Seed rain is an ecological process and its functional attributes are essential for maintaining the dynamics of natural regeneration. The objective of this research was to evaluate the spatial variation of the seed rain in a toposequence of a Seasonal Deciduous Forest defined by three elevations: (Base 512 m; Slope: 534 m and Top: 559 m). 15 collectors of 1 m² were installed at each elevation level. Data were collected monthly from September / 2017 to February / 2019. The seeds were classified according to the dispersion syndrome, habit and size. Non-Metric Multidimensional Scaling (NMDS) was used to verify the variation in species composition and distribution. We identified 20,217 propagules, belonging to 65 species and 30 families, in addition to 4 morphospecies, which represents 449 seeds / m². The families with the highest species richness were Fabaceae, Sapindaceae and Euphorbiaceae. Of the 65 species sampled, 71% were arboreal. Zoochoric species predominated (78%) and very small seeds corresponded to 53% of the sample. We demonstrate that, on a small spatial scale, the relief represents an important source of heterogeneity in the vegetation component, since the
topographic gradient influenced the composition and distribution of the functional attributes of the seed rain.

**Keywords:** Altimetric dimension; Dispersion syndrome; Functional attributes; Heterogeneity; Topographic gradient.

**Resumo**

A chuva de sementes é um processo ecológico e seus atributos funcionais são essenciais para a manutenção da dinâmica de regeneração natural. O objetivo desta pesquisa foi avaliar a variação espacial da chuva de sementes em uma topossequência de uma Floresta Estacional Decidual definida por três cotas altitudinais: (Base 512 m; Declive: 534 m e Topo: 559 m). Foram instalados 15 coletores de 1 m² em cada nível de elevação. Os dados foram coletados mensalmente de setembro / 2017 a fevereiro / 2019. As sementes foram classificadas de acordo com o síndrome de dispersão, hábito e tamanho. Escalonamento Multidimensional Não Métrico (NMDS) foi utilizado para verificar a variação na composição e distribuição das espécies. Identificamos 20.217 propágulos, pertencentes a 65 espécies e 30 famílias, além de 4 morfoespecies, o que representa 449 sementes / m². As famílias com maior riqueza de espécies foram Fabaceae, Sapindaceae e Euphorbiaceae. Das 65 espécies amostradas, 71% eram arbóreas. Espécies zoocóricas predominaram (78%) e sementes muito pequenas corresponderam a 53% da amostra. Demonstramos que, em pequena escala espacial, o relevo representa importante fonte de heterogeneidade do componente vegetacional, uma vez que o gradiente topográfico influenciou na composição e distribuição dos atributos funcionais da chuva de sementes.

**Palavras-chave:** Dimensões altimétricas; Síndrome de dispersão; Atributos funcionais; Heterogeneidade; Gradiente topográfico.

**Resumen**

La lluvia de semillas es un proceso ecológico y sus atributos funcionales son fundamentales para mantener la dinámica de la regeneración natural. El objetivo de esta investigación fue evaluar la variación espacial de la lluvia de semillas en una secuencia superior de un Bosque Deciduo Estacional definido por tres elevaciones: (Base 512 m; Desnível: 534 m e Topo: 559 m). Se instalaron 15 colectores de 1 m² en cada nivel de elevación. Los datos se recolectaron mensualmente desde septiembre / 2017 hasta febrero / 2019. Las semillas se clasificaron según el síndrome de dispersión, hábito y tamaño. Se utilizó la escala multidimensional no métrica (NMDS) para verificar la variación en la composición y distribución de las especies.
Se identificaron 20,217 propágulos, pertenecientes a 65 especies y 30 familias, además de 4 morfoespecies, lo que representa 449 semillas / m². Las familias con mayor riqueza de especies fueron Fabaceae, Sapindaceae y Euphorbiaceae. De las 65 especies muestreadas, el 71% eran arbóreas. Predomina las especies zoochóricas (78%) y las semillas muy pequeñas correspondieron al 53% de la muestra. Demostramos que, a pequeña escala espacial, el relieve representa una fuente importante de heterogeneidad del componente vegetal, ya que el gradiente topográfico influyó en la composición y distribución de los atributos funcionales de la lluvia de semillas.

Palabras clave: Dimensiones altimétricas; Síndrome de dispersión; Atributos funcionales; Heterogeneidad; Gradiente topográfico.

1. Introduction

Forests cover 31 percent of the global land area but are not equally distributed around the globe. (FAO & UNEP, 2020). The most representative phytophysiognomies are the Coniferous Forests, Temperate Forests, Evergreen Forest, Deciduous Forests, Tropical and Subtropical Forests (Reich & Frellich, 2002). Deciduous Tropical Forests, also known as Dry Forests and Seasonal Deciduous Forests, (hereafter called SDFs), occur in ice-free areas, where the mean annual temperature is 17 °C, and the mean annual precipitation is less than 1600 mm, with less than 100 mm of rainfall over five months. The SDFs are usually a transition zone between semi-desert regions and/or savannas with humid forests (Murphy & Lugo, 1986). Leaf loss in these forests can exceed 50% of the vegetation cover, which may rise up to 100% of trees and shrubs defoliation during the drought (IBGE, 2012; Pereira et al., 2011).

In the Americas, the SDFs occurs in a wide area that extends from the Caribbean to the eastern part of the Andes, with an extension of approximately 520 thousand km², distributed between North and Central America (39%), South America (52 %) and Caribbean islands (9%). Mexico has the largest amount of SDFs (38%), followed by Bolivia (25%), Brazil (17%), Colombia (6.5%), and Venezuela (6.2%) respectively (Murphy & Lugo, 1986; Portillo -Quintero & Sánchez-Azofeifa, 2010).

In Brazil, the SDFs are disconnected, mainly in the central and northeastern regions (Salis et al., 2004; Sevilha et al., 2004), with the largest areas located in the so-called “Arco do Pleistoceno”, an extensive area of forests that range from the Caatinga, in the northeast of Brazil, to the southwest through the Cerrado and reach the dry plains of Bolivia and Paraguay,
in the Chaco (Oliveira-Filho et al., 2006). In the South, it occurs between the Mixed Rainforest (Araucaria Forest) and the Campos Sulinos (Pampas), in an area of subtropical climate (IBGE, 2012). It is estimated that the SDFs occupies 4% to 6% of the Brazilian territory (Espírito-Santo et al., 2008). The Bodoquena plateau region, in Mato Grosso do Sul is one of the last and largest remnants of this phytophysignomy in Brazil that is still relatively well-preserved (Pott & Pott, 2003; Salzo & Matos, 2013). Mato Grosso do Sul also has SDFs in some stretches of floodplains by the Paraguay River, in its alluvial formation (IBGE, 2012).

