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Original article

Behavior of organic carbon organic carbon, according to the use of Brown Soils of "La Rosita" farm

Comportamiento del carbono orgánico según el uso de Suelos Pardos de la Finca "La Rosita"

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ABSTRACT: Considering the current importance of the change of organic carbon in soils, according to their management, a study of the change in the content of Organic Carbon Reserves (OCR) in Cambisols and Vertisols soils was carried out, as a reference of a landscape of the Jaruco-Campo Florido pediplane ecosystem, with tropical climate of alternating humidity, in Mayabeque province, Cuba. It was found that in vertic Cambisols soils, under mango grove (*Mangifera indica*) with pastures and with pastures only, OCR content increases in 1.87 t ha^{-1} year^{-1}, for the 0-30 cm layer of the upper thickness of the soil. In these same soils under cultivation, there are losses, in the 0-30 cm layer, from 0.53 to 1.20 t ha year in OCR. It is also shown that in mellow Vertisols, under mango grove (*Mangifera indica*), or under pasture, the organic carbon content increases between 0.11 to 0.14 t ha year, for the 0-30 cm layer of the upper soil thickness; but in the variant under cultivation for 10 years, it decreases to 1.92 t ha year, for the same 0-30 cm layer.

Key Words: edaphological properties, classification, climate change.

RESUMEN: Teniendo en cuenta la importancia que tiene, actualmente, el cambio del carbono orgánico en los suelos, según su manejo, se realiza un estudio del cambio del contenido en Reservas de Carbono Orgánico (RCO) en suelos Cambisoles y Vertisoles, como referentes de un paisaje del ecosistema del pediplano de Jaruco-Campo Florido, con clima tropical de humedad alternante, en provincia Mayabeque, Cuba. Se pudo comprobar que en suelos Cambisoles vérticos, bajo arboleda de mango (*Mangifera indica)* con pastizales y con pastizales solamente, el contenido en RCO aumenta en 1,87 t ha^{-1} año^{-1}, para la capa de 0.-30 cm del espesor superior del suelo; mientras que, en estos mismos suelos bajo cultivo, hay pérdidas, en la capa de 0-30 cm, de 0,53 a 1,20 t ha año en RCO. Se demuestra, además, que en Vertisoles mólicos, bajo arboleda de mango (*Mangifera indica*), o bajo pastizales, aumenta el contenido en carbono orgánico entre 0,11 a 0,14 t ha año, para la capa de 0-30 cm del espesor superior del suelo; pero en la variante bajo cultivo de 10 años, disminuye hasta 1,92 t ha año, para la misma capa de 0-30 cm.

Palabras clave: Propiedades edafológicas, degradación, cambio climático.

INTRODUCTION

Soil is one of the most important components of ecosystems, together with climate, fauna and biological activity. At present, an important factor affecting soil properties is human activity (1-3). The importance of soil carbon content is well known, both from the point of view of soil property degradation and in the mitigation of climate change (4). Carbon sequestration in soils and its possible enrichment by agricultural management has become a current topic of research by soil scientists around the world.

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In recent years, research has been carried out in this regard. In Brazil, results have been obtained on carbon stocks and flow in natural and agricultural systems (5). In Mexico, new results have been obtained on the content and variation of organic carbon in soils, according to their management (6,7). In addition, in subalpine pastures, results have been obtained on changes in carbon (8). In recent years, in the Amazon, changes in organic carbon content before and after deforestation have been determined (9).

For Cuba, it is necessary to conduct these studies in ecosystem soils, by province, to lay the foundations for local development in relation to climate change mitigation and food production (9). Of utmost importance for food production in Cuba is Mayabeque province, whose main objective is to supply food to Havana province, in addition to the small towns and cities that belong to it. In Mayabeque, seven ecosystems can be separated, of which three of them are the most agriculturally important (10).

One of these ecosystems is the specific case of the ecosystem of the karst plain, with Ferrallitic Red and Ferrallitic Red Leached (FRL) soils, where it has been possible to determine how much carbon the FRL soil loses through continued cultivation and how it influences its properties (11). In addition, carbon gains or losses have been quantified in these soils due to management, whether in long-standing groves, fruit plantations, pastures or continuous cropping (12). Another important ecosystem, especially for livestock and the production of tubers and grains (corn and beans), is the ecosystem of the Campo Florido-Jaruco piedmont, with Bronw, Vertisol and Calcimorphic Humic soils. Taking into account the above, edaphological research was initiated in this ecosystem, to know the behavior of carbon in Brown soils, in farms of intensive agricultural and livestock production.

