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Research article

Influence of climatic and geographic factors on the spatial distribution of soil organic carbon in the Tunisian dryland at Kebili oasis

Hatem Ibrahim [a,*], Asma Slama [b], Nadhem Brahim [b]
[a] *University of Carthage, Faculty of Sciences of Bizerte, 7021 Jarzouna, Tunisia.*
[b] *University of Tunis El Manar, Faculty of Sciences of Tunis, Campus El Manar, 2092 Tunis, Tunisia.*
* *Corresponding author. Tel.: +216 99284763, Fax: +216 71885408. E-mail address: brahim_hatem@yahoo.fr*

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Abstract

The effect of climate variables on soil organic carbon (SOC) distribution remains unknown and poorly studied in dryland. This work presents a study of the spatial SOC distribution at continental Guettaaya oasis at Kebili governorate, so that we have an idea about the contribution of arid soils in carbon sequestration. 80 samples were collected from six stations according to a toposequence. Sampling concerned the first 30 centimeters of soil. Physicochemical analysis have identified the main characteristics of the soil. SOC rate varies from one station to another, in some stations it exceeds the rate of 3%, and generally it is abundant in surface layer compared with the underlying layers. Regarding the SOC stock at a depth of 30 cm, the highest stock is 57.7 t/ha and the lowest is 28.7 t/ha, and soil salinity varies from 2 g/l to 12 g/l. We found that SOC stock are influenced by soil salinity, bulk density, and soil texture. The SOC helps to maintain the balance of the oases ecosystem. In this oasis, the organic carbon storage exists with relatively high levels, and appears to be a carbon sink to high potential in comparison with what exists outside the oasis.

Key words: Soil organic carbon, arid soils, salinity, SOC stock, Tunisian oasis.

1. Introduction

Drylands make up 30% of the land, they are characterized by specific conditions: scarcity of rainfall, high temperatures and limited water resources (Gratzfeld, 2004) but despite these conditions, the presence of open water sources allows installation desert oasis.

To maintain the balance of the oasis ecosystem, increased OC as the soil organic matter (OM) could play a responsible role in the chemical fertility of these arid soils; resulting increased cation exchange capacity due to the strong negative charge of OM, which allows the retention of nutriments and make them available for plants. Also the soil OC keeps the physical soil fertility; it keeps the aggregate stability, which ensures good soil structure (Van Camp et al., 2004).

However, soils of these arid regions are characterized by a very high soil salinity of the irrigation water with a more or less salty (Hachicha, 2007), and the low soil OM content not exceeding 0.8% (Gallali, 2004), which leads to degradation of soil quality and decreased fertility.

Man's role for centuries contributed to the formation of a surface horizon humus, which can be likened to a man-horizon (El Fekih and Pouget, 1969). The abundance of OC in the soil is influenced by the physical properties of the soil; D_b and its texture (Zhang and Shao, 2014).

Inside the oasis, the site conditions (soil salinity and physical quality of the soil) and its morphology contributes to the variation of the contents of OC. Hence this study leads to understand the spatial distribution of OC in the soil of a continental oasis and its contribution in sequestering carbon.

2. Materials and methods

2.1. Study area

The Guettaaya oasis is a modern continental oasis located in the south of Tunisia. It is administratively attached to Kebili governorate. It is located between 8.27° to 8.29° N latitude and 33.24° to 33.26° E longitude (Figure 1). It has a dry hot desert climate, and the annual precipitation is irregular and less than 90 mm.