The SDFs are conditioned to regions with climatic seasonality (Pennington et al., 2006), occurring as forest disjunctions among other forest and/or savanna types, with arboreal strata formed by predominantly deciduous species (Veloso et al., 1991). They are called Dry Forest or Limestone Forest, in reference to the local climatic conditions or lithology. The variations found in the structure of dry tropical forest fragments can be attributed to the characteristics of the substrate, position, landform, location in relation to other savannahs, fire history, and land use. The influence of environmental factors, such as altitude, topography and soil types, on the composition and dynamics of forests is well known for tropical rainforests (Charles-Dominique, 1995; Franklin et al., 2012; Homeier et al., 2010; Xia et al., 2016). However, there is still a lack of understanding on the association of the Seasonal Deciduous Forests structure and dynamics with some abiotic components, such as topography for instance (Arruda et al., 2013). Studies on the SDFs in Brazil focus mainly on structural aspects of the vegetation, which include several quantitative inventories and physiognomic-floristic descriptions (Felfili et al., 2007; Ivanauskas & Rodrigues, 2000; Nascimento et al., 2004; Pedralli, 1997; Silva & Scariot, 2003; Scariot et al., 2005).

Seed rain is an important tool that allows information about species composition, availability and seed diversity (Piña-Rodrigues & Aoki, 2014). Since dispersion is characterized as a dynamic and fundamental transport for the reproduction of plant species, as it provides a favorable location for seed germination, away from the mother plant (Howe, 1993; Gomes, 2018). Seed production and dispersion are important functional attributes for the maintenance of plant populations, influencing the spatial distribution of species and the composition of the plant community, in addition to affecting gene flow within and between populations and enabling the colonization of new sites and habitat restoration (Bacles et al., 2006; Howe & Smallwood, 1982; Kroiss & Hillers-Lambers, 2015; Mateo et al., 2016; McConkey et al., 2012; Merritt et al., 2010; Reid et al., 2015; Vellend, 2010).

The propagule size influences the dispersion and establishment of plants and can
become especially important in the face of climate change, as current habitats begin to change (Walck et al., 2011; Westoby et al., 1992). There is evidence that factors such as climate and soil pH can influence seed size (Tautenhahn et al., 2008), in addition to solar radiation (Foster & Janson, 1985; Frenne et al., 2011).

The goal of this research was to evaluate the spatial variation of the seed rain in a toposequence of a SDF, to answer the following questions: is there variation in the seed rain in relation to the position occupied in this toposequence? What environmental factors influence this variation, if any? Are the dispersion syndromes and the propagules size related to the patterns detected?

2. Methods

2.1 Study area

The study was carried out in Serra da Bodoquena National Park under the authorization number 56258-3 at the Chico Mendes Institute for Biodiversity Conservation (ICMBIO). The park is a protected area created in 2000, which covers parts of the municipalities of Bonito, Bodoquena, Jardim and Porto Murtinho, in Mato Grosso do Sul (21°08'02” S; 20°38'26” S; 56°48'31” W; 56°44'28” O) and has an area of over 77.000 hectares and altitudes among 450m and 800 m (ICMBIO, 2013) (Figure 1).
Figure 1. Location of the study area, Serra da Bodoquena National Park, MS.

The area is basically composed of limestone rocks from the Bocaina Formation, Grupo Corumbá, which favors the formation of different types of cavities, such as caves, sinks and resurgences (Sallun-Filho & Karmann, 2007). The climate is humid tropical with dry winter (Aw), according to the Köppen classification, with hot and rainy season between October and April and dry season between May and September, with annual precipitation between 800 and 1800 mm, an annual average of 1400 mm, and average annual temperature of 22 °C, with a predominance of the Polar Atlantic Air Mass over the Continental Tropical Air Mass (IBGE, 2005; Mariani, 2001; Farias de Souza et al., 2004).

During the research period, rainfall ranged from 0.2 mm in July 2018 to 329 mm in October 2018, while the minimum temperature was 19°C in June 2018 and the maximum was 28.8 °C in March 2018 (data from the National Meteorological Institute - INMET/Jardim-MS) (Figure 2). The predominant vegetation is Seasonal Semideciduous Forest and Seasonal Deciduous Forest. The savanna fragments occupy flat areas, while forest fragments occupy rocky outcrops and margins of watercourses (ICMBIO, 2013).
2.2 Experimental design

We established three sample areas along a toposequence, in the Seasonal Deciduous Forest, at the base of the toposequence (512 m), at the intermediate portion (slope 534 m) and at the top (559 m), each with different characteristics in terms of soil depth, litter thickness and moisture. In each area, 15 collectors with 1 m² each were randomly installed, made out of fine mesh screen, smaller than 1 mm, suspended one meter from the ground the collectors were installed in the beginning of August 2017, with the collections carried out every 30 days and completed in February 2019, and the collected material was properly packed in plastic bags and taken for drying and sorting at the Environmental Restoration Laboratory of the Federal University of Grande Dourados. Fruits and seeds were separated from the rest of the material, dried in an oven, or placed in 70% alcohol. Seeds were identified by specialists, specialized literature, and/or comparison with the material available in the herbarium collection of the Federal University of Grande Dourados. The scientific names were obtained in the Flora do Brasil database (Flora do Brasil, 2020). The identified species and/or morphospecies were classified according to life form (Whittaker, 1975) and dispersion syndrome (Van Der Pijl, 1982), being further categorized into five size classes according to Tabarelli & Peres (2002) and Melo et al., (2006) as it follows: 1: very small (<1 to 3 mm) 2:
small (3.1 to 6 mm); 3: medium (6.1 to 15 mm); 4: large (15.1 to 30 mm) and 5: very large (> 30 mm). Seed density was estimated according to Ellenberg & Mueller-Dombois (1974).

2.3 Statistical analysis

The sample ordering was obtained by the Non-Metric Multidimensional Scaling (NMDS), based on the Bray-Curtis dissimilarity matrix using the Vegan package (Oksanen et al., 2018) of the statistical software R, version 3.5.1 (R Core Team, 2018). From species relative abundance, dispersion syndrome, and seed size we obtained the variation in species composition across environmental gradients. We used the Multivariate Analysis of Variance - MANOVA, according to Friedrich et al., (2016).

3. Results

65 species were sampled over 18 months, belonging to 30 families, in addition to four morphospecies. The most representative families were Fabaceae, Euphorbiaceae and Sapindaceae, while the species with the highest number of seeds were Myrsine umbellata (6.489 seeds), Terminalia mameluco (2.381 seeds), Erythroxylum sp. (1.884 seeds) and Cybianthus detergens (1.648 seeds), which represents 38% of the total We registered 20.217 seeds (449 seeds / m²), with 13.820 seeds at the base (68%), 3.898 on the slope (19%) and 2.499 at the top (13%) (Table 1).

