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SOIL AND PLANT NUTRITION - Article

Soil structural quality degradation by the increase in grazing intensity in integrated crop-livestock system

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ABSTRACT: The intensification of soil use, as in integrated crop-livestock system (ICLS), might promote soil structural degradation. A field method to evaluate the soil structural quality is the Visual Evaluation of Soil Structure (VESS). Studies on the application of this method to ICLS are few. This work aimed to evaluate the structural quality of a Dystrudept under ICLS and different grazing intensities through VESS. Thus, the soil structure was evaluated in light grazing (LG) and heavy grazing (HG) in comparison to a neighboring native forest (NF) as reference area. After the grazing period, 10 trenches were dug in each area to collect soil monoliths. The identification of structural differences and the attribution of visual scores were carried out according to the VESS. In NF and HG soils, up to 30 cm deep, it was possible to identify 2 layers with distinct structures, while, in the LG, up to 3 layers were identified. The NF soil presented the best structural quality. Regarding both grazing intensities, there was degradation of the structural quality between soil layers when compared to the NF. The increase in grazing intensity in ICLS promoted in-depth degradation of the soil structural quality. The VESS method was shown suitable to evaluate soils under ICLS management with LG and HG.

Key words: cattle trampling, soil compaction, Visual Evaluation of Soil Structure.

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INTRODUCTION

The growing demand in food production leads to intensification of soil use in agricultural farming and cattle raising integrated production systems, mainly in the integrated crop-livestock system (ICLS) (Carvalho et al. 2014). Nevertheless, the intensification in the soil use might promote degradation of this natural resource (Hamza and Anderson 2005; Drewry et al. 2008; Batey 2009).

Traditionally, soil structure evaluations have been based on laboratory methods. However, careless sampling might cause some deformation to the soil sample, which compromises the reliability of the results (Pires et al. 2004). In this context, alternative methods to evaluate soil structure in the field have been proposed, such as the method suggested by Ball et al. (2007). This method, called Visual Evaluation of Soil Structure (VESS), is based on the visual distinction of the structures present in different soil layers. Therefore, after the soil is sampled, visual scores of structure quality (Sq) are assigned to the layers, according to the aggregates size and appearance, visible porosity, root presence, appearance after handling and description of natural aggregates. The Sq are marks given according to a reference chart (Ball et al. 2007), which range from 1 to 5, that is, the best and worst structural qualities, respectively. According to the reference chart, a Sq between 1 and 3 indicates acceptable conditions of management and soil physical quality, while a Sq from 4 to 5 requires changes in the soil management.

Due to the changes in the soil structure in ICLS and the scarcity of information on VESS applicability in this kind of system, our hypothesis is that the heavy grazing intensity in ICLS negatively affects the soil structure, and this can be evaluated by VESS. In such a context, this study aimed to evaluate the structural quality of a Typic Distrudept clayed under ICLS and different grazing intensities through the VESS.

MATERIAL AND METHODS

The study was carried out in Castro, Paraná, Brazil (lat 24°51′49″, long 49°56′61″, and a mean elevation of 1,020 m), located in the First Paraná Plateau. The climate in the region, according to the Köppen classification, is Cfb (IAPAR 2009). The average annual rainfall is about 1,600 mm, and August is the driest month, while January is the wettest one.

Three areas were evaluated under different uses of a Dystrudept (Soil Survey Staff 2013) or "Cambissolo Háplico distrófico", according to the Brazilian Soil Classification System (Santos et al. 2013). The soil shown in the 0 – 20 cm layer presented: 600, 227 and 173 $g \cdot kg^{-1}$ clay, silt and sand, respectively.

Two areas have been used under no tillage system (NT) since 2004. The crop rotation includes black oat, wheat or annual ryegrass in autumn-winter season as well as soybean or corn in spring-summer season. From 2009, the ICLS was implemented with the NT, with different grazing intensities: (i) heavy grazing (HG) and (ii) light grazing (LG). The crops implemented in rotation since 2009 were: black oat or annual ryegrass in autumn-winter season and corn or soybean in spring-summer season.

The grazing method adopted in the areas under ICLS during the autumn-spring season was in rotation, in paddocks of 5,525 m^2. It was possible to obtain 4 grazing cycles in the areas throughout the period from June to October 2012. In the HG area, the grazing cycles started and ended when the forage (annual ryegrass cv. FABC1 together with cv. Jumbo) was 25 and 10 cm high, respectively, comprising an occupation period of 6 – 7 days. Regarding the LG, the grazing cycles started when the annual ryegrass was above 40 cm, with an occupation period related to the final height of the desired grazing intensity (LG), which was 30 cm. In both areas, 15 Holstein heifers, with an average weight of 300 kg, were used.

