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Research article

Distribution of organic carbon stocks in cambisol under two different crops in semi-arid Tunisian climate

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Abstract

The present study consists of an analysis of the organic matter content of the soil samples taken from two plots with different crops or a study site in north Tunisia, a first plot of which the soil is cultivated with Sorghum (Sorghum bicolor) and in the second plot, the soil is grown with parcel in cereal and market gardening. In the southern Mediterranean zone under semi-arid climate, the pressure of increased climate change induces a change in soil qualities and their potential for production. At the level of its zones, the study of the dynamics of Organic Matter and the associated carbon of soils is subject to certain constraints. In addition, there is the possibility of studying biological and/or abiotic phenomena that control the dynamics and stability of organic matter in soils. On the other hand, deep carbon turnover is particularly slow. The results show that under sorghum cultivation a good improvement of the organic stock is manifested by a high organic carbon content at the surface layer level 0-20 cm with 1.99% in comparison with the cereal plot, which has a maximum content of 0.97 %. Respectively, a clear improvement for bulk densities with 1.26 and 1.28 $g.cm^{-3}$. On the whole profile and 1 meter deep the stock under sorghum is significantly higher, it is of the order of 2.5 times, with a value of 117.47 t/ha against 45.23t/ha for soil under cereals.

Key words: Soil organic carbon, Cambisol, Carbon sequestration, Sorghum/cereals culture, Tunisia.

1. Introduction

Soil organic matter (SOM) defined as dead material coming mainly from plant residues and microorganisms that are present there, it is about the vegetal residues (fall of leaves, residues of culture, root exudates ...), of microorganisms and/or dead animals and undergoes degradation that leads to their mineralization. Its decomposition releases the basic nutrients for different soil organisms (Manlay *et al.*, 2007). It is therefore a source of nutrients for plants and microorganisms (Manlay *et al.*, 2007) and plays a major role in the fertility of agricultural land. It is poorly characterized at the molecular level (Gleixner *et al.*, 2001, Kögel-Knabner 2000) and is due to its complicated structure. However, thanks to the increasing use of new chemical analysis methods (mass spectrometry, spectroscopic methods, etc.), the knowledge of the chemical composition of SOM is improving (Gleixner *et al.*, 2001, Kögel-Knabner 1997, Naafs *et al.*, 2004, Nierop 2001). Some agricultural practices have the effect of mineralizing the SOM. In a system where crop residues returned to the soil, the root biomass contributes more to the SOM than the aerial parts, while the proportion of organic matter contained in the roots is lower. Than that of leaves and stems (Rasse *et al.*, 2005). In order to better, estimate the rate of accumulation of matter Organic distribution in a chronosequence Sorghum and chronosequence cereal and market gardening, indeed their degradation and/or stabilization mechanisms of soil organic matter may act differently depending on the nature of the soil organic matter provided to soils.

The objective of this work is to estimate the rate of accumulation of organic matter, organic carbon and bulk density distribution along two profile in Tunisian agricultural soil in two different cultures and to identify her soil organic carbon stocks after a period of 10 years.

2. Materials and methods

The experimental plots are located in the northern part of Tunisia in the northwestern region of Zaghouan governorate (36° 24’ 33’’ N and10°10’ 24’’E; altitude 140m, slope 0.8% (Figure 1).

The climate is semi-arid; it is characterized by an annual temperature of 18.9°C and precipitations of 416 mm (means 1980-2018).

Fig. 1. Geographical location of study site

We have chosen two adjacent parcels, each of two hectares in size, which have the same type of soil, according to the World Reference Base it was classified a Cambisol, on the same topography and since 10 years it differ only culture:

- First plot, soil A, culture of sorghum and maize.
- Second plot, soil B, culture of barley and hard wheat.

For each of the experimental plots, we dug a pit of one meter. For each of the two pits, we took five samples; it taken every 20 cm (0-20; 20-40; 40-60; 60-80 and 80-100cm) and three repetitions.