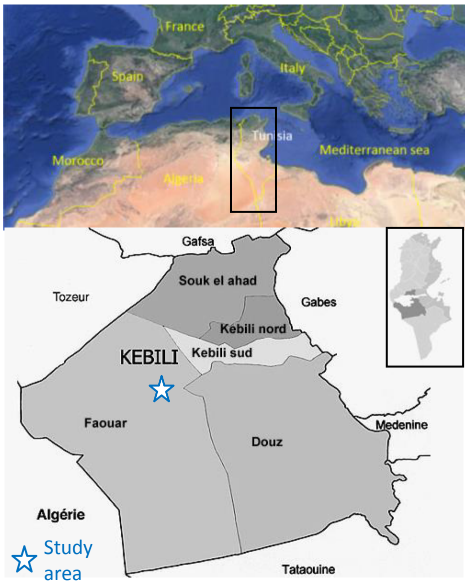

Fig. 1. Location of the study site in the governorate of Kebili in Tunisia

2.2. Sampling and analyzes

Samples was conducted following a linear path about 1 km, the starting point was the center of the oasis on the way to the Chott. 5 profiles have been carried out every 200 meters to 1 km inside the oasis (P1, P2, P3, P4 and P5), and P6 the outside profile of the oasis in the Chott. Sampling concerned the first 30 cm: 0-5; 5-15 and 15-30cm. For each sample, we performed three measurements. The way of calculating SOC stocks for a given depth consists of summing SOC Stocks by layer determined as a product of D_b, OC concentration, and layer thickness. For an individual profile with n layers, we estimated the organic carbon stock by the following equation:

$$SOCs = \sum_{i=1}^{n} Dbi \times OCi \times Di \qquad (1)$$

Where SOCs is the soil organic carbon stock ($t.ha^{-1}$), D_{bi} is the bulk density ($Mg.m^{-3}$) of layer i, OC_i is the proportion of organic carbon ($g\ C.g^{-1}$) in layer i, D_i is the thickness of this layer.

The estimate of carbon stock "S" in soil is the sum of all stocks in the soil's layers:

$$S = S_{layer\ 1} + S_{:\ 2} + \ldots + S_{layer\ n} \qquad (2)$$

4. Results and discussion

Analyses of the size usually indicates that soil texture is sandy loam. The EC values range between 3.2 and 17.1 mmoh/cm. The values of salinity is between 2.3 and 17,2g/l in the oasis. The results show that the layer (0-5cm) is more saline than the underlying layers.

Depending on the values of the salinity, it is deduced that the salinity peaked at P6 (up to 145.84 g/l) and P5 (salinity> 12 g/l), where the texture is smooth. Although the levels of other stations, the values of the salinity range between 2.38 and 13.68 g/l. These values indicate conditions at least saline, with a coarse texture. These results show the close relationship between salinity and soil texture.

The pH is between 6.2 and 8.1. The soil is very rich in low $CaCO_3$ contents there and vary between 2 and 7%.

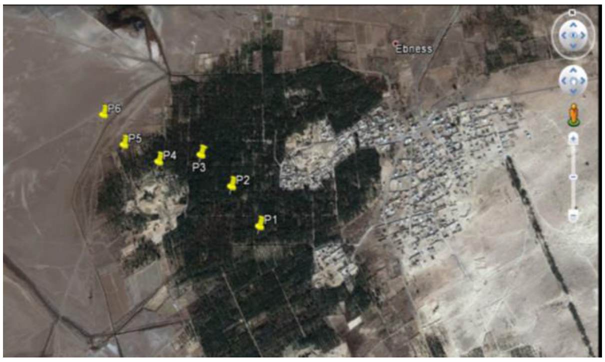

Fig. 2. The location of the sampling point (Google Earth, 2018)

The pH increases gradually as the content OM decreases (Allison, 1973), in the oasis Guettaya, generally, we note that the pH values change with the abundance of OC. Decreased OC is related to increasing pH throughout the profile. According to Pouget (1980) and Trachaud, (1994), the process of humification and mineralization of OM are governed, among others, by the presence of limestone in the soil. Calcium having a protective effect against microbial degradation. Stations that have lower values of $CaCO_3$, are those that have low values in OC (P2 ($CaCO_3$ between 2 and 3%) and P5 ($CaCO_3$ between 2 and 4%).

4.1. Spatial evolution of organic carbon

For P1, P3, P4 stations, P5, P6, the contents of OC are more abundant in the upper layer and they decrease with depth, except for the station P2, where the profile is in contrast to other stations.

