Al-Qadisiyah Journal For Agriculture Sciences (QJAS)
ISSN : 2618-1479 Vol.13, Issue. 1 ,(2023), pp. 36-49
https://jouagr.qu.edu.iq/

Land use and Impact on Soil Organic Carbon Stock in a Semi-Arid Region of Algeria

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Abstract. Atmospheric carbon sequestration in terrestrial ecosystems has become a significant challenge in the global framework of reducing greenhouse gas emissions. The main objective of this study is to provide estimation of organic carbon stocks in the agricultural soils of the Sidi Bel Abbes plain at various depths and according to different land use, namely cereals, olives and,viticulture. We have chosen two toposequences according to the two main types of soils that dominate, namely Chromic Cambisols and Calcareous Cambisols. Organic carbon was determined by the modified method of Walkley and Black. Stored organic carbon values varied significantly ($p < 0.05$) between the different land uses and depth strata. The maximum value of 29.28 t ha^{-1} ± 2.29 was recorded under viticulture in the 30cm to 45cm stratum of Chromic Cambisols. The minimum value of 12.11 t ha^{-1} ± 0.17 was registered under cereal cultivation in the 0 to 15cm stratum of Calcaric Cambisols. With 15.84±3.59 t ha^{-1} as average under cereal cultivation, 19.49 t ha^{-1} ±5 under olive cultivation and 20.50 t ha^{-1} ±5.64 under viticulture. for the stratum ranging from 0 to 15 cm; The recorded stock is between 12.11 t ha^{-1}± 0.17 and 23.60 t ha^{-1}± 2.45. for the stratum ranging from 15 to 30 cm; The recorded stock is between 15.28 t ha^{-1}± 1.25 and 27.62 t ha^{-1}± 3.03 and for the stratum ranging from 30 to 45 cm The recorded stock is between 13.17 t ha^{-1}±4 .18 and 13.17 t ha^{-1}±4.18 .The average for all 54 samples is 18.61 t ha^{-1} ± t/ha. The soil organic carbon stock is 19.56 t ha^{-1} ±6 for Chromic Cambisols and 17.66 t ha^{-1} ±4 for Calcaric Cambisols.

Keywords. Carbon sequestration, Organic carbon stocks, Agricultural soils, Depth, Land use.

1. Introduction

Human activities are responsible for increasing greenhouse gases concentration in the atmosphere, particularly carbonaceous gases (CO_2,CH_4), an increase that has become synonymous with climate change [1-4].
Carbon can be stored in the soil mainly in organic form through photosynthesis of higher plants, which is the almost unique way of biological fixation of atmospheric CO_2 in the form of organic matter [5]. The amount of soil organic carbon(SOC) is estimated at 1.5 trillion Mg, about twice as much as in the atmosphere and three times as much as in terrestrial vegetation [6]. Soil organic matter, composed mainly of carbon, contributes to four principal ecosystem services: water retention, soil fertility, soil erosion resistance, and soil biodiversity [7-9] , in addition it plays an important role in maintaining soil

health and productivity in agro-ecosystems [10] and could play an essential role in combating the increase of greenhouse gases in the atmosphere and thus in preventing climate change [11] .

In recent years, international commitments to combat climate change have taken into account changes in soil organic carbon [12]. According to the "4 by 1000" initiative, 1.2 billion Mg of carbon could be stored in the agricultural topsoils per year, so an annual storage rate of about 0.4%, through management practices adapted to local conditions. These practices not influence carbon inputs only but also carbon outputs through soil carbon stabilization and destabilization mechanisms [13]. Most soils are very far from being saturated with organic carbon, and estimates show that the amount of carbon that could still be sequestered is very significant [14,15]. The carbon dynamics of semi-arid Mediterranean soils have received less attention than the other world regions [16].

According to [17], drylands contain about one-third of the world's stock and cover 40% of the land surface. Continuous research and monitoring of the soil and its condition is very important to build a sustainable future [18]. Thus, increasing soil organic carbon stock (SOCS) by only a few percent represents a significant C sink potential [19,10].

Few studies have addressed the dynamics of organic carbon in agricultural soils in Algeria, notably [20] for a diachronic study (1988-2002) of Ouzéra soils, 90 km south of Algiers, [21]for another diachronic survey (1993-1998) in Beni-Chougrane, 100 km east of our study area, with the same climatic conditions and the same type of soils, and [22] for a comparative study of the soil organic carbon on Beni-Chougrane and Tlemcen mountains, 50 Km west of our study area, also with the same climatic conditions and the same soil types, [23] for another comparative study of the SOCS of Annaba and Setif, in northeastern Algeria, [24] for a four soil study along a toposequence in the Zeramna valley at El Hadaiek, 5 km from Skikda in northeastern Algeria.

According to [25, 26, 27], land use and the land use system significantly influence the dynamics of organic matter and its stabilization. The knowledge of the potential offered by agricultural soils according to land uses and practices is crucial [5].

The main objective of this study is to estimate the variation of the soil organic carbon stock (SOCS) of Sidi Bel Abbes plain according to their occupations. To do so, we (i) quantified the organic carbon according to the main land uses represented by cereal, olive, and viticulture, and (ii) quantified the organic carbon according to three different depths; from 0 to 15cm, from 15 to 30cm and from 30 to 45cm, and finally (iii) determined the variation of the SOC according to the two main soil types of the study area represented by Chromic Cambisols and Calcaric Cambisols.

