EVALUATION OF TOPSOIL QUALITY AND ORGANIC CARBON CONTENT IN DIFFERENT LAND USE TYPES – NORTHEASTERN PART OF ALGERIA

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Abstract. Assessing soil quality and soil organic matter plays a crucial role in the carbon sequestration. This study examined the influence of land use practices on key soil properties in the Northeast region of Algeria. The texture, bulk density, soil moisture, pH, electrical conductivity (EC), equivalent calcium carbonate ($CaCO_3$), soil organic matter (SOM), and soil organic carbon (SOC) were analyzed. Soil samples were collected from the 0-5 cm across land use types: cropland, agroforestry, fruit orchard, pastoral land, and urban land. The results highlight variations in soil properties and show a significant increase in carbon stocks in the agroforestry system. The soil textures were clay and sandy loam, while bulk density varied from 1.3 to 1.6 Mg/m^3. Soil moisture content was moderate. pH values ranged from slightly alkaline to alkaline. $CaCO_3$ contents were moderate to high as well as the EC content. The greater storage of SOC was found at sites with the highest plant diversity, under agroforestry (23.10 t ha^{-1}) and pastoral land (19.98 t ha^{-1}). Moreover, urban areas exhibited the lowest SOM and SOC contents. This research underscores the significant impact of land use practices on soil properties in the region, particularly those related to urban and agricultural uses.

Keywords: *soil organic matter, land use, agroforestry, bulk density, soil organic carbon, urban land*

Introduction

Climate change and food insecurity are major issues for the 21st century. The fact that around 815 million people suffer from malnutrition severely undermines the Sustainable

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Development Goal of ending starvation by 2030 (Richardson et al., 2018; Raza et al., 2019). Furthermore, a large number of human activities are impacted by climate change, particularly those related to agriculture and forestry (Torquebiau, 2017). Changes in land use and land cover lead to alterations in soil physico-chemical properties, resulting decreases in soil organic matter (SOM) and nutrients (Matano et al., 2015), with critical effects on environmental health and food production.

According to Tellen and Yerima (2018), changing land use from savanna to natural forests has direct impact on several physico-chemical properties such as bulk density, electrical conductivity, pH, soil texture, and soil moisture. Previous studies found that the conversion of natural forest to cultivated land led to a significant reduction of SOM (Bounouara, 2018). The changes in land use and land cover (LULC), such as the conversion of woodlands to cultivated land, affect the soil bulk density, carbon, nitrogen, and C/N ratio due to the effect of tillage practice (Yang et al., 2020). Other factors, such as biomass consuming, shifting cultivation and erosion cause a decline in the soil organic carbon (SOC) and nutrient in the soil surface as results of the reduction of natural vegetation (Samota et al., 2024). Intensive land utilization for construction, grazing, or cultivation leads to soil degradation via the elimination of native plant communities and the resultant disturbance of the soil profile (Benslama et al., 2024).

Moreover, natural causes can influence land degradation, such as the slope and the soil's sensitivity to deflation and water erosion, forest fire, landslides, floods and drought, though these causes can be directly or indirectly impacted by human activity (Mahata and Sharma, 2021). Soil degradation and land use change are interrelated and significantly affect our environment, food security, and sustainability (Samota et al., 2024). Soil degradation can be simply defined as physical, chemical, and biological deterioration of the soil including loss of organic matter, and unfavorable variations in salinity, acidity and alkalinity that result in the reduction of the soil fertility (Alam, 2014). Therefore, examining LULC change is essential to assess the interaction between humans and their environment (Bardadi et al., 2021). In addition, the sustainable use of natural resources, including grasslands, forests, and croplands is essential to maintain the health of these ecosystems (Duman, 2023). Even more, the land management sector is crucial for lowering greenhouse gas emissions by sequestering carbon as organic matter in the soil via photosynthesis (Torquebiau, 2017). These findings emphasize on the important contributions of the SOC to achieve objectives for sustainable development that enhance the soil fertility and food production, adaptation of climate change, and the improvement of water availability and plant nutrition (Lefèvre, 2017).

Gualberto et al. (2023) found that the soil surface plays a key role in the mechanisms influencing soil productivity and environmental quality. Increasing the SOC in topsoil is a relevant aspect of the soil quality (Tedone et al., 2023). Furthermore, the upper topsoil, is the most dynamic section of the soil that interacts with the environmental factors such air or rainwater and is the main way to incorporate organic matter into the soil profile. Therefore, the information of SOC or SOM composition in this part is useful for determining effective strategies to improve land management practices and increase SOM storage. Soils supporting a greater variety of vegetation, can increase SOM and SOC, while improving soil biodiversity (Laban et al., 2018). Moreover, maintaining the quality and quantity of SOM is crucial for ensuring long-term soil fertility (Zhao et al., 2015).

