Annual litterfall in an Atlantic Forest fragment in Northeast Brazil

Producción anual de hojarasca en un fragmento de Bosque Atlántico en el noreste de Brasil

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ABSTRACT

The ecological structure of forest fragments is closely related to the dynamics of biological flows directly dependent on the decomposition of the litterfall, which is the main mechanism of recycling nutrients to plants. In this sense, the objective of the present work was to quantify the annual litterfall productionduring the period from April 2013 to March 2014 in Mata do Bebo, an Atlantic Forest fragment located in Macaíba, Rio Grande do Norte. 10 conical collectors were used to obtain the data on the litter contribution, with an average opening area of 0.128 m², placed 1 m above the ground.. The material was collected monthly, dried at air temperature for 48 h, and separated into four fractions: leaves, bark and branches, reproductive material; and miscellaneous material. After separation, the fractions were weighed and stored. The total contribution of litter was uninterrupted and totaled 5,038.72 kg ha^{-1} year^{-1}, with the highest production in September, at the beginning of the dry season, and the lowest in July. The foliar fraction made the largest contribution, with 3,744.26 kg ha^{-1} year^{-1}, followed by the reproductive material, which reached 846.29 kg ha^{-1} year^{-1}, branches and bark, with 396.10 kg ha^{-1} year^{-1}, and miscellaneous material, with 52,069 kg ha^{-1} year^{-1}. The correlations of litterfall production with rainfall and temperature were negative. The litterfall production in the fragment was lower than that obtained in other remaining Atlantic Forest areas, possibly because it is located in a region considered an ecotone between the Caatinga and Atlantic Forest biomes, besides the anthropic effect to which it has been submitted for decades.

Keywords: climate parameters, litter production, nutrient cycling, forest nutrition.

RESUMEN

La estructura ecológica de un fragmento de bosque está estrechamente relacionada con la dinámica de los flujos biológicos, ya que depende directamente de la descomposición de la hojarasca, que representa el principal mecanismo de disponibilidad y retorno de nutrientes a las plantas. El objetivo de este trabajo fue cuantificar la producción anual de hojarasca en un fragmento de Bosque Atlántico en el noreste de Brasil. Para obtener datos sobre la producción de hojarasca se utilizaron 10 colectores cónicos con una superficie media de 0,128 m², situados a 1 m de altura. El material se recogía mensualmente, se secaba a temperatura ambiente durante 48 h y se separaba en fracciones: hojas, corteza, ramas, material de reproducción y miscelánea. Después de la separación las fracciones fueron pesadas y almacenadas. La producción de hojarasca fue ininterrumpida y ascendió a un total de 5.038,72 kg ha^{-1}.año^{-1}, con la mayor producción en septiembre, al comienzo del período seco, y la menor en julio. La fracción foliar fue la que presentó el mayor aporte en la producción de la hojarasca, con 3.744,26 kg ha^{-1} año^{-1}, seguida del material de reproducción que alcanzó a 846,29 kg ha^{-1} año^{-1}, las ramas y las cáscaras con 396,10 kg ha^{-1} añoy material misceláneo con 52.069 kg ha^{-1} año^{-1}. Las correlaciones de la producción de hojarasca con la lluvia y la temperatura resultaron negativas. La producción de hojarasca en el fragmento fue menor que la obtenida en otras zonas del Bosque Atlántico, posiblemente porque se encuentra en una región considerada un ecotono con la Caatinga, además del efecto antrópico al que ha estado sometido durante décadas.

Palabras clave: parámetros climáticos, producción de hojarasca, ciclo de nutrientes, nutrición de los bosques.

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Introduction

The terrestrial ecosystems in tropical regions are considered the most biologically diverse and ecologically complex on the planet, especially the humid tropical forests (Gibson *et al.*, 2011). The Brazilian Atlantic Forest is among the most important large humid tropical forests and is considered one of the world's priority hotspots for conservation due to the high diversity of species and endemism, jeopardized by severe degradation (Joly *et al.*, 2014; Mittermeier *et al.*, 2011).

