December 2009 Volume 4 Issue 6

Trade Science Inc.

Environmental Science
An Indian Journal
Current Research Papers

ESAIJ, 4(6), 2009 [438-446]

Seasonal patterns of nitrogen and phosphorus in the litter and soil surface of transitional Amazon cerrado forest, Brazil

Luciana Sanches[1*], Eliane Dias de Almeida[2], Osvaldo Borges Pinto Junior[3], Jose de Souza Nogueira[3]

[1]Federal University of Mato Grosso, Department of Sanitary and Environmental Engineering, Av., Fernando Correa da Costa s/n Cuiaba, MT, 78, 060-900, (BRAZIL)

[2]Federal University of Mato Grosso, Department of Physics, Av., Fernando Correa da Costa s/n Cuiaba, MT, 78, 060-900, (BRAZIL)

[3]Federal University of Mato Grosso, Department of Physics, Av., Fernando Correa da Costa s/n Cuiaba, MT, 78, 060-900, (BRAZIL)

Email : luciana.sanches@pq.cnpq.br

Received: 2nd October, 2009 ; Accepted: 12th October, 2009

ABSTRACT

Measurements of litter production, and the surface litter pool were made over a 1 year period in a tropical transitional forest near Sinop, Mato Grosso Brazil with the aim of quantifying the seasonal variation of nitrogen and phosphorus in the litter and the annual contribution of nutrients to the soil. Average annual litterfall (+95% confidence interval (CI)) was 8.20 ton ha^{-1} $year^{-1}$ and forest floor litter mass was 58.63 ton ha-1. Nitrogen and phosphorus in the forest floor litter mass was highest during the dry and dry-wet season, being 38% higher than in the wet and wet-dry season. Seasonal variation in the litter and concentration of nutrients was explained by seasonal variations in the climate, for example in the precipition and soil humidity. Average annual nitrogen and phosphorus concentrations in the forest floor mass were 17.24 ton ha-1 and 16.46 ton ha^{-1}, respectively. The more significant forest floor mass fraction for returning soil nutrients was the leaves. The concentration of nutrients was higher in the soil superficial layer (at depths between 0-5cm) than at depths between 30-70 cm, approximately 83% and 93% for total nitrogen and available phosphorus, respectively.

KEYWORDS

Tropical forest;
Litterpool;
Nutrient cycling;
Litterfall.

INTRODUCTION

In the tropical forest, generally vegetation grows in low nutrient soils, so the contrasting vegetation cover is linked to strategies for conservation and recycling of nutrients.

The litter on the forest floor serves as an input-output system for nutrients, and the rates at which forest litter falls and decays, regulates energy flow, primary productivity and nutrient cycling in forest ecosystems. It is particularly important in the nutrient budget of tropical and subtropical forest ecosystems based on nutrient-poor soils, where vegetation depends on recycling of nutrients from plant detritus[24].

Soils act as spatially distributed sources and sinks of nutrients, and the concomitant spatial patterns appear to be very variable in forest ecosystems in general and in tropical forests in particular[31].

Studies on quantitative aspects of litterfall production constitute an important parameter for the forest ecology, to help quantify nutrients in the ground through chemical composition analysis of the litterfall.

Nutrient cycling is part of a closed circuit established between the vegetation and the phedosphera, where macro and micro-nutrients are permanently recycled. The complete understanding of the interaction of plant-soil nutrient cycle processes, its control on canopy assimilation and water use are essential, to foresee changes in an ecosystem as a result of the future climatic changes[4].

The aim of this work was to quantify the seasonal variation in nitrogen and phosphorus in litter and the annual contribution of nutrients to the soil in a tropical transitional forest near Sinop, Mato Grosso Brazil.

