Nutrient input through litter in riparian forest in different stages of ecological succession

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Abstract

This study was carried out from September 2008 to August 2009 and aimed to quantify the production, decomposition and the annual nutrient input from litter in a riparian zone in different stages of development and on different soils (Oxisol and Ultisol), within a representative plot of semideciduous mesophytic forest vegetation. Total litter produced in old and recent riparian forests on Oxisol was, respectively, 10.5 ton/ha/yr and 13.6 ton/ha/yr, while on Ultisol was 10.1 ton/ha/yr in old forest and 11.1 ton/ha/yr. The average time of renewal of forest litter in recent and in old forest was estimated at 0.77 yr and 0.57 yr. The amount of nutrients contributed by litter varied according to the total mass of litter produced, higher in recent forests. The concentration of macro and micronutrients contributed by litter showed the following order: Ca> N> K> Mg> P> S and Fe> Mn> Zn> B> Cu. The results indicated the important and significant role played by riparian forests in the cycling of nutrients and in restoration of soil fertility, conducting to the equilibrium and sustainability of the natural ecosystems.

Key Words

Soil fertility, soil chemistry, nutrient cycling, riparian forest, litter, rehabilitation of degraded areas.

Introduction

Riparian forests have important hydrological functions, such as protection of the riparian zone, sediment filtering, attenuation of xenobiotic molecules present in the flow from the surrounding agroecosystems, minimization of siltation, and control temperature of the aquatic ecosystem (Lima 1989, Martins 2001). The litter is particularly important for acting on the soil surface as a system of nutrient cycling, accumulating vegetal material that decompose and supply the soil and roots with nutrients and organic matter, which is essential in restoring soil fertility in degraded areas (Ewel 1976). The objectives of this experiment were to evaluate the rate of production and decomposition of litter from riparian vegetation in different stages of ecological succession, and estimate the annual nutrient input through litter.

Methods

Study areas

The study was conducted in two tracts of riparian ecosystems of 2 ha each, composed of two populations of semideciduous mesophytic forest, and an agroecosystem cultivated with sugar cane, which concentrically bordering the dam of Santa Lucia sugar mill, located in the São Paulo state, Brazil (22º18'00"S and 47º23'03" W, altitude 611 m). The forested areas differ in age [9 (recent forest - RF) and 18 years (old forest - OF)] and in soil type [Typic Hapludox (TH) and Arenic Hapludult (AH)], constituting four treatments (Figure 1).

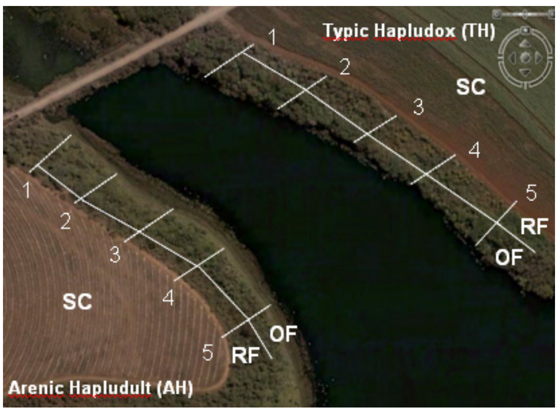

Figure 1. Representation of the transects in the experimental area (OF - old forest; RF - recent forest; SC - sugar cane) (Google Earth).

The climate is CWA (Köppen), i.e., mesothermal with hot and rainy summers and cold and dry winters. The average annual temperature is 21.4 º C and annual rainfall is 1448.8 mm (Brasil 1992).

Experimental characterization

For soil chemical and physical characterization, topsoil (0-0.2 m) and subsoil (0.2-0.4 m) samples were collected along five transects (Camargo *et al.* 1986; Raij *et al.* 2001) (Figure 1). The experimental area was divided into 20 plots of 100 m^2 (20 x 5 m) each (10 plots on the TH and 10 plots on the AH). In each plot were installed two circular collectors (0.5 m^2) for trapping litterfall at intervals of 30 days. The nutrient input from litter was estimated for macronutrients (N, P, K, Ca, Mg, S) and micronutrients (B, Cu, Fe, Mn, Zn) by the relationship between the biomass of total litter produced and the nutrient amount transferred by the biomass. The results were submitted to analysis of variance and differences between means determined by Tukey test at 5% level of probability. The rate of litter decomposition was estimated by the equation $K = L/X$, where K = decomposition coefficient, L = annual litter production, and X = average annual accumulated litter. The time required for decomposition of 50% of the litter (half life – $T_{0.5}$) was estimated by the equation $T_{0.5} = -\ln 0.5/K$. The average time needed to renew the stock of litter was obtained by the equation $tR = 1/K$ (Shanks and Olson 1961; Olson 1963).

Results

Calcium contents were highest in TH, decreasing from old to recent forest, but were low in both depth of AH. Phosphorus concentrations in the topsoil samples were probably due to the deposition, cycling and mineralization of organic matter, and were considered suitable for old and recent forests on the TH, but insufficient at the AH margin, where a less exuberant forest was observed. In general, micronutrients contents decreased from old to recent forest. With the exception of Zn in HA, no deficiency of micronutrients was verified (Table 1).

