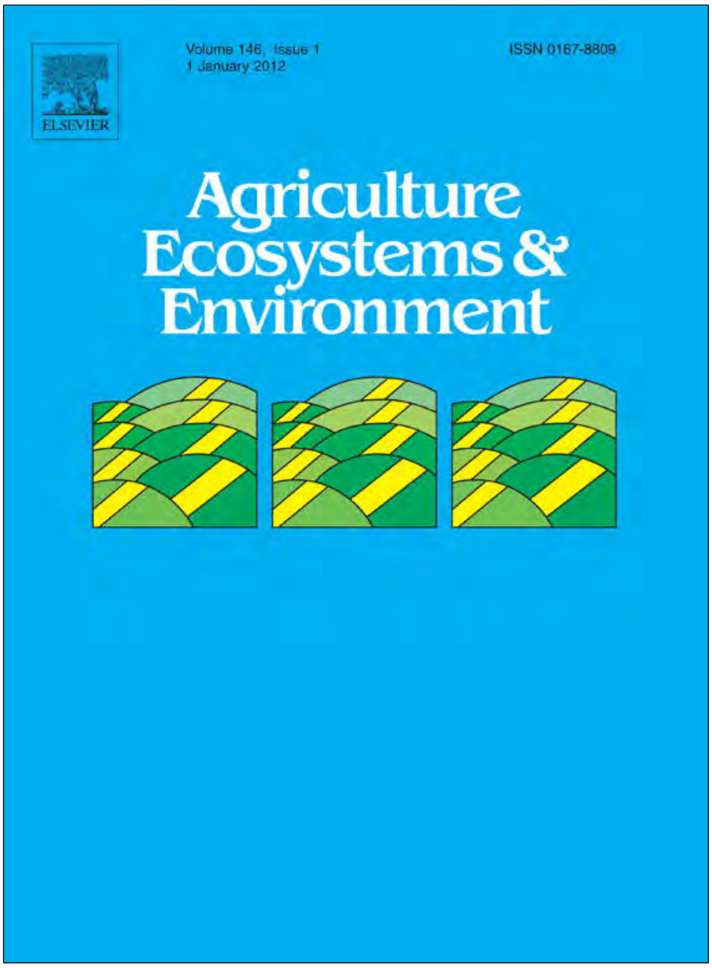
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Effects of sugarcane harvesting with burning on the chemical and microbiological properties of the soil

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ABSTRACT

Soil microbial biomass represents an important and strategic reservoir of plant nutrients that can be quickly altered due to different soil and crop managements. In this context, the aim of this study was to evaluate the influence of sugarcane harvesting systems, with or without burning, on the chemical and biological properties of the soil. The experiment was conducted on a dystrophic red latosol (Oxisol) soil in 2008, in a commercial area of a sugarcane factory in the municipality of Paraguaçu Paulista, São Paulo state, Brazil. The treatments included areas previously burned, areas with mechanical harvesting and no burning and native forest. Soil samples were collected immediately after the sugarcane harvest from the treatments at a depth of 0–20 cm. The parameters evaluated were: microbial biomass C and N (MB-C and MB-N), total organic C (TOC), recalcitrant C (R-C), labile-C (L-C), total nitrogen (TN), pH, exchangeable cations (Ca^{2+} + Mg^{2+} and K^+), exchangeable (Al^{3+}) and potential (H^+ + Al^{3+}) acidity, and P available in the soil. Soil chemical fertility under the sugarcane without burning was better than under sugarcane with burn. The TOC values for native forest and for the harvesting without burn were higher than those under the sugarcane with burn (148% and 54%, respectively). This superiority was also confirmed for TN, L-C and R-C. An even more significant difference was found under natural forest and sugarcane without burn for MB-C, which was 222% higher under native forest and 102% higher under sugarcane without burn than the value under sugarcane with burn, confirming that MB-C could be a reliable indicator of soil quality for monitoring soils under different sugarcane harvesting systems.

