academicJournals

Vol. 11(11), pp. 941-950, 17 March, 2016
DOI: 10.5897/AJAR2015.10001
Article Number: 56F245E57603
ISSN 1991-637X

http://www.academicjournals.org/AJAR

African Journal of Agricultural Research

Full Length Research Paper

Microbiological features of dystroferric and dystrophic red oxisols under sugar cane crops subject to different management procedures

Georgia Ribeiro Silveira de Sant'Ana[1]*, Carlos Eduardo Ramos de Sant'Ana[2], Carlos de Melo e Silva Neto[2], Bruno Bastos Gonçalves[3], Letícia Ribeiro de Sant' Ana[2], Marina Morais Monteiro[2], Anna Clara Chaves Ribeiro[2], Rosana Alves Gonçalves[2] and Selma Simões de Castro[2]

[1]Faculdade de Tecnologia SENAI Roberto Mange, Brazil.
[2]Universidade Federal de Goiás, Brazil.
[3]Universidade Estadual de São Paulo, Brazil.

Received 10 June, 2015; Accepted 20 November, 2015

The Quirinopolis microregion (QMR) is located in the Southwestern Goiás State, and represents the recent expansions of sugar cane crops in the state. The maintenance of the agricultural and forest ecosystem productivity depends largely on the organic matter transformation process and therefore on the microbial biomass. The goal of this study was to evaluate the effects of the different management methods used in sugar cane cultivation on soil microbiological parameters and on indices derived from dystroferric (DfRO) and dystrophic (DRO) red oxisols in the region of Quirinopolis, Goiás. Eight sampling sites were selected in this study within areas occupied by DfRO and DRO, and two reference sites with semidecidual forest vegetation. The microbial biomass of the soil planted with sugar cane responded to changes caused by the two different soil management types (fertilized and not fertilized), so it may be considered a potential soil quality bioindicator. The soil profiles subject to crop succession before planting sugar cane favored the maintenance of the soil microorganism community in regards to other managements. DfRO profiles previously planted with soybean showed the best physical and chemical condition for a dynamic biomass balance. Profiles with vinasse showed no improvement in the development of soil microorganisms nor better physical and chemical conditions.

Key words: Soil quality, bioindicators, organic C, fertilization, soybean crop, vinasse.

INTRODUCTION

Sugarcane (*Saccharum* spp.) expansion in the Brazilian agricultural scenario has been driven by technologies that

*Corresponding author. E-mail: grssantana@gmail.com

contribute to soil conservation, reduction of production cost and higher productivity (Schultz et al., 2010). The recent agriculture expansion has been driven towards the West Central (Brazilian savanna) since the late 1990s, particularly to the states of Mato Grosso do Sul (MS) and Goiás (GO). Both states have landscapes characterized by large - flat areas and weather conditions, especially, due to lower slopes and to the Oxisol domain. Therefore, the Brazilian savanna is considered to have a greater agricultural potential for sugar cane (among others) cropping.

The Quirinopolis microregion (QMR) is located in the Southwestern region of the state of Goiás, and represents this recent expansion process of the sugar cane, having a high aggregation of large mills for sugar and bioethanol production. Sugar cane cultivation at the QMR began in 2004. The first crop was harvested in the 2006/2007 season growing in areas under dystroferric red oxisol (DfRO) (EMBRAPA, 2006), previously intended for grain production (corn and soybean), and dystrophic red oxisol (DRO), previously intended for extensive cattle raising .

The soil is an open system that concentrates plant organic matter (carbon or C) and the products of organic C transformations. The vegetation is the main factor responsible for depositing organic matter into the soil (Santos et al., 2008). Vegetation type and environmental conditions are factors that determine quantity and quality of the organic matter being deposited. Thus, vegetation influences soil heterogeneity and decomposition rates of the material deposited on the soil surface (Moreira & Siqueira, 2002; Scherer-Lorenzen et al, 2007). Continued use of the soil, a natural resource, through anthropic activities, such as sugar cane (*Saccharum* spp.*)* planting may alter environmental structure. Organic C conservation is essential for nutrient recycling, water and energy flow balance, C storage, gas emissions and maintenance of animal and vegetal diversity (Mendes et al., 2009).

The maintenance of agricultural and forest ecosystem productivity depends mostly on the transformation of organic C and, consequently, on the microbial biomass (Gama-Rodrigues and Gama-Rodrigues, 2008). Therefore, the interest in elements of the soil biological function under natural and agricultural systems has grown (Matsuoka et al., 2003). The soil microbial communities are responsible for the decomposition of organic compounds, through nutrient cycling and soil energy flow. Microbial biomass and activity in the soil have been identified as the characteristics most sensible to soil quality changes caused by changes in soil use and management practices (Trannin et al., 2007). For this reason, the microbial community may be an important bioindicator in assessing soil quality, and consequently, the quality of an agroecosystem.

The microbial biomass is the living fraction of soil organic C, and comprises bacteria, fungi, actinomycetes, protozoa and algae. It is an important bioindicator, once it operates in the natural decomposition processes, interacting with nutrient dynamics and regeneration of stability of the aggregates (Franzluebbers et al., 1999; Da Silva et al., 2010). The microbial biomass is influenced by seasonal humidity and temperature variation, soil management, cultivation and by plant residues. The microbial biomass represents a small portion of the active fractions of organic matter (De Luca, 1998; Gama-Rodrigues et al., 2005), comprising only 2 to 5% of the soil organic C. Nevertheless, microbial biomass is more sensible than organic C and total N contents to measure changes in organic matter caused by farming practices (Gama-Rodrigues, 1999).

In this context, the use of microbiological attributes (for example, microbial biomass and derived indexes), has been proposed to assess soil quality, in terms of different management practices (Doran and Parkin, 1994). Thus, studies regarding soil biodynamics in different sugar cane cropping systems may lead to different forms of more sustainable management, mitigating environmental consequences of negative impacts. Therefore, the objective of this study was to monitor microbiological indices to evaluate land-use change in sugarcane cropping on dystroferric and dystrophic red oxisols, in the region of Quirinopolis, Goiás.

MATERIALS AND METHODS

Study area

The study was carried out in Southwest Goiás (GO), at the Quirinópolis microregion (QMR), where the sugar cane expansion is recent. The QMR has rapidly reached prominence as the new sugar cane expansion center (Borges, 2011), replacing grain and pasture areas (Figure 1). The soils of the QMR rest on Cretaceous sandstones and basalts of the Paraná Sedimentary Basin, which sustains a rather smooth relief consisting of plateaus leveled at altitudes ranging from 400 to 1000 m. These plateaus are covered by Oxisols that range from medium to clayey texture, and vary from dystrophic to dystroferric as related to base saturation (Embrapa, 2006). The flat areas were preferred for the sugar cane expansion due to its characteristics, which favor intensive mechanization and soil management for planting. The climate at the QMR is tropical wet and dry (Aw) with two disparate seasons and significant annual variations in regards to humidity, precipitation and temperature, according to climate typology established by Koeppen (1918). The QMR has frequent rainfalls from October to March and a dry winter from June to September, with transitions from wet and dry periods and total average annual precipitation of 1700 mm, average temperature of 24°C and a temperature range of ca. 15°C during the year.