Table 1. List of the seed rain species in the three altimetric levels of the toposequence (base, slope and top), located in the Serra da Bodoquena MS National Park, 2017 / 2019.

| Family            | Species                                      | Habits | S.D | Nº propagules | Size |
|-------------------|----------------------------------------------|--------|-----|----------------|------|
| Anacardiaceae     | *Myracrodruon urundeuva* Allemão             | Tre    | Ane | 138            | VS   |
| Apocynaceae       | *Forsteronia pubescens* A.DC.                | Lia    | Ane | 14             | A    |
| Asteraceae        | *Lessingianthus scabrifolius* (Hieron.) H.Rob.| Bus    | Ane | 10             | VS   |
| Bignoneaceae      | *Callichlamys latifolia* (Rich.) K.Schum.    | Lia    | Ane | 1              | L    |
|                   | *Fridericia florida* (DC.) L.G.Lohmann       | Lia    | Ane | 5              | L    |
|                   | *Handroanthus heptaphyllus.* (Vell.) Mattos. | Tre    | Ane | 99             | 24   |
|                   | *Tanaecium neobrasiliense* L.G.Lohmann       | Lia    | Ane | 6              | A    |
| Cannabaceae       | *Celis iguanaea* (Jacq.) Sarg.               | Tre    | Zoo | 40             | 10   |
| Celastraceae      | *Hippocratesa volubilis* L.                  | Her    | Ane | 14             | 3    |
| Family          | Scientific Name | Common Name | Tre | Ane | Lia | VS | S | L |
|-----------------|-----------------|-------------|-----|-----|-----|----|----|----|
| Rutaceae        | Terminalia mameluco. Pickel. |  |  |  | 2296 | 51 | 34 | VL |
| Dioscoreaceae   | Dioscorea multifloraMart. ex Griseb. |  |  |  | Ane | 13 | 3  | L  |
| Erythroxylaceae | Erythroxylum sp. |  |  |  |  | 1882 | 2 | S  |
| Euphorbiaceae   | Adelia membranifolia (Mull.Arg.) Chodat & Hassl. |  | Aut | 1 | 11 | A  |    |    |
|                 | Croton floribundus Spreng. |  |  |  | Zoo | 20 | 2  | S  |
|                 | Euphorbiaceae 1. |  |  |  |  | 1  | VS |
|                 | Manihot sp. |  |  |  |  | 4  | A  |
|                 | Sebastiania brasiliensis Spreng. |  |  |  | Zoo | 7  | 6  | 32 | S  |
|                 | Sapium glandulosum. (L.) Morong. |  |  |  | Zoo | 10 | 17 | S  |
| Fabaceae        | Anadenanthera colubrina (Vell.) Brenan |  |  |  |  | 5  | 7  | 5  | L  |
|                 | Guibourtia hymenifolia (Moric.) J. Leonard |  |  |  | Zoo | 2  | 6  | 4  | A  |
|                 | inga sp. |  |  |  |  | 93 | A  |
|                 | Parapiptadenia rigida (Benth.) Brenan |  |  |  | Zoo | 276 | 40 | 107 | A |
|                 | Pterogyne nitens Tul. |  |  |  |  | 21 | 2  | 11 | VL |
|                 | Pilocarpus pennatifolius Lem. |  |  |  |  | 6  | 4  | A  |
|                 | Senegalia polyphylla. (DC.) Britton & Rose |  |  |  |  | 6  | 3  | A  |
|                 | Sclerolobium sp. |  |  |  |  | 4  | L  |
| Lauraceae       | Lauraceae 1. |  |  |  |  | 236 | S  |
|                 | Nectandra megapotamica (Spreng.) Mez. |  |  |  |  | 1  | A  |
| Lecythidaceae   | Cariniana legalis (Mart.) Kuntze |  |  |  |  | 112 | 1  | VL |
| Malpighiaceae   | Diplopterys pubipetala (A.Juss.) W.R.Anderson & C.C.Davis |  |  |  |  | 2  | VL |
|                 | Mascagnia cordifolia (A. Juss.) Griseb. |  |  |  |  | 14 | L  |
| Malvaceae       | Celba pubiflora (A.St.-Hil.) K.Schum. |  |  |  |  | 10 | S  |
|                 | Guazuma ulmifolia Lam. |  |  |  |  | 180 | VS |
|                 | Helicteres lotizkyana (Schott & Endl.) K.Schum. |  |  |  |  | 1  | VS |
|                 | Heliocarpus sp. |  |  |  |  | 3  | 22 | VS |
| Meliaceae       | Guarea guidonia (L.) Sleumer |  |  |  |  | 5  | 1  | S  |
|                 | Trichilium catigua A.Juss. |  |  |  |  | 544 | 4  | A  |
|                 | Trichilium claussenii C.DC. |  |  |  |  | 1  | A  |
|                 | Trichilium pallida Sw. |  |  |  |  | 6  | S  |
| Menispermaceae  | Disciphania ernstii Eichler |  |  |  |  | 193 | 2  | 123 | A |
| Moraceae        | Ficus sp. |  |  |  |  | 67 | VS |
|                 | Maclura tinctoria (L.) D.Don ex Steud. |  |  |  |  | 140 | VS |
| Myrtaceae       | Calyptranthes sp. |  |  |  |  | 6  | S  |
|                 | Eugenia sp. |  |  |  |  | 4  | A  |
|                 | Eugenia florid DC. |  |  |  |  | 306 | S  |
|                 | Myrtaceae 1. |  |  |  |  | 2  | 3  | S  |
|                 | Psidium sp. |  |  |  |  | 1  | 4  | VS |
| Nymataginaceae  | Guapira opposita (Vell.) Reitz |  |  |  |  | 2  | 1  | 74 | A  |
| Phyllanthaceae  | Margariaria nobilis L.f. |  |  |  |  | 39 | 72 | 5  | S  |
| Poaceae         | Olyra ciliatifolia Raddi |  |  |  |  |  | 47 | VS |
| Primulaceae     | Cybianthus deterrents. Mart. |  |  |  |  | 1522 | 117 | 9 | VS |
|                 | Myrsine umbellata Mart. |  |  |  |  | 5932 | 141 | 416 | VS |
| Rhamnaceae      | Sageretia elegans (Kunth) Brongn. |  |  |  |  | 108 |   |    |
| Rubiaceae       | Randia ferox (Cham. & Schldl.) DC. |  |  |  |  | 2  | 34 | S  |
| Rutaceae        | Balfouriodendron riedelianum (Engl.) Engl. |  |  |  |  | 1  | 12 | L  |
At the top there were seven exclusive species (Myracrodruon urundeuva, Lessingianthus scabrifoliatus, Diplopterys pubipetala, Olyra ciliatifolia, Tanaecium neobrasiliense, Helicteres lhotzkyana, Trichilia pallida), on the slope, there were ten (Fridericia florida, Euphorbiaceae 1, Manihot sp., Sebastiania brasiliensis, Sclerolobium sp., Trichilia clauseni, Ficus sp., Calyptranthes sp., Chrysophyllum gonocarpum, undetermined 4) and ate the base 13 (Callichlamys latifolia, Parapiptadenia rigida, Lauraceae 1, Mascagna cordifolia, Inga sp., Guazuma ulmifolia, Ceiba pubiflora, Maclura tinctoria, Eugenia sp., Eugenia florida, Sageretia elegans, Sapindaceae 1 and undetermined 3). Most species (21) were shared between the sampling areas, as follows: Handroanthus heptaphyllus, Celtis iguanaea, Terminalia mameluco, Croton floribundus, Sebastiania brasiliensis, Anadenanthera colubrina, Guibourtia hymenifolia, Parapiptadenia rigida, Pterogyne nitens, Disciphania nysia, Disciphania ernia, Discipaia Margaritaria nobilis, Cy bianthus detergens, Myrsine umbellata, Randia ferox, Balfourodendron riedelianum, Zanthoxylum sp., Allophylus edulis, Paraguayan Averrhodium, Serjania caracasana, Vochysia sp and undetermined 1 (Table 1).