MATERIALS AND METHODS

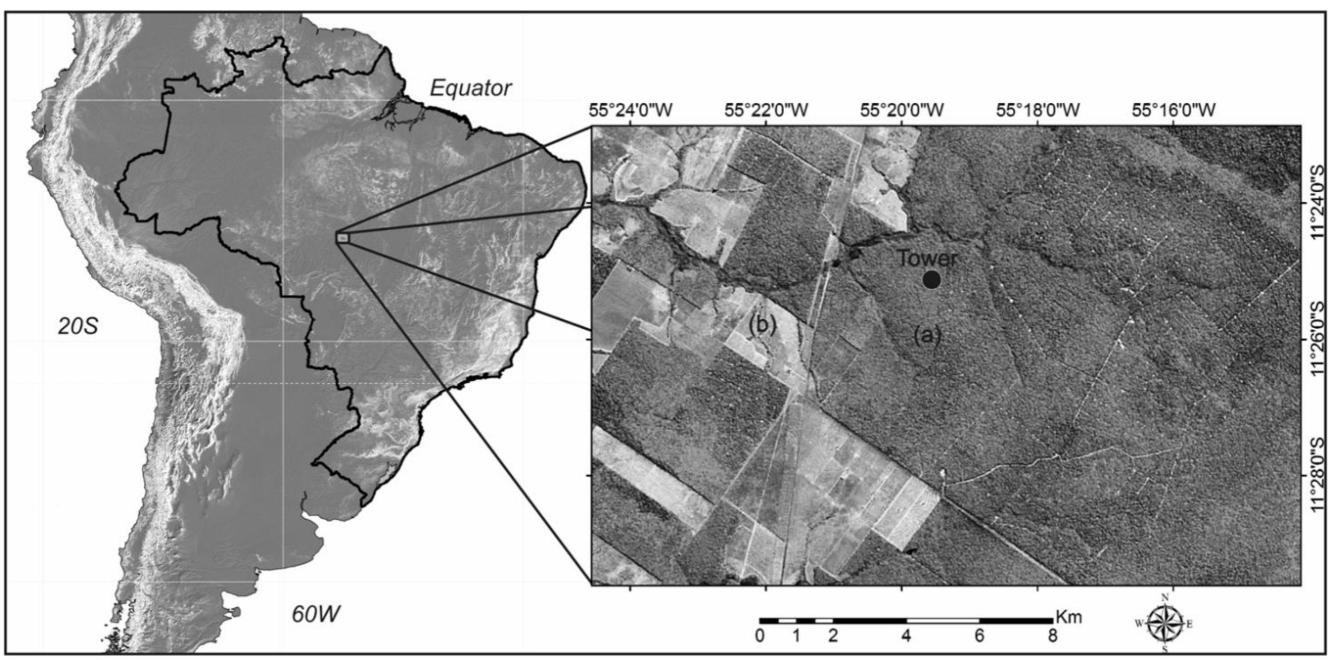
Study area

The study was conducted near the city of Sinop, Mato Grosso, Brazil (11°24′75″ S: 55°19′50W″) (Figure 1). The measurements were conducted in an intact, mature forest with a relatively continuous, 28 to 30m tall canopy. It is constituted by a transition of savanna (cerrado), transitional vegetation (cerradao), and Amazonian forest, situated on the southern fringes of the Amazon Basin near Sinop, recognized as dry (mata seca) or semi-deciduous mesophytic forest[1,8,21,32]. The vegetation consists of evergreen arboreal species, with characteristic species of the Amazonian transition forest, such as Tovomita schomburgkii, Qualea paraensis and Brosimum lactescens.

The host soil is an acidic (pH=4.2), sandy (94% sand), well-drained, nutrient-poor quartzarenitic neosol with low organic matter content (2%). Concentrations of available P (5.2 μgg^{-1}) and exchangeable cations (Ca and Mg) in the surface (0-20cm) are similar to other Amazonian forests with comparable substrate[32], being extremely acid and poor in nutrients.

The climatic characteristics of the transitional forest are similar to tropical forest and open pasture, however, the region approximately receives 200mm less precipitation than tropical forest and 500mm more than open pasture[21,29] and approximately 50% of the annual precipitation happens in the wet season. Soil temperature is higher than air temperature in the wet and dry seasons. In the dry and the dry-wet transition seasons, soil temperature and water content of the soil is lower. Higher air temperatures are verified at different

Figure 1 : Location of the studied area approximately 60 km from Poconé city, Mato Grosso state, Brazil, South America. micrometeorological tower was located in a forest at 16°39′50″ S and 56°47′50″W coordinated using a landsat ETM+Geo cover TM 2000 image



heights in the canopy in the superior stratus. The transitional forest presents a similar seasonality standard to some areas of the Amazon forest, with the distinction of micrometeorological variables, probably due to the difference in the floristic composition and structure of the canopy [29].

Estimate of soil humidity

Monthly samples of soil at a depth of 20 cm were collected at 7 points in November and December 2003; February, April, May, July, August and October 2004. The samples were prepared in plastic bags which were sealed to be airtight, and directed to the laboratory where they were weighed, using a precision scale (humid weight) and dried in a greenhouse at 80°C (forced circulation) until reaching a constant weight. The difference between wet and dry weights was used to determine the soil humidity.

Litter production and forest floor mass estimate (litterpool)

Above ground litter production (>1mm diameter) was measured from January 2001-07 in 20-randomly located 1 m^2 square collectors. Litter accumulated in each collector was retrieved monthly, washed with distilled water, separated into leaves, twigs, and reproductive (flowers and fruits) fractions, dried at 65-70°C for 72 hours, and weighed on a digital balance. Litterfall is expressed as the dry mass per area unit over a period of one month ($g\ ha^{-1}\ mon^{-1}$).