The third area evaluated was a fragment of native forest (NF), taken as reference of soil structural quality. This area (never used for agricultural purposes) is located around 400 m distant from the other 2 areas under study. The forest formation was classified as Mixed Ombrophilous Forest, with primary vegetation.

The VESS was carried out in the 3 areas in October 2012 — soon after the animals were removed from the grazing areas. Ten trenches were dug in each area (HG, LG and NF), measuring 25 × 30 × 40 cm long, thin and deep, respectively, by using shovels. From each trench, a soil monolith of around 15 × 15 × 30 cm long, thin and deep, respectively, was collected. After extracted, the monoliths were deposited on a plain surface, measured and manually disaggregated thoroughly in order to separate them into natural aggregates only.

According to the aggregate characteristic differentiation, the monolith profile layers were identified, measuring the thickness of each one, and then the Sq was given (Ball et al. 2007). Taking the Sq and the thickness of each layer, the monolith final Sq was calculated according to Giarola et al. (2009).

In each grazing intensity and NF, 10 undisturbed soil samples were collected into stainless steel volumetric rings of 5 × 5 cm (external diameter and height), employing an Uhland sampler in the soil layers (0 – 10 and 10 – 20 cm). These soil samples were used to determine the bulk density (BD) (Dane et al. 2002).

The Sq and BD means averages were compared through the confidence interval (α = 0.05). Simple linear correlation analyses were also carried out between Sq and BD. Statistical analyses were performed using the software R, version 3.0.2 (R Core Team 2013).

RESULTS AND DISCUSSION

Soil layers identified

In NF and HG, 2 soil layers were identified, with distinct structures, while, in LG, up to 3 soil layers were observed. However, it is important to highlight that, in LG, the occurrence of 2 layers with 15.5 cm size was more frequent (60%), as well as in HG (Table 1).

The first layer in NF was the one with the lowest Sq, which means the best structural quality (Table 2). This Sq was given to this layer because of the easiness to introduce the shovel in the soil; besides, it presented high friability, porosity and large number of small aggregates and roots all over the soil. In addition, it was possible to observe the richness of the characteristic macrofauna, including annelids, arthropods and small rodents. It is relevant to emphasize the biodiversity of this soil, as the presence of invertebrates, mainly annelids, improves the structure and processes occurring in the soil (Blanchart et al. 2004; Capowiez et al. 2012).

The second layer identified in NF was given higher Sq when compared to the first one (Table 2). However, the value obtained indicates good structure, presenting small-sized round aggregates, high porosity and the presence of roots all over the soil. The results obtained in this study confirmed those obtained by Giarola et al. (2009; 2010), showing that the absence of mechanical stress kept the structural uniformity of the soil.

Two monoliths from LG presented 3 layers (Table 1). The differentiation of these layers was ascribed to the following characteristics: (i) the first layer offered resistance to disaggregation, being rigid, presenting cracks, with roots accumulated and grouped around the aggregates as well as low porosity; (ii) the second layer presented lower resistance to disaggregation in comparison to the first one,

Table 1. Weighted means of soil layers identified by Visual Evaluation of Soil Structure due to the grazing intensity (light or heavy) in the integrated crop-livestock system and under native forest.

Soil use	First layer	Second layer	Third layer	Final
	cm			
Native forest	10.15	16.85	---	27.00
Light grazing	13.30	15.50	13.00	28.30
Heavy grazing	13.10	15.40	---	28.50

The means were calculated considering the number of monoliths (n = 10) that presented the layers identified. Light grazing is an exception in the second (n = 8) and third (n = 2) layers.

Table 2. Score of structural quality and soil bulk density due to the grazing intensity (light or heavy) in the integrated crop-livestock system and under native forest.

Soil use	Structural quality			Bulk density ($g \cdot cm^{-3}$)		
	First layer	Second layer	Final	0 – 10 cm	10 – 20 cm	0 – 20 cm
Native forest	1.00 c	1.75 b	1.46 c	0.95 b	1.13 a	1.04 b
Light grazing	2.78 b	2.49 a	2.52 b	0.98 b	1.06 b	1.02 b
Heavy grazing	3.62 a	2.85 a	3.24 a	1.14 a	1.11 a	1.13 a
CI	±0.41	±0.21	±0.28	±0.032	±0.015	±0.019
CV (%)	13.64	17.03	10.73	3.35	2.83	2.55

CI = Confidence interval (α = 0.05); CV = Coefficient of variation; Means followed by the same letter in each soil layer did not differ from each other by mean confidence interval.

exposing smaller aggregates, few pores and few roots; and (iii) the third layer was easy to disaggregate, using only 1 hand, and the aggregates were small and porous with few roots but large number of annelids, which gave it a lower Sq (Table 2).