At the "La Rosita" farm, located in Habana del Este municipality, Havana, which produces grains, tubers, vegetables, milk, meat and eggs throughout the year, it was began to investigate how much carbon the Brown soil gains or losses, depending on its management. The soils of this farm were initially studied for a Master's Thesis, in which it was shown that the predominant soils are mainly of the genetic type of Brown soils formed from carbonate rocks, in undulating relief, moderately to shallow, with clay type 2:1 (13). The objective of this work is to know the carbon status (gain or loss) of the brown soils in the Rosita farm, after 15 years of having been characterized.

MATERIALS AND METHODS

The study area has an area of 32.29 ha and is located on the road from Minas to Campo Florido, two km before reaching Campo Florido. It has a sub-humid tropical climate, relatively dry, with average annual rainfall of 1.200 mm, average temperature of 24.5 °C and undulating to hilly relief. The source material is Oligocene limestone, consisting of marls (calcium carbonate with a clayey texture), in combination with Cretaceous shales and serpentinites, with the development of Brown soils in the higher and steeper parts of the relief and Vertisols in many flat parts (depressions) (13). The work was based on previous research on the characteristics of Brown soils studied (13). Following the comparative geographic method, five profiles of these soils, with different vegetation covers, were selected and sampled in triplicate (except profile D-8), in February and March 2020. In the Tables of this work, the average of the analyses of the triplicate sampling is presented.

The soil classification (14) is used for the results of the soils in 2020 and the soil classification (15), which was the one used in the edaphological work of the farm "La Rosita" in 2005 (12). Brown soil profiles with their use were made according to the soil classification (15) for the 2005 study and the other soil classification (14) for the 2020 studies.

For this study, behavior results of the Organic Carbon Reserves (OCR) in the five profiles of Brown soils formed from carbonate rock are presented, taking as reference the characterization data previously carried out (13). Sampling was performed in the upper layer of the profile, where the most important changes occur in relation to soil carbon in this time period. These samplings were made for the 0-10 and 10-30 cm layers, in the area around where the soil profile was characterized.

The calculation of COS content was made by the determination of soil Organic Carbon Stocks, with the equation:

$$COS = Dv\left(mg\ m^{-3}\right) \times CO\left(\%\right) \times bulk\left(in\ cm\right) \times \left(1 - I\right)$$

Where:

Dv (Bulk density): the bulk density of the soil was determined in the field by the cylinder method, using a cylinder of 100 cc volume and determining the humidity in an oven at 105 ºC for 24 hours, until constant weight

I: the percentage of inclusions (ferruginous nodules, gravels or stones). In the case of the soils studied, there are no inclusions in the upper layers of the profile, so this part of the formula does not apply.

Organic matter (OM) was determined using the wet combustion procedure (Walkley & Black). Then, from OM %, applying the empirical factor equivalent to 1.724, the organic carbon (OC) % was determined.

The gains or losses of COS were calculated by comparing the results of the profiles studied in 2005 and those sampled in 2020, which gives us a difference of 15 years.

RESULTS AND DISCUSSION

So far, in Cuba, there are very few results on the change of caused by cultivation. Recently, results obtained on the change of Brown soil properties under secondary forest, under cultivation and, later, as pasture and under permanent cultivation have been reported (16).

In this work, it was obtained that, in the profiles studied, the OCR, in the Brown Slitic and Vertic soil, with mango grove or pasture with shrubs, for the 0-10 cm layer, values of 23 t ha^{-1} are presented, and for the 0-30 cm layer, it is not greater than 52 t ha^{-1}. The lowest values for the 0-10 cm layer were obtained in profile D-6, which is an eroded and very shallow soil, on a slope of 15 % (Table 1) (15); according to data from (13).

However, the results obtained after 15 years with somewhat different management show that in those soils that were put under cultivation, the content decreased (profiles D-7 and D-8) while in those that were under mango grove cultivation with pasture (profile D-1) or under pasture (profiles D-10 and D-6), these reserves increased (Table 2).