1. Introduction

Sugarcane (*Saccharum* spp.) is a native plant of India and is now grown throughout the world in regions between 22°N and S of the Equator. It is considered one of the most important crops grown for its energy value, with a global cultivation area of over 20 million ha in more than 70 countries. Brazil is responsible for around a quarter of global production (FAO, 2010). With the greatest area under sugarcane in the world, it is estimated that in the 2011/2012 season crop 8.37 million ha will be under sugarcane in Brazil, with annual production of 571.5 million metric tons (CONAB, 2012).

The highest producing region in Brazil is the southeast, representing 62% of the planted area in Brazil (with São Paulo state alone accounting for 52% of this total area) and average productivity of 69.8 t ha^{-1}, followed by the northeast, with 13% of total area and average productivity of 60.3 t ha^{-1} (CONAB, 2012).

At present, sugarcane cropping is undergoing a period of intense change in management practices due to the introduction of mechanized harvesting, with no pre-harvest burn. However, sugarcane trash burning, still frequently carried out in most producing regions, has profound impacts, as it destroys the soil organic matter, leaving it exposed to erosion, impacting microorganisms and causing significant pollution. Indeed, impacts of burning may be severe and should be considered in a broader view, i.e., focusing not only on agricultural systems, but also on natural ecosystems such as grasslands and forests (Liu et al., 2007, 2010). Interesting, in a temperate steppe in northern China, in a first moment soil microbial biomass was increased and soil respiration was decreased by burning, but the effects were decreased with time (Liu et al., 2007, 2010). Also in tropical forests and natural grasslands of Brazil, burning may in a first moment stimulate soil microbial biomass, but it decreases later, when the readily available C is depleted (Kaschuk et al., 2010). In the Brazilian Amazon, decreases in soil microbial biomass due to burning can be as high as 80% in a short period (Pfenning et al., 1992).

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In view of this scenario, over the last few years the possible prohibition of sugarcane burning has been discussed. In Brazilian legislation, article 2 of Law no. 11.241/2002, relating to the gradual elimination of trash burning, sets forth a sequence of progressive stages for reducing the practice of burning in areas of more than 150 ha, so that by 2021, the use of sugarcane trash burning will be completely eliminated. On the other hand, in areas of mechanized harvesting of sugarcane without burn, the accumulation of trash on the soil's surface can exceed 20 t ha^{-1} (Negrisoli et al., 2007), creating a thick layer of organic waste.

It is thought that some biological properties of the soil are sensitive to changes when the soil is subjected to different types of management and, therefore, would be better indicators of soil quality. This applies to microbiological evaluations, highly sensitive to any disturbances produced by changes in soil management (Tótola and Chaer, 2002; Kaschuk et al., 2010, 2011). Consistent results have shown that determining soil biomass allows edaphic changes to be evaluated faster than analysis based on the soil's chemical and physical properties, and can be used as an indicator of soil quality (Jenkinson and Ladd, 1981; Powlson et al., 1987; Franchini et al., 2007; Souza et al., 2008a,b; Hungria et al., 2009; Kaschuk et al., 2010, 2011). This also applies to few studies performed so far with sugarcane (Santĭana et al., 2009; Kaschuk et al., 2010)

Despite growing interest in aspects related to the biological functioning of the soil under natural and agricultural systems, studies on the impact of different harvesting systems on soil microbial biomass under sugarcane are a recent phenomenon. Against this backdrop, our study was developed with the aim of assessing the influence of harvesting, with or without trash burning, on the chemical and biological properties of the soil.

2. Material and methods

The experiment was conducted in 2008, in Paraguaçu Paulista, state of São Paulo, Brazil (22°29′S and 50°37′W). The soil is classified as dystrophic red latosol (Oxisol), of medium texture, with smoothly undulating terrain. According to the Köppen classification, the climate is mesothermal subtropical (Cwa), characterized by hot, rainy summers, average temperatures higher than 22 °C, and winters with average temperatures below 18 °C, and clearly defined seasons. Mean altitude is of 470 m and average annual rainfall is 1500 mm (CEPAGRI, 2010).The study was conducted in a commercial area of the sugarcane factory Nova America/COSAN. The area under sugarcane treatments had 15 ha and the remaining area of native forest was of 3 ha. Before being turned over to sugarcane, the area was used for growing maize (*Zea mays* L.), soybean (*Glycine max* (L.) Merr.) and cotton (*Gossypium hirsutum* L.). The area had been cropped to sugarcane (*Saccharum* spp.; sugarcane is named without a defined species because modern commercial varieties are founded on interespecific hybrids between *Saccharum spontaneum* and *Saccharum officinarum*) since 1992, and on each cycle of five to seven slashes, the plantation is overhauled. When the samples used in this study were collected, the plantation was on the third slash, in this year of a variety of *S. officinarum*.

