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Dynamics of the production and decomposition of litterfall in a brazilian northeastern tropical forest (Serra de Itabaiana National Park, Sergipe State)

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ABSTRACT. This study was carried out in the Serra de Itabaiana National Park from October, 2006, to October, 2007. The main objective was to quantify litterfall production and analyze decomposition rates in a tropical seasonal semideciduous forest. Forty 0.25 m^2 collectors were used to quantify the litterfall and 36 litterbags to record the rate of decomposition of the foliar biomass. The total litterfall production was 8.6 ton ha^{-1} in 11 months, of which 54.6% of leaves. The constant of leaf decomposition (K) was 0.52, and the half-life of the leaf biomass was estimated to be 495 days. A significant correlation was observed between leaf fall and monthly precipitation, but no relationship was found between decomposition rates and rainfall.

Keywords: nutrient cycling, preciptation, litter.

Dinâmica da produção e decomposição de serapilheira em uma floresta tropical do nordeste do Brasil (Parque Nacional Serra de Itabaiana, Estado do Sergipe)

RESUMO. Este estudo foi desenvolvido no Parque Nacional Serra de Itabaiana, Sergipe, entre outubro de 2006 a outubro de 2007. O principal objetivo foi quantificar a produção de serapilheira e analisar as taxas de decomposição em uma floresta tropical sazonal semidecídua. Quarenta coletores de 0,25 m^2 foram usados para quantificar a serapilheira e 36 litterbags para avaliar a taxa de decomposição da biomassa foliar. A produção total de serapilheira foi 8,6 ton ha^{-1} em 11 meses, dos quais 54,6% de folhas. A constante de decomposição foliar (K) foi 0,52, e o tempo de meia vida estimado em 495 dias. Uma correlação significativamente negativa foi observada entre a queda de folhas e a precipitação, mas nenhuma correlação foi observada entre as taxas de decomposição e a precipitação.

Palavras-chave: ciclagem de nutrientes, precipitação, liteira.

Introduction

The litterfall of a forest is formed by the organic debris deposited from the standing vegetation, and is composed mainly of leaves, branches and plant reproductive structures. The decomposition of this material and its subsequent incorporation into the soil, represents one of the most important processes in the nutrient cycling of tropical forests (VASCONCELOS et al., 2008).

Each ecosystem has its own characteristic pattern of nutrient storage and recycling. As the rate and pattern of nutrient recycling in a natural forest are closely associated with climatic and phenological conditions, good knowledge of local geographic and climatic variables are an important first step in the study of nutrient cycling of any system (PRESCOTT, 2005). The amount of material deposited over a year is related mainly to climatic conditions, and tends to be greater in hot and humid regions in comparison with those of cooler climates (HATTENSCHWILER et al., 2005). Litterfall production may also vary locally, as a result of habitat disturbance, which tends to favor fast-growing pioneer species, which are relatively productive, and produce relatively larger amounts of debris in comparison with primary habitat, which is generally less productive (MORAES; PRADO, 1998).

The decomposition process sustains nutrient recycling, and plays an essential role in the regeneration of degraded areas (COSTA et al., 2004). Knowledge of this process is vital to the diagnosis of environments, and to estimate the effects of natural or anthropogenic impacts (MENEZES et al., 2010). Several factors influence decomposition rates, such as temperature, humidity, aeration, and the chemical content and structure of the litterfall (ZHANG et al., 2008). Variation in the composition of the soil macro- and microfauna also affects the rates of degradation of different types of residue (FERNANDES et al., 2006).

Most of the available studies of the decomposition of leaf litter in the Neotropics are from the Amazon basin, but some studies have focused on other systems such as "restingas", riparian, and semi-deciduous forests, and Cerrado, although few have analyzed the effects of precipitation levels. The aim of present study was to measure the litterfall production and decomposition rates in Serra de Itabaiana National Park, Sergipe State, Brazil, in the context of annual variation in precipitation levels.

Material and methods

The northeastern Brazilian state of Sergipe has an area of approximately 21.994 Km^2, and is characterized by a humid coastal zone dominated by Atlantic Forest, and a semi-arid zone further inland, covered with Caatinga scrub (CARVALHO; VILAR, 2005).