The process of degradation and fragmentation of the Atlantic Forest began during the colonization of Brazil, which started in coastal areas, and is still ongoing, due to the country's main economic and urban centers in its areas (Archanjo *et al.*, 2012). The Atlantic Forest vegetation covers, totally or partially, 17 Brazilian states located along the Atlantic coast. This vegetation occurs from the states of Rio Grande do Sul to Rio Grande do Norte, where 12.4% of its original coverage exists, considering forest fragments above 3 hectares, which include secondary forests and areas restored in different successional stages (Fundação SOS Mata Atlântica, 2019). Thus, the devastation of the biome reflects the uncontrolled occupation and exploitation of natural resources, resulting in a drastic reduction in the area of natural vegetation, with a high concentration of small forest fragments, mostly less than 50 hectares (Ribeiro *et al.*, 2009).

In general, in humid tropical forest ecosystems, the exuberant and dense vegetation is maintained by the organic layer that develops through the deposition of litterfall since, due to local climatic conditions, the soils are acid, with low availability of nutrients and high saturation by Al^{3+}. The nutritional demand is thus met mostly by nutrient cycling (Lima *et al.*, 2018). Litterfall is defined as any organic material deposited on the ground from the phytomass of plants (leaves, bark, branches, and reproductive material), as well as dead animals and insects, their excrement, and unidentifiable material called miscellaneous. The cycling of nutrients enables plants to reuse the deciduous phytomass to maintain their nutritional self-sufficiency by absorbing the nutrients released into the soil through the decomposition of the litterfall.

Information about how this process occurs is fundamental to understanding the soil nutritional dynamics in forest fragments (Alves *et al.*, 2006). According to Carielo *et al.* (2019), the size of the fragment is linked to the dynamics of biological flows and growth rates, influencing the composition of biodiversity. Thus since the litterfall is the main source of nutrients for plants in these ecosystems, the amount produced may indicate the fragment's capacity for self-sufficiency since the material returns to the ecosystem through nutrient cycling.

This work aimed to quantify the annual litterfall production in an Atlantic Forest fragment in the Northeast of Brazil. The following hypotheses were tested: i) Do climatic parameters influence the production of forest litterfall? and ii) Is there a seasonal pattern in litterfall production?

Material and Methods

Study area

The study was conducted on an Atlantic Forest fragment popularly known as Mata do Bebo, located at geographical coordinates 5º53'30'' S and 35º21'30'' W, in the area of the Jundiaí Agricultural School, part of Rio Grande do Norte Federal University (UFRN), in the municipality of Macaíba (Figure 1). The total area of the fragment is 6.5 ha, with elongated geometry in the East-West direction (Araújo *et al.*, 2015). The term "*Bebo*," which gives the fragment its popular name, refers to the topographically lower part of the forested area, characterized by moist soil due to the presence of a small stream along its border. The average altitude of the forest fragment is 40 m, with the steepest slope in the lower third of the area. The declivity degree, between the maximum and minimum altitudes is around 6%, not exceeding 10 m in altitude.

The municipality of Macaíba, according to the climate classification of Köppen, is of type As, with the rainy season between May and July, while the dry season occurs between September and December. The average annual precipitation is approximately 1,280 mm, and the monthly temperature varies between 24 and 28 ºC (Figure 2). The approximate time of insolation is 2,700 h year^{-1}, and the average relative humidity is 74% (Alvares *et al.* 2014; Climate-Date, 2016).