2. Materials and Methods

2.1. Description of the Study Area

The plain of Sidi Bel Abbès, located northwest of Algeria, has a surface area of 2102.85 km^2. The utilized agricultural surface represents 92% of the total area. The altitude varies between 400 and 800 m. The topography is relatively flat and limited to the north by the Tessala mountains, to the south by the mountainous Oued Mimoun, to the west by the Oued Isser valley, and the east by the Beni Chougrane and Bou Hanifia reliefs. It consists of alluvial formations from the quaternary period with a clayey-silted texture. A semi-arid climate with low and irregular rainfall (~400 mm) characterized the Sidi bel abbes plain. The region has a dry period, which lasts six months and seven days [28-30].

2.2. Sampling Strategy and Analyses

Following a toposequential approach, a series of soil samples took place in September 2019.

We chose two toposéquences (Figure1) according to the two main soil types that dominate [28,31] , namely Chromic Cambisols (9302 m long and 904 m wide) and Calcaric Cambisols (3843 m long and 442 m wide).

The choice of the depth of 45cm is according to the recommendations of the IPPC expert group and according to [32,33] .Each toposequence is composed of three stations, and there are three substations for each station according to the main land uses (cereal, olive, and viticulture).

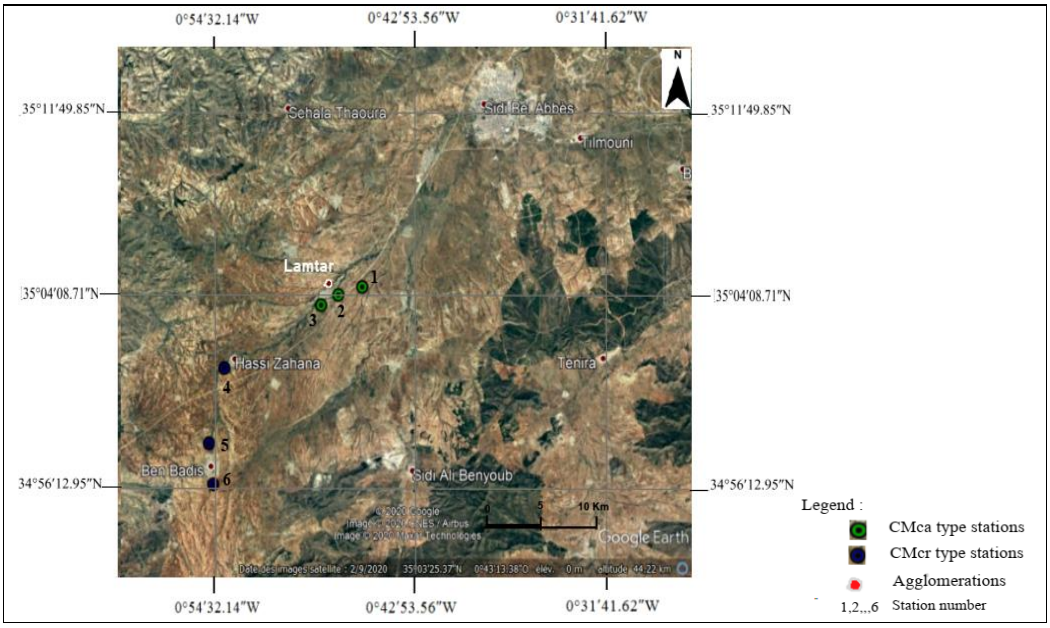

Figure 1. Location of sampling stations.

In each substation were collected three samples at the following depths, H1 between 0 and 15 cm, H2 between 15 and 30 cm, and H3 between 30 and 45 cm.Finally, a total of 54 [2x(3x3x3)]soil samples were collected for the SOCS estimation.

To better understand the dynamics of SOCS, it was interesting to determine other parameters that could directly or indirectly influence the variation of SOCS, namely (grain size, hydrogen potential, electrical conductivity, total limestone, active limestone, organic carbon content, coarse element load, and bulk density). The soil samples were dried at room temperature and passed through a 2 mm diameter sieve . Mineral fractions determination was by the Robinson pipette method after the destruction of organic matter with hydrogen peroxide (H_2O_2), considered fractions being clay (0-2 µm), silt (2-50 µm), and sand (50-2000 µm).

Organic carbon was measured by the modified method of Walkley and Black: extraction of carbon with potassium dichromate in sulphuric medium [34], followed by determination of the excess dichromate with a Mohr's salt solution and volume difference determination.

Total limestone ($CaCO_3$ content) was determined by Bernard's calcimeter method [35] using HCl acid. The pH was measured using a pH meter (Hanna Instruments, Netherlands); For the soil samples suspensions with a ratio of 1: 2.5 (m/v) of the fine earth and water, as shown by [36] . The salinity was evaluated by the electrical conductivity (EC) in millisiemens per centimeter (mS/cm) using a conductivity meter (Hanna Instruments, The Netherlands); a suspension of fine earth and water with a ratio of 1:5 (m/v) was considered for this analysis [37] . The bulk density (BD) in g cm^{-3} was determined by the direct sampling method using a 5.5 cm diameter and 5 cm height cylinder [38]. The samples taken from the cylinder were dried and passed through a sieve with a diameter of 2mm to measure the content of coarse particles .The method used to calculate SOCS is to measure the total organic carbon content at different soil depths and to transform these data by taking into account the bulk density and the coarse element load of the soil.