The description of a typical profile of our soil gives the following characteristics:

- Horizon A : 0-25 cm: Brown (10 YR 5/4). Lumpy structure, loam-clay texture. Presence of calcareous pebbles, presence of roots and rootlets moderately abundant, diffuse limit between horizons, strong effervescence with HCl.

- 25-60 cm: Dark brown (10 YR 3/3). Subangular polyhedral structure, loam-clay texture. Presence of limestone pebbles. Presence of roots and rootlets with low abundance. Limit between diffuse horizon, strong effervescence with HCl.

60-100 cm: Brown (7.5 YR 4/3). Subangular polyhedral structure. silty-clay texture. Presence of limestone pebbles. Low abundance of roots and rootlets. Diffuse boundary between horizons, strong effervescence with HCl.

Soil analysis, including organic carbon % measured of the soil in fraction < 2mm (Walkley-Black method), pH (pH-meter), soil bulk density (D_b) g.cm^{-3} (cylinder method), and granulometry % (Bernard calcimeter method).

Soil organic carbon stocks are estimated by the following equations (Brahim *et al.*, 2014):

$$\text{SOCstock} = \text{OC} \times D_b \times \text{D} \quad (1)$$

Where SOCstock represents soil organic carbon stock in t.ha^{-1}, OC the organic carbon content (%), D_b the bulk density (g .cm^{-3}) and D the sampling depth.

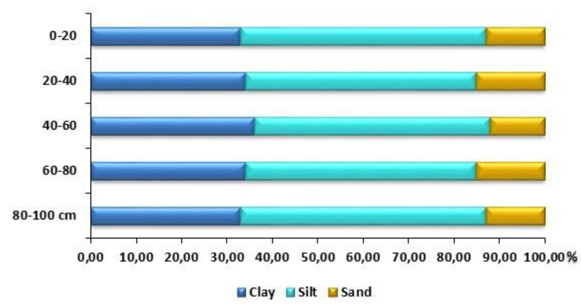
3. Results and discussion

As for the results, we will proceed to present it as comparisons between the different variables after 10 years of treatment of the two plots with the two different vegetation.

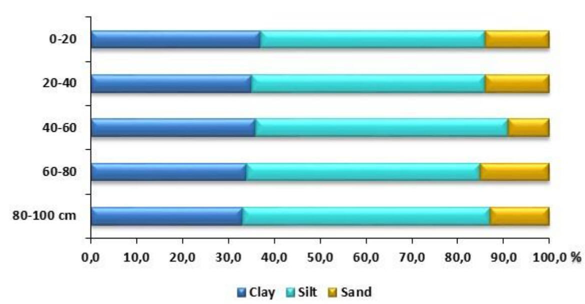
3.1. Evolution of the granulometric fraction

The soil has a loamy clay texture. According to the granulometric analyzes, nothing has changed.

The texture is the same under both vegetation’s; no variation is recorded in both soils A and B (Figure 2).



Soil A



Soil B

Fig. 2. Results of the granulometric analysis at the two soils

3.2. Study of the organic profile

3.2.1. Soil A

a) Content in the different fractions

Analyzes of organic carbon (OC) in the different soil layers at the level of the Soil A profile show that the organic carbon content decreases as a function of depth, and that the highest levels are at the level of the surface layers 0- 20 and 20-40 cm (Table 1 and Figure 3).

What is remarkable is that at the level of the different layers, the clays always have the highest levels in comparison with the contents of the two other fractions (sand and silt). In ascending order, the clays are the first that contain more organic carbon, the sands second and the silts have the lowest levels. In general, this content decreases with depth (Figure 4).

The clays of the 20-40cm layer have a content of 2.36% of organic carbon, which exceeds that of the 0-20cm surface layer (1.99%) this is explained by the very high temperatures and the direct contact with the atmosphere which accelerates the mineralization on the one hand, and on the other hand, by the effect of irrigation which is of the order of 2000 mm and which favors the leaching and the migration of the organic matter towards the deep layers especially since the soil texture shows very good porosity.

In general, the organic matter (OM) at the Soil A profile is very high, it is of the order of 5.06% at the level of the layer 0-20 cm and 7.42% at the level of the layer 20.40 cm. It decreases in depth to reach 2.21% at the 80-100 cm layer. These levels show very well the effect of human activity.