In the Mediterranean basin, the soil processes are governed by a unique convergence of highly different natural factors such as: climate, relief, parent material, and considerable historic human activity (Lagacherie et al., 2018). Several studies confirm that Mediterranean soils are impacted by different forms of physical, chemical, and biological degradation (Piccini et al., 2023). Under the climate change affection, this region has been identified as a major hotspot for drought risk and these effects are going to be more negative for agriculture (Aguilera et al., 2020). According to Aguilera et al. (2020), most of those soils exhibit low to very low SOM content which has not been consciously managed to store or sequester carbon. Furthermore, the climatic conditions become more extreme in the area (Aranda and Comino, 2014). The increased global temperature has caused a decrease in the SOM turnover rate and a reduction in the residence time (Li et al., 2023). In addition, it is important to consider the historical impact of forest fires in the region as a destructive factor (Meddour et al., 2013; Boubehziz et al., 2024). As Zerouali et al. (2023) reported, the natural areas are under increasing pressure from human activities in Algeria, such as urbanization and agriculture, in addition, excessive grazing (Fertas et al., 2024). This pressure indicates that land degradation is still a major challenge in Algeria and it seems that no effective strategies have been applied, affecting seriously the soil properties.

As previously mentioned, SOC is an essential soil quality parameter (Githongo et al., 2022). Agriculture management practices change soil properties, with a significant impact on the physicochemical properties of the soil, quality and functionality (Kuotsu et al., 2014). It was mentioned that Algerian land uses are vulnerable in terms of SOC loss related to soil degradation (Benslama et al., 2024). Furthermore, there is a dearth of data research in various regions of Algeria, one of the largest countries of Africa. Nevertheless, another study on agricultural soils in the country revealed that storing soil organic carbon (SOC) in cultivated areas improves soil quality and productivity, implementing measures such as reducing tillage and increasing plant cover, helping to mitigate climate change (Fenni and Mechane, 2010). Researchers stated that the forest and natural areas in the Northern Algeria have been converted into farms and urban areas due to unsustainable logging practices, urbanization, and the growing need for agricultural land, based on population increase and economic factors (Hind et al., 2022). Similarly, Zanndouche et al. (2022) confirmed this findings, the regressive dynamics of ecosystems have become more severe in the area, that is characterized by reduction of biodiversity and causes a loss and fragmentation of forest habitats. Nevertheless, Algeria's woodland is vulnerable and require further protection (Arfa et al., 2009; Zerouali et al., 2023) since frequent forest fires are causing a constant loss of forest in Northern Algeria. According to Curt et al. (2020), operational models that explain the causes of fire occurrence are still lacking in Algerian fire science and policy.

Under these considerations, this study was conducted in the Northeast of Algeria, which is considered a biodiversity hotspot in the Mediterranean region (Vèla and Benhouhou, 2007). Due to combined effect of climate change, land use changes, unsustainable management practices and the vulnerability of the region, it is necessary a better understanding of the effects produced in the soil that may lead to better guidance for developing appropriate management practices, that constrain soil degradation and contribute to carbon sequestration (Lisec et al., 2024).

The present study assesses the effects of land use types on SOC stock across the top surface layer of (0-5 cm) in this vulnerable region, giving an overview of the soil properties due to land use and planning. We hypothesized that land use types can vary soil organic carbon stock, with agroforestry and pastoral areas having better SOC accumulation in the surface of topsoil. By addressing these knowledge gaps, the aim of this study is the evaluate the soil quality and the potential of sequestration of organic carbon (SOC) in different types of land use (agroforestry, cropland, pastoral land, tree fruit orchards, urban land) in order to improve land management approaches and strategies in a Mediterranean region such is the case of North-East part of Algeria.

Material and method

Description of studied areas

Algeria is located in the North of Africa. This study was conducted in El Tarf and Annaba coastal regions in the Northeast of Algeria (*Figure 1*). The climate is Mediterranean, winter is mild and humid while summer is hot and dry with an annual rainfall average between 608.49 mm and 832.18 mm. The annual average temperature is around 17.15 °C and evaporation rate of 1774.25 mm (Joleaud, 1936; Bounab et al., 2023).

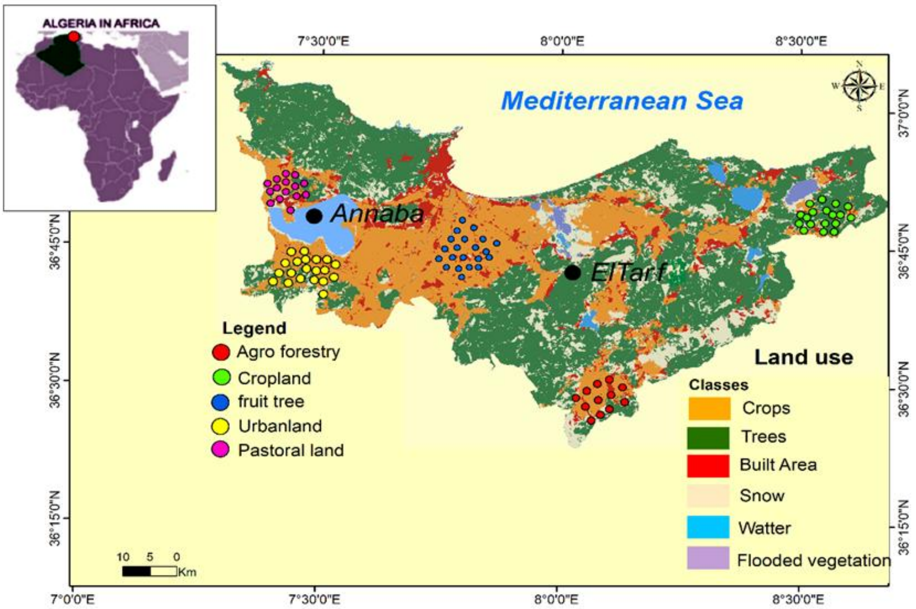

Figure 1. *Study area with soil sampling plots on the land use/ land cover studied in El Tarf and Annaba regions*

