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ORIGINAL ARTICLE

Organic carbon, biomass and microbial activity in an Oxisol under different management systems

Carbono orgânico, biomassa e atividade microbiana em Latossolo Vermelho de cerrado sob diferentes usos e manejo

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Qualidade do solo
Quociente metabólico

ABSTRACT: Soil management can negatively affect soil quality impairing its functionality. One of the possible ways to assess soils is through the use of biochemical indicators. In this study, the aim of this study was to determine how soil management and use interfere with organic carbon, carbon in biomass and microbial activity, as well as with the acid phosphatase activity of an Oxisol in the Brazilian Cerrado. Five soil uses and management systems were used as treatments: no-tillage, coffee plantation, banana plantation, pasture, and native vegetation. Soil samples were collected at four different times: August, September, October, and November. Reductions in the concentrations of total organic carbon, microbial biomass carbon, and acid phosphatase activity were observed with management and use of soil under no-tillage, pasture, coffee plantation, and banana plantation in relation to native vegetation. The soil under pasture showed lower reductions in biochemical characteristics compared to the other land uses and managements studied. The practice of fallow in the no-tillage area promoted reductions in microbial biomass carbon, acid phosphatase activity and soil organic carbon, but increased the metabolic quotient, demonstrating that this management is not appropriate for this type of soil.

RESUMO: *O manejo do solo pode afetar negativamente a sua qualidade, prejudicando a sua funcionalidade. Uma das formas de se avaliarem suas características é por meio do uso de indicadores bioquímicos do solo. O objetivo deste trabalho foi determinar a interferência do uso e do manejo do solo sobre o teor de carbono orgânico e do carbono na biomassa, e na atividade microbiana, bem como na atividade da fosfatase ácida de Latossolo Vermelho Distroférrico no Cerrado. Cinco usos e sistemas de manejo do solo foram utilizados como tratamento: lavoura em plantio direto; cafezal; bananal; pastagem, e cerrado nativo. O solo foi amostrado em quatro épocas diferentes: agosto, setembro, outubro e novembro. Reduções nas concentrações de carbono orgânico total e de carbono da biomassa microbiana, e na atividade da fosfatase ácida foram verificadas com o manejo e o uso do solo sob lavoura, pastagem, café e banana, em relação ao cerrado nativo. O solo sob pastagem apresentou menores reduções nos atributos bioquímicos em relação às demais áreas cultivadas. A adoção de pousio na área de lavoura promoveu reduções no carbono da biomassa microbiana, na atividade da fosfatase ácida e no carbono orgânico do solo, e aumento de quociente metabólico, demonstrando não ser o manejo adequado para este solo.*

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1 Introduction

Soil biomass and microbial activity are key components in the soil quality maintenance process because they act as agents of biochemical transformation of organic compounds and residues in nutrient cycling, and as a reservoir of N, P and other nutrients (SILVA; SENA; SILVA JÚNIOR, 2007). Several studies have shown that these biochemical attributes can be used as soil quality indicators, because they may interfere in the dynamics of important elements in different agroecosystems (FERREIRA et al., 2007). The transformations of an area under native vegetation in an agricultural system can cause alterations in biomass and soil microbial activity. A study carried out in a typical Oxisol showed that anthropic interference causes reduction in microbial biomass carbon (MBC) in relation to the native Cerrado area (PRAGANA et al., 2012). This reduction is related to the alterations that occur in soil structure and in the amount and quality of soil organic matter, which undergo changes with the substitution of native vegetation by a culture.

Microbial metabolic quotient (respiration-to-biomass ratio) or qCO_2 is considered an important factor in assessing the effects of environmental conditions on soil microbial activity, also referred to as microbial biomass-specific respiration rate (ANDERSON; DOMSCH, 1993). High *q*CO2 values are found in locations subjected to adverse conditions, that is, in soils where the microbial biomass oxidizes more carbon for its maintenance. Therefore this index reflects the influx of energy (carbon) through soil microbial biomass. Several studies indicate that the intensity of use and the type soil management, as it occurs in agricultural systems, cause increases in *q*CO2 (FERREIRA et al., 2007; FONSECA et al., 2007; LAGOMARSINO et al., 2009; MARTINS et al. 2010).