Forest floor mass (litterpool) was collected monthly between January 2002-07 within a 25×25 cm quadrate that was randomly placed adjacent to each litterfall collector (n=20). Litter was collected, washed with distilled water, dried at 65-70°C for 72 hours, and weighed on a digital balance. Forest floor mass is expressed as the dry mass per area unit ($Mg\ ha^{-1}$).

Estimate of contained nitrogen and total phosphorus of forest floor mass

Of the 20 collection points used to estimate litterfall, 8 points were chosen for physical-chemical analysis in November and December 03, February, April, May, July, August and October 04 to estimate the nitrogen and total phosphorus in the forest floor mass. After identification, the previously dried samples were directed to the laboratory where they were ground in a stainless steel mill (Willey type), and reduced to a fine dust. They were then sieved facilitating manipulation and assuring homogenization. After that they were submitted for analysis.

Estimate of available total nitrogen and phosphorus in the soil

Deformed samples were collected in the transition forest soil in November and December 03; February, April, May, July, August and October 04, at depths of 0-5; 5-15; 15-30 and 30-70cm. The same points were selected for the estimate of forest floor mass.

The samples were collected and prepared in plastic bags, identified using numbers that corresponded with the litter collection boxes, and were directed to the laboratory. They were dried in a greenhouse of forced circulation at 60-70°C until they reached a constant weight, then were sieved until fine. Later they were prepared in a plastic container, and analysed for total Nitrogen and Available Phosphorus concentrations. Knowing the concentrations of nutrients of each sample, it was possible to estimate the supply of nitrogen and phosphorus in the ground. In August an undeformed sample was removed in order to calculate the soil density and estimate of the supply of nitrogen and phosphorus per hectare.

The physical-chemical analyses of total Nitrogen and Phosphorus were carried out according to Allen and Anderson[2,3,23].

Litter decomposition

The coefficient of litter decomposition (K) was defined as the litterfall (LF) divided by the average forest floor mass (FFM), equation (1),

$$K = \frac{LF}{FFM} \quad (1)$$

The return time (t, years) is the reciprocal one of the return tax, equation (2),

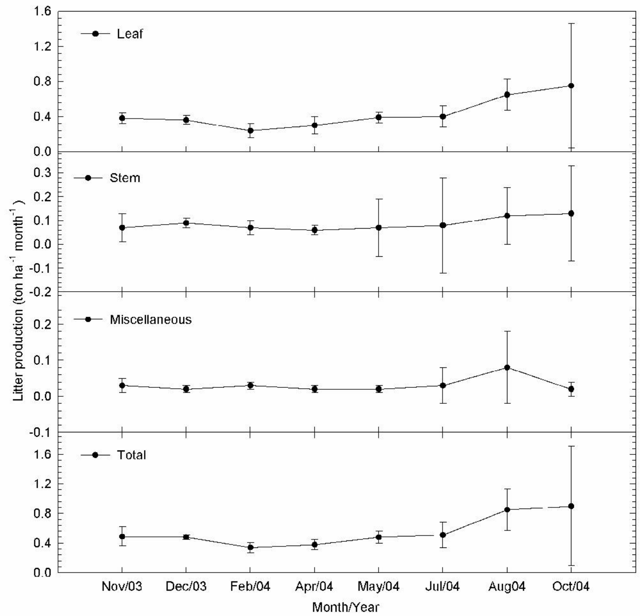
$$t = \frac{1}{K} \quad (2)$$

RESULTS AND DISCUSSION

Litter production

There was seasonal variation in the litter production with reduced production during January and February (Figure 2).

Figure 2 : Average (±sd; n=20) monthly litter production in the transitional forest (leaves, stems and miscellaneous) for November 2003 to October 2004



The annual litter production was 8.20 ton ha^{-1} year^{-1}. The annual litterfall was less than a maritime pine forest (14.20 ton ha^{-1})[12,31]; a wet forest (13.50 to 27.00 ton ha^{-1})[23] and a subtropical wet forest of between 7 and 16 years of age, with 17.49 ton ha^{-1} and a production of 11.90 ton ha^{-1}[5]. The values presented in the dry period were respectively similar to those found in a tropical wet forest in Panama[30].

There was more litter production in the dry and dry-wet season, being approximately 50% higher than the wet and wet-dry season (TABLE 1). The dry and dry-wet season, accounted for 67% of the annual litter production according to Golley[9] who suggests that the biggest litterfall in tropical and subtropical regions occurs in the transition between the seasons dry and wet.

The composition of the litter production was predominantly of leaves (77.1%), followed by twigs (15.6%) and Miscellaneous (flowers, fruits, seeds and material not identified) (7.3%) (TABLE 2).