In profile D-1, the increases for the 0-10 cm layer were greater, as well as for profiles D-10 and D-7, under pasture. In profiles D-7 and D-8, which were under pasture or pasture with shrubs, and which in recent years were put under cultivation, the OCR decreased. Considering these results, when comparing OCR in 2005 for these soils and in 2020, with a difference of 15 years, average gains and losses per year of OCR are obtained for these soils, according to their management (Table 3).

The gains in OCR in profile D-1, under mango grove with pasture for the 0-10 cm layer does not exceed 1 t ha^{-1} yr^{-1}, while for the 0-20 and 0-30 cm layers it increases a little more. In the D-10 and D-6 profiles, under pasture, the OCR gain per year is slightly lower for the 0-10 cm layer, which can be attributed to the fact that under the mango grove there is carbon enrichment not only because of the pasture between the trees, but also because of the amount of leaves left by the grove.

It is remarkable that the gain in OCR in these soils both under fruit groves with pastures and under pastures is lower than what is obtained in Ferrallitic Red Leached Soils (FRL) of the ecosystem of these soils in Mayabeque province, which can be attributed to two things, on the one hand the incidence of a lower amount of rainfall and on the other hand that in the FRL soils, although they have clay of type 1: 1 (kaolinites), which fix less carbon than clays of type 2:1 (montmorillonite), which predominates in Brown soils, they have a good amount of iron, which is an element that captures carbon quickly in the soil (17). It should be noted that in the soil the substances that capture carbon most rapidly are volcanic ash (absent in the soils of Cuba), free iron and calcium carbonates (18). These changes in the losses and gains of carbon in the soil by management, in time, can lead to changes in its properties and therefore in

Table 1. Data on Organic Carbon Reserves (OCR) in mg ha^{-1} in Brown soils, studied in 2005

No. Profile	Soil and vegetation	Soil layers in cm		
		0-10	0-20	0-30
D-1	Vertic dun under mango trees	21	35	52
D-10	Mellow brown under pasture	18	33	46
D-7	Vertic brown under cultivation	19	38	49
D-6	Haplic brown under pasture, highly eroded	13	20	Nd
D-8	Vertic brown under pastures	23	41	51

Table 2. Organic Carbon Reserves (OCR) data in mg ha^{-1}, in brown soils, taken in February 2020

No. Profile	Depth cm	OM %	CO %	Dv kg dm^{-3}	OCR mg ha^{-1}	Soil layers in cm		
						0-10	0-20	0-30
D-1	0 - 10	4.17	2.42	1.19	28.80	29	54	78
	10 - 30	3.24	1.88	1.32	49.63			
D-10	0 - 10	4.56	2.65	0.99	26.2	26	50	74
	10 - 30	4.01	2.33	1.02	47.5			
D-7	0 - 10	1.53	0.88	1.15	10.1	10	20	31
	10 - 30	1.30	0.75	1.35	20.4			
D-6	0 - 10	4.41	2.56	0.97	24.8	25	Nd	Nd
D-8	0 - 9	2.53	1.47	0.90	11.91	14	32	43
	9 - 24	2.98	1.73	1.08	28.30			
	24 - 38	2.21	1.39	1.19	19.92			

Table 3. Calculation of organic carbon gains or losses in the brown soils formed from carbonate rocks at farm "La Rosita" (in t ha^{-1} per layer, in cm)

No. Profile	Year 2005			Year 2020			Net income/loss			Net income/loss in t ha^{-1} year^{-1}		
	0-10	0-20	0-30	0-10	0-20	0-30	0-10	0-20	0-30	0-10	0-20	0-30
D-1	18	35	52	32	57	80	+14	+22	+28	+0.93	+1.47	+1.87
D-10	18	33	46	26	50	74	+8	+17	+28	+0.53	+1.13	+1.87
D-7	19	38	49	10	20	31	-9	-18	-18	-0.60	-1.20	-1.20
D-6	13	20	Nd	25	Nd	Nd	+12	Nd	Nd	+0.80	Nd	Nd
D-8	23	41	51	14	32	43	-9	-9	-8	-0.60	-0.60	-0.53

its classification; especially taking into account the advances in soil classifications in recent years (19). Taking into account these advances and the results obtained, we have applied the 2015 Soil Classification to these profiles, finding notable differences in them (Table 4).

