IOSR Journal of Engineering (IOSRJEN) **www.iosrjen.org**
ISSN (e): 2250-3021, ISSN (p): 2278-8719
Vol. 10, Issue 1, January 2020, ||Series -VI|| PP 53-58

Carbon Sequestration in Corn, Cocoa And Forest Agroecosystems in Tropical Conditions of El Oro Province, Ecuador

Irán Rodríguez Delgado, Mg. Sc. Hipólito Israel Pérez Iglesias, PhD. SaydaNoemi Herrera Reyes, Mg Sc.
TechnicalUniversity of Machala, Ecuador
Received 14 January 2020; Accepted 30 January 2020

Summary: The objective of the study was to estimate the amount of organic carbon that the soil can retain in tropical agroecosystems dedicated to the production of corn, cocoa; and a secondary tropical forest of El Oro province, Ecuador. The research was conducted in the experimental area of the Faculty of Agricultural Sciences, Technical University of Machala. In each agroecosystem, a permanent georeferenced sampling point was established, where three minicalicatas were opened to take soil samples at three depths (0-15, 15-30 and 30-45 cm). The sequestration of carbon by the soil varies depending on the crop used, where corn is grown, less quantity is retained than where perennial crops exist (cocoa and forest); Therefore, the higher the tillage frequency, the less carbon retention on the ground. In the three agroecosystems studied, the content of OCTS decreases as the depth increases. As a consequence of excess tillage, the soil sand content of the corn area is higher than in the cocoa and forest agroecosystems. In the 0-15 cm surface layer, the organic matter content is greater than 3% in the soil where cocoa is grown and greater than 4% in the forest area, however, the light and thick fractions of organic carbon from the soil presented statistically different values in the agroecosystems studied.
Keywords: agroecosystem, organic soil carbon, thick fraction, light fraction.

I. INTRODUCTION

At present, the survival of the human species is threatened by the discharge of large amounts of carbon dioxide in the environment, which has caused an increase in the temperature in the atmosphere and the beginning of a global climate change that influences the melting of ice in the poles, sea level rise (leaving large areas of land under water), increases in storms, loss of animal and plant biodiversity, as well as changes in environmental conditions in different regions and areas. As if this were not enough, the degradation of the land, increasingly limits food production, on a planet with a limited area and with a population in constant movement.

The soil and its fertility are the fundamental basis for obtaining food products for humans and animals. Among the problems that limit soil fertility, one of importance is the decrease in the total organic carbon content of the soil (TSOC) (Robert, 2002). Both problems derive from an inadequate management by the man of the carbon cycle, since the carbon present in the oilfields, in the biomass of the natural forests, eliminated for the development of agriculture and livestock, as well as the incorrect one management of agricultural production systems have contributed to the carbon passing from the earth to the atmosphere with the consequent increase in air temperature.

Agriculture is not only responsible for an important part of greenhouse gas (GHG) emissions, but it can also contribute to its mitigation, through the sequestration of atmospheric carbon, such as soil organic carbon. The retention of carbon in the soil is the removal of it from the atmosphere by photosynthesis of plants and their storage as forms of stable organic matter and long life in the soil (Verhulst, Francois &Govaerts, 2015). Accumulating organic carbon in the soil means improving its properties and its ability to produce biomass and in parallel reducing the pollution of the atmosphere and hydrosphere (Pérez et al., 2016).

The objective of the work was to determine the amount of organic carbon that the soil can retain in three tropical agroecosystems (corn, cocoa and a secondary forest) in El Oro province, Ecuador.

II. MATERIALS AND METHODS

The research was carried out in the experimental area of the Faculty of Agricultural Sciences, belonging to the Technical University of Machala, located at km 5.5 via Pasaje, Machala, El Oro province, Ecuador and at UTM coordinates 620701 south latitude and 9636128 west latitude, at an altitude of 5 meters above sea level. The study area according to the records of INAMHI (2016) has an average annual temperature of 25 ° C, average annual rainfall of 427 mm. According to the areas of natural life of Holdridge, it is classified within the formation of Tropical dry forest (bs-T) (Holdridge, 1967). The predominant soil type in the three agroecosystems is Inseptisol with good drainage, with frank, sandy-loam or loam-silty textural classes (Villaseñor, Chabla& Luna, 2015).