According to the Brazilian Soil Classification System, the area's predominant soil is Dystrophic Red Latosol, which is deep, with slightly wavy relief, acid pH, and base saturation < 50%. The chemical characterization of the soil was performed in previous studies (Table 1). According to a study by Araújo *et al.* (2015), the vegetation is in a medium stage of
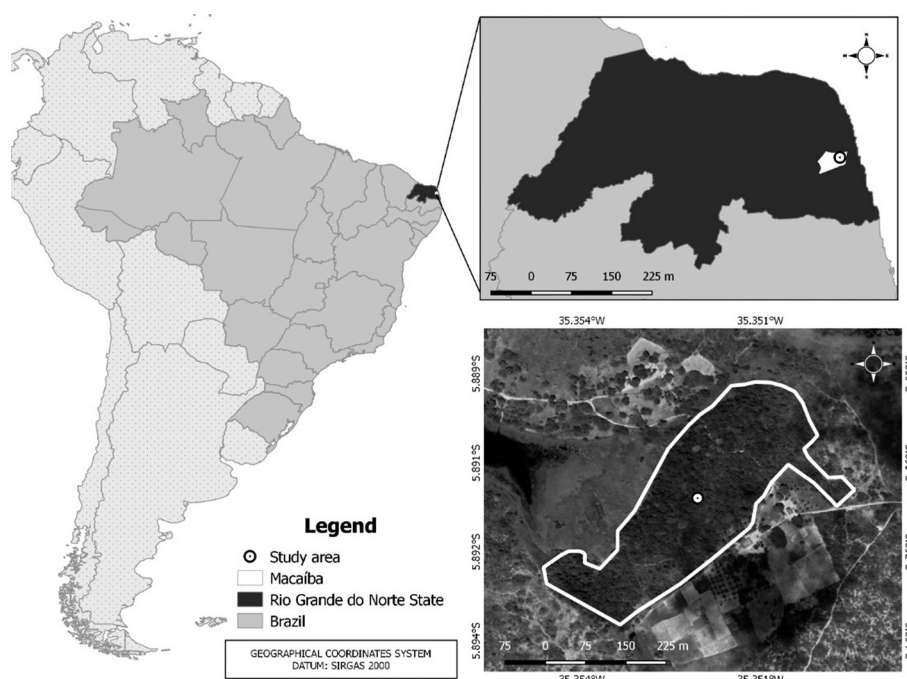
Figure 1. Location of the Atlantic Forest fragment (Mata do Bebo) in Macaíba, RN. Source: Google Earth, with adaptations.
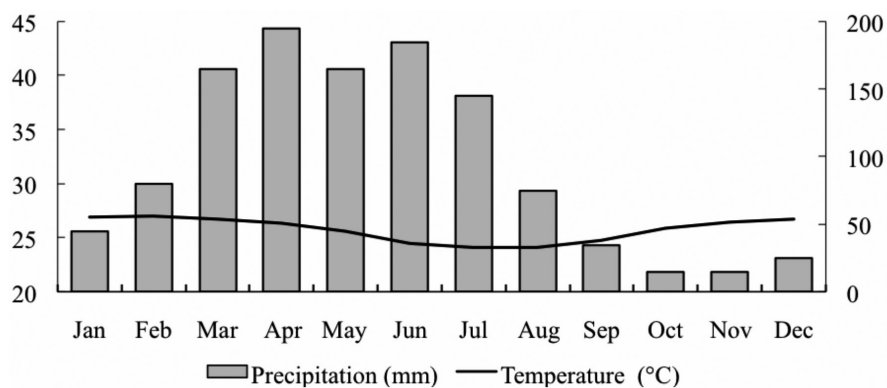

Figure 2. Monthly distribution of precipitation and temperature in the municipality of Macaíba, RN. Source: Climate-data, 2016.

Table 1. Chemical characterization of the Mata do Bebo Atlantic Forest fragment in Macaíba, RN.

