Scientific Paper

Effect of different land use types on soil organic carbon fractions

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Abstract

Objectives: To evaluate the effect of different types of land use on the organic carbon fractions of a chromic vertisol soil.

Materials and Methods: The research was developed in a permanent observation point, located in Holguin province. Soil samples were taken at a depth of 0-20 cm, in three different types of land uses: Neem (*Azadirachta indica* A. Juss) forest, natural pasture (*Paspalum notatum* L.) and sugarcane (hybrid *Saccharum* spp.). Total organic carbon, coarse particulate carbon, fine particulate carbon and carbon associated with minerals were determined after physical particle size fractionation of the samples.

Results: There were significant differences in total organic carbon and its fractions in the different land uses and among them ($p \leq 0,05$). In terms of total organic carbon, the *A. indica* forest was superior (16 and 32 %) to natural grass and hybrid *Saccharum* spp., respectively. This was due to the quantity and quality of plant biomass contributed by each crop and the increase in anthropogenic activity in the different land uses.

Conclusions: As management practices increased, total organic carbon contents and its fractions decreased. The highest organic carbon contents were found in the fraction associated with minerals and fine particulate matter with regards to coarse particulate matter in the different land uses. The *A. indica* forest showed the highest contents, followed by natural pasture and hybrid *Saccharum* spp., respectively.

Keywords: particulate organic carbon, vertisols, agroecosystems

Introduction

Soil is the most important carbon reservoir in the biosphere, containing three times more carbon than the vegetation and atmosphere (FAO, 2022). Soil degradation, biodiversity loss and climate change are three different faces of the same challenge (Arteaga and Burbano, 2018; Arias-Ortega and Rosales-Romero, 2019; IPBES, 2022).

The amount of soil organic carbon (SOC, mg/ha) at a given time is a balance between the input and output rates of this mineral. This simple balance involves interrelated factors (climate, topographic position, quality of the plant material to be degraded, biota, duration of a given vegetation cover and human activity), which control complex processes that vary temporally and spatially in the soil body, both horizontally and vertically (Peri *et al*., 2022).

In Cuba, approximately 57 % (6 226 700 ha) of the country's geographical area is devoted to agriculture, according to 2021 statistics (ONEI, 2022) and, approximately 76,9 % has an associated factor that limits its productivity. From the latter, 70 % with low organic matter and 45 % with low fertility, stand out (Muñiz-Ugarte, 2015). Among the most important causes of the decrease in soil productivity, the inadequate and inappropriate administration of nutrients, monoculture and bad practices in soil and vegetation management are reported. This causes the loss of soil and its quality, which is manifested in the quantity, quality and dynamics of soil carbon stocks (Rodríguez, 2022).

The loss of soil fertility, caused by the change of use, continuous and intensive agricultural exploitation with the application of machinery and fertilizers, as well as inadequate agricultural practices, originate the loss of soil organic carbon and decrease the productive capacity of agroecosystems (Olorunfemia *et al*., 2019; Hernández-Núñez *et al*., 2021).

Therefore, it is necessary to accumulate organic carbon in the soil to improve its physical, chemical and biological properties and, at the same time, to

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reduce CO_2 emissions into the atmosphere (Barrezueta-Unda, 2021), which is a particular characteristic of natural soils.

The restoration of degraded lands has the potential to store up to three million tons of carbon per year (Dickinson, 2019; Cerri *et al*., 2021).

Given these conditions, knowledge of carbon inventories between anthropogenic and natural land uses, as well as their performance with land use change, land management and plant biomass generated by plants is indispensable (Torres-Feijoo *et al*., 2021). Therefore, it is necessary to seek appropriate forms of agricultural management, which maintain and enrich soil carbon, aiming at developing and establishing strategies, methodologies and management practices that will mitigate climate change, maintain biodiversity and protect soils dedicated to food security (Pool-Novelo *et al*., 2019).

Organic carbon fractionation techniques are suitable for quantifying its fractions and characterizing the state of the system. They allow further understanding of the complexity of the transformations that organic carbon undergoes. They also provide tools for the management and monitoring of productive systems and for optimizing storage, improving quality and synchronizing mineralization cycles with crop requirements.

The objective of this work was to evaluate the effect of different types of land use on the organic carbon fractions of a chromic vertisol in Mayarí municipality, Holguín province, Cuba.

