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Changes in allocthonous nutrient sources for a natural lake in southeast Brazil due to *Eucalyptus* spp. plantations

Mudanças nas fontes alóctones de nutrientes para um lago natural no sudeste do Brasil causado por plantios de *Eucalyptus* spp

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Abstract

This paper evaluates the annual *Eucalyptus* spp and Secondary Atlantic Rain Forest (SAF) litter production, its nutritional value, conversion to allochtonous material and, decomposition rates into the lake, as well. SAF estimation of litter deposition was higher than *Eucalyptus*. Thin branches were *Eucalyptus* main fraction. Conversely, the bulk of the SAF litter were leafs. Bark litter was exclusive for *Eucalyptus*. Flowers, fruits and seeds (F,F&S) litter fluctuate from 1 and 5%. *Eucalyptus* thin branches protein content was lower than SAF same fraction. The opposite was found for soluble carbohydrates. Organic nutrients were not significantly different for *Eucalyptus* and SAF leaves, although F,F&S from SAF detained higher protein values and, soluble carbohydrates. *Eucalyptus* leaves proved to be higher in lipids and polyphenols, as well. Allochtonous load was three times to lake surrounded by SAF than the lake surrounded by *Eucalyptus*. As a whole, SAF litter decomposition in water was faster than *Eucalyptus* litter. These results suggesting that replace of natural forests by *Eucalyptus* in lakes catchment could bring changes on both quantity and quality of available nutrients to aquatic biota, with spontaneous effect on biodiversity. Proposal for Best Management Practices (BMP) relay on increase of the "belt" width of riparian ecosystems (littoral zone and forest) and the establishment of a limnological monitoring of BMPs effectiveness.

Keywords: Allochtonous material, Lakes conservation, Litter, *Eucalyptus*, Secondary Tropical forests

Resumo

Compararam-se, em plantios de eucalipto e Floresta Atlântica Secundária (FAS), a produção anual de serrapilheira, seu valor nutricional e sua importância como material alóctone em dois lagos naturais do Sistema Lacustre do Médio Rio Doce, MG. Estimou-se que a FAS produziu mais serrapilheira que o eucalipto. Galhos finos dominaram na serrapilheira de eucalipto, enquanto as folhas representaram a maior parte da serrapilheira na FAS. Cascas foram exclusivas da serrapilheira de eucalipto. Flores, Frutos e Sementes (F,F&S) variaram entre 1 a 5% da serrapilheira. Os galhos finos de eucalipto mostraram menor conteúdo em proteína. Os nutrientes orgânicos não foram significativamente diferentes para os dois tipos florestais, apesar de F,F&S da FAS possuírem mais proteína e carboidratos solúveis. Lipídios e polifenóis foram mais abundantes em folhas de eucalipto. O lago circundado pela FAS recebeu três vezes mais material alóctone e sua decomposição na água foi, em geral, mais rápida. Os resultados sugerem que a substituição de florestas naturais por eucalipto em bacias de lagos pode trazer mudanças na qualidade e quantidade de nutrientes, com possíveis efeitos na biota aquática. Para mitigar esses impactos, sugere-se um aumento na largura da faixa ciliar em lagos com plantios de eucalipto.

Palavras-chave: Allochtonous material, Lakes conservation, Litter, *Eucalyptus*, Secondary Tropical forests

INTRODUCTION

Inland waters dependence upon allochtonous material like the major energy source is well documented, especially for low order river and oligotrophic lakes (BARBOSA *et al.* 1982; FISHER and LIKENS, 1973; GOSZ *et al.*, 1973; DELONG and BURVEN, 1993; BARBOSA and COUTINHO, 1987; COLE, 1990; FRANCE and PETERS, 1995; LIKENS and BORMANN, 1996; SABATER *et al.*, 2000; GRAÇA *et al.*, 2001). Disturbances on catchment vegetation can affect whole aquatic ecosystem metabolism, including anthropogenic generate trophic changes (JOHN *et al.*, 2005). Also, allochtonous material efficiency as energetic source is a function of its easygoingness in liberates organic carbon via decomposition, which depends on the mate-

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rial characteristics, decomposers and water chemistry (SUBERKROOP *et al.*, 1976; CEBRIAN, 1999; GRAÇA *et al.*, 2001; MATHURIAU and CHAUVET, 2002).

In the middle Rio Doce Lake System (Southern Brazil, 19º- 20º S; 42º-43º W), forests in natural lakes catchments have been replaced by Eucalypts plantations since the 1940, with potential consequences to allochtonous input (SABARÁ, 1994; BARBOSA *et al.*, 1997). Despite potential impacts, there are few studies to evaluate the changes on quality and quantity of allochtonous material carried to lakes in comparison with the number of papers about water consumption, silting up or contamination by fertilizers and pesticides (JOHN *et al.*, 2005; IIED, 1996).

