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Soil textural class plays a major role in evaluating the effects of land use on soil quality indicators

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ABSTRACT

Inappropriate land use that negatively affects ecological processes and soil quality is generally considered to be the primary cause of soil degradation in tropical agroecosystems. We hypothesized that in addition to land use, soil textural class also has an important effect on ecological processes and soil quality. To test our hypothesis, effects of land use change on soil organic fractions as well as microbial and biochemical indicators were quantified for clayey and sandy-clay-loam soils within the native Cerrado biome, pasture (*Brachiaria brizantha*) and sugarcane (*Saccharum officinarum*) agroecosystems in southwestern Brazil (Minas Gerais state). Labile carbon, humic substances, soil microbial respiration (SMR), microbial biomass carbon (MBC), metabolic quotient (qCO_2), hydrolysis of fluorescein diacetate (FDA), beta-glucosidase, urease, phosphatase and arylsulphatase activities were measured for each sample. Labile carbon concentrations were not affected by land use but were lower in sandy-clay-loam soil than clayey soil. Humic substances were at the highest concentrations in the native Cerrado and the lowest in sugarcane agroecosystems. Sandy-clay-loam soil had lower humic acid concentrations than clayey soil. Soil microbial indicators (SMR, MBC and FDA) showed lower values in pasture and sugarcane agroecosystems than in the native Cerrado. FDA was a more sensitive microbial indicator than SMR and MBC for detecting land use and textural class differences. The qCO_2 indices were greater in sugarcane systems than in either pasture or native Cerrado systems. The activity of exocellular hydrolytic enzymes, such as beta-glucosidase, urease, phosphatase and arylsulphatase, was smaller in sugarcane and pasture agroecosystems than in native Cerrado ecosystems. Within the same land use, the activity of these enzymes was always greater in clayey soil than in sandy-clay-loam soil, indicating a higher impact of land uses on enzyme activities in clayey soils. Results for the measured indicators support the hypothesis that soil textural class plays a major role in assessing differences between land use systems in the Brazilian Cerrado biome.

1. Introduction

The Brazilian Cerrado has a semi-humid climate and, therefore, is one of the most humid savanna regions of world. It occupies an area of about 204 million ha (approximately 22% of the Brazilian territory) and is the second largest biome in the country. The use of Cerrado soils for productive agricultural activity has been intensified since 1970 (Batlle-Bayer et al., 2010) and includes areas of sugarcane, pasture and annual crops. The sugarcane area in the Cerrado region has increased greatly in the recent years due to ethanol production. Grazing is also a major agricultural activity in the region, mainly used for beef cattle production. Long-term impacts of these agroecosystems, especially, on soil microbial and biochemical indicators are needed to quantify land use and soil type effects.

Changes in land use are one of the most important human activities affecting ecosystem function and impacting soil quality and health (Sylvia et al., 1999; Paul, 2007; Miralles et al., 2012; Vinhal-Freitas et al., 2013). Thus, tropical agriculture has a direct impact on soil chemical, physical, and biological properties when compared with native soil cover (Vinhal-Freitas et al., 2013). In addition, soil texture, defined by the granulometric fraction, influences soil function which changes the intensity of ecological soil processes (Sylvia

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et al., 1999; Dexter, 2004; Dieckow et al., 2009; Paul, 2007; Sugihara et al., 2010). Further studies involving land use and soil texture are still required to assess soil quality in tropical agroecosystems.

Soil organic matter (SOM) is a property that influences soil function and contributes directly to plant and microbial growth through its effects on the chemical, physical, and biological properties of soil (Stevenson, 1994; Batlle-Bayer et al., 2010). Transformation of organic carbon in soils has a direct link to soil microbial attributes (Paul, 2007). One of the results of this transformation in soils is the formation of stable organic fractions consisting of humin and humic and fulvic acids (Stevenson, 1994; Paul, 2007). In long-term agricultural systems, these humic substances are lost due to intensive land use, impacting on soil carbon stock and soil quality (Batlle-Bayer et al., 2010). Studies have shown that the concentration of these constituents depends on soil management and soil type (Masciandaro and Ceccanti, 1999; Lugato et al., 2009; Miralles et al., 2012; Guimarães et al., 2013; Raiesi and Beheshti, 2015). Evidence in literature has shown a positive relationship between clay content and SOM (Dieckow et al., 2009; Wei et al., 2014).

Soil microorganisms are the main responsible for synthesis and release of exocellular hydrolytic enzymes involving carbon (beta-glucosidase), nitrogen (urease), phosphorus (phosphatase) and sulfur (arylsulphatase) cycles in soils. Exocellular hydrolytic enzymes act on the organic matter decomposition and nutrients are released into the soil solution, which become available for microorganisms and plant growth. Besides the enzymes, there are many biochemical parameters that are indicators of microbial activity, such as soil microbial respiration (SMR), microbial biomass carbon (MBC), fluorescein diacetate activity (FDA) and metabolic quotient (qCO_2). In literature, there have been many studies on enzymes and microbial indicators in soils (Doran and Parkin, 1994; Nielsen and Winding, 2002; Lagomarsino et al., 2009; Vinhal-Freitas et al., 2013), but more studies regarding soil function are still necessary in tropical ecosystems. In addition, soil enzyme activities and microbial properties are more sensitive in assessing changes in soil use and management (Visser and Parkinson, 1992; Gil-Sotres et al., 2005; Trasar-Cepeda et al., 2008; Liu et al., 2016; Rincon-Florez et al., 2016).