Materials and Methods

Location. The work was carried out at the permanent observation point[1] (POP), latitude: 20° 40' 21".73 and longitude: 75° 46' 25".05. It was established in 2010 in the locality of Guaro, Mayarí municipality, Holguín province.

Soil characteristics. The soil was classified as calcic and gleyic chromic vertisol (Hernández-Jiménez *et al*., 2015) in different land use types (LUT): *Azadirachta indica* A. Juss forest, natural pasture (*Paspalum notatum* L.) and hybrid *Saccharum* spp. The forest and natural grass were reconverted in 2002. Both came from hybrid *Saccharum* spp. areas.

Experimental procedure. Stratified random sampling with three replicas was conducted in each of the TUTs in 2010 and 2015. Soil samples were taken from 0-20 cm depth.

A physical particle size fractionation was performed by dry sieving (Andriulo *et al*.; 1990, Galantini *et al*., 2008). With the use of 53 and 105 µm sieves, the coarse fraction (CF, > 105 µm), which contains the coarse particulate organic carbon (COPG), medium and coarse sands and medium fraction (FM, 53-105 µm) constituted by the medium particulate organic carbon (COPF) and very fine sands and the fine fraction (FF < 53 µm) which has the organic carbon associated with the mineral fraction (COM) plus silt and clay, were obtained. Organic carbon was determined by the Walkley-Black method (ININ and ONN, 1999).

Statistical analysis. The quality and validation of the databases was checked by normality of the data, using the Shapiro-Wilk's test. Bartlett's test was applied for homogeneity of variance. Duncan's multiple range comparison of means was used when the analysis of variance found significant differences. Statistical processing of the information was performed using Statistica v.8 and Microsoft Excel 2019.

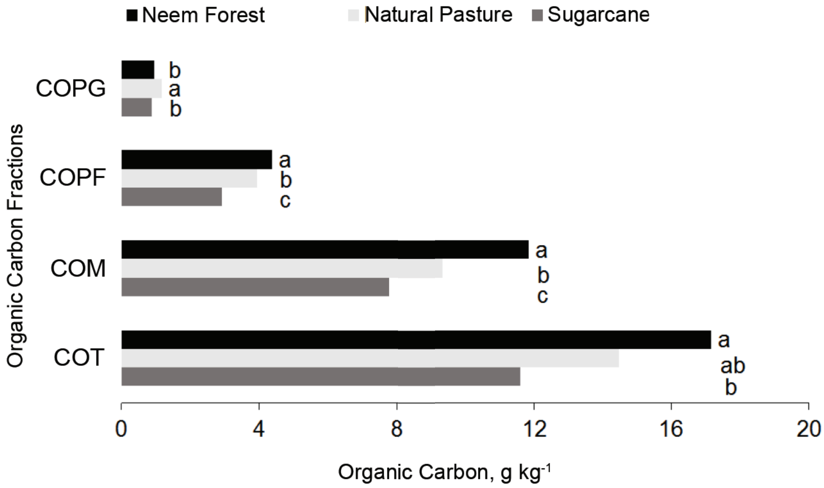
Results and Discussion

The influence of LUT on the contents of total organic carbon and its fractions (figure 1) was evident, as significant differences were observed ($p < 0,05$).

When analyzing the influence of LUTs on the organic fractions of total soil carbon, it was observed that the COPG contents in the natural grass were 20 and 25 % higher than the LUTs *A. indica* forest and hybrid *Saccharum* spp., respectively. The variations can be ascribed to the contribution of plant biomass and its quality, factors that influence the activities of soil microorganisms. These benefit from soil properties associated with nutrient availability and moisture. In addition, this fraction is very sensitive to degradation by agricultural practices to which hybrid *Saccharum* spp. is subject.

During grazing, the removal of aerial biomass causes the loss of part of the roots, which favors regrowth and generates an extensive root system, which remains at a shallow depth and contributes organic carbon only in the first 20 cm. This organic carbon is labile (COPG), increases root exudates that generate 10 to 20 % faster plant growth (Casal *et al*., 2018).

[1] Permanent observation points are stationary points in different soil types, uses and management, which are sampled every year on the same date and at the same point.



Different letters in each organic fraction indicates significant differences among LUT (p < 0,05).
COT- total organic carbon; COPG- coarse particulate organic carbon; COPF: fine particulate organic carbon; COM: organic carbon associated with the mineral fraction.