Depth (cm)	pH (H$_2$O)	P	K	Na	Ca	Mg	Al	Al + H
		mg.dm^{-3}			cmol$_c$.dm^{-3}			
0-20	5.32	2.0	97	15	0.84	0.36	0.00	0.35
20-40	5.16	1.5	90	19	0.59	0.26	0.04	0.46
40-60	5.06	1.0	88	20	0.77	0.32	0.07	0.59

P = phosphorus; K = potassium; Na = sodium; Ca = calcium; Mg = magnesium; Al = aluminum; Al + H = aluminum + hydrogen; H2O = water.

regeneration, 1,873 arboreal individuals distributed in 57 species and belonging to 30 botanical families. According to the cited work, the local vegetation, despite the significant number of families and arboreal species, is dominated by *Eugenia rostrifolia* D. Legrand, *Protium heptaphyllum* (Aubl.) Marchand, *Copaifera cearensis* Huber ex Ducke, *Coccoloba alnifolia* Casar and *Erythroxylum citrifolium* A.St.-Hil., which together account for 49.4% of the density of local vegetation.

Litterfall collection

The litterfall collection was carried out uninterruptedly for 12 months, from April 2013 until March 2014. 10 conical collectors were randomly installed in the forest fragment, made of green nylon mesh with a circular opening and a frame made of rigid wire to obtain the litterfall production data.The average opening area was 0.128 m², and the collectors were placed 1 m above the ground, supported by two PVC pipes buried about 10 cm deep in the soil to fix the collectors better.

The deciduous material was collected in the first week of each month, packed in paper bags, and sent to the Forest Ecology Laboratory of Jundiaí Agricultural School, where it was dried at air temperature for 48 hours. After this period, the material was separated into fractions: leaves, bark and branches, reproductive material, and miscellaneous material. Branches larger than 1 cm in diameter were discarded. The material was packed in paper bags identified by fractions and dried in a forced-air oven at 65 ºC for 72 h. The fractions were then weighed on a precision scale to obtain the dry mass and then transformed into kg ha^{-1}.month^{-1}. The weight data were used to calculate the correlations of litterfall production with the air temperature, rainfall, and delayed rainfall, corresponding to three months' difference. Pearson's correlation coefficient was used with the BioEstat 5.3 statistical software.

Results and discussion

Litterfall production

The total annual litterfall litterfall production in the forest fragment studied was 5,038.72 kg ha^{-1}. These results are lower than those found by Pinto *et al*. (2008) when evaluating litterfall litterfall production in Atlantic Forest segments presenting different successional stages. They found annual litterfall production of 6,310 kg ha^{-1} in the initial forest and 8,819 kg ha^{-1}. In the mature forest. Costa *et al*. (2019), when studying litterfall litterfall production in a fragment of Atlantic Forest in the southern part of the state of Goiás, also found greater results, with litterfall production estimated at 6,340 kg ha^{-1} year^{-1}. Finally, Dick and Schumacher (2020) estimated litterfall litterfall production in an Atlantic Forest fragment in southern Brazil at 7,750 kg ha^{-1} year^{-1}.

In contrast, other studies carried out in Atlantic Forest fragments have quantified average litterfall production similar to this study, with values ranging from 4,900 to 5,730 kg ha^{-1} year^{-1} (Calvi *et al*., 2009; Gomes *et al*., 2010). As a key factor in maintaining nutrients in forest ecosystems, deposition of litterfall, including annual rates of decline of deciduous material and the process of decomposition of this material, should be more widely studied, especially in the tropics where there is a large occurrence of weathered soils with low nutrient availability (Santana and Souto, 2011; Dick and Schumacher, 2020).

The highest litterfall production was observed in September, estimated at 716,628 kg ha^{-1} (Figure 3). The month of September coincides with the beginning of the dry season in the region studied, explaining this high litterfall deposition. There was a large difference in deposition between the periods of the year, with deposition of 255.47 kg ha^{-1} in the rainy season (March - July) and 537.34 kg ha^{-1} in the dry season (August - February). Due to the high production, the period from September to October is the most appropriate for litterfall collection. In this sense, litterfall transposition is an inexpensive nucleation measure, highly recommended for the restoration of degraded areas by stimulating regeneration from moisture retention and insertion of species from reproductive materials and other propagules present in the biomass (Martins *et al*., 2017). It may be a viable alternative for implementation in other projects.