Table 1. Selected chemical attributes of topsoil and subsoil samples of Typic Hapludox (TH) and Arenic Hapludult (AH) collected under riparian forests.

Area	Depth (m)	P (mg/dm^3)	OM (g/dm^3)	pH ($CaCl_2$)	K	Ca	Mg	H+Al	Al	SB	CEC	V (%)	S	B	Cu	Fe	Mn	Zn
					(--------------mmol$_c$/dm^3						-------------)		(----------mg/dm^3					----------)
					Typic Hapludox (TH)													
OF	0-0.2	6.0	33.8	5.2	3.2	35.0	13.2	35.0	0.7	51.4	86.4	59.4	8.4	0.4	5.2	28.4	53.6	1.9
	0.2-0.4	3.6	25.6	5.0	2.3	26.0	10.4	37.0	1.0	38.7	75.7	50.8	5.8	0.3	4.8	23.6	53.8	1.1
RF	0-0.2	12.4	25.2	5.0	2.2	25.0	8.2	42.2	1.5	35.4	77.6	46.3	8.2	0.2	4.4	17.0	49.4	1.1
	0.2-0.4	6.0	20.8	4.9	0.9	20.8	5.0	41.4	1.6	26.7	68.1	39.5	11.8	0.1	3.6	13.6	38.2	0.6
					Arenic Hapludult (AH)													
OF	0-0.2	4.3	24.9	4.7	3.8	19.3	9.4	33.9	2.3	32.5	66.4	48.5	9.7	0.7	2.1	63.8	42.3	1.7
	0.2-0.4	1.3	11.1	4.6	1.9	16.3	6.2	33.3	2.7	24.4	57.7	40.7	9.0	0.3	1.5	30.9	34.2	0.5
RF	0-0.2	5.0	16.3	4.6	3.2	16.6	5.4	35.1	5.6	25.2	60.3	40.9	15.1	0.4	2.1	42.8	20.9	0.5
	0.2-0.4	2.5	11.2	4.4	2.0	15.2	5.1	44.4	9.6	22.3	66.7	34.7	18.7	0.5	1.6	30.5	27.1	0.4

OF – old forest; RF – recent forest; OM – organic matter; SB – sum of bases; CEC – cation exchange capacity; V - level of base saturation

Clay contents varied from 140 g/kg (AH) to 565 g/kg (TH). The amount of soil organic matter (SOM) decreased in depth in all treatments and varied from 11.1 g dm^{-3} to 33.8 g dm^{-3} (Table 1). For 30 non-cultivated topsoil samples collected in areas of native vegetation, Soares and Alleoni (2008) obtained a wide range of SOM from 6.6 g/kg to 213.4 g/kg, while Bayer and Mielniczuk (1997) verified that SOM content of an Ultisol was reduced from 31 g/kg to 18 g/kg due to successive cultivations. Both reduction in the cultivation intensity and forest development are contributing for organic matter addition through litter. The old forest showed higher levels of organic matter than recent forest, pointing to greater equilibrium of old forest in relation to the stability of organic matter and nutrient cycling. Concomitantly, the cation exchange capacity (CEC) under continuous cultivation usually decreases with time due to the reduction of topsoil organic matter (Sanchez *et al.* 1983; Cerri *et al.* 1991). This was evident in the topsoil and subsoil samples from the TH and AH, which showed decrease of CEC values from the old to the recent forest in both layers (0-0.2 m and 0.2-0.4 m). Both SOM and CEC are useful indicators for soil quality and sustainable land management. The mean contribution (per gram) of the SOM for the soil CEC is 1.64 mmol$_c$, i.e., 44 times

higher than the contribution of the clay fraction (Soares and Alleoni 2008). The increase of SOM was an important indicative of soil fertility recovery and land restoration. The total litter produced in old and recent riparian forests on TH was, respectively, 10.5 ton/ha/yr and 13.6 ton/ha/yr, with significant statistical difference. No significant statistical difference was observed for total litter produced by different forests on AH (10.1 ton/ha/yr in old forest and 11.1 ton/ha/yr in recent forest). Tropical forests have continued production of litter throughout the year, and the quantity produced at different times depends on the type of vegetation considered (Leitão-Filho 1993). More disturbed areas have very large number of pioneer species, with fast growing, short cycle and higher nutritional requirements, investing heavily in biomass production in a short time. On the other hand, the less modified areas have a higher number of climax species, with lower production of biomass and nutrients requirement (Martins and Rodrigues 1999). Thus, differences in litterfall between near sites may be related to different degrees of disturbance that are found within the same forest type (Werneck *et al.* 2001). It is believed that the metabolic activity of plants in recent forests is higher than in the old forest, due to lower floristic age which would allow greater biomass production.
Generally, significant statistical difference was verified for N, S and Ca inputs through litter in old and recent riparian forest with respect to soil type, due to the higher vegetal biomass of the forests established on the TH (Table 2).

