Technical Note

Soil quality index in the Animal Husbandry Enterprise El Tablón (Cienfuegos, Cuba)

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Abstract

In 2015, soil fertility studies in the main animal husbandry enterprises of Cuba showed that 90,6 % of the areas were affected by one or more limiting factors; and in Cienfuegos province, 25 % of the agricultural surface of the Animal Husbandry Enterprise El Tablón was not free from such deficiencies. In this study the quality index of a Grayish Brown soil was determined in areas of natural pastures of that entity, from the validation of the software *Sistema Cuantitativo de Evaluación y Monitoreo de la Calidad del Suelo* (Quantitative System of Soil Quality Evaluation and Monitoring, SEMCAS), which integrally analyzes physical, chemical and biological indicators. The measurements were made according to a randomized block design, in two dairy farms and in 4 x 4 m^2 plots. The samples were taken in the rainy and dry seasons. The data were statistically processed, through a simple classification variance analysis. The physical indicators showed high apparent density and hygroscopic moisture below the established optimum range. Acid pH was found; while assimilable phosphorus, cation exchange capacity and base saturation percentage were low. The values of the soil quality index differed statistically between the sampling sites, although discreetly, and in general they were between 0,29 and 0,32. To widen the sampling frequency and to include new indicators in the evaluation are recommended.

Keywords: carbon, soil fertility, physical-chemical properties soil

Introduction

The current predictions indicate that in 2050 mankind will face, from two perspectives: agricultural and animal husbandry, a series of important and transcendental challenges, and the world population can reach around 9 000 million people. But this is not just a reference number, which, in itself, leads to reflect deeply, but it also makes the food situation complex at global level, where the first challenge is based on a multifactorial reality in which the following elements will be involved: water; attention to the effects of global warming; agricultural and animal production; adequate management of agricultural, animal husbandry and human byproducts; and sustainable use of the soil resource, among other factors (Buxadé, 2015).

During 2015, the Ministry of Agriculture (MINAGRI) conducted agrochemical studies in the main animal husbandry enterprises of the country (Lok, 2015). This analysis showed that 90,6 % of the evaluated areas was affected by one or more limiting factors, from them 45 % by low natural fertility. In the Cienfuegos province 25 % of the agricultural area of the Animal Husbandry Enterprise El Tablón (2 200 ha) is not free from the above-mentioned deficiencies, which presupposes scientific-technical actions to mitigate their effects.

The software *Sistema Cuantitativo de Evaluación y Monitoreo de la Calidad del Suelo* (Quantitative System of Soil Quality Evaluation and Monitoring, SEMCAS) allows to evaluate temporarily and spatially soil quality as part of the environment, implement actions in anticipation which prevent the advance of soil degradation, as well as to measure the impact of the application of conservation and amelioration measures with an integrated and sustainable approach (Font, 2008). In that sense, the use of quality indicators in animal husbandry systems proved the importance and interest conferred to the quality analysis of the soils dedicated to pastures and forages in Cuba (Lok, 2015).

The objective of this study was to determine the quality index of a Grayish Brown soil dedicated to the cultivation of pastures and forages in areas of the Animal Husbandry Enterprise El Tablón with the use of SEMCAS.

Materials and Methods

Location of the study area. The study was conducted in two dairy farms of the Animal Husbandry Enterprise El Tablón: dairy farm laboratory 3, Barajagua; and dairy farm 11, genetic farm El Abra, located in the coordinates N: 591-260 and E: 259-250 in the cartographic sheet Barajagua 1: 25 000, Cumanayagua municipality, Cienfuegos province, Cuba.

General soil characteristics. The soil of the area is classified as Grayish Brown (Hernández-Jiménez *et al*., 2015), with flat topography and slope from 0,5 to 1,0 m. The samples were taken on October 30, 2015 (rainy season) and April 25, 2016 (dry season).

Study description. A randomized block design with four treatments and five replicas was used; the evaluated treatments were:

1. Dairy farm laboratory 3, dry season (dairy farm L-3, DS).
2. Dairy farm laboratory 3, rainy season (dairy farm L-3, RS).
3. Dairy farm 11, dry season (dairy farm 11, DS).
4. Dairy farm 11, rainy season (dairy farm 11, RS).