Domingos *et al*. (1997) estimated the annual litterfall production in a segment of the secondary Atlantic Forest and concluded that the production was continuous throughout the year, i.e., without seasonal effects. Meanwhile, Andrade *et al*. (2008) observed higher total litterfall production in the dry season. The authors attributed this to the fact that some species shed their leaves as a means to resist drought. This characteristic of greater litterfall in the dry period has also been observed in other Brazilian
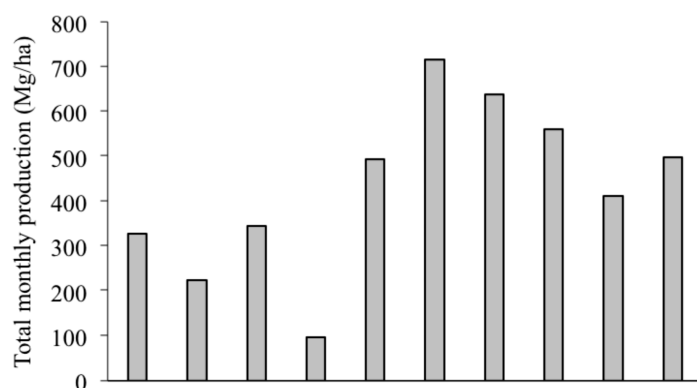
Figure 3. Total monthly litterfall in the Mata do Bebo Atlantic Forest fragment in Macaíba, RN, from 2013 to 2014.

phytophysiognomies (Sales *et al.*, 2020). Also plant phenology can also influence material deposition since deciduous species in warmer places tend to produce more material than perennial species in colder environments, mainly as a drought resistance strategy (Alves *et al.*, 2006).

The month with the lowest litterfall production was July, at 95.2 kg ha^{-1} (1.86%) of the estimated total (Figure 3). This low deposition in July was probably because, in this period, high rainfall still occurs, so plants are in the regrowth phase and do not need to shed leaves to face water stress. This behavior is contrary to what occurs during the dry season and is associated with the fact that this month also has the lowest average temperature, corroborating the information obtained by Costa *et al.* (2019).

The litterfall deposition was uninterrupted but temporal variation during the 12 months, with a mean production of 419.8 kg ha^{-1} month^{-1}. The fact that the deposition is uninterrupted demonstrates that the cycling of nutrients occurs in the soil and is absorbed by the plants, helping to maintain the ecosystem balance and protecting the soil (Costa *et al.*, 2019; Gomes *et al.*, 2010).

Litterfall production by fractions

The leaf fraction presented the largest contribution in the litterfall production during the studied period, corresponding to 3,744.262 kg ha^{-1} year^{-1}, or 74.30% of the total produced (Table 2). This result in percentage was similar to that obtained by

Table 2. Total monthly litterfall in (kg ha^{-1}) from April 2013 to March 2014 in Mata do Bebo, Macaíba, RN.

Months	Leaves	Bark and branches	Reproductive material	Miscellaneous material
April	201.25	45.67	60.66	21.00
May	173.61	37.24	10.46	3.04
June	235.21	49.49	36.69	22.64
July	60.89	12.49	21.86	0.00
August	343.79	14.75	133.57	0.31
September	549.49	29.82	136.22	1.09
October	473.15	63.00	100.78	1.72
November	396.80	96.10	65.34	2.26
December	361.20	1.56	48.48	0.00
January	439.58	1.80	57.38	0.00
February	352.77	5.86	84.54	0.00
March	156.52	38.33	90.32	0.00
Total	3,744.26	396.10	846.29	52.07
Mean	312.02	33.01	70.524	4.34

Domingos *et al.* (1997). They reported that 72% of the contribution corresponded to the leaf fraction and close to the values obtained by Dick and Schumacher (2020), which varied between 69.7 and 80%, with an average value of 75%. The leaf fraction is the main component of the litterfall in tropical communities, concentrating most of the nutrients. The diversity of species in native environments produces a foliar fraction rich in nutrients, so the predominance of certain families in fragments induces selection in the productivity and decomposition of litterfall (Capelesso *et al.*, 2016).

