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Organic carbon stock in some Iraqi soils and factors affecting it

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Abstract

This study was conducted in order to determine the organic carbon stocks in some Iraqi soils and to show the effect of the dominant local factors. Seven study locations were selected in the main physiological units dominated in Iraq which differ in terms of climatic characteristics, land use, topographic location and soil types. Land of the selected locations used for agriculture, natural vegetation under rain feed and irrigation systems Some physiochemical soil properties including organic carbon stocks were determined for soil depth (0- 30 cm). The results revealed that the soils of the study locations showed a variation in their formation and classification, with a large variation in their organic carbon stocks which ranging from 8.25 in desert soil to 316.47 (ton-carbon.ha^{-1}) in the soils of natural forest. Soils of studied locations are considered as weakly developed soils and have low organic carbon stock due to the interaction effect of each of the climatic characteristics, land use and the nature of the topographic location, which led to the lack of accumulation of organic residues and the weakness of the pedogenic processes responsible for soil formation and development. Land use factor has shown a significant role in determining organic carbon stocks. Natural forest soils showed the highest organic carbon stock compared to all other land use types mainly the bar land locations.

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Introduction

Soil is considered one of the most important environmental sources of carbon in nature, where it is the second largest stock of carbon after the waters of the oceans and seas. Soil acts as a source or sink of greenhouse gases like CO_2, CH_4, N_2O etc., depending on the management and land use (Lal, 1999). Further, CO_2 that forms a part of chemical processes, also controls the pH value of the soil as well as Soil Inorganic Carbon (SIC). The spatial pattern of the SIC is basically controlled by chemical and physical processes of the soil formation while biotic processes drive the spatial pattern of the SOC (Shi *et al.,* 2012). Organic matter is considered one of the most important sources of carbon in soil. Soil organic carbon is the amount of carbon present in the organic matter of the soil. Soil organic matter includes all the material of biological origin found in soil like plant residues, living roots, biological organism, and decomposing, decomposed or burnt material of varying sizes. The amount of soil organic carbon has direct relation with the crop productivity, fertility, soil type, physical characteristics and health of vegetation as well to list. Soil organic carbon is the largest terrestrial carbon pool playing as a key variable in the estimation of the terrestrial carbon dynamics. Whenever the organic matter is decomposed it releases some amount of carbon dioxide (CO_2) in the atmosphere. There is always a cycle of entry and exit of the amount of carbon between the terrestrial ecosystem and the atmosphere, making variable amount or level of carbon content in the soil (*Fung et al*., 2007; Hese *et al*., 2005;Ramankutty *et al*., 2007).

There are two types of carbon in the soil, mineral carbon, which is found in carbonate minerals and Bicarbonate of the calcareous soils. Organic carbon, presents in the living and dead components of plant roots, soil microorganisms, vegetative residues, light compounds (organic compounds dissolved in water and enzymes), and humic materials (Stevenson, 1994; Jonsson *et al*., 2010). Soil organic matter content ranges from less than 1% in dry areas to more than 10% in wetlands, with organic carbon accounting for about 58% (Nelson and Sommers, 1982). Carbon plays a large role and is directly related to climatic variations and the associated variations in the temperature of ecosystems. Soil organic carbon content in soil is controlled by many natural and human factors, such as land use, climatic conditions, topographical location and soil quality. The amount of organic matter in soil represents the equilibrium state between the average of addition and accumulation of plant and animal residues to soil and the rate of degradation and the loss of organic residues. The equilibrium state depends on the nature of the climatic conditions and the main soil components. The determinants factor of the quantities and degree of degradation of organic residues are spatially and temporally variability, both locally and globally. The problem of land degradation has been considered as one of the most important environmental problems leading to the loss of organic soil content (FAO, 2017). The amount of soil stock of organic carbon depends on the state of difference between the amount of carbon entering the soil through either add organic residues or exchange of carbon dioxide with the atmosphere, and showed the amount lost to the air by erosion or washing and transport in the soil, in particular the dissolved organic matter and resulted colloids from the decomposition of organic residues (FAO and ITPS, 2015). In general, studies indicate presence of variation in the content of organic matter in Iraqi soil is less than 1% in most of the soil in middle and southern Iraq, to more than 2%, especially in the northern soils, with some cases where organic content reaches more than 5%, especially natural vegetation, as well as the soils land of the marshes and swamps in southern Iraq.in southern Iraq. The decline in organic content in Iraqi soil reflects the impact of the nature of the environmental conditions prevailing in Iraq, which is characterized by drought conditions and lack of vegetation, which helped to accelerate the decomposition of organic residues and loss, which helped the deterioration of land in general. This study was conducted in order to determine the effect of local factors including land use, climate condition and topographic location on the amount of organic carbon stock of some Iraqi soils.