Another important biochemical attribute is the soil enzyme activity, which is used as a tool to monitor alterations that occur as a consequence of anthropogenic factors such as soil use and management (LAMBAIS; CARMO, 2008; LAGOMARSINO et al., 2009; CARNEIRO et al., 2009). Among the many enzymes found in the soil, acid phosphatase acts on the release of P absorbed on clays and organic complexes in forms accessible to plants, gaining prominence especially in tropical soils (PLASSARD; DELL, 2010). Studies show that acid phosphatase activity has been severely affected by intensive soil use, and in conservation tillage systems such as no-till this reduction was lower compared to conventional tillage (MARCHIORI JÚNIOR; MELO, 2000; FONSECA et al., 2007). There has been growing interest in assessing the effects of soil use and management on biochemical attributes and in understanding their importance for the maintenance of agroecosystems; however, there are few studies on soils of the Cerrado Biome, especially in the state of Goiás (FONSECA et al., 2007; CARNEIRO et al., 2009).

In this study, we aimed to determine how soil use and management interfere with organic carbon, carbon in biomass and microbial activity, as well as with the acid phosphatase activity of an Oxisol in the Brazilian Cerrado.

2 Materials and Methods

The present study was carried in the experimental area of the Federal University of Goias - UFG, Jatai Campus, located at 17° 53' S and 52° 43'W, 670 m above sea level, in an Oxisol classified as clayey (424 g kg^{-1} sand, 163 g kg^{-1} silt, and 413 g kg^{-1} clay) according to EMBRAPA (2006). Soil sampling was performed during the following months of 2006 with the following rainfall measures: August, 0.0 mm; September, 58.3 mm; October, 218.3 mm; and November, 181.6 mm.

The study was conducted in five areas with different soil uses as follows: no-tillage, coffee plantation, banana plantation, pasture, and native vegetation (Cerrado), whose chemical attributes can be found in Table 1 and description and history are shown in Table 2. All soil uses are located near each other and within the same soil patch; therefore the environmental conditions of the study were homogeneous. It was no possible to randomize these areas in a planned statistical design, because this is an ecological studu were conducted in natural areas with different soil uses previously established. Following guidance from statisticians, we chose to randomize the sampling points within each area and test the homogeneity of variance. Once homogeneity of variance was verified, data were analyzed as a completely randomized design with five sampling points (pseudoreplications). Each sampling point represented an area of 150 m^2.

Within each sampling point, five subsamples were collected, moving in a zigzag manner, using a mattock at 0-10 cm depth to obtain 500 g soil samples. Soil samples were collected in four periods: August, September, October and November, at the beginning of each month. In the coffee and banana plantations, soil collection was performed on the projection of plant canopies. In the native Cerrado, samples were collected from the inside of the area after leaf litter layer removal. In the

Table 1. Chemical attributes of an Oxisol under different soil uses and management systems.

Attributes	Natural vegetation - Cerrado	Coffee plantation	Banana plantation	No-tillage	Pasture
pH in $H_2O^{(1)}$	5.70	6.40	4.90	6.60	5.90
H+Al$^{(2)}$ ($cmol_c\ dm^{-3}$)	9.90	5.61	9.43	5.11	7.29
Al$^{(3)}$ ($cmol_c\ dm^{-3}$)	0.30	0.03	0.48	0.02	0.25
Ca$^{(3)}$ ($cmol_c\ dm^{-3}$)	1.30	3.52	0.32	3.17	0.33
Mg$^{(3)}$ ($cmol_c\ dm^{-3}$)	0.40	0.61	0.63	1.01	0.63
K$^{(4)}$ (mg dm^{-3})	35.88	60.84	28.08	93.90	10.92
P$^{(4)}$ (mg dm^{-3})	1.01	6.47	4.31	28.75	1.01

1 – water extraction (1:2.5); 2 – $CaCl_2$ 0.01 mol L^{-1} (1:2.5); 3 – KCl 1 mol L^{-1}; 4 – Mehlich I. Contents of P were considered low (3 to 6 mg dm^{-3}) and high (> 12 mg dm^{-3}) in relation to clay content according to Sousa and Lobato (2004).