The greatest number of seeds was found at the end of the dry season and beginning of the rainy season, with the period of highest production between November and February, with peaks in November and December and the lowest production in April and July. The seed rain was seasonal, varying among the elevation levels. Figure 3 shows the variation in the composition and abundance of the plant species sampled in relation to the different altimetric levels.
levels and the collection periods, showing differences between the sampled areas (Pillai = Locations - 0.54478; gl 2 and 4; p <2.2 and -16 - Months = 0.48851; gl 17 and 34; p = 065e-10).

**Figure 3.** NMDS ordering of species composition at sampling sites.

Subtitle: Circle sizes represent the collection months from 1 to 18; the colors represent the gradient: black - base, light gray - top and dark gray - slope. The contribution of each species is given by the position in the graph: the further away from the “0.0” coordinates, the greater the contribution of the species to differentiate the samples. Source: Research authors (2019).

Figure 4 shows the NMDS ranking in relation to the variation in seed size (stress = 0.13, with 98% of the total variance being recovered in the Bray-Curtis distance matrix); altimetric quotas and months of collection explained the variation in seed size distribution (Pillai = Locations 0.03296; gl 1 and 365; p 0.002207; Months = 0.32819; gl 17 and 732; p = 8,165e-14), reinforcing the differences between the sampled areas and between the months of fieldwork.
Figure 4. NMDS ordering of seed size at sampling sites.

Subtitle: Circle sizes represent the collection months from 1 to 18; the colors represent the gradient: black - base, light gray - top and dark gray - slope. The contribution of each size is given by the position on the graph: the further away from the “0.0” coordinates, the greater the size contribution to differentiate the samples. Seed Sizes: PM: very small, P: Small; M: Average; G: Great; MG: Very big.

Source: Research authors (2019)

Very small seeds showed greater variation in abundance between the elevation levels, with 83% at the base, 14% on the slope, and only 3% at the top. At the base, the majority of seeds were very small, which corresponded to 53% of the total (10,637 seeds), represented by 14 species. Small seeds represented 16% (3,312 seeds and 18 species), medium seeds 11% (2,163 seeds and 19 species), large seeds 7% (1,461 seeds and 9 species), and very large seeds 13% (2,547 seeds and 5 species) (see Table 1).

In relation to species habits, 76% (46 species) are arboreal, 9% (3) shrubby, 15% (11) lianas and (2) herbaceous. Tree species accounted for 74.9% of the total sampled seeds (15,155 seeds), while shrubs and lianas accounted for 8% (1,662) and 14.7% (2,976), respectively.

Zoochoric species predominated in the seed rain in the three altimetric levels, corresponding to 78% (15,546 seeds and 37 species), followed by anemochoric species, with 22% (4,031 seeds and 18 species) and autochorous (61 seeds and 6 species) (see Table 1). Figure 5 shows that the ordering of the variation in dispersion syndromes was related to the
elevational quotas and fieldwork period. Ordering in two dimensions resulted in a stress = 0.13 and recovered 98% of the total variance in the matrix (Pillai = Locations 0.04510; gl 1 and 366; p 0.0002148; Months = 0.51756; gl 17 and 734; p <2.2e-16).

**Figure 5.** NMDS ordering of the dispersion syndrome at the sampling sites.

*Subtitle:* Circle sizes represent the collection months from 1 to 18; the colors represent the gradient: black - base, light gray - top and dark gray - slope. The contribution of each syndrome is given by the position on the graph: the further away from the 0,0 coordinates, the greater the contribution of the dispersion syndrome to differentiate the samples. Source: Research authors (2019)

4. **Discussion**

The number of species recorded in the seed rain was similar to that of Scotti et al., (2011) in an SDF area in Rio Grande do Sul, while Battilani (2010), in the Planalto da Bodoquena registered 117 species in three years of sampling. Our results differed a bit from some floristic studies on the shrub-tree component carried out in that same region, however, they were carried out in areas with riverside forests (Baptista-Maria et al., 2009) or in ecotonal areas of forest formations (Zavala et al., 2017), that has greater richness than the SDFs. Nevertheless, the large number of propagules registered in this research shows the potential that the remaining SDFs have to support the restoration of degraded areas, aiming to maintain biodiversity, considering the different reproductive strategies of the species that
compose this type of vegetation. In Deciduous Seasonal Forest, natural regeneration develops satisfactorily, presenting floristic composition and high diversity, with a clear increase in the dominance and density of some key species (Scipioni et al., 2009).

Fabaceae, which stood out as the most representative families in species richness, is considered a typical family of the Brazilian forests (Oliveira-Filho & Fontes, 2000; Oliveira et al., 2016), with great importance for environmental restoration due to the ability to fix nitrogen that several species have and, consequently, improvement of soil conditions. Therefore, its species are considered facilitators of ecological succession (Canosa et al., 2012). Sapindaceae is a very diverse family, especially in the North - Amazon Forest - and Southeast - Atlantic Forest regions of Brazil, with emphasis on the species of *Serjania*, the richest genus in Brazil (Somner et al., 2010). Composed almost exclusively by lianas, species of this genus play a role in environmental dynamics, forming true "biological corridors" in the forest canopy (Aschoff, 2012). Euphorbiaceae, which also stood out in this study, has fast growth as one of its main characteristics, participating in the initial stages of succession and contributing to the rapid plant densification in areas undergoing restoration (Amaral et al., 2013).

Intra and interspecific variations in seed production and dispersion syndromes influenced the spatial distribution of seeds during the fieldwork period. Such variations may be related to the species phenological and reproductive characteristics, as pointed out in other studies of seed rain for both individual and community levels (Araújo et al., 2004; Armesto et al., 2001; Au et al., 2006; Hampe et al., 2004; Masaki et al., 2007; Shen et al., 2007). Variations in the composition of seed rain among collectors and between altimetric levels were influenced by the occurrence of exclusive species of specific habitats and by variations of seed abundance through space. The species composition in the seed rain, in general, is related to the local plant community (Penhalber & Vani, 1997) but tends to be different between areas (Au et al., 2006; Pivello et al., 2006; Rother et al., 2009), between habitats (Martini & Santos, 2007), under trees with different forms of dispersion (Clark et al., 2004) and among seed collectors in the same stretch of the forest (Hardesty & Parker, 2002).