Litter production is being studied in several forests under different climatic conditions. It has been demonstrated that the main constituent of the produced material is the leaves, constituting on average 70% of the deposited material[19,27,28]. In general, some studies report that leaf falls in tropical regions are continuous, but are higher in the dry season[9,16] probably due to a hydric stress. To save water the trees release leaves to

TABLE 1 : Average (±sd, n=20) monthly litter production in the transitional forest (leaves, stems and miscellaneous) in the wet, wet-dry, dry and dry-wet season

Season	Litter production fractions (ton ha^{-1} month^{-1}±sd)			
	Leaves	Stems	Miscellaneous	Total
Wet	0.99±0.07	0.23±0.13	0.08±0.01	1.30±0.10
Wet-dry	1.09±0.11	0.21±0.05	0.07±0.04	1.38±0.07
Dry	2.17±0.46	0.32±0.14	0.18±0.12	2.67±0.54
Dry-wet	2.04±0.43	0.50±0.18	0.32±0.11	2.85±0.56
Annual total(ton ha^{-1} year^{-1})	6.29	1.25	0.65	8.20

TABLE 2 : Percentage of the litter fraction in the transitional forest (leaves, stems and miscellaneous) in the wet, wet-dry, dry and dry-wet season

Season	Litter production fractions (%)		
	Leaves	Stems	Miscellaneous
Wet	76.15	17.69	6.15
Wet-dry	79.00	15.22	5.07
Dry	81.27	11.99	6.74
Dry-wet	71.58	17.54	11.23
Average total (%)	77.09	15.61	7.30

reduce the loss of water by respiration. In the dry-wet season, there is an increase in the twig and miscellaneous fractions (TABLE 2), probably due to increased wind intensity and the commencement of precipitation. The physical force of the rain causes the canopy to fall. Litter production depends on climate conditions. For example, the linear correlation between litter production and soil humidity resulted in a highly significant linear relationship (±95%CI) using the equation, $y=-0.0456x+1.225$ ($R2=0.7354$), where litter production was inversely proportional to soil humidity. A weak correlation was evident between litter production and monthly air and soil temperature.

Forest floor litter mass

One of the most peculiar characteristics of a forest is the formation of a layer of debris on the soil. The amount of this material accumulated on the soil forest depends on the relationship between the production and the decomposition of litter. The accumulation of litter mass was 58.63 ton ha^{-1}, and a greater forest floor mass occurred in the dry and dry-wet season. This approximated 57% of the total litter mass (TABLE 3) ranging between 3.4 and 6.2 ton ha^{-1} per month, similar to values seen in the forest floor litter mass in a subtropical

TABLE 3 : Average (±sd, n=20) monthly litterpool in the transitional forest (leaves, stems and miscellaneous) in the wet, wet-dry, dry and dry-wet season

Season	Forest floor mass fractions (ton ha^{-1}±sd)			
	Leaves	Stems	Miscellaneous	Total
Wet	9.29±3.11	2.95±1.02	1.48±0.50	13.72±4.59
Wet-dry	8.51±0.56	1.80±0.17	1.23±0.06	11.54±0.42
Dry	10.93±0.44	3.73±0.35	1.45±0.43	16.11±0.99
Dry-wet	13.84±0.56	2.71±0.12	0.71±0.12	17.26±0.30
Annual (ton ha^{-1})	42.57	11.19	4.87	58.63

forest (2.9 to 5.4 ton ha^{-1})[14].

Forest floor litter mass was constituted of 72.6% leaves, 19.1% twigs and 8.3% miscellaneous. The biggest litter production occurred in the dry-wet season. Low precipitation air and soil temperatures in the dry-wet season could have intervened in bacterial activity of the microorganism decomposers, diminishing the speed of decomposition.

The relationship between the forest floor mass and the soil humidity can be explained by an exponential equation, where increases in soil humidity diminish forest floor mass, however, the exponential correlation (R2=0.41) is considered very weak, (y=7.26e-0.0307x) probably indicating the influence of other factors, such as strong winds that knock down the fractions (leaves, twigs and miscellaneous) of the trees, increasing in the forest floor mass in the different seasons in the year.

Litter decomposition

The estimated litter decomposition (K) was 1.67 year^{-1}. While our monthly k value is similar to those reported for subtropical forest and tropical forest[14,30], the return time defined as t=1/K was 0.59, inferior to reported values for subtropical forest[14]. In accordance with Pagano[17], high values for K suggest a fast reuse of nutrients by the vegetation. In the present study, the moisture conditions in the surface litter layer during the dry season were conducive for rapid microbial degradation of surface litter.