The area of the Serra de Itabaiana National Park (SINP) is located partly within five municipalities: Areia Branca, Itabaiana, Laranjeiras, Itaporanga d'Ajuda and Campo do Brito (10°40' S, 37°25'W), 45 km from Aracaju, the Sergipe State capital. Maximum altitude is approximately 670 meters above sea level. The local climate corresponds to Köppen's As' category – tropical climate with dry summers and moderate hydrological excess in the winter. Thornthwaite's water balance index varies between 1.3 and 8.8 Im (DANTAS; RIBEIRO, 2010a). The park is located within a zone of transition between the Atlantic Forest and Caatinga morphoclimatic domains (AB'SABER, 2003).

The principal forest at the SINP was classified as semideciduous (GONÇALVES; ORLANDI, 1983), but a recent study classified it as an evergreen forest, probably linked originally to the coastal forests systems (DANTAS; RIBEIRO, 2010b). Its present-day isolation appears to have been the result of anthropogenic deforestation. Important subcategories of the forest are hillside and riparian habitats. There is much anthropogenic fragmentation of habitat, in particular in the northwestern and eastern hillside habitats (DANTAS; RIBEIRO, 2010b).

Litterfall production was measured in four fixed, marked plots of 400 m^2. Ten 0.25 m^2 litter traps made of 2 mm-mesh nylon were distributed randomly within each plot, suspended 30 cm above the ground. All organic material within each trap was collected every 30 days between October, 2006, and August, 2007. The material was air dried and separated by category (leafs, branchs, flowers, fruits, and seeds), and then heated in a laboratory oven at 70°C for 72 hours. Once dried, the material was weighed in order to quantify the biomass of each category produced per month.

The significance of the monthly variation in the dry weight of each category was tested using qui-square test. The relationship between precipitation levels and productivity was evaluated using Pearson's coefficient of correlation (r) test, with significance accepted at $p < 0.05$ (BROWER et al., 1997).

To evaluate litterfall decomposition rates, newly-fallen leaves were collected randomly in October, 2006, and taken to the laboratory to be dried in the oven for 72 hours at 70ºC. Then, 10 g of this material was placed in each of 36 25 x 25cm, 2mm-mesh nylon litter bags (BROWER et al., 1997). Twelve of these bags were then placed randomly at each of three different forest sites. Each month from November, 2006, to October, 2007, one of the bags was collected from each site, and the material was dried in an oven for 72h at 70°C and then weighed on an analytical scale.

The difference in the weight of the material in the bags was used to estimate biomass decomposition rates, based on the constant K (equations 1 and 2) (REZENDE et al., 1999), calculated as follows:

$$X_t = X_0 e^{-Kt} \quad (1)$$

Reorganized to:

$$K = \ln (X / X_0) / t \quad (2)$$

where: X = dry weight of the material after t days, X0 = original dry weight of the material, and K = constant of decomposition.

The constant K was converted into an annual unit for comparison with published studies. The half-life of the foliar biomass ($T_{0,5}$) was estimated using Scherr (2008) sugested equation (3). This is the time necessary for the loss of 50% of the original biomass.

$$T_{0,5} = 0,693 / K \quad (3)$$

Differences in monthly decomposition rates were tested using ANOVA, and the relationship with precipitation levels was analyzed using Pearson's (r) test.

Results and discussion

During the 11 months of the study, the total litterfall production in the SINP was estimated as 8.6 ton ha^{-1}, although considerable differences in productivity were observed between months (Figure 1). In December and January, for example, nearly a third (28%) of total production was recorded. Both these months were the driest with rainfall 43.1 and 1.03 mm respectively, during the period of study. The diurnal temperature during these months was frequently over 35°C.

This work is in accordance with most of the studies done in Brazil, that indicate the driest months as being the ones with the biggest litterfall production (MENEZES et al., 2010; BARBOSA; FARIA, 2006). Nevertheless some other studies affirm that there does not exist a significant increase in the litterfall production during the driest months (VIDAL et al., 2007; PEREIRA et al., 2008).

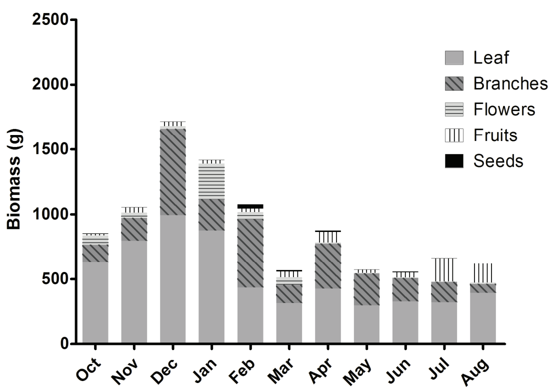

Figure 1. Monthly litterfall production at the Serra de Itabaiana National Park by litter category.

