ENZYMATIC ACTIVITY AS AN EARLY SENSOR IN THE EVALUATION OF SOIL QUALITY IN SILVOPASTORAL SYSTEMS

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ABSTRACT
The demand for food has intensified at the rate that the world population has grown, requiring production models capable of meeting world needs, through high productivity and conciliating with sustainable practices. In this scenario, the silvopastoral system (SPS) has been introduced as an alternative to current production models. Thus, this study aimed to evaluate the current soil condition in an SPS using chemical and microbiological parameters as indicators of soil quality, using a native forest and degraded pasture as a positive and negative reference, respectively. For this, soil samples were collected at a depth of 0-10 cm, and the total carbon and β-glycosidase activity (BGL) were determined. Both SPS sub-areas, in the tree rows (SPS-R) and between rows (SPS-BR) showed potential to store carbon over time. The BGL activity was the parameter that showed greater sensitivity to the land use management, the biological potential of the SPS, and the increased enzymatic activity in the SPS-R as a function of adding trees. The current results showed that low productivity pasture areas' conversion into integrated systems improved both chemical and microbiological soil quality.
Key words: soil quality; enzymatic activity; β-glycosidase

INTRODUCTION

The predicted population increase and the demand for food on the planet, with a role expected from Brazil to meet part of this demand, have driven the expansion of agricultural activities and livestock (BOMMARCO; KLEIJN; POTTS, 2013). However, several environmental problems can be triggered with the expansion, such as the increase in natural resources exploitation.

In this context, the development of sustainable systems has become a topic of global interest and has been used to reverse this situation to satisfy human needs and increase environmental quality. Conservationist practices, such as the use of integrated production systems, have gained prominence, as the adoption of these practices has shown positive effects on both soil chemical and biological attributes (CASTRO LOPES et al., 2018; MENDES et al., 2021, 2019).

The elements and energy contained in organic waste are recycled to maintain balance on Earth. Decomposition and mineralization are processes carried out by enzymes released by living soil organisms (microorganisms and plants) and with outstanding contribution from the microbiota (GHOSH et al., 2020; ZHOU and STAVER, 2019). Furthermore, the abiotic component also contributes to the total sum of enzyme activity, coming from past generations of organisms that lived on the site (non-viable cells). Such enzymes accumulate in the soil and are protected from proteases' action through adsorption on clays and organic matter. In this regard, about 40% to 60% of enzyme activity may come from stabilized enzymes and not necessarily be related to living organisms (WALLENSTEIN and BURNS, 2015).

In the soil, cellulose decomposition is performed synergistically between three cellulases, the endoglucanase, exoglucanase, and β-glycosidase, where the first two enzymes act in the cleavage of polysaccharides, and β-glycosidase completes the final hydrolysis stage converting cellobiose to glucose (SATYAMURTHY et al., 2011; SINGHANIA et al., 2013). With these processes in mind, great emphasis has been given to β-glycosidase (BGL), one of the most found enzymes in the soil, which acts in the final stage of cellulose degradation, and decides the rate of conversion of cellulosic compounds into glucose (TABATABAI, 1994). In general, BGL has demonstrated the ability to respond quickly to the adopted management and has been considered important as a bioindicators of soil quality (MENDES et al., 2021).

A series of studies must be carried out to validate and promote the adoption of silvopastoral systems. Therefore, this study aimed to evaluate two sub-areas of a silvopastoral system under conditions of tropical climate, in the Atlantic Forest biome, in the chemical (total carbon) and microbiological (enzymatic activity) attributes.

MATERIAL AND METHODS

The field experiment was installed at Embrapa Southeast Livestock (21º58 'S and 47º50' W), located in São Carlos, São Paulo state, Brazil. The experimental design was completely randomized and counted with two grazing systems with two replicates per system plus a native forest, here called: i) degraded pasture (DEG); ii) Silvopastoral system with moderate animal stocking rate (SPS) and iii) native forest (NF).

Pastures in the DEG area were established in 1996 with *Brachiaria decumbens* cv. Basilisk under continuous stocking, extensive management and has not been limed or fertilized. Pastures in the SPS were established in same conditions of DEG system. However, in 2008 were planted native forest species. Since then (2008), this system is being managed in a rotational grazing system with six days of occupation and 30 days of rest cycles, as well as being corrected and fertilized with phosphorus and potassium. Each grazing unit (replica) comprises 3.3 ha divided into six paddocks, managed in a rotating system with 6 x 30 days cycles, receiving applications of 40 kg of N-urea ha^{-1} during the rainy season. The SPS trees were planted in sets of three rows, with a distance between 2.5 m x 2.5 m, and spaced 17 m apart from each other, resulting in 545 trees ha^{-1}. The native species planted on the mead row were: "Angico-Branco" (*Anadenanthera colubrina*); "Canafístula" (*Peltophorum dubium*); "Ipê-Felpudo" (*Zeyheria tuberculosa*); "Jequitibá-Branco" (*Cariniana estrellensis*) and "Pau-Jacaré" (*Piptadenia gonoacantha*). To ensure that these species grew straight boles with a minimum of lower branches, the two species "mutambo" (*Guazuma ulmifolia*) and "capixingui" (*Croton floribundus*) were planted in an alternating sequence in the two outer lines of each tree strip. In July 2016, trees were thinned, which consisted of cutting 50% of the trees in each external row, resulting in 350 trees ha^{-1}. Also, the systems were compared with natural vegetation, the Atlantic Forest (Subcaducifolia Tropical Forest).

