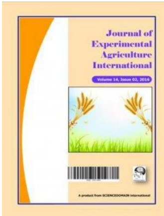

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Biological Activity as an Indicator of Soil Quality under Different Cultivation Systems in Northeastern Brazil

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Authors' contributions

This work was carried out in collaboration between all authors, each one being responsible for one or more steps. The author AP was the supervisor of the master dissertation that originated the scientific article and responsible for the development of the project that originated the dissertation, besides the responsibility of the soil sample collection guidelines in the field, besides reviewing the written article, ordering the text. The author EPBF was responsible for the guidelines of the microbiological analyzes. The author SJRA updated the bibliographic review and the bibliographical citations after the article written. The author RNAF translated the article into English language. The authors RRGF and FSRH formatted the article for publication, besides the revision of the translation into the English language. The author OSO conducted the study, collected the analyzes in the field and did the statistical analysis of the data coming from his dissertation. All authors read and approved the final manuscript.

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ABSTRACT

The objective of this work was to evaluate biological indicators in areas of different land uses in the northeastern region of Brazil. Agricultural areas, located in the municipality of Simão Dias, were selected for the collection of deformed soil samples in the 0-10 cm layer. The areas studied were VNT - native vegetation of caatinga; CTA - pasture of Tanzania grass intercropped with algarobeira; MCF - corn intercropped with beans in conventional cultivation; MPC - corn in monoculture under conventional cultivation and MCM - corn in monoculture under minimum cultivation. The analyzes were total enzyme activity, urease activity, acid phosphatase, β-glucosidase, microbial biomass nitrogen, microbial biomass carbon, soil basal respiration and metabolic quotient. The results were submitted to ANOVA and Tukey's test at a significance level of 5%. The results showed that the most conservationist systems of soil use provided better results through the microbiological indicators: total enzyme, ureic activity and soil microbial biomass. The indicators of acid phosphatase and β-glucosidase activity showed a significant reductions in the soil under anthropic management. They markedly in monoculture of the corn crop and conventional cultivation. The levels obtained are directly related to the different uses of the soil. We propose to make them suitable for soil quality assessment and, therefore, potential indicators for the analysis of environmental sustainability in semi-arid northeastern region Brazil. The results obtained reinforce the need for improvements in the management adopted so as not to compromise the quality of the agricultural soils of the semi-arid region.

Keywords: Sustainability; microbiological parameters; soil quality; microbial biomass; soil enzymes.

1. INTRODUCTION

Agricultural use of intensive and conventional cropping systems based on the use of chemical fertilizers and agrochemicals can modify the soil quality [1]. The soil quality is understood as the ability of this to function within an ecosystem aiming at sustaining productivity, environmental quality, in addition to promoting the health of plants and animals, and can be measured by chemical, physical and biological indicators alone or together [2].

In the last decades, the biological indicators of soil quality have gained highlight [3] and [4], as indicators of changes soil quality and environmental, since they are considered predecessors to the chemical and physical changes undergone by the soil [5].

Among the main biological indicators, the soil microbial community and its activities are responsible for numerous processes and functions, such as the decomposition of residues, nutrient cycling - Carbon (C), Nitrogen (N), Phosphorus (P) and Sulfur (S), synthesis of humic substances, aggregation of soil particles, as well as participation in the soil water cycle through interactions with fauna and soil physical and chemical properties [6] and [7].

Transformations mediated by microbial biomass are catalyzed by enzymes that participate in intercellular metabolic reactions, organic waste decomposition (ligninases, cellulases, proteases, glucosidases, galactosidases), nutrient cycling (phosphatases, amidases, sulfatases), formation of organic matter and structure [8]. For this reason, enzymes have been emphasized as a sensitive indicator to detect differences and changes due to the influence of anthropic actions [9].

Difficulties in interpreting quality biological indicators are one of the major obstacles to be transposed in soil quality assessments [5]. Thus, it is necessary to identify the biological indicators that are most sensitive to changes in soil quality with easy measurement for a tropical region, where an average annual temperature and a higher thermal amplitude is lower, favoring the rapid decomposition of organic residues in the soil. This identification will enable a clear definition of the real conditions of soil quality in the region, being important subsidy the greater guarantee of agricultural production with higher levels of sustainability.