The present study aims to evaluate the major changes caused by the substitution of Secondary Atlantic Rain Forests by *Eucalyptus* on litter quantity and quality plus the load and dynamics of the allochtonous material carried to two natural lakes in the middle Rio Doce Lake System.

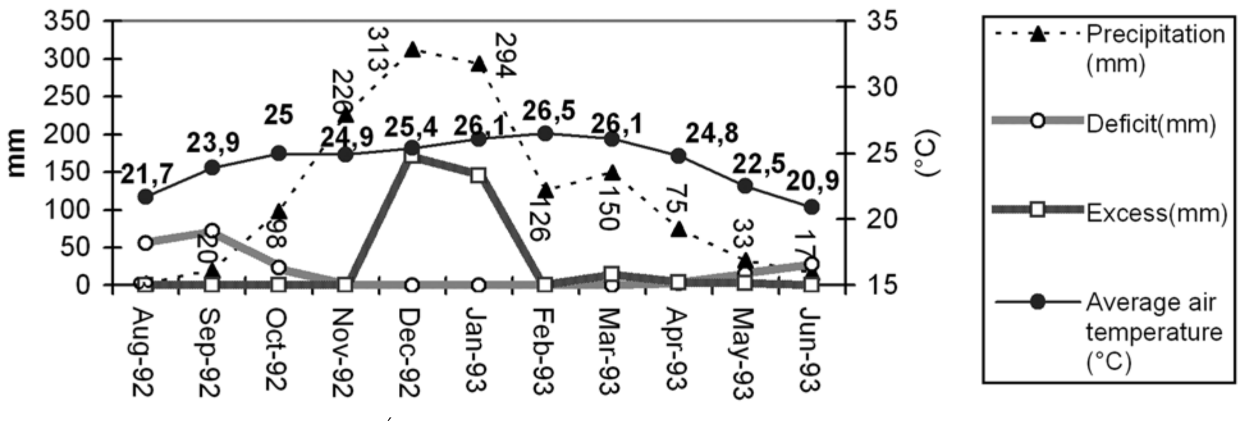
MATERIAL AND METHODS

Semideciduous forest (Atlantic Rainforest Biome) once covers 100% of Rio Doce basin in a hilly landscape. Nowadays less than 5% was left being Rio Doce State Park (36000 ha) the largest remnant (ANTUNES, 1985; BARBOSA *et al.*, 1997). Outside the Park there are many natural lakes with catchments occupied by *Eucalyptus*, Secondary Atlantic Rainforests (SAF) and pastureland. Annual average air temperature is 23ºC, with well delimited dry and wet seasons (October to March).Total rainfall through sampling period (1389 mm) had its minimum (0 mm) in August/1992 and maximum (313 mm) in December/1992 (Figure 1). Average monthly air temperature ranged from 26.5 (Feb./1993) to 20.9 ˚C (June/1993). Water soil balance (Thornthwaite and Matter, 1957 cited in LIMA, 1986), estimate a potential evapotranspiration of 1297 mm and 309 mm in excess. Water deficit and excess figures maxima occurred in September/1992 (72 mm) and December/1992, (145 mm), respectively.

The Lakes chouse for the studies were: i) Lake Pedra, surrounded by a 20 years old SAF growing on abandoned *Eucalyptus* area, with 15 ha of water surface, 8m maximum depth, shore length of 1.53km and a ratio catchment area/lake area of 2.2; ii) Lake Hortência (catchment covered by *Eucalyptus*) has 33 ha, watershed area/lake ratio of 2.9, shore length of 3.18km and, 11m maximum depth.

Litter collection was done from August 1992 to June 1993 by 42 circular litter traps (0.25m^2) per catchment randomly distributed. In July 1993 *Eucalyptus* plantation clear cut begun and the sampling ended. Once a month, the accumulate material was characted in four fractions: leaves, thin branches, bark, flowers, fruits and seeds. From here flowers, fruits and seeds will be referred as F,F&S for short. After oven dried (40º C) until constant weight, we expressed it in kg ha^{-1} month^{-1}.

The loading of allochtonous material to the lakes was estimated by ten semicircular collectors (0,28m radius) per lake shore. In the sampling period, bulldozers opened roads that were locate very near the water (1 to 10 m). It creates dykes 0.5 m tall between road bed and the littoral zones and practically all runoff goes to six road drainers in each lake. Six collectors were then fixed in each drainer (four more collectors distributed randomnly along each lake margins). The blocked material was taken away monthly and treated as described for the litter. Total allochtonous material load was estimated by dividing the sum of its dry mass (kg) by the sum of the widths (m) of the trappers. The result was extrapolated for each lake border length (m).



Fonte: estação climática da ACESITA ENERGÉTICA (1,5 km de distância dos lagos)

Figure 1. Results of water balance (100mm of field capacity). Data source: ACESITA ENERGÉTICA climatic station (1.5 km far from the lakes). (Resultados do balanço hídrico do solo (100 mm de capacidade de campo)).