The rate of OC is influenced by the physical properties of the soil; D_b and its texture. And it is higher in the surface layer (0-10cm) and below (Zhang and Shao., 2014).

Based on the results of obtained D_b, we note that it is low on the surface, showing plenty of OC in this layer, which is characterized by a smoother texture and depth. In the underlying lower layer, which is characterized by a coarser texture relative to the surface layer, we notice low OC relative to the surface layer.

At the P2, low levels of OC are recorded by reports P1, P3, P4 and P5, which are explained by the addition of a fertilizer (sandy contribution) under the palm tree. The decomposition of the OM is important in rich coarse soils that rich medium smooth texture (Pallo et al., 2009).

Table 1. Some analyzes carried out on the soils of the different profiles

Profile	Depth cm	Granulometry %					pH	EC mmho/cm	$CaCO_3$ %	Salinity g/l
		Coarse sand	Fine sand	Coarse silt	Fine silt	Clay				
P1	0-5	2	45	0	33	16	7.2	9.1	3	7.28
	5-15	2	43	0	40	12	7.7	4	3	2.8
	15-30	2	67	1	20	7	8.0	3.4	7	2.38
P2	0-5	13	42	0	34	8	7.7	8.2	3	6.56
	5-15	15	47	0	28	7	8.1	3.2	2	2.24
	15-30	15	48	0	25	8	7.9	5.6	2	3.92
P3	0-5	13	30	0	37	16	7.3	17.1	4	13.68
	5-15	15	42	0	27	12	7.5	7.3	7	5.11
	15-30	31	38	1	23	3	7.7	6.7	7	4.69
P4	0-5	22	44	1	26	4	6.2	16.6	5	13.28
	5-15	27	35	1	26	8	6.2	4	4	2.8
	15-30	22	41	0	27	6	6.6	4.2	3	2.94
P5	0-5	19	24	0	40	15	6.7	34	4	27.2
	5-15	26	23	0	31	16	6.7	15.4	2	12.32
	15-30	21	36	1	35	5	6.6	15.4	2	12.32
P6	0-5	NM	NM	NM	NM	NM	6.9	182.3	3	145.84
	5-15	NM	NM	NM	NM	NM	7.2	139.3	2	111.36
	15-30	NM	NM	NM	NM	NM	7.1	183.5	5	4.55

NM: Not measured.

In the P5, the OC exists in low levels compared to previous stations, because of the absence of organic feed, low refunds and salinity are very important at this station. The salinity there is between 12 32 and 27.2 g/l, which negatively affects the OC soil. Soil salinity reduces crop production, leading to the absence of litter, which reduces the input of soil carbon (Setia et al., 2012).

According to Kadri and Van Ranst (2002), texture evolves from a coarse upstream to downstream smooth texture, near Chott, hence the OM becomes larger downstream of the oasis, we upstream. In our study, there is no logic, the distribution of OC varies from one station to another because of different organic amendments and mineral intakes and the rate of decomposition of the OM. The amount and type of contribution influence OC soil concentration.

However, the presence of the OC in P6 station (at the Chott), even small amounts, is explained by the effect of the slope, where runoff OC accumulate in the lowermost region; the Chott Jerid.

Evaluation and evolution of the stock of organic carbon

Distribution of organic carbon stocks depending on the salinity of 6 stations in the layer (0-5cm). The levels of the stations P1, P3, P4 and P5, litter and vegetation refunds are very abundant, which explains the importance of the stock of OC.

Soil organic carbon stock

The histogram focused on Figure 1 shows the distribution of the carbon stock in the six profiles on the depth of 30 cm. At the same time, we have also shown the evolution of salinity.

