



Litterfall and litter in forest restoration sites in Mato Grosso do Sul, Brazil¹

Poliana Ferreira da Costa²; Zefa Valdivina Pereira³; Shaline Séfara Lopes Fernandes⁴; Caroline Quinhones Fróes⁵; Thiago Oliveira Barbosa⁶; Bruna Souza dos Santos⁷

Abstract: This study aimed to evaluate the potential of litter and litterfall as ecological indicators in three sites in restoration process located in Ivinhema, Jateí and Caarapó – Mato Grosso do Sul state, Brazil, after 12, 13 and 16 years of implantation, respectively. The objective was also to obtain Pearson's simple linear correlation) between monthly litterfall with environmental variables of rainfall and air temperature. To litterfall sampling, 15 litter traps were used (0.80 m x 0.80 m) and, for litter sampling, six collections were carried out in each restoration site, in December 2016, using a frame (0.64 m²). The samples were separated into three components: leaves, twigs, reproductive material (flowers and fruits). The high litter amount, in the three sites evaluated (Ivinhema 9.4 Mg ha⁻¹; Jateí 5.5 Mg ha⁻¹; and Caarapó 7.1 Mg ha⁻¹), demonstrates the importance of litterfall and litter as an indicator for the stages initial succession in restored forests. There were weak correlations between litter and environmental variables, being negative for air temperature and positive for rainfall.

Keywords: Environmental indicators; Nutrient cycling; Environmental variables

Produção e acúmulo de serapilheira em áreas de restauração florestal no Mato Grosso do Sul, Brasil

Resumo: Este estudo teve por objetivo avaliar o potencial da serapilheira produzida e acumulada como indicadores ecológicos em três áreas em processo de restauração, localizadas em Ivinhema, Jateí e Caarapó – Mato Grosso do Sul, Brasil, após 12, 13 e 16 anos de implantação, respectivamente. Objetivou-se também obter a correlação linear simples de Pearson entre a produção mensal de serapilheira com variáveis ambientais de precipitação pluviométrica e temperatura do ar. Para coleta da serapilheira produzida foram utilizados 15 coletores (0,80 m x 0,80 m) e, para a quantificação da serapilheira acumulada foram realizadas seis coletas em cada área de restauração, no mês de dezembro de 2016, com gabarito (0,64 m²). As amostras foram separadas em três frações: folhas, galhos, material reprodutivo (flores e frutos). A elevada produção de serapilheira, nas três áreas avaliadas (Ivinhema 9,4 Mg ha⁻¹; Jateí 5,5 Mg ha⁻¹; e Caarapó 7,1 Mg ha⁻¹), demonstra a importância da serapilheira, produzida e acumulada, como indicadora para os estágios iniciais de sucessão em florestas restauradas. Houve fracas correlações entre a produção de serapilheira e as variáveis ambientais, sendo negativa para a temperatura do ar e positiva para precipitação pluviométrica.

Palavras – chave: Indicadores ambientais; Ciclagem de nutrientes; Variáveis ambientais

¹ Received on 28 August 2019 and accepted for **scientific article** publication on 04 March 2020.

² Technologist in Environmental Management, Dra. Professor at Universidade Estadual do Mato Grosso do Sul, MS, Brazil. E-mail: <poliferreiradacosta@hotmail.com>

³ Biologist, Dra. Professor at Universidade Federal da Grande Dourados, MS, Brazil. E-mail: <zefapereira@ufgd.edu.br>

⁴ Agronomist, Dra. Professor at Universidade Estadual do Mato Grosso do Sul - UEMS, Cassilândia unit, MS, Brazil. E-mail: <shaline_sefara@hotmail.com>

⁵ Environmental Manager, Dra. Universidade Federal da Grande Dourados – UFGD, MS, Brazil. E-mail: <carolqf@hotmail.com>

⁶ Environmental Manager, Director at Departamento Ambiental na Secretaria de Meio Ambiente de Alcínópolis, MS, Brazil. E-mail: <thiago88oliveira84@gmail.com>

⁷ Environmental Technologist, Dra. Universidade Estadual do Oeste do Paraná, PR, Brazil. E-mail: <brusouzasantos@hotmail.com>

Introduction

Litter is the organic layer deposited on the soil, is composed of leaves, stems, reproductive organs and debris (COSTA et al., 2010). That organic material plays an important role in nutrient cycling dynamics, balance and maintenance of ecosystem functions (XIAOGAI et al., 2013). Its production directly controls the nutrients amount that return to the soil and its accumulation is related to decomposing by microorganism's activity, with degree of ecosystems disturbance and can be used as an ecological productivity indicator (CORREIA et al., 2016; BIANCHI et al., 2016).