In view of the above, this work had as objective to evaluate biological indicators in areas of different land uses in the Agreste and Semiarid regions of Sergipe.

2. MATERIALS AND METHODS

Field work was conducted at three localizations: Riachão Farm 10º 40 '25.1 "South and 37º 46'

35.4" West, Settlement Eight October 10º 41 '02.5 "South and 37º 45' 52,1" West and Fazenda Recanto 10º 43 '55.6 "South and 38º 04' 23.5" in the municipality of Simão Dias, state of Sergipe, northeastern Brazil. The climate is classified as Aw according to Köppen, the average annual rainfall is 917 mm and the average annual temperature is 25.1 °C. The soil of the studied areas were classified in YELLOW RED ULTISOL, according to EMBRAPA (2013) [10].

Samples soils with five replicates were collected to analyze microbiological in the 0-10 cm layer in areas with different soil uses: native vegetation of caatinga - VNT; Tanzanian grass pasture associated with algarobeira - CTA; corn and bean intercropping in conventional system of cultivation - MCF; monoculture of maize in conventional system of cultivation - MPC and corn monoculture in minimum cropping system - MCM.

The areas of agricultural use have had a history of superior exploitation for thirty years, and MPC and MCM have been engaged in mechanization of crops, genetic improvement of maize seeds and chemical inputs (fertilizers, insecticides and herbicides) for six and four years. The collected material was kept under refrigeration from the collection to the laboratory analyzes.

Laboratory analyzes were performed at the Embrapa Rice and Bean Soil Biology Laboratory in Goiânia (GO), obeying the operational protocol [11], being determined in triplicate. As biological indicators of soil quality, eight parameters were used: total enzyme activity (AET), urea activity (UA), acid phosphatase activity (APA), β-glucosidase activity (GA), microbial biomass nitrogen contente (MBN), microbial biomass carbon contente (MBC), soil basal respiration (RBS) and metabolic quotient (qCO_2).

For the determination of the biomass indicators, the fumigation-incubation method was used in the evaluation of the nitrogen content of the microbial biomass, according to Brookes et al. [12], with the correction factor KN of 0.54. Distillation was performed by the Kjeldahl method and the titration was done with 0.0025 N sulfuric acid. For the carbon content of the microbial biomass, the fumigation-incubation method was used, according to Vance et al. [13] using the correction factor Kc of 0.33 and correction of humidity to 80% of the field capacity. Carbon determination was carried out by oxidation of carbon with potassium dichromate in sulfuric medium and titration with ammoniacal ferrous sulfate.

Basal respiration was determined according to Vance et al. [13]. The metabolic quotient (qCO_2) was obtained by the relationship between the basal respiration rate, which is the measure of the CO_2 production, resulting from the metabolic activity in the soil, by the carbon unit of the microbial biomass [14]. For the determination of the total enzymatic activity (AET), the hydrolysis method of fluerescein diacetate (FDA) was used, according to Ghini et al. [15]. The evaluation of the activity of acid phosphatase (APA), β-glucosidase (GA) and urease activity (UA) was determined according to Tabatabai [16]. The quantification of each was done by determining the standard curve by plotting the absorbance versus concentration of standard solutions in isolation.

For the evaluation and statistical analysis of the microbiological parameters studied, the Tukey's test was used at the significance level of 5% through the Sisvar program [17].

3. RESULTS AND DISCUSSION

The data of Fig. 1 presented statistically significant differences for total enzyme activity (AET) according to land use. The AET under native vegetation of caatinga (VNT), was statistically superior in comparison to the other uses of the soils. This was due to the large number of hydrolytic enzymes produced by the microorganisms, being an important tool to assess soil quality, in several factors such as climate, environmental changes and soil management. [18] and [7].

Similar results of higher levels of AET in native vegetation area were observed by Evangelista et al. [19], this may be due to the large amount of organic matter under the soil surface of the study areas favoring a larger non-soil microbial biomass, therefore, higher enzymatic activity.

