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Evaluation of soil quality through visual indicators in the Marcelo Déda Settlement Project

Avaliação da qualidade do solo por meio de indicadores visuais no Projeto de Assentamento Marcelo Déda

SILVA, Thiago Lima da[(1)]; REGAZZO, Jamile Raquel[(2)]; BAESSO, Murilo Mesquita[(3)]; MARINO, Regina Helena[(4)]; Reis, Igor Adriano de Oliveira[(5)]

[(1)] 0000-0002-6954-0414; Universidade de São Paulo. Piracicaba, São Paulo (SP), Brasil. thiagolim@usp.br
[(2)] 0000-0002-0329-1208; Universidade de São Paulo. Piracicaba, São Paulo (SP), Brasil. jamile.regazzo@usp.br
[(3)] 0000-0003-4778-6015; Universidade de São Paulo. Pirassununga, São Paulo (SP), Brasil. baesso@usp.br
[(4)] 0000-0002-7295-3746; Universidade Federal de Sergipe. São Cristovão, Sergipe (SE), Brasil. rehmarino@hotmail.com
[(5)] 0000-0002-4941-9932; Instituto Federal de Sergipe. São Cristovão, Sergipe (SE), Brasil. reisigoradriano@gmail.com

A B S T R A C T

The growing concern about accelerated soil deterioration has led to the need to develop tools that promote agricultural production, based on ambitious concepts. Although the definitions of sustainability and soil quality encompass political, social, economic and environmental issues, many scientific studies address soil quality, but only a few seek to quantify visual indicators of sustainable development, especially in agrarian reform settlements. However, these studies that present simple and easily measured alternatives are indispensable for decision-making and monitoring of agricultural systems. Therefore, the objective of this work was to evaluate soil quality through visual indicators in the Marcelo Déda Settlement Project, located in the municipality of Malhador, Sergipe. For this, 4 significant agricultural crops (Acerola, Macaxeira, Yellow passion fruit and pasture) and an area of native forest of the settlement reserve were chosen. The visual indicators selected are linked to the physical-hydraulic, chemical and biological parameters of the soil, being assigned values (1, 5 and 10) according to the visual degree of impact of the management in these indicators, which were classified in a participatory way with the farmers and researchers. The results allowed to classify the soil of the native forest as desirable in comparison to the land uses in the agricultural production systems studied in the Marcelo Déda Settlement Project, and the areas with the use of aceroleira presented more impacted visual indicators, thus indicating the need for essential changes in the management of the crop.

RESUMO

A crescente preocupação com a deterioração acelerada do solo tem levado à necessidade de desenvolver ferramentas que promovam a produção agrícola, com base em conceitos ambiciosos. Embora as definições de sustentabilidade e qualidade do solo englobem questões políticas, sociais, econômicas e ambientais, muitos estudos científicos abordam a qualidade do solo, mas apenas alguns buscam quantificar indicadores visuais de desenvolvimento sustentável, principalmente em assentamentos de reforma agrária. No entanto, esses estudos que apresentam alternativas simples e de fácil mensuração são indispensáveis para a tomada de decisões e o monitoramento dos sistemas agrícolas. Assim sendo, o objetivo deste trabalho foi avaliar a qualidade do solo por meio de indicadores visuais no Projeto de Assentamento Marcelo Déda, localizado no município de Malhador, Sergipe. Para isso, foram escolhidas 4 culturas agrícolas significativas (Acerola, Macaxeira, Maracujá-amarelo e pastagem) e uma área de mata nativa da reserva do assentamento. Os indicadores visuais selecionados estão ligados aos parâmetros físicos-hídricos, químicos e biológicos do solo, sendo atribuídos valores (1, 5 e 10) de acordo com o grau visual de impacto do manejo nestes indicadores, que foram classificados de forma participativa com os agricultores e pesquisadores. Os resultados permitiram classificar o solo da mata nativa como desejável em comparação aos usos do solo nos sistemas de produção agrícolas estudados no Projeto de Assentamento Marcelo Déda, sendo que as áreas com uso de aceroleira apresentaram indicadores visuais mais impactados, indicando, assim, a necessidade de mudanças imprescindíveis no manejo da cultura.

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Introduction

The concept of soil quality may be adapted according to the specificities of the studies in question. However, the definition is widely disseminated as "the capacity of a given soil to establish its functioning within the natural or managed limits of the ecosystem, thus supporting animal and plant production systems, maintaining or improving the quality of natural resources such as water and air, in addition to supporting human health and housing" (USDA, 2022).