As trees periodically replace their structures, both vegetative and reproductive, due to evolutionary factors or in response to environmental stresses, collecting and quantifying the deciduous material brought to the soil is a non-destructive way to estimating the ecosystems productivity, since this attribute it can represent up to 90% of the net primary forest production (CLARK et al., 2001).

Many factors influence the litterfall, as a pioneer species, e.g., usually contribute a greater litterfall amount than the secondary ones (BENVENUTTI-FERREIRA et al., 2009). The presence of species with complementary inputs is important to maintain a regular stock of litter throughout the year (VILLA et al., 2016). The litterfall in forests on initial succession stage, in humid tropical areas, may be superior to that of mature forests, as they present deciduous species and diversified floristic composition (MEGURO, VINUEZA and DELITTI, 1979). The accumulation rate of the litter in greatest population growth period can be a differential in forest restoration, since it is at this moment that plants most need nutrients and ecosystem services, to facilitate entry of more environmentally demanding new species (GONÇALVES, NOGUEIRA and DUCATTI, 2003).

Environmental variables, especially air temperature and rainfall, are one of the main of variation regulators of litterfall and litter supply

over the soil (BIANCHI et al., 2016; ANTONELI and FRANCISQUINI, 2015; SCORIZA and PIÑA-RODRIGUES, 2014). Usually, in dry periods there is greater litterfall in tropical environments, because the forest species use a strategy to minimize the less water availability effects (VILLA et al., 2016). There are divergences in research about the real environmental variables influence on litterfall in different biomes (ANTONELI and FRANCISQUINI, 2015), which denotes the importance of this correlation in litterfall studies.

As it is a key factor for maintenance of nutrients in ecosystem (SANTANA and SOUTO, 2011), the litterfall process, including accumulation rates of deciduous material, must be carefully studied, especially in restored sites conditions, where ecosystem functions are being re-established. This study aimed to evaluate the litterfall and litter in three sites in forest restoration process, and to evaluate the influence of rainfall and air temperature in litterfall.

Material and methods

Study sites

The experiment was carried out in three sites of forest restoration, located in Mato Grosso do Sul state, Brazil, in Ivinhema, Jateí and Caarapó municipalities. The study site in Ivinhema (central geographic coordinates: latitude 22° 18' 17" S and longitude 53° 48' 55" W) constitutes a forest restoration site, carried out by planting seedlings of native tree species in April 2004, it is called of "Recanto Verde Forest Reserve" and has 4.68 ha, historically used for agriculture and livestock.

The native vegetation is a Seasonal Semideciduous Forest (MATO GROSSO DO SUL, 2016). The climate of the region is considered a transition between tropical and subtropical and, according to Köppen's classification, it is Aw humid type with dry winter, rainy summer, where the average



temperature of the coldest month is below 18 °C and that of the month warmer is higher than 22 °C. The average annual rainfall ranges from 1,400 to 1,700 mm, with November, December and January being the rainiest quarter (OLIVEIRA, URCHEI and FIETZ, 2000).

The restoration site located in Jateí (central geographic coordinates: latitude 22° 28' 55" S and longitude 54° 18' 09" W) has 4.71 hectares. It is a forest restoration through the planting of seedlings of native tree species, carried out in May 2003. Previously the forest restoration, the study site was managed with conventional agricultural cultivation and pastures. The native vegetation is a Seasonal Semideciduous Forest (MATO GROSSO DO SUL, 2016). The climate of the region is considered tropical and it is Aw, according to the Köppen classification. In winter, the temperature varies between 14 °C and 15 °C, with frosts occurring. The annual temperature varies between 20 °C and 30 °C and the annual rainfall volume varies between 1,400 and 1,700 mm (OLIVEIRA, URCHEI and FIETZ, 2000).

The forest restoration site located in Caarapó (central geographic coordinates: latitude 22° 38' 02" S and longitude 54° 49' 19" W) has 1.5 hectares, comes from a planting of seedlings of native tree species carried out in 2000. The soil is characterized as an Oxisol with sandy texture (COSTA et al., 2017). The native vegetation is classified as Seasonal Semideciduous Forest (MATO GROSSO DO SUL, 2016). The climate of the region is considered tropical and it is Aw, according to the Köppen classification. The average annual temperature is 22.5 °C and the average annual rainfall is 1,547 mm. Before the restoration, the site was degraded by pastures (OLIVEIRA, URCHEI and FIETZ, 2000). The site was restored to continue a forest fragment.

Data collection and analysis

Fifteen litter traps of 0.64 m² (0.80 m x 0.80 m) were placed in each site, randomly distributed, suspended at approximately 1.30 m above the soil level. The litter traps were made

with an iron structure, were affixed a mesh 70%, with a 20 cm depth. The materials deposited in litter traps were collected monthly, for 9 months, starting in June 2015, being packed in labeled plastic bags and taken for screening in laboratory. As litterfall samples were selected in three fractions: leaves, twigs and reproductive material (flowers and fruits), dried in an oven at 65 °C, for 24 hours and quantified in dry mass in precision balance.