Materials and methods

Sites Description

Seven study locations were selected in Iraq representing the variation status of land use, climatic condition and topographic location within the dominant physiographic units(Figure1).

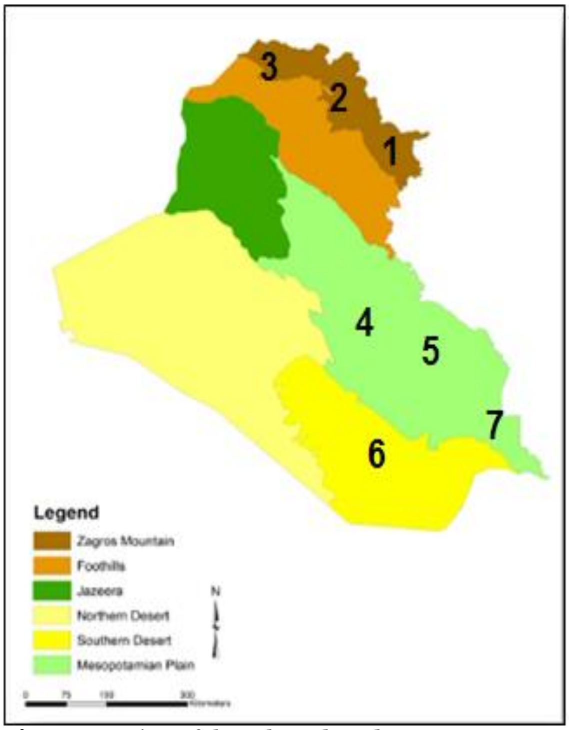

Fig. 1. Location of the selected study.

Three locations are identified represented the status of rain feed agriculture in Sulaymaniyah, Erbil and Dohuk Provinces (locations 1, 2 and 3), respectively. Two locations were selected representatives of irrigated agriculture, in each of Babylon and Wasit Provinces (locations 4 and 5), respectively. And the other two locations representing the desert region in Muthanna Province (location 6) and dried Marshlands in Basra Province. The general characteristics for each location were described, as shown in Table (1). Soil samples were taken from the surface horizons (depth of 30 cm) from each location for the purpose of identifying some physio-chemical soil properties. Practical size distribution was estimated using the international pipette method as described by (Day, 1965). Soil bulk density was estimated by clod method and covering with paraffin wax, according to the method described by (Black and Harthe, 1986). ECe was estimated in the soil extract with water (1: 1) using a WTW EC meter, and the organic carbon content was estimated by the method decribed by (Yeomans and Beremner, 1988).

The content of carbonate minerals was also estimated in the methods as described by (Piper, 1971). The organic carbon stock in the soil of the selected locations and for the depth of 30 cm of the soil body was computed using the method described by (Jurčová and Bielek, 1997). The amount of plant residues were calculated in the unit area in each location. The climatic information, including the monthly temperature, the amount of rainfall and the average amount of water lost by transpiration and evaporation, were collected from the nearest Meteorological Station in each Province.