The experimental design was fully randomized, with three treatments and twenty replications. Sugarcane treatments consisted of the harvesting systems with trash burning (sugarcane with burn) and mechanized harvesting without trash burn (sugarcane without burn). The areas have been established with these treatments since 1992, therefore for 17 years, when the samples were taken, in 2008. In the area with burning, sugarcane was burned every year from the second year, therefore 16 times when the soil sampling from this study were taken. The mechanized harvesting without trash burn started after the burning in 2002; therefore, a six-year period without burning was accumulated at the time of soil sampling. The adjacent savanna native forest (NF) was used as a reference for the initial condition of the soil before it was turned over to farming. Areas with or without burning were located side by side, and the remaining native forest was located perpendicular to both areas. Declivity of the area ranged from 3% to a maximum of 8%.

Soil samples were collected immediately after harvesting the sugarcane, at a depth of 0–20 cm. For each treatment a sampling area of 2 km × 2 km was established, with 20 samples randomly collected, and composed of four discrete sub-samples, two from the sugarcane rows and two from the inter-rows. Sampling was performed with the aid of GPS, georeferenced on a regular grid of 20 m × 10 m. We met all the basic principles of experimentation, repetition and randomization; areas under sugarcane were homogeneous, with the same soil type, cultivar of sugarcane, the same weather conditions; they have also received the same amount of fertilizers and pesticides.

Chemical analysis was carried out using the methods described by EMBRAPA (Brazilian Agricultural Research Company) (1997). Based on the analysis results, values were estimated for the sum of bases (SB), cation exchange capacity at pH 7.0 (*T* pH 7.0), base saturation (*V*%), and aluminum saturation (*m*%). To obtain a physical characterization, soil texture was evaluated using the pipette method with organic matter oxidation, according to Tavares Filho and Magalhães (2008).

The fumigation-extraction method (Vance et al., 1987) was used to assess microbial biomass carbon (MB-C) in the soil, and the method developed by Brookes et al. (1985) to analyze microbial biomass nitrogen (MB-N). Levels of MB-N and total N were determined by wet digestion in a digestor at 350 °C with concentrated sulfuric acid (H_2SO_4) (Bremner, 1965), after which the concentration of N was measured using the semi-micro-Kjeldahl method (Feije and Anger, 1972).

Microbial biomass values are expressed in mg C and mg N in the microbial biomass kg^{-1} of dry soil. The microbial quotient (*q*Mic) was also calculated using the formula (MB-C/TOC) × 100 (Anderson and Domsch, 1990).

Labile carbon (L-C) was determined according to the procedure described by Blair et al. (1995). Recalcitrant carbon (R-C) was determined using the difference between TOC and labile C. The results for labile and recalcitrant C are expressed in g kg^{-1}.We met all the basic principles of experimentation, replicates and randomization. Areas were homogeneous in terms of showing the same soil type, cultivar of sugarcane, the same weather conditions and received the same amounts of fertilizers and pesticides. The area under remaining forest was adjacent to the sugarcane areas and also presented the same soil type and weather conditions. The analysis of variance was performed with the SISVAR program and the Tukeyĭs test ($p \leq 0.05$) (Ferreira, 2008).

3. Results and discussion

3.1. Physical and chemical properties

Topography, climatic conditions and soil type were very similar in the areas, therefore soil granulometry was not very different, as follows (g kg^{-1} of clay, silt and sand, respectively, at the 0–20 cm depth): sugarcane with burn (387, 234, 379); sugarcane without burn (372, 243, 385); native forest (379, 239, 383).