Table 2. Description and history of soil uses and management systems.

Tillage	Area description
Banana plantation	This area had been used as pasture until 2005 when the banana plantation was implanted. Seedlings were planted in pits with 5 L of chicken manure, 100 g of lime, 500 g of superphosphate and 150 g of potassium chloride. The banana seedlings were watered regularly. Area size: 5 ha.
Coffee plantation	Coffee planting was performed in 2001 using *Coffea arabica* cultivar at 3.5 x 0.5 m spacing. Weed control has been done with direct spraying of glyphosate. Fertilization was carried out in four applications during the rainy season corresponding to 400 kg ha^{-1} $year^{-1}$ of N and K_2O, and 40 kg ha^{-1} $year^{-1}$ of P_2O_5. Soil remediation was performed annually, using lime, aiming to achieve base saturation rate of 70%; gypsum application at the rate of 500 kg ha^{-1} was also performed in 2005. Area size: 10 ha.
No-tillage system	The agricultural area had been under no-tillage for approximately 10 years (1996/1997) with soybean and maize and/or sorghum succession. In the 2005/2006 season, planting was performed in late October, using CD 219 transgenic soybean cultivar spaced by 0.45 m between rows. Fertilization was performed with 360 kg ha^{-1} of the 00-23-23 (NPK) fertilizer, and sorghum was planted in the off-season using 150 kg ha^{-1} of the 08-20-10 (NPK) fertilizer. Glyphosate herbicide was applied in the beginning of the planting season for weed control. When soil sampling started, the area was in fallow and infested with weeds. Area size: 40 ha.
Pasture	Pasture area with *Brachiaria decumbens* since 1996 under continuous grazing management. Liming with 2.5 t per hectare of dolomitic limestone was performed in the first semester of 2001. Currently, this area is degraded due to lack of correction maintenance and fertilization, and overgrazing. Area size: 11 ha.
Native vegetation – Cerrado	Area under native vegetation of the Gallery Forest type comprising tree species approximately 5 feet tall, with gnarled trunks and asymmetrical canopies, presenting thick litter with no anthropic intervention. Area size: 48 ha.

plantation areas, sampling was performed in the inter rows. After each collection, the soil samples were placed in thermal containers and sent to the CAJ/UFG soil laboratory and then stored in plastic bags under refrigeration (4 °C).

Total organic carbon (TOC) was assessed only in the samples collected in November through the wet chemical oxidation process with potassium dichromate in sulfuric acid medium (EMBRAPA, 1997). Microbial biomass carbon (MBC) was assessed by the fumigation method – extraction after chloroform incubation in the dark for 24 h, extraction with K_2SO_4 (0.5 mol L^{-1}), oxidation with $K_2Cr_2O_7$ (0.067 mol L^{-1}), and titration with ammonium ferrous sulfate (0.0333 mol L^{-1}) (VANCE; BROOKES; JENKINSON, 1987). Soil microbial respiration (C-CO_2) was estimated from 20 g of incubated soil, whose amount of CO_2 trapped by NaOH at 0.05 mol L^{-1} was assessed after 72 h (ALEF; NANNIPIERI, 1995). Microbial methabolic quotient (*q*CO2) was determined by the respiration-to-biomass ratio (CO_2/MBC) (ANDERSON; DOMSCH, 1993). Acid phosphatase activity (APA) was evaluated using 1 g of soil - where 0.2 ml of toluene, 4 ml of buffer (pH 6.5) and 1 ml of ρ-nitrophenyl phosphate (0.05 mol L^{-1}) were added - incubated for one hour at 35 °C; after incubation, spectrophotometric reading was performed at 410 nm as described by Dick, Breakwell and Turco (1996). The results obtained were submitted to analysis of variance (SAEG 8.0) and the Tukey test at 5% probability level was applied when significant effect was verified.

