Agrotrópica 27(3): 219 - 232. 2015.
Centro de Pesquisas do Cacau, Ilhéus, Bahia, Brasil

EVALUATION OF SOIL QUALITY INDICATORS BY A PARTICIPATORY METHOD IN RURAL SETTLEMENTS IN SOUTHERN BAHIA, BRAZIL

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This study aimed to validate the methodology of empirical evaluation of soil quality indicators in field with farmers in comparison to laboratory analysis. Soil indicators, selected by farmers in two rural settlements of southern Bahia, Brazil, in areas of cocoa crops compared to cassava, coffee and pasture were studied. By the Wilcoxon test, the soil quality indicators of organic matter and mulching showed nearby notes between the empirical and the technical evaluations. Although the notes of empirical evaluations for the indicators erosion, moisture, compaction, microbial activity, and structure have been differentiated of the technical evaluation, the subjective methods proved viable to establish dialogue between technicians and farmers, raising attention to aspects of soil management and conservation, that had been not seen before.

Key words: soil management and conservation, ethnopedology, land uses, cocoa region of Bahia.

Avaliação de indicadores de qualidade do solo por método participativo em assentamentos rurais do sul da Bahia, Brasil. Este estudo objetivou adaptar metodologia de avaliação empírica de indicadores de qualidade do solo, no campo com agricultores, em comparação com análises técnico-científicas em laboratório. Para tanto, estudaram-se indicadores do solo, selecionados pelos agricultores, de dois assentamentos rurais do sul da Bahia, em áreas de cultivos de cacau comparadas aos cultivos de mandioca, café e pasto. Pelo Teste de Wilcoxon os indicadores de qualidade do solo matéria orgânica e cobertura apresentaram notas muito próximas entre a avaliação empírica e a avaliação técnica. Embora as notas das avaliações empíricas para os indicadores erosão, umidade, compactação, atividade microbiana e estrutura tenham se diferenciado da avaliação técnica, os métodos subjetivos se mostraram viáveis para estabelecer o diálogo entre os técnicos e os produtores rurais, despertando a atenção para aspectos de manejo e da conservação dos solos não antes observados por eles.

Palavras-chave: manejo e conservação do solo, etnopedologia, usos da terra, Região cacaueira da Bahia.

Recebido para publicação em 05 de março de 2015. Aceito em 02 de dezembro de 2015.

Introduction

The term “Soil Quality” has been created in the end of the 70’s, directly related to the chemical evaluation of soil fertility, however, nowadays, this term comprises the joint interpretation of soil chemical, physical and biological attributes and also for following the farmer’s socio-economical demands (NRCC, 1993; Bruggen & Semenov, 2000; Karlen et al., 2003; Sposito & Zabel, 2003; Vezzani & Mielniczuk, 2009).

Due to the diversity of aspects related to soil quality, it is important to understand that it can´t be directly estimated (Araújo et al., 2012). By the technical-scientific perspective, the soil quality can be quantitatively measured by a minimum number of attributes (indicators) (Karlen & Stott, 1994; Karlen, 1997; Andrews et al., 2004; Van LIER, 2010). The quantitative evaluations suggest that the agricultural sustainability depends on the soil quality maintenance, since it decreases overtime, especially due to changes in the use of land, like crops in deforested areas (Vezzani, 2001; Spagnollo, 2004).

Apart from the quantitative analysis and its interpretations, it is possible to notice several qualitative soil aspects from the empirical observation, which are much related to the farmer’s daily lives (Feiden, 2005). This author highlights that despite the farmers don’t usually describe the phenomena that take place in their production system in technical-scientific terms, the information that they hold can subsidize the praxis of technicians and researches in the search for solutions of agro system problems. In this context, the Ethnopedology can give instruments of interaction between technicians and farmers, aiming towards documentation and comprehension of local approaches about perception, classification, use and management of soil, since both the approaches include believes about spatial heterogeneity of soil and earth, temporal variability, natural processes and dynamics and interaction with other biophysical factors (Barrera Bassols & Zinc, 2000).

Segments of the scientific community have been questioning the validity of direct interpretation by farmers in regards to soil attributes, supporting that confirmation through analytical procedures stablished by science are necessary (Araujo et al., 2008).

This work is aimed to identify attributes that indicate soil quality by a participatory method, involving technicians and farmers, which will point out the indicators to be empirically evaluated, directly from the farms, and then technically evaluated by traditional scientific methods, such as laboratory analysis. Both evaluation types, empirical and technical, were applied to soil under different crops from two rural settlements in Southern Bahia, Brazil.

Materials and Methods

The study was developed in two rural settlements in Bahia, the “Union and Labour Farmers Association” (APAUT), located in the city of Ilhéus (14° 48’ 54’’ S; 39º 08’ 00’’ W), Japú region and in the “Rural Workers of Freedom Settlement” (ASTRAL), in the city of Maraú (14° 12’ 42’’ S; 39º 23’ 37’’ W). In each of the settlements two sample areas (locations 1 and 2) were chosen, and in each of them, two crops in adjacent quarters (Table 1).

Two soil profiles were described in each of the settlements (APAUT e ASTRAL), in accordance of the Embrapa methodology (2006), and its results were analysed in its physical and chemical properties (EMBRAPA, 2011) in order to know the soil classification in the chosen locations. According to the pedologic classification, the predominant soil in areas of the APAUT and ASTRAL settlements correspond to an Ultisol (*Typic Hapludult*).