The soil samples were collected in the dry season at a depth of 0-10 cm. In the SPS system, soils were collected in the tree rows (SPS-R) and between rows (SPS-BR) at three random points along each sub-area. Three samples were also collected for the DEG and NF systems. The soil samples were air-dried and ground to pass through a 2 mm sieve. Then they were stored under refrigeration at ± 4 ºC until analyzed.

The total carbon (TC) content was determined by dry combustion using an elemental analyzer as chemical analysis. As a microbiological analysis, the β-glycosidase (BGL) enzyme activity was measured according to the procedure described by TABATABAI (1994). These procedures are based on the determination of the p-nitrophenol formed after adding the specific substrate, the p-nitrophenyl-β-D-glycopyranoside for BGL.

RESULTS AND DISCUSSIONS

The different land uses and management had significant effects on the carbon content and enzymatic activity in the topsoil, as shown in Table 1.

Table 1. Total carbon (TC) and β-glycosidase (BGL) activity in the evaluated systems. Silvopastoral system in the tree rows (SPS-R) and between rows (SPS-BR); native forest (NF) and degraded pasture (DEG). The same letters on the same line do not differ at the 5% level of significance.

	SPS-R	**SPS-BR**	**NF**	**DEG**
TC (g kg^{-1})	20.9±3.3 a	19.0±2.1 a	37.4±2.6 b	16.2±1.7 a
BGL (μg p-nitrophenol g^{-1} soil h^{-1})	111±4 a	85±3 b	104±6 a	50±4 c

The carbon content varied according to the soil use. The highest content was found in the native forest and the lowest in the degraded pasture (Table 1). The low carbon content in the degraded pasture may be due to the decline in the entry of organic material, concomitantly with the trampling caused by grazing, making the soil vulnerable to degradation. The higher carbon content in the native forest, on the other hand, is due to the continuous supply of organic matter and decreased anthropic disturbance in this area (QIAO et al., 2014).

Also, the soils in the SPS showed no statistical difference compared to the DEG, and the same behavior was observed between the sub-areas SPS-R and SPS-BR. On the other hand, this management's adoption caused an increase of 17% and 29% in the carbon content in SPS-R and SPS-BR, respectively, to degraded pasture. Conservation systems induce changes in the percentages and carbon stock in the soil in the medium and long term, in transition and consolidation stages (LOSS et al., 2016). Freitas et al. (2020) reported that the conversion of degraded pastures to agrossilvipastoral systems promoted an increase in carbon and nitrogen stocks after three years of implementation in the Brazilian Cerrado. On the other hand, VERGUTZ et al. (2010) showed that the soil's carbon stock occurred only after 12 years of adoption and good management practices. In this study, after 12 years of collecting these soils, it is possible to infer that if good management practices continue, this system has great potential for storing carbon in the soil.

Besides carbon, the enzymatic analysis showed different behaviors among the different soil uses but with greater sensitivity in the differences (Table 1). The BGL activity was higher in the SPS-R system and native forest, where both showed no statistically significant difference, whereas the degraded system showed the lowest enzymatic activity. As much as SPS-R showed lower carbon content than the native forest, both soils showed similar enzymatic activity. One possible explanation may be since the microbiological fauna of this location is more selective and promotes greater conversion of substrate into the product over time (OH et al., 2018). Another hypothesis may be because a large amount of these enzymes are stabilized by humic substances or clays, forming complexes, where the enzymatic activity is independent of microbial regulation (WALLENSTEIN and BURNS, 2015).

Also, studies show that organic matter changes can take years to be detected, whereas enzyme activity can provide reliable results of changes in less time (MENDES et al., 2021; 2019). Therefore, the increase in enzyme activity reflects the increase in biological activity in this soil. This over time, indicates that this system favors the accumulation of carbon, even though the increase in the enzyme activity in the initial stages is not linked to the effective increase in the organic matter content (MENDES et al., 2020).

Additionally, a significant difference ($p < 0.05$) was detected for BGL between the sub-areas of the SPS system (SPS-R and SPS-BR), but this effect on the carbon content was practically negligible. Not only quantity, but the substrate's quality is also a factor to be considered in the enzyme activity, and, according to its composition, be easier or more difficult to degrade (SIX et al., 2006). More easily oxidizable compounds released by tree exudates, which have a lower degree of lignification, may increase the enzyme activity in SPS-R compared to SPS-BR.

Another fact to consider is that the lower carbon content in the degraded system is accompanied by the lower entry of matter labile organic content for the microbial population, which explains the lower enzymatic activity compared to the other systems.

CONCLUSIONS

Both SPS-R and SPS-BR showed potential to store carbon over time. In addition, through the enzymatic activity it was possible to highlight the role of trees in increasing the BGL activity in the soils collected between the rows of trees. This observation indicates biological income for this type of management that has been gaining prominence over the years. Therefore, among the indicators, the enzymatic activity showed greater sensitivity in the results, and was the parameter that most readily responded to different uses and soil management.

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