In relation to soil chemical properties, the majority of variables analyzed differed according to the harvesting system used (Table 1). Areas under sugarcane without burning exhibited the highest values for pH, P, K, Ca, Mg, sum of bases, base saturation (*V*%) and lower values for potential acidity (H + Al), Al^{3+} and aluminum saturation (*m*%).

Table 1
Chemical properties of dystrophic red latosol (Oxisol) under different sugarcane harvesting systems and native forest (reference), at a depth of 0–20 cm.

Management	pH	P	K^+	Ca^{+2}	Mg^{+2}	H + Al	Al^{3+}	SB	*T*	*V*	*m*
		mg dm^{-3}	cmol$_c$ dm^{-3}							%	
Sugarcane with burn	4.52B[a]	10.17B	0.05B	0.71B	0.21B	3.72B	0.19B	0.97B	4.69B	20.98B	16.38B
Sugarcane without burn	5.13A	17.17A	0.10A	1.27A	0.38A	3.18C	0.10C	1.75A	4.93B	35.20A	5.40C
Native forest	4.01C	5.09C	0.04C	0.44C	0.14B	6.70A	0.55A	0.62C	7.32A	8.47C	47.01A
CV (%)	0.32	28.99	29.10	25.03	29.77	7.05	4.89	21.96	6.98	20.10	20.53

[a] Averages followed by different letters in the columns differed statistically in the Tukey test ($p < 0.05$).

There was no difference in the cation exchange capacity (*T*) for the two sugarcane harvesting systems (with or without burn), but *T* was higher than in the area under native forest, which exhibited the highest values for H + Al, Al^{3+} and *m*%. However, the higher *T* value under native forest is directly related to its high potential acidity (6.70 cmol$_c$ dm^{-3}) and the low soil fertility. The higher P, K, Ca and Mg levels under sugarcane without burn are due to the higher contribution of nutrients from the trash left on the soil (Table 1).

The drop in *T* in the area under sugarcane without burn can be attributed to alterations in levels of organic matter (OM), particularly in areas cultivated for long periods. These results are in agreement with those reported by Corrêa et al. (2001), who also observed that the sugarcane without burn management resulted in increases in pH, P, Ca, Mg, S and *V*%, in comparison with the native forest, but in decreases in OM content, *T*, exchangeable Al and *m*%. According to these authors, the lower OM content in soil under sugarcane without burn is believed to reflect the lower contribution of OM over the years of cultivation, compared to the soil under native forest. A similar pattern was also reported by Casagrande and Dias (1999).

The results of our study are also in agreement with those obtained by Canellas et al. (2003), who observed significant changes and increases in the levels of K, Mg and Ca in areas of sugarcane without burn in comparison with burned sugarcane. The addition of the sugarcane without burn residues could increase the pH, leading to the formation of complex of H and Al with plant residue composts, leaving more Ca, Mg and K free in the soil solution. According to Pavinato and Rosolem (2008), it is usual to observe an increase in the availability of P in the soil with the addition of plant residues, both through the release of P from the residue and by competition among organic compounds for adsorption sites in the soil. For the sugarcane without burn management, the microbial attack of organic residues from the sugarcane could also increase the pH by decarboxylation of organic acids, which consumes protons. Mendonza et al. (2000) also observed higher Mg levels for sugarcane without burn but, in contrast to our study, observed higher levels of P and K for sugarcane with burn. The authors explain that, when the sugarcane trash was burned, although P and K levels were higher, it is possible that, in the long term, soil fertility will drop since the nutrients in the ash are likely to be lost through leaching or erosion, especially in soils with low levels of OM.