Results and discussion

Description of the studied Soils

The results of the selected locations indicate the difference in the nature of the Location conditions, especially the climatic conditions, parent materials and land use as shown in Table (1). These variations have effect the general soil properties and their classification status. Soils of the selected locations belong to the following soil orders: Vertisols, Mollisols, Aridisols and Entisols (Muhaimeed *et al.*, 2014). The results indicated that the soil of the northern regions of Iraq belong to the Mollisols and Vertisols which are rich in organic matter , clay content and natural drainage condition, due to the effect of soil forming factors and the type and density of the vegetation at each location. As well as , the effect of rich parent materials in clay minerals that helped the formation of Vertisols in Sulaymaniyah province compared with other locations in the dry region of Iraq, which were characterized by the presence of undeveloped young soils belong to the Entisols(Figures 2,3,4). The results confirm the low amount of plant residues at the irrigation locations and desert compared to other locations, especially those with the natural deciduous forests in northern Iraq or the Reed plants in the areas of dried Marshlands which show high accumulation of plant residues.

Table 1. General description of selected studying locations.

Location	Location Province	Land Use	Slop %	Topographic location	Agriculture system	Parent Material	Soil Classification	Ground water depth (cm)	Drainages state	Plant residues (ton.ha-1)
1	Sulaymaniyah	wheat	2	Plains	Rainfeed agriculture	Sedimentation	Vertisol	200 <	Good	3.8
2	Erbil	Natural forests	6	Down the ramp	Rainfeed agriculture	Thick	Mollisol	200<	Good	7.4
3	Dohuk	Natural forests	3	middle ramp	Rainfeed agriculture	Thick	Mollisol	200<	Good	5.3
4	Babylon	Barley - corn	1	Plains	Irrigation agriculture	Sedimentation	Entisols	150	Average	5.9
5	Wasit	abandoned	1	Plains	Irrigation agriculture	Sedimentation	Aridisol	100	Average	0.0
6	Muthanna	abandoned	2	valley	Desert	Sedimentary	Aridisol	200<	Good	0.0
7	Basra	Marshlands lands	1	Marshlands	Non-cultivated	Sedimentation	Mollisol	80>	Poor	5.16

Climate characteristics of study locations:

The climatic conditions (average temperature, amount of precipitation and ET values) were collected from the weather stations near each of the seven selected locations for this study (1990 to 2010). The collected climatic data(Figure 2,3,4) represent three locations including Erbil, Babylon and Muthanna. Erbil province represents the rain feed agriculture pattern and Babylon province represents the irrigation agriculture pattern as well as the desert areas, represented by Muthanna province.

Table 2. Some physio-chemical traits for the soil of studying locations.

location	Total clay (%)	Apparent density (g.cm-3)	Organic Carbon (%)	Electrical conductivity	Carbonate minerals (%)	Stock of Organic carbon (ton.ha-1)
1	48.5	1.80	1.19	0.62	16.8	54.94
2	55.9	1.35	7.84	0.16	13.44	316.47
3	33.4	1.53	4.04	0.34	20.6	185.44
4	40.7	1.21	0.76	37.4	31.1	27.44
5	20.5	1.35	1.10	268	31.6	44.55
6	20.0	1.20	0.25	0.61	30.2	8.25
7	37.8	1.13	3.78	51.1	38.2	106.76

It is noticed that there is a large variation in the mean annual rainfall, temperature and the amount of moisture lost by evapo-transpiration in those areas.

The amounts of annual rainfall, temperature and moisture content lost by evapotranspiration in Erbil, Babil and Muthanna were (1035.9 mm, 17.65 ^oC, 1882.7 mm, 96.89 mm 25.6 ^oC, 2687.45 mm, 105.6 mm, 27.03 ^oC and 3296.4 mm), respectively.

In general, the northern provinces are characterized by high available moisture for most months of the year, due to high amount of water added to soil by rain compared to amount of moisture lost through the process of evapotranspiration, especially during the months of November to March. While the middle and western regions of Iraq suffer from water shortage throughout the year.

These differences have a great effect on the status of variation in the general characteristics of the soil of the study areas, especially the organic carbon content.