Figure 1. Total organic carbon content and its fractions per LUT.

The root system of grasses is very aggressive and their roots are in constant renewal, causing rhizodeposition, which represents 50 % of the total biomass in perennial forages and 20 % in annual crops, making grasses a good option to increase C sequestration in the tropics. Lopresti *et al.* (2020) add that a large part of the organic carbon in grasses is sequestered through the roots, which gradually become part of the soil biomass (Rivera *et al*., 2021).

Landriscini *et al*. (2020) proved the significant effect of cover crops on SOC. These authors point out that the labile fraction (COPG) was strongly related to the higher production of residues and their quality in the topsoil.

As for COPF, this fraction constitutes a transition material, so it is not as variable as COPG or as stable as COM, according to the report by (Duval, 2015).

The COM mineral fraction showed the least variation compared with the two remaining fractions, which is ascribed to the greater stability among aggregates that confers greater resistance to its physical and biological decomposition. The results showed a decrease in the most labile organic fraction (COPG), in favor of the most humified and stable one (COM).

Márquez-San-Emeterio (2016), in an eutric regosol soil, in three LUTs (*Mangifera indica* L., *Annona cherimola* Mill. and *Persea americana* Mill.) reported that carbon content varies according to the type of fraction present. The fine fraction has a higher proportion with regards to the coarse fraction of the soil. This is carbon strongly bound to the mineral fraction.

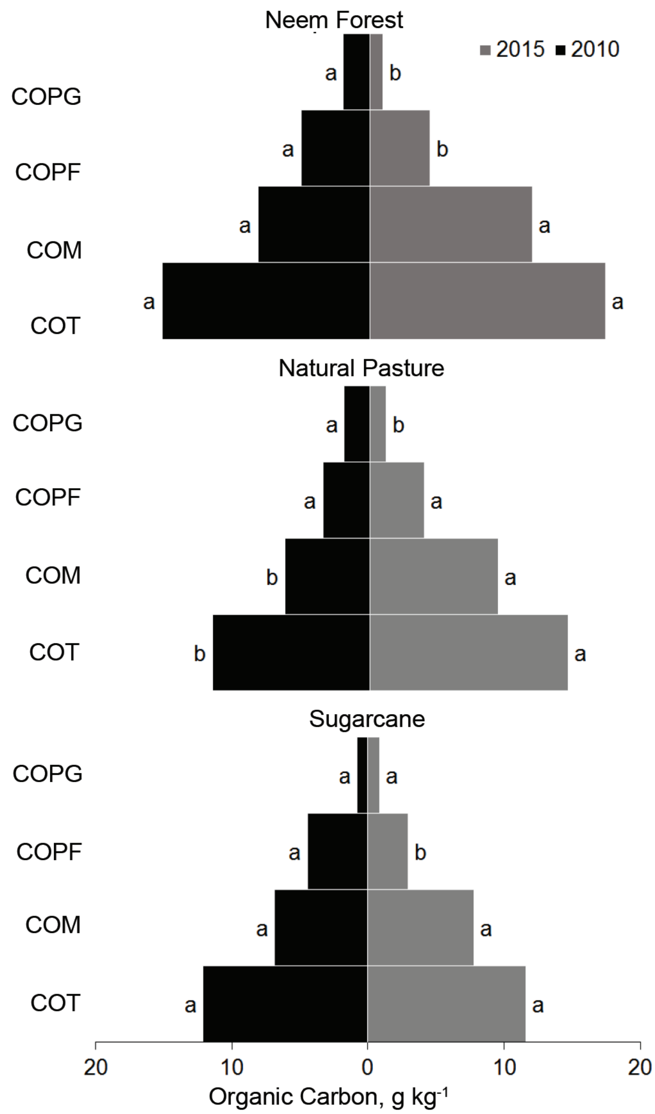
The *A. indica* forest was higher (16 and 32 %) than natural grass and hybrid *Saccharum* spp. in TOC, respectively. These changes in TOC dynamics are related to the type of land use, which determines the vegetation cover and its quality. Torres-Feijoo *et al.* (2021) concluded that transformations related to land use and cover change directly affect soil carbon stocks.