First, we determined the organic carbon stock (SOC) for each sample for the constant depth of 15 cm using the following formula: SOCS (t C. ha^{-1}) = 0.1× C ×BD × T × (1 - CP) [39,24,40] .

Where C represents the concentration of organic carbon in a given soil mass, obtained by laboratory analysis (g C.kg-1), BD is the bulk density of the soil in (g.cm-3), T is the thickness of the soil layer in cm, CP is the coarse particle load in (g.g-1).

Next, we determined the OCS over the depths of 0-30 cm and 0-45 cm by summing the SOC of all soil layers up to the target depth by the following formula [41]:

$$\text{Sum (SOCS) total} = \text{(SOCS) layer 1} + \text{(SOCS) layer 2} + \ldots + \text{(SOCS) layer n}$$

DOI: 10.33794/qjas.2022.135409.1074

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2.3. Data Analysis

A principal component analysis (PCA) was carried out to allow simultaneous observation of the relationships between the different physicochemical parameters. An Ascending Hierarchical Classification (AHC) and, a Parallel Coordinate Plot (PCP) were conducted to verify the information provided by the PCA. Analysis of variance (ANOVA) using Tukey's test ($P < 0.05$) was used to determine the significance of differences between the measured means, firstly according to the land cover based on the three separate and combined layers studied, and secondly, according to the depths (H1, H2, and H3) based on the three land cover types. Bivariate correlation tests with two quantitative variables were carried out to see if there is a link between the SOCS and the different parameters measured. All statistical analyses were performed using Xl STAT software [42].

3. Results and Discussion

3.1. Variation of the Studied Parameters According to the Soil Type

The variation in the parameters of the soil samples is visible after their projection on the PCA. This projection separates the 54 soil samples into two distinct groups. The total contribution of the axes in this PCA is 57.96%, with 38% for the F1 axis, which is better represented than the F2 axis, with only 19.96%. Each group corresponds to a soil type (Figure 2).

Hierarchical Ascending Classification (HAC) with Coordinated Parallel Graph (CPG) was used to see the behavior of each group.

The Cambisol chromic (CMcr) group is characterized by:

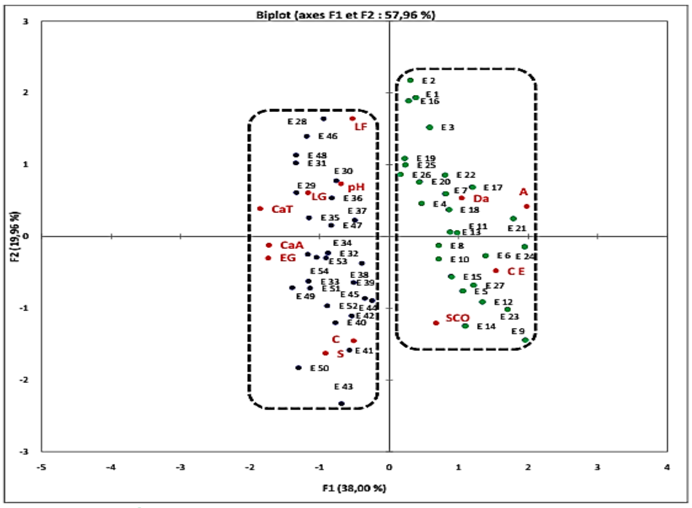
A high salinity with an average of 0.25 ± 0.14, and the Calcaric Cambisol group (CMca) averaged 0,13 ± 0,05. A high clay content with an average of 40.64% ± 3.75, while for the Calcaric Cambisol (CMca) group, an average of 26.87% ± 2.97. With a higher bulk density, an average of 1.47 ± 0.09 g/cm^3, the Calcaric Cambisol (CMca) group has an average of 1.39 ± 0.12 g/cm^3.

The Calcaric Cambisol group is characterized by:

A high content of total limestone and active limestone with 40.09% ± 8.22 %and 6.59 %± 1.35, while for the CMcr group is 20.37% ± 7.00 and 3.63% ± 1.37, it could be explained by the presence of a Calcaric rock [43].

High sand and coarse element contents with 32.41% ± 7.67 and 0.23% ± 0.08 have been recorded. As for the CMcr group, they are 21.02% ± 6.50 and 0.044% ± 0.035. It could also be explained, by a hard limestone rock not deep, less than 45 cm [43].

The samples are agglomerated according to the soil types and not to their occupation (Figure2 and 3).



CMcrsoil type samples
CMcasoil type samples
Studied parameters

Figure 2. Principal component analysis (PCA) of the soil samples and different measured parameters.