El Tarf region stretches over an area of 2891.65 km^2 and is situated between the parallels of latitude North 36°23′25″ and 36°57′7″ and longitudes East of 7°39′49″ and 8°40′52″ (Arfa et al., 2018). The region is characterized by rough topography, the landscape is mostly hilly and mountainous, and the slopes are higher than 12% (Bouazouni, 2004). The agricultural area covers 24% of El Tarf, ca. 71,000 hectares are dedicated to the production of varied crops, while 167,687 hectares are forest area (Bouazouni, 2004). This region contains several wetlands, part of the National Park of El Kala recognized as a conservation area by UNESCO. The combination of marine, dune, lakes, and forest ecosystems and dams, occupies 13,556 ha, 4.70% of the Tarf's territory (Bouazouni, 2004; Arfa et al., 2019). According to the classification of soils types by using the World Reference Base for Soil Resources FAO (2015), the soils resemble brown to dark color and the dominant soils in this area are mainly Luvisols (LV), Fluvisols (FL), Calcisols (CL), most of them developed on limestone rocks. Annaba region is considered the industrial capital of Eastern Algeria, it covers an area of 1411.98 km^2 (Aounallah et al., 2022). The region is located on the northern latitudes of 36°36′ and 37°05′ and the eastern longitudes of 07°17′ and 07°49′. The hills and foothills make up 25.82% of the total area of Annaba (Noui et al., 2023). Annaba region is generally characterized by flat topography with the western border rising to the Edough Mountains' foothills. Most of the soils in this area are composed of recent alluvium with a clayey texture (Daroui et al., 2023). The average annual temperature is around 18 °C and average annual rainfall ranges from 650 to 1000 mm (Aouissi et al., 2021). This region is characterized by mounds exceeding 40 m in altitude, and a depression particularly in Fetzara Lake with little hills between 20 and 40 m, and in Annaba Plain with 11 m (Saboua, 2010). Annaba region has an abundant and varied plant cover that is divided into three zones: the coastal zone, the plains zone, and the mountain zone with the presence of Cork Oak (*Quercus suber*) (Boughediri and Benslama, 2020). Additionally, it features a vast hydrographic network, which includes Fetzara Lake with an area of 18,670 ha, and the Seybouse River known as Oued Seybouse (length: 225 km) (Noui et al., 2023). The dominant soil types are basically the same like in El Tarf, based on FAO (2015). According to Aouissi et al. (2021), Annaba region is affected by intensive urbanization particularly for economic purposes at the expense of the natural green areas (*Table 1*, *Figure 2*).

Table 1. *Geographical characteristics of the sampling sites in El Tarf and Annaba regions*

Land use	Site Code	Latitude (N)	Longitude (E)	Elevation (m)
agroforestry	a	36°48'30"	8°32'13"	124
cropland	b	36°46'08"	8°18'04"	23
tree fruit orchard	c	36°46'36"	7°49'03"	8
pastoral land	d	36°48'34"	7°20'47"	24
urban land	e	36°49'04"	7°42'38"	45

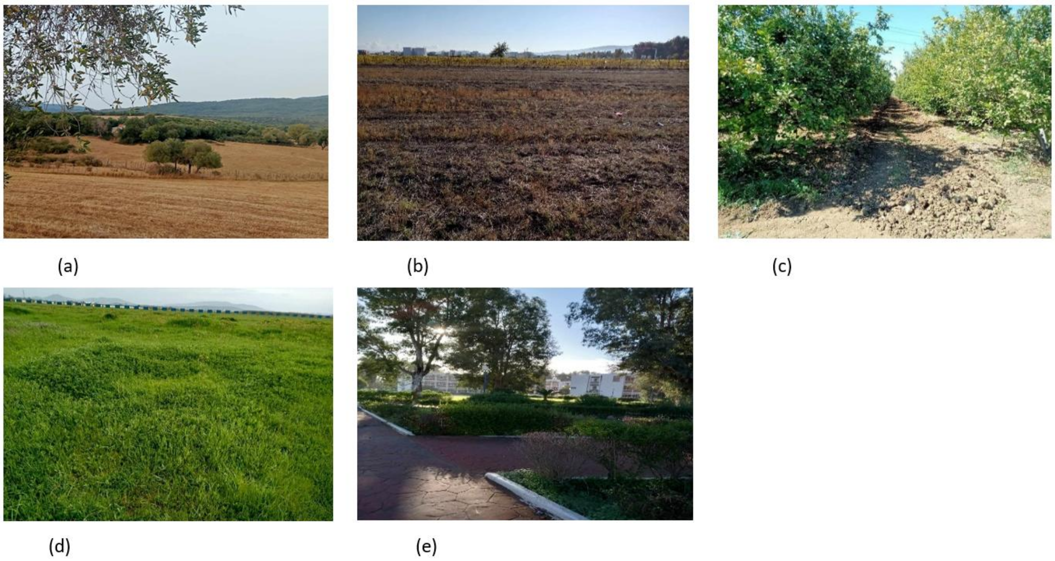
(a) (b) (c)
(d) (e)

