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ASSESSMENT OF ORGANIC CARBON AND ITS COMPONENTS IN DIFFERENT GYPSIFEROUS SOILS USED FOR AGRICULTURAL PURPOSES IN SALAH AL-DIN GOVERNORATE USING THE CARBON MANAGEMENT INDEX

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Abstract. Changes in land use and land cover directly affect the total organic carbon in soil and its health. This study, conducted in Salah al-Din/Tikrit Governorate, aimed to assess differences in total organic carbon (TOC), particulate organic carbon (POC), mineral-associated organic carbon (MOC), and carbon management index (CMI) across four land use types: vegetable crops (L1), unused land (L2), wheat and barley crops (L3), and land planted with shrubs (L4). The study also sought to test the validity of the CMI in detecting soil degradation or improvement following changes in land use. The results showed significant differences between the different patterns. Vegetable lands (L1) recorded the highest values for POC and MOC compared to unused lands (L2), while wheat and barley lands (L3) and shrub lands (L4) had intermediate values. TOC also achieved the highest value in L1 (14.43 g kg^{-1}), compared to the lowest level in L2 (5.33 g kg^{-1}) due to the absence of vegetation cover. No significant differences were found between L3 and L4, but they were lower than L1 and higher than L2. The carbon management index (CMI) at a depth of 0–15 cm reached its highest level in L1 (57.75%), followed by L3 (43.77%) and then L4 (27.99%), while unused land recorded the lowest value (21.34%). The results indicate that intensive cultivation of vegetable crops contributes to improving soil properties, while uncultivated land suffers from a clear deterioration in organic matter and nutrient depletion.

Keywords: CMI 1; TOC 2; POC3; MOC 4.

INTRODUCTION

The Gypsiferious soil contains more than 5% gypsum (calcium sulfate) in the upper layer, this soil in Iraq about 88,000 km2 that make it was very important area for agriculture use but it was suffering from many problems such as weak structure, poor fertility, drought and the appear hard pan layer and sink holes, (AL-Duliami, et al 2020). These soils are located within arid and semi-arid areas that are characterized by high temperatures and rare rainfall. This leads to a lack of vegetation cover, their content of organic matter, and weak biological activity. so that it needs a special management and scientific methods to use them in agriculture (Khalaf, et al 2021) gypsum particle place clay and silt, so we expect the weakening of its biological activity because the micro-organisms are adsorption on the surfaces of clay and silt particle

The global decline in soil quality is largely attributable to increasing human activities, particularly those associated with land use changes and vegetation cover changes .Soil organic carbon has recently gained significant importance in soil quality assessment as it greatly influences the chemical, physical, and biological aspects of soil. The carbon index has been linked to sound land use management and vegetation types. Land use and vegetation types influence the amount of carbon in the ecosystem through the quality of residues, decomposition, and sedimentation. Altai & Yousif. (2024)

Soil carbon can be divided into several parts according to its chemical composition. The variable part is the organic carbon found in organic and decomposed matter and the carbon found in microorganisms in the soil. The first part, which is not related to minerals, consists of plant and animal remains that have not yet completed decomposition. It is characterized by rapid decomposition and change, as well as a relatively lower specific density compared to mineral soil particles. Altai & Yousif. (2024). It is agriculturally important despite its low level due to climatic conditions and agricultural practices such as plowing and harvesting, the lack of added organic matter, as well as overgrazing of grasslands and cutting of native trees and shrubs in the region.

The second part represents mineral carbon associated with soil components and minerals, in addition to carbon dioxide gas present in the soil and resulting from the respiration of living organisms and the decomposition of organic matter. This part is considered the most stable and consistent, accounting for about 90% of the total carbon according to particle size distribution. Most studies indicate that this stable component, due to its resistance to change, is not significantly affected by land use patterns or agricultural management practices. However, other studies show that this fraction is more affected than the variable fraction (Khalaf, et al 2021).

Mineral carbon is less affected by different management systems, due to its protective mechanisms that limit its exposure to external factors, particularly through its association and adsorption on the fine surfaces of soil particles. Its low degradability is also linked to the predominance of clay particles, which have a high capacity to stabilize and strongly retain carbon, reducing the accessibility of decomposing microorganisms and limiting the effect of enzymatic activity responsible for transformation and decomposition processes (Altai, et al., 2025).

The current study aimed to evaluate the carbon content and its organic and mineral components in gypsum soils with different agricultural uses in the province of Salah al-Din, relying on highly sensitive indicators. It also sought to assess the degree of soil degradation and its response to different management practices. The Carbon Management Index (CMI) was used to assess the efficiency of land use in enhancing soil quality, as this index is based on calculating the ratio of variable carbon to non-variable carbon.