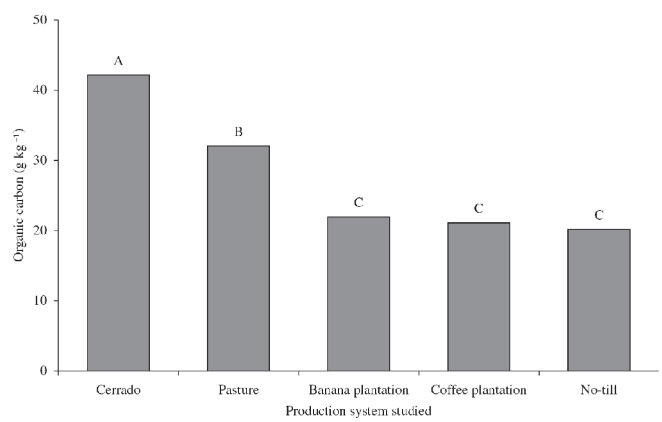

Figure 1. Contents of total organic carbon in an Oxisol under different soil uses and management systems in the Cerrado of Jatai, Goiás state. Means followed by the same letters are not significantly different by the Tukey test at 5% probability level.

3 Results and Discussion

The area under pasture showed total organic carbon (TOC) lower than the control area (Cerrado), but higher ($p < 0.05$) than the other areas studied (Figure 1). This higher level of TOC in the area under pasture may occur because to the grass species root system, which provides increased TOC due to rhizodeposition (CARMO et al. 2012).

Studies show a reduction in TOC contents when soils under native vegetation (Cerrado) are submitted to different management systems compared to soil under Cerrado with no anthropogenic interference (FONSECA et al., 2007; CARNEIRO et al., 2009; PRAGANA et al., 2012). Salton et al. (2011) demonstrated that even the system of crop-livestock integration, considered a conservation system, provides intermediate rate on the accumulation of carbon in the soil in relation to pasture (greater accumulation) and no-tillage (smaller accumulation) management systems.

Regarding microbial biomass carbon (MBC), the management systems analyzed caused sharp reductions compared to the area under native vegetation (Cerrado) in all periods studied. The sharpest reduction was observed in the no-till area (95%) in August and the lowest reduction was verified in the area under pasture (approximately 30%) in October (Table 3).

A study conducted by Fernandes et al. (2012) showed that soil use with eucalyptus plantation (four and five years) reduced MBC compared to the preserved Cerrado. Similar results were found in a study carried out in Sao Paulo state showing the negative effects of different soil uses and management systems on MBC (MARCHIORI JÚNIOR; MELO, 2000). Pragana et al. (2012) also found reduction in MBC when studying the effect of different no-tillage periods. The highest MBC value found in the present study in the area with no anthropogenic interference may have occurred because of the increased availability of nutrients derived from the cycling of organic matter through litter (necromass) and from the roots of plants themselves (rhizodeposition), as previously mentioned. The area under pasture presented, in absolute values, the highest amount of MBC in relation to the other soil management systems. This occurs because of the grass root system, which is extremely efficient in the exploration of soil contributing to soil structure stabilization and the increase in microbial activity by carbon sequestration via rhizodeposition and the roots themselves after death. This fact was also confirmed in a study conducted in soils of the Amazon region (GERALDES; CERRI; FEIGL, 1995).

In contrast, the area under tillage, even being explored through no-till system, presented a reduction in MBC in the first sampling (August) in relation to the other cultivated areas, which can be attributed mainly to the lack of efficient cover crop during the winter, because after the harvest of the off-season maize (May/June) the area remained under fallow and it was infested with weeds that provide low soil cover, mainly when compared to pasture, thus reducing carbon sequestration to the soil system (via necromass and rhizodeposition). Similar results were also observed in studies carried out by Carneiro et al. (2009).