Such variations are related to several factors, such as environmental heterogeneity, floristic composition, phenological patterns of the local community, dispersal agent activities, and topographic gradients. The topographic gradient is an environmental variable that indirectly influences a series of other environmental factors closely related to the patterns of plant distribution in the Atlantic Forest (Eisenlohr et al., 2013; Meireles et al., 2008; Oliveira-Filho & Fontes, 2000; Oliveira et al., 2013; Pedroni et al., 2013). The results of this study
confirm that for the SDFs, the topographic gradient is also important in determining functional patterns and affects the seed rain composition. The differences in richness and abundance of the seed rain between the elevation levels can be a consequence of several factors, such as soil conditions, topography and microclimate characteristics, that change along the elevational quotas (Ferreira-Júnior et al., 2007; Ferreira-Júnior et al., 2012; Jones et al., 2011; Klein, 1980, 1984; Marangon et al., 2013; Veloso & Klein, 1959).

Wolf et al., (2012) observed that greater species richness is expected where topographic variations on a local scale result in greater availability of water in the soil. Some studies carried out in wetland and riverside areas have shown that some species are indicative of each portion of the slope (Borghi et al., 2004; Moro et al., 2001). Considering that several other studies report the influence of topography on the organization of plant species communities (Cardoso & Schiavini, 2002; Higuchi et al., 2012; Higuchi et al., 2013; Rodrigues et al., 2007), the occurrence of indicator species on the slope and top can be partially explained by the ecological requirements of these species, associated with distinct ecological niche. Along the altitudinal gradient studied, environmental variations were observed, which are associated with soil type, slope, humidity, and microclimate, as also registered by Oliveira-Filho et al., (1998), Thomas & Winner (2002) and Homeier et al., (2010), Webb & Peart (1999).

The large amount of small seeds recorded at the base of the slope is related to the presence of species associated with more humid areas, such as _Maclura tinctoria_, _Myrsine umbellata_, and _Cissus erosa_, that are typical of these environments. Generally, species that produce smaller seeds, under favorable environmental conditions, have a higher growth rate compared to larger-seed species. These species may also have the dispersal process optimized since the small size increases the number of seeds ingested by the dispersers (Graham et al., 1995; Larson et al., 2015; Moles & Westoby, 2006; Muller-Landau, 2010; Pereira et al., 2013). On the other hand, large seeds have a greater amount of stored resources, and thus are more likely to germinate (Pesendorfer et al., 2016), and also has a better ability to cope with adverse environmental conditions and competition when in seedling stage (Fenner & Thompson, 2005; Lebrija-Trejos et al., 2016). However, larger seeds are more susceptible to post-dispersal predation due to their greater nutritional value (Jansen et al., 2004).

The diversity in the propagules size is an interesting aspect in the evolution of the plants since it has already been demonstrated that the seed mass strongly influences other important characteristics, in addition to the shape and type of fruit dehiscence, implying in the geographic species distribution and interactions (Barroso et al., 1999). At the base of the
slope, where more zoochorous individuals were recorded, there is greater proximity to a watercourse, where *Myrsine umbellata* is abundant, which has attractive fruits to the fauna and can bring other zoochoric diasporas, confirming the importance of biotic agents in the gene flow in forest formations. Junior et al., (2012) pointed out that the relationship between plants and frugivors is essential for the conservation and maintenance of ecosystems, and the proportion of zoochoric species recorded in this study follows the dispersion pattern described for tropical forests (Howe & Smallwood, 1982; Stefanello et al., 2010).

Anemochorous diasporas occurred in a smaller amount, being generally associated with pioneer species, in dry environments, and less frequent than zoochorous in tropical forests (Wilkander, 1984). Pioneer species play an important role in environmental restoration, as they assist in the forest regeneration, guaranteeing their resilience and facilitating the process of forest succession after natural or anthropic disturbances (Capellesso et al., 2015; Mantovani & Martins, 1988; Martins et al., 2012; Vieira & Scariot, 2006)

5. Conclusion

We demonstrated that, on a small spatial scale, the landform represents an important source of heterogeneity from the vegetational component, determined by the fact that the study area is located in a region formed by geologically complex land, with varied lithologies and a mosaic of phytophysiognomies shaped by the combination of topography, microclimate, and altitude.

Acknowledgments

We are grateful to CAPES, for the scholarship granted to the first author; CNPq for the financial support process nº 427250 / 2016-1; the Graduate Program in General Biology \ Bioprospecting at the Federal University of Grande Dourados; PNSBq for research license, UFGD for transport logistics and Mariana Abrahão for translating the manuscript.

References

Amaral, W. G., Pereira, I. M., Machado, E. L. M., Oliveira, P. A., Dias, L. G., Mucida, D. P., & Amaral, C. S. (2013). Relação das espécies colonizadoras com as características do substrato em áreas degradadas na Serra do Espinhaço Meridional. *Bioscience Journal*, 29(5).
Araujo, M. M., Longhi, S. J., Barros, P. D., & Brenna, D. A. (2004). Caracterização da chuva de sementes, banco de sementes do solo e banco de plântulas em Floresta Estacional Decidual ripária Cachoeira do Sul, RS, Brasil. *Scientia Forestalis, 66*(1), 128-141.

Armesto, J. J., Díaz, I., Papic, C., & Willson, M. F. (2001). Seed rain of fleshy and dry propagules in different habitats in the temperate rainforests of Chiloé Island, Chile. *Austral Ecology, 26*(4), 311-320.

Arruda, D. M., Ferreira-Junior, W. G., Duque-Brasil, R., & Schaefer, C. E. (2013). Phytogeographical patterns of dry forests sensu stricto in northern Minas Gerais State, Brazil. *Anais da Academia Brasileira de Ciências, 85*(2), 623-634.

Au, A. Y., Corlett, R. T., & Hau, B. C. (2006). Seed rain into upland plant communities in Hong Kong, China. *Plant Ecology, 186*(1), 13-22. Bacles, C. F., Lowe, A. J., & Ennos, R. A. (2006). Effective seed dispersal across a fragmented landscape. *Science, 311*(5761), 628-628.

Baptista-Maria, V. R., Rodrigues, R. R., Damasceno Junior, G., Maria, F. D. S., & Souza, V. C. (2009). Composição florística de florestas estacionais ribeirinhas no estado de Mato Grosso do Sul, Brasil. *Acta Botanica Brasileira, 23*(2), 535-548.

Barroso, G. M., Morim, M. P., Peixoto, A. L., & Ichaso, C. L. F. (1999). Frutos e sementes. *Morfologia aplicada à sistemática de dicotiledôneas. Viçosa: UFV*.

Battilani, J. L. (2010). Chuva de sementes em trecho de floresta ripária, Mato Grosso do Sul, Brasil.

Borghi, W. A., Martins, S. S., Del Quiqui, E. M., & Nanni, M. R. (2004). Caracterização e avaliação da mata ciliar à montante da Hidrelétrica de Rosana, na Estação Ecológica do Caiuá, Diamante do Norte, PR. *Cadernos da biodiversidade, 4*(2), 9-18.

Canosa, G. A., de Faria, S. M., & de Moraes, L. F. D. (2012). Leguminosas florestais da Mata Atlântica brasileira fixadoras de nitrogênio atmosférico. *Embrapa Agrobiologia-Comunicado Técnico (INFOTECA-E).*
Capellesso, E. S., Santolin, S. F., & Zanin, E. M. (2015). Banco e chuva de sementes em área de transição florestal no sul do Brasil. *Revista Árvore*, 39(5), 821-829.