The reproductive material contributed 846.292 kg ha^{-1} year^{-1} (16.80%) of the total litterfall production, followed by the bark and branch component, which produced 396.097 kg ha^{-1} year^{-1} (7.86%), and finally, the various fraction, which had the lowest participation, 52.069 kg ha^{-1} year^{-1} (1.03%) (Table 2). Dick and Schumacher (2020) obtained an average value of 10.3% for the various fraction, much higher than that observed in the present study. This fact is probably related to the division of the fractions applied by those authors, who included flowers, seeds, fruits, and other unidentified residues in the miscellaneous fraction.

The previously mentioned results demonstrate that the foliar fraction is the component that should be expected to have the most significant contribution to litterfall, as in our study. For the month with the largest amount of material produced, the most representative fraction remained leaves (Table 2). Also, this pattern was observed for all months, regardless of the amount of litterfall produced. In the last five months of the year (from August), there was an increase in the deposition of reproductive material, indicating that the plant species respond to external stimuli and carry out their reproductive phenophases in those months (Table 2). Dick and Schumacher (2020) also observed an increase in the fraction corresponding to reproductive material starting in August. Concerning miscellaneous material, June presented the highest value, which nevertheless was lower in proportion than the other fractions.

Studies of litterfall contribute to estimating productivity indexes of the ecosystem, provide information on the rate of decomposition of deciduous material, allow quantifying the content of nutrients that return to the soil and also provide important information on the phenological cycle of plants. Another important issue, specifically in the study area, is that litterfall deposits near streams provide different resources for leaching to the aquatic food webs and can be a determining factor for the dynamics of other ecosystems (Tonin *et al.*, 2017).

Correlations with meteorological variables

The variations in the proportions of the litterfall fractions may be linked to local climatic conditions, such as rainfall, wind speed, and air humidity; additionally, to the composition and structure of the forest or situations of local alteration or degradation, reflecting on the deciduousness of the vegetation and the cycling rates of the material (Tonin *et al.*, 2017). The correlations of litterfall production with environmental variables showed similar behavior, with negative correlations. The value of (r) for the correlation between litterfall production and immediate rainfall was r = -0.64 (p < 0.05), and for the correlation of litterfall production and delayed rainfall (three months of difference), it was -0.44. Litterfall production and air temperature correlation were -0.12 (Table 3). The values calculated for r show moderate correlation between rainfall and litterfall production.

Other studies conducted in the Atlantic Forest have also found negative correlations between litterfall deposition and environmental variables. Dick and Schumacher (2020) analyzed the correlation by fractions; only the leaves and branches showed a significant correlation with minimum temperature. Costa *et al.* (2019) observed that the deposition presented a negative and significant correlation with climatic variables of precipitation, humidity, and temperature, with the most robust value (r = -0.83, p < 0.001). Several factors contribute to higher production during the dry season, such as dynamic and successional aspects of the forest and leaf senescence due to the low humidity, which dehydrates the tissues (Scoriza *et al.*, 2014). The data obtained in this study indicate that the litterfall production in the forest fragment studied is moderately influenced by rainfall. At the same time, the air temperature has a weak influence on this production.

Conclusion

Although climatic parameters influence litterfall production, the production took place uninterruptedly throughout the year, with no evidence of seasonality.

Table 3. Correlation between litterfall production and immediate precipitation and delayed precipitation, in the period from April 2013 to March 2014 in the Atlantic Forest fragment.