The research activities were performed in 3 stages:

Stage I - Survey and definition of the soil quality indicators by the farmer's perspective. The empirical evaluation method adopted was the "quick agro-

Table 1. Identification of the sample locations in the APAUT e ASTRAL settlements and their related crops

Settlement	Sample location	Crop
APAUT (Ilhéus, Bahia)	Location 1	Cocoa and Cassava
	Location 2	Cocoa and Coffee
ASTRAL (Maraú, Bahia)	Location 1	Cocoa and Pasture
	Location 2	Cocoa and Cassava

APAUT: Union and Labour Farmers Association;
ASTRAL: Rural Workers of Freedom Settlement.

ecological", an adapted methodology based on Altieri (2002), Altieri & Nicholls (2002). From the soil quality indicators approached and commented, seven were selected: 1 - Organic Matter, 2 - Soil Coverage, 3 - Erosion, 4 - Humidity, 5 - Compaction, 6 - Microbial Activity, and 7 - Structure. For each indicator the following interval of values were assigned: 0 to < 5 is undesirable, 5 to < 7 is moderate, 7 to 10 is adequate; with the exception of the compaction and erosion indicators on which the interpretation was inverse, 7 to 10 is undesirable, 5 to < 7 is moderate, 0 to < 5 is adequate. Following that, were validated methods of empirical evaluation (subjective) for each indicator that was close to the technical evaluation results (objective), in order to obtain information that could be compared.

Stage II - The farmers were separated into five groups of four participants, supported by one technician for the field indicators valuation. Values from 0 to 10 were adopted, according to the classification proposed by Table 2. Each farmer has given his note for each of the indicators, for crops in the two locations of each settlement, thus, obtaining the group average. The five notes average represents the repetitions in each crop in question. Following that, detailed information was found from the empirical evaluation of the soil quality indicators from Table 2: 1) Organic matter - Evaluated by the organoleptic perception through soil odour, texture and colour; 2) Soil cover - visually evaluated, randomly putting a wooden template with measures of 0.5 cm x 0.5 cm, to estimation of the percentage of the covered area; 3) Erosion - evaluated with the visual perception from the soil superficial horizon conservation or degradation (O/A), by means of the observed thickness measurement in a micro-trench; other supporting facts for this evaluation were the observation of the roots exposure, the existence of furrows, ditches and traces of soil particles movement; 4) Humidity (water retention) - visual perception of the water retention capacity by the soil from an unformed soil sample of 5 cm depth collected by a PVC tube (6 mm diameter), which was put inside a translucent plastic recipient and poured with a known water volume (100 mL), then the elapsed time for the water to infiltrate into the sample was recorded, to measure the quantity of infiltrated water, andf to find the water retained by the soil; 5) Soil compaction - a 30 cm wire string (number 14) was used, which was vertically put against the soil and then pressed, to observe, or not, the penetration into the soil, thus estimating the level of compaction. The depth on which the wire string curves itself due to the soil resistance was recorded, to establish a note based on the referential values; 6) Microbial activity: an oxygenated water solution of 3% was used, with 10 drops poured into a portion of approximately 10 g of soil, to verify its effervescence (little, moderate or abundant); 7) Structure - visual evaluation of a clod put into a becker with water to observe the size of the aggregates and, after five minutes, colour changes in the water were observed. The clod was also handled in a way for it to be broken in its fracture points, and under the pressure exerted between the index and thumb fingers, its consistence was observed, in a way that if the clod crumbled faster, it evinced a loose soil and fewer aggregates.

Stage III - The effectiveness of the soil quality indicators empirical values were verified by technical evaluations. The indicators represented by equivalent soil attributes are described in Table 2. The soil sampling collection took place in locations 1 and 2 from each settlement (Table 1), in their respective crops, from the 0 to 20 cm layer, with 5 repetitions on each crop, on which each repetition is represented by a sample composed by 5 simple sub-samples, and then analysed in the laboratories of the Cocoa Research Centre (CEPEC) and the State University of Santa Cruz (UESC), throughout the months of September and December 2012. The physical attributes: soil density (Ds), particles density (Dp), humidity equivalent (EU) and organic carbon (CO), were analysed according to procedures standardized by EMBRAPA (2011). The soil cover was estimated by using photometry on randomly picked areas, with the 50 cm x 50 cm template, on which its true scale photos were used to calculate the covered areas and then expressed in percentage values. The erosion was estimated in five micro-trenches from each crop, in the locations 1 and 2 from the APAUT and ASTRAL settlements, recording the superficial O/A horizon thickness as the indicator of the soil's level of erosion (Lepsch, 1983). Each value (repetition) was represented by the average of four individual O/A horizon measures verified in the micro-trenches. The aggregates' stability in water

Table 2. Identification of the empirical and technical evaluation methods of the soil quality indicators that were selected in the APAUT and ASTRAL settlements