Table 1. Result of organic carbon and total nitrogen analyzes in Soil A.

Profile	Depth (cm)	OC%	OM%	N%	OC/N	D_b g.cm^{-3}
Soil A	0-20	0.72	1.24	0.14	5.15	1.27
		0.23	0.39	0.12	1.92	1.30
		1.99	3.43	0.25	7.96	1.26
	20-40	0.96	1.66	0.14	6.86	1.28
		0.98	1.69	0.15	6.54	1.28
		2.36	4.07	0.29	8.14	1.27
	40-60	1.04	1.79	0.15	6.94	1.33
		0.32	0.55	0.08	4.00	1.35
		1.57	2.71	0.13	12.08	1.41
	60-80	0.36	0.63	0.07	5.14	1.42
		0.88	1.52	0.11	8.00	1.44
		0.45	0.78	0.04	11.25	1.47
	80-100	0.16	0.28	0.01	16.00	1.53
		0.08	0.14	0.01	8.00	1,51
		1.04	1.79	0.06	17.34	1,49

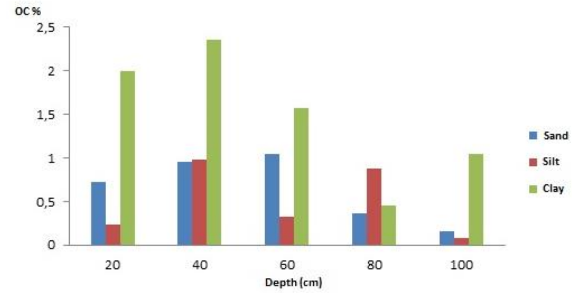


Fig. 3. OC content in the various fractions in the different layers of the Soil A profile

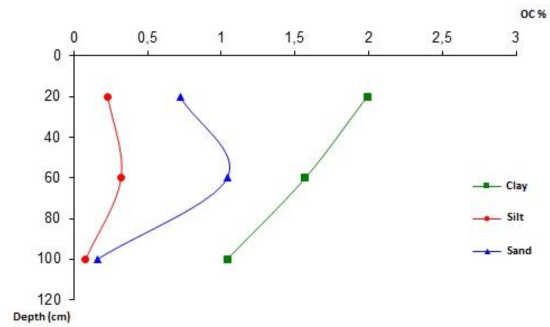


Fig. 4. Variation of organic carbon rate as a function of the depth at the Soil A profile

b) Soil A: Total nitrogen (N) content in the different fractions

Generally, the total nitrogen contents show almost the same variations as the organic carbon in the Soil A profile, with a slight difference between the clay and sand contents, where the sands in the deep layers show a slight rise compared to clays (Table 1 and Figure 5). Roughly, clays have the highest levels, followed by sands and silts.

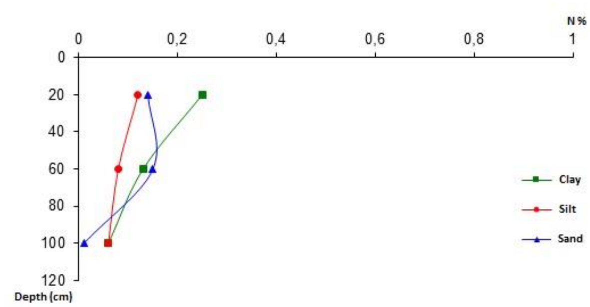


Fig. 5. Variation of the total nitrogen contents at the layers of the Soil A profile

c) Soil A. The variation of the OC/N ratio in the different fractions

Nitrogen plays a major role in microbial activity, translated by the C/N ratio, which gives us information on the rate of biodegradation of soil organic matter. The lower the C/N ratio, the faster the decomposition of organic matter, and consequently the loss of organic carbon by mineralization.

The C/N ratio also intervenes insofar as it directs the decomposition of soil organic matter, either towards low C/N mineralization or towards high C/N humification (Gallali 2004).