It seems important to highlight that, for 2 monoliths evaluated in LG, there was no differentiation of layers up to the total depth evaluated. In those samples, where the profile was uniform, there was a large number of roots all over the soil and easily broken small aggregates.

In general, very firm and hard aggregates, which were difficult to break with 1 hand, with low porosity and presence of cracks were found in the first layer of monoliths in the superficial layer of HG. Roots were mostly found accumulated in macropores inside and around of the aggregates. However, the second layer of HG showed similar characteristics to LG.

Structural quality alteration: relations between Visual Evaluation of Soil Structure and bulk density

There was influence of the grazing intensities in both soil layers on Sq and BD (Table 2). For VESS, the NF presented smaller Sq than LG and HG in both soil layers identified. Among the grazing intensities, the HG presented Sq higher to LG in the first soil layer. However, in the second soil layer, the Sq values were similar between both grazing intensities. The final Sq followed the same trend as the first soil layer (Table 2).

Similarly, the BD at 0 – 10 cm of the HG was higher than NF and LG, which did not differ from each other (Table 2). In the 10 – 20 cm layer, the opposite results were observed in the 0 – 10 cm layer. In this case, the BD of HG was similar to the NF and the both upper LGs. Just as observed for Sq, the BD average of 0 – 20 cm layer followed the same trend as the more superficial soil layer (0 – 10 cm) (Table 2).

Sq and BD showed strong correlations, mainly for grazing intensities. There is any correlation between Sq and BD in the first soil layer identified and 0 – 10 cm soil layer for NF, as a consequence of the small variation in Sq and BD in these layers. On the other hand, the increase in the BD tends to increase the Sq in both grazing intensities and all soil layers evaluated (Figure 1).

These results reinforce the common report in the literature that the effects of animal trampling on soil structure have been restricted to the most superficial soil layer (Drewry et al. 2008; Carvalho et al. 2010; Bell et al. 2011; Andreolla et al. 2014; Auler et al. 2014; Silva et al. 2014; Veiga et al. 2014). However, it is important to emphasize that Sq showed higher sensitivity in detecting structural differences in the soil in relation to BD, considering the greater depth of the first identified soil layer (Table 1) against the sampled layer for the determination of BD (0 – 10 cm).

These results demonstrate that the prior determination of the soil layer to be sampled (0 – 10 and 10 – 20 cm, for example) for the assessment of soil structure, as massively used in research in Soil Physics, might not represent the real

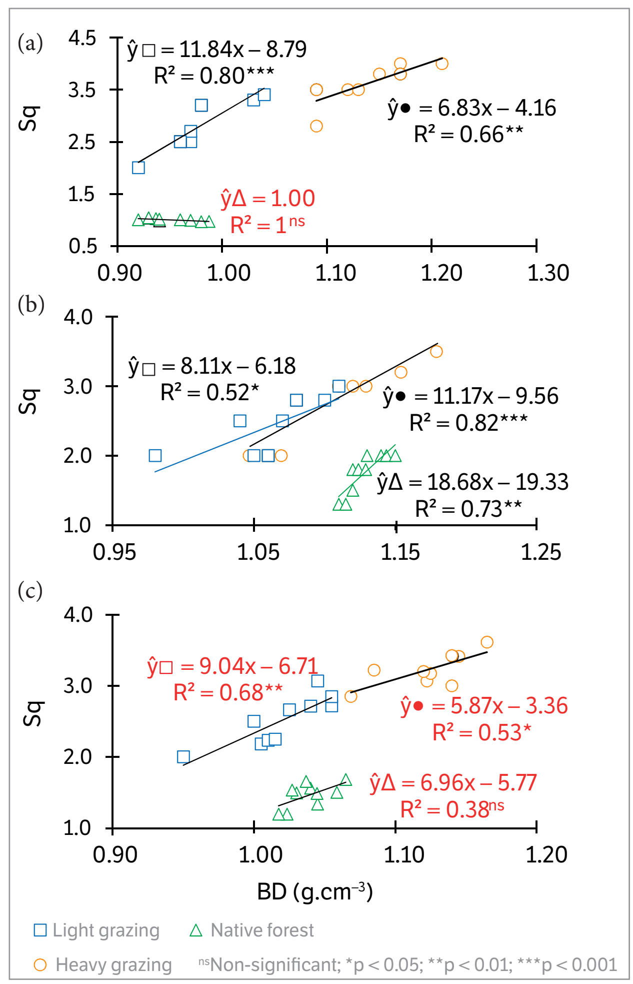

Figure 1. Correlations between score of structural quality (Sq) and soil bulk density (BD) due to the grazing intensity in the integrated crop-livestock system and under native forest: (a) First soil layer versus 0 – 10 cm; (b) Second soil layer versus 10 – 20 cm; (c) Sq final versus 0 – 20 cm.

