v. 2, n. 8, 2022

Journal of
Agricultural
Sciences
Research

CARBON SEQUESTRATION IN OIL PALM AGROECOSYSTEMS (*Elaeisguineensis*Jacq.) IN SOCONUSCO, CHIAPAS

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Abstract: Climate change induced by human activities is a global problem that negatively affects the ecological, economic and social processes that govern the planet, mainly caused by greenhouse gases such as methane, nitrous oxide and carbon dioxide. (CO_2). As for atmospheric carbon content, these have increased mainly due to two human activities: change in land use and fossil fuels. In this study, the storage of organic carbon in soil and roots of *Elaeis was determined.guineensis*Jacq in three different producing areas in Soconusco, Chiapas. For this, three oil palm producing sites were selected. Soil samples were taken to obtain root and soil biomass at five depths: 0-0.2 m, 0.2-0.4 m, 0.4-0.6 m, 0.6-0.8 m and 0.8-1.0 m. For the analysis of carbon present in the soil and roots, the modified Walkley and Black method was used, using a sucrose standard solution. To obtain the calibration curve, the absorbance was measured at 590 nanometers (nm) with the Metash UV spectrophotometer. -6000. The results showed that in all the samples analyzed, the carbon content in the first 20 cm of soil was higher with respect to the subsequent depths, with the "Xochicalco" site of Villa Comaltitlan standing out with 39.40 tha^{-1}. Likewise, the carbon content in roots less than 2 mm in diameter, from the "El Arenal" site in Acapetahua, stood out with 993.02 $kgha^{-1}$ at the depth of 0-20 cm, while in the roots of 2-5 mm in diameter The "Plan de Ayala" site in Huehuetan stood out, with 470.05 $kgha^{-1}$ at a depth of 1.0 m, and in roots greater than 5 mm in diameter, the "Xochicalco" site in Villa Comaltitlan stood out with 866.56 kgh^{-1} at the depth of 1.0 m. depth of 20-40 cm. These results reflect that the accumulation of carbon both in the soil and in the roots of the dripping area of the oil palm according to the texture, fertility and depth of the soil, demonstrate that the amount of organic carbon present in the soil and roots is different in the areas oil palm producers in

the Soconusco Region of the state of Chiapas.
Keywords: Climate change, rhizosphere, Carbon stock, drip area.

INTRODUCTION

Climate change is mainly caused by greenhouse gases such as methane, nitrous oxide and carbon dioxide (CO_2). As for atmospheric carbon content, these have increased mainly due to two human activities: change in land use and fossil fuels (Ibrahim, et al, 2007).One of the ways to reduce emissions and the effects generated by CO_2 is to capture it and keep it in biomass and soil, the main elements for determining the amount of carbon stored by plants. In Mexico, Chiapas continues to be the main oil palm producing state, with more than 45,000 hectares cultivated (SIAP, 2014). Oil palm has a high carbon sequestration potential and high economic productivity; A change of attitude would suffice to go from being a monoculture to being considered an agroforestry system and capitalizing on carbon sequestration in economic and ecological terms. The carbon capture market is an international market, potentially it can also be located within the country. It involves a buying party, generally a developed country, and a selling party, usually a developing country, which offers additional carbon capture (project additivity). This implies that carbon pools have some value, since such value exists; however, additivities are regularly negotiated (Torres and Guevara, 2002). The carbon market captured in forests and jungles is defined in dollars per ton of carbon captured. The economic value of each ton of carbon depends on the marginal costs of climate change, which are very difficult to estimate since this requires a huge number of projections and assumptions. Consulting companies on the subject normally use a standard of US$10/t of C. Given the difficulty of estimating the value of each unit of carbon on the demand side, its value has been established in various ways, generally through the costs associated with the development of projects. Montoya *et al.* (1995) estimated that the costs of carbon capture projects for southern Mexico vary between US$3-11/t of C. This indicates that there will be a very large range in the value of each unit of carbon captured, for so there must be some type of discrimination, probably through the level of risk of the projects, the reputation of the countries and the quality of the monitoring of the projects, among other variables (Torres and Guevara, 2002). Adopting patterns of sustainable development can contribute considerably to mitigating climate change. Policies that favor both climate change mitigation and sustainable development include those related to energy efficiency, renewable energies or the conservation of natural habitats. In general, sustainable development can increase adaptation and mitigation capacity, while reducing vulnerability to the impacts of climate change (IPCC, 2007). In response to what has been described and with the interest of knowing the carbon contributions by oil palm, this research was carried out to obtain quantitative data of carbon captured in the soil and the roots of the plant at different depths of the soil. profile of the dripping area, in different oil palm plantations in Soconusco, Chiapas, as it is a crop in constant expansion of the planted area.

