fruticosum (L.) Juss.	2				P	zo	shr
Primulaceae							
Myrsine umbellata Mart.			1		p	zo	shr
Pteridaceae							
Asplenium L.		12			p	hy	her
Adiantum humile Kunze		1			p	hy	her
Rubiaceae							
Genipa americana L.			1				shr
Richardia brasiliensis Gomes		6	2	2			her
Galianthe angustifolia (Cham. & Schltdl.) E.L.Cabral			1				her
Urticaceae							
Cecropia pachystachya Trécul		19		6	p	zo	shr
Pilea microphylla (L.) Liebm.	2	48		2	p	an	her

Evaluation of the sampling sufficiency using species rarefaction analysis showed that the 60 collections at each sampling site were insufficient to capture the total species richness in these environments. Figure 2 shows a slight upward trend, suggesting that more sampling might reveal additional species. However, it is noteworthy that Figure 2A, corresponding to the PPA, shows a shallower curve, indicating a greater tendency towards stability. A steeper curve was obtained for the area outside the PPA (Figure 2B), suggesting it was further from reaching stability.

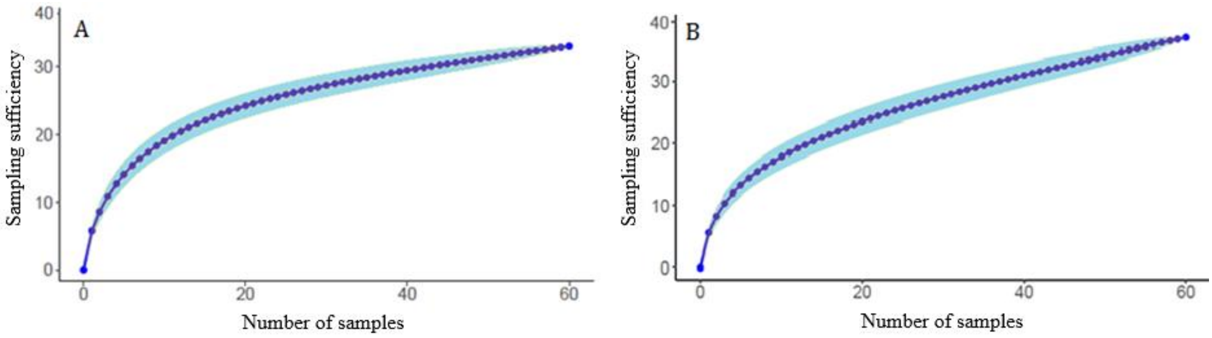

Figure 2. Rarefaction curves for within the PPA (A) and the outside area (B).
Figura 2. Curva de rarefação, dentro (A) e fora da APP (B).

Analysis of species richness using the bootstrap diversity estimator showed differences between the sampled locations. Within the PPA, 33 species were recorded, while the estimator projected 37.95 ± 2.33 species. In the area outside the PPA, 35 species were found, with the estimator projecting 44 ± 2.75 species. Notably, the estimated richness values for the two areas did not overlap, even considering the corresponding standard deviations (40.27 and 41.25, respectively), indicating higher species richness in the area outside the PPA.

In the diversity analysis, the Shannon index (H') showed variation between the two environments, as well as between the winter and summer seasons. Within the PPA, diversity was higher in summer (H' = 2.37) than in winter (H' = 1.40). The same pattern was observed outside the PPA, with diversity being higher in summer (H' = 2.09) and lower in winter (H' = 2.05). These fluctuations in diversity indices were influenced by variations in the species richness and Pielou's evenness values, which were both lower in winter, compared to summer, except for species richness outside the PPA, which was higher in winter (Table 2).

Table 2. Species diversity in the sampled areas in winter and summer. J' = evenness; H' = Shannon diversity index; E.m2 = individuals per square meter.
Tabela 2. Diversidade de espécies nas áreas amostradas no inverno e verão. J'=equabilidade; H'= índice de diversidade de Shannon; E.m2= indivíduos por metro quadrado.

Areas	Indivíduals	Famílies	Species	J'	H'	E.m^2
PPAw	216	9	13	0,54	1,40	120,0
PPAs	311	14	27	0,72	2,37	172,7
OPPAw	304	12	26	0,63	2,05	168,8
OPPAs	224	12	18	0,72	2,09	123,8

In terms of similarity, the determining factor for clustering was not the areas themselves, but rather the seasons (summer and winter). Consequently, two groups were formed: within the PPA in winter (PPAw), grouped with outside the PPA in winter (OPPAw); and within the PPA in summer (PPAs), grouped with outside the PPA in summer (OPPAs). The first group merged at 0.35 similarity and the second at 0.57. The higher the cophenetic correlation of clusters, the greater the reliability of the analysis. In the present case, correlation of 0.83 indicated that 83% of the information was reliably reproduced.