Organic Carbon Content

The results as shown in Table (2) indicated that there is a variation in the general soil properties of the selected locations due to the effect of the variation status of the dominant soil forming factors, especially climatic conditions. It is noticed that the soils of rain feed areas are darker, non-saline and less calcareous compared to the soils of other locations. This reflects the effect of the higher amount of the annual rainfall with the relatively low temperature which has helped to increase the activity of dehumidification and de-calcification processes, and the movement of soluble material and transfer them from the surface horizons to the rest of the other horizons or outside the soil body and forming the dark, non-saline soil and relatively low lime soils, compared to other soils.

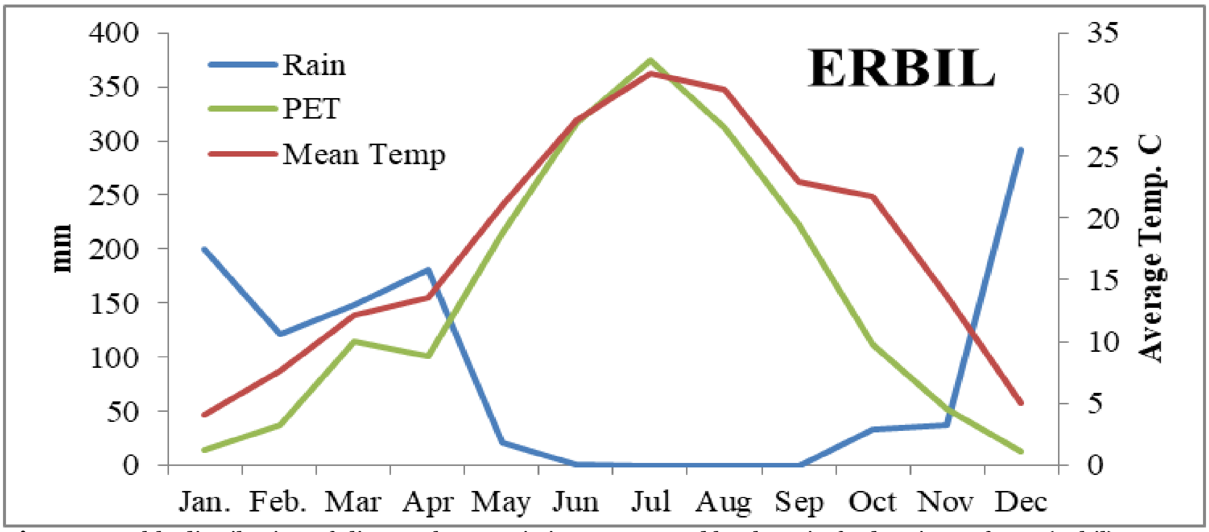

Fig. 2. Monthly distribution of climate characteristics represented by the rain feed regions of Iraq (Erbil).

In general, the soils in northern Iraq were used to grow natural forests, especially in Erbil and Dohuk Provinces, as well as the soil of the Marshlands southern Iraq, which have been used to grow the natural vegetation of Reed which show a higher organic carbon content compared to other soil . The organic carbon content ranged from 0.21% in the desert region soil in Muthanna Province to 7.84% in the soil of Arbil Province as shown in Figure (5). This is due to the effects of the local conditions variation which affect the amount of plant residues added to the soils, the speed of decomposition and the rate of losing from soil body.

