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Soil physical, chemical, and biological properties under soybeans and in an adjacent rainforest in Amazonia[1].

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ABSTRACT: Land use change in the Amazon basin has occurred at an accelerated pace during the last decade, and it is important that the effects on the soil resource induced by these changes are explained. This study investigated soil chemical, physical, and biological properties in a field under cultivation of soy and rice, and an adjacent primary rain forest. Increases in soil bulk density, exchangeable cations, and pH were found in the soy field soil. In the primary forest, soil microbial biomass and basal respiration rates were higher, and the microbial community was metabolically more efficient (a lower metabolic quotient). The sum of basal respiration across the A, AB and BA horizons on a mass per area basis ranged from 7.31 to 10.05 Mg CO_2-C $ha^{-1}.yr^{-1}$, thus yielding estimates for total soil respiration between 9.6 and 15.5 Mg CO_2-C $ha^{-1}.yr^{-1}$ across sites and seasons, estimates that are in very good agreement with values in the literature for Amazonian ecosystems. The estimates of heterotrophic respiration made in this study help to further constrain the estimates of autotrophic soil respiration and will be important in determining effects of future land-use and climate change in Amazonian ecosystems.

Index terms: Amazon, Soil heterotrophic respiration, primary forest.

INTRODUCTION

During the last decade the agricultural frontier in the Amazon has progressively migrated northward away from the crescent of deforestation that arches across the south and southeastern portion of the Amazon basin.

The area under intensive mechanized agriculture in the Brazilian Legal Amazon increased by > 3.6 million ha during 2001-2004, with 87% of this growth in the State of Mato Grosso (Morton et al., 2006). Soybeans occupy a larger area than any other crop in Brazil, and during the last 10 years Amazonia became the region of Brazil with the largest increase in area under soy cultivation (Costa et al., 2007).

The question that arises, in light of these accelerated land-use changes in the Amazon, is how do edaphic resources change due to differing land uses, and specifically, how does the biological component of the soil respond? It is the microbiological constituent of the soil that is responsible for maintaining nutrient cycling in the soil-plant-atmosphere continuum, and therefore the fertility and sustainability of the system.

The primary objective of this sampling was to compare changes in soil properties between primary forest and adjacent agricultural fields through measurements of soil chemical and physical properties, and measurements of microbial biomass and activity. In addition, through analysis of the basal respiration data, this work aimed to provide an estimate of root and total soil respiration in each of the ecosystems studied.

MATERIAL AND METHODS

This study was conducted in the Tapajós National Forest (TNF) and an adjacent (≈ 2 km) agricultural field (soy field). The region has a mean annual temperature of 25 °C and receives approximately 2000mm of rain per year with a dry season lasting from July to December and is located on an old, nearly flat, erosional remnant plateau. Soils are deep and highly weathered with dominantly clayey texture (>80%). The soil type at both sites is a Typic Haplustox (red-yellow Oxisol).

Sampling in the agricultural field was conducted on the farm called "Fazenda Paraiso" at km 77 of the Santarém-Cuiabá highway. The area in which this sampling was conducted was under *Brachiara brizantha* pasture until November 2001, then was placed under a rotation of upland rice and soybean during the previous 4 years. In general, the fertilization scheme used is 50 kg ha^{-1} of a urea-based fertilizer (8% N, 28% P_2O5, 16% K_2O, 0.3% Zn) and a lime application of 2T.$ha^{-1}.yr^{-1}$.

Soil samples for basal respiration and microbial biomass were taken in November 2006 (dry season) and May of 2007 (wet season) at Fazenda Paraíso and TNF. Samples were taken in the entire interval of each of the A, AB, and BA horizons (see Table 1 for depths) at 10 points in each land use type. At each of the 10 sampling points 4 holes were augured and soil from the same horizon from each of the four auger holes was bulked and thoroughly mixed, and one composite sample was taken from this bulked sample. Basal respiration was measured in the laboratory following the alkali base trap technique outlined in Anderson (1982), and soil microbial biomass was measured using the chloroform fumigation-extraction protocol in Vance et al. (1987) with subsequent analysis of the extracts done using the Walkley-Black wet oxidation method. Ten samples were taken for each procedure and in each season, and the samples were stored at 4°C and laboratory analysis of microbial biomass and basal respiration was conducted the next day.