The nutritional value of litter fractions was estimated by the concentrations of crude proteins, soluble carbohydrates and lipids from samples from dry (August-September 1992; May-June 1993) and wet seasons (December 1992). Polyphenols was calculated in blend sub-samples of the whole sampling period. Concentrations of total organic nitrogen multiplied by 6.25 gave percentage of crude protein (RIBEIRO *et al.*, 1987). The analytical methods for lipids and soluble carbohydrates followed Quarmby (1989) and Deriaz (1961) as described in Allen (1989). Polyphenols content (expressed in Optical Density Units (ODU)), were fixed by Folin-Dennis reagent (ESTEVES,1979).

The approach to estimate decomposition velocities was the immersion of pars of litter bags (1mm^2 mesh with10 g of material) in each lake shore. Taken away after 1, 3, 7, 15, 30, 60, and 90 days, remain mass, concentrations of nutrients and polyphenols were obtained as described to litter. The decomposition rate was the first derived from the equations of dry mass and nutrients plotted in function of time (days).

RESULTS

Production and composition of litter fractions

Estimation of total litter for SAF was 8.3kg ha^{-1} y^{-1}, 21% higher than *Eucalyptus* (6.5 kg ha^{-1} y^{-1}). Differences in terms of contributions of litter fractions between vegetation types can be distinguished: leaves in SAF stand for 75.6% (6.2 Kg ha^{-1} ano^{-1}), and 39.4% (2.2 Kg ha^{-1} ano^{-1}) for *Eucalyptus*. In opposition, thin branches did contribute to 56.3% *Eucalyptus* litter (3.6 Kg ha^{-1} ano^{-1}) against 19.6% (1.6 Kg ha^{-1} ano^{-1}) on SAF. F,F&S represented respectively 4,8% (394 Kg ha^{-1} ano^{-1}), and 1.3% (86 Kg ha^{-1} ano^{-1}) of SAF and *Eucalyptus* litter. Bark was 4% (248 Kg ha^{-1} ano^{-1}) of *Eucalyptus* litter. Results were significantly different at ($p < 0.05$) in Mann and Whitney test (Table 1).

Eucalyptus litter productivity range from 1866 Kg ha^{-1} month^{-1} (November 1992) to 68.7 Kg ha^{-1} month^{-1} (May 1993). SAF display a smaller difference: from 1215 Kg ha^{-1} month^{-1} in July 1993, to 348.6 Kg ha^{-1} month^{-1} (May 1993).

The maximum productivity for the SAF leaves (933.3 Kg ha^{-1} month^{-1}) in July 1993, approximately 100 Kg ha^{-1} year^{-1}, was higher than *Eucalyptus* maximum (831.3Kg ha^{-1} year^{-1}) in February 1993. Still, SAF minimum productivity of this fraction (176.7 Kg ha^{-1} year^{-1}) was 670% higher than the minimum in *Eucalyptus* (30.9 Kg ha^{-1} year^{-1}), both figures for May 1993. Depositions of F,F&S lack synchronism: *Eucalyptus* bulky deposition occurred in October 1992 (29.8 Kg ha^{-1} month^{-1}), dropping to 1.8Kg ha^{-1} month^{-1} (March 1993) and 5.7 Kg ha^{-1} month^{-1} (May 1993); In February 1993 SAF main productivity was equal to 126.3 Kg ha^{-1} month^{-1} with lowest value (10.5 Kg ha^{-1} month^{-1}) in June 1993. Bark fall (only for *Eucalyptus*) figures were: November 1992 (214.5 Kg ha^{-1}), December 1992 (14.8 Kg ha^{-1}), and February 1993 (19.0Kg ha^{-1}).

Organic nutrients and polyphenols

There was no significant seasonal effect on nutrient concentration for the fractions (Table 2). The *Eucalyptus* leaves average concentrations of crude proteins (6.8%), lipids (2.61%), and soluble carbohydrates (3.97%) were lower than the average for these fractions in SAF (respectively 7.63%, 3.28%, and 4.17%). The stems crude protein average concentration (2.11%) in *Eucalyptus* was lower than in SAF (6.32%). In contrast, the average concentration of soluble carbohydrates for stems of *Eucalyptus* (4.57%) was higher than the mean for this fraction in SAF (2.93%). The lipids average concentration for stems of *Eucalyptus* was 0.96%) and 0.72% for SAF.