Profile D-1, maintains its same classification, although the carbon content has a tendency to increase, until obtaining values in organic matter equal to or greater than 4 %, for the 0-20 cm layer of the upper soil thickness, which would put it in the humic subtype. It still does not reach it; it is really a tendency, in several years under this management it would reach it (Table 4). In the case of profile D-10, which was classified as Brown mellow soil, in 2020, it presents an organic matter content slightly higher than 4 % for the first cm of the upper horizon, so it has to be classified as fluffy and humic, according to the most updated classification of 2015.

On the other hand, soil profiles D-7 and D-8, have lost 0.60 t ha^{-1} yr^{-1}, for the upper 0-10 cm layer, which is due, not only to oxidation of organic matter by the crop, but also, possibly, to carbon losses with erosion, as these soils are on slopes. This, when applying the current classification (14), places them in the erogenous subtype (Table 4).

Profile D-6, which was classified as ochric and lithic, has gained organic carbon for the upper 0-10 cm layer. This soil was eroded, since according to (12) it was a BA-BkCk profile, with light colors on the surface and now has the well-developed A horizon, with a high organic matter content and dark gray colors. All this is due to the action of the pastures, being the gain in carbon of 0.60 t ha^{-1} yr^{-1}, on average, in these last 15 years. As it is eroded due to old management, it must be erogenic, but we wonder how an erogenic soil has such a high content of organic matter, so it is possible that in the future these soils could be classified as posterogenic, as Tonkonogov and Gueraimova proposed in 2005 (20). That is to say, man caused the erosive process, but as they have been fallow with pastures for so many years. This action must be reflected in their classification, therefore, in the future, for eroded soils that have been fallow, the concept of posterogenic must be considered; according to the current principles of soil classification in the world, which must reflect the anthropogenic action in them (21).

For erogenous soils (profiles D-7 and D-8), it is necessary to study and apply management technologies that lead to the conservation and improvement of their properties. Anti-erosion measures can be considered as recommended (20); but the cost results of the application of these measures are highly expensive. Above all, when calculating them against the money invested, the conservation measure leads to a cost of 8 000 Cuban pesos per hectare and, in this case, it is necessary to make an evaluation of the Benefit: Cost ratio that its application would entail, in order not to cause economic losses (22).

Finally, it is necessary to emphasize that the gains in carbon of the profiles obtained in this study is a palpable sample of the environmental services provided by the soil, as a very important component in the ecosystems for the capture and sequestration of carbon, as is well reflected (19).

CONCLUSIONS

- Brown soils formed from carbonate rocks of farm "La Rosita" change in carbon stocks over time.
- It should be considered for the classification of soils of Cuba the changes in time in the properties of the soil, which can lead to changes in the type or subtype of soils.
- Brown soils of farm "La Rosita", under woodland with pasture or with grassland, gain in organic carbon reserves, but under cultivation, they obtain losses in organic carbon reserves.

RECOMMENDATIONS

- It is recommended to look for effective management measures for soils of this farm, with the objective of not causing losses in their properties and to obtain crop yields that give economic benefits.
- Continue this type of studies in the most important soils of the ecosystem of the Campo Florido to Jaruco pediplano, with Brown, Vertisols and Calcimorphic Humic soils, which would serve the Mayabeque province to outline a soil management strategy in this ecosystem, in order to capture carbon and obtain good agricultural yields in food production.
- With the results obtained, it is recommended to calculate the contribution of carbon capture, annually, in Brown pasture soils, in the ecosystem of Campo Florido to Jaruco

Table 4. Changes in Soil Classification, caused by anthropogenesis in 15 years of handling

No. Profile	Soil Classification in 2005	Soil Classification in 2020
D-1	Vertic and calcic brown, washed	Slitic, vertic and calcic brown, washed
D-10	Mellow and calcic brown, moderately washed	Mellow, humic and calcic brown, moderately washed
D-7	Vertic and calcic brown, moderately washed	Erogenic, slitic and calcic brown, moderately washed
D-6	Ochric and lithic brown, carbonated	Posterogenic (?) and lithic brown, carbonated
D-8	Vertic and calcic brown, washed	Erogenic, vertic and calcic brown, carbonated

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