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Evaluation of soil structure using participatory methods in the semiarid region of Brazil


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Available in: http://www.redalyc.org/articulo.oa?id=195326432028
Evaluation of soil structure using participatory methods in the semiarid region of Brazil

Avaliação da estrutura do solo utilizando métodos participatórios na região semiárida brasileira

Ana Leônia de Araújo, Renato Teixeira de Oliveira, Tiago Osório Ferreira, Ricardo Espíndola Romero e Teógenes Senna de Oliveira

ABSTRACT - Conservation practices are important in improving the environmental protection of agroecosystems in semiarid regions, as these are considered to be fragile environments. Soil-quality indicators are useful elements in evaluating the impact of some agricultural management practices, and the use of recognized indicators which are able to be measured by farmers is an innovative approach that seeks to integrate both scientific and local knowledge. This study aimed to evaluate the impact of various management practices through indicators of soil quality related to soil structure, in areas of family farming where agroecological consortiums are employed. These indicators were identified as important by the farmers themselves, and methodologies were suggested for field application by the farmers, which were later compared to applications made in the laboratory. The indicators used were penetration resistance of the soil and stability and dispersion of aggregates for areas of agroecological consortium and natural vegetation. It can be concluded that agroecological consortia contribute to the conservation of soil structure and that the involvement of farmers plays an important role in developing research.

Key words: Soil structure. Soils - management. Family farm.

RESUMO - Práticas conservacionistas são importantes na melhoria da proteção ambiental de agroecossistemas em regiões semiáridas por estes serem considerados ambientes frágeis. Indicadores de qualidade do solo são elementos úteis na avaliação do impacto de algumas práticas de manejo agrícola e a utilização de indicadores reconhecidos e possíveis de serem mensurados por agricultores é uma abordagem inovadora que busca integrar conhecimento científico e local. Este estudo objetivou avaliar o impacto de algumas práticas de manejo em áreas de agricultores familiares que utilizam consórcios agroecológicos através de indicadores de qualidade do solo relacionados à estrutura do solo. Estes indicadores foram apontados como importantes pelos próprios agricultores, sendo propostas metodologias para aplicação em campo por eles mesmos, que foram posteriormente comparadas com aplicações em laboratório. Os indicadores utilizados foram resistência do solo à penetração, estabilidade e dispersão de agregados para áreas sob consórcio agroecológico e vegetação natural. Pode-se concluir que os consórcios agroecológicos contribuem para a conservação da estrutura do solo e o envolvimento dos agricultores é uma importante parte do desenvolvimento da pesquisa.

INTRODUCTION

The Brazilian northeastern is one of the most densely populated semi-arid regions in the world (INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA, 2010). The intensive use of natural resources, lack of adoption of conservative management practices and climatic limitation (frequent droughts) can lead to soil quality degradation, restricting agricultural production. Nowadays, more than half of the area in the northeastern region is considered degraded in different levels (BRASIL, 2005).

Thereby, sustainable agriculture represents an important alternative for food production (GLIESSMAN et al., 2007). Multi cropping system (MCS) is a model of sustainable agriculture, promoting diversity of diet, reducing risk of losses, efficient use of labor, and low external inputs (HYVÖNEN et al., 2003) as well as smaller erosion risks (DAELLENBACH et al., 2005).

Under these agroecosystems, soil quality is a substantial element as it is related to the capacity of a soil to be functional, within the limits imposed by the ecosystem and land use, to preserve the biological productivity and environmental quality, and promote plant, animal and human health (DORAN; PARKIN, 1994). Using an approach to gather farmers and their knowledge, technicians and researchers to evaluate soil quality is an innovative way to create a shared knowledge, and many researchers have identified that this synergism is important (BARRERA-BASSOLS; ZINCK, 2003; BARRIOS et al., 2006; GROSSMAN, 2003; MAIRURA et al., 2007; PAYTON et al., 2003).

Scientific methods are based in standard procedures and can be used to evaluate the practices developed in MCS, however, in a complementary way, using methods developed or adapted to the farmer’s perception enables to get a more realistic assessment (GUIMARÃES; BALL; TORMENTA, 2011; MUELLER et al., 2009). Farmer’s perception related to soil quality indicators were identified by Sousa (2006) and a group of technicians and researchers from Universidade Federal do Ceará (UFC) and Viçosa (UFV). Some family farmers led by ESPLAR, a non-governmental organization (NGO), were stimulated to participate in soil conservation (UFV). Some family farmers led by ESPLAR, a non-governmental organization (NGO), were stimulated to participate in soil conservation practices and climatic limitation (BARRIOS et al., 2007; PAYTON et al., 2003).