Table 1. Litter fractions annual productivity, monthly average, and minimum, maximum monthly productivity. Standard deviation (s) was calculated for monthly productivity. Dates refer for each minimum and maximum value. (Produtividade anual das frações da serrapilheira, média mensal e produtividades mensais máximas e míminas. O desvio padrão (s) foi calculado para a produtividade mensal. Os dados referem a valor máximo e mínimo)

	Annual litter productivity	% of total	Monthly minimum productivity		Monthly maximum productivity		Monthly average productivity	(s)
Litter fraction	kg ha^{-1} year^{-1}				kg ha^{-1} month^{-1}			
leaves – SAF	6246.0	75.6	176.7	May/93	933.3	Jun/93	567.8	248.0
leaves – Euc.	2554.0	39.4	30.9	May/93	831.9	Feb/93	232.3	216.0
stems – SAF	1619.0	19.6	31.2	Mar/93	372.7	Nov/92	147.1	110.0
stems – Euc.	3649.0	56.3	32.1	May/93	1350.0	May/93	331.7	386.0
F,F&S - SAF	394.0	4.8	10.5	Jun/93	126.3	Feb/93	35.8	33.0
F,F&S – Euc.	86.0	1.3	0.0	Dec/92	29.8	Oct/93	8.2	9.5
bark – Euc.	248.0	3.8	0.0	Jan/93	214.05	Nov/92	22.6	64.0
bark – SAF	0.0	0.0	0.0	-	0.0	-	0.0	0.0
Total – SAF	8259.0	100.0	348.6	May/93	1215.0	Nov/92	750.7	284.0
Total – Euc.	6537.0	100.0	68.7	May/93	1866.0	Nov/92	589.3	574.0

Table 2. Average concentration (% of dry weight) of crude protein (CP), lipids (L) and soluble carbohydrates (SC) in litter fractions. Values for leaves, fruits and seeds from Eucalyptus correspond to material collected in dry period (August - September 1992). (Concentração (% de peso seco) de proteína bruta (CP), lipídios e carboidratos solúveis (SC) nas frações da serrapilheira. Valores para folhas, frutos e sementes de Eucalyptus correspondem ao material coletado no período de seca (agosto – setembro de 1992))

Fraction	Nutrients	*Eucalyptus*	SAF
		average	average
leaves	CP	6.85	7.63
	L	2.61	3.28
	SC	3.97	4.17
stems	CP	2.11	6.32
	L	0.96	0.72
	SC	4.57	2.93
Leaves, fruits and seeds (L,F&S)	CP	5.68	7.48
	L	6.31	1.56
	SC	3.46	3.97

The lipids represented the highest difference in F,F&S: 1.56% (SAF) and 31% (*Eucalyptus*). F,F&S crude proteins were 7.48% in SAF against 5.68% in *Eucalyptus*. Variation for soluble carbohydrates among *Eucalyptus* (3.9%) and SAF (3.5%) was 15%.

Polyphenols in *Eucalyptus* leaves (12.03 ODU) were 630% higher the concentration in SAF leaves (3.58 ODU). *Eucalyptus* stem polyphenols were 660% higher (28.058 ODU) than SAF (7.809 ODU). Bark polyphenols results were 19.541 ODU.

Load and nutritional value of the allochtonous material to the lakes

The allochtonous material deposition was observable only in December 1992 and January 1993 (wet season), suggesting a close reliance between allochtonous load and runoff. The SAF total load (1670 Kg) was 360% superior to *Eucalyptus* (650 Kg) (Table 3).

The allochtonous material composition was similar between basins in terms of litter: 81.8% in leaves (1366 Kg) for SAF and 86.2% (560 Kg) to *Eucalyptus*. Stems were 13.5% in *Eucalyptus* (230 Kg) and 88 Kg (5.3%) in SAF. F,F&S represented 4.4% (74 Kg) of load to SAF and zero to *Eucalyptus*. Bark summed 0.3% to Hortência (2Kg).

To estimate organic nutrients masses, we multiply litter average nutrients concentrations by the loads of allochtonous material as suggested by Barbosa and Coutinho (1987). Thus, crude protein estimation was 115 Kg to SAF and 38 Kg to *Eucalyptus*. The SAF lake received 400% more lipids (46Kg) and 500% more soluble carbohydrates (66Kg) than *Eucalyptus* lake.

Litter decomposition on water

After 90 days of incubation in water, results suggested that SAF has faster decomposition rates. The biomass loss in SAF leaves was equal to 28.6% against 21.2% in *Eucalyptus* leaves. SAF and *Eucalyptus* branches decreased 13.8% and 10% respectively of their original biomass. However, soluble carbohydrates loss was faster in *Eucalyptus* leaves (63%), while SAF leaves lost 33%. *Eucalyptus* branches lost 44% of these compounds, against 26% in SAF. SAF leaves lost 71% of lipids, while *Eucalyptus* leaves lost 63%. In the end of the experiment, SAF branches lost 18% of lipids, while *Eucalyptus* branches increased 6%. Student T test results were significant at $p>0.001$.

SAF leaves crude protein increased 9% and 16% for *Eucalyptus* after 90 days. Crude proteins decreased 71% in the SAF stems and 17% in *Eucalyptus* ones. Polyphenols fade away in SAF branches after 30 days, although 2% still remained in *Eucalyptus* branches after 90 days. *Eucalyptus* and SAF Leaves decreased 97 and 96% respectively of original amount of polyphenols.