Regarding microbial respiration (Table 3), we observed that the area under native vegetation (Cerrado) stood out from the others at all periods, except for the samples collected in September when there were no significant differences between the management systems studied. This fact may be associated with the increased MBC concentration found in the soil area under Cerrado, allowing a significantly higher respiration rate. In the first sampling, the area under no-till did not differ from the native Cerrado area with respect to microbial respiration. This attribute reflects the decomposition of organic residues and soil organic matter itself (CAPUANI et al., 2012). High respiration rate may indicate mineralization of carbon and other elements in the short term, and loss of carbon from the soil system in the long term (RICE; MOORMAN; BEARE, 1996). Thus, the increased microbial activity in the Cerrado area indicates mineralization of organic residues derived from litter, which is released to this soil in large amounts and maintains the cycle of elements.

With respect to the area of tillage, because of the low MBC value, a situation of loss of carbon from the system can be expected, because there is a situation in which a small microbial population requires large amounts of energy (C) for its maintenance, causing the release of this element to the atmosphere. As for metabolic quotient (qCO_2) (Table 3), a difference ($p < 0.05$) was observed between the management systems (Table 3) in the samples collected in August and November. In August, the area under tillage showed high

Table 3. Microbial biomass carbon (MBC), microbial respiration (C-CO_2) and microbial metabolic quotient (qCO_2) in an Oxisol under different soil uses and management systems.

Systems	August	September	October	November	Mean
	MBC (μg g^{-1} soil)				
Cerrado	1820 a	1296 a	883 a	1088 a	1272 a
Banana plantation	391 b	743 b	588 b	225 b	487 bc
Coffee plantation	312 b	485 b	292 b	95 c	296 c
No-tillage	88 c	739 b	307 b	322 b	364 c
Pasture	525 b	834 b	631 a	477 b	617 b
	Respiration (mg CO_2 g^{-1} h^{-1} in the soil)				
Cerrado	8.9 a	3.7 a	9.9 a	13.6 a	9.0 a
Banana plantation	2.7 c	1.5 a	3.6 b	5.3 b	3.3 b
Coffee plantation	3.7 bc	2.2 a	2.4 b	6.3 b	3.7 b
No-tillage	6.0 ab	2.5 a	3.9 b	6.8 b	4.8 b
Pasture	4.8 bc	2.9 a	3.8 b	5.4 b	4.3 b
	qCO_2 (mg CO_2 mg MBC^{-1})				
Cerrado	5.1 b	2.9 a	11.9 a	19.7 c	10 b
Banana plantation	8.7 b	1.8 a	6.7 a	25.8 c	11 b
Coffee plantation	14.6 b	4.6 a	8.6 a	83.5 a	28 a
No-tillage	71.2 a	3.3 a	14.8 a	46.7 b	34 a
Pasture	11.0 b	3.8 a	6.2 a	12.2 c	8 b

Means followed by the same letters are not significantly different by the Tukey test at 5% probability level.

qCO2, exceeding the others, which did not differ among themselves. In September and October, no difference was observed ($p > 0.05$) between the studied areas. In November, the area under coffee cultivation showed high qCO2 differing significantly from others, and the areas under banana plantation and pasture presented similar qCO2 values to that of the Cerrado area. The qCO_2 provides important information because it indicates how much energy the microbial population needs for its maintenance and growth (ANDERSON; DOMSCH, 1993). Higher qCO_2 values are found in adverse conditions to microbial population, where microorganisms expend more energy (C) for their maintenance. This occurs in areas undergoing some kind of stress, for instance, under conventional tillage (ANDERSON; DOMSCH, 1993). In this sense, in the first sampling, the area under no-till presented high qCO_2 in relation to the other areas because of the low cover crop associated mainly with low soil humidity (water stress). In the other samplings, these values decreased as a function of soil cover with the development of the soybean crop as from the second half of September (the beginning of the rainy season). In the last sampling, performed in November, the qCO_2 values were higher in the areas under intensive cultivation such as the coffee plantation and in the no-tillage area when compared to the areas under pasture and native vegetation (Cerrado), which may indicate the occurrence of carbon loss in these soil uses. Acid phosphatase activity was most active in the Cerrado similarly to the other biochemical attributes evaluated in this study (Figure 2). The area under native vegetation showed higher values in the activity of this enzyme in all periods studied, differing significantly from the other areas ($p < 0.05$).