Soil sampling was made in five 4 x 4 m^2 plots, by the method of random framework, in zigzag; and 10 composite samples were taken per plot, at a depth between 0 and 20 cm (IGAC, 2006).

Measurements. From the physical indicators real density and apparent density (Dr and Da) were selected; the former was conducted by the picnometer method in xylol, the latter through the ring method (NRAG 370, 1980), and hygroscopic moisture (Hy) by gravimetry (NC 110, 2001).

The chemical indicators included pH in potassium chloride, through the potentiometric method (NC-ISO-10390, 1999); electrical conductivity (NC ISO-112, 2001) and cation exchange capacity (CEC), by the modified Melich method (Schactschabel), according to NC ISO-65 (2000).

The biological analyses included organic matter, by the colorimetric Walkley-Black method (NC ISO-51, 1999); and basal respiration (BR), according to Calero et al. (1999). Visual observations were made of the macrofauna and mesofauna at the moment of sampling, to quantify and identify the specimens.

To determine the soil carbon reserve (CR) at a depth of 0-20 cm, the organic carbon was calculated from Kass equation: % OC = % OM/1,724 (Bojórquez-Serrano *et al*., 2015); then the CR was quantified, by the formula:

CR (mg/ha^{-1}) = % OCS x AD x Ds (Hernández-Jiménez *et al*., 2013),

where:

RC: organic carbon reserve in the soil (mg/ha^{-1}).

% OCS: percentage of organic carbon in the soil.

AD: apparent density (g/cm^3)

Ds: soil depth (cm).

The soil quality index (SQI) was estimated according to the SEMCAS methodology, from a software program created for that purpose, whose value varies in a range from zero to one (0-1); the values closer to 1 will have higher quality, while in the ones closer to zero their quality will decrease progressively (Font, 2008).

Statistical analysis. The results were statistically processed through a simple classification ANOVA, and Duncan's (1955) multiple range test for was used mean comparison, with a reliability of 95 %, using as tool the statistical program SPSS (version 15.0).

Results and Discussion

The real density (Dr) did not show differences between the two dairy farms (table 1), with an average value of 2,61 g/cm^{-3}. This indicator can vary with the proportion of the elements that constitute the soil. In general, if the organic matter content is low, the apparent density is around 2,65 g/cm^{-3} (De Boodt *et al*., 1967).

Table 1. Physical indicators.

Sampling site	Dr (g/cm^{-3})	Da (g/cm^{-3})	Hy (%)
Dairy farm laboratory 3, DS	2,64	1,72	2,95^b
Dairy farm laboratory 3, RS	2,60	1,81	3,33^a
Dairy farm 11, DS	2,62	1,70	2,99^b
Dairy farm 11,RS	2,56	1,81	3,27^a
SE ±	0,178	0,141	0,189*

a, b: Different letters indicate significant differences at $p \leq 0,05$ (Duncan, 1955).

The above-mentioned criterion coincides with the results of this research, in which Dr values were obtained between 2,56 and 2,64, without statistical differences, in the presence of an average content of organic matter (2,14 and 2,15 % for dairy farm laboratory 3 and dairy farm 11, respectively). Martin and Durán (2011), in a scale for different types of tropical soils, placed real density values between 2,40 and 2,60 as moderate, and lower than 2,40 as low, for which the ones reached in this study are included in the first range.

The apparent density reached similar values in both dairy farms, without differences between the seasons. These results are in correspondence with the ones obtained in a compacted soil (values higher than 1,60), reported by Martin and Durán (2011).

Romero-Barrios *et al*. (2015), in quality studies conducted on forestry and animal husbandry soils of the National Park La Malinche –Tlaxcala state, Mexico–, with acid pH and loamy sandy texture class, obtained an apparent density of 1,5 g cm^{-3}; which indicated compaction, due to the use of inadequate management practices and to grazing, fires and indiscriminate felling, factors that caused the increase of Da.