Cardoso, E. & Schiavini, I. (2002). Relação entre distribuição de espécies arbóreas e topografia em um gradiente florestal na Estação Ecológica do Panga (Uberlândia, MG). *Revista Brasileira de Botânica*, 25(3), 277-289.

Charles-Dominique, P. (1995). Food distribution and reproductive constraints in the evolution of social structure: Nocturnal primates and other mammals. In *Creatures of the dark*, 425-438. Springer, Boston, MA.

Clark, C. J., Poulsen, J. R., Connor, E. F., & Parker, V. T. (2004). Fruiting trees as dispersal foci in a semi-deciduous tropical forest. *Oecologia*, 139(1), 66-75.

Coutinho, L. A. (2012). Variação sazonal e longitudinal na ecologia do guariba-de-mãos-ruivas, alouatta belzebul (Primates, Atelidae), na Fazenda Pacatuba, Paraíba.

Eisenlohr, P. V., Alves, L. F., Bernacci, L. C., Padgurschi, M. C., Torres, R. B., Prata, E. M., & Martins, F. R. (2013). Disturbances, elevation, topography and spatial proximity drive vegetation patterns along an altitudinal gradient of a top biodiversity hotspot. *Biodiversity and conservation*, 22(12), 2767-2783.

Ellenberg, D., & Mueller-Dombois, D. (1974). *Aims and methods of vegetation ecology*. New York: Wiley.

Espírito-Santo, M. M., Fagundes, M., Sevilha, A. C., Scariot, A. O., Sanchez-Azofeifa, G. A., Noronha, S. E., & Fernandes, G. W. (2008). Florestas estacionais decíduas brasileiras: distribuição e estado de conservação. *MG Biota*, 1(2), 5-13.

FAO and UNEP. 2020. The State of the World’s Forests 2020. Forests, biodiversity and people.
Farias de Souza, A. L., Malheiros Ramos, A., Cunha Conde, F., Massambani, O., & Recuero, F. S. (2004). Comparação de dados climatológicos modelados e observados utilizando a técnica dos quantis.

Felfili, J. M., Nascimento, A. R. T., Fagg, C. W., & Meirelles, E. M. (2007). Floristic composition and community structure of a seasonally deciduous forest on limestone outcrops in Central Brazil. Brazilian Journal of Botany, 30(4), 611-621.

Fenner, M. K., Fenner, M., & Thompson, K. (2005). The ecology of seeds. Cambridge University Press.

Ferreira Júnior, W. G., Schaefer, C. E. G. R., & Silva, A. D. (2012). Uma visão pedogeomorfológica sobre as formações florestais da Mata Atlântica. Ecologia de florestas tropicais do Brasil, 2, 141-174.

Flora do Brasil 2020 em construção. Jardim Botânico do Rio de Janeiro.

Foster, S., & Janson, C. H. (1985). The relationship between seed size and establishment conditions in tropical woody plants. Ecology, 66(3), 773-780.

Franklin, O., Johansson, J., Dewar, R. C., Dieckmann, U., McMurtrie, R. E., Brännström, Å., & Dybzinski, R. (2012). Modeling carbon allocation in trees: a search for principles. Tree Physiology, 32(6), 648-666.

Frenne, P., Brunet, J., Shevtsova, A., Kolb, A., Graae, B. J., Chabrerie, O., & Gruwez, R. (2011). Temperature effects on forest herbs assessed by warming and transplant experiments along a latitudinal gradient. Global Change Biology, 17(10), 3240-3253.

Friedrich, S., Konietzchke, F., & Pauly, M. (2016). Analysis of Multivariate Data and Repeated Measures Designs (R Package Version 0.0. 4). Manova. Rm.

Gomes, L. C. (2018). Síndromes de dispersão do estrato arbóreo-arbustivo em dois fragmentos florestais do Pantanal Sul, MS. Biodiversidade, 17(2).
Graham, C. H., Moermond, T. C., Kristensen, K. A., & Mvukiyumwami, J. (1995). Seed dispersal effectiveness by two bulbuls on Maesa lanceolata, an African montane forest tree. *Biotropica*, 479-486.

Hampe, A. (2004). Extensive hydrochory uncouples spatiotemporal patterns of seedfall and seedling recruitment in a ‘bird-dispersed’ riparian tree. *Journal of Ecology*, 92(5), 797-807.

Hardesty, B. D., & Parker, V. T. (2003). Community seed rain patterns and a comparison to adult community structure in a West African tropical forest. *Plant Ecology*, 164(1), 49-64.

Higuchi, P., da Silva, A. C., de Almeida, J. A., da Costa Bortoluzzi, R. L., Mantovani, A., de Souza Ferreira, T., ... & da Silva, K. M. (2013). Florística e estrutura do componente arbóreo e análise ambiental de um fragmento de Floresta Ombrófila Mista Alto-Montana no município de Painel, SC. *Ciência Florestal*, 23(1), 153-164.

Higuchi, P., da Silva, A. C., de Souza Ferreira, T., de Souza, S. T., Gomes, J. P., da Silva, K. M., & da Silva Paulino, P. (2012). Influência de variáveis ambientais sobre o padrão estrutural e florístico do componente arbóreo, em um fragmento de Floresta Ombrófila Mista Montana em Lages, SC. *Ciência Florestal*, 22(1), 79-90.

Homeier, J., Breckle, S. W., Günter, S., Rollenbeck, R. T., & Leuschner, C. (2010). Tree diversity, forest structure and productivity along altitudinal and topographical gradients in a species-rich Ecuadorian montane rain forest. *Biotropica*, 42(2), 140-148.

Howe, H. F., & Smallwood, J. (1982). Ecology of seed dispersal. *Annual review of ecology and systematics*, 13(1), 201-228.

Howe, H. F. (1993). Aspects of variation in a neotropical seed dispersal system. In *Frugivory and seed dispersal: ecological and evolutionary aspects* (pp. 149-162). Springer, Dordrecht.

IBGE - Instituto Brasileiro de Geografia e Estatística (2005). Mapa de Clima do Brasil.

IBGE, R. (2012). Manual técnico da vegetação brasileira.
Instituto Chico Mendes de Conservação da Biodiversidade – ICMBio. (2013). Plano de Manejo do Parque Nacional da Serra da Bodoquena, Encarte 3.

Ivanauskas, N., & Rodrigues, R. R. (2000). Florística e fitossociologia de remanescentes de floresta estacional decidual em Piracicaba, São Paulo, Brasil. *Brazilian Journal of Botany, 23*(3), 291-304.

Jansen, P. A., Bongers, F., & Hemerik, L. (2004). Seed mass and mast seeding enhance dispersal by a neotropical scatter-hoarding rodent. *Ecological Monographs, 74*(4), 569-589.

Junior, M. M., Barbosa, R. I., da Silva, S. J. R., & Casadio, G. M. L. (2012). Reproductive phenology of the main tree species in the Roraima savanna, Brazilian Amazon.