Indicator	Empirical Evaluation				Technical Evaluation		
	Method	Note	Conception	Reference	Analysis	Method	Reference
Organic matter (1)	Tactile and visual evaluation	0 5 10	Absence of humus Small presence of humus Abundance of humus	USDA (2001)	C organic	Walkley Black	EMBRAPA (2011)
Soil cover (2)	Wooden template (50 cm x 50 cm)	0 5 10	Exposed soil 50% covered 100% covered	Gama-Rodrigues (1997)	Measure/Surface	Square (50 cm x 50 cm)	Gama-Rodrigues (1997), Sodré et al. (2000)
Erosion (3)	Visual evaluation	10 5 0	Channels (furrows, ditches) Roots exposition O/A horizon presence	USDA (2001)	Measurement of A horizon thickness	Thickness of A horizon	Lepsch (1983)
Humidity (water retention) (4)	Small (Retention), Average, High. Complementary - Tactile / texture	0 5 10	Low retention Average retention High retention	USDA (2001)	Equivalent humidity	Centrifuge	EMBRAPA (2011)
Compaction (5)	Wire string nº 14 - 30 cm	10 5 0	Curves Penetrates 15 cm Penetrates 30 cm	Altieri (2002)	Resistance to penetration (MPa)	Penetrometer	Stolf et al. (1983)
Microbial activity (6)	Application of oxygenated water 3% (H_2O_2)	0 5 10	No effervescence Average effervescence High effervescence	Gama-Rodrigues (1997); Sodré et al. (2000)	Mineralizable carbon	Evolution of CO_2	Silva et al. (2007)
Structure (7)	Clod in Water / Size of aggregations consistence / Pressure between fingers	0 5 10	Loose, without aggregations Aggregates break with little pressure Aggregates difficult to be broken	USDA (2001); EMBRAPA (2011)	Stability of aggregates in water	Yoder	Kemper & Rosenau (1986)

was stablished by the Kemper & Rosenau (1986) method, and by procedures standardized by EMBRAPA (2011). The microbial activity (CO2 evolution) was stablished by the method described by Silva et al. (2007).

The obtained data from the field and laboratory measurements have different magnitudes and cannot be compared. The field measurements are measured in the 0 to 10 scale, meanwhile the laboratory ones have different scales according the specific variable. For this reason, the laboratory data were divided by the scientific literature's highest related value and then multiplied by 10 (Table 3).

The Wilcoxon (rank sum test) test was chosen (Wilcoxon, 1945) for the independent samples of the technical and empirical evaluation for each quality indicator, in order to determine whether or not the two evaluations are statistically different from each other. The association degree between the technical and empirical evaluations for each soil quality indicator was determined by the correlation coefficient rank of Spearman - rank correlation - (Lehmann, 1979). The analysis was running in the environment R (R Development Core Team, 2012), and the Vim-R-plugin editor was used as the graphical interface in the R (Aquino & Faria, 2012).

Results and Discussion

It was observed from the empirical evaluation that the cocoa crops, in all the studied locations in the APAUT e ASTRAL settlements, had more advantageous notes in comparison to the cassava, coffee and pasture crops (Table 4).

When evaluating the organic matter indicators in the crops, the farmers had the opportunity to explore their organoleptic skills and, in several cases, for the first time have they realized the significance of soil colour, odour and texture as an indicator of soil quality, so that they attributed the best notes to the cocoa crops (Table 4).

In the soil cover indicator empirical evaluation, the farmers realized the fundamental differences between each crop, observing that some of them expose the soil to the weather more than others (Table 4). The highest averages notes of empirical evaluation were attributed to the cocoa crops, due to the other crops (cassava, coffee and pasture), from the adjacent plantations, had inadequate quality averages (Table 4).

The empirical evaluation of the erosion indicator presented the best results for the cocoa crops in contrast with the other crops (cassava, coffee and pasture) (Table 4). In this subjective evaluation, the farmers attended to the soil superficial layers decreasing, rich in organic matter, as the result of changes in the crop and inadequate soil management practices.

In regards to the humidity soil quality indicator, the farmers attributed the highest average notes to the cocoa crops in comparison to the other studied crops (cassava, coffee and pasture) (Table 4); they realized the importance of good soil physical conditions for some phenomena such as water infiltration and retention.

By using a wire string of 30 cm (nº 14), the farmers evaluated the compaction indicator, attributing the highest notes average to the most compressed crops, which corresponded to the cassava, coffee and pasture crops (Table 4); the best conception was attributed to cocoa crops (Table 4), on which, by its arboreal composition, deposition of residues that covers the soil

Table 3. Highest values defined by science for the related attributes to the soil quality indicators to the technical evaluation

Attribute	Soil quality indicator	Unit	Highest value[1]	Reference
Organic matter	Organic Matter	$g\ kg^{-1}$	47	Embrapa (2006)
Soil cover	Soil cover	%	100	Bertoni & Lombardi Neto (1990)
Equivalent humidity	Soil Humidity	$kg\ kg^{-1}$	400	Ruiz et al. (2003)
Resistance to penetration	Compaction	MPa	2,2	Stolf et al. (1983)
Microbial activity	Microbiotic Activity	$mg\ CO_2\ kg^{-1}soil$	30	Silva et al. (2007)
IEA (Aggregate Stability Index)	Structure	%	100	Ferreira (2010)
			Interval	
Superficial O/A Horizon	Erosion (loss of O/A Horizon)	cm	0-40	Bertoni & Lombardi Neto (1990)

[1]Highest values assuming Ultisols of the humid tropical climate.

and its consequent protection on the superficial horizon, contains a soil conditions that presents less obstructions for the roots penetration.

The empirical evaluation of the microbial activity indicators evinced that the farmers noticed a higher effervescence of the oxygenated water solution poured into soil samples of the cocoa crops (Table 4). The farmers did not have any difficulty in attributing notes to the effervescence level they visualized in the soil samples, and also, they were somehow curious when they realized that the soil is full of life.