The microbial biomass and basal respiration data were analyzed using ANOVA with site, season, and horizon as fixed effects. Scheffe's post hoc test was used to separate means, and a probability level of $\alpha = 0.05$ was used for all tests. The microbial biomass and basal soil respiration data were $\log_{10}$ transformed for the ANOVA analysis to correct for slight deviations from normality.

RESULTS E DISCUSSIONS

Soil chemical properties are presented in **table 1** for the TNF and soy field.

Compared to the TNF, the soy field shows large differences in pH, exchangeable cations, and P, differences which are most likely related to liming and fertilization. The TNF soil has a higher concentration of Al in the upper horizons, a difference that is once again an effect of the liming that the soy field receives, which raises the pH. The total carbon to two meters was 129.0 and 151.5 $Mg.ha^{-1}$ in the soy field and TNF, respectively. Total N in the soy field to two meters was 28.1 $Mg.ha^{-1}$, and 15.9 $Mg.ha^{-1}$ in the TNF. The TNF had a higher C:N in all horizons (TNF:12.5 – 8.9 and soy: 8.1 to 3.1, A and BW3 horizons, respectively). There are striking differences in bulk density throughout the profile to 2 meters depth, with the Fazenda soil always having a larger bulk density than the TNF at all depths, with the largest differences in the A, AB, and BA horizons (for example, 0.76 and 1.4 $Mg.m^{-3}$, A horizons in TNF and soy field, respectively).

The microbial biomass data followed a trend of a larger biomass in the TNF, in the all three horizons, and in the wet season, and comparing within a site, the TNF and the soy field had greater biomass values in the wet season than in the dry for all 3 horizons (**Figure 1**). Basal respiration was greater in the TNF than in the soy field only in the A horizon in the wet season, and there were no other significant differences. The mean microbial activity, which was measured as basal respiration in the soil horizons, ranged from to 2.97 to 6.85 µg $CO2-C.g^{-1}.soil\ h^{-1}$ during the sampling period, with a general trend of greater respiration in the superficial horizons in the wet season. The results for the microbial biomass analysis (**Figure 1**) are within the range of data reported from other studies done in Amazonian forests and other land uses. Feigl et al. (1995) reported a range of 890 to 1,100 $\mu gC.g^{-1}$, and Luizão et al. (1992) reported 765 to 1,290 $\mu gC.g^{-1}$. Moreira & Malavolta (2004) found a range of 148 to 708 $\mu gC.g^{-1}$, in primary forest, pastures, and agroforest. Marschner et al. (2002), working in an Amazonian agroforest found between 850 and 1,500 $\mu gC.g^{-1}$ during the rainy season, and between 200 and 350 $\mu gC.g^{-1}$ in the dry season, and Matsuoka et al. (2003) found large decreases in soil organic matter and microbial biomass in soy fields on Oxisols in Mato Grosso.

CONCLUSIONS

1. Compared to nearby primary forest, soil under a soy and rice rotation presented higher pH, exchangeable cations, and bulk density to 2 meters depth.
2. Soil microbial biomass and respiration were greater in primary forest, and the microbial community in the forest demonstrated higher metabolic efficiency.
3. Estimates of total soil respiration values for the forest and soy field based on the heterotrophic respiration values found in this study are within the range of total soil respiration values found in the literature for these ecosystems.