For the present study, three farmers were selected among the ones who worked with ESPLAR and in the research conducted by Sousa (2006). The MCS were composed by cotton (*Gossypium hirsutum*), maize (*Zea mays*), cowpea (*Vigna unguiculata*), and sesame (*Sesamum indicum*) under different arrangements. The natural vegetation (NV) areas are near the MCS, were not used for cropping and reflected a natural situation.

The study area is located in Choró county in the central part of Ceará state, Brazil, around the coordinates 4°40′20″ S; 39°10′46″ W with mean altitude of 250 m and topography predominantly gently slope with tropical warm semi-arid climate (BSw’h) based in Köppen. Annual mean rainfall and temperature are 922 mm and 27 °C, respectively. Rainfall is concentrated in a few months characterizing a long period with water scarcity. The natural vegetation is characterized as Caatinga, predominantly shrubs trees, with adapted mechanisms to resist dry seasons (MOREIRA et al., 2006). A characterization of the areas and soil classification is described in Table 1.

Aggregate stability

Stability of aggregates was determined by the standard method (SM) proposed by Yoder (1936). The alternative method used aggregates of 15 mm of diameter weighing 50 g that were put in a plastic bottle of 1 L capacity with 800 mL of water and shaken at breast height for 20 s. After shaking, the material was transferred to a sieve of 2 mm and the material which remained in the sieve was put in an iron plate to dry and its moisture was calculated. To weigh the soil a simple balance was used with a horizontal stick fastened in a vertical structure and two containers in the horizontal extremities, one for soil and other for a standard weight (100 g). A moistened soil sample weighed in this balance was heated and then...
Table 1 - Soil classification, main physical and chemical soil attributes and historical use of multi cropping system (MCS) and natural vegetation (NV) areas from studied family farmers

<table>
<thead>
<tr>
<th>Areas</th>
<th>Soil classification</th>
<th>Physical and chemical attributes</th>
<th>Historical use of MCS and NV areas</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hor.1/Depth (cm)</td>
<td>Texture (g kg\textsuperscript{-1})</td>
<td>SOC\textsuperscript{2} (g kg\textsuperscript{-1})</td>
</tr>
<tr>
<td>1</td>
<td>Inceptic Haplustalfs</td>
<td>A</td>
<td>770</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0-6</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B</td>
<td>480</td>
</tr>
<tr>
<td></td>
<td></td>
<td>19-41</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Aquic Haplustult</td>
<td>A</td>
<td>830</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0-8</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>B</td>
<td>630</td>
</tr>
<tr>
<td></td>
<td></td>
<td>34-89</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Typic Ustipsamments</td>
<td>A</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0-22</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>740</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22-48</td>
<td></td>
</tr>
</tbody>
</table>


transferred to the container. Putting the sample again in the balance, it showed an imbalance due to the loss of water and soil, therefore, using a syringe, some water was put in the container with the soil sample until a balance was reached. The iron plate heating was done with 200 mL of ethyl alcohol and time of heating of 20 minutes. To define shaking time of 20 s, different time intervals were tested (20; 40; 60 and 80 s) and compared to the SM. With times established, the proceedings were done in the field by farmers and then repeated in laboratory by authors to compare the performance of the methodology.

Aggregate dispersion

The methodology proposed by Emerson (1967) and Cerda (1998) was applied with no adaptations. Ten aggregates of 10 mm were put in 200 mL of water to evaluate its dispersion after 12; 24 and 36 hours, considering the scale: 0: no dispersion and aggregates completely stable; 1: dispersion of some particles, milkiness close to the aggregates; 2: Aggregates partly dispersed or divided into different smaller aggregates; 3: Considerable dispersion with most of the aggregates have been dispersed and milkiness very intense; 4: Total dispersion. This analysis was done in the laboratory by authors and in the field by farmers using samples from MCS and NV.