Table 3. Load (mass in Kg - dry weight) and nutrients (%) content of allochtonous material to the Lake Hortência and Pedra. Figures between brackets represent the percentage of each fraction in total. SC: Soluble Carbohydrates (%). L: Lipids (%); CP: Crude Protein. TN: Total nutrients (kg). TM: total mass (kg). (Carga (massa em kg – peso seco) e conteúdo de nutrients (%) de material alóctone para os lagos Hortência e Pedra. Valores entre parênteses representam a porcentagem de cada fração sobre o total. SC: Carboidratos Solóveis (%); L: Lipídios (%); CP: Proteína Bruta; TN: Nutrientes totais (kg); TM: massa total (kg))

		Fractions				
		leaves	stems	F,F&S	bark	TM
Lake Pedra SAF	mass	1366 (81.8%)	230 (13.8%)	74 (4.4%)	0	1670
	SC	59	6	1	0	66
	L	43	2	1	0	46
	CP	97	13	5	0	115
	TN	199	21	7	0	227
Lake Hortência *Eucalyptus*	mass	560 (82.3%)	88 (13.5%)	0	2 (0.3%)	650
	SC	18	4	0	0.1	22
	L	14.1	0.7	0	0.02	15
	CP	36	2	0	0.1	38
	TN	68.1	6.7	0	0.2	75

A correlation analysis (ZAR, 1995), between the ratio nutrients: polyphenols optical density, mass and nutrients along the incubation period reveled a significant negative value ($p < 0.05$) of r between the ratio for leaves of SAF and the mass loss of this fraction (-0.97); similarly it was recorded a negative value between the ratio % crude-protein: optical density units for the leaves of *Eucalyptus* and their content of soluble carbohydrates (-0.99) and lipids (-0.95). For the stems of *Eucalyptus*, r value was –0.99, indicating the greater the ratio % crude-protein: optical density units the lower the mass and the concentration of soluble carbohydrates in this fraction.

The polynomial model reproduces better the original lost of biomass and organic compounds (Table 4). Polyphenols results appear to indicate that the y = axb representation is more accurate.

Equations imply that all fractions losing of substances occurred faster from day 1 to 3rd. SAF litter showed the fastest loss. In the first 24 hours, leaves loss rates was 0.205 (SAF) and 0.124 g day^{-1} (*Eucalyptus*). Branches loss rates were 0.239 g day^{-1} (SAF) and 0.048 g day^{-1} (*Eucalyptus*). In day 3, leaves loss rates were 0.115 g day^{-1} (SAF) and 0.054 g day^{-1} (*Eucalyptus*), while branches lost 0.092 g day^{-1} (SAF) and 0.017 g day^{-1} (*Eucalyptus*). Along the rest of the incubation period, loss rates for SAF leaves decreased from 0.071 g day^{-1} (7th day) to 0.007 g day^{-1} (90th day). The mass of *Eucalyptus* leaves demonstrated a distinct pattern, decreasing between the 7th day (0.025 g day^{-1}) and the 30th day (0.012 g day^{-1}), increasing after the 60th day of incubation (0.020 g day^{-1}) and reaching 0.029 g day^{-1} in 90th day. It suggests the removal of some decomposition retardants for *Eucalyptus* leaves between the 30th and 60th days. In 90th day, rates of biomass loss for SAF stems (0.015 g day^{-1}) and *Eucalyptus* (0.20 g day^{-1}) were higher than the reported at 60 days (0.02 g day^{-1} and 0.012 g day^{-1}, respectively), and after 30 days, this rate was negative for SAF stems (-0.07 g day^{-1}), very likely a result of microbial colonization (BARBOSA and COUTINHO, 1987; GRATTAN and SUBERKROPP, 2001) remaining positive (0.05 g day^{-1}) for *Eucalyptus*.

Loss rates for carbohydrates in SAF leaves were: 0.256 % day^{-1} at the 1st day incubation, 0.197% day^{-1} at the 3rd day, and 0.115 % day^{-1} at the 7th day. These rates were followed by *Eucalyptus* leaves (0.185, 0.101, 0.061 % day^{-1}) and stems of SAF (0.130, 0.046, 0.022 % day^{-1}). Similarly, lipids faster loss rates were for leaves from SAF

Table 4. Decaying equations (dry weight) for leaves and steams: mass lost (MS) of *Eucalyptus* (EC) and (SAF); soluble carbohydrates (SC); crude protein (CP), lipids (L) and poliphenols (Pol). Significant r² are $p < 0.05$(*), $p < 0.01$(**) and $p < 0.001$(***). t = time (days). (Equações de decaimento (peso seco) para folhas e galhos: perda de massa (MS) de *Eucalyptus* (EC) e (SAF); carboidratos solúveis (SC); proteína bruta (CP); lipídios (L) e polifenóis (Pol). Valores de r² são significativos para $p < 0.05$ (*); $p < 0,01$(**) e $p < 0,001$(***). t = tempo (dias))

