Biomass hyperdynamics as a key modulator of forest self-maintenance in a dystrophic soil in the Amazonia-Cerrado transition

Hiperdinâmica da biomassa como modulador-chave para a automanutenção de floresta sobre solo distrófico na transição Amazônia-Cerrado

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Resumo

Neste estudo, procuramos por diferenças no aporte de serapilheira entre cerradão (formação florestal) e cerrado típico (formação savânica) e buscamos relacionar a dinâmica da vegetação com a biomassa aportada e os possíveis efeitos positivos deste processo. Realizamos coletas de serapilheira e testamos a hipótese que o cerradão, por apresentar maior biomassa e alta dinâmica, apresentaria maior aporte de serapilheira e, portanto maior intensidade de ciclagem e maior possibilidade de auto-manutenção em solos pobres em nutrientes. O aporte total de serapilheira foi maior no cerradão (7,71 em 2011, 9,76 em 2012 e 8,70 Mg.ha⁻¹.ano⁻¹ em 2013) em relação ao cerrado típico (3,84, 4,10 e 4,23 Mg.ha⁻¹.ano⁻¹, respectivamente), corroborando nossa hipótese. Estes resultados demonstraram que a produção primária líquida é distinta entre as fitofisionomias, com maior intensidade no cerradão, condição-chave de hiperdinâmica da biomassa que pode favorecer a ciclagem de nutrientes e consequentemente a sua manutenção em solos distróficos.

Palavras-chave: produção primária líquida, cerradão, cerrado típico, conservação.

Abstract

In this study, we looked for differences in litterfall between cerradão (forest type) and typical cerrado (savanna type) and sought to relate the dynamics of vegetation with the biomass input and the possible positive effects of this process. We collected litter and tested the hypothesis that the cerradão, due to its greater biomass and higher dynamics, presents a higher litterfall and therefore a higher intensity of cycling and is more likely to self-maintain in poor nutrient soils. The total litterfall input was higher in cerradão (7.71 in 2011, 9.76 in 2012 and 8.70 Mg.ha⁻¹.year⁻¹ in 2013) compared to typical cerrado (3.84, 4.10 and 4.23 Mg.ha⁻¹.year⁻¹, respectively), confirming our hypothesis. These results demonstrated that the net primary production is distinct among the phytophysionomies, with greater intensity in cerradão. This biomass hyperdynamics condition can promote nutrient cycling and its maintenance in dystrophic soils.

Keywords: net primary production, cerradão, typical cerrado, conservation

INTRODUCTION

The Cerrado Biome is predominantly of the type cerrado *strictu sensu*, a savanna formation composed by the sub-types dense cerrado, typical cerrado, sparse cerrado e rock outcrop cerrado (RIBEIRO; WALTER, 2008). The typical cerrado is the more common kind in the biome, appearing on dystrophic and alic soils, normally incapable of sustaining a vegetation of higher biomass (MARIMON-JUNIOR; HARIDASAN, 2005).

The Cerrado Biome is mainly composed of typical cerrado vegetations; but there are also forest formations like cerradões (plural of cerradão) (RIBEIRO; WALTER, 2008), which normally occur

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on dystrophic soils, especially in the belt where Cerrado and Amazonian forest meet (RATTER et al., 1973). These areas are known as ecological tension zones (ETZ), where the floras of these two largest Brazilian biomes mix along ecotones (IBGE, 2012).

The maintenance of *cerradões* on typical cerrado dystrophic soils is not yet fully understood. Some authors state that *cerradões* maintain their larger biomass on typical cerrado areas because in the past there were enough nutrients, which are still there because of an efficient recycling system (e.g. HARIDASAN, 2000). Part of this mechanism of *cerradão* may be related to the high growth rates, as found by Rossatto et al. (2009), and also due to the hyperdynamics of the vegetation, which results in high mortality and tree recruitment (MARIMON et al., 2014). These hyperdynamics may help in nutrient cycling by litter decomposition, keeping them in a quick cycle between vegetation and soil, and thus guaranteeing a higher nutrient flow, which is required by the *cerradões*, as compared to *cerrados* of less biomass.

In several places of ETZs in Mato Grosso State, typical cerrado and *cerradão* occur next to each other, under similar edaphic conditions (MARIMON-JUNIOR; HARIDASAN, 2005). Nevertheless, differences between the two phytophysognomies, mainly due to the floristic structure of the vegetation (FRANCZAK et al., 2011), may result in variations in litterfall, which represents the main organic part of the soil.