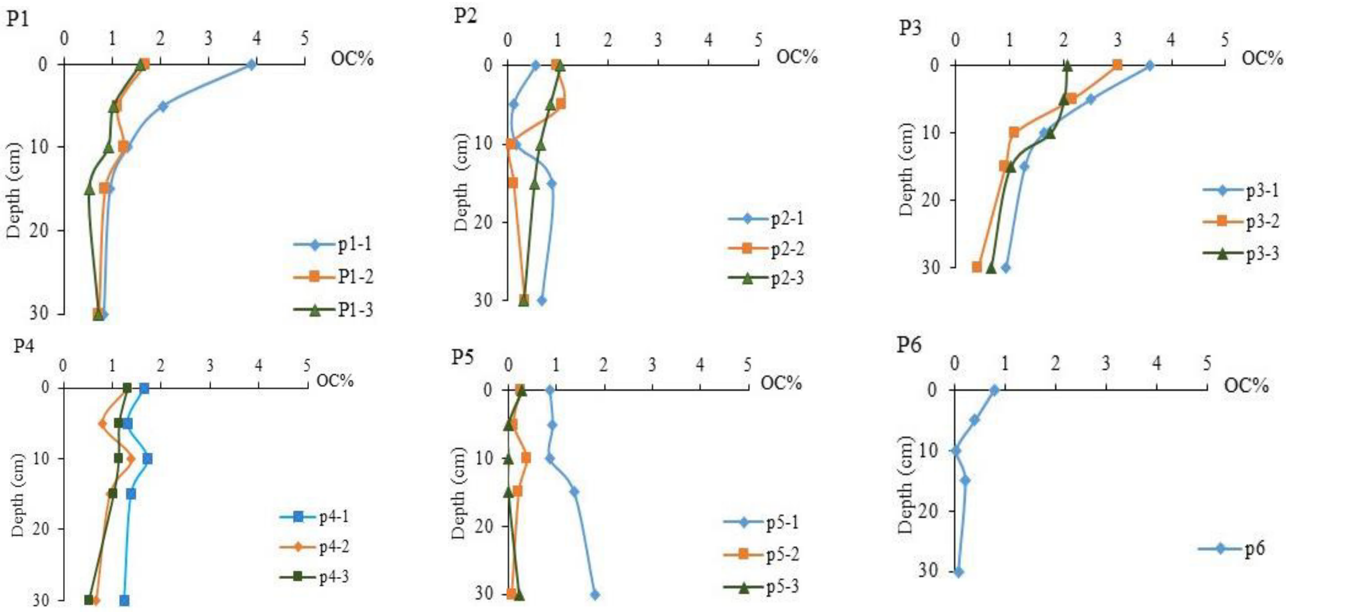

Fig. 3. The distribution of organic carbon in the six profiles.