Each litter trap was used to estimate the monthly and annual litterfall in forest restoration sites. Once quantified, the fractions amounts, in grams (g), were converted into kilograms per hectare (kg ha⁻¹), where the litterfall (PAS), monthly and annual, was estimated using the mathematical expression (LOPES, DOMINGOS and STRUFFALDIDE VUONO, 2002): $PAS = (PS \times 10,000)/Ac$, where: PAS = average annual litterfall (kg ha⁻¹ year⁻¹); PS = average monthly litterfall (kg ha⁻¹ month⁻¹); and Ac = litter trap area (m²) then obtaining the litterfall estimate in kg ha⁻¹.

For correlation analysis between litterfall with environmental variables, was used monthly meteorological data including average air temperature and rainfall. These variables were chosen because air temperature and rainfall are among the environmental variables that affect litterfall (VILLA et al., 2016; SANTANA and SOUTO, 2011; SCHUMACHER et al., 2003). The meteorological data used in the study come from the weather station located in Ivinhema site (Ivinhema - IVINHEMA/INMET: 01/09/66 – 08/26/16); and from automatic sensor of Jateí site (Jateí - TRMM.1010/AGRITEMPO: 01/03/00 – 10/10/16); and from automatic sensor of Caarapó site (Caarapó - TRMM.1007/AGRITEMPO: 01/03/00 – 10/10/16) available by INMET (“Instituto Nacional de Meteorologia”), through the Agrometeorological Monitoring System (AGRITEMPO, 2016). Pearson's simple linear correlation (r) between litterfall and environmental variables was performed. The values of r can vary between -1 to 1 and can be classified qualitatively, according to Callegari-

Jacques (2003), as follows: 0.0 to 0.30 weak correlation; 0.30 to 0.60 moderate correlation; 0.60 to 0.90 strong correlation; 0.90 to 1 very strong correlation.

Litter was carried out in December 2016, with a frame with an area of 0.64 m² (0.80 m x 0.80 m) placed on soil surface, and all material organic present inside was collected and stored in paper bags. Were made six collections inside of each forest restoration site, at random. Samples were taken to laboratory and inserted in a closed circulation oven and air renewal at 65 °C, until reaching constant dry mass.

Subsequently, the material was weighed.

Results

The largest annual litterfall occurred in Ivinhema site (9.41 Mg ha⁻¹), being formed, in its majority, by leaves (63.0%). The lowest production was registered in Jatéi site, with 5.52 Mg ha⁻¹ (62.9% leaves). In Caarapó site, the total litterfall was 7.09 Mg ha⁻¹, with 70.7% of leaves, which proves the great importance of this fraction for the litterfall (Table 1).

Table 1 - Litterfall (kg ha⁻¹) in forest restoration sites in Mato Grosso do Sul state, Brazil, during the period of June 2015 to February 2016.

Tabela 1 - Produção de serapilheira (kg ha⁻¹) em áreas de restauração florestal no estado do Mato Grosso do Sul, Brasil, durante o período de junho/2015 a fevereiro/2016.

Sites	Month	kg ha ⁻¹			Total
		Leaves	Twigs	Reproductive material	
Ivinhema	Jun	343.04	106.42	168.52	618.75
	Jul	551.45	56.56	43.17	651.56
	Aug	1,114.85	306.39	221.48	1,642.19
	Sep	731.05	345.99	306.31	1,382.81
	Oct	233.59	64.47	194.92	493.75
	Nov	534.73	155.47	292.54	982.81
	Dec	665.27	130.85	305.70	1,101.56
	Jan	1,035.10	141.46	129.66	1,306.25
	Feb	745.03	142.59	339.09	1,226.56
	Average	661.57	161.13	222.38	1,045.14
Total	5,954.13	1,450.20	2,001.39	9,406.25	
Jatéi	Jun	405.43	80.96	50.44	536.82
	Jul	333.15	69.98	40.36	443.49
	Aug	915.20	303.69	209.74	1,428.63
	Sep	165.76	118.76	340.86	625.39
	Oct	99.41	53.44	22.24	175.08
	Nov	297.03	110.36	42.20	449.59
	Dec	304.99	136.83	60.98	502.80
	Jan	615.18	124.02	142.68	881.88
	Feb	338.58	80.72	59.68	478.98
	Average	386.08	119.86	1,076.9	613.63
Total	3,474.72	1,078.76	969.18	5,522.65	
Caarapó	Jun	527.09	81.49	160.21	768.79
	Jul	535.48	71.02	80.54	687.04
	Aug	1,399.02	119.48	260.52	1,779.02
	Sep	389.34	71.34	109.69	570.38
	Oct	315.14	53.83	84.54	453.51
	Nov	390.71	98.06	203.09	691.86
	Dec	364.14	130.88	189.04	684.05
	Jan	820.44	65.64	76.98	963.05
	Feb	271.50	81.61	138.64	491.75
	Average	556.98	85.93	144.81	787.72
Total	5,012.85	773.35	1,303.25	7,089.45	



Regarding the litterfall composition, leaf fraction was the most representative for the three sites, varying from 62.91 to 70.70%, being the highest value found in Caarapó site. The reproductive material was the one with the second largest contribution, with values between 17 and 22%, followed by twigs, with values between 10 and 20% (Figure 1).