MATERIAL AND METHODS

Selection of study site. The study area is located within the administrative boundaries of Tikrit District, Salah al-Din Governorate, Iraq, between latitudes 43°39'27.954"E and 43°36'9.913"E and latitudes 34°42'35.68"N and 34°39'28.655"N. The study area covers an area of 23 km2 and is 119 meters above sea level (Figure 1). The climate of the study area is classified as arid and semi-arid, with low rainfall rates not exceeding 200-250 mm and high temperatures in summer reaching above 40°C. The topography of the area ranges from flat to semi-flat. Fig. 1) The soils of the study sites are classified as dry Calcigypsid soils with low fertility, loose structure, low moisture retention capacity, and poor organic matter content. The predominant agricultural use in the area is the cultivation of wheat in winter and vegetables and corn in summer, with most of the vegetation being natural.

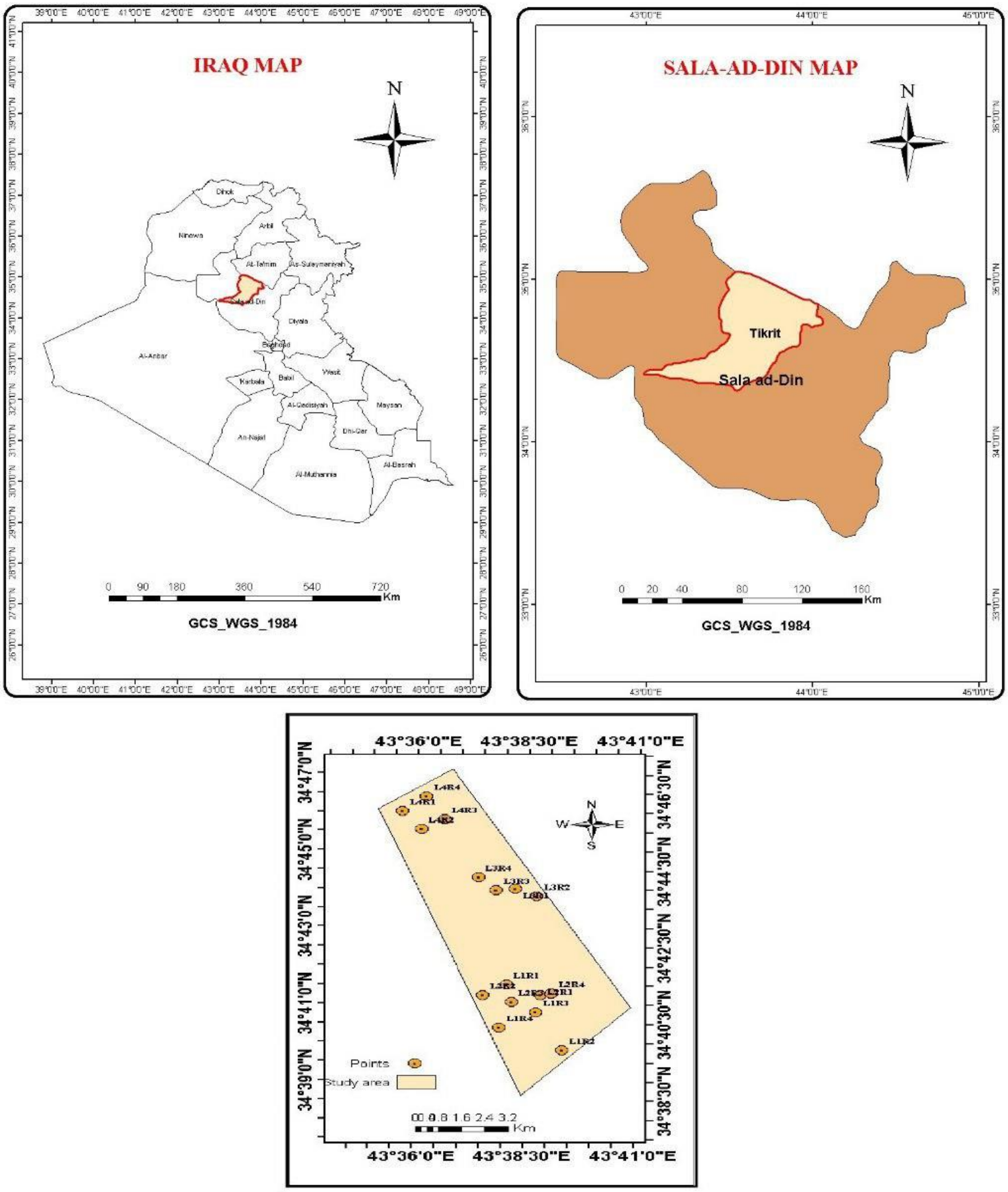

Figure 1. Map of the study area

Sample collection and laboratory work. Sixteen (16) samples were collected from four different soil areas on September 25-2019, distributed across the study area at a depth of 0-15 cm, according to the nature of the prevailing agricultural use, which is land cultivated with wheat and barley crops, land cultivated with shrubs, land cultivated with vegetable crops, and uncultivated land. Their coordinates were fixed using a GPS device. Electrical conductivity (EC) and soil reaction (pH) were measured using soil extract (1:1), as described in Page et al. (1982), and gypsum was estimated using the acetone precipitation method, as described in Richards (1954). Organic matter was estimated according to Tandon (1998).

Study factors

Four types of land use:

1- Land cultivated with vegetable crops L1 University soil

2- Uncultivated land L2 Outside the university

3- Land cultivated with wheat and barley crops L3 Before baling

4- Land cultivated with shrubs L4 Baling

5- Four samples were taken from each site R1, R2, R3, R4

Physical and chemical properties studied

The soil properties studied in this study included physical and chemical characteristics, including total organic carbon (TOC), particulate organic carbon (POC), mineral organic carbon (MOC), and carbon management index (CMI), across four different land use types.

The concentration ratio of degradable carbon (labyl) was calculated by dividing its value by the total organic carbon for the same land use type. The Carbon Management Index (CMI) is an assessment model that illustrates the impact of a particular land use type on soil fertility compared to a reference soil with a specific use. This index is formulated according to the following equation:

$$\boldsymbol{CMI = CPI \times LI \times 100} \dots\dots\dots \ (\mathbf{1})$$

Where CPI refers to the carbon stock index, while LI represents the lability index of soil under a given land use type.

Carbon Pool Index (CPI)

$$\boldsymbol{CPI} = \frac{(\boldsymbol{Total\ carbon\ in\ the\ treatment, g\ kg^{-1}})}{(\boldsymbol{Total\ carbon\ in\ the\ reference, g\ kg^{-1}})} \dots\dots\dots \ (\mathbf{2})$$

Lability Index (LI)

$$\boldsymbol{LI} = \frac{\boldsymbol{L}}{\boldsymbol{L}_{\mathrm{r}}} \ \dots\dots\dots \ (\mathbf{3})$$

where L is the carbon lability of the soil and L_r is the carbon lability of the reference soil.

Carbon Lability (L)

$$\boldsymbol{L} = \frac{(\boldsymbol{Content\ of\ labile\ C})}{(\boldsymbol{Content\ of\ non-labile\ C})} \dots\dots.\dots \ (\mathbf{4})$$

(Sainepo et al, 2018)

Statistical analysis

Analysis of variance (ANOVA) and least significant difference (LSD) tests were performed to compare the means using SAS 9.1.3 software. A statistical significance level of $P < 0.05$ was adopted for evaluating the results. The effect of land use and soil depth was studied using two-way ANOVA, while simple linear regression analysis was used to explore the relationship between total organic carbon (TOC) and its components.

RESULTS AND DISSCUSION

Table (1) shows that the hydrogen values were (7.81, 7.51) for the soil samples studied, while the organic matter values for the soil samples studied ranged from (19.15-7.20) g. Therefore, there is a direct relationship between organic matter and hydrogen ion concentration, which is due to the role of organic matter in improving the regulatory capacity of soil, especially in gypsum soils, because it interacts with bases such as calcium, which is consistent with (Gerritse & Van Driel, 1984).

The electrical conductivity values ranged from 2.22 to 2.84 dS/cm. m-1 for the studied soil samples and showed an inverse relationship with organic matter content, as the electrical conductivity decreased at the highest organic matter content, while it increased to 2.8 dS/cm m-1 at lower organic matter content. This is due to the role of organic matter in reducing dissolved salts, as increased organic matter helps reduce soil salinity and improve chemical properties. (Singh et al., 2023)

The organic matter values for the studied soil samples ranged from 19.68 to 7.08 g. kg-1 for soils with gypsum content (28.00, 131.00) g. kg-1. The results indicate an inverse relationship between organic matter and gypsum content in the soil. This is consistent with the findings of several researchers:(Araújo et al., 2019: de Carvalho et al., 2023).