Following the soil management of the studied areas, it was verified that in relation to the VNT, the CTA, presented a reduction of 37.90% of the level of total enzymes measured in the soil. MCM, MCF and MPC, respectively, showed reductions of 28.31% and 41.52% of the quantitative total enzymes measured in soil with respect to CTA, and the area under minimum cultivation did not differ statistically from CTA.

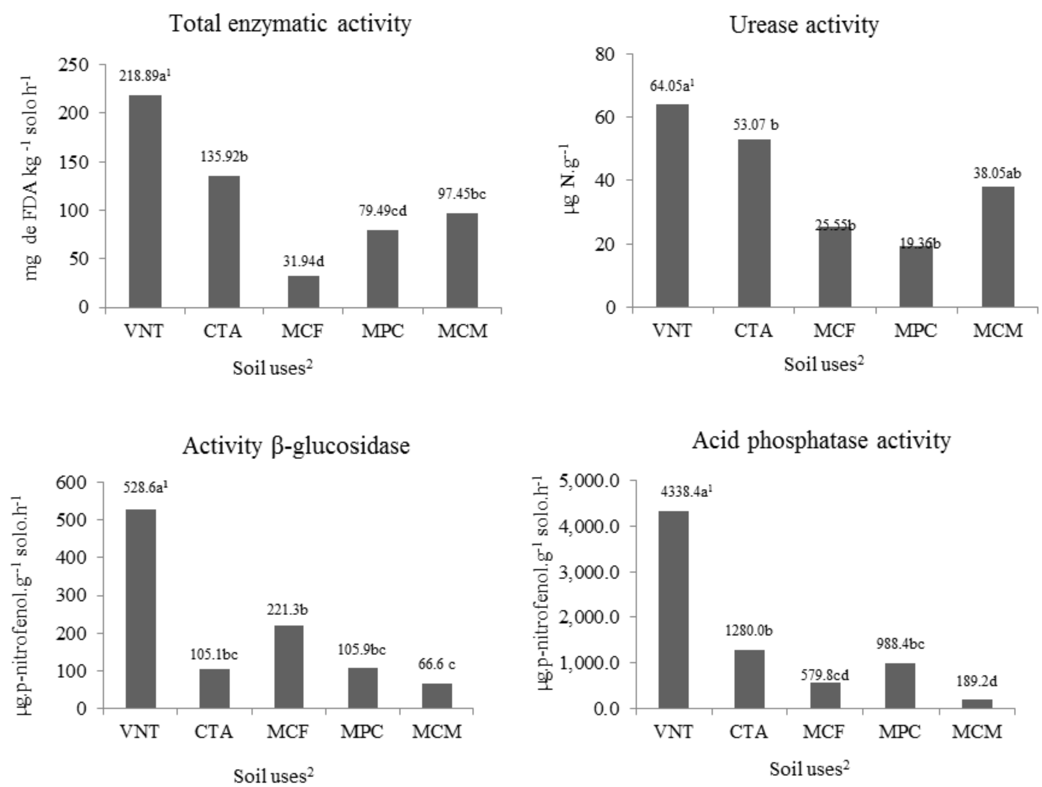

Fig. 1. Behavior of the different enzymatic parameters in soil samples from areas under different uses. [1]Averages followed by the same letter do not differ among themselves by the Tukey test at 5% probability. [2]VNT = native vegetation of caatinga; CTA = pasture of tanzania grass intercropped with algarobeira; MCF = corn intercropped with beans in conventional cultivation; MPC = corn in monoculture under conventional cultivation and MCM = corn in monoculture under minimum cultivation

The soil with MCF presented the lowest quantitative total soil enzymes, corresponding to only 14.59% of the contents found in the VTN (Fig. 1).

It should be noted that the results indicate that there was an improvement in the AET of the soil cultivated with maize when it was adopted MCM soil conservation systems in relation to the use of conventional soil preparation systems MCF and MPC. This behavior can probably be attributed to forms of soil use that provoke different intensities of soil mobilization, altering its structure, humidity, temperature and exposing organic matter present to rapid degradation due to the high temperatures and thermal amplitude of the region [20].