Sampling design

Eight sampling sites were selected in dystroferric red oxisol (DfRO) and Dystrophic red Oxisol (DRO) areas, and two reference profiles, with native vegetation (semidecidual forest). Semidecidual forests

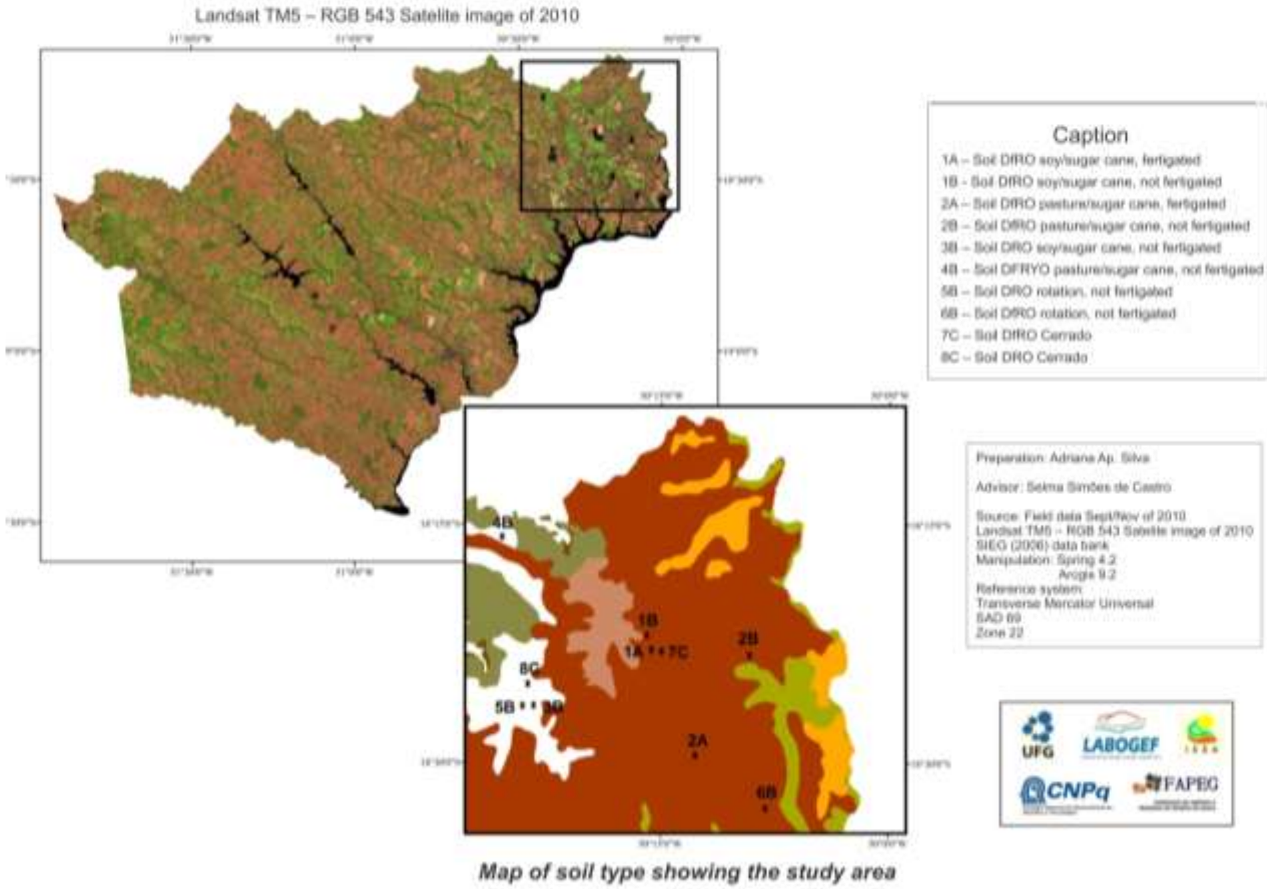

Figure 1. Map of the Quirinopolis micro-region, Goiás with the location of the studied soil profiles. DFRO means dystroferric red oxisol, DRO means dystrofic red oxisol and DFRYO means dystroferric red-yellow oxisol. Source: Silva (2012).

occupied most of the southern QMR before 1980 (Figure 1). The cultivated soil profiles were described following recommendations made by Santos et al. (2005) and were chosen in regards to management history. All sugarcanes are plantations in 4th cutting of the 1st productive cycle. The same sugar cane cultivar (SP81-3250) was planted. Planting and harvesting of sugarcane were performed by machines, and the crop was harvested without prior burning (June, 2008, May, 2009 and May, 2010). Soil preparation (plowing and harrowing) was the same at all sites, varying to fertigation with vinasse only. Detailed description, land use and management of each site are present in Table 1.

The profiles were analyzed in open trenches (near 2 × 1.5 × 2.5 m) where morphological descriptions regarding the identification of compressed horizons were performed. Samples were gathered and described in May, 2010 (dry season; profiles 1A, 1B, 2A, 2B and 7C) and September, 2010 (rainy season; 3B, 4B, 5B, 6B and 8C). The samples were carried out in each profile at five depths and three replicates of soil samples, with approximately 1.5 kg each. Soil samples were homogenized and divided into two parts: 1 kg for physical and chemical characterization and 0.5 kg to determine biotic variables. Soil samples for biological studies were gathered in sterile containers and stored in a cold chamber (4°C) until analysis.

Soil samples for physical and chemical characterization were stored in gas-permeable plastic bags. These soil samples were air-dried and subsequently sieved through 2.0 mm mesh opening. The following variables were determined: pH in $CaCl_2$ (ratio of 1:2.5 for soil and solution – v/v); P and K (extraction with Mehlich^{-1}, P determination by colorimetry and K by flame photometry); Ca and Mg (extracted with 1 mol L^{-1} KCl, determined by atomic absorption spectrophotometry and titration, respectively); organic C (determined using sodium dichromate and colorimetry); potential acidity (H + Al/potentiometer); cation exchange capacity (CEC); base saturation (V%). All variables were determined according to Embrapa (1997). The microorganisms (fungi and bacteria) were quantified and underwent microbial biomass analyzes, following Moreira and Siqueira (2002). Fungi and bacteria were quantified using the pour plate technique (Filho and Oliveira, 2007).

Microbial biomass C (MB-C) was determined using the microwave irradiation technique followed by oxidation with potassium dichromate ($K_2Cr_2O_7$ 0.066 mol L^{-1}) and titration with $(NH_4)_2Fe(SO_4)_2$ 0.033 mol L^{-1}. The MB-C was estimated (mg kg^{-1} of soil MB-C) using the following equation: MB-C (mg kg^{-1}) = CF × k_c, where CBM is the microbial biomass C; CF represents the flow of C obtained from the difference between the C quantity (mg kg^{-1}) in the extract of the irradiated sample and in the non-irradiated sample, and kc is the correction factor (Mendonça and Matos, 2005). Basal respiration was also determined (CO_2-C) through sample incubation with CO_2 trapping in NaOH 1 mol L^{-1} solution for seven days, as

Table 1. Characterization of the studied soil profiles.