Figure 2. *Land uses studied: a) agroforestry; b) cropland; c) tree fruit orchard; d) pastoral land; e) urban land across El Tarf and Annaba regions*

Sampling and laboratory analysis methods

Soil sampling was centered in the topsoil surface as this is the most active part of the soils and it was conducted between October 2021 and July 2022 in El Tarf and Annaba regions. In El Tarf, three locations were selected: the agroforestry area that integrates olive trees and herbaceous plants, mainly barley and wheat; the cropland that includes wheat cultivations, and the orchards with fruit crops (citrus trees). In Annaba, two locations were selected: the pastoral land that is a flood plain with rich vegetation cover, this area is protected and restricted to farming or overgrazing. The second location was the suburban land characterized by a combination of buildings and soil plots with limited vegetation (*Figure 2*). A total of 86 soil samples with three replications for each point were obtained based on the land use (*Figure 2*). Those include cropland (18 sampling points), agroforestry (12 sampling points), tree fruit orchard (21 sampling points), pastoral land (15 sampling points), and urban land (20 sampling points). The selection was based on obtaining the maximum number of sites, in areas where the coverage is entirely determined by the land use type, without influence from other factors or mixed land use types. Global positioning system (GPS) was applied for sampling location. The sampling method was based on a core sampling (metal cylinder of 5 cm diameter and 5 cm height). The soil samples were then put into plastic bags and transferred to the laboratory for analysis. Soil samples were oven-dried at 105 °C and sieved using a 2 mm sieve after eliminating gravel and fresh coarse roots. The main soil properties determined in the laboratory were: soil texture, soil bulk density, soil moisture, soil pH, electrical conductivity, equivalent calcium carbonate, organic carbon and organic matter.

The granulometry and textural class was determined by the Robinson's pipette technique (Baize, 2000). The bulk density was also determined using the core method for all of the soils sampled (Blake and Hartge, 1986). The soil moisture content was gravimetrically determined by drying the soil at 105 °C during 24 h (Delcour, 1981). The pH was determined using a pH-meter, in soil and distilled water suspension with the ratio (1:2.5) (w/v) (Baise, 1995), while the electrical conductivity (EC) was determined by using a conductivity-meter with a suspension of soil and water with a ratio of 1:5 (w/v) (Rhoades, 1996). The equivalent calcium carbonate was measured by the titrimetric method (Mathieu, 2003). Soil organic carbon (SOC) was analyzed by using the modified Walkley–Black method that uses sulfuric acid to a potassium dichromate solution to oxidize the organic carbon (Nelson, 1982). The SOM was determined by using the Loss on Ignition method based on weighting the difference after 4 h under 450 °C in muffle furnace incineration (Morel, 1986).

The soil organic carbon stocks were estimated according to the selected depth of (0-5 cm) using the equation (1) proposed by Pearson (2007):

$$SOC\ stock = BD \times D \times C \qquad \text{(Eq.1)}$$

where,
$SOC = soil\ organic\ carbon\ stock\ per\ unit\ area\ in\ t\ ha - 1$
$BD = soil\ bulk\ density$
$D = depth\ of\ soil\ horizon\ at\ which\ the\ sample\ was\ taken\ in\ cm$
$C = organic\ carbon\ concentration\ in\ \%$

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Data analysis

The statistical analysis was conducted using R software (R Core Team), version 3.6.2. The results were expressed as mean value and standard deviation (m ± sd). After checking the normal distribution of the data by Shapiro-Wilk test and the homogeneity of variances, parametric tests were applied. Soil physico-chemical properties were compared between them with the analysis of variance (ANOVA) supplemented by Tukey's test for comparing differences between group means. Following this analysis, the significance level for all tests was set at $p = 0.05$. in the tables, means with the same letter indicate a homogenous group in which the samples are not significantly different. We assign the higher mean letter (a) and the lower mean letter (b).

Results and discussion

The mean values and the standard deviation of the soil characteristics are presented in the *Table 2* for the five selected land uses across different land-use types in El Tarf and Annaba regions.

Table 2. *The mean values of the soil properties in El Tarf and Annaba regions*

Parameters	**Land Use**				
	Agroforestry	**Cropland**	**Pastoral**	**Tree Fruit**	**Urban Land**
Texture	Clay	Clay loam	Clay loam	Sandy clay loam	Loam
Clay (%)	42 ± 5^{a}	35 ± 14^{b}	38 ± 8^{b}	26 ± 8^{b}	21 ± 4^{c}
Silt (%)	21 ± 6^{a}	30 ± 13^{a}	27 ± 3^{a}	19 ± 3^{a}	31 ± 4^{a}
Sand (%)	37 ± 5^{b}	35 ± 6^{b}	35 ± 6^{b}	55 ± 5^{a}	48 ± 5^{a}
SM (%)	3.7 ± 1.2^{a}	2.6 ± 1.1^{b}	2.9 ± 1.2^{a}	2.9 ± 0.5^{a}	2.3 ± 1.42^{b}
SBD (Mg/m^3)	1.26 ± 0.1^{a}	1.45 ± 0.1^{b}	1.34 ± 0.1^{a}	1.46 ± 0.1^{b}	1.56 ± 0.1^{c}
pH	7.5 ± 0.4^{a}	7.4 ± 0.4^{b}	7.2 ± 0.2^{b}	7.6 ± 0.2^{a}	7.2 ± 4^{b}
EC (µS/cm)	236.8 ± 119.4^{b}	331.9 ± 65.0^{a}	210.5 ± 32.2^{b}	292.1 ± 46.9^{b}	277.9 ± 75.9^{b}
$CaCO_3$ (%)	22.2 ± 0.3^{b}	22.3 ± 0.4^{b}	21.9 ± 0.2^{b}	22.2 ± 0.5^{b}	23.1 ± 1.9^{a}