In Ivinhema site the litterfall increased in August, when there was an increase in temperature, and in the spring and summer period (Figure 2). In August there was the highest litterfall value ($1,642.19 \text{ kg ha}^{-1}$). In October, there was a reduction in litterfall and, with the exception of this month, the increase in litterfall followed the increase in air temperature until the last month evaluated.

Moderate correlation was found between litterfall and average monthly air temperature ($r = 0.38$). In Jateí site, the month of August also had the highest litterfall ($1,428.63 \text{ kg ha}^{-1}$) and

lowest in October ($175.08 \text{ kg ha}^{-1}$), in following months there was a small gradual increase in litterfall, which decreased again in February, showing a weak correlation between litterfall and air temperature ($r = -0.11$). Similar results were found in Caarapó site, where the largest litterfall occurred in August ($1,779.02 \text{ kg ha}^{-1}$), with a decrease in October, but not as significant as in Jateí site and, in the following months, there was a small increase, with a weak and inverse correlation of $r = -0.28$ with air temperature. The correlation between litterfall and rainfall, with exception of Ivinhema site, which presented a moderate correlation of $r = 0.05$, for the other sites was weak, where in Jateí site the r was -0.38 and Caarapó site the value is -0.66 .

The litter amount was similar for Ivinhema and Caarapó sites ($14,221.40$ and $14,126.71 \text{ kg ha}^{-1}$, respectively) and lowest values were found in Jateí site ($8,289.84 \text{ kg ha}^{-1}$).

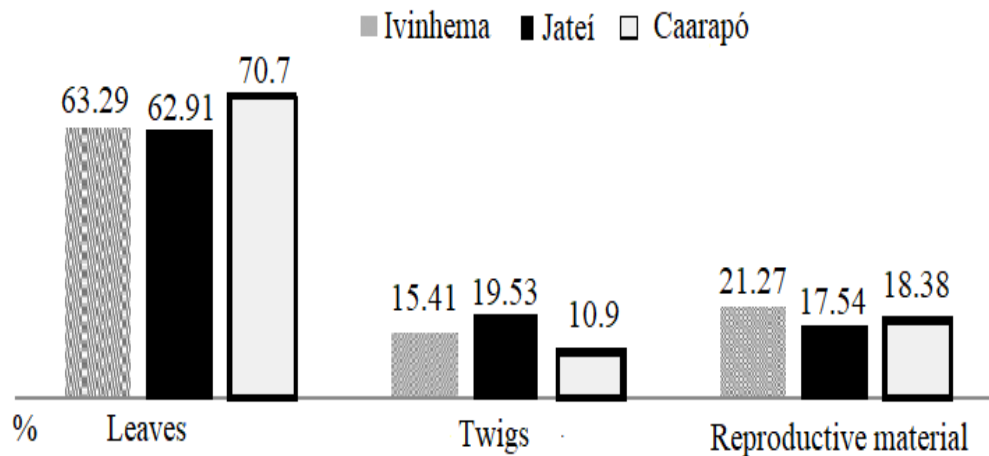


Figure 1 - Percentage values of litterfall fractions (leaves, twigs and reproductive material), in forest restoration sites in Mato Grosso do Sul state, Brazil.

Figura 1 - Valores percentuais das frações da serapilheira (folhas, galhos e material reprodutivo) em áreas de restauração florestal no estado do Mato Grosso do Sul, Brasil.