In the evaluation of the structure indicator, the farmers also empirically distinguished the different crops, awarding the best notes to the cocoa crops when compared to the cassava, coffee and pasture crops (Table 4). Empirically, the farmers started to realize the effects of water over the soil aggregations, and to understand how the soil structure is important to its quality maintenance.

The soil quality indicators averages from the technical evaluation in the APAUT e ASTRAL settlements are presented in Table 5.

Table 4. Overview of the empirical evaluation of the soil quality indicators in the studied Ultisol under different crops at APAUT and ASTRAL rural settlements

Settlement	Location	Crop	ORG	COV	ERO	HUM	COM	MIC	STR
			Evaluation notes average (n = 5) and concept[1]						
APAUT Ilhéus, Bahia	1	Cocoa	7,76 a	9,70 a	1,28 a	5,70 m	4,32 a	7,02 a	7,62 a
		Cassava	4,62 i	6,42 m	6,68 m	4,32 i	6,54 m	3,50 i	5,92 m
	2	Cocoa	6,20 m	7,84 a	1,64 a	4,88 i	4,04 a	4,92 i	7,48 a
		Coffee	3,64 i	3,60 i	6,02 m	3,04 i	6,76 m	2,60 i	3,38 i
ASTRAL Maraú, Bahia	1	Cocoa	4,74 i	9,34 a	1,58 a	6,42 m	4,86 a	4,84 i	5,56 m
		Pasture	3,72 i	3,06 i	5,30 m	1,68 i	8,42 i	2,02 i	2,78 i
	2	Cocoa	7,18 a	8,50 a	1,02 a	8,20 a	4,54 a	4,94 i	7,78 a
		Cassava	5,02 i	4,10 i	5,30 m	4,58 i	7,50 i	1,68 i	5,94 m

ORG: organic matter(sensorial evaluation, texture, odour, colour) = soil organic matter content (g kg^{-1}); SUR: surface = soil cover measurement (%); ERO: erosion = highest value equivalent to the absence of O/A horizons (cm); HUM: humidity = equivalent humidity (g kg^{-1}); COM: compaction = highest value equivalent to the resistance of penetration of 2 MPa; MIC: microbial activity = evolution of carbon dioxide (mg CO_2 $kg^{-1}$of soil); STR: structure = Aggregates stability index (%).[1]Farmer's evaluation average estimated in a scale with values from 0 to 10, quality conception: a - adequate, m –moderate and i - inadequate; [2] Inverse conception interpretation for the COM and ERO indicators.

Table 5. Overview of the technical evaluation of the soil quality indicators in the studied Ultisol under different crops at APAUT and ASTRAL rural settlements

Settlement	Location	Crop	ORG	COV	ERO	HUM	COM	MIC	STR
			Evaluations Average (n = 5)						
APAUT (Ilhéus, Bahia)	1	Cocoa	45	9,70	12	264	1,40	17,4	98
		Cassava	38	4,80	12	273	1,61	24,5	86
	2	Cocoa	56	9,00	21	397	1,29	17,5	89
		Coffee	30	1,40	13	222	1,60	23,6	94
ASTRAL Maraú, Bahia	1	Cocoa	47	9,80	23	226	1,79	17,4	90
		Pasture	25	6,60	19	170	2,04	16,6	86
	2	Cocoa	37	9,80	24	263	1,58	14,9	92
		Cassava	45	1,40	19	274	1,73	10,8	91

ORG: soil organic matter content (g kg^{-1}); COV: soil cover (%); ERO: loss of A horizon (cm); HUM: equivalent humidity (g kg^{-1}); COM: resistance to penetration (MPa); MIC: carbon dioxide evolution (mg CO_2 $kg^{-1}$of soil); STR: Aggregates stability index (%).

To proceed with the statistical analysis, the resulted values from the technical evaluation were standardized to a scale with values from 0 to 10 (Table 6), on the basis of the highest values and the values intervals present in the scientific literature (Table 3), with the aim of allowing the comparison with the empirical evaluation values.

In the technical evaluation of the soil organic matter indicator, all the cocoa crops from the APAUT e ASTRAL locations presented the best notes average in comparison to the other crops (cassava, coffee and pasture), with the exception of the cocoa crop in ASTRAL location 2, which presented an inferior note in relation to the cassava crop (Table 6). The cocoa agro-system in the called "cocoa-cabruca" system is privileged for having an arboreal extract which has similarities to the native forestry and, in comparison with other crops, presents several positive features from the soil preservation perspective, such as carbon sink (Inácio et al., 2005; Gama-Rodrigues; Gama-Rodrigues; Nair, 2011; Araujo et al., 2013).

The technical evaluation of the erosion indicator presented an inadequate quality conception to the cocoa and cassava crops in the APAUT location 1 (Table 6). In the other locations, 2 (APAUT), 1 and 2 (ASTRAL), the cocoa crops presented an adequate quality conception in regards to the erosion indicator in relation to the moderate conceptions of the coffee, pasture and cassava crops (Table 6). Some researches indicate that agro-systems, such as coffee and cassava plantations in conventional cultures and degraded pastures, are more susceptible to the hydric erosion effects, on which a higher loss of soil takes place (Thomazini et al., 2012; Silva Júnior et al., 2005; Araújo et al., 2012; Inácio et al., 2005).