Where: SM = soil moisture, SBD = soil bulk density, EC = electrical conductivity, $CaCO_3$ = equivalent calcium carbonate

Soil texture

The results revealed that the textural class of the different types of land uses was clay, clay loam, loam and sandy clay loam (*Table 2*). However, the clay content exhibited a significant difference ($p \leq 0.001$) under all the different land uses (*Table 3*). The levels of clay content were found to be 35 % in cultivated soils such as cropland and orchards with fruit crops 26%. The agroforestry and pastoral lands presented a mean value of 42% and 38%, probably due to the effect of long-term conventional cropping. Moreover, in terms of soil texture, the clay particles are more impacted by high temperatures (Verma and Jayakumar, 2012) owing to the historical impact of fire in the area. The results agree with those reported by Yitbarek et al. (2013), finding a lower clay level content under cultivated lands compared to forest land and grazing systems in the Abobo area, western Ethiopia. The results found maybe influenced by the irrigation in cultivated lands, favouring the leaching of fine particles, and the agroforestry and pastoral land with reduced tillage, which contributes to the accumulation of SOC and soil aggregation, potentially protecting the clay particles by the formation of clay-humus complex. Those under the urban land exhibited the lowest value of clay content 21%.

Table 3. *ANOVA test applied to the physicochemical parameters across different land-use types in El Tarf and Annaba regions*

Parameters	F value	*p* value	Significance
Clay	7.2823	0.0005472	***
Silt	2.5224	0.06749	ns
Sand	4.1556	0.0401	***
SBD	72.261	2.2e−16	***
SM	3.0133	0.02283	*
pH	5.8388	0.000361	***
EC	7.4187	3.986e−05	***
$CaCO_3$	3.8547	0.006511	***
SOC	61.928	2.2e−16	***
SOM	91.507	2.2e-16	***
SOC Stock t ha^{-1}	7.0359	5.371e-07	***
SOM Stock t ha^{-1}	78.446	5.705e-12	***

NB: * ($p \leq 0.05$), ** ($p \leq 0.01$), *** ($p \leq 0.001$), ns ($p > 0.05$)

Several studies have reported the positive effects of the clay content on increased soil organic carbon accumulation in soil horizons, promoting a synergistic effect clay-organic matter. According to Kibet et al. (2022), the presence of clay preserves SOC from microbial oxidation and helps maintaining carbon stability. Even more, a high clay concentration stimulates the formation of a protective humus-clay complex (Lakehal et al., 2023; Benslama et al., 2024). The variation in the silt content of the soil under land use shows no significant differences (p > 0.05) across land use types (*Table 3*). The lack of significant variations might be related to the similar parent material as Oguike et al. (2009) reported, the soil texture is linked to their parent materials. For the sand content, although the differences between urban soils and orchards with fruit crops than the others land uses were statistically significant, which are assessed at 48% for urban land and 55% for tree fruit orchard respectively (*Table 2*). The increase in sand content could be attributed to being converted from natural forest to cultivated land or disturbed areas. Similar finding has been obtained by Tellen and Yerima (2018) in the north west region of Cameroon. They reported that the increased proportion of sand in the surface layer is due to the effects of management practices as converting natural forest to cropland, while those under cropland and agroforestry land had intermediate sand levels. Moreover, the soil under pastoral land exhibited (35%) content of sand fraction (35%), which is mainly attributed to the history of this site, including their protection against disturbance factors such as overgrazing and fire. Our results are consistent with the majority of related studies, affirming significant variations in the distribution of texture classes among different land use types and management practices. Tellen and Yerima (2018) and Chemeda et al. (2017) reported that these variations in the soil texture throughout the land use type, underscoring that impact of land use on the soil properties, are resulting from the effect of management practices and land use.

Soil bulk density

Soil bulk density (SBD) is a fundamental aspect that influences root development, aeration, infiltration, and plant growth and it is essential for determining the size of SOC and mineral nutrients (Prakach and Shimrah, 2023; Regasa, 2023). A statistically significant difference between urban area and agroforestry land use for the SBD, with higher values recorded in urban area, while it was lower in agroforestry land use at