The highest levels of total organic carbon (TOC) shown in Table 2 were found under native forest (20.10 g kg^{-1}), followed by the sugarcane without burn (12.48 g kg^{-1}) and the sugarcane with burn (8.10 g kg^{-1}) management. Marchiori and Melo (2000) studying a purple latosol (Oxisol), also observed higher TOC values for native forest and lower values under sugarcane. Turning native forest areas over to agriculture is generally accompanied by a drop in the quantity of OM, which is explained by an increase in the mineralization rate, among other factors, which can have a significant impact on OM levels, and even more drastic results in some ecosystems (Kaschuk et al., 2010, 2011). In the study conducted by Marchiori and Melo (2000), the area under sugarcane exhibited decreases of 41.3% to 49.1% at a depth of 0–10 cm and, in the 10–20 cm layer, the drop was of the order of 23.7% to 35.8%. These values are close to those found in our study, with drops of 37.9% under sugarcane without burn and 59.7% under sugarcane with burn.

In the comparison between the harvesting systems, mechanized harvesting (without burning) on the plantation provided a dense layer of trash over the soil, increasing TOC levels. This could be due to the higher contribution of plant material, to the lower level of tillage and to the non-destruction of plant material and OM by fire. Severe losses of TOC under the cane plantations by comparison with native forest were also reported by Cerri et al. (2010), and given the high plant biomass production capacity of sugarcane cultivation, these losses were attributed to burning.

In a study conducted in Australia by Noble et al. (2003), the authors observed an increase in TOC content from 14.7 g kg^{-1} in treatments with trash burning, to 30.0 g kg^{-1} under sugarcane without burn. In the soils of South Africa, Dominy et al. (2002) also found high levels of TOC under sugarcane without burn (45 g kg^{-1}), whereas under the burned sugarcane, TOC did not exceed 30 g kg^{-1}. Assessing stocks of C and N in soil under different management systems and uses, Rangel and Silva (2007) observed that stocks of TOC were significantly affected by the management system, and those involving no-tillage or minimum tillage exhibited a tendency to store more TOC. Similar results were obtained in a meta-analysis of various trials conducted in Brazil (Kaschuk et al., 2011).

The treatments involving sugarcane without burning and the native forest reference produced significantly different results in terms of labile and recalcitrant C by comparison with the sugarcane with burning. In the sugarcane with burn management, the greatest proportion of the TOC (74%) was readily metabolizable labile C, but for sugarcane without burning this value was of 54%. Under native forest, only 36% of the TOC was labile C. These results indicate that burning results in higher availability of mineralizable and easily-decomposed C. Therefore, greater proportions of recalcitrant C were observed under native forest (64%) and sugarcane without burn (46%) and, according to Loss et al. (2009), it results in the slower release of nutrients with a lower rate of plant residue decomposition and consequently, lower loss of C.

However, in an integrated production system, it would be advantageous to balance the C in the oxidizable fractions, with the same proportions of C distributed between the fractions. Therefore, part of the organic matter would be easily decomposable by mineralization of nutrients and the other part would be more resistant, helping to improve or maintain the physical properties of the soil (Loss et al., 2009).

Mineralization of SOM is responsible for annually converting from 2% to 5% of organic N into mineral N. This process is regulated by soil management and use (D'andréa et al., 2004; Kaschuk et al., 2010, 2011). In our study, the soil TN content was also influenced by the type of management system, with the highest values observed under native forest (3.14 g kg^{-1}), followed by the sugarcane without burn treatment (2.10 g kg^{-1}), and then the sugarcane with burn (1.13 g kg^{-1}). In the soil under native forest, there may have been lower decomposition of organic matter, raising the levels of TN. The higher figures for TOC indicate higher availability of TN, since more than 95% of the TN in the soil is present in organic forms (Camargo et al., 1999). In the area under native forest, the

Table 2
Average values for total organic carbon (TOC), total nitrogen (TN), labile carbon (L-C), recalcitrant carbon (R-C) and C/N ratio in a dystrophic red latosol (Oxisol) under different sugarcane harvesting systems and native forest (reference).