Table 1 shows the difference in the distribution of soil texture components (sand, silt, and clay) with changes in organic matter content. When the organic matter content decreases to 7.08 g/kg, the content of silt and clay increases compared to when the organic matter content is higher, while the sand content reaches 533 g/kg. kg-1, the silt and clay content increases compared to when the organic matter content is higher, while the sand content reaches 533 g. kg-1. When the organic matter content rises to 19.68 g. kg-1, the sand content increases to 612 g. kg-1 and the silt content decreases to 155 g. kg-1, while the clay content increases relatively to 233 g. kg-1. This may be due to the variation in the role of texture in controlling the accumulation of organic matter, as clay particles have a larger specific surface area, which helps to stabilize organic matter and prevent its decomposition, while soils with high sand content lead to varying rates of organic matter accumulation depending on management conditions and particle size distribution. Overall, the results indicate an overlap between soil texture and organic matter content, which is reflected in their chemical and physical properties. This is consistent with (Plante et al., 2006).

Table1. Chemical and physical properties of Soil.

Sample symbol	Coordinate		EC	pH	$CaSO_4.2H_2O$	O.M	Texture		
	X	y					Sand	Silt	Clay
			dS.m⁻¹		g kg⁻¹				
L1R1	34.67825	43.63923	2.22	7.59	16.00	18.71	612.00	155.00	233.00
L1R2	34.68231	43.64865	2.24	7.77	24.00	19.51	612.00	155.00	233.00
L1R3	34.68113	43.64457	2.32	7.81	37.00	19.15	612.00	155.00	233.00
L1R4	34.67749	43.6114	2.36	7.79	28.00	19.68	612.00	155.00	233.00
L2R1	34.68471	43.64707	2.63	7.51	122.00	7.20	533.00	284.00	183.00
L2R2	34.68765	43.62705	2.71	7.55	127.00	7.11	533.00	284.00	183.00
L2R3	34.68661	43.63534	2.78	7.57	131.00	7.08	533.00	284.00	183.00
L2R4	34.68758	43.65250	2.58	7.58	112.00	7.15	533.00	284.00	183.00
L3R1	34.73314	43.63754	2.82	7.68	68.00	15.11	588.00	228.00	184.00
L3R2	34.73071	4364586	2.84	7.65	57.00	14.07	588.00	228.00	184.00
L3R3	34.73345	43.62951	2.32	7.81	52.00	15.53	488.00	278.00	224.00
L3R4	34.76272	43.65617	2.29	7.78	98.00	13.75	568.00	238.00	194.00
L4R1	34.76704	43.5946	2.45	7.71	43.00	11.08	725.00	74.00	202.00
L4R2	34.76099	43.60386	2.48	7.68	52.00	8.34	614.00	92.00	294.00
L4R3	34.76348	43.60981	2.51	7.74	48.00	9.55	612.00	155.00	233.00
L4R4	34.77324	43.60342	2.42	7.81	34.00	8.67	614.00	92.00	294.00

Molecular organic matter

Particulate organic carbon (POC)

For the soil fractions studied, POC was the fraction most affected by land use, as shown in Table 2 and Figure 2. At the L1 site, POC was the highest compared to uncultivated land, reaching (4.81 and 1.77) g kg-1, respectively, which can be attributed to its high organic matter content and the activity of carbon-rich microorganisms, which enhanced biological processes and the decomposition of organic matter [Altai, et al. (2025)]. Meanwhile, the non-agricultural land L2 had lower POC values and lower molecular organic carbon values, as this area has various non-agricultural uses, such as residential buildings and green spaces used for grazing. These factors have significantly affected the molecular organic carbon content due to the low organic matter content, soil compaction caused by vehicle traffic, and water scarcity.

The POC of land cultivated with grass crops (L3) and land with shrubs (L4) was lower than that of vegetable crops and higher than that of unused soil. It reached (3.64 and 2.34) g kg-1, respectively, due to variable carbon, which depends heavily on management practices. Agriculture increases the rates of decomposition and mineralization. The concentration of POC in cultivated areas is mainly influenced by tillage practices, as some studies assume that the breakdown of aggregates and the reduction of binding factors lead to the breakdown of soil structure, releasing variable carbon in a free state; this, in turn, significantly increases the loss of variable carbon from the soil. Compared to agricultural land with dense vegetation cover, agricultural land with less vegetation cover during seasonal periods lost higher concentrations of variable carbon. (Sainepo et al. 2018)

The type of vegetation cover also has a significant impact on the POC index, as evidenced by the difference between land planted with vegetables and grasses and land planted with shrubs (L4) and land not used for agriculture (L1) (Alatawi et al 2024).