For the development of the study, three corn, cocoa and forest plantation agroecosystems were selected with native species over 40 years of age (Figure 1). In each agroecosystem, a permanent georeferenced sampling point was established, where three minicalicatas were opened to take the soil sample at three depths (0-15, 15-30 and 30-45 cm).

The determination of the total organic carbon content in the soil was carried out by the wet combustion method described by Walkley-Black (Carreira, 2004). The technique described by Arzola& Machado, 2013 was used to determine the light and thick fraction of organic carbon. The estimation of the soil organic matter content (MOS) was made by multiplying the percentage of carbon by the factor 1, 724, known as the Van Bemmelen coefficient (Martínez, Fuentes & Acevedo, 2008).

Figure 1. Location of theagroecosystemunderstudy in Granja Santa Inés.

To determine whether there is a significant statistical difference between the corn, cocoa and forest agroecosystems for each soil depth based on the total organic carbon, light and thick carbon fraction, an analysis of variance of an intergroup factor (agroecosystems) was performed. Previously, compliance with the requirements for independence of observations, normality of data and homogeneity of variances was verified. When there were statistical differences between the agroecosystems, posthoc tests of multiple comparisons (Scheffe) were carried out in order to determine similarities or differences between the agroeco systems evaluaded.

The data analysis was carried out with the SPAA statistical program, version 24 for Windows, with a 95% reliability in the estimate.

III. RESULTS AND DISCUSSION

Total organic carbon

In a general, the total carbon content of the soil (TSOC) decreases as the depth of the soil increases and as the soil profile deepens, the amount of carbon retained is reduced, which is accentuated for this type of poorly evolved soil. (Inseptisol). However, the OCTS values were significantly lower in the corn agroecosystem, relative to the cocoa and forest agroecosystems in the 0-15 cm layer. The values obtained in this layer were 0.59%, 2.21% and 2.75% for the area of corn, cocoa and forest respectively, without presenting the difference between these last two agroecosystems (Table 1).

Table 1 Percentage of total organic soil carbon and soil organic matter in the agroecosystems of corn, cocoa and forest determined in three soil depths.

Depth of soil (cm)*	Corn		Cocoa		Forest	
	C	MO	C	MO	C	MO
0-15	0.59a	1.02a	2.21b	3.81b	2.75b	4.74b
15-30	0.43a	0.64a	1.01ab	1.74ab	1.74b	3.00ab
30-45	0.32a	0.50a	0.90a	0.78a	1.08a	1.86a

*different letters differ statistically between agroecosystems within each soil depth for p<0.05.

The fact that the TSOC is significantly lower in the corn agroecosystem is associated with the frequency of tillage in the area (short cycle crop), unlike cocoa and forest, which are perennial plantations where branches and fallen leaves are detached and maintained on the surface of the soil and when decomposed contribute organic matter that increases the percentage of COTS in the topsoil layer of 0-15 cm.

Production systems cocoa and forest have the highest values of TSOC at all depths with no significant differences between the different depths of these agroecosystems, though the forest has the highest values, which is conditioned to a root system deep within the arboreal species and the greater accumulation of MO in the soil of this agroecosystem that presents contents from high 4.74% in the layer of 0-15 cm to medium in the depths of 15-30 and 30-45 cm, with values of 3.00% and 1.86% respectively (Rodriguez H. and Rodriguez, 2015) (Table 2).

Table 2 Agronomic classification according to levels of soil organic matter.

Soilorganicmatter (%)	Agronomicclassification
<0.60	Verylow
0.60 - 1.80	Low
1.81 - 3.50	Medium
3.51 - 6.0	High
>6.0	Verysmall

Source: Rodríguez, H; Rodríguez (2015).

Agricultural activities mainly affect TSOC reserve, degradation of soil carbon leads to significant losses in quality and represents a threat to agricultural production systems and food security. ensure the removal of carbon dioxide from the atmosphere into the soil, it increases the sustainability of agricultural systems (Verhulst et to the, 2015). The carbon accumulated in the soil depends on the type of soil, its use, management and depth. These aspects are determining factors for the existence and decomposition of organic matter as a primary source of carbon storage (Lok, Fraga, Noda & García, 2013).