Profile	Elements of the physical environment				Use and management	
	Soil	Geology	Declivity	Altitude (m)	Land use before cane/vegetation	Fertigation
1A	DfRO	Basalt	0 to 3%	576	Soybean	Fertigated
1B				540	Soybean	Not Fertigated
2A				503	Pasture	Fertigated
2B				460	Pasture	Not Fertigated
6B				458	Succession: pasture/soybean/sugar cane	Not Fertigated
7C				545	Natural vegetation	-
3B	DRO	Sandstone	0 to 3%	558	Soybean	Not Fertigated
4B			3 to 6%	595	Pasture	Not Fertigated
5B			0 to 3%	633	Succession: pasture/soybean/sugar cane	Not Fertigated
8C			3 to 6%	589	Natural vegetation	-

Source: Silva (2012)

proposed by Jenkinson and Powlson (1976).

The metabolic quotient (qCO$_2$) was obtained following the Anderson and Domsch (1990) protocol after measurement of MB-C and CO_2-C. The qCO$_2$ was calculated by the ratio CO_2-C/MB-C. In turn, microbial quotient (qMic) was obtained by the ratio of MB-C and organic C. The parameters regarding microbial biomass, derived indices and the physical and chemical variables were submitted to multivariate analysis (MANOVA) by the principal component analysis (PCA), using the software PAST 2.17c (Hammer et al., 2001). PCA was carried out for each horizon, containing the biological and chemical parameters {Chemical variables: H+Al (potential acidity); CEC (cation exchange capacity); OM (organic C); K (potassium); Ca (Calcium); pH (hydrogen potential); V (percent base saturation); Mg (magnesium); P (phosphorus); Microbiological variables: CO2q: Carbon dioxide quotient (metabolic quotient); C-CO2: basal respiration: MICq: microbial quotient; MBS-C: microbial biomass; Bacteria (Bac-UFC); Fungi (F-UFC)} and the different dystroferric and dystrophic red oxisol profiles with the different management types.

RESULTS AND DISCUSSION

The DRO and DfRO profiles and its different management types had different locations in horizon A. Profiles 7C (native vegetation) and 1B (soybean as prior management and currently with sugar cane not fertigated) were grouped with most physical and chemical variables (Figure 2). Such results indicate that profile 1B favors a better balance of soil chemical components, compared to the other profiles evaluated.

The fertigated profiles 1A (soybean as prior management type) and 2A (with pasture as prior management type) were grouped with H + Al and P (Figure 2). This result indicates that the use of vinasse directly influences soil dynamics, and may alter soil chemical parameters in horizon A. The native vegetation (for DfRO and DRO) was grouped with most biological parameters related to soil microbial biomass in horizon A (Figure 3). Therefore, horizon 1A favors biological community maintenance. These results support previous findings that report a greater diversity of processes in natural ecosystems reducing soil imbalance factors (Roscoe et al., 2006).

Profiles 6B and 4B had an overall tendency similar to natural environments (Figure 3). Thus, better conditions for the development of the soil microbial community were observed in horizon A. The maintenance of plant residues on the soil surface and the absence of soil disturbance enabled better conditions for soil biological activity (Lisboa et al., 2012). On the other hand, the fertigated profiles (1A and 2A) did not have grouped biological attributes, indicating that stressful conditions for biological soil communities exist in horizon A (Figure 2).

The chemical variables of profile 7C (Horizon AB; DfRO) are grouped with the chemical variables of the native vegetation (Figure 3). This result may be due to the increased nutrient recycling in the natural system, consequent of the higher input of organic substrates into the soil of horizon 7C. Organic C is a key nutrient source for plants, providing elements such as N, P, K, Ca, Mg and micronutrients (Mielniczuk, 2008; Salton et al., 2011). The profile among the ones with different managements most similar to the native vegetation was profile 1B.

The biological attributes (Figure 3) of horizon AB are grouped within the native vegetation profiles (7C and 8C), along the principal component axes. Probably, the lack of anthropogenic interference coupled with the accumulation of leaf litter on the soil surface led to this result. Profiles 6B (succession pasture/soybean/cane, not fertigated, DfRO) and 5B (succession pasture/soybean/cane, not fertigated, DRO) had the best conditions among the soils that underwent management, indicating the occurrence of an organic C of better quality among the profiles.