1.26 Mg/m^3. These differences might be attributed to the higher input of the SOC, resulting from the implementations of effective management practices, which promote the enhanced accumulation of the SOM. Consequently, these lands are managed on a reasonable sustainable basis. The present findings are in agreement with those reported by Kibet et al. (2022), where the researchers found a lower SBD 1.30 g cm^{-3} under agroforestry land for the same depth of soil (0-5 cm) in Western Kenya. According to Prakach and Shimrah (2023), a lower SBD indicated that the soils are less compacted. A higher SBD was recorded in the urban land in the range of 1.56 Mg/m^3, which might be associated to the managing use of the area that led to a lower organic matter content and cause soil compaction. The outcomes of this study are in correspondence with the results of Benslama et al. (2024), who reported that the higher value reflects the compaction expected in the urban soils. The bulk density values were lower in grassland and cropland and higher in urban soils at 1.42 Mg/m^{3}·in Spain. However, the SBD was recorded for the cropland at 1.45 Mg/m^3 and the tree fruit orchards at 1.46 Mg/m^3. Nevertheless, no statistical significance between cropland and tree fruit orchards was found, which differed from urban soil, where the mean value was the lowest. The effect of converting from natural forest to cultivated lands in SBD is probably due to the increase of soil compaction due to agricultural practices and the use of machinery. According to Yitbarek et al. (2013) and Kakaire et al. (2015), when the cultivation period was increased in a plot, the bulk density increased significantly. Several studies highlighted that the SBD may be affected by the land use change and the content of SOC (Seifu et al., 2020; Mishra and Sarkar, 2020). If the organic matter decreases, this leads to an increase in bulk density, and a reduction in porosity, which in turn reduces soil infiltration and the storage capacity of water and air (Vandana et al., 2023).

Soil moisture

Soil moisture in the soil surface is directly associated to the environmental conditions and the soil management practices. So, it is expected that soil moisture will be influenced by irrigation or the proximity of wetlands areas, and the weather conditions affecting the soil surface and the seasons. Although significant differences across the different types of land uses ($p \leq 0.05$) where found (*Table 3*), the validity of these results in the soil surface is relative, since soils are constantly affected by environmental changes and moisture varies rapidly in the top. However, the highest soil moisture content was recorded for the agroforestry land at 3.7% and pastoral land at 2.9%. The soil moisture for the tree fruit orchards was found to be 2.9%, which may be attributed to a combination of irrigation management practices and organic amendment in the top surface layer. The lowest soil moisture has been recorded for the urban 2.3% and cropland 2.6% areas. Similar findings were reported, lower values of soil moisture under cropland compared to grassland in Oromia region, Ethiopia, by Girma et al. (2023). It could be attributed to the continued plowing along with the exposure of the upper layer to the higher solar radiation, resulting in a significant loss of soil moisture. According to Fu et al. (2003), the differences in the soil moisture are caused by the differences in the distribution of roots and the physical characteristics of the soil. In this case, the influence of SBD and SOM in the surface is in question.

Soil pH

The soil pH ranged between neutral and slightly alkaline. The highest mean pH was recorded under the tree fruit orchards and agroforestry land in the range of 7.6 and 7.5, respectively. This could be attributed to the abundant presence of alkaline cations in these farming systems. The topography, the type of parent material, and the type of plant cover are some of the variables that affected the soil pH (Lakehal et al., 2023). The soils under cropland and pastoral land exhibited pH values of 7.4 and 7.2, respectively. These results corroborate the findings reported by Regasa (2023), where the pH value was lower in cultivated and grassland due to the depletion of basic cations caused by crop harvesting and animal feeding in western Ethiopia. The results also showed that the soils under urban land use had a pH value of 7.2. This could be attributed to the conversion of natural areas to urban areas that alters the surface cations and progressive decrease of vegetation cover.

Electrical conductivity

The electrical conductivity is an indicator of the mineralization degree of the soil and provides information about soil salinity and electrolytes in the soil solution and is directly linked to the quality of the ionizable compounds (Duchaufour, 1982). The electrical conductivity was of 236.8 µS/cm for the agroforestry land, 210.5 µS/cm under pastoral land, and 292.1 µS/cm under tree fruit orchards, which indicated a moderate to low level of salinity. The electrical conductivity was higher under the cropland at 331.9 µS/cm, owning to the existence of some samples close to salt flats of the valley in that area with combination of intensive agriculture practices (fertilization and irrigation). According to the reported outcomes by Benslama et al. (2024), the combination of geological factors in the Mediterranean area with intensive agriculture practices led to a higher level of salinity in the surface layer.

Equivalent calcium carbonate

It was noticed that the equivalent calcium carbonate determined was moderately distributed across the different types of land use (*Table 2*). It was found that the content of $CaCO_3$ was 22.2% under agroforestry, 21.9% for pastoral land, 22.2% under tree fruit orchard, and 22.3% under cropland. These results indicated the influence of the lithology of the area, carbonate rocks. While, the highest value was recorded for urban land at 23.1%, although the differences between urban soils and the others were statistically significant, with a higher amount of carbonate found in urban areas at 23.1%, reflecting the impact of urbanization and human activities. In addition, a higher calcium carbonate alters the original soil and can impact the permeability ratio and the development of welded or solid layers (Noori and Ismaeal, 2023).