Management	TOC	TN	L-C	R-C	C/N ratio
	g kg^{-1}				
Sugarcane with burn	8.10C[a]	1.13C	6.01C	2.10C	7.20A
Sugarcane without burn	12.48B	2.10B	6.81B	5.66B	5.93C
Native forest	20.10A	3.14A	7.37A	12.73A	6.41B
p Values	0.0000	0.0000	0.0000	0.0000	0.0000
CV (%)	4.14	3.85	5.01	8.67	2.20

[a] Averages followed by different letters in the columns differed statistically in the Tukey test ($p < 0.05$).

source of organic residues in the soil is associated with the natural deposition of plant residues which reach the soil, as well as organic substances from root decomposition. When comparing sugarcane harvesting systems, Canellas et al. (2003) also observed an increase of 47% and 50% at depths of 0–20 cm and 20–40 cm, respectively, in TN levels under sugarcane without burn in comparison to the figures obtained under sugarcane with burn.

The highest C/N ratio figures were obtained under sugarcane with burning. This may be due to accelerated loss of N caused by burning. The figures for the C/N ratio in the areas studied by Canellas et al. (2003) under continuous sugarcane cultivation varied from 7.6 to 10.2 for treatments without addition of vinasse and sugarcane without burn, respectively, and according to the authors, these figures indicate the presence of stable organic matter.

3.2. Microbiological properties

Microbial biomass consists of the living fraction of the OM in the soil and in general contains from 1% to 4% C and 3% to 5% N. It therefore represents a reservoir of plant nutrients, contributing to the processes of organic matter decomposition, and enhancing biological sustainability and ecosystem productivity (Schloter et al., 2003; Ferreira et al., 2007).

First, it is important to point out that the coefficients of variation for carbon and nitrogen in the microbial biomass (MB-C and MB-N) are acceptable and in agreement with the work carried out by Souza et al. (2008a). According to these authors, the maximum acceptable CV for these parameters is 35%. There was a significant difference in MB-C between the treatments evaluated (Table 3), with the native forest exhibiting the highest level (523.79 mg kg^{-1}), sugarcane without burn in second position (328.45 mg kg^{-1}), and the lowest levels in the sugarcane with burn. The levels observed reflect better environmental conditions for the development of the microbial population. According to Kaschuk et al. (2010, 2011), cultivated systems generally exhibit lower levels of MB-C than soils under native vegetation. Under native forest, abundant plant residues provide a substrate for soil microorganisms to accumulate biomass rapidly through the decomposition of residues. The low level of MB-C under the sugarcane with burn can be explained by the high impact and disruption that this system causes to the microbial community, stressing microbial populations as a result of higher swings in temperature, moisture content and aeration.

The results of our study are in agreement with those of Mendonza et al. (2000), who verified that the sugarcane without burn system used for cultivation in a Yellow Podzolic sandy/medium soils in the state of Espírito Santo, Brazil, resulted in an increase in MB-C levels at a depth of 0–20 cm in comparison with the sugarcane with burning. With the additions of sugarcane trash, there is a predominance of carbon immobilized in the microbial biomass, mainly in the top 5 cm.

Our results differed from those reported by Marchiori and Melo (2000), who evaluated the effects of different types of soil management on organic matter and microbial biomass in a red latosol (Oxisol) and obtained higher MB-C figures in soils under sugarcane than under natural forest. According to the authors, this increase in microbial biomass under sugarcane could be due to the intrinsic characteristics of the crop, such as the organic substances generated by the plants cultivated, especially the roots. However, in the great majority of trials conducted, MB-C was found to be higher under native forest, and especially primary forest.

In general, MB-C and MB-N are more sensitive to changes in environmental conditions than the soil chemical and physical properties (Franchini et al., 2007; Souza et al., 2008a,b; Kaschuk et al., 2010, 2011). For instance, in studies comparing different soil management systems, conservationist systems produced significant increases in MB-C and MB-N (D'andréa et al., 2002; Franchini et al., 2007; Hungria et al., 2009; Silva et al., 2010).

The average figures for MB-N varied among the treatments evaluated (Table 3), with higher values under native vegetation and sugarcane without burning, indicating higher immobilization of N under these conditions. N immobilization by microbial biomass is a temporary phenomenon, since as the microorganisms die, it is mineralized and the immobilized nutrients released, which is why microbial biomass is considered an important component of potentially mineralizable N (Perez et al., 2005).