Studies of allocation of the net primary production (NPP) in tropical forest ecosystems suggest that the measurement of annual litter production is a good indicator of NPP (ARAGÃO et al., 2009; GIRARDIN et al., 2010; MALHI et al., 2011). Litter production and the return of nutrients through decomposition is a fundamental process in the maintenance of vegetation on tropical dystrophic soils (VITOUSEK; SANFORD JR., 1986). In this sense, we describe differences on litter increase in a *cerradão* (forest formation) compared with typical cerrado (savanna formation) in the transition of Amazonia to Cerrado, in order to understand how the *cerradão* recycles the produced organic matter. Litter production is the product of the interaction between climatic and edaphic factors and of the physiology of each species, culminating in a special dynamic of organic matter cycling by the vegetation (MARIMON-JUNIOR, 2007).

In this case, the floristic composition ends up being one of the most important factors, exerting a large influence on the biogeochemical cycles, such as the decomposition of the litter layer (WARDLE et al., 1997) and the return of the nutrients to the vegetation. In other words, the larger biomass area of the *cerradão* when compared to the typical cerrado (MARIMON-JUNIOR; HARIDASAN, 2005; FRANCZAK et al., 2011) and the hyperdynamics of the vegetation may be increasing the processes tied to nutrition of the *cerradão* vegetation through the contribution of litter.

Based on these processes, we established the hypothesis that the *cerradão*, because it has a higher biomass and an accelerated dynamics of the vegetation, results in higher litterfall when compared with adjacent typical cerrado. This hyperdynamics ecosystem process of the organic matter may be the key to understanding the maintenance of vegetation with forest size on dystrophic soils, which normally are typical of savanna kind formations of cerrado and rarely of forests. Those edaphic conditions, due to the poverty in nutrients, theoretically could not sustain a forest vegetation of larger biomass such as the *cerradão*, except through the existence of an efficient recycling system, which is what we tried to show through this work.

MATERIAL AND METHODS

Site description

We did the study in the Municipal Park of Bacaba (MPB), Nova Xavantina municipality, MT (14°42'02,3"S and 52°21'02,6"W) (Figure 1). In the MPB, the physiognomy is that of a typical cerrado, followed by that of *cerradão* (forest kind cerrado), gallery forest, field and swampy area. (MARIMON et al., 2001; MARIMON-JUNIOR; HARIDASAN, 2005; ABAD; MARIMON, 2008). *Cerradão* (CD) and typical cerrado (TC) occur side by side in the MPB. The soil in these formations is a Oxisol, with similar acidity levels, high amounts of exchangeable Al and a low base saturation (Table 1), which reveals strong fertility restriction.

The area lies in the transition Amazonia-Cerrado, formed by the intrusion of the Amazonian Forest through the Sedimentary Lowland Plain of Bananal, which characterizes the depression between

en the Goiás Central Plateau and the Parecis Plateau (BRASIL, 1981). The climate is Aw according to Köppen, with well-defined dry (April to September) and rainy (October to March) periods (SILVA et al., 2008). Mean annual precipitation is 1,500 mm and mean temperature is 25.4 °C (MARIMON et al., 2010).

Figure 1. Location of the study area in Mato Grosso and distribution of litterfall collection points in the cerradão and in typical cerrado sampled in the Municipal Park of Bacaba Nova Xavantina, Mato Grosso State, Brazil.

Figura 1. Localização da área de estudo em Mato Grosso e distribuição dos pontos de coleta de serapilheira aportada no cerradão e no cerrado típico amostrados no Parque Municipal do Bacaba, Nova Xavantina, Mato Grosso, Brasil.

Table 1. Soil attributes in cerradão (CD) and typical cerrado (TC) in an Amazonia-Cerrado transition zone, Nova Xavantina, Brazil. Depths collection from 0-10 and 10-20 cm; CEC= effective cation exchange capacity; V(%)= base saturation level; SOM= soil organic matter. Adapted from Marimon-Junior and Haridasan (2005).

Tabela 1. Atributos do solo no cerradão (CD) e cerrado típico (TC) na zona de transição Amazônia-Cerrado, Nova Xavantina, Brasil. Nas profundidades coletadas de 0-10 e 10-20; CTC efetiva; V (%)= nível de saturação de bases; SOM= matéria orgânica. Adaptado de Marimon-Junior e Haridasan (2005).