These agroecosystems integrate agroecology, soil and landscapes, and the insertion of agricultural systems and their management can directly influence sustainability indicators, especially when these are developed for monitoring soil quality (Simane *et al.*, 2013). The intensified activities in the soil subsystems alter their components, causing a change in the basic functioning and thus decrease the capacity of the availability of natural resources essential for the quality of agricultural activities.

Thus, there is a need to monitor and understand the spatial and temporal variability of soil properties, understanding that this heterogeneity is essential to decide on which management practices contribute to the improvement of nutrient reserves, quality of indicators and productivity gain of the crops implanted, even in different crop systems (Kisaka *et al.*, 2023).

The knowledge of visual indicators of soil quality is presented as an alternative of fundamental importance for the establishment of good agricultural practices, especially in crop management activities in the soils, because in addition to simple measurement, the impacts of the management applied during agricultural practices on soil attributes must be perceived for immediate action. Corrêa *et al.* (2009) confirm this information, when in their work they report that the monitoring of changes in established soil indicators will provide important data on soil quality and its production capacity.

Despite the large number of scientific papers that focus on soil quality, few have presented suggestions for quantifying the levels of visual qualities, not to mention that in most of them the measurement has been carried out with technological equipment, modern methodologies and research management systems that often have their results presented with difficulties in the dimensioning and contextualization of the diagnosis, impairing the suitability of these for the real conditions of the rural property (Chang *et al.*, 2016).

Although many soil quality assessment methodologies are presented for studies within agroecosystems, methodologies that use visual indicators emerge as a viable alternative to the producer for rapid, reliable and simple measurement diagnosis. Therefore, the objective of this work was to evaluate the soil quality through visual indicators in the Marcelo Déda Settlement Project, located in the municipality of Malhador, Sergipe.

Development

The work was developed in the Marcelo Déda Settlement Project that is located in the municipality of Malhador, Sergipe, Brasil. The settlement in question is made up of 201 families and has established a partnership with 10 farmers. It´s located 44 km from the capital Aracaju, with access made by BR-101, following towards Maruim. The region presents characteristics of humid megathermal climate, with average annual rainfall of 1,411.0 mm, average temperature in the year of 23.0ºC, with geographical coordinates 10º39'33", south latitude and 37º18'12" west longitude, and from March to August is the wettest period. The relief is represented by the pediplanate, fluvial, erosive tabular surfaces and dissected tabular and crested features. The predominant soils are red-yellow Argisols and quartzarenic Neosols, which support a vegetation of "Campos Limpos", "Campos Sujos", "Capoeira" and "Caatinga" (Solos, 2013).

Characterization of crop management

The crops used for the work were acerola (*Malpighia emarginata*), manioc (*Manihot esculenta*), yellow passion fruit (*Passifloria edulis*) and pasture (*Brachiaria decumbens*) and was compared to the native reserve forest of the settlement. The crops chosen for the study were the most representative in terms of production and importance within the settlement. The culture of cassava and passion fruit stand out for being tropical plants and produce in periods of drought, for their tropical characteristics present good developments in these areas, especially in periods of scarce rainfall. The spacing used, in the case of cassava, is 1 meter between lines and 0.60 meters between plants, while passion fruit, in spacing of 4 meters between lines and 2 meters between plants. They are manual plantings with semi-conventional systems and manual cultural treatments. In these areas, the cultural remains of weeding and brushing are used as mulch, but for the secondary preparation of the soil tractor and implements are used to revolve the soil.

Acerola is managed conventionally, which is worked without consortium and soil without physical protection (mulch), in which the control of cultivated plants is done through cultural treatments carried out with herbicide application. The spacing is 4 meters between rows and plants and the fertilization is carried out with the use of conventional organic and synthetic inputs. Already the pasture is used intensively for the creation of cattle, goats and sheep, with organic and conventional fertilization and without control of pests and spontaneous plants, it´s not made of rotation of animals in the pasture. The native forest is in the reserve area of the settlement, it´s a secondary forest with representation of Atlantic forest and shrubby and arboreal "Caatinga".

The experimental design was in randomized blocks with 4 replications in a factorial of 5x4, that is, there were five (5) land uses (passion fruit, cassava, acerola, pasture and native forest), with four (4) blocks that were the lots sampled. In the case of the forest, they were sampled in 4 different parts to maintain the degree of statistical freedom within the acceptable parameters for the analysis of variance. The data were submitted to analysis of variance and the means were compared by the Scott-Knott test at 5%, using the statistical program Sisvar (Ferreira, 2000).