Regarding the growth form of the emergent species in the seed bank, 84% were classified as herbaceous, 12% as trees, and 4% as climbers. For both the PPA and the surrounding area, only four species were classified as trees. No tree species were recorded for PPAw (Figure 3).

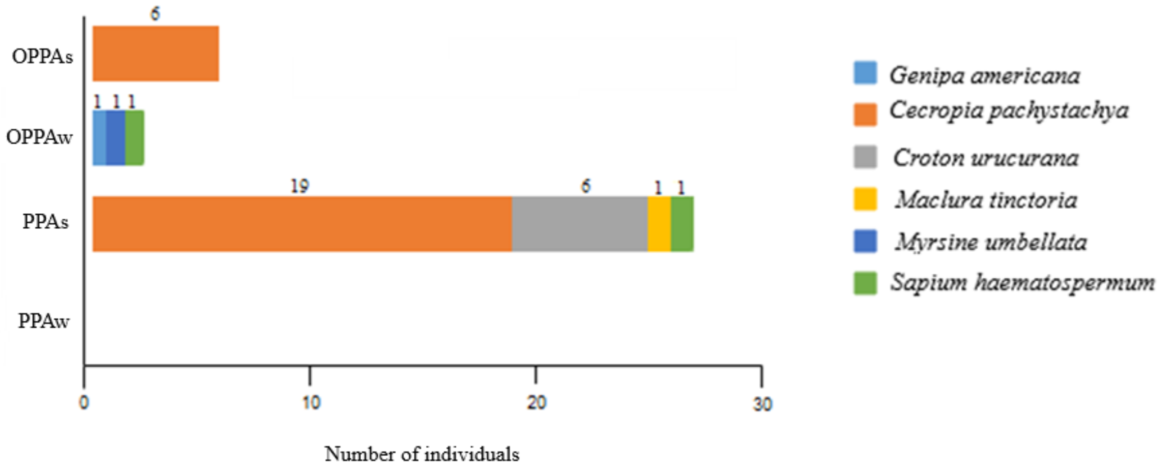

Figure 3. Abundance of tree species in each area and season.
Figura 3. Abundância das espécies arbóreas em cada área e estação.

DISCUSSION

The results indicated that for both the PPA and the surrounding area, the seed bank was dominated by herbaceous plants, particularly grasses. An abundance of herbaceous plants has also been observed in other studies (Medeiros-Sarmento *et al.*, 2021; Narducci *et al.*, 2021), with the presence of these plants, especially from the Poaceae and Cyperaceae families, being associated with pastures in the surrounding areas. The abundance of grasses within these PPAs is concerning, especially because the areas are generally narrow, which facilitates greater entry of the propagules of herbaceous plants into the PPA.

The predominance of invasive exotic grasses, such as *Cynodon dactylon*, *Urochloa decumbens*, and *Cyperus aggregatus*, found in both environments in this study, indicated that the environmental services expected to be provided by the seed bank were under significant anthropogenic pressure. Therefore, it would be necessary to remove the factors causing this disturbance, controlling the exotic species that could inhibit the establishment of native regenerants in the seed bank. The condition of a degraded area can deteriorate further, when exotic species are able to exclude native species by competition. As reported by Hua *et al.* (2022), a lack of native vegetation, combined with low diversity, reduces the ability of an ecosystem to return to its original state, consequently impairing the provision of environmental services. The fact that the sampled areas contained high levels of exotic grass species and early-successional species confirmed the degraded state of the Apa River headwaters region, as also observed by Silva *et al.* (2016) in a study of seed rain as a way to restore these headwaters.

The rarefaction curves for the two areas, each obtained with sixty samples, evidenced that there was no stabilization of species richness. However, despite the rarefaction curves not reaching vertices, a stabilization trend could be seen, as confirmed by the bootstrap estimates, which predicted species richness of 37.95 in the PPA and 44 in the surrounding area. The observed and estimated richness values became even closer when considering the standard deviation of the bootstrap for each area (2.33 and 2.75, respectively). Notably, the seed bank richness was higher outside the PPA than within it, which could be explained by a more open canopy, allowing the entry of light and stimulating seed germination, especially of Poaceae (Martins *et al.*, 2012), the family with the greatest richness in this study.

In the similarity analysis, there was grouping between the different environments: OPPAw with PPAw, and OPPAs with PPAs. This showed that the richness within the PPA had become close to that of its surroundings, which was a degraded environment dominated by grasses. This clustering pattern was also observed by Plue *et al.* (2013). The elongated and narrow (approximately 100 m) shape of the preservation area allowed the influence of edge effects to alter its composition and structure.