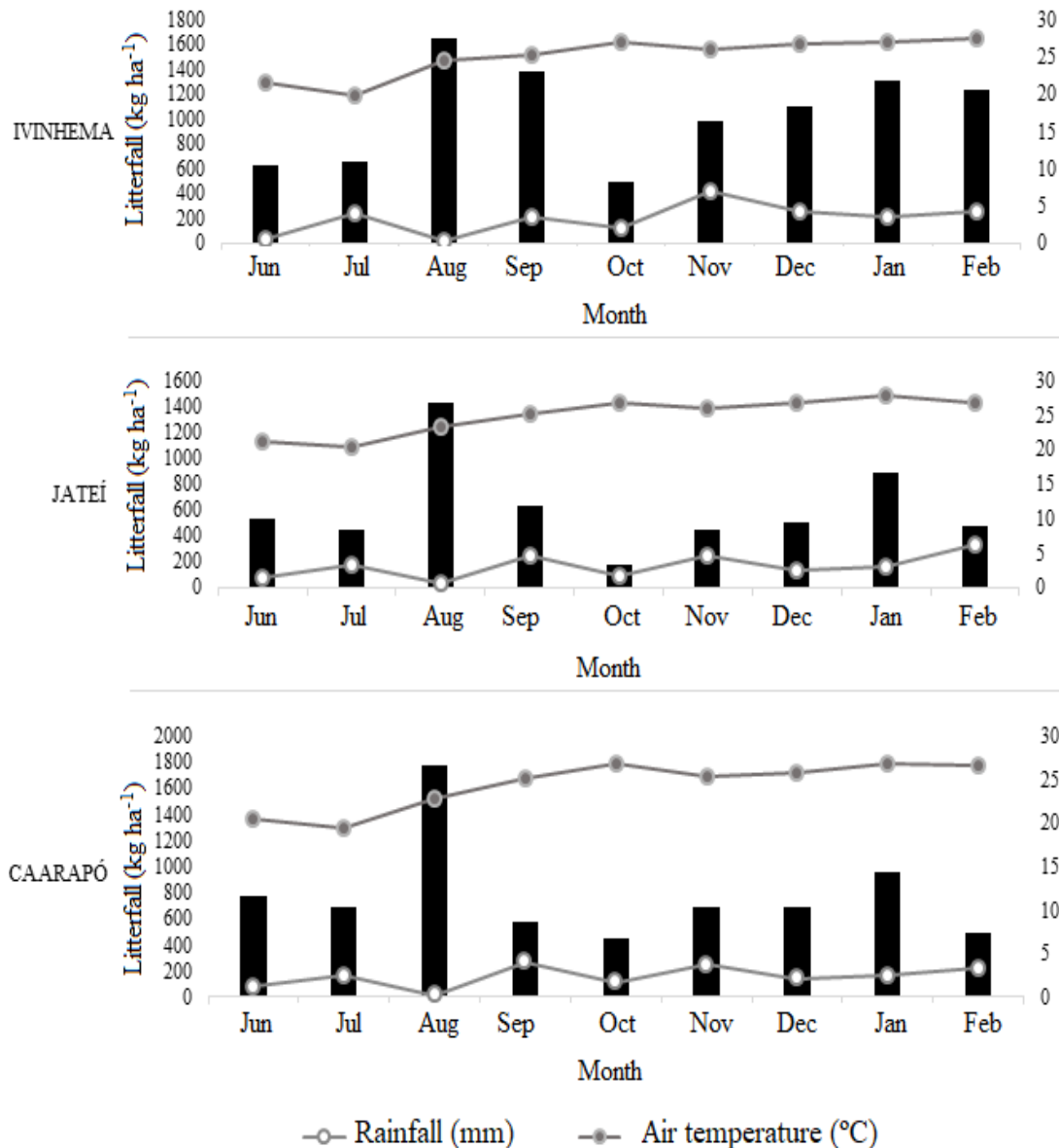


Figure 2 - Seasonality of litterfall (kg ha^{-1}) in forest restoration sites in Mato Grosso do Sul state, Brazil, during the period of June 2015 to February 2016.

Figura 2 - Sazonalidade da produção de serapilheira (kg ha^{-1}) em áreas de restauração florestal no estado do Mato Grosso do Sul, Brasil, durante o período de junho/2015 a fevereiro/2016.

Discussion

In forest restoration after 12 years, the Ivinhema site, there was an increase in litterfall that was superior to the other sites. In this condition, the species found in this site in the most recent restoration may have been conducive to the greater litterfall, probably due to its greater deciduity. Machado, Piña-

Rodrigues and Pereira (2008) employing litterfall as a bioindicator, to compare different stages of regeneration of secondary forest, capoeira and pasture and a densely planted model of revegetation in Atlantic Forest, found that litterfall may be related to perennial behavior or deciduous of the trees, but not

always with climatic factors.

The results obtained in this research are within the range found for non-degraded tropical forests, which allows to positively infer about the restoration status of evaluated ecosystems. High litterfall is essential for maintenance and improvement of edaphic factors linked to plant nutrition, since this organic material will be in soil deposited and will decompose, providing nutrients, and consequently, promote the ecological balance and sustainability of these systems (MACHADO et al., 2015).