The organic carbon/nitrogen ratio shows three scenarios:
• C/N <8: Rapid decomposition of the OM.
• C/N: 8-12: Average decomposition of OM.
• C/N> 12: Slow decomposition of OM.

In our case, for the Soil A profile, we calculated the C/N ratio for the three layers: 0-20cm surface, average 40-60cm and the deepest 80-100cm. Figure 6 below shows their pace.

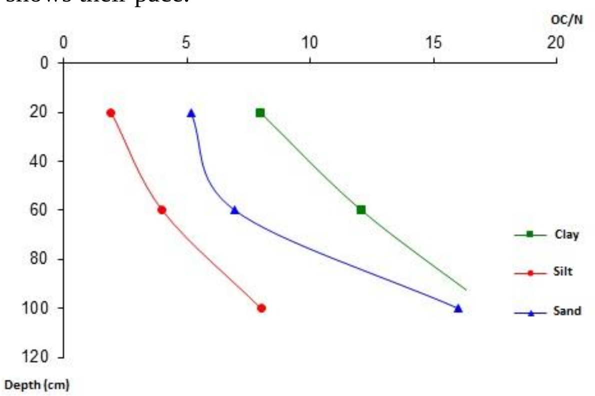


Fig. 6. Variation of the OC/N ratio of the layers of the Soil A profile

The OC/N ratio is very low at the level of the surface layers (<8), which proves a very rapid mineralization of the organic matter and which also explains the low contents of organic matter and organic carbon at the level of the layer surface area 0-20 cm.

The OC/N ratio is higher at the deep layers where values are close to 15, degradation of organic matter is slow.

3.2.2. Soil B

a) OC content in the different fractions

Analyzes of organic carbon in the different soil layers at the Sol B profile show that the organic carbon content decreases with depth, and that the highest levels are at the surface layers 0-20 and 20-40 cm (Table 2 and Figure 7).

The two 0-20 and 20-40 cm surface layers show that the clays always have the highest levels in comparison with the contents of the other two fractions (sand and silt). On the other hand, at the deepest layers, usually silts have the highest levels (Figure 8).

In comparison with Sol A, it is noted that the contents of organic carbon and organic matter are lower. This is explained by two things (i) the profile does not receive the same organic restitution received from the vegetation (Brahim and Ibrahim, 2018).

Table 2. Result of organic carbon and total nitrogen analyzes in Soil B

Profile	Depth (cm)	OC%	OM%	N%	OC/N	D_b
Soil B	0-20	0.61	1.05	0.13	0.61	1.28
		0.54	0.94	0.12	0.54	1.31
		0.98	1.69	0.15	0.98	1.28
	20-40	0.24	0.41	0.03	0.24	1.32
		0.11	0.19	0.01	0.11	1.31
		0.41	0.70	0.04	0.41	1.29
	40-60	0.11	0.19	0.02	0.11	1.36
		0.46	0.55	0.04	0.46	1.33
		0.35	2.71	0.03	0.35	1.47
	60-80	0.17	0.63	0.02	0.17	1.44
		0.14	1.52	0.02	0.14	1.44
		0.19	0.78	0.01	0.19	1.46
	80-100	0.23	0.28	0.02	0.23	1.47
		0.31	0.14	0.03	0.31	1,44
		0.15	1.79	0.01	0.15	1,53

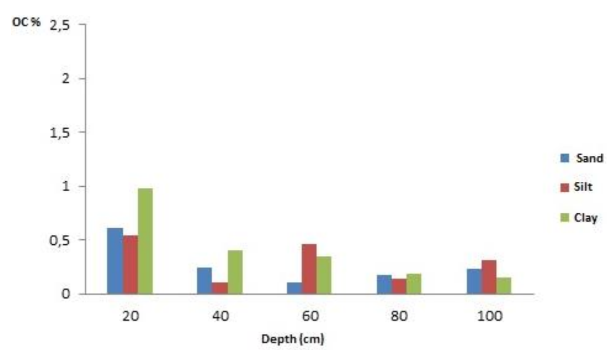


Fig. 7. OC content in the various fractions in the different layers of the Soil B profile