			Equation	r²
Leaves	MS	EC	$\hat{y} = 9.9783 + 0.0625t - 0.0051t^{1.5} - 0.3588\ t^{0.5}$	0.99***
	MS	SAF	$\hat{y} = 10.0287 + 0.0070t + 0.0006t^{1.5} - 0.4266t^{0.5}$	0.99***
	SC	EC	$\hat{y} = 4.4959 + 0.0615t - 0.0040t^{1.5} - 0.5182t^{0.5}$	0.97**
	SC	SAF	$\hat{y} = 5.9645 - 0.2257t + 0.0327t^{1.5} - 0.0001t^{2.5}$	0.91*
	CP	EC	$\hat{y} = 6.7745 + 3.955t^2 \ln(t)$	0.72*
	CP	SAF	$\hat{y} = 7.6968 - 0.5869t + 0.0174t^2 - 0.0013t^{2.5} + 1.5845t^{0.5}$	0.96*
	L	EC	$\hat{y} = 0.39 - 0.0073t + 3.6107\ .\ 10\text{-}06\ t^3 - 1.719e^t + 0.3184e^{-t}$	0.97*
	L	SAF	$\hat{y} = 2.0675 - 0.0155t + ct3 - 1.966et + 1.1516e\text{-}t$	0.97*
	Pol.	EC	$\hat{y} = 1.1562t - 0.1154$	0.99***
	Pol.	SAF	$\hat{y} = 0.7872t - 0.0987$	0.99***
Stems	MS	EC	$\hat{y} = 10.025 + 0.0389t - 0.0035t^{1.5} - 0.1632t^{0.5}$	0.96**
	MS	SAF	$\hat{y} = 9.8441 + 0.1417t - 0.0082t^{1.5} - 0.7359t^{0.5}$	0.88*
	SC	EC	$\hat{y} = 2.8032 + 0.2849t - 0.1403t^{1.5} + 0.0169t2 - 6.0878t^3$	0.93*
	SC	SAF	$\hat{y} = 2.1571 - 0.2718t + 0.0173t^{1.5}\ 1.124t^{0.5} + 2.0397e^{-t}$	0.91*
	CP	EC	$\hat{y} = 2.0472 + 0.0565t - 0.0370t^{1.5} + 0.0051t^2 - 2.0825t^3$	0.90*
	CP	SAF	$\hat{y} = 6.3618 - 1.0635t + 0.319t^{1.5} - 0.027t^2 + 5.204.\ 10^{-5}t^3$	0.96*
	L	EC	$\hat{y} = 0.9667 + 0.0816t - 0.0183t^{1.5} + 1.733t^3 - 3.35.\ 10^{-39}\ e^t$	0.96*
	L	SAF	$\hat{y} = 2.697 - 0.049t + 0.008t^{1.5} - 5.66.\ 10^{-06}\ t^3 + 9.9.\ 10^{-40}e^t$	0.91*
	Pol	EC	$\hat{y} = 0.4743t - 0.1014$	0.99***
	Pol	SAF	$\hat{y} = 0.2790 + 0.965t - 0.1459t^2 + 0.0058t^3$	0.99***

in the first 24 hours (0.262 % day^{-1}), *Eucalyptus* leaves (0.070 % day^{-1}) and SAF stems (0.047 % day^{-1}). After three days the rates were: 0.191 % day^{-1} for SAF, 0.037 % day^{-1} for *Eucalyptus* leaves, and 0.022 % day^{-1} for SAF stems. Thin branches from *Eucalyptus* showed negative rates for soluble carbohydrates at the first day (-0.123 % day^{-1}), -0.019 % day^{-1} at the 3rd day and –0.027 % day^{-1} after 60 days. Lipids loss rates were similar with along the incubation period (-0.062 % day^{-1} at first day, -0.039 % day^{-1} at 3rd day, -0.009 % day^{-1} at 7th day, and –0.020 % day^{-1} at the 60th day), indicating "gains" of these compounds in stems. In the end of the experiment, loss rates of soluble carbohydrates were positive for *Eucalyptus* leaves (0.040 % day^{-1}) and thin branches (0.123 % day^{-1}), while SAF leaves (-0.073 % day^{-1}), and thin branches (0.036 % day^{-1}) was negative (= gains). Also, lipids loss rates at the end of experiment were positive for *Eucalyptus* leaves (0.045 % day^{-1}) and thin branches (0.051 % day^{-1}) being however very low or even negative for SAF leaves (0.002 % day^{-1}) and stems (-0.001 % day^{-1}).

