GLOBAL SYMPOSIUM ON SOIL ORGANIC CARBON, Rome, Italy, 21-23 March 2017

Mapping of Soil Organic Carbon Stock in the Arab Countries

Darwish, T. and Fadel[1], A.*

[1]National Council for Scientific Research, Beirut. Lebanon P.O. Box: 8281
*Corresponding author: tlldarwish@gmail.com

Abstract
Soil organic matter is a key soil component and plays a critical role in ecosystem functions including soil productivity and resilience to erosion and drought. Most Arab countries are located in semi-arid and arid areas with dominance of drylands soils with poor organic matter content and soil quality. Soil organic carbon (OC) stock in the Arab countries was assessed and mapped using the FAO-UNESCO Digital Soil Map of the World (DSMW). Results were compared with one national large scale OC mapping. They showed low OC stock in the topsoil of more than 69% of the cultivated soils with dominance of Xerosols, Arenosols and Lithosols. The average soil OC stock in the Arab countries is 37±36 ton/ha in the topsoil and 78±69 ton/ha in the standard soil depth. The total OC stock in the arable lands of the Arab countries was estimated at 50 Billion tons with Sudan, Saudi Arabia and Algeria placed on top. The average total OC stock per one Arab country is 0.8 ±1.7 million tons. With increased pressure on limited soil resources, policies must address C sequestration to support soil productivity and improve food production.

Keywords: C sequestration, landuse impact, climate change, drought tolerance.

Introduction, scope and main objectives
Soils are at the core of the terrestrial ecosystem. Long time interaction and carbon sequestration lead to soil organic carbon (OC) stocks nearly three times larger than stocks in the vegetation ecosystems (Post et al., 1990) and twice larger than stocks in the atmosphere (Eswaran et al., 1993). Accurately quantifying SOC stores in soils and monitoring their changes are considered essential to global climate change modeling (Janzen, 2004) and to assessing the state of land degradation.
The Arab countries are spread around the east and north Mediterranean Sea and Arabic peninsula thus they receive the direct impact of arid climate dominating in the surrounding Sahara. Mismanagement disrupts the equilibrium of inherited characteristics of a given soil type, cumulatively built under prevailing land cover and climate (Bhogal et al. 2008). Ploughing and landuse change cause a rapid loss of SOC (Guo and Gifford, 2002). Appropriate soil management and even land abandonment may enhance the soil carbon pool (Atallah et al., 2015; Boukhoudoud et al., 2016). Mapping and quantifying SOC contents and distributions in the Arab countries using available soil data is crucial to assess the nature and potential of available soil resources. Thus, the purpose of this work was to assess and map the soil OC stock at the Arab and national levels to enhance C sequestration.

Material and Methods

Soil OC density was linked to each soil unit and corresponding map to produce soil OC stock and distribution maps in twenty two Arabic States using the digital soil map of the world (DSMW) and its attribute database at 1:5 Million scale (FAO, 2003). Arc Map 10.1 was used for the mapping. The calculation of OC stock in the upper topsoil (0.3m) and subsoil (0.3-1.0m) was done using the following equation:

OC Stock (ton) = [Soil Area (m^2)*Soil Depth (m)*Bulk Density*$OC_{content}$ (%)]/100 equation 1

The OC Content ton ha^{-1} was calculated following the equation:

OC Content ton ha^{-1} = OC Stock/Soil Area (ha) equation 2

Results

A total of 17 major soil groups and 66 soil units were identified for the Arab countries. The identified major soil groups are Yermosols, Lithosols, Regosols, Arenosols, Xerosols, Cambisols, Fluvisols, Luvisols, Solonchaks, Solonets, Andosols, Vertisols, Ferralsols, Gleysols, Kastanazems and Anthrosols. The total area of the arable soils in the Arab region is 11.6 Million SQM (Table 1). The most abundant major soil group is Yermosols with an area of 5.1 million SQM. The second most abundant major soil group in the Arab countries is Lithosols followed by Regosols having 2.3 and 1.05 million SQM respectively. Arenosols and Xerosols have almost equal area of 0.7 million SQM. Ferralsols, Andosols, Kastanozems and Gelysols are the most enriched with OC stock varying from 69 to 232 ton ha^{-1} (Figure 1, Table 1).