The degradation accelerated of the organic matter causes rapid release of elements, decreasing of the community of microorganisms, and synthesis of enzymes [7]. In this way, soil management that adopts conservationist practices tends to mobilize less soil, to accumulate higher levels of organic matter promoting beneficial results to the edaphic and microbiological properties of the soil [21]. According to the results found by Ferreira et al. [22], observed that among the evaluated cropping systems, the system of direct sowing (conservation system) differed statistically from the conventional plantation, presenting higher levels of AET.

Considering the results with corn cultivation, it can be said that the adoption of conservation systems should be preferred to conventional farming systems. Another important aspect observed in the corn areas used in this study is the fact that the AET results showed a direct and consistent relationship with the average maize yield. Thus, it was observed locally that the 22% increase in total enzyme activity (Fig. 1) provided a 66% increase in corn productivity when grown as a monoculture in the minimum growing system (MCM) over the conventional cropping system (MPC), reinforcing the beneficial effects of the use of conservationist systems of cultivation in these areas, with typically tropical soil and climatic conditions.

Based on the results obtained, VNT, followed by agricultural areas using CTA and MCM conservation systems, promoted an increase in the total activity of hydrolytic enzymes within the living cells of the microorganisms, in relation to the use of conventional soil preparation systems MCF and MPC. It was observed that there is a promotion of the hydrolysis of fluorescein diacetate, which is a good indicator of soil quality improvement, due to the good estimation of the total microbiological activity of the soil [23], since the amount of fluorescein produced is directly proportional to the microbial population [24].

The values of urease activity (Fig. 1) showed a similar behavior to that observed for AET, in which, higher values were obtained in VNT followed by CTA and the lower rates found in maize growing areas. There was also a trend of increased urease activity in the area under minimum cultivation compared to the other two forms of conventional maize cultivation - MPC and MPF. Similar data were found by Freitas [25], where all cultivated areas presented values significantly lower than those shown for areas under native cerrado. The activity of this enzyme can provide indications about changes in nitrogen cycling, showing that the results show the negative effects promoted by inadequate soil management.

In the data collected (Fig. 1), a decrease of 67.76% to 60.11 of the urea was observed when comparing the area under native vegetation with the areas under conventional system. Areas under conventional cultivation decreased of 49.11 to 32.85% in comparation with minimum cultivation. This evidencing a strong influence of the management system under the weed produced by the microbial community of the soil. As highlighted by Doran and Parkin [26], the soil use system has great influence on the enzymatic activity.

When evaluating the distribution and correlation of urease with organic matter and nutrients, in soil samples from Ranga Reddy, India, Kumari et al. [27] identified that soil urease activity levels tend to increase according to the elevation of organic matter content present. On the other hand the conservationist systems of preparation as already mentioned tend to present higher levels of organic matter when compared to the conventional systems of cultivation. Thus, the observed behavior for the urea (Fig. 1) confirms the tendency that soil use in conventional systems, favorece a conditions for a lower supply of organic materials on the soil surface to the microbiota, thus compromising the enzymatic activity.

The levels of β-glycosidase activity and acid phosphatase in the soil of the VNT were statistically higher when compared to soil under different uses. Similar behavior was recorded for urease and AET, as shown in Fig. 1. These two soil enzymes, as well as urease, can be complexed and stabilized by the organic matter present in the soil, protecting them from biodegradation. Therefore, soils with higher levels of organic matter tend to present higher enzymatic activities [4], corroborating the data presented in this study.

Similar results were also found by Ferreira et al. [22], when evaluating the effects of the direct and conventional management systems on attributes of microbial biomass, enzymatic activity and microorganisms population, where the values of β-glycosidase and acid phosphatase were higher in the native forest soil. In turn, the production of β-glucosidase in the area MCF and MPC, presented higher values than those found in the areas under pasture and minimum cultivation. The same behavior was also observed for acid phosphatase whose MPC and MCF values were higher than those found in the MCM area, exhibiting behavior different from that seen for AET and urease. In this way, it was observed that in areas cultivated with maize they contributed to decreases in phosphatase relative to the native area in the following order: 23 times for the minimum cultivation system, 7.5 times for corn intercropped with beans, 4.4 times for conventional maize and 3.4 times for areas used with pasture associated with algarobeira.