Months	Production (kg ha^{-1})	Air temperature (ºC)	Precipitation (mm)	Delayed precipitation (mm)
April	328.57	27.12	131.06	229.64
May	224.36	26.13	306.36	154.94
June	344.03	25.08	191.78	136.40
July	95.24	24.25	229.64	9.40
August	492.43	24.34	154.94	24.13
September	716.63	24.60	136.40	5.84
October	638.64	25.57	9.40	56.38
November	560.50	25.70	24.13	25.90
December	411.24	26.39	5.84	154.93
January	498.75	26.27	56.38	6.60
February	443.17	26.39	25.90	25.65
March	285.17	26.60	154.93	338.59
Correlation		–0.12	–0.64*	–0.44

* significant at the 5% probability level by Pearson's correlation test.

The highest production occurred in the month that coincided with the beginning of the dry season, while the lowest production occurred in the rainy season.

Given the intense anthropic pressure suffered by the Atlantic Forest biome, associated with its extreme importance in maintaining biodiversity, information on the litterfall production in a fragment is of great importance. The results obtained can be used as a theoretical basis for future reforestation work, recovery of degraded areas, nutrient cycling, environmental education, and to propose public policies to protect the biome.

Literature cited

Alvares, C.A.; Stape, J.L.; Sentelhas, P.C.; Gonçalves, J.L.M.; Sparovek, G.
2014. Köppen's climate classification map for Brazil. *Meteorologische Zeitschrift*, 22(6): 711-728.

Alves, A.R.; Souto, J.S.; Souto, P.C.; Holanda, A.C.
2006. Aporte e decomposição de serrapilheira em área de Caatinga, na Paraíba. *Revista de Biologia e Ciências da Terra*, 6(2): 194-203.

Andrade, R.L.; Souto, J.S.; Souto, P.C.
2008. Deposição de serrapilheira em área de Caatinga RPPN "Fazenda Tamanduá", Santa Terezinha, PB. *Revista Caatinga*, 21(2): 223-230.

Araújo, L.H.B; Silva. R.A.R.; Chagas, K.P.T.; Nóbrega, C.C.; Santana, J.A.S.
2015. Composição florística e estrutura fitossociológica de um fragmento de Floresta Ombrófila Densa no município de Macaíba, RN. *Revista Agro@mbiente On-line*, 9(4): 455-464.

Archanjo, K.M.P.; Silva, J.S.; Chichorro, J.F.; Soares, C.P.B.
2012. Estrutura do componente arbóreo da reserva particular do patrimônio natural cafundó, Cachoeiro de Itapemirim, Espírito Santo, Brasil. *Revista Floresta*, 42(1): 145-160.

Brasil. Climate-data.org. Presidência da República. Clima Macaíba.
2016. Available: <http://pt.climate-data.org/location/42744/>. Consulted: 06/dic/2016.

Calvi, G.P.; Pereira, M.G.; Espíndula Júnior, A.
2009. Produção de serapilheira e aporte de nutrientes em áreas de Floresta Atlântica em Santa Maria de Jetibá, ES. *Ciência Florestal*, 19(2): 131-138.

Carielo, P.; Campos, L.B.; Pereira, V.T.Y.; Henriques, N.P.
2019. Levantamento fitossociológico do fragmento da trilha "capitão do campo" no parque estadual do Aguapeí, estado de São Paulo. *Brazilian Journal of Development*, 5(12): 29881-29896.

Costa, S. V.; Pesquero, M.A.; Junqueira, M.H.M.
2019. Litterfall deposition and decomposition in an Atlantic Forest in Southern Goiás. *Floresta e Ambiente*, 26(2). DOI: 10.1590/2179-8087.074417

Dick, G.; Schumacher, M.V.
2020. Litterfall in the Semideciduous Seasonal Forest in Southern Brazil. *Floresta e Ambiente*, 27(2). DOI. 10.1590/2179-8087.029818

Domingos, M.; Moraes, R.M.; Vuono, Y.S.; Anselmo, C.E.
1997. Produção de serapilheira e retorno de nutrientes em um trecho de Mata Atlântica secundária, na Reserva Biológica de Paranapiacaba, SP. Revista Brasileira de Botânica, 20(1): 91-96.