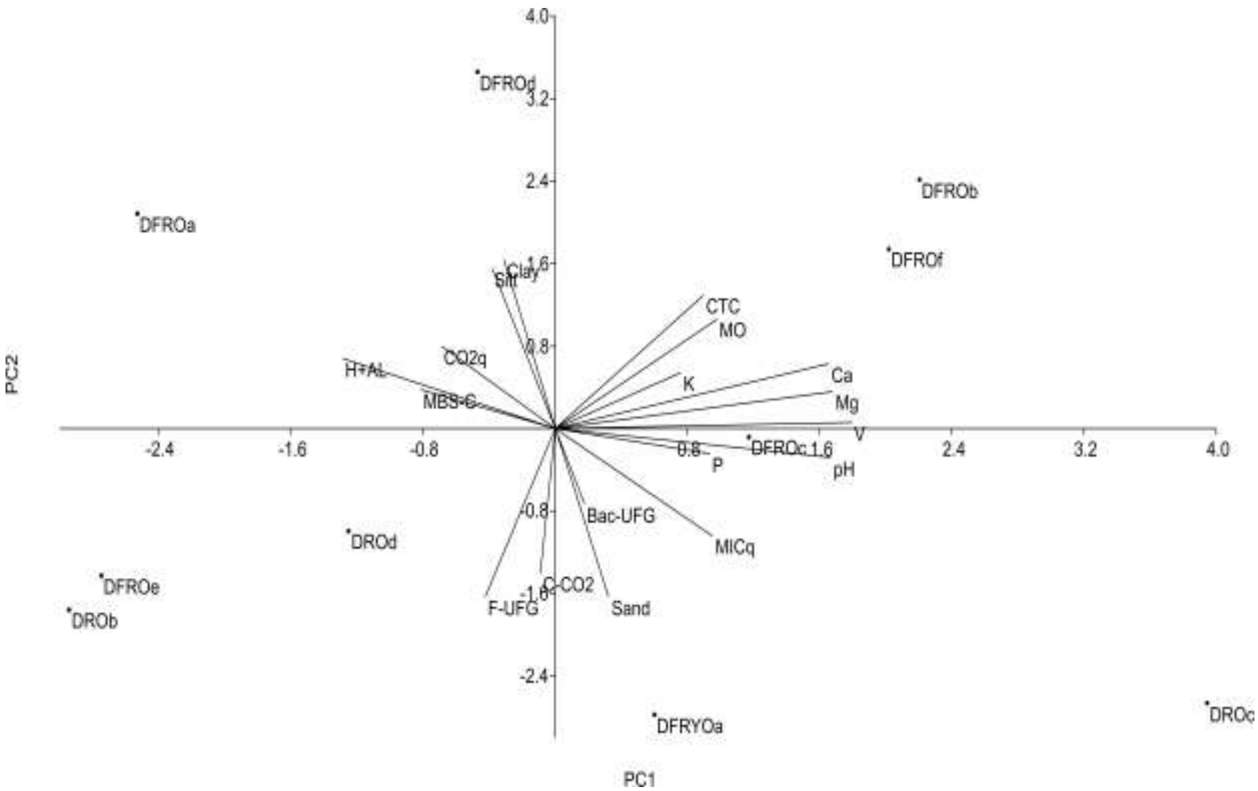

Figure 2. Principal component analysis of the biological, physical and chemical attributes of the dystrophic (DRO) and dystroferric (DfRO) red Oxisols, with different managements in horizon A, Quirinópolis, Goiás. DfROa: 1A – soybean/sugarcane, fertigated; DfROb: 1B – soybean/sugarcane, not fertigated; DfROc: 2A – pasture/sugarcane, fertigated; DfROd: 2B – pasture/sugar cane, not fertigated; DfROe: 6B – Rotation pasture/soybean/sugarcane, not fertigated; DfROf: semideciduous forest; DFRYOa: 3B – soybean/sugarcane, not fertigated; DROb: 4B – pasture/sugarcane, not fertigated; DROc: 5B – Rotation pasture/soybean/sugarcane, not fertigated; DROd: 8C – semideciduous forest. Physical Variables: sand, silt and clay; Chemical variables: H+Al (potential acidity); CEC (cation exchange capacity); OM (organic C); K (potassium); Ca (Calcium); pH (hydrogen potential); V (percent base saturation); Mg (magnesium); P (phosphorus); PC1 and PC2: 71%. Microbiological variables: CO_2q: Carbon dioxide quotient (metabolic quotient); C-CO_2: basal respiration: MICq: microbial quotient; MBS-C: microbial biomass; Bacteria (Bac-UFC); Fungi (F-UFC) (PC1 and PC2: 74%).

The physical and chemical characteristics of horizon BA (Figure 4) are grouped with profile 7C (native vegetation, DfRO) and 1B (soybean/sugar cane, not fertigated) along the principal component axes. Chemical characteristics such as pH and available N, P and K are used as soil quality indicators. The elements N, P and S, are nutrients that comprise the organic C. Thus, these nutrients are available to the plants and are directly influenced by the mineralization process (Vezzani et al*.*, 2008).

Organic C is not an endless source of N, P and S. The annual mineralized quantity of each of these nutrients must be restored to the soil, either through biological fixation (as for N), or fertilization (for N, P and S). Thus, the OM is a reservoir for these elements and crucial for biological cycling, enabling the soil to store and promote cycling of elements to the atmosphere (Duxbury et al., 1989; Pôrto et al, 2009).

Profile 1B has a better condition in establishing organic C and, consequently, for nutrient cycling, although not consisting of native vegetation due to prior soil management using fertilization and other techniques. The biological attributes in the PCA of horizon BA were once again grouped with profile 8C (DfRO) and 7C (DRO), both with native vegetation (Figure 4). Profile 4B (previously managed with pasture/sugar cane not fertigated) has a high organic C content, as shown by the high correlation between MICq and B-BMC. This profile consists of horizon BA and has pasture as the previous soil use. Pasture soil management does not revolve the soil, thus conserving soil structure, and has the aggressive and abundant grass root system. Pasture soil management confers such characteristics to horizon AB, which in turn support results found in other studies (Marchiori-Júnior, 1998; Matsuoka et al*.*, 2003).

Profile 3B (DRO with soybean/sugar cane, not fertigated) was highly correlated with CO_2q (Figure 4)

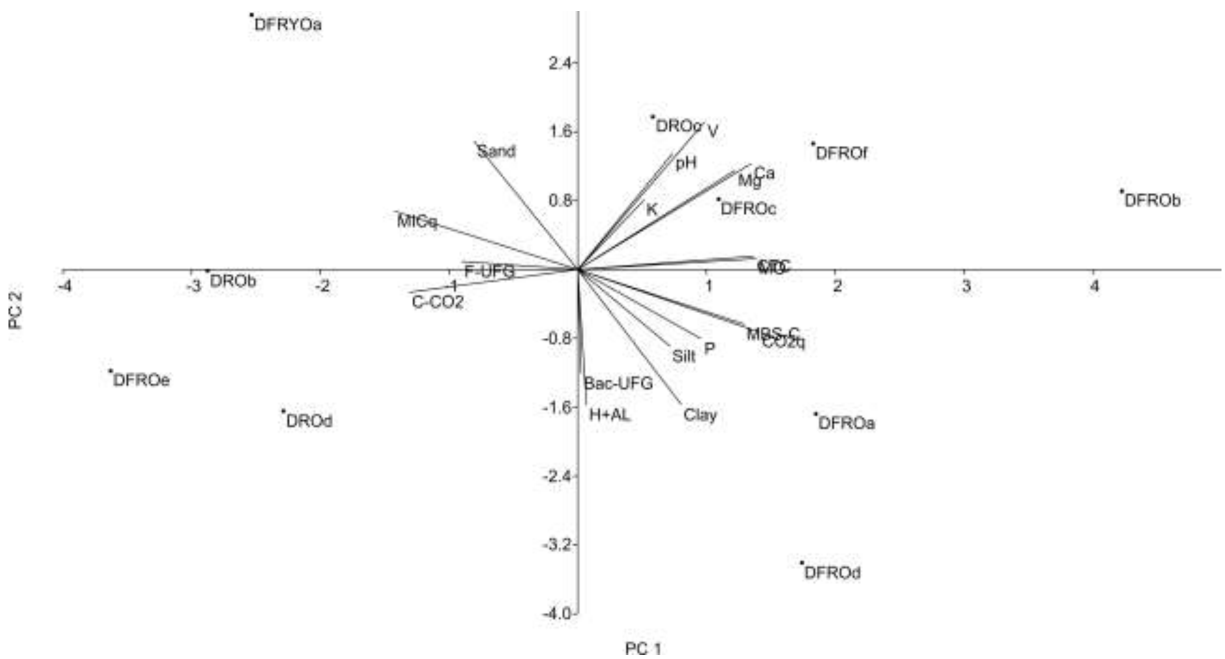

Figure 3. Principal component analysis of the physical and chemical attributes of the dystrophic (DRO) and dystroferric (DfRO) red oxisols, with different managements in Horizon AB, Quirinópolis, Goiás. DfROa: 1A – soybean/sugarcane, fertigated; DfROb: 1B – soybean/sugarcane, not fertigated; DfROc: 2A – pasture/sugarcane, fertigated; DfROd: 2B – pasture/sugarcane, not fertigated; DfROe: 6B – Rotation pasture/soybean/sugarcane, not fertigated; DfROf: semideciduous forest; DFRYOa: 3B – soybean/sugarcane, not fertigated; DROb: 4B – pasture/sugarcane, not fertigated; DROc: 5B – Rotation pasture/soybean/sugarcane, not fertigated; DROd: 8C – semideciduous forest. Physical Variables: sand, silt and clay; Chemical variables: H+Al (potential acidity); CEC (cation exchange capacity); OM (organic C); K (potassium); Ca (Calcium); pH (hydrogen potential); V (percent base saturation); Mg (magnesium); P (phosphorus); PC1 and PC2: 65%. Microbiological variables: CO_2q: Carbon dioxide quotient (metabolic quotient); C-CO_2: basal respiration: MICq: microbial quotient; MBS-C: microbial biomass; Bacteria (Bac-UFC); Fungi (F-UFC) (PC1 and PC2: 78%).

indicating an environment with stressful conditions for soil microbiota. The CO_2q is considered important to assess the effects of environmental conditions on microbial soil communities (Anderson and Domsch, 1993; Zhang et al., 2008). Higher CO_2q values under stressful conditions (for example, excess or lack of nutrients in the soil, altering the physical and chemical soil structures) have implications in more carbon used in biomass maintenance.