Kroiss, S. J., & HilleRisLambers, J. (2015). Recruitment limitation of long-lived conifers: implications for climate change responses. *Ecology, 96*(5), 1286-1297.

Larson, J. E., Sheley, R. L., Hardegree, S. P., Doescher, P. S., & James, J. J. (2015). Seed and seedling traits affecting critical life stage transitions and recruitment outcomes in dryland grasses. *Journal of Applied Ecology, 52*(1), 199-209.

Lebrija-Trejos, E., Reich, P. B., Hernández, A., & Wright, S. J. (2016). Species with greater seed mass are more tolerant of conspecific neighbours: a key driver of early survival and future abundances in a tropical forest. *Ecology Letters, 19*(9), 1071-1080.

Mantovani, W. & Martins, F. (1988). Variações fenológicas das espécies do cerrado da Reserva Biológica de Moji Guacu. *Revista brasileira botanica, 11*, 101-12.

Mariani, M. A. P. (2001). *Geografia e turismo no paraíso das águas: o caso de Bonito* (Doctoral dissertation).

Martins, S. V., Rodrigues, R. R., Gandolfi, S., & Calegari, L. (2012). Sucessão ecológica: fundamentos e aplicações na restauração de ecossistemas florestais. *Ecologia de florestas tropicais do Brasil, 2*, 21-52.
Martini, A. M. Z., & Dos Santos, F. A. M. (2007). Effects of distinct types of disturbance on seed rain in the Atlantic forest of NE Brazil. *Plant Ecology, 190*(1), 81-95.

Mateo, R. G., Broennimann, O., Normand, S., Petitpierre, B., Araújo, M. B., Svenning, J. C., & Suarez, G. M. (2016). The mossy north: an inverse latitudinal diversity gradient in European bryophytes. *Scientific Reports, 6*, 25546.

McConkey, K. R., Prasad, S., Corlett, R. T., Campos-Arceiz, A., Brodie, J. F., Rogers, H., & Santamaria, L. (2012). Seed dispersal in changing landscapes. *Biological Conservation, 146*(1), 1-13.

Meireles, L. D., Shepherd, G. J., & Kinoshita, L. S. (2008). Variações na composição florística e na estrutura fitossociológica de uma floresta ombrófila densa alto-montana na Serra da Mantiqueira, Monte Verde, MG. *Brazilian Journal of Botany, 31*(4), 559-574.

Melo, F. P. L., Dirzo, R., & Tabarelli, M. (2006). Biased seed rain in forest edges: evidence from the Brazilian Atlantic forest. *Biological conservation, 132*(1), 50-60.

Merritt, D. M., Nilsson, C., & Jansson, R. (2010). Consequences of propagule dispersal and river fragmentation for riparian plant community diversity and turnover. *Ecological Monographs, 80*(4), 609-626.

Moles, A. T., & Westoby, M. (2006). Seed size and plant strategy across the whole life cycle. *Oikos, 113*(1), 91-105.

Moro, R. S., Schmitt, J., & Diedrichs, L. A. (2001). Estrutura de um fragmento da mata ciliar do Rio Cará-Cará, Ponta Grossa, PR. *Publicatio UEPG-Biological and Health Sciences, 7*(1), 19-38.

Muller-Landau, H. C. (2010). The tolerance–fecundity trade-off and the maintenance of diversity in seed size. *Proceedings of the National Academy of Sciences, 107*(9), 4242-4247.

Murphy, P. G., & Lugo, A. E. (1986). Ecology of tropical dry forest. *Annual review of ecology and systematics, 17*(1), 67-88.
Nascimento, A. R. T., Felfili, J. M., & Meirelles, E. M. (2004). Florística e estrutura da comunidade arbórea de um remanescente de Floresta Estacional Decidual de encosta, Monte Alegre, GO, Brasil. *Acta Botanica Brasileira, 18*(3), 659-669.

Oksanen, J., Blanchet, F. G., Kindt, R., Legendre, P., Minchin, P. R., O’Hara, R. B., & Wagner, H. Community Ecology Package. R package version 2.5-2; 2018.

Oliveira, A. K. M., de Freitas Lemes, F. T., & Pulchério-Leite, A. (2013). Consumo de frutos de Cecropia pachystachya trícul e Ficus gomelleira Kunt & CD Bouché por Platyrhinus lineatus (E. Geoffroy, 1810) e seu efeito sobre a germinação de sementes. *Revista de Biologia Neotropical/Journal of Neotropical Biology, 10*(2), 1-8.

Oliveira, M., Ril, F. L., Peretti, C., Capellesso, E. S., Sausen, T. L., & Budke, J. C. (2016). Biomassa e estoques de carbono em diferentes sistemas florestais no sul do Brasil.

Oliveira-Filho, A. T., Jarenkow, J. A., & Rodal, M. N. (2006). Floristic relationships of seasonally dry forests of eastern South America based on tree species distribution patterns. *Systematics Association Special Volume, 69*, 159.

Oliveira-Filho, A. T., & Fontes, M. A. L. (2000). Patterns of floristic differentiation among Atlantic Forests in Southeastern Brazil and the influence of climate 1. *Biotropica, 32*(4b), 793-810.

Oliveira-Filho, A. T., Curi, N., Vilela, E. A., & Carvalho, D. A. (1998). Effects of Canopy Gaps, Topography, and Soils on the Distribution of Woody Species in a Central Brazilian Deciduous Dry Forest 1. *Biotropica, 30*(3), 362-375.

Pedralli, G. (1997). Florestas secas sobre afloramentos de calcário em Minas Gerais: florística e fisionomia. *Bios, 5*(5), 81-88.

Pedroni, F., Eisenlohr, P. V., & Oliveira-Filho, A. T. (2013). Changes in tree community composition and structure of Atlantic rain forest on a slope of the Serra do Mar range,
southeastern Brazil, from near sea level to 1000 m of altitude. *Flora-Morphology, Distribution, Functional Ecology of Plants*, 208(3), 184-196.

Pennington, R. T., & Ratter, J. A. (Eds.). (2006). *Neotropical savannas and seasonally dry forests: plant diversity, biogeography, and conservation*. CRC press.

Pereira, B. A. D. S., Ventu roli, F., & Carvalho, F. A. (2011). Florestas estacionais no cerrado: uma visão geral. *Pesquisa Agropecuária Tropical*, 41(3), 446-455.

Pereira, S. R., Laura, V. A., & Souza, A. L. T. D. (2013). Seed dormancy overcoming as a strategy for forest restoration in tropical pasture. *Pesquisa Agropecuária Brasileira*, 48(2), 148-156.

Pesendorfer, M. B., Sillett, T. S., Morrison, S. A., & Kamil, A. C. (2016). Context-dependent seed dispersal by a scatter-hoarding corvid. *Journal of Animal Ecology*, 85(3), 798-805.

Piña-Rodrigues, F. C. M., & Aoki, J. (2014). Chuva de sementes como indicadora do estádio de conservação de fragmentos florestais em Sorocaba-SP. *Ciência Florestal*, 24(4), 911-923.