Soil Quality Indicators

The evaluation of soil quality was analyzed through participatory evaluation, based on Comin *et al.* (2016), in which it was possible to describe the field, together with farmers, technicians, students and researchers, soil indicators linked to the cultural profile and physical-hydraulic, chemical and biological parameters of the soil.

In the chosen managements, the indicators received scores on a scale that can vary between 1, 5 and 10, in which grade 1 was awarded for the worst situation, grade 5 was the minimally acceptable condition and 10 was the acceptable or ideal condition. Table 1 shows the indicators and characteristics considered for the score of the grades, following the methodology adopted by Vezzani *et al.* (2019).

Table 1.

Soil quality indicators with respective values and characteristics of evaluation in the soil under different uses in P. A. Marcelo Déda, in the municipality of Malhador, SE.

Indicator	Value	Characteristic
Color, odor and organic matter content (Organic matter).	1	Lighter coloration, unpleasant odor, very low organic matter content.
	5	Darker coloration, no striking odor, little organic matter.
	10	Dark coloration, odor of forest earth, lots of organic matter.
Deep in the soil exploited by the roots (Rooting).	1	Volume of soil exploited does not exceed 10 cm.
	5	Volume of soil explored between 10 and 20 cm.
	10	Volume of soil exploited exceeding 40 cm.
Soil structure (Structure).	1	Dusty soil, with no visible aggregates.
	5	Soil with few visible aggregates, which break with slight

		pressure.
	10	Soil with many aggregates, which maintains shape after light pressure.
Compaction and infiltration (compression).	1	Very compacted layer, presenting high resistance to the penetration of the knife tip and with little or no water infiltration.
	5	Compacted layer, presenting medium resistance to the penetration of the knife tip and with slow infiltration of water.
	10	Without the presence of a compacted layer, the tip of the knife easily penetrates the soil and with rapid infiltration of water.
Erosion (Erosion).	1	Severe erosion, presence of grooves and erosion channels.
	5	Erosion barely visible (laminar), runoff does not create grooves.
	10	No visible signs of erosion.
Moisture retention (Humidity).	1	Fast dry soil.
	5	Low moisture holding capacity during prolonged drought.
	10	High moisture holding capacity, even during prolonged drought.
Biological activity (Macrofauna).	1	No signs of the presence of earthworms and/or arthropods.
	5	Presence of earthworms and/or arthropods.
	10	Abundance of earthworms and/or arthropods.
State of the remains vegetables and ground cover (straw).	1	Little or no straw, no signs of decomposition.
	5	Thin layer of straw, ground cover less than 50%.
	10	Thick layer of straw, vegetable remains in different stages of decomposition, soil cover greater than 90%.

Source: Vezzani *et al.*, 2019.

Results and discussion

Table 2 presents the results of the analysis of variance. It´s observed that for the indicator organic matter, the use of the forest soil presented better results, however, it did not differ statistically from the use of cassava and passion fruit. High values of organic matter in native forests are expected, since the systems are preserved and the processes of litter decomposition and nutrient cycling are occurring.

Table 2.

Average values of Organic Matter, Rooting, Structure, Compaction, Erosion, Moisture, Macrofauna and Straw in the soil under different uses in P. A. Marcelo Déda, in the municipality of Malhador, SE.

	Types of land use					
Indicators	**Manioc**	**Passion fruit**	**Acerola**	**Pasture**	**Forest**	**Cv (%)**
Organic matter	7,5a	7,5a	5,0b	4,0b	10a	29,90
Rooting	4,0a	6,25a	5,0a	5,0a	5,0a	28,35
Structure	8,75a	6,25b	4,0b	8,75a	10a	28,25
Compaction	5,0b	5,0b	4,0b	5,0b	10a	15,42
Erosion	8,75a	5,0b	3,0b	5,5b	10a	43,07
Moisture	6,5a	7,5a	5,0a	7,5a	10a	36,59
Macrofauna	5,0b	4,0b	1,0c	4,0b	10a	26,35
Straw	5,0b	4,25b	1,0c	4,0b	10a	43,49

Means accompanied by the same letter horizontally do not differ significantly at 5% by the Scott-Knott test.
Source: The authors (2023).

According to Tesfay *et al.* (2020), the decomposition and release of litter nutrients can contribute to the improvement of soil chemical parameters, such as carbon stock and soil fertility, improving plant development in these environments, which causes a decrease in impacts in degraded areas.