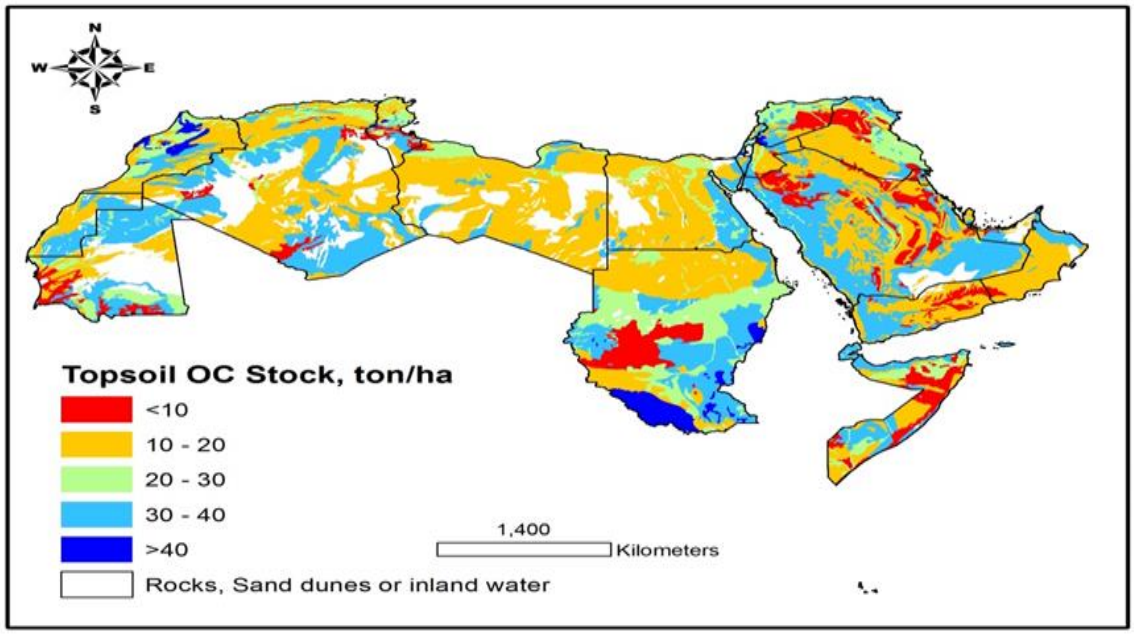

Figure 1. Spatial distribution of OC stock in topsoil (0.3 m) of the Arab countries calculated from the soil information from the DSMW, FAO, 2003

C enrichment of major soil groups is preconditioned by climate and geographic conditions favoring denser and richer vegetation cover and native fertility. Fluvisols, Cambisols, Phaezems, occupy intermediate place in OC stock ranging between 43-95 ton ha^{-1} and 56-114 ton ha^{-1} for the topsoil and entire soil respectively. These soils are affected by their nature, origin of sediments and agricultural practices. The spatial distribution of soil OC in the Arab countries shows relatively high values in topsoil for the soils developed from Mollic type accumulation of soil material, which is positively affected by the geographic, vegetation and climatic conditions, notably Gleysols, Kastanazems and Phaeozems (Figure 1).

The assessment of the total soil OC stock in the entire soil profile to a depth of 1m in the Arab countries revealed the dominance of soils with poor and moderate OC enrichment with more than 83% of the of cultivated soil area containing less than 60 ton ha^{-1} of total OC stock. These soils are in general Lithosols, Arenosols, Regosols, Solanchcks, saline, sodic and gypsic soil units as well as rocky and stony versions of Yermasols and Xerosols with few representatives of Luvisols, Cambisols and Fluvisols. At the national level, the lowest OC stock was observed in the Gulf countries, i.e., Kuwait, UAE, Oman, Bahrain, Saudi Arabia, Yemen and Somalia with a content varying between 11 tons ha^{-1} and 57 tons ha^{-1} in the topsoil and entire soil profile respectively.

Four Arab countries are placed on top concerning C sequestration and build up in the soil. These are Lebanon, Morocco, Sudan and Comoros Islands with a soil OC stock varying between 30 ton ha^{-1} and 92 ton ha^{-1} in the topsoil and entire soil respectively. The geographic location and pedoclimatic conditions favor higher C sequestration in these countries despite the observed risk of soil water erosion.