The technical evaluation of the soil cover indicator distinctly highlighted the cocoa crops with the higher notes average (Table 6). Cocoa plantations presented litter or a typical organic layer that resembles the deposition of vegetal residues from a natural ecosystem (Inácio et al., 2005; Gama-Rodrigues; Gama-Rodrigues; Nair, 2011). In the conventional cassava plantation, due to the low plant foliar area occurrence, the soil stays almost uncovered, as well as some conventional coffee plantations do not contain vegetal covering, like mulching (Silva Júnior et al., 2005; Thomazini et al., 2012). Degraded pastures also presented uncovered soil area (Moraes, 2002).

In APAUT, the technical evaluation of the compaction indicator presented a moderate quality on the cocoa crops over the others (Table 6). In ASTRAL, location 1, the cocoa crops presented a moderate quality conception, similar to cassava, and on location 2, the cocoa and pasture crops presented an inadequate conception (Table 6).

A moderate quality of the humidity indicator was presented in the comparison between the cocoa and cassava crops on location 1 from the APAUT and

Table 6. Overview of the standardized notes of technical evaluation in the studied Ultisol under different crops at APAUT and ASTRAL rural settlements

Settlement	Location	Crop	ORG	COV	ERO	HUM	COM	MIC	STR
			Evaluations Average (n = 5)						
APAUT (Ilhéus, Bahia)	1	Cocoa	45	9,70	12	264	1,40	17,4	98
		Cassava	38	4,80	12	273	1,61	24,5	86
	2	Cocoa	56	9,00	21	397	1,29	17,5	89
		Coffee	30	1,40	13	222	1,60	23,6	94
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		Pasture	25	6,60	19	170	2,04	16,6	86
	2	Cocoa	37	9,80	24	263	1,58	14,9	92
		Cassava	45	1,40	19	274	1,73	10,8	91

ORG: soil organic matter content (g kg^{-1}); COV: soil surface (%); ERO: loss of A horizon (cm); HUM: equivalent humidity (g kg^{-1}); COM: resistance to penetration (MPa); MIC: carbon dioxide evolution (mg CO_2 $kg^{-1}$of soil); STR: Aggregates stability index (%).[1]Farmer's evaluation average estimated in a scale with values from 0 to 10, quality concept: a - adequate, m – moderate and i - inadequate; [2] Inverse conception interpretation for the COM and ERO indicators

ASTRAL settlements (Table 6). The same concepts of soil quality related to the humidity and compaction indicators were observed on locations 1 and 2 from ASTRAL settlement (Table 6).

The microbial activity presented the best behaviour in the cassava crops on location 1 and the coffee crops on location 2 from APAUT settlement, when compared to the cocoa crops (Table 6). On location 1 from ASTRAL settlement, a moderate quality conception was presented for the microbial activity in regards to the cocoa and pasture crops, and inadequate on location 2 for the cocoa and cassava crops (Table 6). Mercante et al. (2008) researched cassava plantation systems and native vegetation and verified that the organic matter influences the soil microbiota, since it is a metabolism energy source. However, these authors did not find any significant differences between the microbial activity averages and metabolic/microbial quotients for the cassava and native vegetation under different soil management systems. On the other hand, Glaeser et al. (2010) verified that the microbial activity in a dense organic coffee plantation was superior to the other coffee plantations, and even superior to the native vegetation.

The evaluation of the structure indicator by the aggregates stability index presented an adequate quality conception for all of the different crops (Table 6).The changes in the crops were not enough to influence on the soil disaggregation, like it would be observed in management systems where constant practices of soil tillage would break and pulverize such aggregates (Silva Júnior et al., 2005; Ferreira, 2010).

By the Wilcoxon test it was possible to compare, in the APAUT and ASTRAL settlements, the soil quality indicator notes for the technical evaluation in relation to the empirical evaluation ones (Tables 7 and 8).

The notes averages from tables 7 and 8 only represent the different researched evaluations, because the Wilcoxon test is based on the difference between the positions for both evaluations in relation to the median.

The evaluation of the organic matter indicator, in all the crops of the APAUT and ASTRAL settlements, did not differ statistically from each other by the Wilcoxon test (Tables 7 and 8). The empirical method for the organic matter evaluation can be adopted by the farmers to assist them in the technical interpretation on this soil quality indicator.

With the exception of the pasture crops in the ASTRAL settlement, there were not any significant statistical differences between the soil cover indicator's for technical and empirical evaluations in the remaining crops (Tables 7 and 8), which can be explained by the similarities from the adopted methods.

The erosion indicator presented significant statistical differences between the technical and empirical evaluations in all the researched crops from the APAUT settlement, and only in the pasture and cassava crops from the ASTRAL settlement (Tables 7 and 8). The differences found in ASTRAL (Table 8) for the pasture and cassava crops, indicate that the erosion phenomenon needs to be observed more carefully by the farmers, due to in this initial experience the subjective method (USDA, 1999) did not reflect the evaluation done by the objective method (Lepsch, 1983).

The technical and empirical evaluations of the humidity indicator statistically differed for almost all the researched crops in APAUT and ASTRAL settlements, with the exception of the cocoa crops in location 1 in APAUT (Table 7) and the cassava crops on location 2 in ASTRAL settlement (Table 8).The empirical evaluation of the humidity indicator was used to verify two simultaneous physical phenomena, the water infiltration and retention by the soil, and this can explain the discrepancy between the technical evaluation values, which is only based on the actual soil humidity (Table 8).