In the acerola production system, the low amount of organic matter may indicate that the management employed does not favor the conservation and the contribution of this component in the soil. According to a study on chemical attributes of soils under different uses, carried out by Corrêa *et al.* (2009), the fruit-growing and pasture areas presented lower total organic carbon content when compared to areas of short-cycle crops, discarded areas and areas with native vegetation, according to the authors the low rate of deposition of organic material in the areas of fruit growing and pasture may have influenced this result, which may also be the case, in this study, in addition, the mobilization of the soil by the intensive entry of animals in the pasture areas and cultural treatments required for the areas of aceroleiras make the environment more oxidative, resulting in a lower accumulation of total organic carbon, confirming the low values of the visual indicators for the item organic matter in pasture and aceroleira.

When analyzing the values of the straw indicator, there are significantly different averages of all uses compared to the forest. This data may have an influence of the management in the cultural treatments, with the removal of organic materials during manual weeding, which does not contribute to the residual accumulation in the production systems, leaving the soil without protection and conducive to the appearance of erosion, leading it to physical, chemical and biological degradations, impacting on other indicators, such as humidity, macrofauna and organic matter.

The lack of straw and organic matter has a direct influence on the scores of macrofauna indicators. The organisms of the edaphic macrofauna are essential elements of the soil biota, as they act as shredders and leaf litter transformers (Swift *et al.*, 2010), improving the physicochemical and structural characteristics in these agroecosystems (Velásquez *et al.*, 2010). The impacts of crop management on organic matter affect organisms in the soil, this is due to mobilization in intensive crops and the use of inputs (Rovedder *et al.*, 2009; Fragoso *et al.*, 1999).

Due to the conditions of natural deposition of organic material from the native forest and the cultural treatments carried out in agricultural areas, such as weeding and removal of residues, it was expected that the values of presence of microorganisms in the forest would be higher than the crops, which was confirmed in the visual analyses surveyed. Within agricultural production areas such as those found in this study, indicators that link the presence of edaphic macrofauna to the proper management of crops is essential for the search for sustainable systems, since the edaphic fauna contributes to the evaluation of a natural system, through the sensitive responses to anthropogenic actions of degradation and biological interactions in the soil/plant system (Hoffmann *et al.* 2009).

As for the rooting depth indicator, there was no statistical difference between the treatments. Possibly the areas studied are implemented in newer, shallow soils or with physical impediments typical of the quartzarenic neosols of occurrence in the region, which may have caused low values attributed to this indicator. Shallow soils, dense or with cohesive layers and outcrops of rocks, combined with low precipitation in the studied area, can influence the deepening of the root system, even in areas of native vegetation, because the resistance to the penetration of roots into the soil can present values greater than 2,5 Mpa (Leão *et al.*, 2004).

Values attributed to soil moisture indicators did not differ from each other. The preparation of the soil in the areas of agricultural production may have influenced the results, since the mobilization of the soil in adequate depth allows the increase of the available water capacity. According to Pacheco (2011), the lack of proper management throughout the soil preparation can cause increased soil resistance, affecting moisture retention, which can generate demand for the use of scarifiers and subsoilers in the lots, so that the crops need a greater development of the root system, which possibly did not occur in the areas of this study.