Santana and Souto (2011) found similar values of 79.90%, 9.27%, 7.91% and 2.92% for leaves, twigs and bark, miscellaneous and reproductive material, respectively, evaluate the litterfall of an ecological station. In another study, similar values were obtained by Villa et al. (2016), in Seropédica municipality, Rio de Janeiro state, in an site of 12 years of forest restoration, with a greater contribution of leaves (75.0%), followed by twigs (7.7%) and to a lesser extent reproductive fractions and miscellaneous. According to these authors, leaf fraction of litterfall usually varies from 60-80%, for Atlantic Forest.

Phytosociology at the sites evaluated in present study was characterized by Costa et al. (2017), who found a significant number of pioneer species in floristic composition. The pioneer species, typical of initial stages of forest succession, produce a large amount of litterfall, since they produce a greater amount of biomass in a short period of time, which results in great leaf renewal (LEITÃO-FILHO et al., 1993).

Schumacher et al. (2003), observed an increase in litterfall in spring and summer season, with an increase from November, lasting until February. According to these authors, the high air temperature promoted greater litterfall amount in many species, so that the greater plants physiological activity in this period also causes an intense foliage exchange, resulting in new foliage and photosynthetically more active.

In forest restoration sites studied, the highest

rainfall volumes occurred in July, September and, from November to February (OLIVEIRA, URCHEI and FIETZ, 2000). In Jateí and Caarapó sites the highest litterfall were found in August, September and January, resulting in a weak correlation between litterfall and rainfall. Costa et al. (2014), evaluating the litterfall and correlation with rainfall, and soil moisture, in National Forest of Caxiuana municipality, Pará state, Brazil, found that the monthly litterfall responded to rainfall regime, with an inverse correlation; the greatest litterfall occurred during the least rainfall period. However, Lima et al. (2015), observed a significant correlation ($r = 0.62$) between litterfall and rainfall, demonstrating that there may be a directly proportional influence on deciduous material deposition.

However, this correlation between litterfall and environmental variables is usually weak and variable in Atlantic Forest areas (SCORIZA and PIÑA-RODRIGUES, 2014). According to these authors, with evaluating the rainfall and air temperature effect on litterfall, in fragments of Atlantic forest, located in Sorocaba municipality, São Paulo state, Brazil, found that variables did not immediately influence the litterfall, but the more significant effects were evident a few months later. They also pointed out that there was a tendency for less litterfall when there was an increase in air temperature and rainfall.

According to Arato, Martins and Ferrari (2003), it can take up to two months for vegetation to respond to water stress. However, Scoriza and Piña-Rodrigues (2014), emphasize the importance of air temperature and rainfall in biomass supply. Confirming this presupposition, Bianchi et al. (2016), evaluating a Seasonal Semideciduous Forest, in “Serra da Concórdia” area, Valença municipality, Rio de Janeiro state, found that air temperature and rainfall did not immediately influence the litterfall, but showed more significant effects a few months later. In the present study, an inversely proportional correlation was also observed, indicating less input and litterfall when there was a greater rainfall volume, but

one or two months after the occurrence of rainfall, litterfall increased.

Sperandio et al. (2012), when evaluating the litter in two forest restoration systems, being a consortium between eucalyptus and acacias and a system with different species in Alegre municipality, Espírito Santo state, Brazil, found litter average values of 5,610 kg ha⁻¹. Alves, Viera and Schumacher (2014), evaluated the forest fragmentation effect on litter in Deciduous Seasonal Forest in Silveira Martins municipality, Rio Grande do Sul state, with greater litter amounts, resulting in an accumulation of 6,950 kg ha⁻¹.

The litter analysis in forest restoration sites of this study was carried out in December 2016, a time when high levels of rainfall occurred, mainly in November, which resulted in greater accumulation and deposition of organic material. According to Vogel et al. (2013), the amount of organic material produced during the year is mainly related to climate conditions of the region where the site is located, because in places where higher temperatures occur, the vegetation, consequently, has a lower leaf mass index, with less deposition. On the contrary, in regions of low temperatures, or high humidity, where the vegetation adapts better, there is a greater litter amount o.

Jateí was the site with the lowest litterfall and litter. This is probably related to high number of late secondary species in this site, in addition to being a less dense planting, with greater spacing between lines compared to other sites. With a smaller number of trees, consequently there is less litterfall and litter, in addition this site may also have a lower number of deciduous species in its floristic composition.

However, forest types in initial stage of formation, due to the great presence of pioneer species, deposit more litter, and more accumulation and stock of deciduous biomass. In forests in an advanced stage of succession, or primary forest, conserve the largest stock of biomass in the living plant mass (FERNANDES et al., 2007). This statement may suggest that the greater litter amount in

forest restored site of Ivinhema, considering only the litterfall, may be related to the greater presence of pioneer species in relation to the other evaluated sites.

Conclusions

High litterfall were found in the three sites, demonstrating the importance of this environmental indicator for the initial stages of succession in restored forests. Litterfall showed a higher correlation with air temperature than with precipitation, demonstrating the greater influence of this factor on litterfall.