The low richness of tree species in both areas indicated that the environmental service that should be provided by the seed bank was severely compromised and inadequate for regulating ecological processes. There are various anthropogenic factors that can cause the suppression of native vegetation (Pinheiro *et al.*, 2020) and lead to a reduction of biodiversity, which is one of the main factors that can intensify the encroachment of grasses into preservation areas (Gonzáles *et al.*, 2020), as observed both inside and outside the PPA of the Apa River headwaters. Furthermore, the low diversity of tree species and dominance of grasses found in this study supports the ecological theory proposed by Odum (2004), which states that the lower the diversity of a community, the more unstable it will be. Therefore, it could be inferred that the locations studied here presented ecological instability, posing a risk to ecosystem services.

As a fundamental characteristic of the environmental service provided by the seed bank in a PPA, it is expected that there should be high potential for recovery of a natural area. However, the sites studied here were observed to have low resilience, negatively impacting the environmental services that should be provided by the seed bank. If a degraded area has high resilience, it has the capacity to recover its ecological processes (Eldridge *et al.*, 2010), but this was not the case for the sites sampled in this study. Furthermore, in addition to compromising resilience, significant disturbance in a community can shift it from a stable state to an alternative and unknown condition, potentially leading to drastic changes in species composition. Therefore, it is necessary to isolate the factors negatively impacting the seed bank and to enrich the area with native tree species. This approach will be essential to ensure the maintenance of environmental services around the Apa River headwaters.

CONCLUSIONS

- The agricultural production systems surrounding the headwaters of the Apa River negatively influenced the seed bank in the region.
- The narrow width of the PPA around the headwaters of the Apa River facilitated the entry and establishment of invasive herbaceous species from adjacent areas, consequently hindering the establishment of native vegetation, including tree species.
- In the two areas studied, the environmental service that should be provided by the seed bank was compromised. Therefore, loss of native vegetation around the headwaters of the Apa River could trigger the germination of a large quantity of invasive grasses such as *Urochloa decumbens*, which were present in the seed bank.

REFERENCES

ALVARES, C. A.; STAPE, J. L.; SENTELHAS, P. C.; GONÇALVEZ, J. L. M.; SPAROVEK, G. Köppen's climate classification map for Brazil. **Meteorologische Zeitschrift**, Stuttgart, v. 22, n. 6, p. 711 - 728, 2014.

APG; CHASE, M. W.; CHRISTENHUSZ, M. J. M.; FAY, M. F.; BYNG, J. W.; JUDD, W. S.; SOLTIS, D. E.; MABBERLEY, D. J.; SENNIKOV, A. N.; SOLTIS, P. S.; STEVENS, P. F. An update of the angiosperm phylogeny group classification for the orders and families of flowering plants: APG IV. **Botanical Journal of the Linnean Society**, Londres, v. 181, n. 1, p. 1-20, 2016.

BRASIL. Lei nº 12.651, de 25 de maio de 2012. Dispõe sobre a proteção da vegetação nativa; altera as Leis nos 6.938, de 31 de agosto de 1981, 9.393, de 19 de dezembro de 1996, e 11.428, de 22 de dezembro de 2006; revoga as Leis nos 4.771, de 15 de setembro de 1965, e 7.754, de 14 de abril de 1989, e a Medida Provisória no 2.166-67, de 24 de agosto de 2001; e dá outras providências. **Diário Oficial da União**, Brasília, DF, vinte cinco de maio de 2012. Disponível em: <http://www.planalto.gov.br/ccivil_03/_Ato2011-2014/2012/Lei/L12651.htm>. Acesso em: 21 maio 2023.

CAPELLESSO, E. S.; SANTOLIN, S. F.; ZANIN, E. M. Banco e chuva de sementes em área de transição florestal no sul do Brasil. **Revista Árvore,** Viçosa. v. 39, n. 5, p. 821-829, 2015.

COSTA, J.; GOMES, L.; PACHECO, D.; PEREIRA L. Ecosystem services provided by seaweeds. **Hydrobiology**, Basileia, v. 2, n. 1, p. 75-96, 2023.

COSTA, J. R.; FONTES, J. R. A.; MORAIS, R. R. **Banco de sementes do solo em áreas naturais e cultivos agrícolas**. Manaus: Embrapa. 1 ed. 2013, 35 p.

ELDRIDGE, D. J.; LUNT, I. D. Resilience of soil seed banks to site degradation in intermittently flooded riverine woodlands. **Journal of Vegetation Science**, Hoboken, v. 21, n. 1, p. 157-166, 2010.

FERRAZ, R. P. D.; PRADO, R. B.; PARRO, L. M.; CAMPANHA, M. M. **Marco referencial em serviços ecossistêmicos**. Brasília: Embrapa, 1 ed. 2019, 121 p.

GANDOLFI, S.; LEITÃO-FILHO, H. F.; BEZERRA, C. L. F. Levantamento florístico e caráter sucessional das espécies arbustivo-arbóreas de uma floresta mesófila semidecídua no município de Guarulhos, SP. **Revista Brasileira de Biologia**, São Paulo, v. 55, n. 4, p. 753-767, 1995.