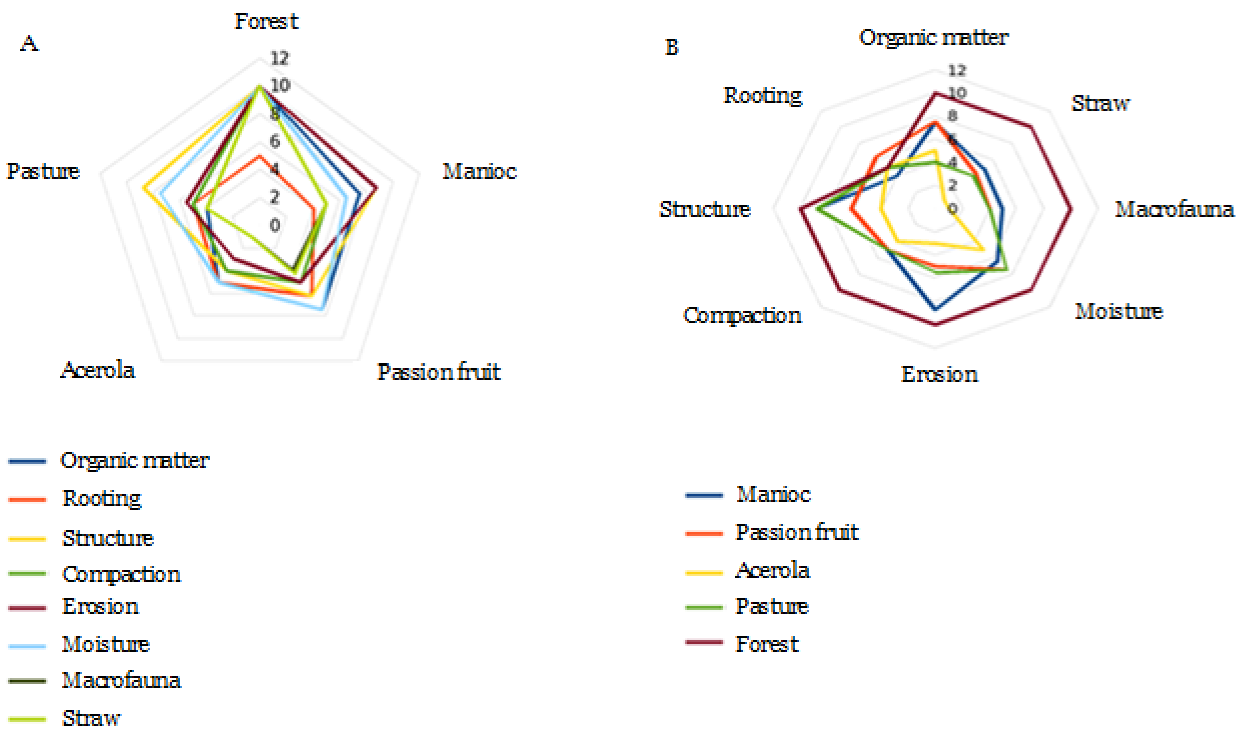
In the soil structure indicator, the forest presented maximum score, differing statistically from the areas of aceroleira and passion fruit. The management employed in these uses of pasture and cassava may have contributed to the formation of aggregates in the soil, since after the mobilization of planting it´s common to wait for the period of development of the crop without entry of animals (pasture), and the areas with cassava after planting require less cultural treatment when compared to the acerola and passion fruit crops. These constant anthropic interventions, in addition to interfering in the structure can decrease the speed of basic infiltration (VIB) in the soil, as observed by means of the compaction indicator (soil infiltration).

The lack of soil structure contributes to the increase in apparent density and resistance to penetration, consequently leading to compaction in these areas. The evaluation of soil quality generally takes into account several physical attributes, such as soil density and resistance to penetration (GOMES and FILIZOLA, 2006). These attributes are used to analyze the response of the soil to the management practices employed, since they are directly related to its structure. Thus, an analysis of soil resistance to penetration, such as the one proposed in this work, can provide important information about the overall soil quality.

Soils affected by compaction present difficulty in entering water into their profile by the infiltration process, thus increasing surface runoff and, consequently, leaving the areas susceptible to erosion, as can be observed by the values attributed to the indicators in areas of acerola, pasture and passion fruit. The management of these crops in the settlement has as a characteristic the movement of animals and people for cultural treatment frequently, which does not occur in the cultivation of manioc and in the native forest.

For a better understanding of the data, below (Figure 1) is presented a graph of the web type, in which the values of the arithmetic means are used to compare the performance between the uses and indicators of the soil. This type of representation facilitates the visualization of soil quality and what factors contribute to performance, or even where the producer needs to intervene, so values close to the lines on the outside of the graph represent better management conditions or proximity to the most appropriate production system (VEZZANI *et al*., 2019).

Figure 1.
Graphic representation of the values attributed to the visual indicators within the land uses (A), and the assigned values of the land uses within each visual indicator (B), in the Marcelo Déda Settlement Project, in the municipality of Malhador, in Sergipe.



Source: The authors (2023).

It´s observed in Figure 1A that the forest obtained maximum score in most of the visual indicators in P. A. Marcelo Déda, this shows that the forest area is preserved and in balance, and only the depth of the root system received notes similar to those of the management used in the settlement, probably due to the influential pedological characteristics of the soils of that region. The area of the settlement is established in new soils, which causes the non-deepening of the root system, due to physical impediments.

Figure 1B shows the influence of land use on the indicators. It´s verified that the forest presents itself as a reference or with adequate conservation management, in relation to other land uses, due to its graphic line being closer to the exterminated of the web and well balanced in relation to the maximum values of the indicators, followed by the use of cassava. On the other hand, acerola cultivation presents worrying soil quality results, since it received the most unwanted and minimally acceptable notes, followed by pastures and passion fruit, indicating the need for brief changes in their management and guided by the indicators raised.

Conclusions

The visual indicators proved to be an effective tool in the qualification of management in the land uses of the Marcelo Déda Settlement Project.

The management employed in the land use of acerola does not preserve variables of natural resources for production and sustainable development.

Through the visual indicators of the soil it was possible to classify the native forest with a desirable situation, compared to the management used in the land uses in the Marcelo Déda Settlement Project.

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