	V(%)	pH (H ₂ O)	Sand	Silt	Clay	OM	N	P	Al	K	Ca	Mg	CEC
					%			mg kg ⁻¹					cmol _c dm ⁻³
CD													
0-10	9.24	4.95	77.1	1.5	21.4	2.69	0.08	0.3	1.2	0.1	0.25	0.58	2.13
10-20	5.76	4.82	70.7	5.1	24.2	1.88	0.05	0.1	1.15	0.06	0.04	0.33	1.58
TC													
0-10	8.76	4.92	78.5	4.3	17.2	1.73	0.06	0.4	0.96	0.11	0.23	0.49	1.79
10-20	4.45	4.86	76.2	5.5	18.3	1.23	0.04	0.2	1.02	0.07	0.03	0.2	1.32

Annual litter production

To quantify the annual litterfall, we placed 30 collectors of 60 cm diameter distributed randomly within one hectare in each phytophysiology (Figure 1). The sampled area lies within that recommended for samples of litter production, which considers a minimum of 20 collectors with a minimum of 60 cm diameter each (PROCTOR, 1983; MARTINS; RODRIGUES, 1999).

Collections were done monthly for three years (2011, 2012 e 2013). Samples were separated into leaves, reproductive organs, fine branches and miscellany. Litter was quantified to constant dry weight after drying in an oven to 70 °C and weighing on a precision scale.

Data analysis

Analysis of variance was used (One way ANOVA) to determine the litter found along each year period. Total litter and biomass of the fractions were defined as being variables dependent on the months. The choice of this analysis was justified by the many category variables involved (ZAR, 2010). ANOVA with repeated measures was used, in order to compare litter production between CD and TC. This kind of ANOVA verifies distinctions of measures evaluated on several occasions, as in the cases in which sampling is done repeatedly on the same sites along a time gradient (GIRDEN, 1992), as is the case with litter production.

When there were significant differences, a Tukey test was applied later to identify monthly/yearly differences between months/years and phytophysiology. The residue normality was tested through the Shapiro-Wilk test, and the homogeneity of the variables through the Levene test, as these tests were more robust for the analyses made. Where no variance homogeneity was found data were transformed into Log₁₀ (ZAR, 2010). Where assumptions were not met, ANOVA the Welch F test was used for unequal variances (ZAR, 2010), followed by the Tukey test. Analyses were done through the PAST 2.15 Program (HAMMER et al., 2001).

RESULTS

Litter production in cerradão was higher than that in typical cerrado during the whole study period (Table 2). During the three years sampled, CD yielded about double what was found on TC. The leaf fraction contributed with a higher percentage to the total production in both phytophysiology. Reproductive parts, fine branches and miscellany were also different in both kinds of vegetation in the years 2011, 2012 and 2013 (Table 2).

The highest litter production months in CD compared to the other months, were August 2011 and 2013, with means of 1.29 and 1.50 Mg. ha⁻¹.year⁻¹, respectively. However, in both years there was no difference for the months July and September (p>0.05) (Figure 2E). In 2012, highest litterfall was in September (1.81 Mg.ha⁻¹.year⁻¹), with no difference to August (Figure 2E). The months with least litterfall were January in 2011 (0.22 Mg.ha⁻¹.year⁻¹), November in 2012 (0.40 Mg.ha⁻¹.year⁻¹) and March in 2013 (0.34 Mg.ha⁻¹.year⁻¹) (Figure 2E).

Table 2. Total litterfall input and fractions ($\text{Mg} \cdot \text{ha}^{-1} \cdot \text{year}^{-1}$) in the cerradão and in typical cerrado in 2011, 2012 and 2013 in the Municipal Park of Bacaba, Nova Xavantina, MT.

Tabela 2. Aporte total de serapilheira e frações ($\text{Mg} \cdot \text{ha}^{-1} \cdot \text{ano}^{-1}$) no cerradão e no cerrado típico em 2011, 2012 e 2013 no Parque Municipal do Bacaba, Nova Xavantina, MT.

	2011		2012		2013	
	Cerradão	Typical Cerrado	Cerradão	Typical Cerrado	Cerradão	Typical Cerrado
Leaves	5.53 (71.63%) a	3.17 (82.45%) b	5.99 (61.38%) a	3.39 (82.26%) b	6.71 (77.20%) a	3.64 (85.91%) b
Reproductives parts	0.89 (11.60%) a	0.25 (6.57%) b	1.51 (15.47%) a	0.17 (4.24%) b	0.68 (7.69%) a	0.22 (5.26%) b
Fine branches	0.79 (10.28%) a	0.31 (7.97%) b	1.41 (14.41%) a	0.39 (9.68%) b	0.87 (10.11%) a	0.23 (5.46%) b
Miscellany	0.50 (6.50%) a	0.11 (3.00%) b	0.85 (8.74%) a	0.15 (3.82%) b	0.44 (5.00%) a	0.14 (3.38%) b
Total	7.71 a	3.84 b	9.76 a	4.10 b	8.70 a	4.23 b

Means followed by the same lower case on the line do not differ.