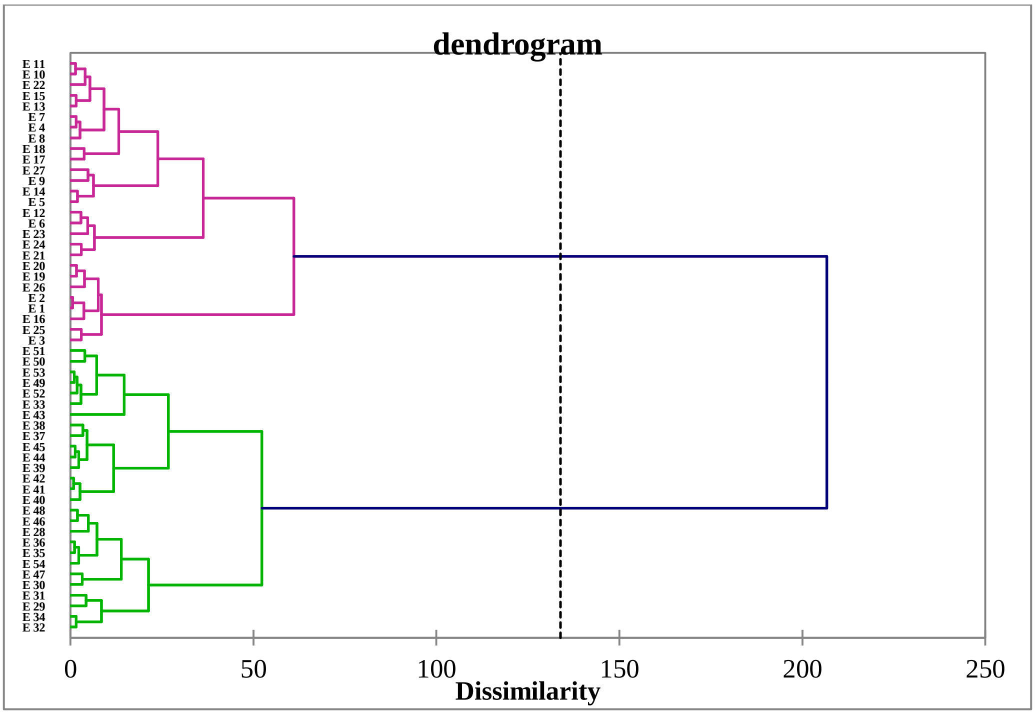


Figure 3. Hierarchical cluster analysis of the 54 samples.

3.2. Variation of SOCS According to Land Use

According to [16] in a study on two plots- The first plot is cultivated continuously with forage sorghum (Sorghum vulgare sudanense) and The second plot is cultivated with tomatoes, peppers, durum wheat, and is fallow one year out of five - the type of vegetation influences the organic matter content of the agricultural soils. Figure4 highlights the effect of land use on SOCS, the average stock is 18.61 t ha^{-1} ± 5.15 for all 54 soil samples of the study area taken at 15cm with 19.56 ± 6.01 t ha^{-1} for CMcr and 17.66 t ha^{-1} ± 3.99 for CMca.

There is a lack of synergy in the distribution of SOCS values; SOCS varies significantly ($p < 0.05$) between the different land-use modes along the two topo-sequences, with the highest values recorded under viticulture at the level of the stratum ranging from 30 to 45 cm and that under olive trees ranging from 15 to 30 cm; both concern MCcr with 29.28 t ha^{-1} ± 2.29 and 27.62 t ha^{-1} ± 3.04 respectively . The lowest stocks are recorded under cereal crops for MCca in the superficial stratum from 0 to 15 cm and the third stratum of MCcr from 30 to 45 cm, with 12.11 t ha^{-1} ± 0.17 and 13.18 t ha^{-1} ± 4.18.

3.2.1. Variation of SOCS under Cereals

The highest stock is 20.35 t ha^{-1}±1.66 recorded for the 15-30 cm stratum of the CM ca, while the lowest value (12.11 t ha^{-1} ±0.17) is noted for the 0-15 cm stratum for the same soil type. There is no similarity in the SOCS distribution between the layers for the different soil types.

For the CMca soil type, the stratum from 15 to 30 cm is the best represented with 42%, while the stratum from 0 to 15 cm of the CMcr soil type is the best represented with 39% of the stored organic carbon.

No correlation was found between cereal crop occupancy and the different parameters studied.