Leaf material was responsible for 54.6% of this total (4.7 ton ha^{-1}), although significant seasonal differences, and total production in the dry summer months (October-February) was double that of the rainy months, between April and July ($\chi^2 = 120$; df = 10; $p < 0.05$). There was a significant negative correlation between monthly precipitation levels and the production of leafy material ($r = -0.734$; df = 9; $p < 0.05$: Figure 2).

This fact could be explained by the increased plant demand for water, dispensing leaves during the dry season as a strategy aimed at reducing water requirements during a period of water deficit (BARBOSA; FARIA, 2006). In addition to this fact, leaves may also be shed in response to physical damage or low temperatures (ONODA et al., 2011). All these factors may cause disorder in cellular activity, and thus induce senescence, although this state can also be induced by natural variation in hormone levels over the plant's life cycle (MUNNÉ-BOSH; ALEGRE, 2004).

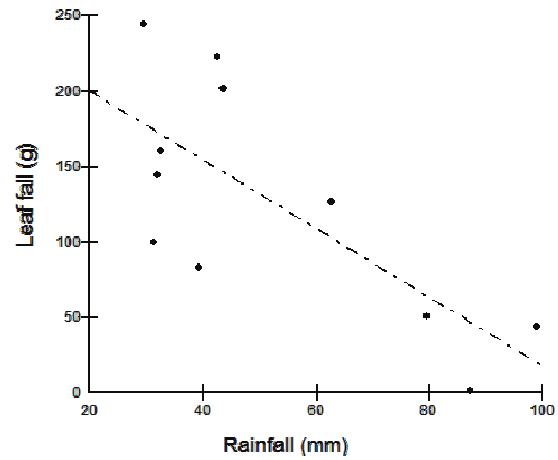

Figure 2. Correlation between leaf litterfall biomass and rainfall.

In a Transitional Seasonal Lowland Forest, Sanches et al. (2009) recorded a synchronization of leaf fall with reduced rainfall, while in the Pinheiral forest in southeastern Brazil, two peaks of maximum leaf fall, one at the height of the winter (dry season), in June and July, and one in December and January (wet season), coinciding with a dip in precipitation (MENEZES et al., 2010). A diferent relationship between leaf fall and precipitation levels was found at Atlantic Seasonal "Tabuleiros" Forest sites in Rio de Janeiro, where there was not correlation between both variables (PEREIRA et al., 2008). There are, as well, studies that found the biggest leaf fall in wet period (PIRES et al., 2006). These differences of the seasonal variation in the production of the leaf fraction between tropical formations are explained by Scheer et al. (2009). The author affirms that there exists a tendency that in tropical forests the biggest amount of the litterfall is produced in the driest months, however when the environment has less hydric restriction, the period of biggest litterfall production changes to the wet season.

Branches corresponded to 31% of total litterfall (Figure 1), once again with significant monthly variation ($\chi^2 = 127$; df = 10; $p < 0.05$), and peaks in December and April. However, no relationship with precipitation was found ($r = 0.06$; df = 9; $p > 0.05$). While this finding agrees with that of Valenti et al. (2008), for cerrado vegetation, the peaks in December and April appeared to have been caused by the random collection of large, heavy branches. Malhi et al. (2004) affirm that the timing of treefall and the shedding of large branches tend to be random in Neotropical forests, and depends on species, age, competition, disease, and the successional stage of the vegetation. If the larger branches are excluded from the analysis, the production of this item was constant during the study period.

Some studies describe the biggest production in the branches fraction in the wet season. Vidal et al. (2007) observed that in an ombrophilous Atlantic forest the biggest amount of cauline elements was collected right after the first rains after the dry season. According to the same authors these first rains can cause the fall of a lot of dead braches that still was connected to the plant. For Lopes et al. (2009), in a Northeast semi-arid Brazilian forest, the biggest production of the branches was in the wet rainy season. The differences found in diverse studies on the differences in the production of the branches fraction, indicate that each vegetal community has its own personal characteristics, being influenced by diverse factors such as: pluviometric regime, water availability, soil fertilization, age of the plants, forest fires, plagues, brush and trees architecture, fragmentation and stage of succession.