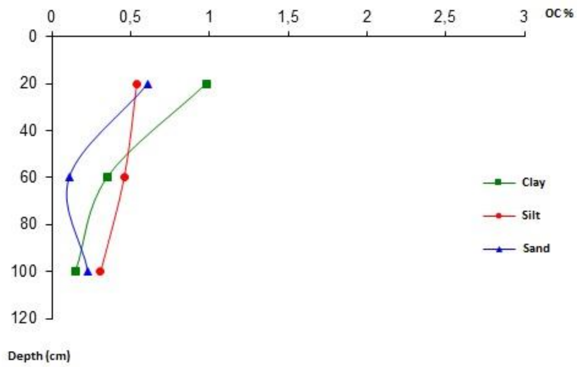


Fig. 8. Variation of the OC% rate as a function of the depth at the Soil B profile.

b) Soil A: Total nitrogen (N) content in the different fractions

The total nitrogen contents show almost the same variations under the different fractions of clay, silt and sand. Nitrogen is higher at the surface layers and decreases with depth.

The clay fraction is richer in total nitrogen than the other two silt and sand in the 0-20 cm level; however, at the very deep layers (80-100 cm), the silty fraction becomes the richest nitrogen fraction compared to the other two fractions (Figure 9).

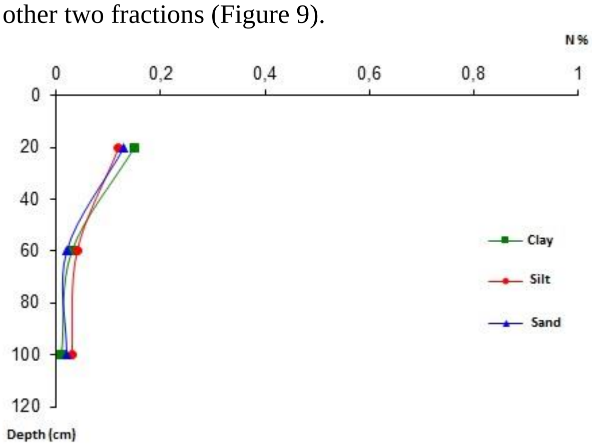


Fig. 9. Change in total nitrogen content at the Soil B profile layers

c) Soil B. The variation of the OC/N ratio in the different fractions

For the Soil B profile, we calculated the OC/N ratio for the three layers: 0-20 cm, average 40-60 cm and the deepest 80-100 cm. Figure 10 below shows their different speeds.

The OC/N ratio is very low at the level of the surface layers (<8), which proves a very rapid mineralization of the organic matter.

At the intermediate layer 40-60 cm, the ratio is of the order of 10 is that the decomposition is average. At the level of the deep layers which are close to one meter deep, the decomposition is very slow, thus a conservation of the organic matter.

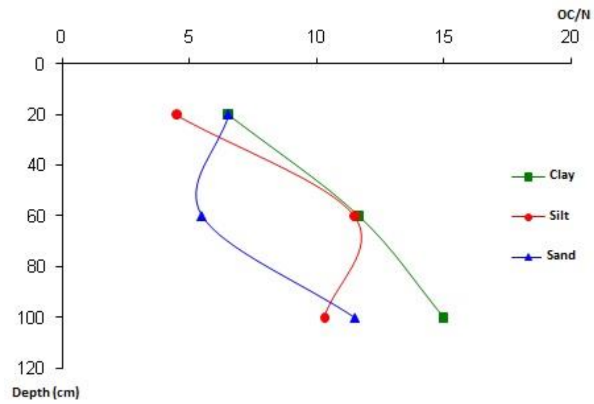


Fig. 10. Variation of the OC/N ratio of the layers of the Soil B profile

3.3. Comparison of the two profiles of Soil A and Soil B

The two plots of both soils have the same morphology with the difference in the mode of use. Our two profiles of Sol A and Sol B were chosen on this basis. From a grain-size point of view, the two soils are similar.

With regard to the organic profile, organic carbon, organic matter and total nitrogen, according to the two profiles, the organic matter, the Sol A is richer than the Sol B. In general, the organic matter is more concentrated in them surface layers only in the deep layers.