In the end of incubation, all fractions showed positive values of crude proteins with leaves and stems from SAF loosing crude proteins faster than *Eucalyptus*. After 24 hours SAF leaves plus leaves and thin branches of *Eucalyptus* increased their crude protein contents: -0.237 % day^{-1}, -0.05 % day^{-1}, and - 0.086 % day^{-1}, respectively for SAF leaves, leaves and thin branches of *Eucalyptus*. Only thin branches from SAF lost crude-protein in the first 24 hours (0.555 % day^{-1}). Decaying for this portion were: 0.409 % day^{-1} (3rd day), 0.206 % day^{-1} (7th day), -0.013 % day^{-1} (15th day), -0.101 % day^{-1} (30th day), increasing of 0.078 % day^{-1}, near the end of incubation (60th day). Thin branches of *Eucalyptus* rates were positive between the 3rd (0.006 % day^{-1}) and the 30th day (0.001 % day^{-1}) reaching the limit at the 15th day (0.020 % day^{-1}). *Eucalyptus* leaves showed gain of crude-proteins in the 3rd day (-0.055 % day^{-1}), 7th day (-0.015 % day^{-1}), and 60th day (-0.50 % day^{-1}). Crude-protein leaching from SAF leaves were recorded from the 3rd day (0.042 % day^{-1}) increased at the 7th day (0.106 % day^{-1}) and decreased afterwards. At the end experiment the loss of crude-protein was equal to 0.215% day^{-1}. Polyphenols fate in the first 24 hours move along this way: 0.984 ODU day^{-1} (SAF leaves); 0.421 ODU day^{-1} (*Eucalyptus* branches) 0.214 ODU day^{-1} (SAF branches) and, 0.191 ODU day^{-1} (*Eucalyptus* leaves). All fractions had an exponential mass and nutrients shrink until the 30th day. Afterwards polyphenols values occur to be very low.

DISCUSSION

Litter production

Although Lima (1993) claims that leaves may represent 60-80% of total litter of *Eucalyptus*, the present results showed that thin branches can represent up to 56 % of total litter, even surpassing leaves, which accounted for only 39%. It matches well to Pressland (1982) findings, with leaves being 49% of total litter in a native Australian *Eucalyptus* forest. Litter composition of SAF was similar to other 20 years old SAF inside Rio Doce State Park which leaves were 79.2% and thin branches 17.8% (BARBOSA and COUTINHO, 1987).

Differences between SAF and *Eucalyptus* litter are likely due to the difference in forest types. Lugo (1992) extensive revision, suggests that young tropical secondary forests in tropics bend over the greater part of primary production to litter production instead wood accumulation. Conversely, cultivate *Eucalyptus* is selected to drive primary production for wood accumulation (IIDE, 1996). Thoranisorn *et al*. (1991) reports that some young *Eucalyptus* species hold 82% of above ground biomass on to trunks, along with an intense thin branches fall as the trees are growing.

The absence of litter production in February 1993 was a possible consequence of variation in soil water content. Jordan (1985) sustains that in tropical areas with well marked dry season some trees increase litter fall as soil water declines. The same is recorded to natural *Eucalyptus* forests in Australia, which exhibits peaks of litter fall in periods of low soil water content (PRESSLAND,1982).

The *Eucalyptus* F,F&S summed 1% against 5% in SAF. Ashton (1975) and Hatch (1955) cited in Pressland (1982), recorded 0.6% and 15% in natural *Eucalyptus* forests, respectively. Pressland (1982) finds for F,F&S between 2 and 5% in the same forests. SAF value was higher than Barbosa and Coutinho (1987) results (3%), but lower than Morellato (1992) (11%) and Veneklaas (1991) (9.4-6.3%). These results lack a satisfactory explanation, but flowering, fructification and seeds are complex interaction between plant reproduction strategy, day length, temperature, soil water, plant hormones, and pollinators availability, as well (RICKEFLS and MILLER, 2000).

Chemical composition of the litter

The absence of significant differences between dry and rainy periods for the levels of nutrients was demonstrated previously for the litter nitrogen content of a secondary forest (PAGANO, 1989). Jordan (1985) suggests that high temperature and humidity along the year guarantee a continuous nitrogen fixation within tropical forests.

As reported by Lima (1987), nitrogen concentration among distinct *Eucalyptus* fractions seems to be consistently lower than the observed in natural forests, particularly in the stems. Besides, Barbosa *et al.* (1982) recorded higher levels of crude proteins, lipids and soluble carbohydrates in the litter from secondary forest of the Rio Doce State Park than the present data for crude proteins in leaves (12.4%), stems (9.35%) fruits and seeds (12.3%). These authors also calculated higher levels of polyphenols (3.9 ODU g^{-1}) for leaves and lower ones (2.3 ODU g1) for stems than the present results. Leaves and stems of *Eucalyptus* litter showed polyphenols levels 450% higher than recorded for the same fractions from SAF. Literature mentions higher concentrations of polyphenols in *Eucalyptus*. Kirkby and Buckerfield (1975) recorded, for the leaves from 20 species, concentrations between 3.03 and 16.53 % dry weight. Other study (BARBOSA *et al.*, 1982) measured lower polyphenols values: 1.27 and 0.53 ODU.g^{-1} for SAF leaves and stems, respectively. Polyphenols seems to be an evolutionary response of *Eucalyptus* to herbivore pressure in Australia. Conversely, in Neotropical forests, levels of secondary products, like polyphenols tend to decrease as succession proceeds. However, *Eucalyptus* seems to keep high levels of polyphenols all along its life (BEGON *et al.*, 1996; RICKEFLS and MILLER, 2000).