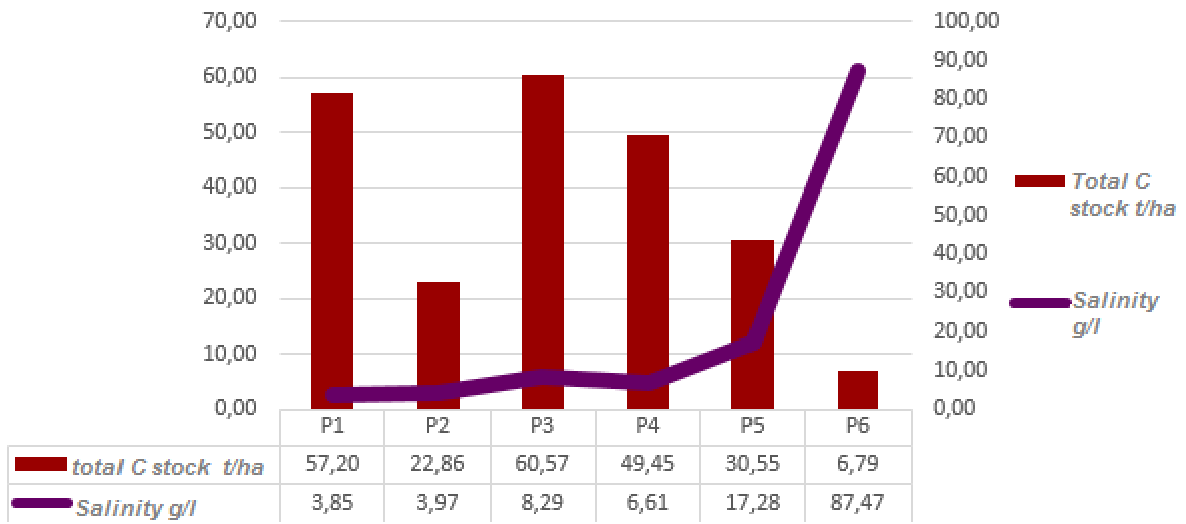

Fig. 4: The organic carbon stock and the evolution of salinity in the six profiles

Despite the fact that these soils are desert, the stock is relatively high in all the profiles. For P6 it is a holomorphic soil in full Chott. At the oasis, the highest stock is 60.57 t/ha, the lowest stock is 22.86 t/ha. At the level of the Chott the stock is much less low it is of the order of 6.79 t/ha. The stock appears to be dependent on two variables, that of organic addition and soil salinity.

The rate of organic carbon is influenced by the physical properties of the soil; bulk density (D_b) and its texture (Bernoux et al., 2002; Brahim et al., 2014), and it is higher in the surface layer (0-10cm) and below (Bernoux et al., 2002). The underlying layer is characterized by a coarser texture, we notice low organic carbon relative to the surface layer. Indeed, the decomposition of OM is important in soils with coarse texture (Gallali, 2004). Soil salinity reduces crop production, leading to the absence of litter, which reduces the input of organic matter (Bouajila et al., 2016; Gallali, 2004). More, salinity affects negatively on plants and therefore it tends to decrease the amount of litter resulting in the decrease in input organic carbon in soil (Gallali, 2004). At the oasis Guettaya, soil organic carbon stocks at the surface layers are very similar to stocks encountered in agricultural soils of the northern Tunisia (Chevallier et al., 2016; Brahim and Ibrahim, 2018). As a result, arid and desert soils could be carbon sinks if properly maintained and could contribute to the reduction of atmospheric greenhouse gases (Chevallier et al., 2016).

5. Conclusions

According to the obtained values of organic carbon, we recorded the highest values in the first 4 stations with the largest at the station P3. P5, the station which is the nearest to the Chott, the rate org C is very low. This may be related to low intake, see his absence, low plant refunds and salinity students very soil. The special was at the station P2, where we noticed that it is abundant in depth and surface and this may be due to the sandy contribution under the date palm in the first ten centimeters.

These variant organic carbon levels are controlled by the influence of the conditions of each station: the amount and type of contribution, soil salinity and texture. We found that the surface horizons have the highest concentrations in the OC depth horizons.

Comparing organic carbon values within the oasis and outside the P6 station, we noticed that it has the lowest rate with an average organic carbon, and this small amount comes by accumulation under the effect of the slope and halophilic vegetation that occupies.

As regards the stock in OC, we noticed that it varies from one station to another, with the largest stock that is recorded at the station P3 (57.7 t/ha) and the stock lowest at the station P2 (28.7 t/ha). The OC stock is influenced by the soil bulk density, texture and salinity.

By comparing the values of OC stock inside the oasis with the stock of the station outside the oasis, we concluded that oasis well store the OC. The Guettaya oasis stores an average of about 43 t/ha on the depth of 30cm, a value comparable to calcimagnesic soils (41.6 t C/ha) and vertisols (45 t C/ha) in the north (Brahim, 2011).

All these findings allow us to strengthen the capacity of arid soils sequester organic carbon, even with a small percentage. These areas can provide an idea of the capacity of soil to the contribution to sequestring global OC, while fighting against the desertification. In these particular areas and privileges, adding intake OM continuously, will strengthen the functioning of soils and improved their physical, chemical and biological, and fertility. It is important to measure the OM residence time in these soils by isotopic analyses to determine the time of renewal and residency of OC stock.