The β-glycosidase is bound to the carbon cycle and acts at the final stage of the cellulose decomposition process, hydrolyzing the cellobiose residues [28]. As cellobiose is a disaccharide of rapid decomposition in the soil, the greater activity observed in the area of native vegetation and agricultural areas, may be related to the quantity and the quality of the vegetal residue that is returned to the soil. According to

Moscatelli et al. [29], land use systems that provide greater diversity and quantity of organic residues, such as MCF, tend to favor the development of microorganisms and promote increased enzymatic activity.

In the native areas, the greater diversity of plant species contributes to the fact that the organic residue that returns to the soil is more complex, which would explain the high β-glycosidase activities observed in these areas. Taking into account that the cultivated plants also constitute sources of enzymes for the soil it is possible that the composition of these plants also influences in this aspect. Thus the same principle can also be observed in systems where two plant species are present MCF and CTA, since more uniform crops tend to reduce the diversity of the waste added to the soil responsible for the continuous supply of organic material for cycling.

Phosphatase plays an important role in the cycling and transformation of phosphorus from the organic form of this element, making it available to plants, since it is an essential mineral for plant nutrition [30]. Chemical fertilizers with high solubility phosphorus sources allow a substantial contribution of labile forms of this element in the soil, producing less dependence on the organic forms of phosphorus and, consequently, a lower demand for this enzyme [31]. Thus, the higher levels of acid phosphatase activity observed in the native areas are due to the low natural levels of phosphorus (P) characteristic of the type of soil under study. Being the cycling done by solubilization processes of poorly soluble sources and mainly by the mineralization of P of the organic matter by the phosphatases.

Studying the enzyme phosphatase in cerrado soils Matsuoka et al. [32] observed that the level of acid phosphatase is inversely proportional to soil P levels. Thus, the agricultural activities and consequently fertilizations of P inhibit the activity of the acid fostatase, whose behavior corroborates with the one obtained in the present work. Allison et al. [33] demonstrate that phosphatase production is controlled by biological demand and enzyme activity tends to be lower when inorganic phosphate is more abundant. Research on enzymatic activity in soil affected by changes caused by agricultural practices in Italy Gianfreda et al. [34] also suggest the inhibitory effect of labile phosphate contents on soils that presented lower levels for phosphatase.

As a moving element in the soil, phosphorus is easily leached in the profile, especially when it comes from external sources as in the case of chemical fertilizers carried out in the planting areas [35]. In conventional cropping systems, the soil, being intensely stirred in the preparation process, associated to direct exposure to the climate, contrary the conservationist crops, favors leaching in the soil and the percolation of water in the profile, tending to the loss of phosphorus added via chemical fertilization. Thus, areas with conventional crops, as MCF and MPC, favor lower content of labile phosphorus in the soil, inducing a greater activity of the acid fostatase, as seen in this research. In the CTA the nutritional demand of this element is low, not having an intense external contribution of this element when comparing the nutritional demands of corn and beans, justifying the low levels of labile phosphorus in the soil, favoring also a greater activity of acid phosphatase.

The inhibitory effect of soluble forms of phosphorus applied in the studied soils can be even more accentuated considering the imbalance of the applied doses. Pedrotti et al. [36], studying the use of chemical fertilizers by family farmers in the study region, found that 97% of the farmers surveyed use mineral fertilizers with phosphorus sources, although 84% of them never performed soil analysis. The opinion of third parties, without any technical-scientific basis, are the determining criteria for soil fertilization. This fact reflects negatively on the soil system, and surely is one of the factors that may be contributing in a deleterious way to the quality of land use and the sustainability of agricultural activity in the region. For the above, this enzyme showed great sensitivity to the possible effect of the application of highly soluble forms of inorganic phosphorus in the studied soils.