Table 1. Organic carbon stock in the soils of the Arab countries

Country	Area of Arable lands, SQM	OC stock topsoil tons	OC stock subsoil tons	Total OC Stock tons	OC content topsoil, ton ha^{-1}	OC content subsoil , ton ha^{-1}	OC content 1m, ton ha^{-1}
Algeria	1741562	4,257,645,624	6,319,312,381	10,576,958,005	22.06	30.46	52.52
Bahrain	571	668,070	1,119,160	1,787,230	11.70	19.60	31.30
Comoros	1618	7,460,439	9,011,653	16,472,092	44.55	47.73	92.28
Djibouti	21851	77,058,474	115,526,859	192,585,333	27.92	37.11	65.03
Egypt	842087	1,625,889,954	2,423,066,569	4,048,956,523	23.58	32.20	55.78
Gaza	324	1,108,080	1,394,820	2,502,900	34.2	43.05	77.25
Iraq	431447	761,792,829	1,118,616,632	1,880,409,461	23.01	31.98	54.99
Jordan	89357	170,855,847	263,266,045	434,121,892	22.89	34.58	57.47
Kuwait	17410	28,569,330	31,361,050	59,930,380	18.05	25.77	43.82
Lebanon	10302	29,840,676	42,845,404	72,686,080	30.91	44.78	75.70
Lybia	1246767	2,050,368,240	3,130,508,465	5,180,876,705	24.27	34.50	58.77
mauritania	725140	1,845,098,922	2,846,361,539	4,691,460,461	26.55	38.56	65.10
Morocco	406472.5	1,131,025,853	1,584,351,976	2,715,377,828	29.55	40.17	69.72
Oman	302370	471,041,643	761,251,477	1,232,293,120	16.33	25.13	41.46
Qatar	11384	21,423,936	31,977,575	53,401,511	28.19	40.36	68.55
Saudi Arabia	1852910	4,246,786,230	6,141,018,261	10,387,804,491	20.41	30.09	50.50
Somalia	635989.5	1,251,717,333	1,919,830,644	3,171,547,977	23.19	33.65	56.84
Sudan	2456235.5	6,363,846,111	7,431,089,785	13,794,935,896	35.13	43.45	78.58
Syria	187462	427,844,685	630,335,048	1,058,179,733	27.58	39.77	67.34
Tunisia	137483.5	315,546,645	436,483,614	752,030,259	23.50	31.43	54.92
UAE	50690	125,579,628	170,510,830	296,090,458	19.96	30.07	50.03
Yemen	414580	814,658,622	1,273,523,083	2,088,181,705	20.26	29.35	49.61
Total/average*	11584013	26,025,827,171	36,682,762,869	62,708,590,039	25.17	34.72	59.89

Sudan, Alegria and Saudi Arabia represent the Arab countries with the richest stock in total soil OC among the twenty two Arab countries with a total stock varying between 14 billion tons and 10 billion tons respectively. Lybia, Mauritania, Egypt, Somalia and Morocco represent the intermediate group among Arab countries with a total OC stock ranging in decreasing order between 5 billion tons and 2.7

billion tons respectively. Gulf countries represent the lowest total OC stock reaching as low as 53 thousand tons in Qatar.

Discussion

Yermosols, Arenosols, Lithosols and. Xerosols soil groups contain the lower C stock varying between 12-30 ton ha^{-1} and 19-40 ton ha^{-1} respectively. Long history of water and wind erosion affect the productivity of these soil groups, thus they require anti-erosion measures. The dominant part of the Arab countries represent semi-arid to arid climate with rare wetlands and Ustic or Udic soil moisture regime. That is why 69% of the area of the cultivated soils has low OC stock below 30 ton ha^{-1}, considered by Batjes and Sombroek (1997) as threshold for poor soil OC content. These soils belong to the arid soils groups like Arenosols, Xerosols, Yermosols, Solanchaks and Solonetz. This is in agreement with the findings of Minasny et al., (2017). Poor soil quality and the need to produce more food for increased population justifies good soil management and conservation notably crop rotation, application of manure and compost to improve C sequestration and hasten background soil productivity and resilience to drought. Similar good practices resulted in the improvement of C content in the soil after the sowing of legumes between the fruit trees (Darwish et al., 2012) and following the application of composted material including treated sludge (Atallah et al., 2012). Due to their large geographic distribution, Yermosols, Lithosols and Regosols represent the major soil groups with the highest total OC stock reaching 19 billion tons, 9 billion tons and 7 billion tons respectively. Despite the high OC content in the soil, Gelysols, Fluvisols and Cambisols represent low total OC stock due to their restricted area. Despite their frequent occurrence, Arenosols and Xerosols represent the lowest OC storage.