field conditions. These problems may be further aggravated considering the soil moisture conditions and the sampling method used in the collection of undisturbed samples, which might cause deformation of the samples and compromise the reliability of the results (Pires et al. 2004).

It is important to emphasize the advancement of studies about VESS in recent years, especially in Brazil, which manifest its applicability (Giarola et al. 2009; 2010; 2013; Müller et al. 2012; Cherubin et al. 2016). Although the results of the VESS have been highly correlated with other soil physical attributes evaluated in laboratory (Mueller et al. 2009; Guimarães et al. 2011; 2013), as also observed in this study (Figure 1), this methodology provides only semi-quantitative information about the state of the soil physical quality (Mueller et al. 2009). Thus, the VESS does not dispense the use of a laboratory method to assess soil structure.

In both grazing intensities, there was degradation of the soil structural quality in relation to the NF, and the most noticeable effects were in the HG (Table 2), differing from the results found by Giarola et al. (2010; 2013) and Guimarães et al. (2011). Giarola et al. (2010) verified that, even with the increase in Sq due to the soil use, the in-depth gradient of 2 soils with different texture (clayey and sandy) exclusively under NT was similar to that in the forest. Guimarães et al. (2011), evaluating several British soils and 2 Brazilian ones, found results like those by Giarola et al. (2010; 2013); from the 8 soils under evaluation, none had been submitted to animal grazing. Thus, comparing the results found in the literature with the ones obtained in this study, it seems that changes in the soil structural quality in soils under ICLS occur in a different way from those exclusively under NT.

Thus, the highest Sq values of the first soil layer and BD at 0 – 10 cm of the HG (Table 2) show the evidence of compressive processes which promote the soil structure degradation. These compressive processes might be attributed to the conditions of intense trampling combined with higher soil moisture during the winter season, which tends to favor a more intense pressure in the soil and might cause the compaction of the soil surface layer (Hamza and Anderson 2005; Drewry et al. 2008).

Final considerations to the soil management

It seems important to highlight that, in their original study, Ball et al. (2007) propose that systems with final Sq between 1 and 3 indicate acceptable conditions of soil management and physical quality. In this case, only HG presented final Sq higher than 3, while the NF presented the best structural quality (Table 2). The LG presented suitable structural quality, however, it needs periodical monitoring considering that the final Sq found was close to the Sq = 3 (Table 2).

Results found for LG and HG confirmed the findings from Drewry et al. (2008) and Bell et al. (2011). Those studies highlight that the use of suitable intensity grazing, with proper forage offer, does not reach levels that might compact the soil. However, restrictions at the soil superficial layer occur with heavier grazing (Flores et al. 2007). Thus, the first measure to improve the structure of the soil under HG would be reduction in the grazing intensity, since grazing areas managed with suitable intensity might favor the increment of organic matter in the soil (Souza et al. 2008) as well as the forage root system. Such factors, when interlinked, tend to favor the soil structure, preventing possible superficial compaction caused by the excess of animal trampling (Flores et al. 2007; Drewry et al. 2008).

The effects caused by animal trampling to the most superficial layer of the soil in both grazing intensities might be reduced by the summer crop sowing operations in ICLS (Batey 2009; Conte et al. 2011; Andreolla et al. 2014). However, for this, furrow openers mechanisms should be used, acting in higher depth, such as tine or runner types, to break this soil layer denser for the summer crop establishment (Munir et al. 2012), considering the greater depth of the first soil layer identified by VESS (Table 1).

Therefore, in the LG and HG areas, periodical evaluations of the soil structure should be carried out, aiming to measure and plan properly the traffic of machinery on this area, as well as the grazing intensity according to the soil capacity and its humidity conditions.

CONCLUSION

The hypothesis in study was confirmed, demonstrating that heavy grazing intensity in integrated crop-livestock systems compacts the soil in relation to light grazing intensity.

The Visual Evaluation of Soil Structure method was shown suitable to evaluate soils in integrated crop-livestock systems with light and heavy grazing in relation to the evaluation of soil bulk density.

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