In the LUTs *A. indica* forest and natural pasture, all organic fractions were higher compared with the LUT hybrid *Saccharum* spp., which may have been influenced by the frequent use of agricultural implements during soil preparation for planting the crop, which occurs on average every three years. In addition, with the inversion of the upper horizons, the aggregates are broken and the protection of the organic-mineral complexes decreases. Annual crop tillage is also carried out, including deep cultivation (35-40 cm), specifically in the vertisol, where it is harvested in a mechanized way.

Pineda-Ruiz *et al.* (2023) found that the conventional management to which a soil planted with hybrid *Saccharum* spp. was subject caused gradual carbon loss, which became more pronounced as time passed. This was manifested in the performance of the replacement cycles, due to soil disturbance during preparation for planting, where the carbon stocks accumulated during a whole cycle are lost, reaching 47 % in more than 30 years.

The effects of agroecosystem reconversion have contributed to reestablish the dynamic balance of organic carbon forms over time (10 years), from the decomposition of organic material from the new uses.

At the end of the period, the fractions of COPG and COPF were lower (p < 0,05) in the LUT *A. indica* forest and natural pasture and in COPF *A. indica* forest and hybrid *Saccharum* spp. Only in the LUT natural grass there was an increase (p < 0,05) in COM obtained (figure 2). In all the LUTs, a tendency to faster mineralization of residues was observed. Therefore, COM and TOC were very stable, due to a greater humification of the organic material, attributable to higher stability among the aggregates



Different letters in the organic fractions indicate significant differences between years (p < 0.05).
COT-total organic carbon; COPG-coarse particulate organic carbon; COPF-fine particulate organic carbon; COM-organic carbon associated with the mineral fraction.

Figure 2. Mean content of total organic carbon and its fractions by different types of land use.

that confer greater resistance to physical and biological decomposition.

The dependence of the fractions on the quantity and quality of the input of organic material, according to the type of plant and agricultural management, was proven. The difference between the LUTs with the lowest anthropic activity (*A. indica* forest and natural pasture), which showed the highest increases (13 and 26 %), was evident. Meanwhile, the LUT hybrid *Saccharum* spp. decreased 4 %, due to the fact that the crop is subject to greater agricultural activity. These results coincide with those of Pérez-Iglesias *et al*. (2021) in tropical agroecosystems of the Ecuadorian coastal region, who found decreases in organic carbon content of 3, 20, 31 and 79 % in *Musa* sp., *Theobroma cacao* L., pasture and *Zea mays* L., respectively, compared with secondary forest. *Z. mays* had the lowest content, due to the excessive tillage to which it is subject because it is a short-cycle crop.

According to the results reported by Solano-Pinzon *et al*. (2018) and Huamán-Carrión *et al*. (2021), soils with natural grass cover represent higher rates in organic carbon accumulation, compared with forests and other crops of the same ecological floor.

The performance of carbon in the different organic fractions showed increases inversely to the diameter of the fraction, in the order COM > COPF > COPG. This is related to the content of clays or fine particles in the texture, which favored the carbon protection mechanisms. This evidenced that they are the most sensitive fractions to undergo transformations with LUT changes and management, thus affecting the physical, chemical and biological properties of the soil. Duval *et al*. (2016) and Fernandez *et al*. (2016) proved that these organic fractions can be used to measure the effects of LUTs and soil properties, as well as their quality index.

Conclusions

As management practices increased, total organic carbon content and its fractions decreased. Differences were found among land use types, being higher in the *A. indica* forest. It was followed by natural grass and hybrid *Saccharum* spp.

The highest organic carbon contents were found in the fractions associated with minerals and fine particulate matter with regards to coarse particulate matter in all land use types. *A. indica* forest showed the highest contents, followed by natural grass and hybrid *Saccharum* spp., respectively.

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Conflict of interests

The authors declare that there is no conflict of interests among them.

Authors' contributions

- George Martín-Gutiérrez. Designed the research, directed and carried out the field sampling, performed the statistical analysis and interpretation of results, and wrote the manuscript.
- Pablo Pablos-Reyes. Designed the research and collaborated in the analysis and interpretation of results and in drafting the manuscript.
- Yakelin Cobo-Vidal. Collaborated in the analysis and interpretation of the results and in writing the paper.
- Juan Alejandro Villazón-Gómez. Performed field sampling, collaborated in the analysis and interpretation of results and in drafting the manuscript.
- Adrián Serrano-Gutiérrez. Performed field sampling and collaborated in writing the manuscript.

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