Médias seguidas da mesma letra em minúscula na linha não diferem entre si.

Figure 2. Average monthly input of litterfall ($\text{Mg} \cdot \text{ha}^{-1} \cdot \text{month}^{-1}$) and fractions in 2011, 2012 and 2013 in cerradão (●) and typical cerrado (○) in the Municipal Park of Bacaba, Nova Xavantina, MT., Nova Xavantina, MT.

Figura 2. Aporte médio mensal de serapilheira ($\text{Mg} \cdot \text{ha}^{-1} \cdot \text{mês}^{-1}$) e frações nos anos de 2011, 2012 e 2013 em cerradão (●) e cerrado típico (○) no Parque Municipal do Bacaba, Nova Xavantina, MT.

Taking into account that the foliar fraction (Figure 2A) predominated in the litter of both phytophysiognomies during the period of sampling; production peaks were also similar to the total litter produced. However, the fraction of reproductive parts (Figure 2B), fine branches (Figure 2C) and miscellany (Figure 2D) did not follow this trend.

On TC, the month of August yielded the highest mean of total production in the three years sampled, with 0.84; 0.88 and 0.92 Mg.ha⁻¹.year⁻¹ in 2011, 2012 and 2013, respectively. There was, however, no difference in the month of July in the three years ($p>0.05$). January yielded the lowest mean of litter in 2011 (0.42 Mg.ha⁻¹.year⁻¹) and 2012 (0.89 Mg.ha⁻¹.year⁻¹). In 2013, December yielded the lowest mean (0.10 Mg.ha⁻¹.year⁻¹) (Figure 2E). When comparing total litter production and the fractions during the three years, cerradão always presented higher values than did typical cerrado (Figure 3).

Figure 3. Litterfall input between the leaves fractions (A), reproductive parts (B) fine branches (C), miscellany (D) and total litterfall (E) in kg.ha⁻¹.year⁻¹ between cerradão and typical cerrado in 2011 (○), 2012 (□) and 2013 (◇) in the Municipal Park of Bacaba.

Figura 3. Aporte de serapilheira entre as frações folhas (A), partes reprodutivas (B) ramos finos (C), miscelânea (D) e serapilheira total (E) em kg.ha⁻¹.ano⁻¹ entre cerradão e cerrado típico em 2011 (○), 2012 (□) e 2013 (◇) no Parque Municipal do Bacaba, Nova Xavantina, MT.

DISCUSSION

For the cerrado the total litterfall in the three years of sampling was higher than that registered by Cianciaruso et al. (2006) and Giacomo et al. (2012) data. Those authors obtained amounts for cerrado areas of 5.64 Mg.ha⁻¹.year⁻¹ in São Paulo State and of 2.50 Mg.ha⁻¹.year⁻¹ in Minas Gerais State, respectively. The CD also presented more amounts than the forest transition in northeastern state of Mato Grosso, which was 5.00 Mg.ha⁻¹.year⁻¹ (ROCHA et al., 2013). One of the main reasons for higher estimates could be associated to the cerrado hyperdynamic, as seen in the work of Marimon et al. (2014). These authors, after extensive work on the forest vegetation dynamics along the contact of Amazonian forest with Cerrado, showed for the first time that the transition belt of the ETZ corresponds to an immense hyperdynamic belt of transitional forests to the east and south of the Amazon forest, which includes the cerrado from this work.

The fact that the tree populations in the transition zone between the Amazonia and the Cerrado Biome are more dynamic than those found in the central region of Amazonia (MARIMON et al., 2014), can be reflected in the energy flux, nutrient cycling and carbon cycling. Therefore, the hypothesis of more litterfall in the cerrado has support. It is important to point out that, while they occur in the same physiographic unit and with similar soil properties, the main factor for the distinction between cerrado and typical cerrado is the structure and plant composition of the vegetation (MARIMON-JUNIOR; HARIDASAN, 2005).

The differences can be attributed to the key species in the community, which are important for the biogeochemical cycles, such as production and decomposition of litter (ISBELL et al., 2011). In the CD, *Hirtella glandulosa* Spreng, *Tachigali vulgaris* L.G. Silva & H.C. Lima and *Xylopia aromatica* (Lam.) Mart. make up approximately 30% of the total IVI (importance value index), where *T. vulgaris* is the key species in the process of vegetation dynamics (FRANCZAK et al., 2011). For the TC, the most important species were *Qualea parviflora* Mart., *Davilla elliptica* A. St. - Hil. and *Roupala montana* Aubl., which together added 20% of the total of IVI (MEWS et al., 2011). These results reveal a large floristic difference between the areas and a lesser tree dominance in the typical cerrado, with a larger participation of only one species as a key element of the dynamics of the cerrado.