The categories flower, fruit, and seed corresponded to 6, 7, and 1% of total litterfall, respectively. The production of flowers varied significantly over the course of the year ($\chi^2 = 120$; df = 10; $p < 0.05$), and was inversely correlated with precipitation ($r = -0.567$; df = 9; $p < 0.05$). There thus tended to be greater productivity of floral structures during the drier months, although, while significant, the relationship was relatively weak.

Fruitfall also varied among months ($\chi^2 = 51$; df = 10; $p < 0.05$), but was not related with precipitation ($r = 0.04$; df = 9; $p > 0.05$). The production of seeds also vary significantly during the course of the year ($\chi^2 = 13$; df = 10; $p < 0.05$), and was not correlated with precipitacion ($r = 0.37$; df = 9; $p > 0.05$)

Decomposition rates vary considerably across different Brazilian regions and vegetation types, and appear to be related primarily to variation in climate and the fertility of the soil (ZHANG et al., 2008). The constant of foliar decomposition (K) recorded at the SINP was 0.52, a relatively low value for a tropical forest, as values of less than one are not typical (PIRES et al., 2006). In Brazil, however, lower values have been recorded in the south (BACKES et al., 2005; SCHEER, 2008), southeast (VITAL et al., 2004; COSTA et al., 2005), northeast (LOPES et al., 2009) and central (FERNANDEZ; SCARAMUZZA, 2007) regions (Table 1).

While decomposition rates are generally correlated with the climate and the evapotranspiration rate of the vegetation (PRESCOTT, 2005), the ratio of nitrogen to lignin in the litterfall is more important than climate (ZHANG et al., 2008; BAKKER et al., 2011). It is interesting to note that habitats with K values of less than one (Table 1) are characterized by relatively stressful environmental conditions that cause lignification of the leaf structure. In southern Brazil, where precipitation is constant and the soil is relatively fertile, sclerophylly is determined by the reduced temperatures. In restingas and Cerrado, sclerophylly is caused by deficiency of certain nutrients, while in the northeastern it is related to water deficit (RIZZINI, 1997).

Table 1. Values of K (constant of decomposition) in different Brazilian forest ecosystems.

Local ecosystem	K	Reference
Seasonal Lowland Forest – SP	1.9	Moraes and Prado (1998)
Seasonal Lowland Forest – SP	1.7	Vital et al. (2004)
Seasonal Lowland Forest – SP	1.6	Morellato (1992)
Seasonal Lowland Forest – SP	1.5	Pagano (1989)
Seasonal Lowland Forest – SP	1.4	Diniz and Pagano (1997)
Seasonal Forest Montana – SP	1.3	Morellato (1992)
Seasonal “Tabuleiros“ Forest – SP	1.1	César (1993)
Pioneering formations (Restinga) – SP	1.1	Moraes and Prado (1998)
Pioneering formations (Restinga after-beach) –PR	0.92	Pires et al. (2006)
Ombrophilous Forest Montana – RS	0.86	Backes et al. (2005)
Seasonal “Tabuleiros” Forest – RJ	0.84	Pereira et al. (2008)
Seasonal “Tabuleiros” Forest – RJ	0.82	Costa et al. (2005)
Ombrophilous Lowland Forest – PR	0.75	Scheer (2008)
Semi-arid Forest – CE	0.71	Lopes et al. (2009)
“Cerradão” – MT	0.53	Fernandez and Scaramuzza (2007)
Seasonal Lowland Forest – SE	0.52	This study
“Cerradão” – SP	0.52	Valenti et al. (2008)
Cerrado *Strictu sensu* – SP	0.36	Valenti et al. (2008)

SP = São Paulo State; RJ = Rio de Janeiro State; PR = Paraná State; RS = Rio Grande do Sul State; MT = Mato Grosso State; RN = Rio Grande do Norte State; CE = Ceará State; SE = Sergipe State.

Another factor affecting K value is the successional stage of the vegetation. In initial stages, while litterfall is greater, decomposition rates tend to be lower, leading to an accumulation of litter. In more later stages, decomposition is fast (PINTO; MARQUES, 2003). Among other factors, nitrogen and potassium levels increase, and this favors microbial activity (PENÃ et al., 2005). Another important factor is litterfall quality. Boeger and Wisniewski (2003) observed that the sclerophylly of leaf tissue tends to decrease in more advanced stages, which favors microbial attack.