References

AGRITEMPO. Sistema de Monitoramento Agrometeorológico. Disponível em: <https://www.agritempo.gov.br/agritempo/jsp/Estadisticas/index.jsp?siglaUF=MS>. Consultado em outubro de 2016.

ALVES, M. P.; VIERA, M.; SCHUMACHER, M. V. Efeito da fragmentação florestal sobre o acúmulo de serapilheira em Floresta Estacional Decidual. *Ecologia e Nutrição Florestal*, Santa Maria-RS, v.2, n.3, p.63-71. 2014. <https://periodicos.ufsm.br/enflo/article/view/16014>

ANTONELI, V.; FRANCISQUINI, V. Influência de alguns elementos climáticos na produção de serrapilheira em um reflorestamento de pinus na FLONA (Floresta Nacional) de Irati- PR. *Caderno de Geografia*, v.25, n.44, 2015. <http://periodicos.pucminas.br/index.php/geografia/article/view/9561>

ARATO, H. D.; MARTINS, S. V.; FERRARI, S. H. Produção e decomposição de serrapilheira em um sistema agroflorestal implantado para recuperação de áreas degradadas em Viçosa-MG. *Revista Árvore*, v.27, n.5, p.715-721,



2003.
<http://www.scielo.br/pdf/rarv/v27n5/a14v27n5.pdf>
- BENVENUTTI-FERREIRA, G. et al. Dendrometry and litterfall of neotropical pioneer and early secondary tree species. *Biota Neotropica*. 2009; v. 9(1): 65-71. http://www.scielo.br/scielo.php?pid=S1676-06032009000100008&script=sci_arttext
- BIANCHI, M. DE O.; SCORIZA, R. N.; E CORREIA, M. E. F. Influência do clima na dinâmica de serrapilheira em uma floresta estacional semidecidual em Valença, RJ, Brasil. *Revista Brasileira de Biociências*, Porto Alegre, v. 14, n.2, p. 97-101. 2016. <http://www.ufrgs.br/seerbio/ojs/index.php/rbb/article/view/3377>
- CALLEGARI-JACQUES, S. M. Bioestatística: princípios e aplicações. Porto Alegre: Artmed, 2003. 255 p.
- CLARK, A.D. et al. Net primary production in tropical forests: an evaluation and synthesis of existing field data. *Ecological Applications*, v.11, n.2, p.371-384, 2001. <https://esajournals.onlinelibrary.wiley.com/doi/10.1890/1051-0761%282001%29011%5B0371%3ANPPITF%5D2.0.CO%3B2>
- CORREIA, G. DE S. G. et al. Estoque de serrapilheira em floresta em restauração e em floresta atlântica de tabuleiro no sudeste brasileiro. *Revista Árvore*, Viçosa-MG, v.40, n.1, p.13-20, 2016.
http://www.scielo.br/scielo.php?pid=S0100-67622016000100013&script=sci_abstract&tlng=pt
- COSTA, C.C.A. et al. Análise comparativa da produção de serrapilheira em fragmentos arbóreos e arbustivos em área de caatinga na Flona de Açú - RN. *Revista Árvore*, n.34, v.2, p.259-265, 2010. http://www.scielo.br/scielo.php?script=sci_abstr&pid=S0100-67622010000200008&lng=en&nrm=iso&tlng=pt
- COSTA, M. C. et al. Correlação entre precipitação pluviométrica e umidade do solo na produção de serrapilheira em Caxiuanã (PA). *Revista Ibero-Americana de Ciências Ambientais*, Aquidabã, v.5, n.1, p.170-179, 2014. <https://pdfs.semanticscholar.org/580d/5e159cba867c28d3581efc86aa1accd69856.pdf>
- COSTA, P. F. et al. Composição florística e estrutura fitossociológica de três áreas de restauração florestal localizadas no estado do Mato Grosso Do Sul, MS. In: Adriane Theodoro Santos Alfaro; Daiane Garabeli Trojan. (Org.). *Descobertas das Ciências agrárias e ambientais 3*. 3ed. Ponta Grossa, PR: Editora Atena, 2017, v. 2, p. 107-145.
- FERNANDES, M.E.B., NASCIMENTO, A.A.M., CARVALHO, M.L. Estimativa da produção anual de serrapilheira dos bosques de mangue no Furo Grande, Bragança-Pará. *Revista Árvore*. v.31: p.949- 958. 2007. http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0100-67622007000500019
- GONÇALVES, J. L. M.; NOGUEIRA, L. R. JR.; DUCATTI, F. Recuperação de solos degradados. In: Kageyama PY, Oliveira RE, Moraes LFD, Engel VL, Gandara FB. *Restauração ecológica de ecossistemas naturais*. Botucatu: FEPAF; 2003.
- LEITÃO-FILHO, H.F. et al. *Ecologia da mata atlântica em Cubatão*, SP. São Paulo: EDUNESP/EDUNICAMP, 1993. 86p.
- LIMA, R.P. et al. Aporte e Decomposição da Serrapilheira na Caatinga no Sul do Piauí. *Floresta e Ambiente*. v. 22, n.1. p:42-49. 2015. <http://www.scielo.br/pdf/floram/v22n1/2179-8087-floram-22-1-42.pdf>
- LOPES, M. I. S.; DOMINGOS, M.; STRUFFALDIDE VUONO, Y. Ciclagem de