The chemical attributes of horizon Bw_1 were grouped with profile 7C (native vegetation, DfRO), 1B (soybean/sugar cane, not fertigated) and 2B (pasture/sugar cane not fertigated) (Figure 5). The microbiota is fostered in different soil management systems, due to plant residue composition (that is, residues from different plant species) and soil preparation methods. This leads to differences in the microbial activity, in the nitrogen immobilization-mineralization relationship and residue decomposition rates (Resck et al., 2008).

The number and location of the organic residue input sites affects the active pool of organic C (Hernández and Hernandez and Hernandez, 2002). This explains why profiles 1B (previously with soybean) and 2B (previously with pasture) have higher concentrations of elements, that is, two previous management types presenting an active cycling of nutrients in the same horizon.

In horizon Bw_1, P was highly correlated with profile 2A (pasture/fertigated sugar cane, DfRO) and 3B (soybean/sugar cane not fertigated, DRO) (Figure 5). Cambuim and Cordeiro (1986), studying the use of vinasse as a fertilizer and soil conditioner, observed a meaningless phosphorous accumulation, while potassium, calcium and magnesium contents occurred almost in direct proportion to the vinasse dose. This high correlation between phosphorus and the soil profiles (Cambuim and Cordeiro, 1986) is not due to vinasse, but to previous soil managements, also explaining why profile 3B was also highly correlated with phosphorus in this study.

The variables representing biological attributes were grouped with profile 8C (native vegetation, DRO) (Figure 5). Profiles 4B (pasture/sugar cane, DRO), 5B (succession/pasture/soybean/sugarcane/not fertigated,

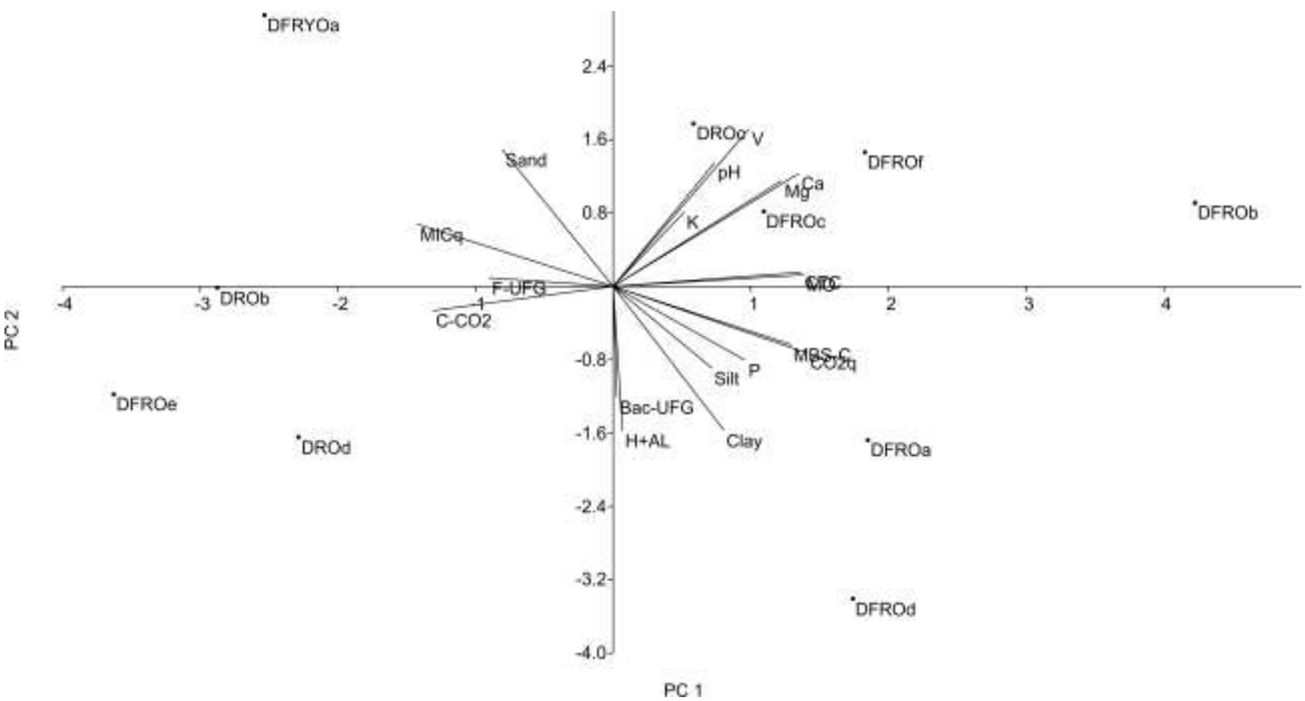

Figure 4. Principal component analysis of the physical and chemical attributes of the dystrophic (DRO) and dystroferric (DfRO) red oxisols, with different managements in Horizon BA, Quirinópolis, Goiás. DfROa: 1A – soybean/sugarcane, fertigated; DfROb: 1B – soybean/sugarcane, not fertigated; DfROc: 2A – pasture/sugarcane, fertigated; DfROd: 2B – pasture/sugarcane, not fertigated; DfROe: 6B – Rotation pasture/soybean/sugarcane, not fertigated; DfROf: semideciduous forest; DFRYOa: 3B – soybean/sugarcane, not fertigated; DROb: 4B – pasture/sugarcane, not fertigated; DROc: 5B – Rotation pasture/soybean/sugarcane, not fertigated; DROd: 8C – semideciduous forest. Physical Variables: sand, silt and clay; Chemical variables: H+Al (potential acidity); CEC (cation exchange capacity); OM (organic C); K (potassium); Ca (Calcium); pH (hydrogen potential); V (percent base saturation); Mg (magnesium); P (phosphorus); PC1 and PC2: 74.34%. Microbiological variables: CO_2q: Carbon dioxide quotient (metabolic quotient); C-CO_2: basal respiration: MICq: microbial quotient; MBS-C: microbial biomass; Bacteria (Bac-UFC); Fungi (F-UFC) (PC1 and PC2: 81.99%).

DRO) and 6B (succession/pasture/soybean/sugarcane/not fertigated, DfRO) are similar to the native vegetation in horizon Bw_1, as indicated by cluster of the microbial biomass parameters and microbial quotient in the soil profiles. These results support the statement that a greater balance and diversity of factors would occur in natural environments, possibly mitigating negative impacts in the soil (Júnior, 2012).

On the other hand, profile 3B (soybean/sugar cane not fertigated, DRO) was grouped with the metabolic quotient (CO_2q), indicating that profile 3B provides stressful environmental conditions for soil biological communities on horizon Bw_1 (Figure 5). In horizon Bw_2, the variables CEC, Ca, V, Mg, K and pH were grouped with profiles 1B (soybean/sugarcane not fertigated, DfRO) and 2B (pasture/sugarcane not fertigated, DfRO), and were positioned near the native vegetation (DfRO, 7C). Clay and silt were grouped in profile 7C (Figure 6). These results show that profiles 1B, 2B and 7C have a higher cationic exchange capacity, favoring the chemical, physical and biological soil relationships. Consequently, these systems favor a better balance of chemical and physical soil components.