Soil penetration resistance (SPR)

The penetrometer method was chosen as the standard method (STOLF; FERNANDES; FURLANI, 1983) and the alternative method used an iron bar, common in civil engineering that consists of a bar with 5,12 kg and a cone basal area of 6,15 cm\textsuperscript{2}. 
To obtain an equation of SPR from the iron bar, it was assumed that all the energy was transformed in soil penetration, so: $E = t$ and $E = m \cdot g \cdot h$, where: $m$ = weight of the iron bar (kg), $g$ = gravity’s acceleration ($m \cdot s^{-2}$) and $h$ = height of release (m). Considering that SPR is energy per area, and the tool’s basal area is $6.15 \times 10^{-4} \text{m}^2$, it follows that $SPR = \frac{E}{\text{Basal area}}$ or $SPR = \frac{81.586.9}{h}$. Considering also the tool penetration by impact influencing the SPR value we will obtain the final equation as $SPR = 81.5 \text{N} \cdot \text{h}$. Where $N = \frac{1}{\text{Penetration's depth (m)}}$ and $h$ = height of tool’s release (m).

In the alternative method, the iron bar was released from 4 heights (0.2; 0.4; 0.6 and 0.8 m), and the penetration into the soil surface was quantified. The two methods were applied simultaneously in MCS and NV areas.

### Statistical analysis

The results were analyzed, except for soil penetration resistance, using analysis of variance (ANOVA) with a completely randomized design with split plot, comparing means using Tukey test ($\alpha = 0.10$) as was used field and farmer’s measurements. Statistical analyses were performed using SAEG 6.0 (FUNDAÇÃO DE APOIO À UNIVERSIDADE FEDERAL DE VIÇOSA, 1993).

### RESULTS AND DISCUSSION

Although just the area 2 showed differences between MCS and NV (Table 2) this result outpoints a similarity between MCS and the reference situation (NV) in soil structure, which may be related to the management practices as the addition of organic matter and decreasing soil handling (BERTOL et al., 2004; PEIGNÉ et al., 2007). Besides, a high earthworms activity was noted in these areas during the cropping season, which can be related to favourable effects on structural condition (MAHBOUBI; LAL, 1998). Allied to it, root action in promoting aggregation and surface protection led by the spontaneous plants also contributed to these results (SILVA et al., 2008).

An evaluation of mean weight diameter (MWD) revealed larger values for NV, what could indicate a better soil structural condition. In the alternative method, the time of shaking of 20 s, was chosen considering NV as a reference condition. No significant differences were found when the alternative method was applied in the field or in the laboratory, except for area 1 (Table 2).

Comparing the application in the field and in the laboratory did not reveal differences (Table 3), what could predict that it is an accurate way to evaluate aggregate stability and is accessible for farmers. It was not possible to obtain results from field measurements due to lack of data from field measurements.

Aggregate dispersion values from area 1 showed differences between times and applications, with dispersion increasing with time (Figure 1). Furthermore, significant differences were found between MCS and NV in area 2 with a smaller dispersion class for MCS, with two times of evaluation with zero dispersion (Figure 2).

Despite the conflicting results (Figure 1 and 2) in the situations observed, the values found were low,

### Table 2 - Aggregate stability of MWD, C1 (4-2 mm) and C5 (< 0.25 mm) obtained using the standard method (SM) and the alternative method with shaking times of 20; 40 and 60 s for multi cropping system (MCS) and natural vegetation (NV) areas

<table>
<thead>
<tr>
<th>Areas</th>
<th>Classes</th>
<th>SM</th>
<th>20s</th>
<th>40s</th>
<th>60s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MWD</td>
<td>4.33 Aa</td>
<td>3.57 Aa</td>
<td>2.43 Ab</td>
<td>3.06 Aa</td>
</tr>
<tr>
<td>2</td>
<td>C1</td>
<td>3.61 Aa</td>
<td>6.13 Aa</td>
<td>4.69 Aa</td>
<td>5.36 Aa</td>
</tr>
<tr>
<td>3</td>
<td>C5</td>
<td>2.03 Aa</td>
<td>4.15 Aa</td>
<td>2.22 Aa</td>
<td>3.53 Aa</td>
</tr>
</tbody>
</table>

Means with same upper case letters in column compare each class (MWD, C1 and C5) for the situations MCS and NV and means with same low case letters in row compare methods with the situations MCS and NV do not differ by Tukey test ($\alpha = 0.10$).
Table 3 - Mean stable aggregates > 2.0 mm in water by shaking for 20 s in alternative methodology to multi cropping system (MCS) and natural vegetation (NV) areas, under laboratory and field conditions for areas 1 and 2

<table>
<thead>
<tr>
<th>Areas</th>
<th>Situation</th>
<th>Laboratory</th>
<th>Field</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MCS</td>
<td>59.47 Aa</td>
<td>67.33 Aa</td>
</tr>
<tr>
<td></td>
<td>NV</td>
<td>66.37 Aa</td>
<td>68.33 Aa</td>
</tr>
<tr>
<td>2</td>
<td>MCS</td>
<td>67.17 Aa</td>
<td>66.50 Aa</td>
</tr>
<tr>
<td></td>
<td>NV</td>
<td>72.40 Aa</td>
<td>65.67 Aa</td>
</tr>
</tbody>
</table>