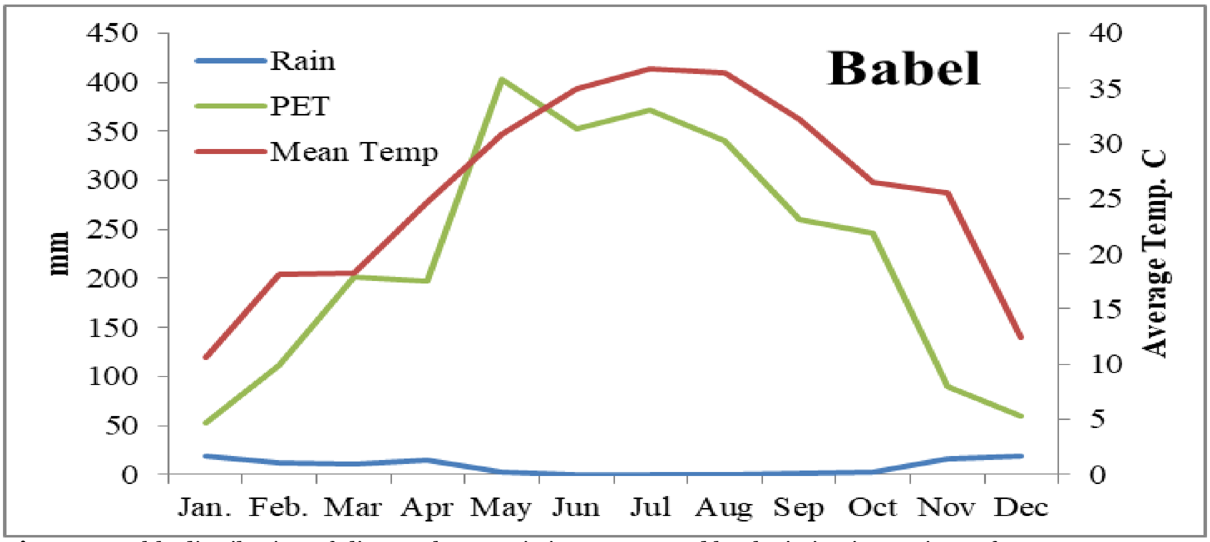

Fig. 3. Monthly distribution of climate characteristics represented by the irrigation regions of Iraq.

The increase in the organic carbon content in soil of the natural vegetation can be attributed to the non-stirring of surface soils components due to the non-use of various types of tillage methods, which has helped to reduce the degradation and loss of organic residues compared to the exploited land for agricultural purposes, as confirmed by (Guareschl, *et al.*, 2013). The increase in the organic carbon content in soils of Erbil location used for the natural forests compared to the other locations (Figure 5), due to the effect of the typography location, where the study area is located in the bottom of the valley, which helped to accumulate the rainwater from the upper locations and increase the moisture stock of the soil, thus increasing the density of the vegetation and the amount of organic residues added to the surface of the soil. Where Figure (2) and table (2) shows that the soil of the desert has shown the lowest values of the organic carbon content compared to the rest of the soil of other locations, this is due to the impact of drought conditions and the lack of plant residues as well as increasing the speed of degradation and loss of organic waste in those soils. Marschner *et al.,* (2008) explained that one of the most important determinants of the degradation of organic matter in soil is both frost and thermal content (associated with the nature of climatic characteristics) that directly affect the activity of microbial organisms that decompose these substances and thus the organic carbon content in which.