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References

Allison F.A. 1973. Soil organic matter and its role in crop production. Amsterdam: Edi. Elsevier, 634 p.

Bernoux M.; Carvalho M.D.S.; Volkoff B.; Cerri C.C. 2002. Brazils soil carbon stocks. Soil Sci. Soc. Am. J., 66, pp. 888-896.

Bouajila A., Brahim N., Gallali T. 2016. Rôle des différentes fractions organiques dans la stabilité structurale des sols à textures riches en sables du nord et du centre de la Tunisie. Etude et Gestion des Sols, 23, pp. 77-90.2016.

Brahim N., Ibrahim H. 2018. Effect of Land Use on Organic Carbon Distribution in a North African Region: Tunisia Case Study. In book: Soil Management and Climate Change, Effects on Organic Carbon, Nitrogen Dynamics, and Greenhouse Gas Emissions. Elsevier edition, Chapter 2 pp.15-24.

Brahim N., Gallali T., Bernoux M. 2014. Soil organic carbon stocks and its variation according by different land uses in Tunisia. International Journal of Research in Applied Sciences, 02, pp. 8-11.

Brahim N. 2011. Réchauffement climatique et vulnérabilité des sols méditerranéens: Spatialisation et séquestration du carbone en Tunisie. Thèse de doctorat en Géologie: Université de Tunis El Manar. 300 p.

Chevallier T., Hamdi S., Gallali T., Brahim N., Cardinael R., Bounaouara Z., Cournac L., Chenu C., Bernoux M. 2016. Soil carbon as an indicator of Mediterranean soil quality. In The Mediterranean Region Under Climate Change. Edition AllEnvi., pp. 627-636.

El Fekih M., Pouget M. 1969. Les sols des oasis anciennes du sud tunisien. Les sols méditerranéens. pp.11

Gallali T. 2004. Clés du sol. Centre de publication Universitaire. Tunis. pp.366

Gratzfeld J. 2004. Industries extractives dans les zones arides et semi-arides: planification et gestion de l'environnement. UICN, Gland, Suisse et Cambridge, Royaume-Uni. Viii +112 p.

Hachicha M. 2007. Les sols salés et leur mise en valeur en Tunisie. Science et changements planétaires / Sécheresse., 18, pp. 45-50

Kadri A., Van ranst E. 2002. Contraintes de la production oasienne et stratégies pour un développement durable. Cas des oasis de Nefzaoua (Sud tunisien). Science et changements planétaires / Sécheresse, 13, pp. 5-12.

Pallo F.J.P., Sawadogo N., Zombré N,P., Sedogo M.P. 2009. Statut de la matière organique des sols de la zone nord-soudanienne au Burkina Faso. BASE (en ligne), 13, pp. 139-142. URL : https://popups.uliege.be:443/1780-4507/index.php?id=3623

Pouget, M. 1980. Les relations sol- végétation dans les steppes sud Algéroises. Travaux et documents de l'ORSTOM. 116. Paris. 555 p.

Setia R., Gottschalk P., Smith P., Marschne P., Baldock J., Setia D., Smith J. 2012. Soil salinity decreases global soil organic carbon stocks. Science of the Total Environment, 465, pp. 267-272

Trachaud L. 1994. post fire plant community dynamics in the Mediterranean bassin. Univ. Moreno.The role of the fire in Mediterranean. Type ecosystems , pp. 1-15

Van-Camp L., Bujarrabal B., Gentile A.R., Jones R.J.A., Montanarella L., Olazabal C., Selvaradjou S.K. 2004. Reports of the Technical Working Groups Established under the Thematic Strategy for Soil Protection, EUR 21319 EN / 3, 872 p., Office for Official Publications of the European Communities, Luxembourg, 872 p.

Zhang P., Shao M. 2014. Spatial variability and stocks of soil organic carbon in the Gobi desert of northwestern China. PLoS ONE 9(4): e93584. https://doi.org/10.1371/journal.pone.0093584