These differences were also found for fundamental aspects connected to phenological characteristics. The most important species of TC in this study showed a phenological adjustment related mainly to water availability (SILVÉRIO; LENZA, 2010). The covering of the crown of each phytosociology is also a relevant factor. While evaluating transpiration of *R. montana* in the same sample plots of CD and CT in this work, Kreutz et al. (2015) found that this species which occurs on both the cerrado or typical cerrado, had a higher transpiration rate in the TC. This emphasizes how much the environment can influence the water balance behavior of tree species.

The floristic composition which cerrado has, is the main reason for its accelerated dynamics (FRANCZAK et al., 2011), and therefore its aboveground biomass gain and litter production. It can be concluded that the hyperdynamics of this vegetation is reflected directly in the larger amount of biomass given to the ground through litterfall. In this case, the larger dynamics of the vegetation, given by the tree species of larger IVI, results in larger dynamics of litter production and can thus be connected to the key processes which maintain the cerrado on dystrophic soils. However, studies of cycling, taking into account litter production and decomposition and the resulting nutrient liberation, must still be done to confirm this hypothesis.

The biomass stock of litter was calculated by MARIMON-JUNIOR et al. (non-published data) as being 6.54 Mg.ha⁻¹ in CD and 5.99 Mg.ha⁻¹.year⁻¹ in TC in 2013, with significant differences between the two areas ($p < 0.05$). Taking the low natural fertility of the soil in both areas into consideration (Table 1); both the addition and the considerable amount of material in the litter permit the enrichment of the interface litter/soil. This scenario is fundamental so that there be nutrition of the vegetation even under a low base saturation and a strong limitation of P in the system. In this case, even though the soil is poor, litter is rich in nutrients (OLIVEIRA et al., in revision), thus guaranteeing a maintenance of the tree component.

Calculations done by Oliveira et al. (in revision) showed the strong participation of *H. glandulosa* and *T. vulgaris* in the biogeochemical cycles of CD, showing them to be key species in the functional parts of the ecosystem. The effective participation of both species in that community may play a

crucial role in carbon stock and balance, as shown by MARIMON-JUNIOR (2007) in work with *Brosimum rubescens* Taub. in a mono-dominant forest in Nova Xavantina-MT municipality. It is possible that the hyperdominance of a few tree species found in all Amazonia area (ter STEEGE et al., 2013) may be producing a similar effect as found in CD in this work.

The total litterfall in typical cerrado was higher than that found by Peres et al. (1983), who found 2.10 Mg.ha⁻¹.year⁻¹ in the typical cerrado around Brasília. Nevertheless, Abdala et al. (1998) found 5.2 Mg.ha⁻¹.year⁻¹ in study also in typical cerrado in Brasília-DF. These diverse findings in typical cerrado sites are due to the constant climatic and edaphic variations to which the phytophysiologicals are exposed to (BUCCI et al., 2004); and are also a result of the variety of Cerrado vegetation forms and densities along the biome (RIBEIRO; WALTER, 2008) and of the transition zone of Amazonia-Cerrado (RATTER et al., 1973). As happened with CD, TC also has species with a high IVI, which contribute to litter production, as shown by Oliveira et al. (in revision). According to these authors, species such as *Q. parviflora*, *D. elliptica* e *R. montana* were responsible for the contribution of 20% of all litterfall in 2013.

The foliar fraction, with contributions of over 60% of the total input, was the main responsible for the total biomass formation in both phytophysiologicals. Such a pattern is commonly found in tropical forests, where the foliar fraction contributes with most of the litter produced (VITOUSEK; SANFORD JR. 1986). In this case, the efficiency of nutrient use (EUN) which largely is part of the relocation before senescence and foliar abscission take place (VITOUSEK, 1982); is strongly influenced by the foliar fraction of the litter and could also be related to the maintenance of the vegetation in dystrophic soils.

It is remarkable that in the comparison between the peak months of litter production, August was a month of peak litter production in the three years studied in TC. Nevertheless, in CD there was an exception in 2012: when the month of September presented the highest monthly value of biomass in the year. Monthly comparisons along the years confirm a pattern compatible of maximum litter production together with the seasonality described for that region in both phytophysiologicals. The addition of leaves, which represents the largest fraction composing litter, is concentrated in the dry season, thus supporting the strong relationship between deciduity and climatic seasonality for the majority of vegetation of Central Brazil (FRANCO et al., 2005; FRANCO et al., 2014). The difference in total biomass production between the phytophysiologicals strengthens the difference between forest and savanna vegetation.