On the other hand, Muscolo *et al*. (2014) stated that when Da increases, the soil compaction is higher and it can affect water holding capacity and limit root growth, because Da is modified by the solid particles and pore space, which in turn conditions the organic matter, for which Da and OM are inversely proportional. In soils of fine texture the Da varies between 1,0 and 1,2 g cm^{-3}; while in sandy soils it is higher: between 1,02 and 1,62 g cm^{-3}. In this study the results exceeded this range.

The Hy did not show differences between the dairy farms, with the highest values in the rainy season (table 1). It was significant that it did not vary between 6 and 8 %, range recommended by MINAG (1984) for an adequate development of tropical cultivable species, but it was well below; hence it is inferred that a Hy content lower than 6 % holds water less, typical characteristic of Grayish Brown soils.

Menghini *et al*. (2015), in soils with high content of sand and little depth of the southeast of the Argentinean province of Buenos Aires, where there was also a level of variable rainfall and framed in seasonal periods, found limitations to maintain adequate moisture. This coincides with the results of this study, because the hygroscopic moisture was not within the established range, also in a sandy soil.

Table 2 shows the pH and CEC values. It was observed that between the different sites there were no differences in pH and that the average value was 4,7. According to the report by Martin and Duran (2011), they are classified as acid soils. These authors also refer that in soils with this pH, phosphorus fixation; low organic matter content; deficiencies because of magnesium, calcium and potassium depletion; restrictions for specific crops; and proportionality between pH and CEC, are very frequent.

Table 2. Values of pH and cation exchange capacity.

Sampling site	pH	CEC (cmol kg^{-1})
Dairy farm laboratory 3, DS	4,81	10,54^{a}
Dairy farm laboratory 3, RS	4,92	10,11^{ab}
Dairy farm 11, DS	4,64	9,96^{ab}
Dairy farm 11,RS	4,53	9,28^{b}
SE ±	0,016	0,493*

a, b: Different letters indicate significant differences at $p \leq 0{,}05$ (Duncan,1955).

Regarding CEC, the results of this study coincide with the ones reported by MINAG (1984) and by Martin and Durán (2011), which considered as very low the CEC values lower than 10 cmol kg^{-1}; and as low, those between 10 and 19 cmol kg^{-1}. Thus the CEC turned out to be from very low to low.

Pulido-Fernández (2014) considered CEC as an accurate indicator for estimating soil quality, given the interaction it causes with its other chemical, physical and biological factors.

Table 3 shows the results of electrical conductivity (EC), saturation of bases (V) and calcium/magnesium ratio (Ca^{2+}/Mg^{2+}). The EC of the studied areas oscillated between 0,40 and 0,71 dS m^{-1} and it was higher in the dairy farm laboratory 3, in the dry as well as the rainy season, with difference from dairy farm 11 under equal conditions.

The V percentage in Cuban soils varies in a range of 70-90 %, according to MINAG (1984). If it is higher than 90 % it can be inadequate for plants sensitive to high levels of carbonates, and if it is lower than 50 % it corresponds to acid soils, as it is observed in table 3 (45,10 and 46,32, respectively). This author also states that the V value is closely related to pH and CEC, because they are directly proportional. On the other hand, the V percentages did not show differences between the two dairy farms.

Martin and Durán (2011), in their evaluation scale for Cuban soils, referred that with base satu-

Table 3. Saturation of bases, calcium-magnesium ratio and electrical conductivity.

Sampling site	V (%)	Ca^{2+}/Mg^{2+}	EC (dS/m) -
Dairy farm laboratory 3, DS	45,75	3,72[a]	0,71[a]
Dairy farm laboratory 3, RS	46,32	3,72[a]	072[a]
Dairy farm 11, DS	45,10	2,65[b]	0,40[b]
Dairy farm 11,RS	46,05	2,57[b]	0,41[b]
SE ±	1,134	0,166*	0,105*

a, b: different letters indicate significant differences at $p \leq 0,05$ (Duncan,1955).

ration percentages higher than 75 % the saturation level is reached, and between 40 and 75 % the soils are moderately unsaturated (as occurred in both dairy farms). These results can evidently influence the response pastures could have in time, because the interaction of the V value with other indicators occurs spontaneously and, generally does not obey anthropogenic factors that could disturb the ecosystem.