According to the agronomic classification established by Rodriguez, H. and Rodriguez, 2015, for the interpretation of the TSOC content (Table 3), it can be seen that in the 0-15 cm layer, for the three agroecosystems, the TSOC content presents the low categories (0.59% in corn); medium (2.21% in cocoa) and high (2.75% in the forest). While at a depth of 15-30 cm, cocoa and corn are grouped in the low category with values of 1.01% and 0.37% respectively and the forest has an average content with a value of 1.74%. At a depth of 30-45 cm, the trend continues to correspond to corn, the category of very low (0.29%); to cocoa the low category (0.45%) and to the forest the medium category (1.08%).

Table 3. Agronomic classification for interpretation based on the levels of total organic carbon in the soil.

total organic soil carbon (%)	agronomic classification
<0.35	Verylow
0.35 - 1.05	Low
1.05 - 2.30	Medium
2.30 - 3.50	High
>3.50	Verysmall

Source: Rodríguez y Rodríguez (2015).

Organic carbon in soils that are in agricultural use is lower than in forest soils, which is related to a minimum proportion of organic matter from plant remains that these crops contribute (Polished, M; Flores, Rondon, Hernández RM and Lozano, 2010). This is accentuated in the case of corn where the soil is carved more frequently because it is a short cycle crop.

Organic carbon light fraction (OCLF)

Plant residues that are not integrated into the soil particles and that maintain the properties of their source material are those that are considered as OCLF (Martínez, Fuentes, & Acevedo, 2008). According to the statistical analysis of the comparison of means, it is observed that there are significant differences between agroecosystems at the same depth and it can also be assessed where there is a greater proportion of plant debris and at what depth are the light carbon fractions in the soil.

In the three agroecosystems it was possible to demonstrate, as as the profile deepens, the OCLF content decreases. The cocoa and forest agroecosystems show the highest content of this carbon fraction in the 0-15 cm surface layer of 1.28% and 1.32% respectively; Both production systems are significantly superior to the corn agroecosystem that reached a value of 0.24% of OCLF (Table 4).

Table 4. Percentage of organic carbon light fraction and soil organic matter in the agroecosystems of corn, cocoa and forest determined in three soil depths.

Soil depth (cm) *	corn		cocoa		forest	
	C	MO	C	MO	C	MO
0-15	0.24a	0.41a	0.93ab	2.21b	1.32b	2.28b
15-30	0.19a	0.33a	0.44a	0.76a	0.72ab	1.24ab
30-45	0.15a	0.26a	0.35a	0.60a	0.44a	0.76a

* Different letters differ statistically between agroecosystems within each soil depth for $p < 0.05$.

The less vegetation cover the soil has, the lower the MO content, the lower the amount of carbon and therefore the greater degradation affecting the quality and fertility of the soil (Muñoz-Rojas et al., 2015), which is more serious in relation to the fractions light organic matter, because they are more sensitive to changes produced by soil and crop management (Eiza, Fioriti, Studdert, &Echeverría, 2005).

According to the agronomic interpretation established by Rodríguez and Rodríguez (2015), the organic matter of the light fraction in the cultivation of corn, presents values from the layer of 0-15 cm to 30-45 cm below 0.60%, which is considered very low, being the light fraction of the organic matter in the shortest time is mineralized; leaving the nutrients it contains available for cultivation. While cocoa and forest agroecosystems have a higher MOFL content with values ranging from 2.21% to 2.28% in the 0-15 cm layer, respectively, as the light fraction of organic matter decreases more deeply in the soil profile fast in the cocoa system than in the forest (Table 4).

One of the main functions of organic matter is that it acts as a reservoir of carbon and nutrients for plants. The type of soil determines the effect of agricultural management on fractions of organic matter (Pulido et al., 2010). The labile or light fraction is composed of plant, animal and fungal remains at different degrees of decomposition and has a high C / N ratio (Eiza, Fioriti, Studdert, &Hernán, 2005)

At a depth of 0-15 cm, the highest OCTF content in the three agroecosystems is evident, the forest content being higher (1.43%) compared to cocoa (0.93%), without presenting a statistical difference between them, while the agroecosystem of corn has a lower content of this carbon fraction (0.35%), which differs significantly with the forest system and not with cocoa.

From 30-45 cm deep it is observed that cocoa and the forest have similar OCTF contents (0.55% and 0.52%), while the corn agroecosystem has the lowest content (0.17%), although without statistical difference between them.