Table 2. Macronutrients annual inputs (kg/ha) through litter of riparian forests.

Soil	N		P		K		Ca		Mg		S	
	OF	RF	OF	RF	OF	RF	OF	RF	OF	RF	OF	RF
TH	188.7 Aa	278.0 Ba	13.4 Aa	15.5 Aa	27.8 Ba	43.9 Aa	215.8 Ba	265.2 Aa	20.7 Ba	31.4 Aa	13.9 Ba	18.5 Aa
AH	159.6 Bb	183.9 Ab	11.4 Aa	12.9 Aa	34.2 Aa	39.5 Aa	164.6 Bb	219.8 Ab	24.7 Ba	30.5 Aa	11.0 Aa	13.5 Ab

TH – Typic Hapludox; AH – Arenic Hapludult; OF – old forest; RF – recent forest
Different capital letters in the line for the same nutrient indicate statistical differences according to Tukey test (p<0.05)
Different lowercase letters in the column for the same riparian forest indicate statistical differences according to Tukey test (p<0.05)

The concentration of nutrients contributed by litter followed the order: Ca> N> K> Mg> P> S. Morellato (1992) observed an annual addition through litter of 206 kg N/ha, 11.2 kg P/ha, 37.8 kg K/ha, 269.2 kg Ca/ha and 29.9 kg Mg/ha. In our experiment, we obtained the following range of N, P, K, Ca and Mg, consecutively: 159-278; 11.4-15.5; 27.8-43.9; 164.6-265.2 and 20.7-30.5 kg/ha /yr (Table 2).
For micronutrients, significant statistical difference was verified for Fe and Mn inputs through litter in old and recent riparian forest with respect to soil type (Table 3).

Table 3. Micronutrients annual inputs (kg/ha) through litter of riparian forests.

Soil	B		Cu		Fe		Mn		Zn	
	OF	RF	OF	RF	OF	RF	OF	RF	OF	RF
TH	0.35 Ba	0.47 Aa	0.28 Aa	0.28 Aa	106.1 Aa	84.2 Ba	1.76 Ba	2.32 Aa	0.50 Aa	0.54 Aa
AH	0.33 Aa	0.34 Aa	0.21 Aa	0.21 Aa	53.8 Bb	77.2 Aa	1.44 Aa	1.43 Ab	0.42 Aa	0.46 Aa

TH – Typic Hapludox; AH – Arenic Hapludult; OF – old forest; RF – recent forest
Different capital letters in the line for the same nutrient indicate statistical differences according to Tukey test (p<0.05)
Different lowercase letters in the column for the same riparian forest indicate statistical differences according to Tukey test (p<0.05)

The concentration of nutrients contributed by litter followed the order: Fe> Mn> Zn> B> Cu.Vital *et al.* (2004) observed annual addition through litter of 18.3 kg Fe/ha, 5.6 kg Mn/ha, 0.33 kg B/ha, 0.22 kg Zn/ha and 0.15 kg Cu/ha. Compared with the study of Vital *et al.* (2004), our results indicated that the inputs of B, Fe, Zn and Cu were higher; whereas Mn was lower (Table 3). It is evident that, in the recent forest, the input of macronutrients and micronutrients through litter was higher than in the old forest; regardless of soil type (Tables 2 and 3). The decomposition coefficient (K) of old forest was lower than of recent forest. In semideciduous mesophytic forest, this parameter ranges from 1.2 to 1.9 (Morellato 1992). The renewal average time of forest litter in recent forest on TH was estimated at 0.53 years, i.e., 193 days. In the recent forests on TH and on AH, the time required for decomposition of 50% of the litter was estimated at 0.37 years and 0.43 years, i.e., 135 days and 157 days, respectively. These values are close to 150 days reported by Vital *et al.* (2004) (Table 4).

The results indicate rapid release and recycling of nutrients by the vegetation. Decomposition rate differences of litter from tropical forests could be attributed to the type of vegetation, quality of material, the soil microbiota activity, and environmental conditions, especially temperature and humidity.

Table 4. Decomposition rate (K), time required for decomposition of 50% of the litter ($T_{0.5}$) and mean litter renewal (tR) for riparian forests.

Soil	K		$T_{0,5}$ (years)		tR (years)	
	OF	RF	OF	RF	OF	RF
TH	1.29	1.89	0.54	0.37	0.78	0.53
AH	1.31	1.63	0.53	0.43	0.76	0.61

TH – Typic Hapludox; AH – Arenic Hapludult; OF – old forest; RF – recent forest

Conclusions

The amount of nutrients contributed by litter varied according to the total mass of litter produced, in higher quantity in the recent forests in comparison with the old forest, regardless soil type. In the recent forests, the cycling of nutrients occurred more quickly. Since in the old forests, this time was larger, providing nutrients more slowly, indicating a better equilibrium and sustainability of the forest. The results indicated the important and significant role played by riparian forests in the nutrients cycling and in soil fertility restoration.

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