The optimum Ca^{2+}/Mg^{2+} ratio is around 6:1; below 2:1 it is low and problems can occur because of Mg^{2+} excess, higher than 10:1 it is high and indicates well-marked deficiencies of this element (Muñiz, 2004). It was observed that this ratio statistically differed between the two dairy farms (table 3) and it was higher in dairy farm 3. The values, in all the cases, were below 6:1; although they were not lower than 2:1.

The performance of organic matter, carbon reserve and basal respiration are shown in table 4. The organic matter content did not show differences between the different sites. Martin and Durán (2011), in their gradation scale of organic matter for Cuban soils, stated that the range of 1,5-3,0 % is low; while Crespo *et al.* (2009) framed it between 1,3 and 3,0 %. Both criteria coincide with the results in this study, in which the mean value was 2,13 % (low).

Font (2008), when applying the SEMCAS methodology, acknowledged OM as fundamental among its indicators; because it is considered one of the most important components to define quality and influences the performance of other properties. The report by Fernández *et al.* (2016) should not obviated, concerning the fact that the type of soil use significantly influences the contents of OM and its fractions, by modifying its physical properties. It must be emphasized that a decrease of OM in the soil brings about an increase of Da, as occurred in this study.

The organic matter is more specific in its relations with CEC, Dr and Da; and can reach a proportional correlation, according to Menghini *et al.* (2014). The OM content is essential to interpret the soil quality results. These authors found, in acid soils cultivated with pastures, that when intercropping tree legumes a seasonal increase of organic matter occurred, but without influencing the CEC.

Although the physical, chemical and biological indicators do not separately determine soil quality, most of the studies coincide in stating that OM is the main indicator, and undoubtedly the one that has a more significant influence on soil quality and productivity (Duval *et al.*, 2013).

Regarding basal respiration and carbon reserves, no differences were found between the two dairy farms (table 4). As a result of the application of the SEMCAS methodology on different soil types of Camagüey, Font (2008) considered 18,37 mmol CO_2 kg^{-1} as standard value. The results of this study were lower in all the sampled sites, which could indicate lower biological activity.

Table 4. Organic matter, carbon reserve and basal respiration.

Sampling site	OM %	CR mg/ha^{-1}	BR mmol CO_2 kg^{-1}
Dairy farm laboratory 3, DS	2,17	43,34	16,49
Dairy farm laboratory 3, RS	2,12	44,52	16,08
Dairy farm 11, DS	2,14	42,16	16,34
Dairy farm 11,RS	2,16	45,25	16,65
SE ±	0,236	1,364	0,561

Soil respiration in the ecosystems is very variable, spatially as well as temporarily, and is determined by moisture, temperature, dissolved oxygen, pH, nutrient content and other indicators, according to Riestra (2012), who found variations when measuring this indicator in different soils and phenological stages of different tropical crops.

Ambrosino (2015), when evaluating the decomposition and dynamics of nutrients in a slightly acid soil of natural pasturelands in the Argentinean Buenos Aires southeast, referred that its moisture content increased as the foliage cover was reduced; while the basal respiration increased according to temperature, as the existing biota was activated. This performance is characteristic of temperate climates.