Allocthonous material as organic carbon source

The role of allochtonous sources to the metabolism of lakes are well demonstrated by Barbosa and Coutinho (1987), which verified that it represented 0.68 g C m^{-2} day^{-1} in lake Carioca (Rio Doce State Park), against a daily phytoplankton production of 0.3 g C m^{-2} day^{-1} in the dry season. Similarly, Hall *et al.*, (2001) verified that thin branches and bark represented 62% of the energy entering in a stream in Australia. Mathuriau and Chauvet (2002) propose that 98% of organic carbon in a small intermittent Colombian stream come from litter, in the pools formed during droughts.

Litter processing is affected by temperature, nutrients content, secondary products, water chemistry, dissolved oxygen and shredder abundance. Fungi appear to be a very important group in decomposition (GEHRKE *et al.*, 1993; GRAÇA *et al.*, 2001). Decomposition experiments in water using several litter types suggest a positive correlation between incubation time and the concentration of organic nitrogen, associated with microbial colonization (GOSZ *et al.*, 1973; SUBERKROPP *et al.*, 1976; BARBOSA and COUTINHO, 1987; PETERSEN *et al.*, 1989). Also, higher the dissolved nitrogen in water, faster seems to be the litter colonization by fungi and bacteria (GRATTAN and SUBERKROPP, 2001). Sabará, (1994) found more dissolved nitrogen in SAF Lake and a dominance of Cyanophyta which could speed up SAF litter decomposition. For Robarts (1986) and Aumen *et al.*, (1990) decomposition of stems and wood debris in water is often delayed by the lower specific area, content of lignin and oxygen inside the material. Also, higher polyphenols concentration on *Eucalyptus* litter may well retard colonization by N fixing organisms like Cyanophyta.

Among the major classes of organic compounds of plant litter, only phenolic compounds are know by their powerful toxic properties and solubility in water. Along with the 22 phenolic compounds known for *Eucalyptus* leaves, 10 are toxic soluble in water such as galic acid found in *Eucalyptus* litter in California (GEHRKE *et al.*, 1993). The availability of proteins in leaves can be better expressed like a ratio protein:polyphenols and thus, the higher this ratio, the higher the palatability and hence the biological degradation rate (EDWARDS and WRATTEN,1981). Lower correlation between the incubation time of the fractions and the soluble carbohydrate content in the leaves of *Carya claba* and *Quercus alba* was connected to complex molecules formation with polyphenols. For lipids, some authors pointed out that the high complexity of the generically named ´lipids´ is the responsible for the constancy and low processing rate of leaves of six species in a mixed temperate forest (Krumholz, 1972, cited by SUBERKOPP *et al.*, 1976; GRATTAN and SUBERKROPP, 2001).

The acceleration of polyphenols decaying can be explained as a sequence in decomposition of plant material in water: Step 1 is the mechanical leaching of the soluble compounds to be incorporated in the organic dissolved carbon pool. More resistant compounds need bacterial colonization to decay (Step 2). In Step 3 N fixing organisms can become attached resulting in a N increase on litter (ROBARTS, 1986, CEBRIAN, 1999; GRATTAN and SUBERKROPP, 2001, MATHURIAU and CHAUVET, 2002).

CONCLUSIONS

Mass loss rates along the incubation time showed significant differences ($p < 0.01$) according to the decreasing sequence: SAF leaves > leaves of *Eucalyptus* > SAF stems > stems of *Eucalyptus*. These results suggest that *Eucalyptus* is a poor source of allochtonous material to water environments, in both qualitative and quantitative ways, due its lesser litter production and the dominance of stems, which has an inferior nutritional value. Comparatively, the SAF litter gave 5 times more nutrients to the lake. In addition *Eucalyptus* fractions had slower decomposition rates in water. In face of it, the replacement of native vegetation on Lake Hortência catchment by *Eucalyptus* resulted in less nutrients availability with potentially effects to the lake metabolism.

Some years after this study, recommended Best Management Practices (BMP) expand the riparian "belt" of terrestrial vegetation width to at least 100 m from the margins, with a new road constructed further up at the catchment. It is the expected environmental mitigation from these BMP recommendations on observed differences among both quantity and quality of allochtonous material.

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