Soil organic carbon and organic matter

The results obtained indicate significant variations in the soil organic carbon (both SOC and SOM) with the different types of land use. The results varied in the following order: agroforestry>pastoral land>tree fruit orchards>cropland>urban land. It was found that the agroforestry and pastoral areas were significantly higher ($p \leq 0.001$) compared to other types of land use (*Table 3*), with SOC mean value of 2.5% under agroforestry land use and 2.3% under pastoral land use. The higher levels could be corresponded to the higher input of vegetation cover and the contribution of crops residue in top surface layer (0–5 cm), which can favor an increase in the organic matter content. This is important in the sense that this is the first step to accumulate organic matter in the soil and increase the storage, favoring the strategy to combat climate change. Additionally, the pastoral and agroforestry lands were found to be significantly less compacted compared to the other land use types. Earlier research has indicated that there are greater amounts of SOM and SOC in the upper soil layers in comparison to the sub-soil and sub-surface soil layers (Olujobi et al., 2022; Vandana et al., 2023). This was attributed to the higher input from decomposing and decaying leaf litter. Conversely, urban land showed the least amount of soil organic carbon, with an average of 0.4%, as it was expected, where no addition of organic wastes and plant residues is practiced. Moreover, this is also attributed to the removal of topsoil during infrastructure development (Kalambukattu et al., 2013; Daroui et al., 2018). Furthermore, cropland and tree fruit orchard exhibited lower concentrations of SOC, ranging from 1.2% to 1.4%, respectively. These results can be explained as on the land managing history of these areas, the conversion of native forest to cultivated area as well as the intensive cultural practices led to a decline in the SOC content. In addition, it should be considered the influence of forest fire that causes the loss in the aboveground biomasses in the top surface soil constituted of plant litter (Yitbarek et al., 2013). These findings were also validated by other studies demonstrating the influence of land use conversion on the accumulation of the SOC, as native forest to farmland or plantation and grassland to cultivated lands (Navarro-Pedreño et al., 2021).

SOC and SOM stock across land use types

The storage of soil organic carbon exhibited a significant difference ($p \leq 0.001$) under all the different land uses (*Table 3*). However, the highest storage of soil organic carbon is in the sites with the highest plant diversity which, can favor an increase in organic matter with 23.10 t ha^{-1} and 19.98 t ha^{-1} under agroforestry and pastoral lands, respectively (*Table 4*). However, a study conducted by Marselianti et al. (2023), indicates a significant correlation between SOC stock and plant formation in the top surface layer. Several studies indicated that SOC stocks can vary regionally influenced by variables environmental factors including soil texture, land use, plant cover, temperature and precipitation (Cai et al., 2016; Chen et al., 2020; Machado et al., 2024). The minimum stocks value was recorded under urban land compared to all land use types with 8.89 t ha^{-1} which, mean there is less organic matter decomposition and limited input, while the soils under cropland and tree fruit orchard contain 14.51 t ha^{-1} and 14.46 ha^{-1} for each (*Table 4*). May be attributed to the organic amendments which, contribute to soil carbon accumulation. Our results are in the range of previous findings for urban lands in Mediterranean areas such as Spain, where the storage of SOC equal to 5.254 t ha^{-1}, noted that at a depth of 0-5cm, the SOC stock was significantly lower compared to grassland and cropland (Benslama et al., 2024). In another study carried out in northern Tunisia under almost similar climatic condition, Annabi et al. (2009) indicates that SOC stocks is lower in cultivated soils compared to forest soils. In the same way, the study carried out by Arrouays et al. (2001) showed that orchards would store less organic carbon with 50 t ha^{-1} in the top soil surface for arable land in France. Bounoura et al. (2017) reported that cultivated soils in northern Algeria are mostly poor in organic matter, their content was about 0.8% in the topsoil surface.

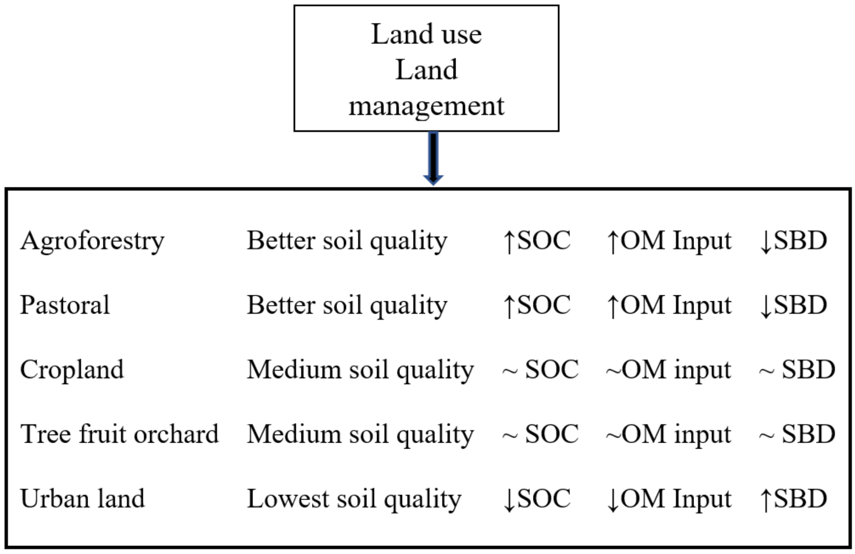
As previously mentioned, SOM is an essential soil regulator for many environmental factors that have an impact on cultural productivity, particularly in unfertile and altered soils (Schulze et al., 2009). According to Verma et al. (2012), changes in land use, vegetation cover, and soil management are likely to affect SOM levels and the accumulation in soils. Moreover, soil properties are linked to the accumulation of SOM proceed and change fast when organic matter is incorporated or removed, while the properties linked to weathering usually take longer time to change (Navarro-Pedreño et al., 2021; Samota et al., 2024). The impact of management practices considering cultivated soils has been reported by Blanco et al. (2013), finding that management practice as no-till farming plays an essential role in increasing the SOC in the surface layer and stimulate the microbial activities. These findings were also validated by other studies (Amanuel et al., 2018), demonstrating the influence of a number of factors in the increment of SOC, including the quality and production of both litter above and below ground, placing organic matter deeper in the soil either directly through increasing below-ground inputs or indirectly through improving surface mixing by soil organisms, and enhancing physical protection through organic mineral complexes or intra-aggregates and microclimate change.