The technical and empirical evaluations of the compaction indicator in APAUT settlement, significantly differed in the cocoa crops, and did not differ in the cassava and coffee crops (Table 7); in the ASTRAL settlement, there was only a significant difference between the cocoa crops on location 1 (Table 8). The differences between the subjective evaluation of the compaction quality indicator (Altieri, 2002) and the objective evaluation by the penetrometer scientific method (Stolf et al., 1983), suggest that the empirical interpretation of the compaction phenomenon should be re-discussed with the farmers.

By the Wilcoxon test no significant statistical differences were detected between the technical and empirical evaluations for the microbial indicator in the cocoa crops on locations 1 and 2 from the APAUT and ASTRAL settlements (Table 7), only differences in the cassava and coffee crops were found from the APAUT settlement (Table 7), and also pasture and cassava from the ASTRAL settlement (Table 8). The scientific method proposed by Silva et al. (2007), to evaluate the microbial activity, did not present an acceptable association with the empirical method proposed by Gama-Rodrigues (1997) and Sodré et al. (2000), so that adjustments in the empirical evaluation execution and interpretation are necessary or even replacement of such methods.

Table 7. Overview of the Wilcoxon test for comparison of the technical and empirical evaluations of the Ultisol quality indicators, under different crops in the APAUT settlement, Ilhéus, Bahia

Location	Crop	Evaluation	ORG	COV	ERO(2)	HUM	COM(2)	MIC	STR
			Evaluation Notes Average (n = 5) (1)						
1	Cocoa	Technical	6,94 m	9,70 a	7,00 i	5,28 m	6,98 m	5,79 m	9,80 a
		Empirical	7,76 a	9,70 a	1,28 a	5,70 m	4,32 i	7,02a	7,62 m
		p-value[1]	0,46	0,10	0,03	0,46	0,03	0,07	0,03
	Cassava	Technical	5,86 m	4,80 i	7,00 i	5,45 m	8,04 i	8,15 a	8,29 a
		Empirical	4,62 i	6,42 m	6,68 m	4,32 i	6,54 m	3,50 i	5,92 m
		p-value[1]	0,06	0,12	0,03	0,03	0,21	0,03	0,03
2	Cocoa	Technical	8,67 a	9,00 a	4,75 i	7,93 a	6,02 m	5,85 m	9,27 a
		Empirical	6,20 m	7,84 a	1,64 a	4,88 i	4,04 a	4,92 i	7,48 a
		p-value[1]	0,10	0,14	0,04	0,04	0,04	0,22	0,04
	Coffee	Technical	4,66 i	1,40 a	6,25 i	4,43 a	8,43 m	7,87 i	9,39 i
		Empirical	3,64 i	3,60 m	6,02 a	3,04 i	6,76 m	2,60 i	3,38 i
		p-value[1]	0,08	0,14	0,04	0,04	0,69	0,04	0,14

ORG: organic matter (sensorial evaluation, texture, odour, colour) = soil organic matter content (g kg^{-1}); COV: soil cover (%); ERO: erosion = the maximum value equivalent to the loss of O/A horizons (cm); HUM: humidity = equivalent humidity (g kg^{-1}); COM: compaction = the maximum value equivalent to the resistance to penetration of 2 MPa; MIC: microbial activity = carbon dioxide evolution (mg CO_2 $kg^{-1}$of soil); STR: structure = Aggregates stability index (%).(1)Farmer's evaluation average estimated in a scale with values from 0 to 10, quality conception index: a - adequate, m - average e i - inadequate; (2) Inverse conception interpretation for the COM e ERO indicators. *p-value*[1]*: Asymptotic significance on* 5% error level.

Table 8. Overview of the Wilcoxon test for comparison of the technical and empirical evaluations of the Ultisol quality indicators under different crops in the ASTRAL settlement, Maraú, Bahia

Location	Crop	Evaluation	ORG	COV	ERO(2)	UMID	COM(2)	MIC	STR
			Evaluation notes average (n = 5) (1)						
1	Cocoa	Technical	7,16 a	9,80 a	4,25 a	4,51 i	7,23 i	5,79 m	9,04 a
		Empirical	4,74 i	9,34 a	1,58 a	6,42 m	4,86 a	4,84 i	5,56 m
		p-value[1]	0,08	0,27	0,04	0,04	0,04	0,22	0,04
	Pasture	Technical	3,78 i	6,60 m	5,15 m	3,41 i	8,23 i	5,54 m	8,57 a
		Empirical	3,72 i	3,06 i	5,30 m	1,68 i	8,42 i	2,02 i	2,78 i
		p-value[1]	0,50	0,04	0,89	0,04	0,89	0,04	0,04
2	Cocoa	Technical	5,69 m	9,80 a	4,10 a	5,26 m	6,38 m	4,98 i	9,21 a
		Empirical	7,18 a	8,50 a	1,02 a	8,20 a	4,54 a	4,94 i	7,78 a
		p-value[1]	0,35	0,07	0,04	0,04	0,22	0,89	0,04
	Cassava	Technical	6,96 m	1,40 i	5,15 m	5,47 m	6,96 m	3,61 i	9,15 a
		Empirical	5,02 m	4,10 i	5,30 m	4,58 i	7,50 i	1,68 i	5,94 m
		p-value[1]	0,14	0,07	0,69	0,22	0,42	0,04	0,04

ORG: organic matter (sensorial evaluation, texture, odour, colour) = soil organic matter content (g kg^{-1}); COV: soil cover (%); ERO: erosion = the maximum value equivalent to the loss of O/A horizons (cm); HUM: humidity = equivalent humidity (g kg^{-1}); COM: compaction = the maximum value equivalent to the resistance to penetration of 2 MPa; MIC: microbial activity = carbon dioxide evolution (mg CO_2 $kg^{-1}$of soil); STR: structure = Aggregates stability index (%).(1)Farmer's evaluation average estimated in a scale with values from 0 to 10, quality conception index: a - adequate, m - average e i - inadequate; (2) Inverse conception interpretation for the COM e ERO indicators. *p-value*[1]*: Asymptotic significance on* 5% error level.