Nitrogen and phosphorus in the forest floor litter mass

Nutritional dynamics of the forest can be influenced by the litter. There was a continuous variation in nitrogen and phosphorus in the forest floor litter mass, with

Figure 3 : Average (±sd; n=20) monthly total nitrogen in the leaf, stem, miscellaneous (flower + fruit) and total litter production for November 2003 to October 2004

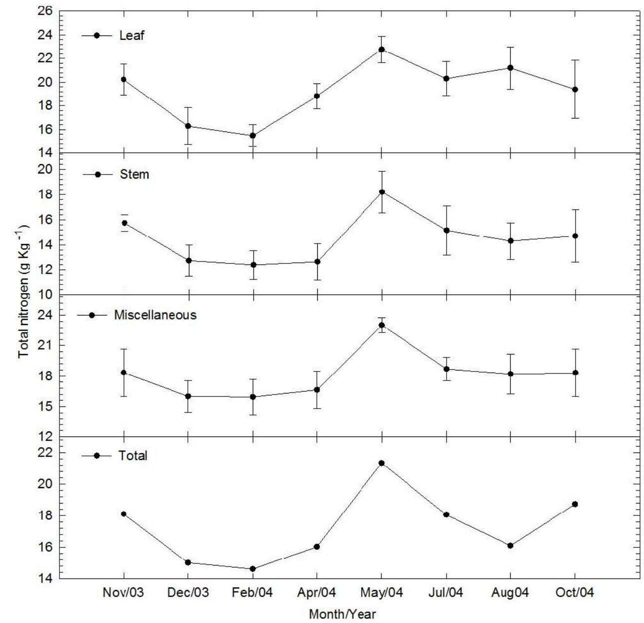
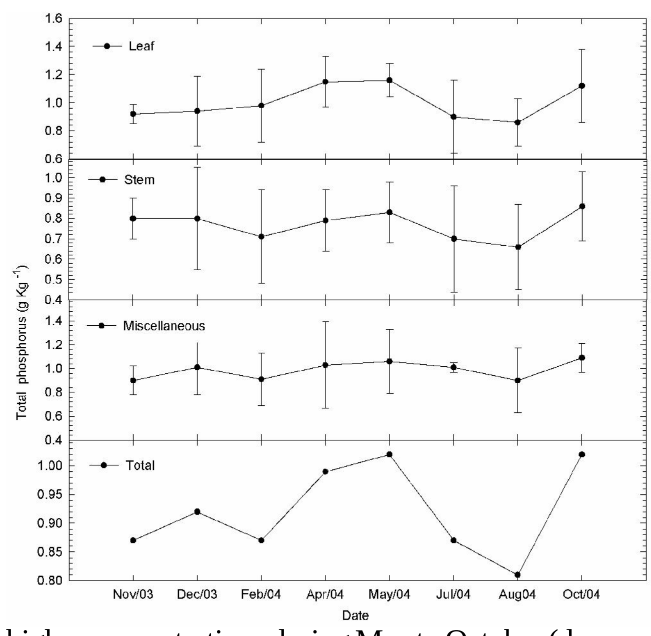


Figure 4 : Average (±sd; n=20) monthly total phosphorus in the leaf, stem, miscellaneous (flower+fruit) and total litter production for November 2003 to October 2004



higher concentrations during May to October (dry season and beginning of dry-wet season) and a reduction during the wet season from an average (+95% CI) seasonal peak in February (Figure 3 and Figure 4).

The biggest nutrient concentration of the floor litter mass was derived from leaves and miscellaneous. The total nitrogen and total phosphorus of the miscellaneous fraction was very similar to the leaf fraction (TABLE 4).

TABLE 4 : Average (±sd) total nitrogen and phosphorus in the litterpool in the wet, wet-dry, dry and dry-wet season

Season	Total nitrogen (g Kg^{-1}±sd)			
	Leaves	Stems	Miscellaneous	Average
Wet	18.26±2.48	14.24±1.82	17.17±2.26	16.56±2.08
Wet-dry	17.16±1.98	12.53±1.26	16.28±1.77	16.72±0.62
Dry	21.54±1.78	16.68±2.36	20.88±2.42	21.21±0.47
Dry-wet	21.79±1.75	16.25±2.79	20.08±2.55	20.94±1.21
Average annual	19.69±2.33	14.93±1.92	18.60±2.22	17.24±2.39
	Total phosphorus (g Kg^{-1}±SD)			
Wet	0.99±0.25	0.76±0.21	0.99±0.23	0.91±0.13
Wet-dry	0.99±0.42	0.73±0.25	0.83±0.48	0.85±0.13
Dry	0.88±0.32	0.77±0.21	1.03±0.19	0.89±0.13
Dry-wet	0.99±0.25	0.76±0.21	0.99±0.23	0.91±0.10
Average annual	0.93±0.08	0.77±0.03	0.95±0.09	0.92±0.08

TABLE 5 : Contribution of forest floor mass fraction (kg ha^{-1}) in the total quantity and percentage of nitrogen and phosphorus developed in the soil in the wet, wet-dry, dry and dry-wet season