To test the precision of the used soil database, a comparison between the identified major soil groups in large scale soil information at 1:50,000 scale (Darwish et al., 2009) and in small scale soil information derived from the DSMW (1:5 Million) was made. A significantly different number of identified major soil groups of 13 and 5 was found in the first and second soil classification respectively. Topsoil OC stock in Lebanon was 38,047.122 tons, in the first study, compared to 42,845,404 tons representing 11% overestimation in the FAO soil database. The fact that the average values of OC accumulation in the topsoil of the Arab countries shows large standard deviation (100-300) points to the human effect on soil quality through different management systems, practices and land use in the most cultivated lands (Luvisols, Cambisols and Fluvisols).

Conclusions

Estimation of soil OC stock in the Arab countries using the small scale soil database of the DSMW showed acceptable results for the regional assessment. Alarming figures regarding the low OC stock were found in more than 80% of the area of the studied soil groups. Poor soil quality can affect soil productivity and resilience to drought and erosion. Enormous standard variation values of soil OC stock within the major soil groups were found in intensively managed arable soils indicating human pressure and impact on CO_2 emission. In the frame of week awareness on the role of OC in soil and ecosystem functions, attention must be paid to awareness rising to improve policies and practices oriented to increase C sequestration and meet the sustainable development goals.

Acknowledgement

Part of this work was extracted from a background paper on land degradation prepared for ESCWA.

References

Atallah T., K. Sitt, E. El Asmar, S. Bitar, L. Ibrahim, M. N. Khatib, and T. Darwish. 2015. Effect of abandonment of olive orchards on soil organic carbon sequestration in Mediterranean Lebanon. Soil Research, 2015, 53, 745–752 http://dx.doi.org/10.1071/SR14170.

Bhogal, A., Chambers, B. J., Whitmore, A. P., and Powlson, D. S., (2008) "The Effects of Reduced Tillage Practices and Organic Material Additions on the Carbon Content of Arable Soils" Summary

Report for DEFRA Project SP0561, Department for Environment, Food and Rural Affairs, London, United Kingdom.
Boukhoudoud N., Gros, R., Darwish T., Farner Da Silva, A.M. 2016. Agriculture practice and coastal constraint effects on microbial functional properties of soil in Mediterranean olive orchards. European Journal of Soil Science. DOI: 10.1111/ejss.1234. July 2016, 67: 470-477.
Darwish, T. Abou Daher, M., Jomaa, I, and Atallah, T. (2009). Soil organic carbon stock estimation in Lebanese territories. 10th International Meeting on Soils with Mediterranean Type of Climate. CNRS-Lebanon, Book of Extended Abstracts 113-118.
Darwish, T.M., Jomaa, I., Atallah, T., Hajj S., Shaban, A., Zougheib, R., and Sibai Ouayda F. 2012. An agropastoral system as a practice to enhance organic matter in Lebanese inland mountainous soils. Lebanese science journal, vol. 13, No. 1: 1-14.
Eswaran, H., E.V. Van Den Berg, and P. Reich. 1993. Organic carbon in soils of the world. Soil Sci. Soc. Am. J. 57:192–194.
FAO, 2003. The Digital Soil Map of the World. Food and Agriculture Organization of the United Nations. Version 3.6, completed January 2003.
Guo L-J, Lin S, Liu T-Q, Cao C-G, Li C-F (2016) Effects of Conservation Tillage on Topsoil Microbial Metabolic Characteristics and Organic Carbon within Aggregates under a Rice (Oryza sativa L.) –Wheat (Triticum aestivum L.) Cropping System in Central China. PLoS ONE 11(1): e0146145. doi:10.1371/journal.pone.014614
Janzen, H.H. 2004. Carbon cycling in earth systems-a soil science perspective. Agric. Ecosyst. Environ. 104:399–417.
Minasny, Budiman et al., 2017. Soil carbon 4 per mille. Geoderma, 292 (2017) 59–86
Post, W.M., T.H. Peng, and W.R. Emanuel. 1990. The global carbon cycle. Am. Sci. 78:310–326.