For the microbial biomass nitrogen (NBM), biomass carbon contente (CBM), soil basal respiration (RBS) and qCO_2 microbial biomass indicators the results are shown in Fig. 2. When analyzing NBM, a distinct differentiation can be observed due to the effect of different soil uses (Fig. 2), providing a statistically significant difference between treatments. The highest value of NBM was verified in the VNT and the lowest in the MCF, registering a variation of 40.68 mg N kg^{-1} of soil between the two treatments. Maize cropping systems also showed a decrease in relation to the native area, however, there was an upward trend in the values of MPC areas, and especially in the MCM area, approaching the values of the CTA area.

Results similar to the present study NBM was observed by Mazzetto et al. [37] studied the differentiation of soil microbial biomass activity patterns under different natural vegetation, pastures in use, and recently implanted agricultural systems, and found no statistically significant differences for NBM in soils under native vegetation and pasture. It is worth noting that the high NBM found in the area under pastures indicates that this crop behaves as an important storage compartment of N in the soil, being available for the absorption of the plants after the death of microorganisms [38] and [39].

For the values obtained from CBM (Fig. 2), no significant statistical difference was observed regarding the effect of different soil uses, suggesting that the history of the various forms of land use and management have not yet significantly altered the carbon compartment from the microbiota of the soil in the soil and climatic conditions of the present study. These results are similar to those found by Almeida et al. [40], when evaluating areas with 5, 7, 8 and 9 years of cultivation, comparing with an area with native vegetation, indicating that there were no significant differences between the systems to CBM.

Although there was no significant statistical difference between the study areas, the highest value of CBM was found in the pasture area. These results are similar to those found by Assis et al., [39] when assessing the changes in soil biological properties due to the conversion of degraded pastures into an integrated crop and livestock system in order to identify suitable properties to detect changes in soil biological