CONCLUSIONS

The results found in this study show that adjacent savanna and forest phytophysiologicals belonging to the same physiographic unit are distinct as to litter production. The hypothesis of this work was supported, and the relationship between the hyperdynamics of the vegetation and the litter production is evident. In other words: higher recruitment and mortality and higher individual growth rates of the main species in IVI; result in higher amounts of litter produced and, consequently in a higher cycling intensity. This dynamic state can generate a positive feedback between growth rates, mortality and recruitment and litterfall, intensifying cycling and thus introducing more nutrients back into the vegetation. This could be the main mechanism for maintaining a larger biomass of cerradão in the same kind of soil as in the typical cerrado. This information may be useful for management plans which intend to preserve the integrity of the vegetation of the Amazonia-Cerrado transition.

REFERENCES

- ABAD, J. C. S.; MARIMON, B. S. Caracterização e diagnóstico ambiental do Parque Municipal do Bacaba, Nova Xavantina (MT). In: SANTOS, J. E.; GALBIATI, C. (Org.). *Gestão e Educação Ambiental: Água, Biodiversidade e Cultura*. São Carlos: RiMa, 2008. p. 23-56.
- ABDALA, G. C.; CALDAS, L. S.; HARIDASAN, M.; EITEN, G. Above and below-ground organic matter and root-shoot ratio in a cerradão in central Brazil. *Brazilian Journal of Ecology*, São Paulo, v. 2, n. 1, p. 1-23, 1998.

- ARAGÃO, L. E. O. C. et al. Above and below-ground net primary productivity across ten Amazonian forests on contrasting soils. **Biogeosciences**, Göttingen, v. 6, p. 2759-2778, 2009.
- BRASIL. DNPF / PROJETO RADAMBRASIL. **Folha SD-22/Goiás**. Rio de Janeiro, 1981. v. 25.
- BUCCI S. J.; SCHOLZ F. G.; GOLDSTEIN, G.; MEINZER, F. C.; HINOJOSA, J. A.; HOFFMANN, W. A.; FRANCO, A. C. Processes preventing nocturnal equilibration between leaf and soil water potential in tropical savanna woody species. **Tree Physiology**, Victoria, v. 24, n. 10, p. 1119-1127, 2004.
- CIANCIARUSO, M. V.; PIRES, J. S. R.; DELITTI, W. B. C.; SILVA, E. F. L. P. Produção de serapilheira e decomposição do material foliar em um cerrado na Estação Ecológica de Jataí, município de Luiz Antônio, SP, Brasil. **Acta Botanica Brasilica**, São Paulo, v. 20, n. 1, p. 49-59, 2006.
- FRANCO, A. C.; BUSTAMANTE, M.; CALDAS L. S.; GOLDSTEIN, G.; MEINZER, F. C.; KOZOVITS, A. R.; RUNDEL, P.; CORADIN, V. T. R. Leaf functional traits of Neotropical savanna trees in relation to seasonal water deficit. **Trees**, New York, v. 19, n. 3, p. 326-335, 2005.
- FRANCO, A. C.; ROSSATTO, D. R.; SILVA, L. C. R.; FERREIRA, S. C. Cerrado vegetation and global change: the role of functional types, resource availability and disturbance in regulating plant community responses to rising CO₂ levels and climate warming. **Theoretical and Experimental Plant Physiology**, Rio de Janeiro, v. 26, n. 1, p. 19-38, 2014.
- FRANCZAK, D. D.; MARIMON, B. S.; MARIMON-JUNIOR, B. H.; MEWS, H. A.; MARACAHIPES, L.; OLIVEIRA, E. A. Changes in the structure of a savanna forest over a six-year period in the Amazon-Cerrado transition, Mato Grosso state, Brazil. **Rodriguésia**, Rio de Janeiro, v. 62, n. 2, p. 425-436, 2011.
- GIÁCOMO, R. G.; PEREIRA, M. G.; MACHADO, D. L. Aporte e decomposição de serapilheira em áreas de cerrado e mata mesofítica na estação ecológica de Pirapitinga-MG. **Ciência Florestal**, Santa Maria, v. 22, n. 4, p. 669-680, 2012.
- GIRARDIN, C. A. J.; MALHI, Y.; ARAGÃO, L. E. O. C.; MAMANI, M.; HUARACA HUASCO, W.; DURAND, L.; FEELEY, K. J.; RAPP, J.; SILVA-ESPEJO, J. E.; SILMAN, M.; SALINAS, N.; WHITTAKER, R. J. Net primary productivity allocation and cycling of carbon along a tropical forest elevational transect in the Peruvian Andes. **Global Change Biology**, Hoboken, v. 16, n. 12, p. 3176-3192, 2010.
- GIRDEN, E.R. **ANOVA: repeated measures**. New Delhi: Sage, 1992. 84 p.
- HAMMER, O.; HARPER, D. A. T.; RYAN, P. D. PAST: Paleontological statistics software package for education and data analysis. **Palaeontologia Electronica**, Oslo, v. 4, n. 1, p. 1-9, 2001.
- HARIDASAN, M. Nutrição mineral de plantas nativas do cerrado. **Revista Brasileira de Fisiologia Vegetal**, Viçosa, v. 12, n. 1, p. 54-64, 2000.
- IBGE. INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Manual técnico da vegetação brasileira**. 3.ed. Rio de Janeiro: IBGE, 2012.
- ISELL, F.; CALCAGNO, V.; HECTOR, A.; CONNOLLY, J.; HARPOLE, W. S.; REICH, P. B.; SCHERER-LORENZEN, M.; SCHMID, B.; TILMAN, D.; RUIJVEN, J. V.; WEIGELT, A.; WILSEY, B. J.; ZAVALETA, E. S.; LOREAU, M. High plant diversity is needed to maintain ecosystem services. **Nature**, London, v. 477, n. 1, p. 199-203, 2011.
- KREUTZ, C.; SOUZA, R. F.; MARIMON-JUNIOR, B. H. Transpiração de *Roupala montana* AUBL. em cerrado típico e cerrado no Parque do Bacaba, Nova Xavantina-MT. **Revista de Ciências Agro-Ambientais**, Alta Floresta, v. 11, p. 113-118, 2015.