Fraction of forest floor mass	Forest floor mass (ton ha^{-1})	N (kg ha^{-1})	N (%)	P(kg ha^{-1})	P (%)
Wet season					
Leaves	9.29	169.64	71.56	7.80	67.53
Stems	2.95	42.01	17.72	2.36	20.43
Miscellaneous	1.48	25.41	10.72	1.39	12.03
Total	13.72	237.06	-	11.55	-
Wet-dry season					
Leaves	8.51	146.03	77.42	8.42	78.25
Stems	1.80	22.55	11.96	1.31	12.17
Miscellaneous	1.23	20.02	10.61	1.02	9.48
Total	11.54	188.61	-	10.76	-
Dry season					
Leaves	10.93	235.43	71.79	9.62	68.81
Stems	3.73	62.22	18.97	2.87	20.53
Miscellaneous	1.45	30.28	9.23	1.49	10.66
Total	16.11	327.92	-	13.98	-
Dry-wet season					
Leaves	13.84	301.57	83.80	13.70	83.23
Stems	2.71	44.04	12.24	2.06	12.52
Miscellaneous	0.71	14.26	3.96	0.70	4.25
Total	17.26	359.87	-	16.46	-

The miscellaneous fraction presents high concentrations of nitrogen and phosphorus due to its composition, including non-identified vegetation, tree and twig fractions, bird excrement, flowers and fruits, etc.

Seasonally, the total nitrogen in the forest floor mass was lesser in the wet and wet-dry seasons approximately 38% more than dry and dry-season (TABLE 5).

In the forest floor litter mass, the leaf fraction was more significant than the twig and miscellaneous fractions, contributing with a bigger N and P percentage. In the wet-dry season, the leaves presented a larger contribution of nitrogen and total phosphorus, respectively. On the other hand, in this same season there was a lesser contribution from the miscellaneous fraction, 4.0% and 4.3% of nitrogen and total phosphorus, respectively (TABLE 5).

N: P ratio in the wet, wet-dry, dry and dry-wet seasons were approximately 18:1, 20:1, 24:1 and 23:1, respectively. In general, the concentration of nutrients in the fractions of the forest floor mass is not the same for all the plants, ample variation exists[25].

There was a significant correlation (±95% CI, r=0.74) between the total phosphorus monthly average and the soil temperature average.

Nitrogen and phosphorus in the soil

The greatest amount of nutrients was in the superficial soil layer (0-5) cm diminishing with an increase in depth (TABLE 6). The results of this research was similar to values estimated in the Manaus region, which estimated that the nitrogen and phosphorus content, in the superficial soil layer was between 2.1 and 1.8 g kg^{-1} for total nitrogen and 5.0 and 6.0 and mg kg^{-1} for phosphorus[15].

TABLE 6 : Average monthly total nitrogen and available phosphorus in the soil in the wet, wet-dry, dry and dry-wet season at various soil depths (0-5; 5-15; 15-30 and 30-70cm)

Season	Soil depth (cm)			
	0-5	5-15	15-30	30-70
	Total nitrogen (g Kg^{-1}±sd)			
Wet	2.80±0.47	1.28±0.29	0.87±0.11	0.61±0.18
Wet-dry	3.21±0.48	1.31±0.31	0.54±0.23	0.17±0.11
Dry	2.60±0.33	1.22±0.47	0.75±0.20	0.49±0.23
Dry-wet	2.97±0.60	1.32±0.19	0.98±0.14	0.61±0.17
	Available phosphorus (mg Kg^{-1}±sd)			
Wet	9.43±1.05	1.31±0.27	0.90±0.10	0.60±0.14
Wet-dry	9.40±1.74	1.38±0.29	0.72±0.16	0.46±0.15
Dry	8.81±1.36	1.31±0.21	0.83±0.12	0.60±0.15
Dry-wet	8.58±1.38	1.39±0.19	0.93±0.12	0.71±0.10

The higher nitrogen concentration in the superficial soil layers was due to a higher intensity of mineralization processes. There was considerable fine root activity in a soil layer depth of between 0-10cm. This was due to a larger availability of nutrients in the ground and, biogeochemical cycles of deposition and mineralization of the litterfall[10,11]. At a depth of 0-20cm there was more nutrients available for root absorption and therefore tree growth[10,11]. A significant correlation (5% CI) was made between total nitrogen in the different soil depth layers and the soil temperature. However the relationship was not significant with air temperature, precipitation, or soil humidity.

A significant correlation was found between available phosphorus in the different soil depth layers and the soil temperature, air temperature and soil humidity (±95%CI). In general, air temperature under the forest cover displays similar behavior to the solar radiation that supplies air energy for all biological processes in the canopy, from root growth to microorganism activity.