It seems likely that the low K value recorded at the Serra de Itabaiana National Park is related to the successional stage of the local forests which, despite having been protected for some 30 years, are still subject to illegal logging. Another important factor may have been the aggregation of fungi and roots with the leaves on the ground. This may have masked partially the loss of plant material, by substituting it with fungal mass, despite the care taken to separate out this material. A similar situation was recorded by Peh et al. (2012), both within and outside the test bags.

The half-life of the foliar biomass was estimated to be 495 days. By contrast, Backes et al. (2005) recorded a value of 316 days for a mixed rainforest in Rio Grande do Sul, Brazil, while Vital et al. (2004) reported 150 days for a seasonal semideciduous forest in the center of the city of São Paulo (southeastern Brazil). Clearly, decomposition rates may vary considerably in relation to the characteristics of the study area. The short half-life represents the quick available of nutrients trapped in the plant structure for the biota. This process maintains soil fertility and is resposible for high productivity in tropical forest sites, even when soils ara naturally infertile (SCHEER, 2008).

Abouth monthly decomposition rates, an average of 0.34±0.08 g was lost per month, and there was no significant variation among months ($F = 0.55$; $df = 35$; $p > 0.05$). The best adjustment for the data was a negative linear regression (Figue 3). This contradicts Coûteaux et al. (1995) model, which is based on a negative exponential curve, and separates the process into two stages: (i) initial fast phase, in which labile substances such as nitrogen, phosphorus, potassium, and other soluble substances are lost, and (ii) second slow phase, when lignin and other recalcitrant compounds are degraded (this phase tends toward linearity).

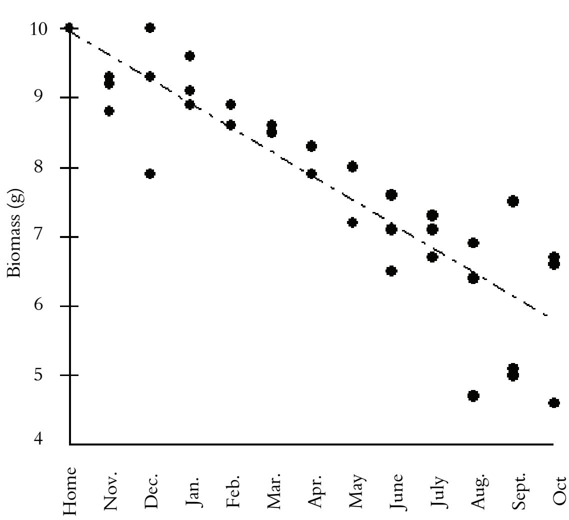

Figure 3. Monthly non-leaf litterfall biomass.

In their study, Powers et al. (2009) demonstrated that the decomposition of materials with higher concentrations of labile and leached substances tends to follow a linear model, at least in the first year. It thus seems likely that the linear pattern observed in the present study was related to relatively high concentrations of recalcitrant compounds in the litter, which was indicated by the low K value. In fact, it is possible that the amount of labile substances in the leaf litter was so small that it was decomposed within the first month, with the process moving immediately into the second phase.

No significant relationship was found between rainfall and monthly decomposition rates ($r = 0.15$, $p > 0.05$). A similar pattern was recorded by Zang et al. (2008) and Bakker et al. (2011), who concluded that the chemical composition of the litter is more important than climatic factors. In addition, Penã et al. (2005) found no significant seasonal variation in the microbial activity of the soil of dense rainforest in southern Brazil. This further reinforces the conclusion that precipitation is not a factor affecting decomposition rates, at least at the local level. Considering that, at global scales, precipitation influences decomposition rates (POWERS et al., 2009).

Conclusion

A distinct phenological pattern was observed in the production of litterfall in the SINP, where no trees were observed to completely lose their leaves during the study period. The diferent rainfall in the northeaster mountain ranges, the fog humidity or the water sheet outcrops can be responsible for the reduction of the water deficit in the forests of the SINP, making possible, that the vegetation supports the great part of its leaves, even in the dry season.

The linear pattern of decomposition observed at the Serra de Itabaiana National Park, in contrast with the standard, two-phase exponential model, appears to reflect the characteristics of the chemical components of the leaf litter at this site.

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References

AB'SABER, A. N. **Os domínios de natureza no Brasil**: potencialidades paisagísticas. São Paulo: Ateliê Editorial, 2003.