Similar to the erosion indicator, the structure indicator presented significant differences in almost all the researched crops, with the exception for the coffee crops in the APAUT settlement (Tables 7 and 8). The subjective evaluation of the structure indicator comprises the perception of several physical aspects of the aggregate (clod), that could have caused it to stand apart from the empirical notes attributed to the technical evaluation (Tables 7 and 8).

The Spearman rank correlation (Lehmann, 1979) between the technical and empirical evaluations of each soil quality indicator, to the APAUT and ASTRAL settlements, can be found on Table 9. Using Spearman's correlation coefficient was found the degree of association between general data sets.

In the APAUT settlement, the correlations between the empirical and technical evaluations highlight the significant and positive differences between the indicators organic matter, soil cover and compaction. The inverse correlation between the empirical and technical evaluation of the microbial activity indicator, suggests that one of the methods needs to the revised to represent the microbial activity in the soil. The non-significant correlation coefficients suggest that the empirical and technical methods cannot be equivalent like this research proposed, or that are necessary other technical interventions for the empirical evaluation revision and calibration. In the ASTRAL settlement there were positive and significant correlation, between the empirical and technical evaluations, to the indicators soil cover, erosion, and humidity (Table 9B). Also, the mismatch between some empirical and technical methods suggested the necessity to a more insightful empirical evaluation for the perception on the studied phenomena and /or the adoption of different technical methods to get best association between the empirical and technical methods.

It was decided to check the graphic of the distances of the means of both evaluations, through Figures 1 and 2, that show the radial charts represented by the soil quality indicators for empirical and technical evaluation, and for each local and land uses, at APAUT and ASTRAL settlements, respectively.

By the polygons, it can be observed that the APAUT settlement empirical evaluations underestimate most of the quality indicators of technical evaluations (Figure 1), however, approximation tendencies can be observed on the notes of both evaluations, for most of the indicators, especially in the cocoa and cassava crops.

Similar to the APAUT settlement empirical and technical evaluations, the polygons formed by the soil quality averages from the ASTRAL settlement show approximation tendencies between both the evaluations types, especially for the cocoa and cassava crops (Figure 2).

Table 9. Spearman correlations for the quality indicators of the technical and empirical evaluations of the Ultisol in the APAUT and ASTRAL settlements

(A) APAUT

Indicators		Technical Evaluation						
		ORG	COV	ERO	HUM	COM	MIC	STR
Empirical Evaluation	ORG	0,45*						
	COV		0,88**					
	ERO			0,31				
	HUM				0,16			
	COM					0,55*		
	MIC						-0,65**	
	STR							0,24

(B) ASTRAL

Indicators		ORG	COV	ERO	HUM	COM	MIC	STR
Empirical Evaluation	ORG	0,04						
	COV		0,78**					
	ERO			0,65**				
	HUM				0,46*			
	COM					0,08		
	MIC						0,39	
	STR							0,40

ORG: organic matter; COV: soil surface; ERO: erosion; HUM: humidity; COM: compaction; MIC: microbial activity; STR: structure.