Table 4. *Soil organic carbon and matter content across different land-use types in El Tarf and Annaba regions*

Land use	SOC (%)	SOC Stock (t ha^{-1})	SOM (%)	SOM Stock (t ha^{-1})
Agroforestry	2.5 ± 0.4 ^{a}	23.1 ± 1.36 ^{a}	4.6 ± 0.7 ^{a}	35.9 ± 0.99 ^{a}
Cropland	1.2 ± 0.5 ^{b}	14.5 ± 0.86 ^{b}	2.4 ± 0.2 ^{b}	23.22 ± 1.72 ^{b}
Pastoral land	2.3 ± 0.6 ^{a}	19.98 ± 1.34 ^{a}	4.1 ± 1.1 ^{a}	32.35 ± 1.41 ^{a}
Tree fruit orchard	1.4 ± 0.4 ^{b}	14.51 ± 0.74 ^{b}	2.8 ± 0.5 ^{b}	24.38 ± 1.47 ^{b}
Urban land	0.4 ± 0.1 ^{c}	8.89 ± 0.43 ^{c}	0.8 ± 0.4 ^{c}	19.44 ± 0.93 ^{c}

Where: SOC = soil organic carbon, SOM = soil organic matter

The results of the presented study (*Figure 3*), an overview of different soils under different land use types, agree with the most recent results about SOC accumulation in the top surface layer (Tedone et al., 2023). In addition, it has been emphasized that the accumulation of the SOC in the surface layer plays a significant function as a carbon sink or source of greenhouse gases, as the upper first few centimeters are arguably the most dynamic part of the soil-atmosphere exchange (Benslama et al., 2024).



Land use
Land
management

Agroforestry	Better soil quality	↑SOC	↑OM Input	↓SBD
Pastoral	Better soil quality	↑SOC	↑OM Input	↓SBD
Cropland	Medium soil quality	~ SOC	~OM input	~ SBD
Tree fruit orchard	Medium soil quality	~ SOC	~OM input	~ SBD
Urban land	Lowest soil quality	↓SOC	↓OM Input	↑SBD

Figure 3. *Overview of the effects on organic matter in soils and bulk density depending on the land use in El Tarf and Annaba regions*

The scarcity of data, especially on the impact of the management practices on Algerian soil's physicochemical properties, underscores the significant challenge posed by increasing anthropogenic activities in this part of North Africa. This is particularly relevant in the context of climate change affecting the Mediterranean basin and population growth fueling agricultural land conversion. Considering the intricate nature of the soil and these difficult conditions, we integrated findings from a literature review and our experimental data. By using this data that could help for future studies related to land use impact, physicochemical properties of the soil and carbon sequestration and soil storage (SOC) can be understand and it will be know what is expected depending on the land use type. So, policy makers can predict the actions that will need to be taken to protect and improve the soil, promoting the accumulation of organic matter. For example, not strictly speaking but searching for solutions taking into account that:

a) The statistical tests confirmed differences in soil parameters between land uses. Future research should explore additional physicochemical parameters in terms of conservation planning to ensure their long-term preservation.

b) While management practices can affect significantly topsoil layers, but it seems that the disturbed lands where more affected.

c) To restrict the various factors contributing to soil degradation, there is a need for interdisciplinary studies involving on sustainable management practices that could reduce soil degradation.

d) The findings of this study can contribute to comprehending the important role of the soil as an organic sink. Increasing SOC improve soil quality and promote agriculture productivity.

e) The dataset reflects the fragile state of the study area, which elevated influence on a protected area causing soil degradation. It is necessary the implication of socio-economic initiative for sustainable management.

Conclusion

The present work exhibits significant differences in terms of soil organic carbon (SOC) and soil organic matter (SOM), soil bulk density (SBD), texture, pH value, soil moisture, equivalent calcium carbonate ($CaCO_3$), and electrical conductivity across the different types of land uses. These variations may be attributed to the variability of management practices, land management history, and the characteristics of the study sites. Better soil properties that can increase the soil quality were detected under agroforestry and pastoral land uses, owing to the higher input of organic matter related to the richness of the plant cover in the surface layer and the absence of overgrazing. In contrast, urban soils exhibited the lowest quality, considering the measured parameters. The significant relationship between the SOC and SBD illustrates a strong effect on the bulk density of SOC content in the soil. The variability of SOC stock across the land use types highlights the ability of enhancing carbon inputs through the implementation of sustainable practices, thus contributing to greater SOC sequestration. The results of this study illustrate the potential to improve land management practices in vulnerable Mediterranean regions, while aiding in climate change mitigation, taking into account potential alterations in soil characteristics. In some way, the most affected soils presented in urban areas should be manage to improve their quality following strategies close to those applied in agroforestry and extensive pastoral uses, adapted to the urban environment and future research can be done in this line.

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