MATERIALS AND METHODS

The present study was carried out in the state of Chiapas, in the Soconusco region, during the period from January to December 2017, in the municipalities of Huehuetan, Villa Comaltitlan and Acapetahua, considered to be the ones with the highest oil palm production. The climate of the Soconusco is not very variable, the warm humid prevails in all the surface, with temperatures of 22 to 3 2°C, the pluvial precipitation oscillates between 2000 to 2500 annual mm. Varied soils are found,

predominantly Luvisols and Regosols, with loamy and loamy-sandy textures, with flat and slightly inclined topography (CEIEG, 2015). Of these municipalities, five sites were identified in each municipality, with oil palm plantations between 8 and 12 years of age. Five plants were selected to be sampled for each municipality, one for each sampling site. To take samples, a soil profile was opened on the drip area at a depth of 100 cm, from which soil and root information was obtained to determine the carbon present in each sampled part.

For the study of soil and roots, a trench 0.9 m wide by one meter deep and four meters long was opened, with small stakes and hemp thread, the sampling area was divided into a matrix according to each depth of 0 -0.2 m, 0.2-0.4 m, 0.4-0.6 m, 0.6-0.8 m and 0.8-1.0 m, covering a profile wall of 4.0 $m^{2.}$ Five rectangular samples of 0.1 m wide by 0.2 m deep and 4.0 m long were extracted, corresponding to each depth, which were found on one of the sides of the profile. Subsequently, the samples were deposited in duly labeled plastic bags, to be processed and analyzed in the Soil Analysis Laboratory of the Faculty.

For the determination of carbon, the soil samples were dried at room temperature for 24 hours, later they were disintegrated and sieved with a 1 mm mesh to separate the roots, wash them and remove the adhering soil. The roots were then left to rest for 12 hours at room temperature on butcher paper. Root samples from each depth were separated by diameter: > 5 mm, 2 to 5 mm and < 2 mm. These were placed in polypaper bags for drying at 60°C for 48 hours in a forced draft oven. With the help of an analytical balance, the dry weights were obtained and the samples were ground with a Willey Mil mill for their corresponding carbon analysis. For the analysis of the radical biomass, the roots found in each sample of each depth were weighed, classified according to the measures described, (<2, from 2 to 5 and >5 mm), determining the organic carbon using the method of wet combustion from Walkley and Black (1934) modified (Schlichting*et al.*, 1995), and quantifying the carbon of both root biomass and soil at the different depths sampled.

RESULTS AND DISCUSSION

According to the results obtained in the municipalities of Soconusco, Chiapas, the root biomass, quantity and percentage of carbon stored in five depths of the soil profile were calculated, in the fifteen sampling sites of the three agroecosystems as shown in the table 1.

CONCLUSIONS

According to the results obtained from the calculations applied in this investigation, it is concluded that: The amount of organic carbon found in the different sampling sites differs due to the edaphoclimatic conditions both in the soil and in the roots. The highest amount of organic carbon in soil and roots was found in the oil palm producing areas of the Xochicalco site in the municipality of Villa Comaltitlan and Plan de Ayala in the municipality of Huehuetan in the Soconusco region, Chiapas state with 39.40 t ha^{-1} and 36.10 t ha^{-1} respectively.In the oil palm of Soconusco, Chiapas, the greatest amount of biomass and carbon are found in the first 20 cm of depth and in greater proportion the roots smaller than 2 mm, so as the depth increases the number of roots decreases found.

Carbon storage occurs in a greater proportion in the soil than in the root biomass of oil palm. Oil palm represents an important potential for carbon sequestration in soils and roots, due to the abundant superficial root system that this plant presents in the first soil horizon, so that despite being a monoculture in Soconusco, Chiapas, it can influence the mitigation of climate change.