nutrientes minerais. In: SYSLVESTRE, L. S.; ROSA, M. M. T. Manual metodológico para estudos botânicos na mata atlântica. Seropédica: EDUR – UFRRJ, 2002.p.72-102.

MACHADO, D. L. et. al. Ciclagem de nutrientes em diferentes estágios sucessionais da mata atlântica na bacia do Rio Paraíba Do Sul, RJ. Bioscience Journal, Uberlândia, v. 31, n. 4, p. 1222-1237. 2015. <http://www.seer.ufu.br/index.php/biosciencejournal/article/view/23092>

MACHADO, M. R.; PIÑA-RODRIGUES F. C.M.; PEREIRA, M. G. Produção de serapilheira como bioindicador de recuperação em plantio adensado de revegetação. Revista *Árvore*, Viçosa-MG, v.32, n.1, p.143-151, 2008.

http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0100-67622008000100016

MATO GROSSO DO SUL-SEMACE/MS. Secretaria de Estado do Meio Ambiente e Desenvolvimento Econômico. Caderno Geoambiental. Região de Planejamento do Estado de Mato Grosso do Sul. Disponível em: <http://www.servicos.ms.gov.br/semace_download/Caderno%20Ambiental/Caderno_Geoambiental.pdf>. Acessado em: 20 de dezembro de 2016.

MEGURO, M.; VINUEZA, G. N.; DELITTI, W. B. C. Ciclagem de nutrientes minerais na Mata Mesófila secundária. Produção e conteúdo de nutrientes minerais do folheto. Boletim de Botânica da Universidade de São Paulo 1979; 7: 61-67.

OLIVEIRA, H. de; URCHEI, M.A.; FIETZ, C.R. Aspectos físicos e socioeconômicos da bacia hidrográfica do rio Ivinhema. Dourados MS: Embrapa, p.52. 2000.

SANTANA, J. A. DA S.; SOUTO, J. S. Produção de serapilheira na Caatinga da região semi-árida do Rio Grande do Norte, Brasil. *IDESIA* (Chile). V. 29, Nº 2. P. 87-94. 2011.

SCHUMACHER, M. V. et. al. Retorno de nutrientes via deposição de serapilheira em um povoamento de acácia-negra (*Acacia mearnsii* de Wild.) no estado do Rio Grande do Sul. *Revista Árvore*. v.27. n.6, p.791-798. 2003. http://www.scielo.br/scielo.php?pid=S0100-67622003000600005&script=sci_abstract&tlng=pt

SCORIZA, R. N.; PIÑA-RODRIGUES, F. C. M. Influência da precipitação e temperatura do ar na produção de serapilheira em trecho de floresta estacional em Sorocaba, SP. *Floresta*, Curitiba, PR, v. 44, n. 4, p. 687 - 696. 2014. <https://revistas.ufpr.br/floresta/article/view/34274>.

SPERANDIO, H. V. et al. Emprego da Serapilheira Acumulada na Avaliação de Sistemas de Restauração Florestal em Alegres. *Floresta e Ambiente*. V. 19. N.4. P. 460-467. 2012.

http://www.scielo.br/scielo.php?pid=S2179-80872012000400008&script=sci_abstract&tlng=pt

VILLA, E. B. et al. Aporte de Serapilheira e Nutrientes em Área de Restauração Florestal com Diferentes Espaçamentos de Plantio. *Floresta Ambiente*.V.23, n.1. 2016. http://www.scielo.br/scielo.php?pid=S2179-80872016000100090&script=sci_abstract&tlng=pt

VOGEL, H. L. M. et al. Efeito de borda no estoque de serapilheira e nutrientes em um fragmento de floresta nativa na região do Bioma Pampa-RS. *Ecologia e Nutrição Florestal*, v. 1, n. 1, p. 46-45, jan./abr. 2013. <https://periodicos.ufsm.br/enflo/article/view/14743>

XIAOGAI, G. et al. Effect of litter substrate quality and soil nutrients on forest litter decomposition: A review. *Acta Ecologica Sinica*. Vol. 33, Issue 2, P. 102–108. 2013. <https://www.sciencedirect.com/science/article/pii/S1872203213000115>