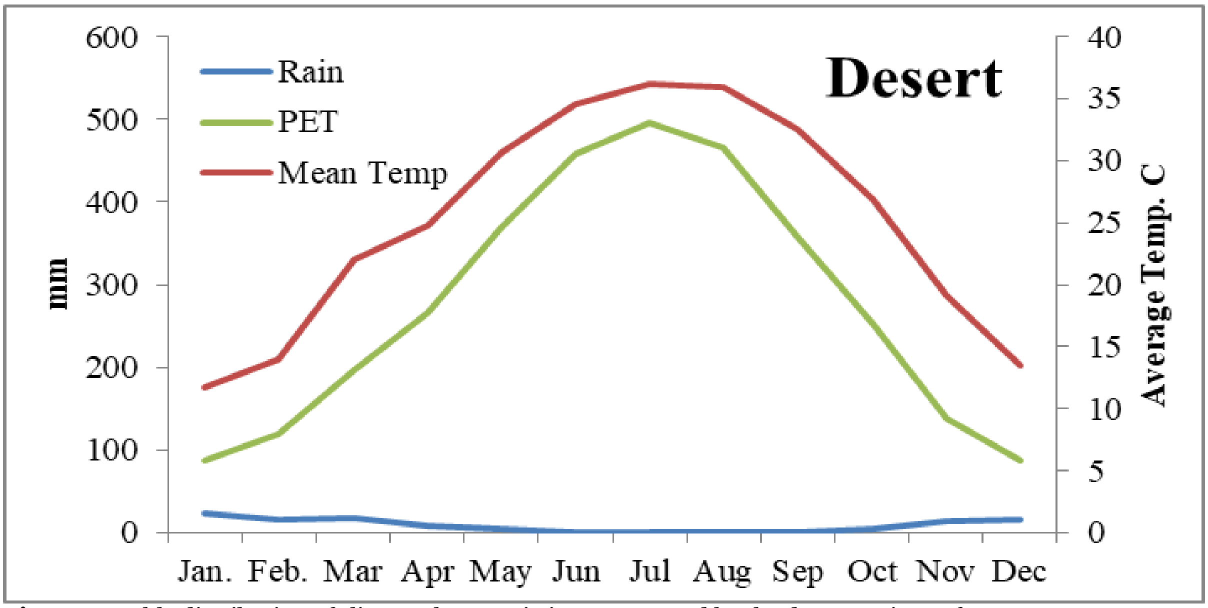

Fig. 4. Monthly distribution of climate characteristics represented by the desert regions of Iraq.

Stocks of Organic carbon

The results as shown in Table (2) and Figure (6) show the variability of organic carbon stocks in the soils of the study locations for the depth of 30 cm (ton-carbon.ha^{-1}). The organic carbon stocks ranged from 8.25 (ton-carbon.ha-1) in the alluvum soils of the desert areas of Muthanna province to 316.47 (ton-carbon.ha^{-1}) in the soil of the deciduous forests in Erbil province.

These results are similar to the organic carbon content in the soil of the study locations. The decrease in the organic carbon stock in the soils of the desert areas is due to the effect of the dry climatic conditions and the soil texture, as well as the low amount of organic residues added to the soil in the dry areas (Silva and Mendonca, 2007). The results also indicate the role of the land use factor and the type of vegetation on the average of adding plant residues and their accumulation in the soil. The soil stock of organic carbon depends on the state of the dynamic balance between the average of addition of carbon to the soil, which is represented by the plant residues and the added organic fertilizer and the average of carbon loss resulting from the decomposition of organic residues, which depends mainly on the type and quantity of residues (Aerts, 1997; Jensen *et al.* 2005; Jensen, 2007) and the nature of climatic conditions (Melillo, 1989) and the type of soil traits (Frouz, 2015). Soil moisture content is also considered a factor in the degradation of organic waste (Tulina, 2009).

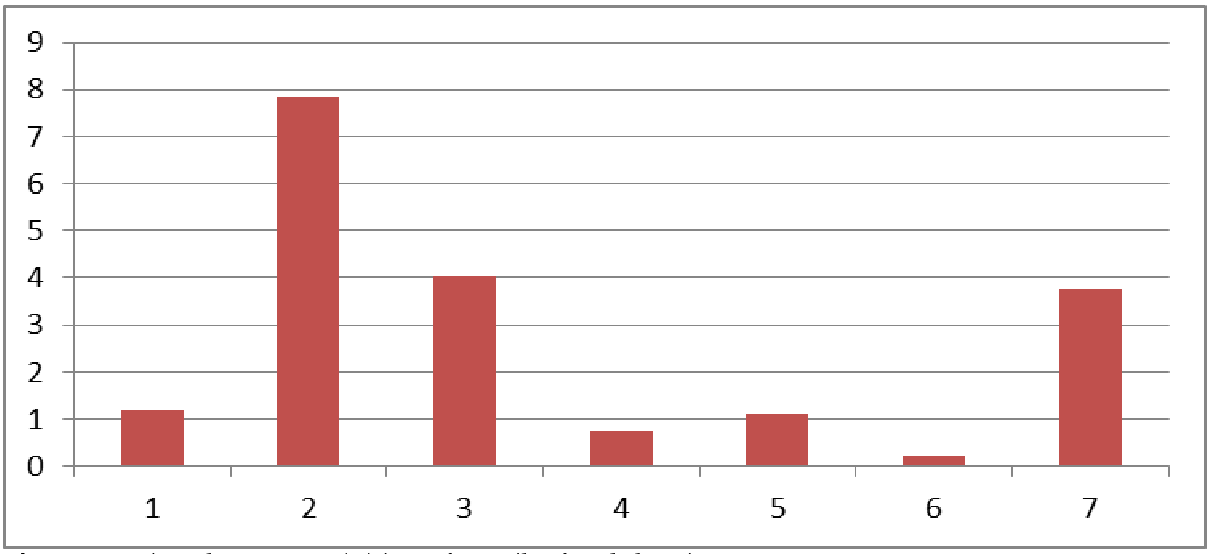

Fig. 5. Organic carbon content (%) in surface soils of study locations.