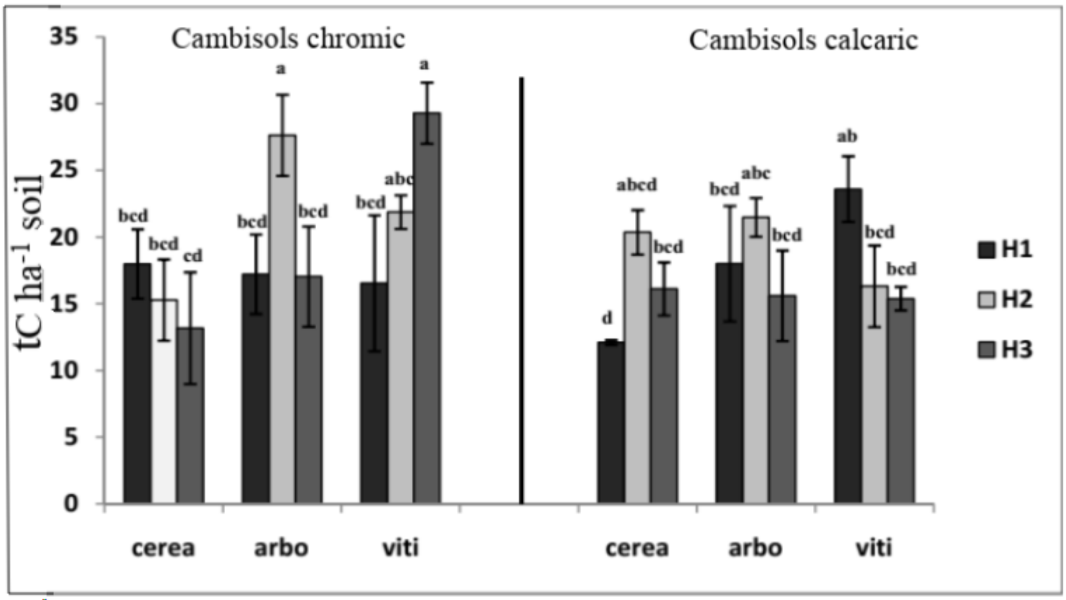


Figure 4. Variation of SOCS according to land use in the three strata studied.

cerea: cereal growing, arbo: olive growing, viti: viticulture, H1: layer from 0 to 15cm, H2: layer from 15 to 30cm, H3: layer from 30 to 45cm. Values are means (n = 3) and histograms with the same letter are not significantly different at the 5% threshold according to the Tukey test for multiple pairwise comparisons.

3.2.2. Variation of SOCS under Olive Cultivation

The highest stock is 27.63 t ha^{-1}± 3.04 recorded in the 15-30 cm CMcr layer. The lowest value is 15.6 t ha^{-1}± 3.39 recorded in the 30-45 cm CMca layer. The 15-30 cm layer is the best represented for both soil types, accounting for 45% and 39% of the organic carbon stored respectively on CMcr and CMca .No correlation was found between land use by olive cultivation and the different parameters studied.

3.2.3. Variation of SOCS under Viticulture

The highest stock is 29.28 t ha^{-1}, recorded for the CMcr, at the level of the layer from 30 to 45cm, while the lowest was noted for the same stratum of the CMca, with 15.38 t ha^{-1}±0.88.An inverse distribution of OCS according to soil type and layers were found. Indeed, for CMcr, the OCS increases according to depth, with a maximum rate of 43% recorded for the layer from 30 to 45cm, which is the best represented in both soil types. For the CMca, the SOCS decreases with depth with a rate equivalent to 28% in the layer from 30 to 45cm, the latter representing the lowest value recorded for both soil types**.**

The positive correlation between clay, and SOCS (Figure5) could be explained by the characteristics of clay, which acts as an aggregating factor, binding particles together and influencing decomposition and CO turnover [44] .The positive correlation between EC and SOCS could be explained by the salinity tolerance of the vine [45].

Contrary to the results of [46], who discussed the positive correlation between calcium carbonates and SOC based on the results of several authors (notably [47-49] for grassland soils), a negative correlation was found (Figure 5).

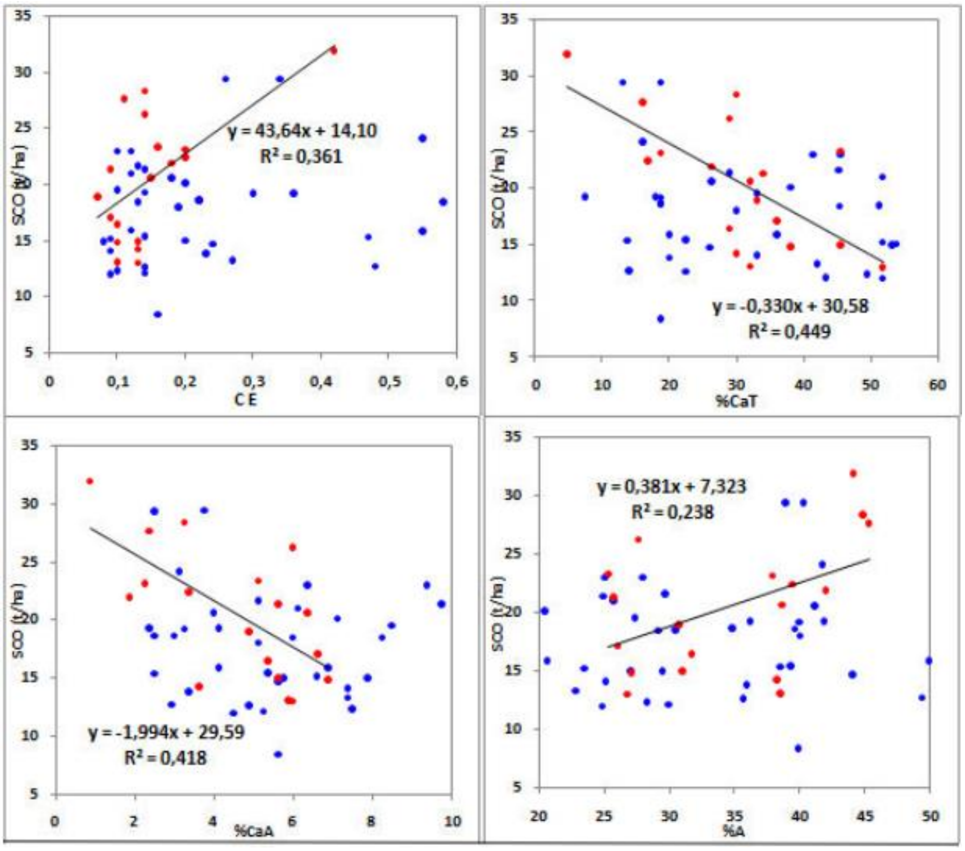


Figure 5. Correlation between SOCS and electrical conductivity, total and active limestone and clay under viticulture.