In relation to organic matter, it can be seen that the corn agroecosystem has very low contents of the thick fraction, from the surface layer of 0-15 cm to that of 30-45 cm deep, which demonstrates that the soil of this agroecosystem It is the most degraded compared to cocoa and forest that have values of 1.60% and 2.47% respectively, with no significant statistical difference between them. This demonstrates the close relationship that exists with the decrease in the content of organic matter as the profile is deepened, since the thick fractions have a lower degree of transformation. However, the forest agroecosystem presents statistical difference with the corn in the 0-15 cm deep layer, which reaffirms that the soil of the corn agroecosystem is the one with the highest degree of degradation, which can be attributed to the greater tillage and compaction; and at the lowest fertility and retention of soil water (Table 5).

Table 5. Percentage of organic carbon coarse fraction of the soil and organic matter in the agroecosystems of corn, cocoa and forest determined in three depths of the soil.

Soil depth (cm) * Cocoa Corn Forest	**Corn**		Cocoa		Forest	
	C	**OM (%)**	**C**	**OM (%)**	**C**	**OM (%)**
0-15	0.35a	0.60a	1.28ab	1.60ab	1.43b	2.47b
15-30	0.24a	0.41a	0.57a	0.98a	1.02ab	1.48ab
30-45	0.17a	0.29a	0.55a	0.95a	0.64a	0.90a

* Different letters differ statistically between agroecosystems within each soil depth for p<0.05.

The OCTF associated with fine soil particles showed different values in corn, cocoa and forest agroecosystems, due to variations in textural classes. The textural composition of the corn crop soil is sandy loam, increasing the percentage of sand as the profile is deepened (Table 6), while cocoa and the forest have higher clay and silt contents; results similar to those found by Figuera, Lozano &Rivero (2011).

Table 6. Textural composition of the soil in corn, cocoa and forest agroecosystems at depths of 0-15, 15-30 and 15-45 cm.

Soil depth (cm)	Agroecosystems	Percentage (%)		
		Sand	Silt	clay
0-15	Corn	45,33	31,80	22,87
	Cocoa	26,43	36,00	37,57
	Forest	22,00	39,77	38,23
15-30	Corn	48,90	30,05	21,05
	Cocoa	21,10	41,33	37,57
	Forest	22,33	45,20	32,47
30-45	corn	53,10	40,03	6,87
	Cocoa	23,37	52,30	24,33
	forest	21,57	54,20	24,23

Physically separated organic carbon fractions are important indicators for detecting changes caused by management practices in most soils (Ferrer &Centrales, 2016).

IV. CONCLUSIONS

Soil carbon sequestration is variable, conditioned to the crop that is used. Short-cycle crops retain less carbon than perennial crops, the higher the frequency of tillage, the less carbon sequestration through the soil. In the three agroecosystems studied, the total organic soil carbon content (TSOC) decreases as the depth of the profile increases. In the corn agroecosystem, the TSOC is significantly lower than the cocoa and forest production system, which is associated with the frequency of tillage that is carried out in this area, because corn is a short-cycle crop, also as a consequence from the excess of tillage, the sand content of the corn sown soil is higher than in the soil planted with cocoa and in the forest. The cocoa and forest production systems show the highest values of TSOC at all depths without differences between them. The forest area has the highest TSOC content, which is associated with the greater accumulation of plant remains on the soil surface and the non-use of tillage. In the 0-15 cm surface layer, the organic matter content is higher than 3% in the soil where cocoa is grown and greater than 4% in the forested area; the latter with the highest content of organic matter at all depths evaluated. The light and thick fractions of organic soil carbon in the soil presented a similar situation in the three agroecosystems evaluated.

BIBLIOGRAPHY

[1]. Carreira, D. (2004). Carbono orgánico (Método de Walkley & Black). Ciencias Ambientales, 4.

[2]. Eiza, M. J., Fioriti, N., Studdert, G. A., & Echeverría, H. E. (2005). Fracciones de carbono orgánico en la capa arable: Efecto de los sistemas de cultivo y de la fertilización nitrogenada. Ciencia Del Suelo, 23(1), 59–67.

[3]. Ferrer, J., & Centrales, L. (2016). Fraccionamiento físico de la materia orgánica del suelo bajo diferentes usos en la Colonia Tovar , (August).