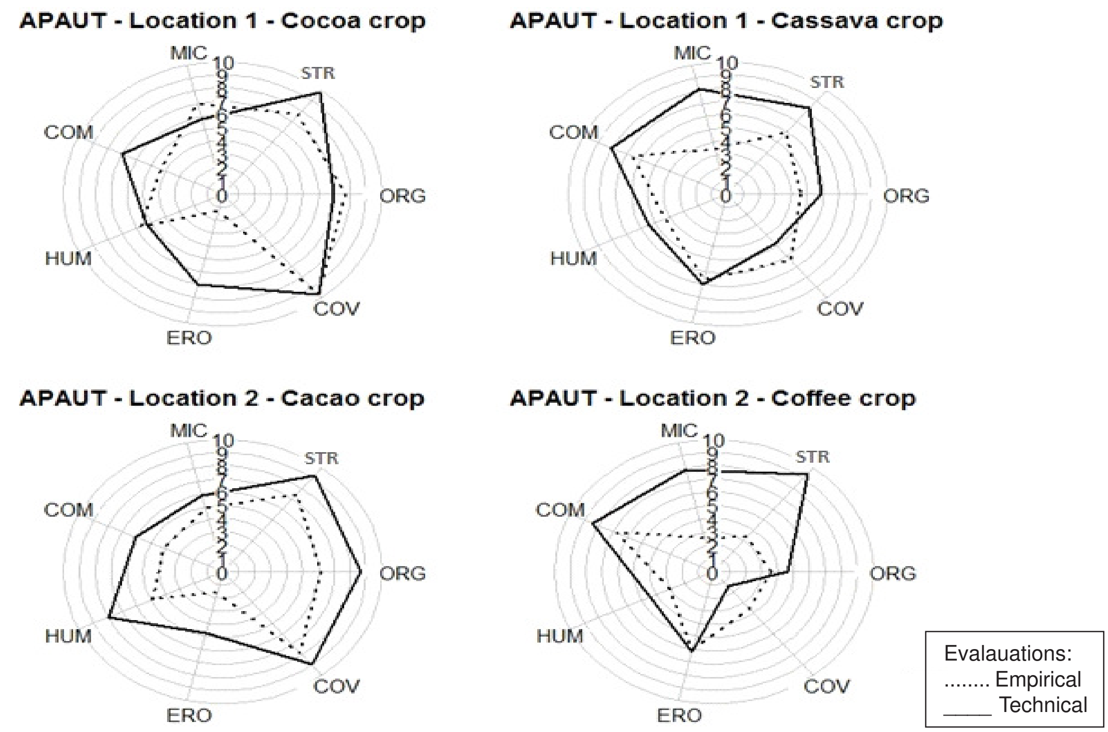

Figure 1. Radial charts of the soil quality indicators for empirical and technical evaluations at APAUT settlement. ORG: organic matter; COV: soil cover; ERO: erosion; HUM: humidity; COM: compaction; MIC: microbial activity; STR: structure.

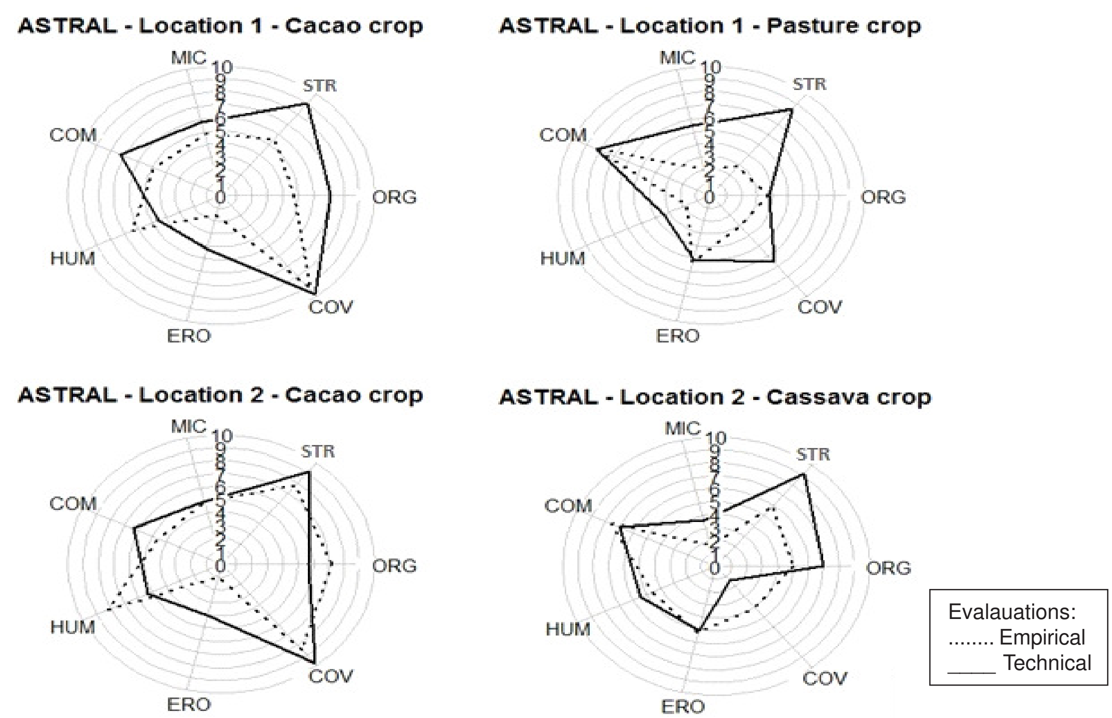

Figure 2. Radial charts of the soil quality indicators for empirical and technical evaluations at ASTRAL settlement. ORG: organic matter; COV: soil cover; ERO: erosion; HUM: humidity; COM: compaction; MIC: microbial activity; STR: structure.

As discussed on the Wilcoxon test (Tables 7 and 8) and by the Spearman rank correlations (Table 9), the empirical evaluations are submitted to the farmer's subjectivities. These farmer's first experiences with the participatory method was satisfactory from the technical interaction and responsiveness perspective in regards to the new information they acquired, but it´s necessary that these empirical methods could be replicated or even replaced to adjust them into the technical diagnosis reality for the soil quality, always encouraging the farmer's autonomy and participation in the identification and search for solutions on issues related to soil management and conservation.

Conclusions

1. The farmers from the APAUT and ASTRAL settlement were capable of differentiate the crops by the empirical evaluations of soil quality indicators.

2. In general, the empirical evaluations by the farmers underestimated the technical ones, however, both evaluations followed an approximation tendency, suggesting the necessity of the empirical methods reproduction to determine what can be improved or replaced during the evaluations.

3. The soil cover and organic matter empirical evaluation methods appeared to be capable to represent the technical evaluations of these same soil quality indicators.

4. The participatory methods utilization in the APAUT and ASTRAL settlements sparked the farmer's interest to better understand and evaluate the soil quality indicators. Also, the execution of the empirical method promoted the interaction between them and the technicians in the discussions related to soil management and conservation.

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