Even if the identification of the mechanisms responsible for this correlation remains undefined [46], in the case of this study and given the climatic conditions, it would be possible to explain the results by putting forward the following hypotheses: (i) The presence of limestone in the soil could lead to a significant drop in yield, and consequently in carbon reserves, except under good water conditions [50]. (ii) SOC could, in some cases, accelerate the loss of calcium carbonates [51] . This variation in the vertical distribution of SOCS according to land use can be explained by the difference in the depth of roots depending on the species occupying the land, as plant roots contribute in a primordial way to the formation of soil organic matter [52], according to [53] the variation in SOCS would be linked to root activity and root length rather than the root mass. This variation could also come from the difference in plant inputs which differ in quantity and quality between species [54,52], as well as the composition of above- and below-ground plant tissues between species [55] .The results of [56] reinforce this hypothesis as they found that shrubs had the deepest rooting, followed by trees and that herbaceous plants had the shallowest rooting. The highest COS value for about half of the stations in the middle layer (15-30 cm). It could be because the surface profile is the most exposed to natural (erosion) and anthropogenic (plowing) disturbances [57,26], which would facilitate the decomposition of organic matter and its release as carbon dioxide emission [58]. Unlike the subsoil layers, which are conditioned by specific processes regulating organic carbon storage [59]. However, the mechanisms delaying organic matter decomposition in the subsoil layers need further investigation [60].

3.3. Variation in Combined SOCS

No significant differences in SOCS for the different land-use modes at either 30cm or 45cm were observed (Figure 6). [61] made the same finding for Tanzania soils at 30 cm with the land use classes (woodland, shrubland, grassland, and cropland), in contrast to the observations of [62] recorded a significant difference between the different land-use types (forest, scrubland, savannah, grassland, and cropland) ranging from 47 t/ha^{-1} to 118 t/ha^{-1} for Nigeria soils.

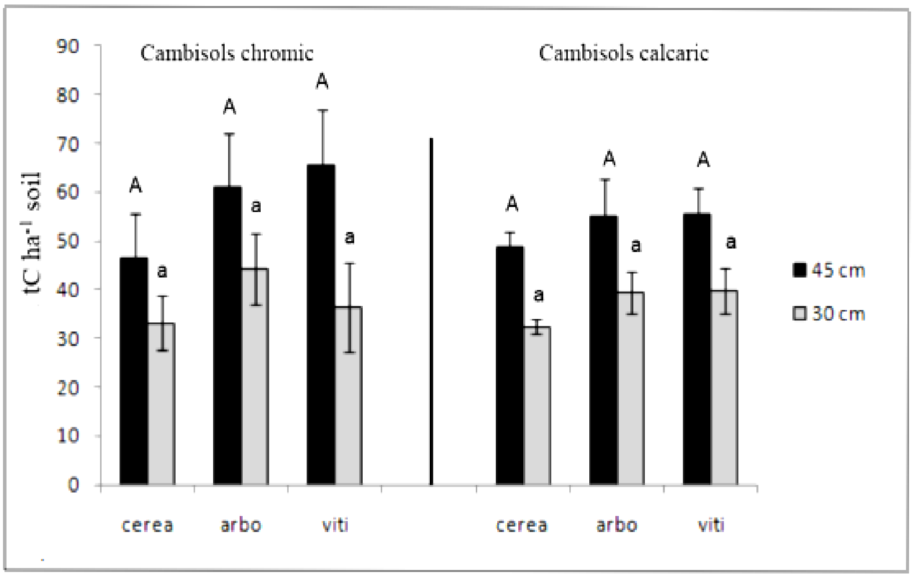


Figure 6. Variation of SOCS by land use according to combined strata. Values are means (n = 3), and histograms with the same letter are not significantly different at the 5% level according to the Tukey test for multiple pairwise comparisons. cerea: cereal growing, arbo: olive growing, viti: viticulture.

3.3.1. Variation in SOCS for the 30 cm

The average SOCS recorded for all soils is 37.58 t ha^{-1}. This value is not far from the one found by [63] in Tunisia for the same soil type and at the same depth with 41.6 t ha^{-1}.We recorded almost the same amount for both soil types, with 37.89 t ha^{-1}and 37.28 t ha^{-1}for CM cr and CM ca (Figure 6**).**

In CMcr under olive trees, the highest value (44.10 t ha^{-1}± 7.3) was recorded, which is higher than that recorded for the soils of peninsular Spain [64], characterized by the same occupation and depth with 39.9 t ha^{-1}±28.3 and only 30 t/ha for French soils [11]. The lowest value (32.46 t ha^{-1}±1.51) was under cereal cultivation. This value is still higher than that recorded for soils in arid regions of Australia with only 10 t ha^{-1} [65]. For both studied soil types, cereals represent the least storing land use with only 33.26 t ha^{-1}and 32.46 t ha^{-1}for CMcr and CMca respectively. It could be explained mainly by the crop management method. These values are lower than those recorded for Spanish soils at the same depth with 50.8 t ha^{-1}± 33.7 [64] and for French arable land with 51 t/ha [11].