Municipality	Sampling site	Depth (m)	Root biomass (kg ha $^{-1}$)			
			<2mm	2-5mm	>5mm	Total
Acapetahua	the sandbank	0.2	17.53	2.36	1.73	21.63
Acapetahua	the sandbank	0.4	13.43	3.72	13.56	30.71
Acapetahua	the sandbank	0.6	4.07	2.59	12.15	18.81
Acapetahua	the sandbank	0.8	0.68	1.55	1.85	4.07
Acapetahua	the sandbank	1.0	0.89	1.43	0.77	3.09
Huehuetan	Ayala Plan	0.2	11.88	1.41	0.99	14.28
Huehuetan	Ayala plan	0.4	2.89	0.84	2.29	6.02
Huehuetan	Ayala plan	0.6	1.63	0.90	7.33	9.86
Huehuetan	Ayala plan	0.8	0.35	0.94	7.72	9.01
Huehuetan	Ayala Plan	1.0	1.17	9.97	3.63	14.77
Villa Comaltitlan	Xochicalco	0.2	13.51	1.71	4.72	19.94
Villa Comaltitlan	Xochicalco	0.4	4.49	1.67	14.92	21.07
Villa Comaltitlan	Xochicalco	0.6	2.11	1.08	3.62	6.81
Villa Comaltitlan	Xochicalco	0.8	1.46	0.89	1.86	4.21
Villa Comaltitlan	Xochicalco	1.0	0.87	0.40	1.37	2.64

The greatest amount of biomass, as observed in Table 1, is found in roots less than two millimeters at a depth of 0-20 centimeters, where 17.53 kgha $^{-1}$ was found at the "El Arenal" site in Acapetahua, while that the least amount of biomass, with 0.35 kgha $^{-1,}$ was found at the "Plan de Ayala" site in the municipality of Huehuetan at a depth of 60-80 cm in roots less than 2 mm. However, the largest amount of carbon captured in roots of the three sizes sampled was at the "El Arenal" site in the municipality of Acapetahua with 30.71kgha $^{-1}$ at a depth of 20-40 cm, followed by the "Xochicalco" site in the municipality from Villa Comaltitlan, at the same depth of 20-40 cm, with 21.07 kgha-1. This shows that the greatest number of absorbing roots are found in the superficial part. These absorbent roots have " trichoblasts " on their exterior, which are the structures responsible for the absorption of nutrients and water from the soil by the plant and therefore are found near the surface, where the organic matter is decomposing and the available nutrients and water.

Table 1. Oil palm root biomass according to different depths in three agroecosystems of Soconusco, Chiapas.

Municipality	Sampling site	Depth (m)	Percentage of C in root (%)		
			<2mm	2-5mm	>5mm
Acapetahua	the sandbank	0.2	39.61	40.15	37.40
Acapetahua	the sandbank	0.4	40.52	40.24	40.24
Acapetahua	the sandbank	0.6	43.98	36.69	40.92
Acapetahua	the sandbank	0.8	34.26	37.85	38.94
Acapetahua	the sandbank	1.0	39.88	37.04	36.01
Huehuetan	Ayala Plan	0.2	43.59	43.13	39.70
Huehuetan	Ayala plan	0.4	38.31	37.94	40.92
Huehuetan	Ayala plan	0.6	39.88	44.27	42.15
Huehuetan	Ayala plan	0.8	45.03	40.42	46.42
Huehuetan	Ayala Plan	1.0	36.10	32.99	41.69
Villa Comaltitlan	Xochicalco	0.2	37.41	36.31	41.96
Villa Comaltitlan	Xochicalco	0.4	42.94	41.01	40.63

Villa Comaltitlan	Xochicalco	0.6	40.78	42.58	41.94
Villa Comaltitlan	Xochicalco	0.8	48.55	40.81	41.15
Villa Comaltitlan	Xochicalco	1.0	47.26	43.36	45.64

The highest percentage of carbon in the radical part, as observed in Table 2, is found in roots less than two millimeters at a depth of 60 to 80 cm, where 48.55% was found, at the "Xochicalco" site in Villa Comaltitlan. While the lowest percentage was 32.99% and was found at the "Plan de Ayala" site in the municipality of Huehuetan, at a depth of 0.80 to 100 cm, in roots of 2 to 5 mm. The average carbon percentage of palm oil in Soconusco, Chiapas is 41.05%.