BACKES, A.; PRATES, F. L.; VIOLA, M. G. Produção de serapilheira em floresta ombrófila mista em São Francisco de Paula, Rio Grande do Sul. **Acta Botanica Brasilica**, v. 19, n. 1, p. 155-160, 2005.

BAKKER, M. A.; CARRENÕ-ROCABADO, G.; POORTER, L. Leaf economics traits predict litter decomposition of tropical plants and differ among land use types. **Funtional Ecology**, v. 25, n. 1, p. 473-483, 2011.

BARBOSA, J. H. C.; FARIA, S. M. Aporte de serapilheira ao solo em estágios sucessionais florestais na reserva biológica de Poço das Antas, RJ, Brasil. **Rodriguésia**, v. 57, n. 3, p. 461-476, 2006.

BOEGER, M. R. T.; WISNIEWSKI, C. Comparação da morfologia foliar de espécies arbóreas de três estádios sucessionais distintos de floresta ombrófila densa (Floresta Atlântica) no Sul do Brasil. **Revista Brasileira de Botânica**, v. 26, n. 1, p. 61-72, 2003.

BROWER, J. E.; ZAR, J. H.; VON ENDE, C. N. **Field and laboratory methods for general ecology**. 4th ed. Iowa: W.C. Brown Publishers, 1997.

CARVALHO, C. M.; VILAR, J. C. **Parque Nacional Serra de Itabaiana** – levantamento da biota. Aracaju: Ibama, 2005.

CÉSAR, O. Produção de serapilheira em mata mesófila semidecídua da fazenda Barreiro Rico, município de Anhembi-SP. **Revista Brasileira de Biologia**, v. 55, n. 1, p. 671-681, 1993.

COSTA, G. S.; FRANCO, A. A.; DAMASCENO, R. N.; FARIA, S. M. Aporte de nutrientes pela serapilheira em uma área degradada e revegetada com leguminosa arbórea. **Revista Brasileira de Ciência do Solo**, v. 28, n. 5, p. 919-927, 2004.

COSTA, G. S.; GAMA-RODRIGUES, A. C.; CUNHA, G. M. Decomposição e liberação de nutrientes da serapilheira foliar em povoamentos de *Eucalyptus grandis* no norte fluminense. **Revista Árvore**, v. 29, n. 4, p. 563-570, 2005.

COÛTEAUX, M. M.; BOTTNER, P.; BERG, B. Litter decomposition, climate and litter quality. **Trends in Ecology and Evolution**, v. 10, n. 1, p. 63-66, 1995.

DANTAS, T. V. P.; RIBEIRO, A. S. Estrutura populacional de *Kielmeyera rugosa* Choisy (Clusiaceae) no Parque Nacional Serra de Itabaiana, Estado de Sergipe. **Acta Scientiarum. Biological Sciences**, v. 32, n. 2, p. 141-146, 2010a.

DANTAS, T. V. P.; RIBEIRO, A. S. Caracterização da vegetação do Parque Nacional Serra de Itabaiana, Sergipe/Brasil. **Biotemas**, v. 23, n. 4, p. 13-23, 2010b.

DINIZ, S.; PAGANO, S. N. Dinâmica de folhedo em floresta mesófila semidecídua no município de Araras, SP. I Produção, decomposição e acúmulo. **Revista do Instituto Florestal**, v. 9, n. 1, p. 27-36, 1997.

FERNANDES. M. M.; PEREIRA, M. G.; MAGALHÃES, L. M. S. C.; GIÁCOMO, A. R.; GUIMARÃES, R. Aporte e decomposição de serapilheira em áreas de Floresta secundária, plantio de sabiá (*Mimosa caesalpiniaefolia* Benth.) e andiroba (*Carapa guianensis* Adbl.) na Flona Mário Xavier, RJ. **Ciência Florestal**, v. 16, n. 2, p. 163-175, 2006.

FERNANDEZ, F. C. S.; SCARAMUZZA, W. M. L. P. Produção e decomposição de liteira em fragmento florestal em Campo Verde (MT). **Revista de Ciências Agrárias**, v. 1, n. 47, p. 173-186, 2007.

GONÇALVES, L. M. C.; ORLANDI, R. P. Vegetação. In: BRASIL, MINISTÉRIO DE MINAS E ENERGIA. (Ed.). **Projeto RadamBrasil, folhas SC 24/25 Aracaju/Recife**. Rio de Janeiro: Série LNR, 1983. v. 30, p. 573-639. (Levantamento de Recursos Naturais, 30).