With 44.10 t ha^{-1}, this value is above the value recorded by [66] at the same depth for all Tunisian soils with an average of 26.12 t/ha, but still below the global average value for tree-covered areas with 66.84 t ha^{-1}and 46.57 t ha^{-1}for shrub-covered areas [67]. Our results contradict those of [11] who reveal that vineyards and orchards would store less CO with 30 t/ha^{-1} and 50t/ha^{-1} for arable land.

3.3.2. Variation in SOCS for the 45 cm

The average SOCS recorded for all the soils is 55.35 t ha^{-1}, with 57.72 t ha^{-1} for CMcr and 52.99 t ha^{-1} for CMca. These values are higher than those recorded for the soils of southern Spain for the same type of soil and a depth of 50 cm, with 46.2 t ha^{-1} for herbaceous vegetation and 35.9 t ha^{-1} for arable land [68]. Cereal cultivation is the least storing land-use type for both soil types, with 46.44 t ha^{-1}±9.25 and 48.58 t ha^{-1}±3.24 for CMcr and CMca. Viticulture allows the best storage of CO for the CMcr, with 65.59 t ha^{-1}± 11.27. The percentages of OCS in the third stratum ranging from 30 to 45cm of the total soil stock underline the importance of the depth parameter in storage since 32.09% of the CO stored in the studied soils resides in this layer, this observation was confirmed by [16] for deep soil layers under a semi-arid Mediterranean climate, these authors, the rooting of crops would strongly contribute to these high values of SOCS in the subsoil. In addition to the high temperature and the non-availability of nutrients for microorganisms in the subsoil layers restricting the degradation of stored CO [60], other authors have explained this high content through the migration of SOCS to the deep layers by leaching [69].

DOI: 10.33794/qjas.2022.135409.1074

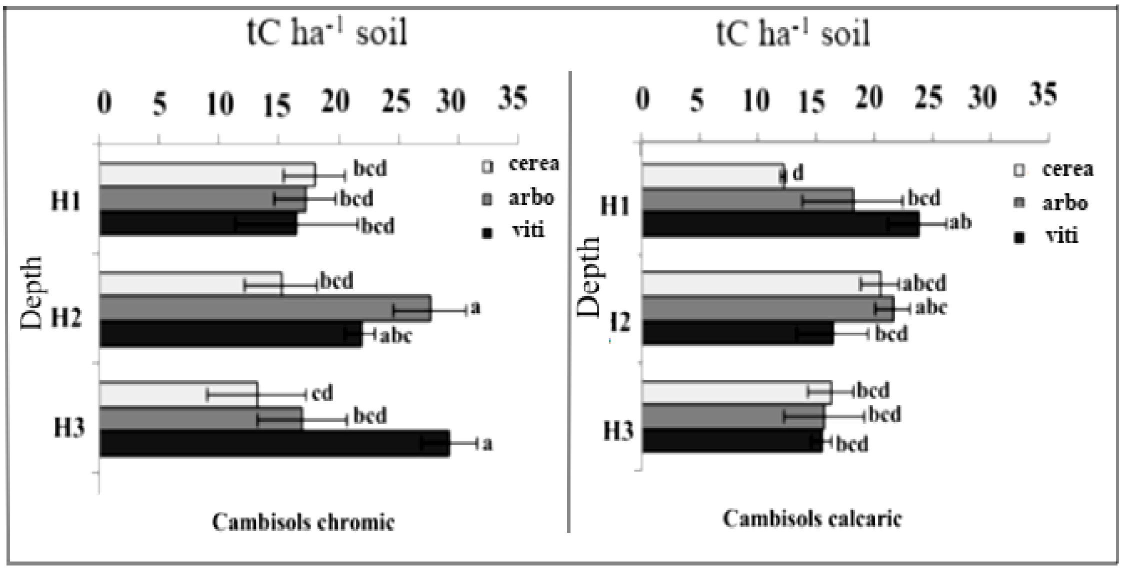


Figure 7. Variation of the SOCS according to depth in function of the land use. H1: layer from 0 to 15cm, H2: layer from 15 to 30cm, H3: layer from 30 to 45cm, cerea: cereal growing, arbo : olive growing, viti : vine growing . Values are means (n = 3) and histograms with the same letter are not significantly different at the 5% threshold according to the Tukey test for multiple pairwise comparisons.

3.4. Variation of SOCS with Depth

The SOCS varies significantly ($p < 0.05$) between the different soil strata studied (Figure 7). Indeed, [70] report that the distribution of the SOCS is likely to vary with depth across soil types.

3.4.1. Variation of SOCS for the 0-15 cm Stratum

This stratum contains an average of 29% and 34% of stored OC depending on the land use for CMcr and CMca.The highest stock is 23.60 t ha^{-1}± 2.45, recorded under viticulture for the CMca, representing 44% of the SOCS for this stratum according to land use. The lowest value recorded under cereal cultivation for the same soil type is 12.11 t ha^{-1}± 0.17, accounting for 23% of the stored CO.