GONZALEZ, A. V.; GÓMES-SILVA, V.; RAMÍRES, M. J.; FONTÚRBEL, F. E. Meta-analysis of the differential effects of habitat fragmentation and degradation on plant genetic diversity. **Conservation Biology**, Washington, v. 34, n. 3, p. 711-720, 2020.

HAINES-YOUNG, R.; POTSCHIN, M. **Common international classification of ecosystem services** - guidance on the application of the revised structure. Nottingham: European Environment Agency, 5 ed. 2018.

HUA, F.; BRUNIJNZEEL, L. A.; MELI, P.; MARTIN, P. A.; ZHANG, J.; NAKAGAWA, S.; MIAO, X.; WANG, W.; MCEVOY, C.; PEÑA-ARANCIBIA, J.; BRANCALION, P. H. S.; SMITH, P.; EDWARDS, D. P.; BALMFORD, A. The biodiversity and ecosystem service contributions and trade-offs of forest restoration approaches. **Science**, Washington, v. 376, n. 6595, p. 839-844, 2022.

IBGE (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA). **Mapa de biomas do Brasil**. Disponível em: <https://www.ibge.gov.br/geociencias/cartas-e-mapas/informacoes-ambientais/15842-biomas.html> Acessado em: 12/04/2023.

LIMA, M. V. Cattle raising activity and the transformation of the riparian forest of the Orós Dam/CE: A work with students and small cattle ranchers. **Brazilian Journal of Developmente**, São José dos Pinhais, v. 7, n. 9, p. 91148-91162, 2021.

MARTINS, S. V.; RODRIGUES, R. R.; GANDOLFI, S.; CALEGARI, L. Sucessão ecológica: fundamentos e aplicações na restauração de ecossistemas florestais. In: MARTINS, S. V. **Ecologia de Florestas Tropicais do Brasil**. Viçosa: 1 ed. UFV, 2012, 371 p.

MEDEIROS-SARMENTO, P. S.; FERREIRA, L. V.; GASTAUER, M. Natural regeneration triggers compositional and functional shifts in soil seed banks. **Science of the Total Environment**, Nanjing, v. 753, p. 141934, 2021.

NARDUCCI, T. S.; YARED, J. A. Z.; BRIENZA-JÚNIOR, S. Banco de sementes do solo sob plantios de Tachigali vulgaris (L.G.Silva & H.C.Lima) em diferentes espaçamentos na região leste do Estado do Pará, Amazônia. **Scientia Forestalis**, Campinas, v. 49, n. 132, p. 3719, 2021.

ODUM, E. P.; BARRETT, G. W. **Fundamentals of Ecology**. Philadelphia: Cengage Learning , 5 ed. 2004, 624 p.

PINHEIRO, L. A.; PEREIRA, N. F.; BRAGA, D. L. J. P. Espécies indicadoras dos campos de altitude do planalto de Poços de Caldas e Serra de Caldas, em Minas Gerais. **Regnellea Scientia**, Poços de Caldas, v. 6, n. 3, p. 17-29, 2020.

PIJL, L. V. **Pinciples of dispersal in higher plants**. New York: Springer-Verlag, 3 ed. 1982, 218 p.

PLUE, J.; FRENNE, P.; ACHARYA, K.; BRUNET, J.; CHABRERIE, O.; DECOCQ, G.; DIEKMANN, M.; GRAAE, B. J.; HEINKEN, T.; HERMY, M.; KOLB, A.; LEMKE, I.; LIIRA, J.; NAAF, T.; SHEVTSOVA, A.; VERHEYEN, K.; WULF, M.; COUSINS, S. A. O. Climatic control of forest herb seed banks along a latitudinal gradient. **Global Ecology and Biogeography**, Nova Iorque, v. 22, n. 10, p. 1106-1117, 2013.

SILVA, E. P.; FIGUEIREDO, F. G.; FERNANDES, S. S. L.; PEREIRA, Z. V. Evaluation of the potential of seed rain as an alternative for forest restoration in permanent preservation areas. **Revista Árvore**, Viçosa, v. 40, n. 1, p. 21-28, 2016.

TRAMONTINA, J.; KUPLICH, T. Floristic-structural characterization of degraded forest in the arc of deforestation, Brazilian amazon. **Floresta**, Curitiba, v. 54, n. 1, p. 1-10, 2024.

ZAMBRANO, J.; GARZON-LOPES, C. X.; YEAGER, L.; FORTUNEL, C.; CORDEIRO, N. J.; BECKMAN, N. G. The effects of habitat loss and fragmentation on plant functional traits and functional diversity: what do we know so far? **Oecologia**, New York, v. 191, p. 505-518, 2019.