During the wet-dry season there was a higher percentage of available total nitrogen in the soil. In the wet and wet-dry season, the activity of microorganism decomposers in litter production was favored and there was more nutrient cycling in the soil by the infiltration of precipitation. However in the wet season the volume of forest floor mass did not allow total draining of precipitation. This can be evidenced by the high soil humidity in the wet-dry season (February to April 03). The higher water drainage in the wet-dry season favored a higher ratio of nutrients in the soil available to the root system in the transition forest. On average, 15.6% of the total annual nitrogen estimated in the forest floor mass was available for the superficial layer of the soil, whereas 2.5% of total nitrogen was available at a soil depth between 30-70cm. On average, in the soil superficial layer (0-5 cm depth) the concentration of nutrients was higher then at depth between 30-70cm approximately 83 and 93% for total nitrogen and available phosphorus, respectively.

CONCLUSIONS

Overall, our results suggest variability in litter production, forest floor litter mass and nutrient dynamics. Seasonal variations in litterfall dynamics were coincidental with associated variations in forest floor litter mass.

On a seasonal basis, the total nitrogen in the litter production varied markedly and presented a decline in the wet season, while the total phosphorus presented an incline in wet-dry season.

The more significant forest floor mass fraction was from leaves for return of soil nutrients.

In the soil superficial layer (at depth between 0-5cm) the concentration of nutrients was higher than at depths between 30-70cm, approximately 83 and 93% for total nitrogen and available phosphorus, respectively.

ACKNOWLEDGEMENTS

This research was supported in part by the Universidade Federal de Mato Grosso (UFMT), Conselho Nacional de Desenvolvimento Científico e Tecnologico (CNPq), Mato Grosso State Research Support Foundation (FAPEMAT), the Coordenacao de Aperfeicoamento de Pessoal de Nivel Superior (CAPES) and Centro Federal de Educaçao Tecnologica do Mato Grosso (CEFET-MT).

REFERENCES

[1] D.D.Ackerl, W.W.Thomas, C.A.C.Ferreira, J.R.Pirani; The forest-cerrado transition zone in southern Amazonia: Results of the 1985 Project Flora Amazônica Expedition to Mato Grosso, Brittonia, **(41)**, 113-128 **(1989)**.

[2] S.E.Allen; Chemical Analysis of Ecological Materials.London.Ed.Blackwell, 531 **(1989)**.

[3] J.M.Anderson; Tropical Soil Biology and Fertility.A Handbook of methods.Eynsham-UK.Ed.Information Press, 420 **(1996)**.

[4] M.A.Arain, F.Yuan, T.A.Black; Soil-plant nitrogen cycling modulated carbon exchanges in a western temperate conifer forest in Canada.Agricultural and Forest Meteorology **(140)**, 171-192 **(2006)**.

[5] A.Aruachalam, K.M.Aruachalam, H.N.Pandey; Forest Ecology and Management, 209-219 **(1998)**.

[6] A.A.Carpanezzi; Deposiçao de material orgânico e nutrientes em uma floresta natural e em uma

plantaçao de eucaliptos no interior do estado de Sao Paulo.Master's Thesis, Escola Superior de Agricultura Luiz de Queiroz, Universidade de Sao Paulo, Sao Paulo, 115 **(1980)**.

[7] D.W.Cole, M.Happ; Elemental cycting in forest ecosystems.In: Reichele, D.E.Dynamic properties of forest ecosytems, Cambridge: University Press, 341-409 **(1980)**.

[8] G.Eiten; The Cerrado vegetation of Brazil, Bot.Rev., **(38)**, 201-341 **(1972)**.

[9] F.B.Golley; Ciclagem de nutrientes em ecossistema de floresta tropical wet, EPU.Ed.da Universidade de Sao Paulo (traduçao de Eurípedes Malavolta), **(1983)**.

[10] J.L.M.Gonçalves; Características do sistema radicular de absorçao de Eucalyptus grandis sob diferentes condiçoes edáficas.Thesis. Escola Superior de Agricultura Luiz de Queiroz, Universidade de Sao Paulo, Sao Paulo, 84 **(1994)**.

[11] J.L.M.Gonçalves, F.Poggiani, J.L.Stape, M.I.P.Serrano, S.L.M.Mello, K.C.F.S.Mendes, L.A.C.Jorge; Efeito de pratica de cultivo mínimo e intensivo do solo sobre cilagem de nutrientes, fertilidade do solo, configuracao do sistema radicular e nutriçao mineral de povoamentos de Eucalyptus grandis, Piracicaba, 94 **(1997)**.

[12] V.A.Kavavadias, D.Alifrages, G.Brofas; Litter fall, litter acumulation and litter decomposition rates in four forest ecosystems in northen Greece. Forest Ecology and Management, **(144)**, 113-127 **(2001)**.

[13] F.G.Koonig, E.J.Brun, M.V.Schumacher, S.J.Longhi; Devoluçao de nutrientes via litterfall em um fragmento de floresta de Santa Maria, RS.Brasil Florestal, **(74)**, 45-52 **(2002)**.

[14] N.Lodhiyal, L.S.Lodhiyal; Biomass and net primary productivity of Bhabar Shisham forest in central Himalaya, India, Forest Ecology and Management, **(176)**, 217-235 **(2003)**.