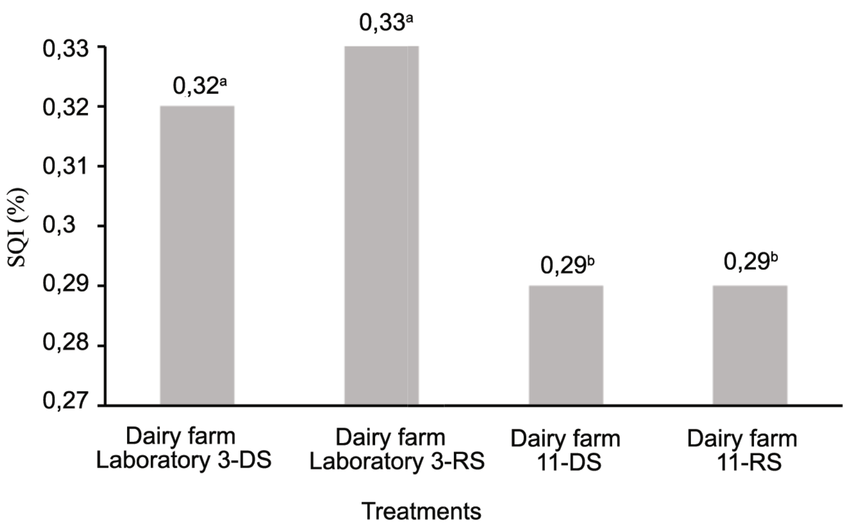
On the other hand, Andrade *et al*. (2014) and Andrade (2016) found, in the Colombian paramos, a higher content of organic carbon of the soil in pasturelands than in forest areas, which they ascribed to the dynamics of the fine roots of pastures; which, because of their senescence or defoliation due to grazing, cause large quantities of carbon to be incorporated to the soil. In subsequent studies Cabrera-Dávila (2012) considered that, from the biological point of view, to evaluate the soil and ecosystem conservation-disturbance status the edaphic macrofauna can be taken into consideration, which groups invertebrates higher than 2 mm diameter (Annelida: Oligochaeta), termites (Insecta: Isoptera) and ants (Insecta: Hymenoptera: Formicidae), which act as ecosystem engineers in the pore formation, water infiltration, and organic matter humification and mineralization.

The above-expressed facts could be noticed in visual observations made during sampling, because macrofauna specimens were found, such as coleopterans, ants and earthworms, but in all cases very scarce (less than 10 individuals).

Monitoring the physical, chemical and biological properties is essential to take appropriate and timely measures with regards to management, and integrates relations and functions among the different indicators that are measured and which are important for agroecosystem sustainability (Moreno *et al*., 2015).

From the analysis of the evaluated indicators, once the SEMCAS methodology was applied, SQI values were reached between 0,29 and 0,32 in the 0-1 scale, which differed statistically between the evaluated sites (fig. 1). The SQI was higher in the dairy farm laboratory 3, although with discreet differences.

Leyva-Rodríguez (2013) made an estimation of quality indicators to design and implement management technologies in Luvisols, in La Veguita municipality (northern zone of Las Tunas province, Cuba), in five soil use systems (grove, natural pasture, cultivated pasture and two silvopastoral systems); for such purpose, she selected a minimum group of physical, chemical and biological indicators and integrated them in a quality index. In their interpretation she used the scale of transformation into five soil quality classes, proposed by Cantú *et*



SE ± 0,124*. Different letters indicate significant differences at $p \leq 0,05$ (Duncan, 1955).
Figure 1. Soil quality index.

al. (2009). The SEMCAS methodology does not contemplate a range of classes, for which, according to Cantú *et al*. (2009), the SQI reached corresponds to a fourth class.

Soil fertility and quality can be different from one place to another within the same area, according to Rosa (2013). These changes occur even in very short distances and originate extraordinary spatial variability, for which soils in the landscape represent a huge mosaic of endless tiles. This criterion can support the statistical difference found in the SQI between the two dairy farms, even under similar management conditions.

When implementing the SEMCAS methodology in different soil types of Camagüey province –Cuba–, Font (2008) found points of approach and differences in the SQI values, which is in correspondence with the fluctuation trend of the SQI indicated by other methodologies worldwide.

Ramirez (2013) conducted for the first time in Cuba, in areas of intensive turfgrass production, on a lixiviated Ferralitic Red soil with pH between 5,6 and 6,4 of Matanzas province –Cuba–, an independent study of soil quality indicators (physical, chemical and biological), and could correlate the biological variables with the physical and chemical ones. It was proven that the soils were degraded, mainly, in their physical indicators (compaction, resistance to penetration and little porosity).

It is concluded that the validation of the SEMCAS methodology allowed to determine the quality of the Grayish Brown soil in natural pasture areas, with indexes between 0,29 and 0,32 in the 0-1 scale, which indicates a low quality level. There was a marked correspondence between the individual analysis of some indicators and the SQI, and it was also observed that estimating soil quality is essential to diagnose the concrete situation of the production areas and to outline strategies for their sustainability; likewise, the need to include new indicators and to establish monitoring programs in time, is not discarded.

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