Pivello, V. R., Petenon, D., Jesus, F. D., Meirelles, S. T., Vidal, M. M., Alonso, R. D. A. S., ... & Metzger, J. P. (2006). Chuva de sementes em fragmentos de Floresta Atlântica (São Paulo, SP, Brasil), sob diferentes situações de conectividade, estrutura florestal e proximidade da borda. *Acta Botanica Brasiliica*, 20(4), 845-859.

Portillo-Quintero, C. A., & Sánchez-Azofeifa, G. A. (2010). Extent and conservation of tropical dry forests in the Americas. *Biological conservation*, 143(1), 144-155.

Pott, A., & Pott, V. J. (2003). Espécies de fragmentos florestais em Mato Grosso do Sul. *Fragmentação florestal e alternativas de desenvolvimento rural na Região Centro-Oeste. Campo Grande: UCDB*, 26-52.

Reich, P. B., Frelich, L., & Munn, T. (2002). Temperate deciduous forests.
Reid, J. L., Holl, K. D., & Zahawi, R. A. (2015). Seed dispersal limitations shift over time in tropical forest restoration. *Ecological Applications*, 25(4), 1072-1082.

Rodrigues, L. A., Carvalho, D. A. D., Oliveira Filho, A. T. D., & Curi, N. (2007). Efeitos de solos e topografia sobre a distribuição de espécies arbóreas em um fragmento de floresta estacional semidecidual, em Luminárias, MG. *Revista Árvore*, 31(1), 25-35.

Rother, D. C., Rodrigues, R. R., & Pizo, M. A. (2009). Effects of bamboo stands on seed rain and seed limitation in a rainforest. *Forest Ecology and Management*, 257(3), 885-892.

Salis, S. M., Silva, M. P. D., Mattos, P. P. D., Silva, J. S., Pott, V. J., & Pott, A. (2004). Fitossociologia de remanescentes de floresta estacional decidual em Corumbá, Estado do Mato Grosso do Sul, Brasil. *Brazilian Journal of Botany*, 27(4), 671-684.

Sallun-Filho, w.; Karmann, I. (2007). Geomorphological map of the Serra da Bodoquena karst, west-central Brazil. *Journal of maps*, 3(1), 282-295.

Salzo, I., & Matos, A. M. (2013). Plano de Manejo do Parque Nacional da Serra da Bodoquena. *ICMBio. Brasília: Instituto Chico Mendes de Conservação da Biodiversidade*.

Scariot, A., Sousa-Silva, J. C., & Felfili, J. M. (2005). *Cerrado: ecologia, biodiversidade e conservação*. Ministério do Meio Ambiente.

Scipioni, M. C., Longhi, S. J., Araújo, M. M., & Reinert, D. J. (2009). Regeneração natural de um fragmento da floresta estacional decidual na Reserva Biológica do Ibiricuí-Mirim (RS). *Floresta*, 39(3).

Sccotti, M. S. V., Araujo, M. M., Wendler, C. F., & Longhi, S. J. (2011). Mecanismos de regeneração natural em remanescente de Floresta Estacional Decidual. *Ciência Florestal*, 21(3), 459-472.

Sevilha, A. C., Scariot, A., & Noronha, S. E. (2004). Estado atual da representatividade de unidades de conservação em Florestas Estacionais Deciduais no Brasil. *Biomas florestais. Editora da Universidade Federal de Viçosa*, Viçosa, 1-63.
Silva, L. Á. D., & Scariot, A. (2003). Composição florística e estrutura da comunidade arbórea em uma floresta estacional decidual em afloramento calcário (Fazenda São José, São Domingos, GO, Bacia do Rio Paraná). *Acta Botanica Brasílica, 17*(2), 305-313.

Somner, G. V., Ferrucci, M. S., & Acevedo-Rodríguez, P. R. Coelho G. 2010. Sapindaceae. *Catálogo de Plantas e Fungos do Brasil, 2*, 1606-1620.

Stefanello, D. (2010). Síndromes de dispersão de diásporos das espécies de trechos de vegetação ciliar do rio das Pacas, Querência-MT. *Acta Amaz, 141*-150.

Tautenhahn, S., Heilmeier, H., Götzenberger, L., Klotz, S., Wirth, C., & Kühn, I. (2008). On the biogeography of seed mass in Germany—distribution patterns and environmental correlates. *Ecography, 31*(4), 457-468.

Thomas, S. C., & Winner, W. E. (2002). Photosynthetic differences between saplings and adult trees: an integration of field results by meta-analysis. *Tree physiology, 22*(2-3), 117-127.

Trustees, E. (2007). Influence of soils and topographic gradients on tree species distribution in a Brazilian Atlantic Tropical Semideciduous Forest. *Edinburgh Journal of Botany, 64*(2), 137-157.

Van der Pijl, L. (1982). Principles of dispersal. *Berlin: SpringerVerlag.* Vellend, M. (2010). Conceptual synthesis in community ecology. *The Quarterly review of biology, 85*(2), 183-206.

Veloso, H. P., Rangel-Filho, A. L. R., & Lima, J. C. A. (1991). *Classificação da vegetação brasileira, adaptada a um sistema universal. Ibge.*

Vieira, D. L., & Scariot, A. (2006). Principles of natural regeneration of tropical dry forests for restoration. *Restoration ecology, 14*(1), 11-20.

Walck, J. L., Hidayati, S. N., Dixon, K. W., Thompson, K. E. N., & Poschlod, P. (2011). Climate change and plant regeneration from seed. *Global Change Biology, 17*(6), 2145-2161.
Webb, C. O., & Peart, D. R. (1999). Seedling density dependence promotes coexistence of Bornean rain forest trees. *Ecology, 80*(6), 2006-2017.

Westoby, M., Jurado, E., & Leishman, M. (1992). Comparative evolutionary ecology of seed size. *Trends in Ecology & Evolution, 7*(11), 368-372.

Whittaker, RH (1975). Comunidades e Ecossistemas, Macmillan Publishing Co. Inc., *Nova York, Nova York*. 385p.

Wikander, T. (1984). Mecanismos de dispersión de diaspors de una selva decidua en Venezuela. *Biotropica*, 276-283.

Wolf, J. A., Fricker, G. A., Meyer, V., Hubbell, S. P., Gillespie, T. W., & Saatchi, S. S. (2012). Plant species richness is associated with canopy height and topography in a neotropical forest. *Remote Sensing, 4*(12), 4010-4021.

Xia, S. W., Chen, J., Schaefer, D., & Goodale, U. M. (2016). Effect of topography and litterfall input on fine-scale patch consistency of soil chemical properties in a tropical rainforest. *Plant and soil, 404*(1-2), 385-398.

Zavala, C. B. R., Fernandes, S. S. L., Pereira, Z. V., & Silva, S. M. (2017). Análise fitogeográfica da flora arbustivo-arbórea em ecótono no Planalto da Bodoquena, MS, Brasil. *Ciência Florestal*, 27(3), 907-921.

**Percentage of contribution of each author in the manuscript**

Cleide Brachtvogel – 40%
Zefa Valdivina Pereira – 35%
Sandro Menezes Silva– 25%