Phosphorus and sand were more correlated with profile 2A (Pasture/sugarcane fertigated, DfRO) (Figure 6). These results show that, as observed by Cambuim and Cordeiro (1986), this high correlation of phosphorus with profile 2A, is not a consequence of phosphorus input from the neighboring population. In contrast, such correlation was due to the soil preparation methods and input of residues and other elements from managements prior to the sugar cane. Organic C was grouped with profile 6B (succession pasture/soybean/sugarcane not fertigated, DfRO) (Figure 6). The proximity between OM and profile 6B suggests that a dynamic soil management (as in succession) leads to more complex biotic interactions, and a greater likelihood of emerging important soil regulation properties and approaching natural conditions (Beare et al., 1995).

The biological attributes of horizon Bw_2 were grouped with profile 4B (pasture/sugarcane not fertigated, DRO) and profile 1B (soybean/sugarcane not fertigated, DfRO)

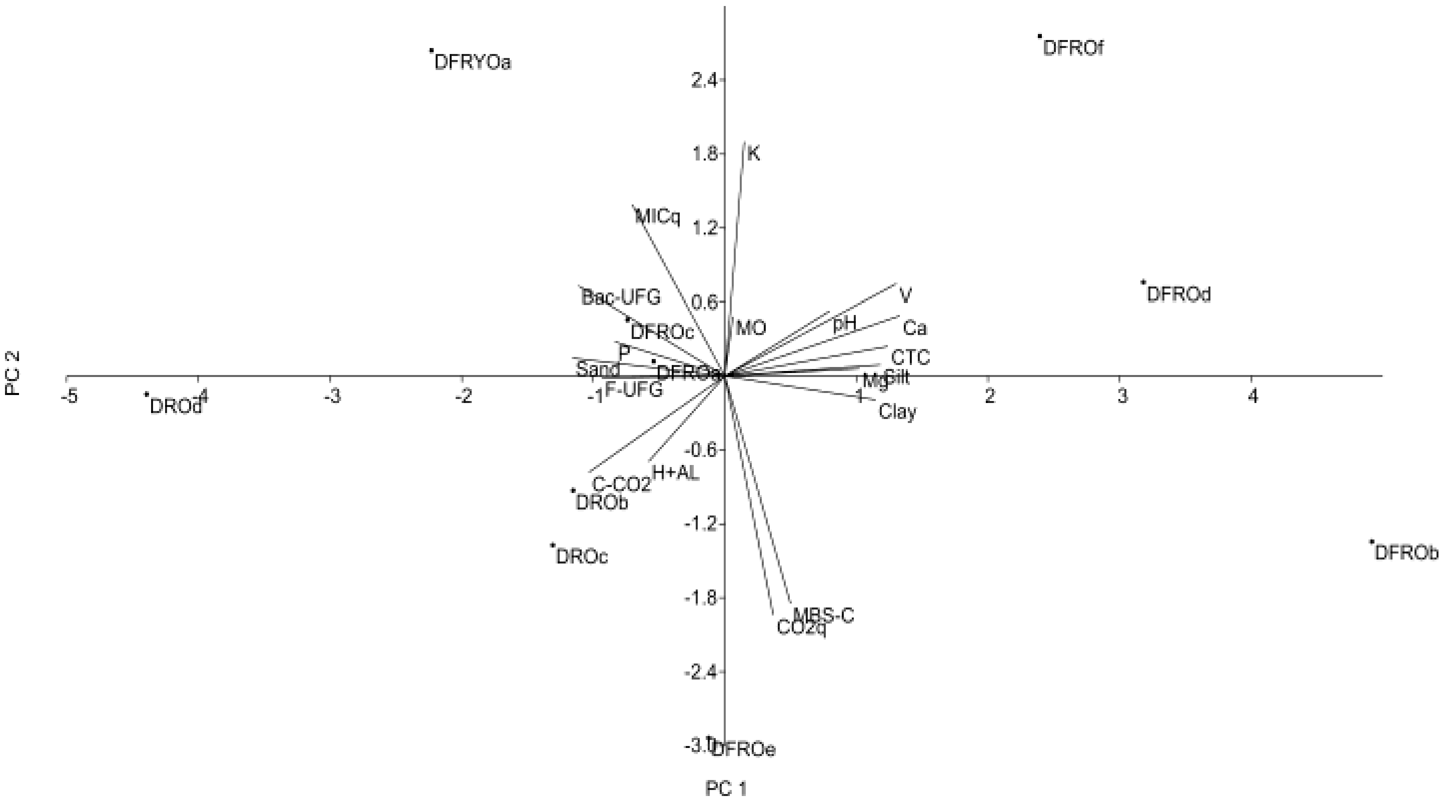

Figure 5. Principal component analysis of the physical and chemical attributes of the dystrophic (DRO) and dystroferric (DfRO) red oxisols, with different managements in Horizon Bw_1, Quirinópolis, Goiás. DfROa: 1A – soybean/sugarcane, fertigated; DfROb: 1B – soybean/sugarcane, not fertigated; DfROc: 2A – pasture/sugarcane, fertigated; DfROd: 2B – pasture/sugarcane, not fertigated; DfROe: 6B – Rotation pasture/soybean/sugarcane, not fertigated; DfROf: Semideciduous forest; DFRYOa: 3B – soybean/sugarcane, not fertigated; DROb: 4B – pasture/sugarcane, not fertigated; DROc: 5B – Rotation pasture/soybean/sugarcane, not fertigated; DROd: 8C – semideciduous forest. Physical Variables: sand, silt and clay; Chemical variables: H+Al (potential acidity); CEC (cation exchange capacity); OM (organic C); K (potassium); Ca (Calcium); pH (hydrogen potential); V (percent base saturation); Mg (magnesium); P (phosphorus); PC1 and PC2: 67.67%. Microbiological variables: CO_2q: Carbon dioxide quotient (metabolic quotient); C-CO_2: basal respiration: MICq: microbial quotient; MBS-C: microbial biomass; Bacteria (Bac-UFC); Fungi (F-UFC) (PC1 and PC2: 82.26%).

(Figure 6). Organic C preservation tends to be larger in pasture soil, because soil revolving is minimal. Carbon input is higher in pasture soil than in cultivated areas (Lathewell and Bouldin, 1981; Carneiro et al, 2008). According to Silveira et al. (2005), legumes are crucial as nutrient suppliers, once this plant group promptly provides nutrient for succeeding cultures due to the rapid residue decomposition. The previous management with soybean or pasture leads to an organic C increase and, consequently, an increase of microorganisms (Silveira et al, 2005; Carneiro et al, 2008). Profiles 4B and 1B exhibited a similar characteristic for horizon Bw_2 due to prior soil management.

The variables basal respiration (C-CO_2) and metabolic quotient (CO_2q) were grouped with profile 8C (native vegetation, DRO) (Figure 6). This correlation may have occurred due to the large amount of roots or to the deposition of organic substrates in horizon Bw_2 (Silva et al*.,* 2010).

Conclusions

The microbial biomass of the soil may be a bioindicator used to assess soil quality, once it responds to the changes caused by the two different management types (fertigated and not fertigated). The profiles undergoing culture succession before sugar cane planting favor the soil microbial community in regards to other management types. The profile previously planted with soybean in the DfRO, had the best physical and chemical conditions for the dynamic balance of the soil biomass.