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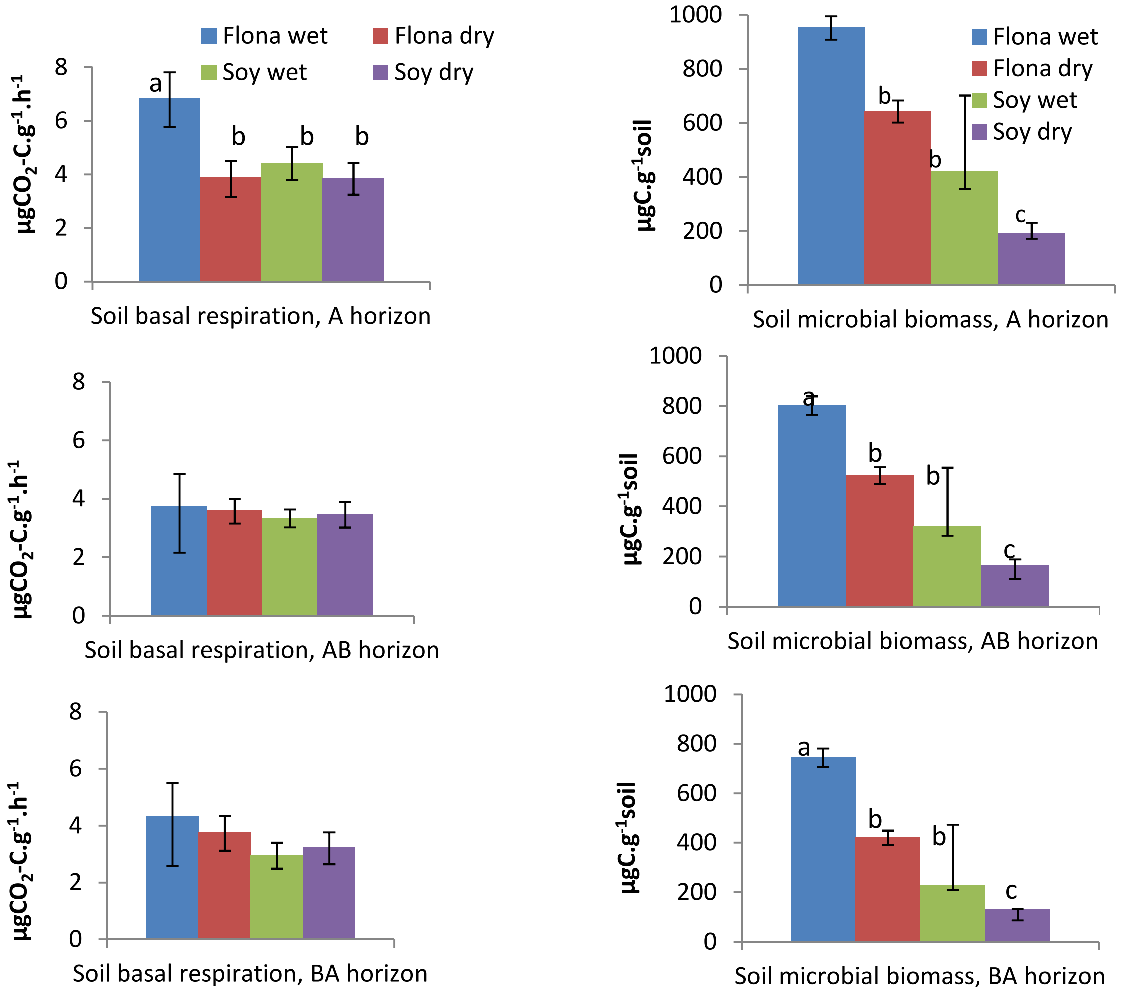

Figura 1 – Soil basal respiration and microbial biomass in primary forest (FLONA) and an agricultural field, in 3 horizons across rainy and dry seasons. Bars are 95% confidence intervals. Different letters indicate significant difference at $\alpha = 0.05$.).

Table 1. Soil chemical properties in the TNF and soy field.

Site	Horizon (cm)	%C	%N	pH	P	K	Na	Ca+Mg	Al
Soy field	Ap (0-10)	1.88	0.23	5.2	28.8	102.0	26.6	2.9	0.4
	AB (10-22)	1.07	0.18	4.7	6.9	55.0	17.1	1.5	1.0
	BA (22-48)	0.70	0.14	4.8	2.1	39.4	12.5	0.9	1.3
	BW1 (48-85)	0.43	0.11	4.6	1.1	19.5	8.8	0.8	1.3
	BW2 (85-163)	0.36	0.09	4.7	1.1	12.8	6.6	0.82	1.2
	BW3 (163-200)	0.22	0.07	4.7	1.0	11.5	6.7	0.87	1.2
TNF	A (0-8)	1.88	0.26	3.2	8	57	25	1.0	3.4
	AB (8-21)	0.71	0.16	3.6	3	22	10	0.2	2.3
	BA (21-48)	0.47	0.11	4.0	1	10	6	0.2	1.7
	BW1 (48-76)	0.26	0.07	3.9	1	8	4	0.2	1.3
	BW2 (76-125)	0.18	0.06	4.0	1	0.2	0.7	0.2	0.8
	BW3 (125-200)	0.11	0.04	4.3	1	6	4	0.2	0.7

P, K, Na = mg.dm-3; Ca + Mg and Al = cmolc.dm-3.