The area under pasture showed the highest acid phosphatase activity among the agricultural areas, differing significantly from the other tillage areas in the samplings performed in September and November. Acid phosphatase is an enzyme produced mainly by microorganisms in the soil that catalyzes the hydrolysis of phosphorus esters (it acts in the P cycle) and it is able to react with several substrates promoting the release of P to the soil solution. Therefore high enzyme activity tends to promote higher P availability for microorganisms and plants. Jakelaitis et al. (2008), when assessing several soil uses and management systems, verified that areas under pasture presented increased acid phosphatase activity compared to other tillage systems, corroborating the results found in this study. Results indicate that the biochemical attributes studied can be efficient and consistent indicators of soil quality, corroborating other studies conducted in the Cerrado in the state of Goiás (FONSECA et al., 2007; CARNEIRO et al., 2009). Microbial biomass is considered the living fraction of soil organic matter and a labile reservoir of nutrients, working actively in the process of decomposition/mineralization of organic residues, in the energy flow, and in the nutrient cycling (KASCHUK; ALBERTON, HUNGRIA, 2010). Strategies for soil use and management that promote reductions in this biochemical attribute may indicate degradation of the area in question in the short term. In this sense, in the present study, we observed that the management systems studied caused reductions in the TOC content of soils as well as in the biochemical attributes assessed, and that the most increased reduction occurred in the area under no-tillage. Future studies should address changes in the currently used practices, such as the introduction of a cover crop that is efficient in phytomass production, enabling coverage in between rows of perennial cultures or during the off-season of annual crops and the utilization of rotation crop systems that are more balanced in order to seek increased residual biomass production on soil surface.

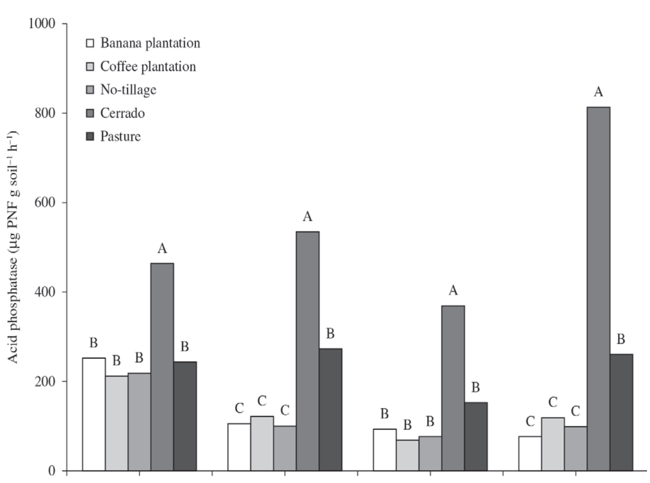

Figure 2. Acid phosphatase activity of an Oxisol under different soil uses and management systems in the Cerrado at different periods. Means followed by the same letters are not significantly different by the Tukey test at 5% probability level.

4 Conclusions

Soil use and management in areas under no-tillage, coffee plantation and banana plantation cause reductions in the contents of total organic carbon, microbial biomass carbon, microbial activity, and acid phosphatase activity compared to the area under native vegetation (Cerrado).

The area under pasture presented higher contents of total organic carbon and microbial biomass carbon in relation to the other areas under tillage.

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