Table 2. Percentage of carbon in oil palm roots at different depths of the soil profile in three agroecosystems of Soconusco, Chiapas.

Municipality	Sampling site	Depth (m)	C content in root (kg ha $^{-1}$)		
			<2mm	2-5mm	>5mm
Acapetahua	the sandbank	0.2	993.02	135.64	92.75
Acapetahua	the sandbank	0.4	778.43	214.06	780.32
Acapetahua	the sandbank	0.6	256.09	135.84	710.98
Acapetahua	the sandbank	0.8	33.25	83.65	102.87
Acapetahua	the sandbank	1.0	50.88	75.88	39.47
Huehuetan	Ayala plan	0.2	740.27	86.80	56.36
Huehuetan	Ayala plan	0.4	158.33	45.68	133.81
Huehuetan	Ayala plan	0.6	93.16	57.28	441.57
Huehuetan	Ayala plan	0.8	22.66	54.48	512.18
Huehuetan	Ayala plan	1.0	60.32	470.05	216.50
Villa Comaltitlan	Xochicalco	0.2	722.72	88.75	283.51
Villa Comaltitlan	Xochicalco	0.4	275.45	98.03	866.56
Villa Comaltitlan	Xochicalco	0.6	123.10	65.81	217.07
Villa Comaltitlan	Xochicalco	0.8	101.21	52.07	109.44
Villa Comaltitlan	Xochicalco	1.0	58.60	24.93	89.39

The largest amount of carbon, as shown in Table 3, is found in roots smaller than 2mm at a depth of 0 to 20 cm, where 993.02 kg of C ha $^{-1}$ was found at the "El Arenal" site in Acapetahua., while the lowest amount of C was 24.93 kgha $^{-1}$ and was found at the "Xochicalco" site in Villa Comaltitlan in roots from 2 to 5 mm and at a depth of one meter. Etcheverset *al.* (2001) found figures of 14.42 t C ha $^{-1}$ in roots of oak forests, 6.07 t C ha $^{-1}$ in meadows, 1.03 t C ha $^{-1}$ in live barriers, 1.94 t C ha $^{-1}$ in roots of soils with tillage conventional and conservation, 7.78 t C ha $^{-1}$ in acahuales and 4 t C ha $^{-1}$ in coffee roots, in Oaxaca, Mexico. This indicates that oil palm is similar in carbon sequestration to the roots of living barriers, but inferior to acahuales and oak forests and prairie soils of natural systems, since on average it stores 0.72 t C ha $^{-1}$ in its roots, according to the data obtained in the sampling sites of Soconusco, Chiapas.

Box 3 . Carbon content in oil palm roots at different depths of the soil profile in three agroecosystems of Soconusco, Chiapas.

Municipality	Sampling site	Depth	Carbon
		(m)	(%)
Acapetahua	the sandbank	0.2	1.31
Acapetahua	the sandbank	0.4	1.78
Acapetahua	the sandbank	0.6	0.97
Acapetahua	the sandbank	0.8	0.37
Acapetahua	the sandbank	1.0	0.31
Huehuetan	Ayala plan	0.2	2.01
Huehuetan	Ayala plan	0.4	0.66
Huehuetan	Ayala plan	0.6	0.24
Huehuetan	Ayala plan	0.8	0.23
Huehuetan	Ayala Plan	1.0	0.01
Villa Comaltitlan	Xochicalco	0.2	2.47
Villa Comaltitlan	Xochicalco	0.4	1.57
Villa Comaltitlan	Xochicalco	0.6	0.51
Villa Comaltitlan	Xochicalco	0.8	0.49
Villa Comaltitlan	Xochicalco	1.0	0.33

The highest percentage of carbon in the soil, as observed in Table 4, is found at a depth of 0 to 20 centimeters with 2.47%, at the Xochicalco site in the municipality of Villa Comaltitlan, while the lowest percentage was 0.01%. and it was found at the "Plan de Ayala" site in Huehuetan, at a depth of one meter. Segura *et al.* (2005), mention that the soils of Mexico have C contents that vary from 0.006 to 16.40% in the superficial horizon (0 to 20 cm deep), which is relatively higher than what was found in the present investigation, where it was obtained 0.89% C in the soil profile of the oil palm drip area.