- MALHI, Y.; DOUGHTY, C.; GALBRAITH, D. The allocation of ecosystem net primary productivity in tropical forests. *Philosophical Transactions of the Royal Society B*, London, v. 366, n. 1582, p. 3225-3245, 2011.
- MARIMON, B. S.; FELFILI, J. M.; LIMA, E. S.; DUARTE, W. M. G.; MARIMON-JUNIOR, B. H. Environmental determinants for natural regeneration of gallery forest at the Cerrado/Amazonia boundaries in Brazil. *Acta Amazonica*, Manaus, v. 40, n. 1, p. 107-118, 2010.
- MARIMON, B. S.; FELFILI, J. M.; LIMA, E. S.; RODRIGUES, A. J. Distribuição de circunferências e alturas em três porções da mata de galeria do Córrego Bacaba, Nova Xavantina-MT. *Revista Árvore*, Viçosa, v. 25, n. 3, p. 335-343, 2001.
- MARIMON, B. S.; MARIMON-JUNIOR, B. H.; FELDPAUSCH, T. R.; OLIVEIRA-SANTOS, C.; MEWS, H. A.; LOPEZ-GONZALEZ, G.; LLOYD, J.; FRAN CZAK, D. D.; OLIVEIRA, E. A.; MARACAHIPES, L.; MIGUEL, A.; LENZA, E.; PHILLIPS, O. Disequilibrium and hyperdynamic tree turnover at the forest-cerrado transition zone in southern Amazonia. *Plant Ecology & Diversity*, London, v. 7, n. 1-2, p. 281-292, 2014.
- MARIMON-JUNIOR, B. H. *Relação entre diversidade arbórea e aspectos do ciclo biogeoquímico de uma floresta monodominante de Brosimum rubescens Taub. e uma floresta mista no Leste Mato-grossense*. 2007. 233 p. Tese (Doutorado) - Universidade de Brasília, Brasília, 2007.
- MARIMON-JUNIOR, B. H.; HARIDASAN, M. Comparação da vegetação arbórea e características edáficas de um cerradão e um cerrado sensu stricto em áreas adjacentes sobre solo distrófico no leste de Mato Grosso, Brasil. *Acta Botanica Brasilica*, São Paulo, v. 19, n. 4, p. 913-926, 2005.
- MARTINS, S. V.; RODRIGUES, R. R. Produção de serrapilheira em clareiras de uma floresta estacional semi-decidual no município de Campinas, SP. *Revista Brasileira de Botânica*, São Paulo, v. 22, n. 3, p. 405-412, 1999.
- MEWS, H. A.; MARIMON, B. S.; MARACAHIPES, L.; FRAN CZAK, D. D.; MARIMON-JUNIOR, B. H. Dinâmica da comunidade lenhosa de um Cerrado Típico na região Nordeste do Estado de Mato Grosso, Brasil. *Biota Neotropica*, Campinas, v. 11, n. 1, p. 73-82, 2011.
- OLIVEIRA, B. *Dinâmica de nutrientes na serrapilheira em duas fitofisionomias na transição Amazônia/Cerrado em Mato Grosso Nova Xavantina Mato Grosso – Brasil*. 57 p. 2014. Dissertação (Mestrado) - Universidade do Estado de Mato Grosso, Nova Xavantina, 2014.
- PERES, J. R. R.; SUHET, A. R.; VARGAS, M. A. T.; DROZDOWICS, A. Litter production in areas of Brazilian "cerrados". *Pesquisa Agropecuária Brasileira*, Brasília, v. 18, n. 9, p. 1037-1043, 1983.
- PROCTOR, J. Tropical forest litterfall. I. Problems of data comparison. In: SUTTON, S. L.; WHITMORE, T. C.; CHADWICK, A. C. (Ed.). *Tropical rain forest: ecology and management*, Oxford: Blackwell Scientific. 1983. p. 267-273.
- RATTER, J. A.; RICHARDS, P. W.; ARGENT, G.; GIFFORD, D. R. Observations on the vegetation of the northeastern Mato Grosso. I. The woody vegetation types of the Xavantina-Cachimbo Expedition area. *Philosophical Transactions of the Royal Society of London B*, London, v. 266, n. 880, p. 449-492, 1973.
- RIBEIRO, J. F.; WALTER, B. M. T. As principais fitofisionomias do Bioma Cerrado. In: SANO, S. M.; ALMEIDA, S. P.; RIBEIRO, J. F. (Ed.). *Cerrado: ecologia e flora*. Planaltina: Embrapa, 2008. p. 151-212.
- ROCHA, W.; METCALFE, D. B.; DOUGHTY, C. E.; BRANDO, P.; SILVÉRIO, D.; HALLADAY, K.; NEPSTAD, D. C.; BALCH, J. K.; MALHI, Y. Ecosystem productivity and carbon cycling in intact and annually burnt forest at the dry southern limit of the Amazon rainforest (Mato Grosso, Brazil). *Plant Ecology & Diversity*, Abingdon, v. 7, n. 1-2, p. 25-41, 2013.