Deforestation and burning plant material cause modifications in soil biological characteristics. Temporary increases have been related in temperate regions (Liu et al., 2007, 2010), but in general, these practices decrease microbial activity (Moreira and Malavolta, 2004; Kaschuk et al., 2010), which was confirmed by the data

Table 3
Average values for microbial biomass carbon (MB-C) and nitrogen (MB-N), microbial quotient (*q*Mic) and C/N ratio of the MB under different sugarcane harvesting systems and native forest (reference).

Management	MB-C	MB-N	*q*Mic	MB-C/MB-N
	mg kg^{-1}		%	
Sugarcane with burn	162.70C[a]	57.80B	2.01B	2.82B
Sugarcane without burn	328.45B	79.45A	2.61A	4.13B
Native forest	523.79A	83.87A	2.64A	6.80A
p Values	0.0000	0.0090	0.0014	0.0001
CV (%)	13.96	25.21	15.90	37.35

[a] Averages followed by different letters in the columns differed statistically in the Tukey test ($p < 0.05$).

obtained in our study for MB-N. Hernández-Hernández and López-Hernández (2002) also reported that, in undisturbed areas in which plant residues were left on the surface, there was a greater concentration of MB-N.

The C/N ratio of the biomass is often used to describe the structure and conditions of the microbial community (Moore et al., 2000). This ratio indicates the potential for N mineralization and alterations in microbial composition, with values above 10 indicating predominance of fungi, and below 10 predominance of bacteria (Campbell et al., 1991; Li et al., 2004).

In our study there were no significant differences in the biomass C/N ratio between the managements with or without burning. However, the soil under native forest exhibited a higher biomass C/N ratio, possibly due to the lower decomposition rate (Table 3). In a study conducted by Moreira and Malavolta (2004) on a soil subjected to a succession of plant covers and management systems in Western Amazonia, the primary forest also exhibited a higher biomass C/N ratio and similar results are available in literature.

The microbial quotient (*q*Mic, MB-C/TOC) expresses the efficiency of the microbial community in immobilizing C in organic residues in the soil (Sparling, 1992; Gama-Rodrigues et al., 2008a). Furthermore, it indicates how much of the microbial biomass represents a labile reservoir in the dynamics of the organic matter (Gama-Rodrigues et al., 2008b), and this is why it is used to relate microbial biomass to the availability of organic C in the soil (Ferreira et al., 2007). The dramatic impact of soil management on *q*Mic was demonstrated by Franchini et al. (2007), in the state of Paraná, Brazil, where, in a conservationist system with crop rotation the *q*Mic was 5.2%, whereas in a tillage system and with soybean and wheat (*Triticum aestivum* L.) cropped serially, this quotient was of only 1.7%.

In regard to the effects of the treatments on the *q*Mic, the soil under native vegetation and the sugarcane without burn system exhibited values of 2.64% and 2.61%, respectively, significantly higher than the value for the sugarcane with burn system (2.01%) (Table 3). As it has been discussed before (Anderson and Domsch, 1986, 1993; Ferreira et al., 2007; Maluche-Baretta et al., 2007), higher *q*Mic figures indicate higher availability of substrates for microorganisms, having a positive influence on microbial biomass. We can therefore infer that, in our study, native forest and the sugarcane without burning are the most favorable to maintain and increase the soil microbial biomass (Table 3). However, it was clear that there was a greater balance in the microbial biomass under native forest from the analysis of the MB-C/MB-N ratio, which was statistically higher than those of the cultivated areas.

As concluding remarks, we may say that the results reported in our study show that by eliminating the burning management at the sugarcane harvesting there is an improvement in soil fertility—mainly in terms of organic matter—and soil microbial biomass. However, it is still possible to improve soil quality in comparison to the conditions under native forest. TOC levels under native forest and sugarcane without burn were higher than those under sugarcane with burn by 148% and 54%, respectively, and the soil TN, L-C and R-C parameters were also better. By comparison with the sugarcane with burn, the native forest and the sugarcane without burn also resulted in higher values for MB-C (222% and 102%, respectively) and MB-N (45% and 34%, respectively). The higher sensitivity of microbiological parameters in response to different sugarcane harvesting systems also shows the potential of using these parameters as indicators of soil quality.

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