Means with same upper case letters in column compare the situations MCS and NV for each area and means with same low case letters in row compare applications in laboratory and in field do not differ by Tukey test (α = 0.10)

Figure 1 - Mean aggregate dispersion classes in water in 12; 24 and 36 hours in laboratory and field application of area 1. Means with same upper case letters compare application in each time of dispersion and means with same low case letters compare application with times of dispersion do not differ by Tukey test (α = 0.10)

Figure 2 - Mean aggregate dispersion classes in water in 12; 24 and 36 hours in multi cropping system (MCS) and natural vegetation (NV) of area 2. Means with same upper case letters compare time of dispersion for each situation and means with same low case letters compare situation for each time do not differ by Tukey test (α = 0.10)

Soil structure practices. Soil cover management in tropical areas protects it from surface sealing in rainy periods and from crusting during dry periods. Furthermore, these benefits can reduce SPR (THIERFELDER; AMÉZQUITA; STAHN, 2005).

Literature account that SPR values higher than 1960 kN m$^{-2}$ can be considered as limiting to root growth and crop development (AGGARWAL et al., 2006). However, superior values were observed in MCS from area 1 (Figure 3), which can be related to a high concentration of stones, conditioning root development among them.

Values for SPR obtained with a penetrometer in MCS and NV from area 1 tended to rise from the 0.1 m depth, due to clay content increase below this depth, since this soil class has an “Abrupt Textural Change” (SOIL SURVEY STAFF, 1999). Increasing in
Figure 3 - Mean soil penetration resistance in kN m\(^{-2}\) obtained with standard and alternative methodology (release heights of 0.2; 0.4; 0.6 and 0.8 m) and mean soil moisture (mass based) of multi cropping system (MCS) and natural vegetation (NV) from areas 1 and 2

clay content may promote an increment in soil density and expression of adhesion and cohesion strength (PEDROTTI et al., 2001). In area 2, SPR with standard method in both situations (MCS and NV) showed a tendency to increase until 0.1 m, decreasing from then on.

Comparing methodologies is possible to conclude that the height of releasing of 0.6 m from alternative methodology show results resembled to 0.05 m from standard methodology. It is important to mention that soil moisture obtained in the moment of SPR evaluation did not show significant difference between conditions MCS and NV.

In general, results obtained in the laboratory and in the field, showed that the better soil conditions observed in MCS are probably related to the conservative management practices adopted. These results are related to a better soil structural condition favoured by the increase in organic matter and residues (BRONICK; LAL, 2005; GHANBARI et al., 2010). Values obtained for aggregate dispersion and penetrometer resistance confirm the statements assumed above as found also by Cerda (1998), Castro Filho et al. (2002), Zeleke et al. (2004) and Andrade and Stone (2009).

Farmer’s impressions on the research were obtained through a questionnaire and they reported that it was an interesting evaluation as it enabled them to obtain results about management practices they are currently using. However, some farmers reported that soil structure evaluation methods could have been faster and more practical.

CONCLUSIONS

1. Alternative methods development to be applied in the field by farmers, based on standard methods were an approved manner to measure changes in the agroecosystems and may favour environment monitoring and evaluation of areas under conservative practices. Moreover, a holistic approach is necessary to understand the impact of sustainable practices and to reach multiple benefits through the development of environmental programs and projects;
2. Soil quality is positively affected by conservative management practices as multi cropping system areas showed similar conditions to natural vegetation ones. Seeing the farmer’s direct involvement in indicators identification and mainly in methodologies performance, one can presume an advance in formal and local knowledge integration;

3. A positive point in this experiment is that farmers had an opportunity to associate empiric observations to measured values, what represents an important step in building the bridge between local and formal knowledge.

ACKNOWLEDGEMENTS

We would like to thank the opportunity given from CNPq, funding the project. We thank all the farmers who were involved with this study with multi cropping systems, specially those directly involved in this research Mrs. Maria Liduína, Mr. João Félix, Mr. José Alberto and Mr. Antônio Alberto. We would also like to thank the staff from NGO ESPLAR who helped with the set up for this project and also with field work, as well as other people involved from UFC such as Maria Valdenira Oliveira, Vágner Silva and Pollyanna Silva.

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