HATTENSCHWILER, S.; TIUNOV, A. V.; SCHEU, S. Biodiversity and litter decomposition in terrestrial ecosystems. **Annual Review of Ecology Evolution and Systematics**, v. 36, n. 1, p. 191-218, 2005.

LOPES, J. F. B.; ANDRADE, E. F.; LOBATO, F. A. O.; PALÁCIO, H. A. Q.; ARRAES, F. D. D. Deposição e decomposição de serapilheira em área da Caatinga. **Revista Agro@mbiente On-line**, v. 3, n. 2, p. 72-79, 2009.

MALHI, Y.; BAKER, T. R.; PHILLIPS, O. L.; ALMEIDA, S.; HIGUCHI, N.; LAURANCE, W. F.; LEWIS, S. L.; NUÑEZ, P. V.; SILVA, J. N. M.; VINCETI, B.The above-ground coarse wood productivity of 104 neotropical forests plots. **Global Change Biology**, v. 10, n. 1, p. 563-591, 2004.

MENEZES, C. E. G.; PEREIRA, M. G.; CORREIA, M. E. F.; DOS ANJOS, L. H. C.; PAULA, R. R.; DE SOUZA, M. E. Aporte e decomposição da serapilheira e produção de biomassa radicular em florestas com diferentes estágios sucessionais em Pinheiral, RJ. **Ciência Florestal,** v. 20, n. 3, p. 439-452, 2010.

MORAES, J. A. P. V.; PRADO, C. H. B. A. Photosynthesis and water relations in cerrado vegetation. In: SCARANO, F. R.; FRANCO, A. C. (Ed.). **Ecophysiological strategies of xerophytic and amphibious plants in the neotropics**. Rio de Janeiro: Universidade Fedeal do Rio de Janeiro, 1998. p. 45-63.

MORELLATO, L. P. C. Nutrient cycling in two south-east Brazilian forests. I. Litterfall and litter standing-crop. **Journal of Tropical Ecology**, v. 8, n. 1, p. 205-215, 1992.

MUNNÉ-BOSH, S.; ALEGRE, L. Die and let live: leaf senescence contributes to plant survival under drought stress. **Funtional Plant Biology**, v. 31, n. 1, p. 203-216, 2004.

ONODA, Y.; WESTOBY, M.; ADLER, P. B.; CHOONG, A. M. F.; CLISSOLD, F. J.; CORNELISSEN, J. H.C.; DÍAZ, S.; DOMINY, N. J.; ELGART, A.; ENRICO, L.; FINE, P. V. A.; HOWARD. J. J.; JALILI, A.; KITAJIMA, K.; KUROKAWA, H.; McARTHUR. C.; LUCAS, P. W.; MARKESTEIJN, L. PÉREZ-HARGUINDEGUY, N.; POORTER, L.; RICHARDS, L.; SANTIAGO, L. S.; SOSINSKI, E. E.; VAN BAEL, S. A.; WARTON, D. I.; WRIGHT, I. J.; JOSEPH WRIGHT, S.; YAMASHITA, N. Global patterns of leaf mechanical properties. **Ecology Letters**, v. 14, n. 1, p. 301-312, 2011.

PAGANO, S. N. Produção de folhedo em mata mesófila semidecídua do município de Rio Claro, SP. **Revista Brasileira de Biologia**, v. 49, n. 1, p. 633-639, 1989.

PEH, K. S. H.; SONKÉ, B.; TAEDOUNG, H.; SÉNÉ, O.; LLOYD, J.; LEWIS, S. L. Investigating diversity dependence of tropical forest litter decomposition: experiments and observations from Central Africa. **Journal of Vegetation Science**, v. 23, n. 1, p. 223-235, 2012.

PENÃ, M. L. P.; MARQUES, R.; JAHNEL, M. C.; ANJOS, A. Respiração microbiana como indicador de qualidade do solo em ecossistema florestal. **Floresta**, v. 35, n. 1, p. 117-127, 2005.

PEREIRA, M. G.; MENESES, L. F. T.; SCHULTZ, N. Aporte e decomposição da serapilheira na Mata Atlântica, ilha de Marambaia, Mangaratiba, RJ. **Ciência Florestal**, v. 18, n. 4, p. 443-454, 2008.