Soil texture affects microbial activity by directly affecting water content and the temperature of soil (Chodak and Niklińska, 2010; Sugihara et al., 2010). The textural class is also important for soil aggregation and porosity. In addition, soil texture plays a key role in gas exchange (respiration of roots and microorganisms) between soil and atmosphere. Heavily-textured soils, within the same soil class, have a greater microbial activity and carbon stock than light-textured soils. Thus, soil texture is an important component in assessing the soil fragility to different land uses in agroecosystems (Dieckow et al., 2009; Wei et al., 2014). Studies of microbial and biochemical indicators and soil texture can lead to a better understanding of the ecological processes and soil function. Accordingly, we hypothesized that soil textural class plays an important role to evaluate the effects of land uses on soil quality indicators in the Brazilian agroecosystems. Therefore, the present study aimed to evaluate the impacts of land use systems in two soils with different textural classes on organic fractions, microbial and biochemical indicators of soil quality under the native Cerrado ecosystem, pasture and sugarcane agroecosystems.

2. Materials and methods

2.1. Sites

The study was performed in areas located near Uberaba and Uberlandia cities in the state of Minas Gerais, Brazil. The climate is classified as Cwa according to Köppen (Alvares et al., 2014), and is characterized by a well-defined dry season during fall-winter (April to September) and a hot and rainy season during spring-summer (October to March). Both soils were classified as Typic Acrustox (Soil taxonomy- USDA, 1992), one with a very clayey texture (Uberaba region) and the other one with a sand-clay-loam texture (Uberlandia region) (Table 1). In both areas, three sites with different land use systems were evaluated. The first site is a native Cerrado, and its plant species can be found in Vinhal-Freitas et al. (2013). The second site is a pasture, with *Brachiaria brizantha* (Capim braquiária) as the predominant species, and it has been used for cattle grazing for over 18 years. The third site is a sugarcane crop (*Saccharum officinarum*), grown for over 8 years. This site, before it was a sugarcane plantation, was used for annual crops (soybeans and corn).

2.2. Soil sampling

Soil samples from each study area were collected during the rainy season, in January and October 2012, from the top 0–5 and 5–10 cm of soil. In each area, four points were sampled within roughly a 1 ha area. Four subsamples (spaced 5 m apart) were collected from each point to form a composite sample, totaling 16 samples per area studied (2 periods x 2 depths x 4 replicates). The samples were conditioned in a sealed plastic bag and transported to the laboratory where they were sieved (2 mm sieve) and stored in a plastic bag in a refrigerator at 4°C. Microbial and biochemical analyses were performed within 5 days.

2.3. Physical and chemical characterization

Particle size distribution (texture) of the soil was determined using air-dried samples according to the pipette method (Gee and Bauder, 1986; EMBRAPA, 1997) (Table 1). The following chemical analyses were performed: pH in water (1:2.5 soil/water); soil organic carbon (SOC) determined according to Yeomans and Bremner (1988); total nitrogen (NT) by the Kjeldahl method (Black, 1965); P, K^+, Ca^{2+}, Mg^{2+} and Al^{3+} were determined according to Tedesco et al. (1995), in samples which had been dried, sieved (<2 mm) and crushed in a porcelain crucible.

2.4. Analysis of labile carbon and humic substances

The labile carbon was determined in air-dried soil samples (Blair et al., 1995). Humic substances were extracted according the International Society of Humic Substances (Swift, 1996). Humic acid (HA), fulvic acid (FA) and humin fractions (HF) were obtained based on differential solubility in alkaline and acid solutions. Humic C was determined for each fraction by dichromate oxidation (Yeomans and Bremner, 1988). A portion of soil (0.5 g) was transferred into a falcon tube (50 mL) with 25 mL of $KMnO_4$ (33 mmol L^{-1}). The solution was agitated for an hour and then centrifuged at 5,000 × *g* for 5 min. Then, 1.0 mL of supernatant was transferred into a 250 mL volumetric flask, and distilled water was added to complete the volume (250 mL). Aliquots of 1.0 mL from six standard $KMnO_4$ solutions, with concentrations ranging from 25 to 33 mmol L^{-1}, were diluted in the same manner, and the absorbance of the diluted solutions was determined in a spectrophotometer at 565 nm. Variations in $KMnO_4$ concentration, estimated from a standard-curve, were used to estimate the concentration of labile carbon assuming that 1.0 mol of MnO_4^- is consumed by the oxidation of 0.75 mol (9 g) of carbon.

2.5. Soil microbial respiration and microbial biomass carbon

Soil microbial respiration (SMR) was measured by the CO_2 released from 100 g samples of field moist soil in 500 mL hermetically sealed bottles (Stotzky, 1965) at 25°C for 10 days.