ROSSATTO D. R.; HOFFMANN, W. A.; FRANCO, A. C. Differences in growth patterns between co-occurring forest and savanna trees affect the forest-savanna boundary. **Functional Ecology**, Hoboken, v. 23, n. 4, p. 689-698, 2009.

SILVA, F. A. M.; ASSAD, E. D.; EVANGELISTA, B. A. Caracterização Climática do Bioma Cerrado. In: SANO, S. M.; ALMEIDA, S. P.; RIBEIRO, J. F. (Ed.). **Cerrado: Ecologia e Flora**. Planaltina: Embrapa, 2008. p. 69-88.

SILVÉRIO, D. V.; LENZA, E. Fenologia de espécies lenhosas em um cerrado típico no Parque Municipal do Bacaba, Nova Xavantina, Mato Grosso, Brasil. **Biota Neotropica**, Campinas, v. 10, n. 3, p. 205-216, 2010.

STEEGE, H. et al. Hyperdominance in the Amazonian Tree Flora, **Science**, Washington, v. 342, n. 6156, p.1243092-1-1243092-9, 2013.

VALADÃO, M. B. X. **Ciclo do carbono e correlações com variáveis microclimáticas em duas fitofisionomias na transição Cerrado/Amazônia**. 65 p. 2014. Dissertação (Mestrado). Universidade do Estado de Mato Grosso, Nova Xavantina, 2014.

VITOUSEK, P. M. Nutrient cycling and nutrient use efficiency. **American Naturalist**, Chicago, v. 119, n. 4, p. 553-572, 1982.

VITOUSEK, P. M.; SANFORD JR., R. L. Nutrient cycling in moist tropical forest. **Annual Review of Ecological Systematics**, Palo Alto, v. 17, p. 137-167, 1986.

WARDLE, D. A.; BONNER, K. I; NICHOLSON, K. S. Biodiversity and plant litter: Experimental evidence which does not support the view that enhanced species richness improves ecosystem function. **Oikos**, Copenhagen, v. 79, n. 2, p. 247-258, 1997.

ZAR, J. H. **Biostatistical analysis**. 5.ed. New Jersey: Prentice Hall, 2010. 944 p.

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