PINTO, C. B.; MARQUES, R. Aporte de nutrientes por frações da serapilheira em sucessão ecológica de um ecossistema da floresta atlântica. **Revista Floresta**, v. 33, n. 3, p. 257-264, 2003.

PIRES, L. A.; BRITEZ, R. M.; MARTEL, G.; PAGANO, S. N. Produção, acúmulo e decomposição de serrapilheira em uma restinga da Ilha do Mel, Paranaguá, PR, Brasil. **Acta Botanica Brasilica**, v. 20, n. 1, p. 173-184, 2006.

POWERS, J. S.; MONTGOMERY, R. A.; ADAIR, E. C.; BREARLEY, F. Q.; DEWALT, S. J.; CASTANHO, C. T. Decomposition in tropical forests: a pan-tropical study of the effects of litter type, litter placement and mesofaunal exclusion across a precipitation gradient. **Journal of Ecology**, v. 97, n. 1, p. 801-11, 2009.

PRESCOTT, C. Do rates of litter decomposition tell us anything we really need to know? **Forest Ecology and Management**, v. 220, n. 1-3, p. 66-74, 2005.

REZENDE, C. P.; CANTARUTTI, R. B.; BRAGA, J. M.; GOMIDE, J. A.; PEREIRA, J. M.; FERREIRA, E.; TARRÉ, R.; MACEDO, R.; ALVES, B. J. R.; URQUIAGA, S.; CADISCH, G.; GILLER, K. E.; BODDEY, R. M. Litter deposition and disappearance in *Brachiaria* pastures in the Atlantic Forest region of the south of Bahia, Brazil. **Nutrient Cycling Agroecology**, v. 54, n. 1, p. 99-112, 1999.

RIZZINI, C. T. **Tratado de fitogeografia do Brasil**: aspectos ecológicos, sociológicos e florísticos. Rio de Janeiro: Âmbito Cultural Edições Ltda., 1997.

SANCHES, L.; VALENTINI, C. M. A.; BIUDES, M. C.; NOGUEIRA, J. S. Dinâmica sazonal da produção e decomposição de serrapilheira em floresta tropical de transição. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v. 13, n. 2, p. 183-189, 2009.

SCHEER, M. B. Decomposição e liberação de nutrientes da serapilheira foliar em um trecho de floresta ombrófila densa aluvial em regeneração, Guaraqueçaba (PR). **Floresta**, v. 38, n. 2, p. 253-266, 2008.

SCHEER, M. B.; GATTI, G.; WISNIEWSKI, C.; MOCOCHINSKI, A. Y.; CAVASSANI, A. T.; LORENZETTO, A.; PUTINI, F. Patterns of litter production in a secondary alluvial Atlantic Rain Forest in southern Brazil. **Revista Brasileira de Botânica**, v. 32, n. 3, p. 805-817, 2009.

VALENTI, M. W.; CIANCIARUSO, M. V.; BATALHA, M. A. Seasonality of litterfall and leaf decomposition in a cerrado site. **Brazilian Journal of Biology**, v. 68, n. 3, p. 459-465, 2008.

VASCONCELOS, S. S.; ZARIN, D. J.; ARAÚJO, M. M.; RANGEL-VASCONCELOS, L. G. T.; CARVALHO, C. J. R. D.; STAUDHAMMER, C. L.; OLIVEIRA, F. D. A. Effects of seasonality, litter removal, and dry-season irrigation on litterfall quantity and quality in eastern Amazonian forest regrowth, Brazil. **Journal of Tropical Ecology**, v. 24, n. 1, p. 27-38, 2008.

VIDAL, M. M.; PIVELLO, V. R.; MEIRELLES, S. T.; METZGER, J. P. Produção de serapilheira em floresta Atlântica secundária numa paisagem fragmentada (Ibiúna, SP): importância da borda e tamanho dos fragmentos. **Revista Brasileira de Botânica**, v. 30, n. 3, p. 521-532, 2007.

VITAL, A. R. T.; GUERRINI, I. A.; FRANKEN, W. K.; FONSECA, R. C. B. Produção de serapilheira e ciclagem de nutrientes de uma floresta estacional semidecidual em zona ripária. **Revista Árvore**, v. 28, n. 6, p. 793-800, 2004.

ZHANG, D.; HUI, D.; LUO, Y.; ZHOU, G. L. Rates of litter decomposition in terrestrial ecosystems: global patterns and controlling factors. **Journal of Plant Ecology**, v. 1, n. 2, p. 85-93, 2008.

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