The profiles with vinasse showed no improvement regarding soil microorganism development or physical and chemical conditions. Therefore, previous soil use was important to identify soil quality conditions. Better

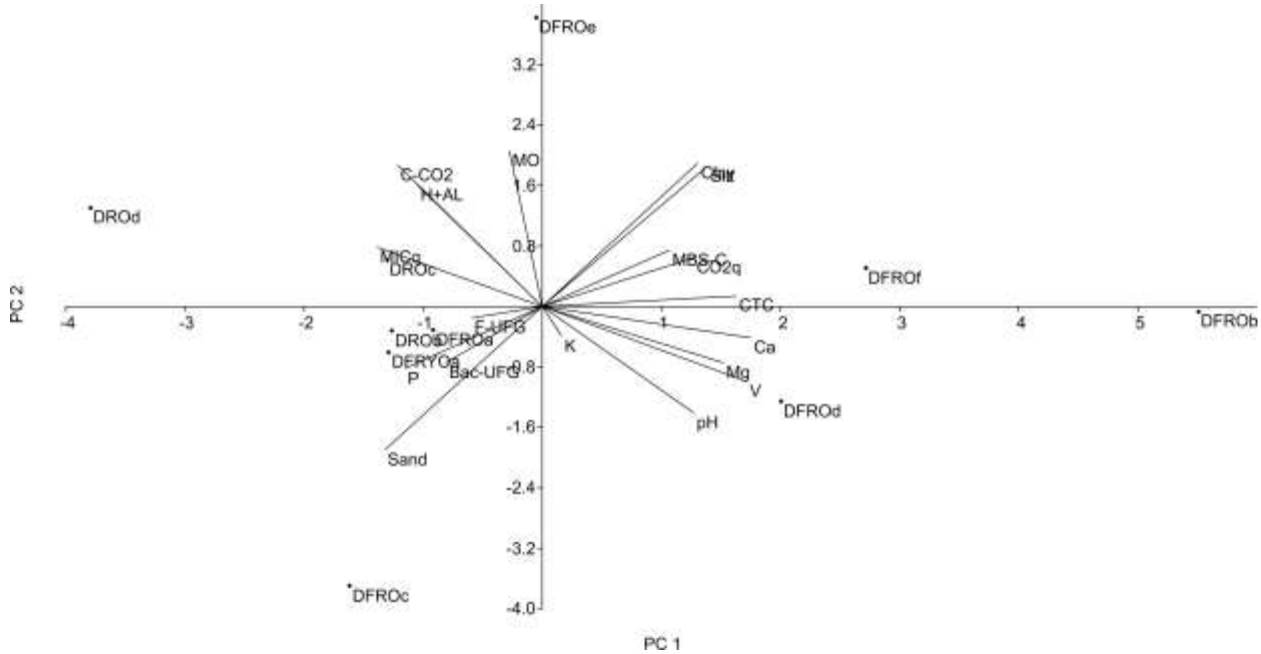

Figure 6. Principal component analysis of the physical and chemical attributes of the dystrophic (DRO) and dystroferric (DfRO) red oxisols, with different managements in Horizon Bw_2, Quirinópolis, Goiás. DfROa: 1A – soybean/sugarcane, fertigated; DfROb: 1B – soybean/sugarcane, not fertigated; DfROc: 2A – pasture/sugarcane, fertigated; DfROd: 2B – pasture/sugarcane, not fertigated; DfROe: 6B – Rotation pasture/soybean/sugarcane, not fertigated; DfROf: Semideciduous forest; DFRYOa: 3B – soybean/sugarcane, not fertigated; DROb: 4B – pasture/sugarcane, not fertigated; DROc: 5B – Rotation pasture/soybean/sugar cane, not fertigated; DROd: 8C – Semideciduous forest. Physical Variables: sand, silt and clay; Chemical variables: H+Al (potential acidity); CEC (cation exchange capacity); OM (organic C); K (potassium); Ca (Calcium); pH (hydrogen potential); V (percent base saturation); Mg (magnesium); P (phosphorus); PC1 and PC2: 72.34%). Microbiological variables: CO_2q: Carbon dioxide quotient (metabolic quotient); C-CO_2: basal respiration: MICq: microbial quotient; MBS-C: microbial biomass; Bacteria (Bac-UFC); Fungi (F-UFC). (PC1 and PC2: 78.20%).

conditions were found for soil that underwent a succession and were planted with crops prior to sugar cane.

Conflict of interests

The authors have not declared any conflict of interest

REFERENCES

Anderson JPE, Domsch KH (1993). The metabolic quotient (qCO2) as a specific activity parameter to asses the effects of environmental conditions, such as pH, on the microbial biomass of forest soils. Soil Biol. Biochem. 25:393-395.

Anderson TH, Domsch KH (1990). Application of ecophysiological quotients (qCO2and qD) on microbial biomasses from soils of different cropping histories. Soil Biol. Biochem. 22:251-255.

Beare MH, Coleman DC, Crossley DA, Hendrix PF, Odum EP (1955). A Hierarchical approach to evaluating the significance of soil biodiversity to biogeochemical cycling. Plant soil 170:5-22.

Borges VMS (2011). Formação de uma nova centralidade do setor sucroenergético no Cerrado: o caso de Quirinópolis, Estado de Goiás. 2011. 333 f. Tese (Doutorado) Instituto de Estudos Socioambientais, Universidade Federal de Goiás, Goiânia, Cambuim FA, Cordeiro D (1986) A Ação da vinhaça sobre pH, acidez total, acumulação e liviviação de nutrientes em solo arenoso. STB 4(4):27-33.

Carneiro MAC, Assis PCR, Melo LBC, Pereira HS, Paulino HB, Neto ANS (2008). Atributos Bioquímicos em dois solos de Cerrado sob diferentes sistemas de manejo e uso. Pesquisa Agropecuária tropical 38(4):276-283.

Da Silva RR, Silva MLN, Cardoso EL, Moreira FMS, Curi N, Alovisi AMT (2010). Biomassa e atividade microbiana em solo sob diferentes sistemas de manejo na região fisiográfica Campos das Vertentes – MG. Rev. Bras. Cienc. Solo 34:1585-1592.

De Luca TH (1998). Relationship of 0,5 M K2SO4 extractable anthronereactive carbon to indices of microbial activity in forest soils. Soil Biol. Biochem. 30:1293-1299.

Doran JW, Parkin TB (1994). Defining and assessing soil quality. In: Doran JW, Oleman DC, Bezdicek DF, Stewart BA. (eds). Defining soil quality for a sustainable environment. Madison, Soil Sci. Soc. Am. pp. 107-124..

Duxbury JM, Smith MS, Doran JW, Jordan C, Szott L, Vance E (1989). Soil organic matter as a source and a sink of plant nutrients. In: Dynamics of soil organic matter in tropical ecosystems. Coleman DC, Oades JM, et al. (eds.). Honolulu: NIFTAL Project. pp. 33-67.

EMBRAPA (1997). Manual de métodos de análise de solos. Centro Nacional de Pesquisas de Solos, Rio de Janeiro, Brasil, 2ª Ed. 212p.

EMBRAPA (2006). Sistema Brasileiro de Classificação de solos. Centro Nacional de Pesquisas de Solos, Rio de Janeiro, Brasil, 2ª Ed.

Filho GNS, Oliveira VL (2007). Microbiologia: Manual de aulas práticas. Editora UFSC, Florianópolis, Brasil. 160p.