Fundação SOS Mata Atlântica.
2019. Atlas dos remanescentes florestais da Mata atlântica: Relatório técnico: período 2017-2018. INPE. São Paulo, Brasil. 35 p.

Gibson, L.; Lee, T.M.; Koh, L.P.; Brook, B.W.; Gardner, T. A.; Barlow, J.; Peres, C.A.; Bradshaw, C.J.A.; Laurance, W.F.; Lovejoy, T.E.
2011. Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature*, 478(7369): 378-381.

Gomes, J.M.; Pereira, M.G.; Pinã-Rodrigues, F.C.M.; Pereira, G.H.A.; Gondim, F.R.; Silva, E.M.R.
    2010. Aporte de serrapilheira e de nutrientes em fragmentos florestais da Mata Atlântica, RJ. *Revista Brasileira de Ciências Agrárias*, 5(3): 383-391.

Joly, C.A.; Metzger, J.P.; Tabarelli, M.
    2014. Experiences from the Brazilian Atlantic Forest: ecological findings and conservation initiatives. *New Phytologist*, 204(3): 459-473.

Lima, M.S.; Freire, F.J.; Marangon, L.C.; Almeida, B.G.; Ribeiro, E.P.; Santos, R.L.
    2018. Solos florestais em fragmento de floresta urbana na mata de Dois Irmãos, Recife, Pernambuco, Brasil. *Ciência Florestal*, 28(2): 542-553.

Martins, D.A.P.; Lanzarini, A.C.; Heinz, C.F.; Vieira, F.S.; Bonatto, R.A.; Kanieski, M.R.
    2017. Avaliação da transposição de serapilheira e do banco de sementes do solo em uma área degradada no Planalto Catarinense. *Revista Floresta*, 47(3): 237-246.

Mittermeier, R.A.; Turner, W.R.; Larsen, F.W.; Brooks, T.M.; Gascon, C.
    2011. Global Biodiversity Conservation: the critical role of hotspots. In: Zachos, F. E.; Habel, J. C. (Eds). Biodiversity Hotspots: distribution and protection of conservation priority areas. Springer Berlin Heidelberg. Berlin, Germany. pp. 3-22.

Pinto, S.I.C.; Martins, S.V.; Barros, N.F.; Dias, H.C.T.
    2008. Produção de serapilheira em dois estádios sucessionais de Floresta Estacional Semidecidual na Reserva Mata do Paraiso, em Viçosa, MG. *Revista Árvore*, 32(3): 545-556.

Ribeiro, M.C.; Metzger, J.P.; Martensen, A.C.; Ponzoni, F.J.; Hirota, M.M.
    2009. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. *Biological Conservation*, 142(6): 1141-1153.

Sales, M.C.G.; Campos, M.C.C.; Martins, T.S.; Brito Filho, E.G.; Pinheiro, E.N.; Cunha, J.M.; Fraga, V.S.; Souza, F.G.
    2020. Litter input in cerrado, cerradão and forest environments in Amazon, Brazil. *Revista Brasileira de Ciências Agrárias*, 15(2): e7383.

Santana, J.A.S.; Souto, J.S.
    2011. Produção de serapilheira na Caatinga da região semiárida do Rio Grande do Norte, Brasil. *Revista IDESIA*, 29(2): 87-94.

Scoriza, R.N.; Pereire, M.G.; Pereira, G.H.A.; Machado, D.L.; Silva, E.M.R.
    2012. Métodos para coleta e análise de serapilheira aplicados à ciclagem de nutrientes. 2. ed. Floresta e Ambiente. Seropédica, Brasil. 18 p.

Tonin, A.M.; Gonçalves, J.F.; Bambi, P.; Couceiro, S.R.M.; Feitoza, L.A.M.; Fontana, L.E.; Hamada, N.; Hepp, L.U.; Lezan-Kowalczuk, V.G.; Leite, G.F.M.
    2017. Plant litter dynamics in the forest-stream interface: precipitation is a major control across tropical biomes. *Scientific Reports*, 7(1): 10799.