At the level of these layers, the fine fraction which is the clay fraction is always the richest in organic matter than the other coarse fractions of silt and sand. At P1 and P2, the deep layers contain organic matter. The OC/N ratios show high depth layer values (> 60 cm). This explains their weak decomposition by lack of oxygen and their sequestration in the clay sheets.

Under both vegetation bulk density (D_b) values are relatively low at the surface and increase with depth. The two extreme values for Soil A are 1.26 g.cm^{-3} at the layer 0-20cm and 1.53 g.cm^{-3} for of 80-100cm depth, and for Soil B 1.28 g.cm^{-3} for 0-20 cm layer and 1.53 g.cm^{-3} for the deep layer 80-100cm.

3.4. Soil organic carbon stock under two profiles of Soil A and Soil B

For the calculation of organic carbon stocks, we used the average of the three measurements made for OC contents and D_b.

Table 3 display different results of the stock. Figure 11 shows the very clear difference of stocks in each layer. Comparing the stock in each layer, we note that soil A is richer in organic carbon than soil B in all layers up to the depth of 1 m. The difference in total is very clear, 117.47 $t.ha^{-1}$ for soil A against 45.23 $t.ha^{-1}$ for soil B. In 10 years, Soil A has grown with 72.24 $t.ha^{-1}$ the equivalent of 7.22 $t.ha^{-1}.year^{-1}$.

Table 3. Organic carbon stock in both soils

Depth (cm)	Soil OC stock (t/ha)	
	Soil A	Soil B
0-20	25.09	18.32
20-40	36.61	6.55
40-60	26.66	8.62
60-80	16.13	4.93
80-100	12.98	6.81
Total	117.47	45.23

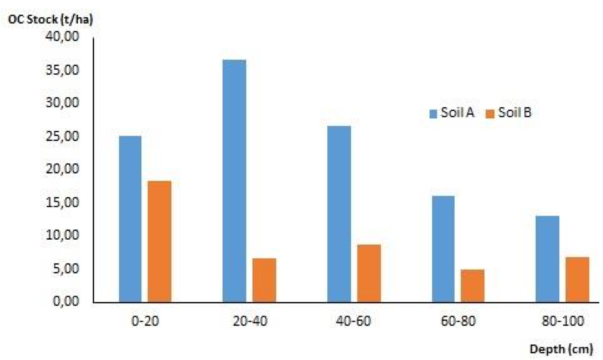


Fig. 11. Evolution of carbon stocks per layer under both soils

The type of vegetation influences the organic matter content in agricultural soils; the latter has a positive effect in improving the porosity of soils, hence the decrease in the values of surface apparent densities in comparison with the values of the deep layers. Parcel A under sorghum benefits from an abundant supply of organic restitution and a more abundant root system in comparison with that of wheat in plot B. This result is concretely observed on the carbon stock in the two corresponding soils A and B.

According to the FAO classification, our soils are Cambisols. Comparing our results with the results of Brahim *et al.*, (2014) where they made an average stock for each soil type in Tunisia; for Cambisol they calculate 41.60 t/ha on 0-30cm and 101.80 t/ha on 0-100cm, their values very close to our results for the Soil A, however, our results for Soil B are very low.

Our results for soil A corroborate with those estimated by Batjes (1996) where he showed that Cambisols had average stocks of the order of 50 t/ha to a depth of 30cm and 96 t/h at one meter of depth. But, for the soil B of the wheat plot, soil OC stock is lower than the world averages from Cambisols, which requires intervention to correct this lack of organic stock.

4. Conclusion

The mode of agriculture and especially the choice of vegetation influence the organic matter content, if there is improvement, the bulk density decreases.

In our soil, after 10 years of following the effect of two types of vegetation, although the grain size is the same, the slope is the same, the climate is the same, the effect of sorghum on the improvement of the organic carbon stock in Cambisol is very clear compared to wheat. Moreover, the stock of organic carbon has even exceeded national and international standards in this type of soil.

Acknowledgment

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