Effect of Land Use

In order to demonstrate the effect of the land use factor represented by the vegetation type on the organic carbon stock in the soil of the study locations, the average stock was calculated for the soils formed under similar vegetation type as shown in Figure (7). The results indicate that there is a significant difference in carbon stock between the different soils. Where the abandoned soil showed the lowest value of the carbon stock while the natural deciduous forests showed the highest value for the carbon stock.

The values of the carbon stock average for forest, marsh. agriculture and abandoned soils were (250.5 106.76, 50.1, 17.8 tons-carbon.ha^{-1}), respectively.

These variations are mainly due to the type and density of vegetation prevailing in each location, as well as soil properties, especially soil texture and agricultural activities.

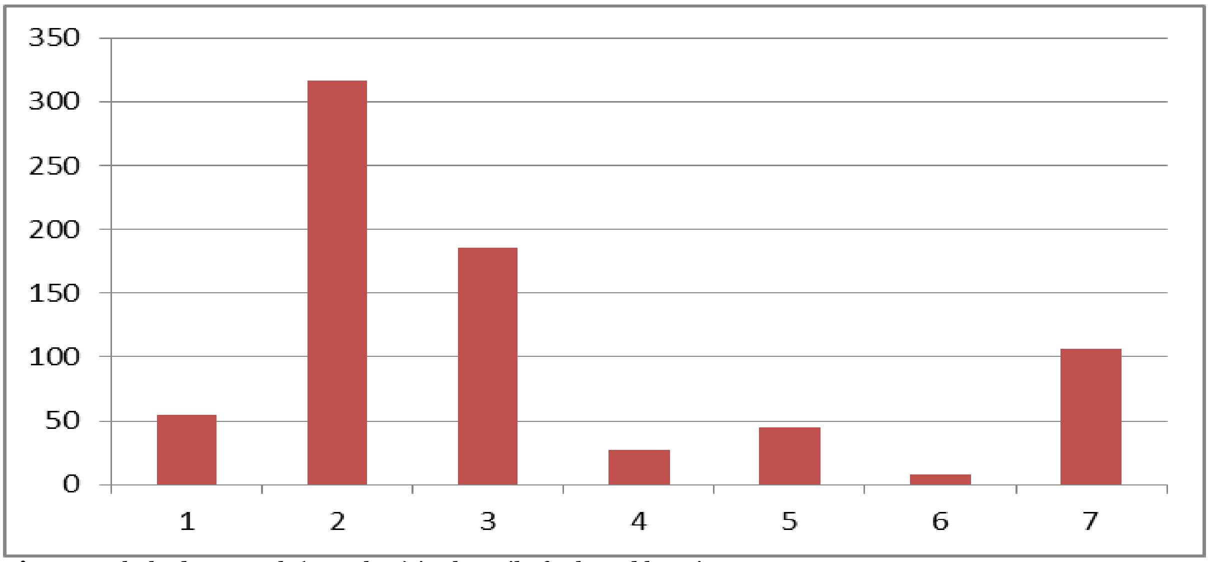

Fig. 6. Carbohydrate stock (tons. ha^{-1}) in the soil of selected locations.

The excelling of the carbon stock values in the soil of forest locations attribute to the high density of foliage trees, which add high amounts of plant residues added annually to their soil, as well as the increased moisture content due to the topographic and geographic location of the soil, have helped to reduce the rate of degradation and loss of organic matter in their soils. As well as with the soil of the dried marshes also characterized by the high content of carbon stock due to the shallow level of ground water causing to the exposure of these soils for saturation periods with water during the year and thus reduce the average of degradation and loss of organic matter. As for the soil used for agricultural purposes, both in the rain feed and irrigation areas, it is noted that the organic carbon stock is lower than the rest of other locations.