Table 4. Percentage of carbon in the soil of the oil palm drip area at different depths of the profile, in three agroecosystems of Soconusco, Chiapas.

Municipality	Location	Depth	Carbon
		(m)	(t ha $^{-1}$)
Acapetahua	the sandbank	0.2	23.47
Acapetahua	the sandbank	0.4	29.81
Acapetahua	the sandbank	0.6	19.33
Acapetahua	the sandbank	0.8	7.87
Acapetahua	the sandbank	1.0	6.50
Huehuetan	Ayala plan	0.2	36.10
Huehuetan	Ayala plan	0.4	14.39
Huehuetan	Ayala plan	0.6	5.05
Huehuetan	Ayala plan	0.8	4.66
Huehuetan	Ayala plan	1.0	0.24
Villa Comaltitlan	Xochicalco	0.2	39.40
Villa Comaltitlan	Xochicalco	0.4	28.98
Villa Comaltitlan	Xochicalco	0.6	10.53
Villa Comaltitlan	Xochicalco	0.8	9.53

Villa Comaltitlan	Xochicalco	1.0	6.53

The largest amount of carbon, as observed in Table 5, is found at a depth of 0 to 20 centimeters, in the "Xochicalco" site of Villa Comaltitlan with 39.4 t C ha $^{-1.}$ While the smallest amount was 0.24 t C ha $^{-1}$ and was found at the "Plan de Ayala" site in Huehuetan at a depth of one meter. This shows that in the superficial part is where the largest amount of organic matter derived from the decomposition of organic waste is found, therefore, at greater depths, less carbon. The data obtained in the present investigation reveal that in Soconusco, Chiapas, there is greater carbon storage in the soil cultivated with oil palm compared to that reported by (Caleb *et al.* 2015), who found that oil palm stores only 33.2 t ha $^{-1}$ in the soil at a depth of 0-20 cm in Knust, Ghana. For their part (Cañari and Panduro 2014) found that the soil of 10-year-old oil palm plantations stores 43.66 t C ha $^{-1,}$ at two sampling depths: 0-15 cm and 15-30 cm, being a figure slightly higher than that found in the agroecosystems of Soconusco, Chiapas, however there are other investigations where the opposite is revealed. (Leblanc *et al.* 2006), for example, found that in the soil of the 7-year-old oil palm in Costa Rica, the largest amount of carbon is stored with respect to aerial biomass, with figures ranging from 73.34 t C ha $^{-1}$ at 103.35 t C ha $^{-1}$ in profiles of 0-30 cm and 0-50 cm depth, respectively. On the other hand (Kanninen (2000), describes that the storage of carbon in agroforestry systems in an initial state is 8.9 t C ha $^{-1,}$ and after 9 years it is 24.1 t C ha $^{-1,}$ so that oil palm in Soconusco it exceeds these figures after 12 years of being established.However, in another investigation carried out by (Schroeder, 1994), it can be observed that oil palm stores a similar amount of carbon than agroforestry systems in tropical areas., since a storage of 21 to 50 t C ha $^{-1 \text{ can be obtained}}$ in subhumid and humid zones, respectively.On the other hand, oil palm does not surpass forests in terms of carbon storage, as indicated (Etchevers 2001), who determined that in 15-year-old forest soils around 240 t C ha $^{-1 \text{ is stored,}}$ likewise, in tropical forests near Manaus (Brazil), it was determined that the carbon deposit in the soil is 162 t C ha $^{-1}$ (IPCC, 2000), while (Catriona, 1998), states that in tropical forests, carbon sinks in the soil vary between 60 and 115 t C ha $^{-1,}$ much higher than the oil palm soils of Soconusco, Chiapas, Mexico.

Box 5 . Carbon content in the soil of the oil palm drip area at different depths of the profile, in the three sites of Soconusco, Chiapas.

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