3.4.2. Variation of the SOCS for the Stratum from 15 to 30 cm

Depending on land use, this stratum contains 37% and 36% of the stored CO for CMcr and CMca. The highest stock was registered under olive trees for CMcr (27.62 t ha^{-1}± 3.03), representing 43% of the CO stored in this stratum according to land use. Under cereal crops for the same soil type, the lower value was registered (15.28 t ha^{-1}± 1.25), this latter presenting 23% of the stored CO.

3.4.3. Variation of the SOCS for the Layer from 30 to 45 cm

Depending on the land use, this layer contains 34% and 30% of the stored CO for CMcr and CMca. The highest stock (29.28 t ha^{-1}±2.45) was recorded under viticulture for the CMca, representing 49% of the CO stored for this layer according to land use. The lowest rate recorded was 13.17 t ha^{-1}±4.18 under cereal cultivation for the same soil type, corresponding to 22% of stored CO.

The variation in the distribution of CO by depth could be explained by the difference in the distribution and depth of roots that control CO storage and stabilization [52], also by root inputs at different depths of the soil profile [71], and even by the leaching of CO leaching from the deep layers [69].

3.5. Variation of SOCS by Soil Type

According to [72], soil type and land use play a significant role in the dynamics of stored CO, [70] also concluded that the distribution of stored CO as a function of depth is likely to vary between soil types.

Estimates by soil type showed that the average COS for depth (0-30cm) is 37.58 t ha^{-1}, with 37.89 t ha^{-1}for CMcr and 37.28 t ha^{-1}for CMca. The values on the histograms represent the average of SOCS for each land use (Figure 8). Other authors found almost the same results; [40] for West African soils for the same soil types and depth with an average of 36.9 t ha^{-1}and [73] with 38.4 t ha^{-1}for soils of Murcia Province (S.E. Spain).

These values are below the global average value for Cambisols of 50 t ha^{-1}for the same depth [74] and the values recorded in the soils of peninsular Spain for Cambisols with 71.4 t ha^{-1}±57.8 for the same depth [64].

These values are also above the value recorded for Jordanian soils for Cambisols and at the same depth as 23 t ha^{-1} [75].

Regarding depth (0-45cm), an average of 55.35 t ha^{-1}was recorded, with 57.72 t ha^{-1}for CMcr and 52.99 t ha^{-1}for CMca.These are below the global average value for Cambisols with 69 t ha^{-1} (0-50cm) [74] and above the value recorded for Jordanian soils for Cambisols and a depth of 50 cm with 34 t ha^{-1} [75].

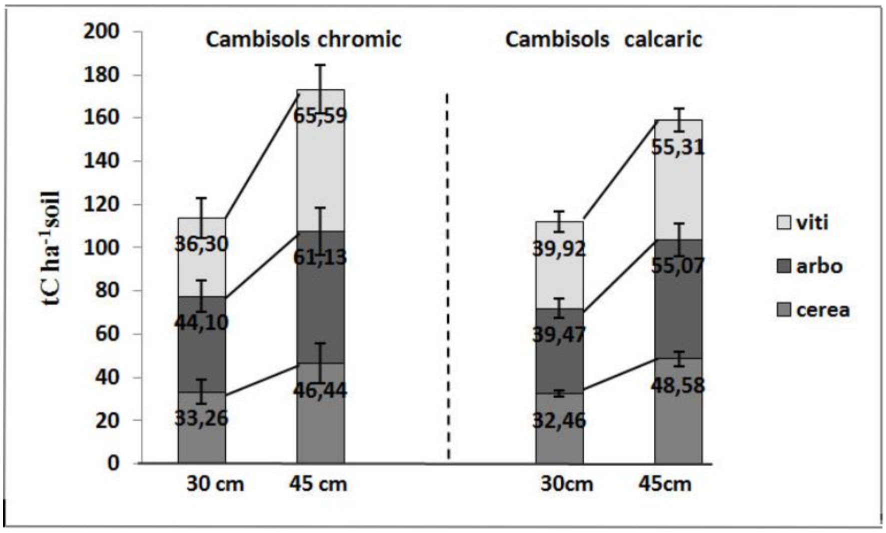


Figure 8. Variation of SOCS according to soil type.

Conclusion

The present study focused on soil organic carbon stock estimated in agricultural soils of the Sidi Bel Abbes plain according to land use, depth, and soil type. The results showed that the SOCSwould vary significantly ($p < 0.05$) between the different modes of land use, with an average of 18.61 ± 5.15 t ha^{-1} for all 54 samples , with 15.84±3.59 t ha^{-1} under cereal cultivation, 19.49±5 t ha^{-1} under olive cultivation and 20.50 ±5.64 t ha^{-1} under viticulture. The SOCS also varied significantly ($p < 0.05$) between the different depth layers, with an average of 17.57 t ha^{-1} for the 0-15 cm layer, 20.48 t ha^{-1} for the 15-30 cm layer, and 17.76 t ha^{-1} for the 30-45 cm layer. A SOCS of 19.56±6 t ha^{-1} was also recorded for Chromic Cambisols and 17.66±4 t ha^{-1} for Calcaric Cambisols.

The data generated by this study will be helpful and contribute to the design of land management strategies for better conserving existing organic capital and increasing carbon sequestration in agricultural soils in arid and semi-arid zones.

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