[15] L.M.S.Magalhaes, W.B.H.Blum; Concentraçao e Distribuiçao de nutrientes nas folhas de especies florestais, na Amazonia Ocidental.Floresta e Ambiente, **(6)**, 127-137 **(1999)**.

[16] M.Merguro, G.N.Vinueza; Ciclagem de nutrientes minerais na mata mesofila secundaria.Sao Paulo.Boletim de Botanica da Universidade de Sao Paulom, **(22)**, 9-16 **(1979)**.

[17] S.N.Pagano; Nutrientes minerais no folhedo produzido em mata mesofila semidecídua no município de Rio Claro, SP, Revista Brasileira de Biologia, **(49)**, 41-47 **(1989)**.

[18] F.Poggiani; Ciclagem de Nutrientes em Ecossistema de Plantaçoes de Eucalyptus e Pinus.Implicaçao silviculturais.Piracicaba, Thesis.Escola Superior de Agricultura Luiz de Queiroz-Universidade de Sao Paulo., 229 **(1985)**.

[19] N.Priante Filho, M.M.S.Hayashi, J.de S.Nogueira, J.H.Campelo Junior, P.C.Nunes, L.Sanches, E.C.Couto, W.Hoeger, F.Raiter, J.L.Trienweiler, E.J.Miranda, P.C.Priante, L.C.Pereira, M.S.Biudes, C.L.Fritzen, M.Lacerda, G.S.Suli, S.Shiraiwa, M.Silveira, G.L.Vourlitis; Comparison of the mass and energy exchange of a pasture and a mature transitional tropical forest of the southem Amazon basin during the wet-dry season transition.Global Change Biology, **(10)**, 863-876 **(2004)**.

[20] W.L.Prichet; Properties and management of forest soils.New York: John Wiley and Sons, 500 **(1987)**.

[21] J.A.Ratter, G.P.Askew, R.F.Montgomery, D.R.Gifford; Observations on the vegetation of northeastern Mato Grosso.II. Forests and soils of the Rio Suia-Missu area, Proc.R.Soc.London, Ser., B, **(203)**, 191-208 **(1978)**.

[22] H.E.Street, H.Opik; Fisiologia das Anginospermas: crescimento e desenvolvimento.Sao Paulo, EDUSP., 332 **(1974)**.

[23] M.J.Swift, O.W.Heal, J.M.Anderson; Decomposition in Terrestrial Ecosystems.Blackwell, Oxford, 372 **(1979)**.

[24] S.M.Sundarapandian, P.S.Swamy; Litter production and leaf-litter decomposition of selected tree species in tropical forests at Kodayar in the Western Ghats, India, Forest Ecologycal Management, **(123)**, 231-244 **(1999)**.

[25] J.I.Valle-Arango; Calidad, calidad y nutrients reciclados por la hojarasca fina en bosques pantanosos del pacífico sur colombiano, Interciência, **(28)**, 443-449 **(2003)**.

[26] D.R.Vanden; Prediction of mineral nutrient status of trees by foliar analysis, The Botanical Review, **(40)**, 347-394 **(1974)**.

[27] A.C.Vibrans, L.Sevegnami; Deposiçao de nutrientes através da queda de litterfall em dois remanesccentes de Floresta de Ombrófila Densa em Blumenau-SC, Revista de Estudo Ambientais, Blumenau, **(2)**, 2-3 **(2000)**.

[28] M.T.Vilani, L.Sanches, J.S.de Nogueira, N.Priante-Filho; Seasonality of radiation, temperature and humidity in an Amazon Cerrado-Forest Transition (in Portuguese with abstract in English), Rev.Brasileira Meteorol., **(21)**, 119-131 **(2006)**.

[29] G.L.Vourlitis, N.Priante-Filho, M.M.Hayashi, J.S.de Nogueira, F.Caseiro, J.H.Campelo Junior; Seasonal variations in evapótranspiration of a transitional tropical Forest of Mato Grosso, Brasil, Water Resources Research, **(38)**, 30-1-30-11 **(2002)**.

[30] R.K.Wieder, S.J.Wright; Tropical forest litter dynamies and dry season irrigation on barro Colorado, Panamá, Ecology, **(76)**, 1971-1979 **(1995)**.

[31] W.Wilcke, S.Yasin, C.Valarezo, W.Zech; Change in water quality during the passage through a tropical montane rain forest in Ecuador, Biogeochemistry, **(55)**, 45-72 **(2001)**.

[32] J.Thompson, J.Proctor, V.Viana, W.Milliken, J.A.Ratter, D.A.Scott; Ecological studies on a lowland evergreen rain forest on Maraca Island, Roraima, Brazil.I.Physical environment, forest structure, and leaf chemistry, Journal Ecology, **(80)**, 689-703 **(1992)**.