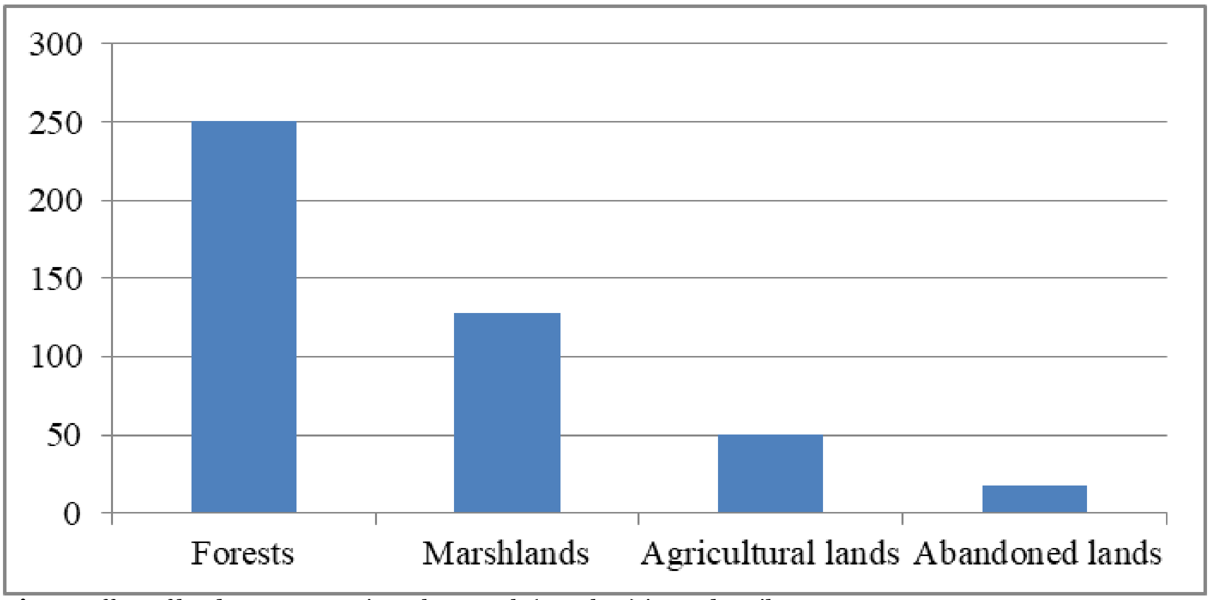

Fig. 7. Effect of land use on organic carbon stock (tons.ha^{-1}) in study soils.

This is due to the role of the agricultural activities, which are mainly tillage, which lead to the dismantling and softening of the surface soil components, helps to increase the activity of biological activities that decompose and loss of organic matter and thus the lack of organic carbon stocks (Batlle - Bayer *et al.*,2010; Guareschl, *et al.*, 2013). There is also a role for both the bulk density and soil texture has a role in influencing the stock of soils carbon. Bulk density values have been used to calculate the organic carbon stock in soil, which often has different values from soil to soil and sometimes within a single soils for many reasons. Soil texture has also played a major role in determining organic carbon stocks, particularly soft texture varieties, by forming complex compounds between hydrochemical and clay minerals, thus reducing carbon loss from soil (Oades, 1993; Stevenson, 1994; Zinn *et al.*, 2005; Tristram and Six, 2007).

Conclusions

The results revealed that the soils of the forest and marshes showed the highest amount of SOC stocks compared to other soils of the desert and irrigated area which showed the lowest amount of SOC stocks. These variations are due to the effect of vegetation type, climatic conditions and topographic location. Also, the results indicated the effect of agricultural activities mainly tillage, lead to decrease the amount of SOC stocks by dismantling and softening of the surface soil components and helped to increase the biological activities that decompose and loss of organic matter and thus the lack of organic carbon stocks.

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