[4]. Figuera V., K., Lozano P., Z., & Rivero, C. (2011). Caracterización de diferentes fracciones de la materia orgánica de tres suelos agrícolas venezolanos. Venesuelos, 13(1), 34–46.

[5]. Holdridge, L. R. (1967). Life zone ecology. Tropical Science Center, 206. https://doi.org/Via 10.1046/j.1365-2699.1999.00329.x

[6]. INAMHI. (2016). Boletín Climatológico Anual, 31.

[7]. Lok, S., Fraga, S., Noda, A., & García, M. (2013). Almacenamiento de carbono en el suelo de tres sistemas ganaderos tropicales en explotación con ganado vacuno. Revista Cubana de Ciencia Agrícola, 47(1), 75–82.
[8]. Martínez, E., Fuentes, J. P., & Acevedo, E. (2008). Carbono orgánico y propiedades del suelo. Revista de La Ciencia Del Suelo y Nutricion Vegetal, 8(1), 68–96. https://doi.org/10.4067/S0718-27912008000100006
[9]. Muñoz-Rojas, M., Jordán, A., Zavala, L. M., De la Rosa, D., Abd-Elmabod, S. K., & Anaya-Romero, M. (2015). Impact of Land Use and Land Cover Changes on Organic Carbon Stocks in Mediterranean Soils (1956-2007). Land Degradation and Development. https://doi.org/10.1002/ldr.2194
[10]. Pérez, H., Rodríguez, I., & Arzola, C. (2016). Aprovechamiento sostenible de los Residuos de origen orgánico y la zeolita en la agricultura. Retrieved from http:// repositorio.utmachala.edu.ec/ handle/48000/6844
[11]. Pina, N. A., & Machado De Armas, J. (2013). Nuevo enfoque para el diagnóstico de la necesidad de fertilizantes fosfóricos de la caña de azúcar New focus for the phosphoric fertilization of sugar cane. Centro Agrícola, 40(3), 23–28.
[12]. Pulido, M; Flores, B., Rondon, T., Hernandez R. M;, & Lozano, Z. (2010). Cambios en fracciones dinámicas de la materia orgánica de dos suelos, inceptisol y ultisol, por el uso con cultivo de cítricas. Bioagro, 22(3), 201–210. Retrieved from http:// dialnet.unirioja.es/servlet/ dcart?info=link& codigo=3710059& orden=309622
[13]. Robert, M. (2002). Captura de carbono en los suelos para un mejor manejo de la tierra. Informe sobre recursos mundiales de suelos No. 96. Fao. Retrieved from http://books.google.es/ books?hl=es&lr=&id=OKZt9agfRksC&oi=fnd&pg=PR3&dq=CAPTURA+DE+CARBONO+EN+LOS+SUELOS+PARA+UN+MEJOR+MANEJO+DE+LA+TIERRA&ots=5xOjDqvtWf&sig=c9-6h5Q4W_qU0xBHudD4IqchYyc
[14]. Rodríguez, H; Rodríguez, J. (2015). Métodos de análisis de suelos y plantas. Criterios de interpretación. Retrieved from https://www.libreriadelau.com/metodos-de-analisis-de-suelos-y-plantas-criterios-de-interpretacion-editorial-trillas-9786071722430-agropecuario/p
[15]. Verhulst, N., François, I., & Govaerts, B. (2015). Agricultura de conservación, ¿mejora la calidad del suelo a fin de obtener sistemas de producción sustentables? Nicaro, (505), 27. Retrieved from http://www.fao.org/ag/ca/Training_Materials/AC_Material_Nicaragua/AC_Tomo2.pdf
[16]. Villaseñor, D., Chabla, J., & Luna, E. (2015). Caracterización física y clasificación taxonómica de algunos suelos dedicados a la actividad agrícola de la provincia de El Oro. Ordenamiento Territorial, Urbanismo y Sostenibilidad, 1, 28–34. Retrieved from http://investigacion.utmachala. edu.ec/cumbres/index.php/ Cumbres/article/view/15

Irán Rodríguez Delgado, etal. "Carbon sequestration in corn, cocoa and forest agroecosystems in tropical conditions of El Oro province, Ecuador". *IOSR Journal of Engineering (IOSRJEN)*, 10(1), 2020, pp. 53-58.