Franzluebbers AJ, Haney RL, Hons FM (1999) Relationships of chloroform fumigation-incubation to soil organic matter pools. Soil Biol. Biochem. 31:395-405.
Gama-Rodrigues EF, Gama-Rodrigues AC (2008). Biomassa microbiana e ciclagem de nutrientes. In: Fundamentos da matéria orgânica do solo: ecossistemas tropicais e subtropicais. Santos GA, Silva LS, Canellas LP, Camargo FAO (eds.). Metrópole, Porto Alegre, Brasil. pp. 7-16.
Gama-Rodrigues EF (1999). Biomassa microbiana e ciclagem de nutrientes. In: Fundamentos da matéria orgânica do solo: ecossistemas tropicais e subtropicais. Santos GA, Camargo FAO. (eds.). Gênesis, Porto Alegre, Brasil. pp. 227-244.
Gama-Rodrigues EF, Barros NF, Gama-Rodrigues AC, Santos GA (2005). Nitrogênio, carbono e atividade da biomassa microbiana do solo em plantações de eucalipto. Rev. Bras. Cienc. Solo 9:893-901.
Hammer Ø, Harper DAT, Ryan PD (2001). PAST: Paleontological statistics software package for education and data analysis. Palaeontol. Electronica 4(1):9.
Hernandez-Hernandez RM, Hernandez DL (2002). Microbial biomass, mineral nitrogen and carbon content in Savana soil aggregates under conventional and no-tillage. Soil Biol. Biochem. 34(11):1563-1570.
Jenkinson DS, Powlson DS (1976). The effects of biocidal treatments on metabolism in soil. V. A method for measuring soil biomass. Soil Biol. Biochem. 8:209-213.
Junior PP (2012). Bioindicadores de qualidade do solo em cultivos de cana-de-açúcar sob diferentes manejos. Dissertação (Mestrado – Agronomia) – Universidade Estadual de Mato Grosso do Sul – UEMS, 95 f.
Kõppen W (1918). Klassifications dês klimate nach temperatur, niedershlag und jahrelauf. Petermanns Geogr. Mitt. Goth 64:193-203.
Lathewell DJ, Bouldin DR (1981). Soil organic matter and soil nitrogen behaviour inoxidizing, thiosulfate producing heterotrophs in soil. Soil Biol. Biochem. 20(4):577-578.
Lisboa BB, Vargas LK, Silveira AO, Martins AF, Selbach PA (2012). Indicadores Microbianos de Qualidade do Solo em Diferentes Sistemas de Manejo. Rev. Bras. Cienc. Solo 36:45-55.
Marchior-Junior M (1998). Carbono, nitrogênio, biomassa microbiana e atividade enzimática num solo sob mata natural ou cultivado com pastagem ou algodoeiro 1998. 89 f. Dissertação (Mestrado em Agronomia – Produção Vegetal) – Universidade Estadual de São Paulo, Jaboticabal).
Matsuoka M, Mendes IC, Loureiro MF (2003). Biomassa microbiana e atividade enzimática em solos sob vegetação nativa e sistemas agrícolas anuais e perenes na região de Primavera do Leste/MT. Rev. Bras. Cienc. Solo 27:425-433.
Mendes IC, Hungria M, Reis-Junior FB, Fernandes MF, Chaer GM, Mercante FM, Zilli JE (2009). Bioindicadores para avaliação da qualidade dos solos tropicais: utopia ou realidade? Embrapa Cerrados, Planaltina, Brasil, Documentos. 246 p.
Mendonça ES, Matos ES (2005). Matéria orgânica do solo: métodos de análises. UFV ,Viçosa, Brasil. 107p.
Mielniczuk J (2008). Matéria orgânica e a sustentabilidade de sistemas agrícolas. In: Fundamentos da matéria orgânica do solo: ecossistemas tropicais e subtropicais. Santos GA, Silva LS, Canellas LP, Camargo FAO. (eds.). Metropole, Porto Alegre, Brasil pp. 01-07.
Moreira FMS, Siqueira JO (2002). Microbiologia e bioquímica do solo. UFLA, Lavras, Brasil. 626p.
Pôrto ML, Alves JC, Diniz AA, Souza AP, Santos D (2009). Indicadores biológicos de qualidade do solo em diferentes sistemas de uso no Brejo Paraibano. Ciência Agrotecnica 33:1011-1017.
Roscoe R, Mercante FM, Mendes IC, Reis Junior FB, Santos JCF, Hungria M (2006). Biomassa microbiana do solo: fração mais ativa da matéria orgânica. In: Dinâmica da 20 matéria orgânica do solo em sistemas conservacionistas: modelagem matemática e métodos auxiliares. Roscoe R, Mercante FM, Salton JC. (eds.). Embrapa Agropecuária Oeste, Dourados, Brasil. pp. 163-198.
Salton JC, Mielniczuk J, Bayer C, Fabricio AC, Macedo MCM, Broch DL (2011). Carbono no solo e em frações da matéria orgânica do solo sob sistemas de integração lavoura-pecuária em Mato Grosso do Sul. Pesqui. Agropecu. Bras. 46:1349-1356.
Santos GA, Silva LS, Canellas LP, Camargo FAO (2008). Fundamentos da matéria orgânica do solo: ecossistemas tropicais e subtropicais. Porto Alegre: Metrópole pp. 7-16.
Santos RD , Lemos RC , Santos HG, Ker JC, Anjos LHC (2005). Manual de descrição e coleta de solo no campo. EMBRAPA, Viçosa, Brasil, 5ª Ed.
Scherer-Lorenzen M, Bonilla JL, Potvin C (2007). Tree species richness affects litter production and decomposition rates in a tropical biodiversity experiment. Oikos 116(12):2108-2124.
Schultz N, Lima E, Pereira MG, Zonta E (2010). Efeito residual da adubação na cana-planta e da adubação nitrogenada e potássica na cana-soca colhidas com e sem a queima de palhada. Rev. Bras. Cienc. Solo 34:811-820.
Silva RR, Silva MLN, Cardoso EL, Moreira FMS, Curi N, Alovisi AMT (2010). Biomassa e atividade microbiana em solo sob diferentes sistemas de manejo na região fisiográfica Campos das Vertentes, MG. Rev. Bras. Cienc. Solo 34:1585-1592.
Silveira PM, Pereira AJB, Kliemann HJ (2005). Adubação nitrogenada do feijoeiro cultivado sob plantio direto em sucessão de culturas. Pesqui. Agropecu. Bras. 40:377-381.
Trannin ICB, Siqueira JO, Moreira FMS (2007). Características biológicas do solo indicadoras de qualidade após dois anos de aplicação de biossólido industrial e cultivo de milho. Rev. Bras. Cienc. Solo 3:1173-1184.
Vezzani FM, Conceição PC, Mello NA, Dieckow J (2008). Matéria Orgânica e Qualidade do Solo. In: Fundamentos da matéria orgânica do solo: ecossistemas tropicais e subtropicais. Santos GA, Silva LS, Canellas LP, Camargo FAO (eds.). Metropole. Porto Alegre, Brasil, pp. 01-07.
Zhang Y, Zhang H, Su Z, Zhang C (2008). Soil microbial characteristics under long-term heavy metal stress: A case study in Zhangshi wastewater irrigation area, Shenyang. Pedosphere 18(1):1-10.