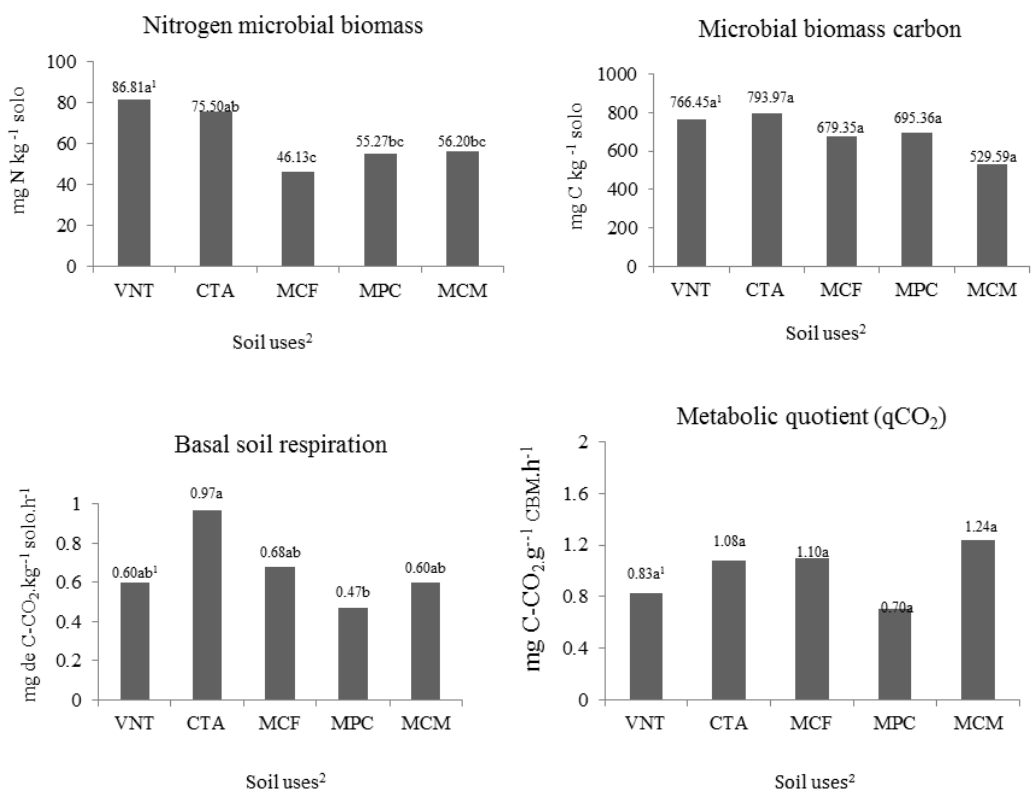

Fig. 2. Behavior of the different parameters of biological activity in soil samples from areas under different uses. [1]Averages followed by the same letter do not differ among themselves by the Tukey test at 5% probability. [2]VNT = native vegetation of caatinga; CTA = pasture of tanzania grass intercropped with algarobeira; MCF = corn intercropped with beans in conventional cultivation; MPC = corn in monoculture under conventional cultivation and MCM = corn in monoculture under minimum cultivation

quality. The best performance of pasture areas results from the increase of dead organic matter in the soil from the pasture, which activates the soil microbiota, associated with the protection of the dense root system in the rhizosphere environment [41] and [42], and the production of substances with antimicrobial activity found in the organic matter produced by this species.

Kaschuk et al. [43] considered CBM to be one of the most promising indicators of soil quality by responding promptly to environmental changes often sooner than physical and chemical parameters. In this sense, Lal [44] pointed out the decline of CBM as an indicator of soil degradation process. Considering that the average value of CBM was 692.94 mg of CBM kg^{-1} of soil, associated with no statistically significant difference among the values the studied areas, may be an indication that, at least quantitatively, microbial biomass has not been strongly impacted by the effect of the different managements and uses of the soil.

Contrary to expectations, there was no increase in CBM in the area of maize under a system of minimum cultivation, a system that was implemented four years ago, and the form of more conservationist soil is considered of the areas of maize studied. Balota et al. [45] studying the CBM under different soil tillage and crop succession, cited several studies in which the use of conservation management, such as no-till system, significantly increased this indicator of soil quality. However, contrary to the results of the present experiment, Follet and Shimel [46], when performing an experiment in the USA, reported a decrease of 175% of the CBM when comparing areas under no-tillage with areas under native grasses and without submission to the crop.

Differing from the results found by Belo et al. [47], it was verified that the area under pasture had higher CBM contents. This can be attributed to the rhizosphere effect, which is exerted more intensely by these plants, in the soil analyzed, where there is a greater exudation of compounds such as amino acids, enzymes, proteins, sugars, complex carbohydrates, alcohols, vitamins and hormones that are readily used by microorganisms as substrate, which results in an increase in the number of organisms and their diversity in this area [48].

Considering the C / N ratio of microbial biomass probably qualitative changes in the microbial population provoked by the different uses of the soil. The highest values were found in maize areas under conventional tillage (12.6 / 1) and corn intercropped with beans (15.2 / 1). In areas with more conservation systems, this ratio was lower: 8.7 / 1 in the native vegetation area, 9.7 / 1 in maize in a minimum growing system and 10.8 / 1 in the grass area associated with the algarobeira. Jiang et al. [49] report that high C / N ratio of microbial biomass means that microbial biomass contains a higher proportion of fungi while low values indicate that bacteria are dominant in the population of soil microorganisms.

According to Moore et al. [50] and Jiang et al. [49] stated that in cultivated areas, C / N ratios of the microbial biomass varied from 4.3 / 1 to 11.4 / 1. These data coincide with the behavior observed in the present study, considering that the area of maize under minimum cultivation has a history of only four years, presenting results close to those observed in native vegetation areas. Thus, the change in the microbial population possibly produced in the areas under conventional crops is less desirable because they move away from more stable systems such as in native vegetation areas and pasture associated with the algarobeira.

The soil basal respiration (RBS) showed significant statistical difference only between grassland and conventional corn crop area (Fig. 2), most likely due to the beginning of the dry season during collection, where lower soil moisture, decreases the level of metabolic activity of the soil biota. This indicates that studies with this indicator should be done at different times during the harvest, preferably taking samples during the rainy and dry periods to have a more complete analysis of their behavior, and thus be able to express their behavior as a reliable indicator and sensitive soil quality.

RBS is an indicator that reflects the biological activity of the soil [51]. It represents CO_2 production or O_2 consumption as a result of metabolic processes of living soil microorganisms, having a close relationship with soil abiotic factors such as humidity, temperature and aeration [52]. This was confirmed by the higher CO_2 production in the area under pasture associated with the algarobeira, double that in the area under conventional maize, probably due to the greater amount of organic residues in the soil, better structuring and consequent increase of the residence time of the water in its profile. Thus, it is perceived that the increase of the available carbon content in the soil increases the RBS of the microorganisms [53].

Differing from the results obtained in this study, Silva et al. [54], found higher RBS values in three forest fragments compared to annual and perennial areas of agriculture. In the present study, the VNT presented the same basal respiration rate as that found for the area under minimum maize cultivation (0.60 mg $C\text{-}CO_2$ $kg^{-1}.h^{-1}$). Islam and Weil [55] pointed out that high respiration rates may reflect stress conditions for the microbiota, especially when it comes to degraded areas or a high level of productivity of agricultural systems. The high rates of RBS may still be related to soil reversal, which when intense promotes accelerated decomposition of the easily decomposable fraction of the organic material added to the soil [56], favoring its increase.

However, Zornoza et al. [57] studied the effects of no-tillage and conventional cultivation systems on microbial indicators of soil quality, found no significant differences for RBS and metabolic quotient (QM) when compared with native vegetation area. It is also worth noting that RBS is a sensitive indicator of soil stress due to anthropogenic actions and should be included in the sustainability analysis of agricultural areas, and the results should be interpreted taking into account the particularities of each system, associating where possible with other indicators.

According to the data obtained for qCO_2 in the present study, there was no significant statistical difference for this indicator (Fig. 2) which indicates the current non-existent serious deleterious effects on the local soils imposed by the studied forms of exploration. This corroborates with the diagnoses of Oliveira et al. [58], which identified non-marked impacts in the soil environment in the same region of this research.

Similar results were found by Cherubim et al. [56], evaluating the changes in soil quality through physical, chemical and biological indicators, verified that there were no significant differences in the treatments with qCO2. Although there was no statistical difference among the areas, it was observed higher values qCO_2 in the cultivated area with maize in the system of minimum cultivation and lower values qCO_2 in area cultivated with maize conventional system. This parameter measures the efficiency of microorganisms in the soil that use soil carbon sources [43], being sensitive to the degree of disturbance to which a soil is subjected, as evidenced by the data collected.

It is also observed that the native vegetation area presented the second lowest value of qCO_2, as well as observed for RBS. According to Kaschuk et al. [43], stress soils are expected to have elevated qCO_2 levels, since there is an increase in energy required for microorganisms to perform their functions in the soil. In this way, smaller values were found in the native vegetation area, when compared to the values found in the areas cultivated with maize and pasture.

With this, the possibility of using microbiological parameters as indicators of soil quality for semiarid regions is evident, since they were efficient to detect changes that occurred in the soil, due to the management system and its incorporation into the agricultural activity. They also demonstrate that the indicators used, in particular enzymatic activity assessments, can detect these changes in the conditions of the present study.

Consequently, the greatest challenge is the need for greater repeatability of these studies, even in the semi-arid region for greater accuracy in assessing the current state of the soil biological component and to monitor evolution. This will be used for the formation of subsidies that can with this information provide the interpretation of the values of these parameters, defining their level and necessary, as in the soil chemical parameters, defining a real condition of agricultural soil quality.

4. CONCLUSIONS

The systems of minimum cultivation and/or pasture associated with the algarobeira, because they provided better conditions for the biological activity.

Biological indicators of acid phosphatase and β-glucosidase activities showed a significant reduction in soil under anthropic management, markedly under monoculture of the corn crop and conventional cultivation.

Variations in the values of microbial biomass carbon, basal soil respiration and metabolic quotien are generally indicative that recent technological changes in the region may have a significant impact on the sustainability of agricultural activity in the semi-arid region.

The behaviors identified in the present study reinforce the need for adjustments of the adopted technologies aiming at the non-future commitment to the quality of the agricultural soils of the semi-arid region.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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