Mineral Organic Carbon (MOC)

The mineralization of carbon by microorganisms is an important biological process in soil (its fixation between soil particles).

MOC has always been higher than POC due to the activity of microorganisms that convert unstable carbon forms into more stable forms, as shown in Figure 1. At site L1, MOC was higher than at uncultivated site L2, reaching 9.62 and 3.56 g kg-1, respectively, while at sites L3 (cultivated with grass crops) and L4 (cultivated with shrubs), MOC was lower than at sites L5 (cultivated with vegetable crops) and higher than at uncultivated sites. They reached (7.29 and 4.69) g kg-1, respectively, which is attributed to variable carbon that depends heavily on management practices. The figure above shows that the high gypsum content affected the presence of decomposed organic matter (Table 1), and that cultivation increases the rates of decomposition and mineralization.

The type of vegetation cover also plays a major role in influencing the MOC carbon index, hence the difference between land planted with vegetables and grasses and land where shrubs grow (L4) and land that is not used for agriculture (L1).

The decrease in unused soils can also be attributed to erosion breaking down particles according to their size, as there are high levels of clay particles in these areas compared to the study area in this research. Therefore, fine silt and clay particles were highly enriched with MOC.

Total organic carbon in soil (TOC)

TOC represents the sum of stable organic carbon (MOC) and unstable organic carbon (POC) to reflect the total amount of carbon in the soil. TOC (Table 2 and Figure 2) in L1 was highest in the surface layer (14.43 g kg^{-1}), which was significantly different ($P < 0.05$) from other land use types, possibly because it was used for vegetable cultivation. L2 had the lowest level at 5.33 g kg^{-1} due to the absence of soil vegetation cover. Total organic carbon differed significantly among all research tables at 0-15 cm. L3 and L4 did not show significant differences between them, and their levels were relatively lower compared to L1. Land cultivated with vegetable crops recorded the highest TOC, which was significantly different from uncultivated land (5.33 g/kg).

The high organic carbon in area L1 is attributed to the restoration of biomass above and below the soil surface, which was significantly higher compared to areas L2, L3, and L4. The presence of organic matter in the soil, together with the high moisture content resulting from the shade provided by trees, promotes the accumulation of organic carbon. These results are consistent with a study by Mganga (2011) in arid areas of southern Kenya, which showed that increases in carbon inputs lead to higher total organic carbon. However, some studies suggest that roots have a greater effect on organic matter content in the short term (Rumpel, 2004). Furthermore, vegetation cover helps protect the soil from surface carbon loss compared to other sites, as erosion studies have shown that protective cover reduces the effects of wind and water on surface layers (Lal, 2004). The decrease in total organic carbon in L3 and L4 may be attributed to tillage practices that destroy soil accumulation (10.94 and 7.04), indicating that the properties of organic matter at these sites promote a faster rate of decomposition of carbon inputs (Gelaw, 2015).

The presence of organic matter encourages microbial activity, contributing to an increase in total organic carbon in the soil. However, harvesting above-ground biomass for animal feed rather than leaving it as straw may lead to a decrease in total organic carbon content (Wang, 2009). In area L4, Table 1 data for the analysis of physical and chemical properties showed that organic matter content and gypsum quantity have a significant effect on carbon content, with carbon inputs being lower than outputs. Furthermore, vehicle tracks increase the apparent density of the soil, which hinders shoot growth and promotes surface runoff. and expose the area to high erosion rates (Maina, 2013), which transport total organic carbon (TOC) to the surface, as it is lighter in weight (Lal, 2008; Were, 2015). Franzluebbers (2000) showed that grasslands have a greater capacity to store total organic carbon than other areas. The lower TOC in L3 and L4 compared to L1 can be explained by the distribution of plant root systems, as plant species influence the vertical distribution of organic carbon (Jobbágy, 2000; Jackson, 2000). Grasses are characterized by shallow roots, while shrubs have deeper roots, which explains the high TOC in L1 and low TOC in L4 in the subsurface layers. The presence of shrub roots in the lower horizons enhances the concentration of total organic carbon through root exudates, microbial soil biomass, and hydrogen removal activity (Cao, 2015). Some studies also indicate that short grass cultivation has a greater effect on organic matter accumulation than shrubs and reduces the impact of soil erosion caused by climatic factors (Lalitha, 2016).

Table2. carbon management index

Sample symbol	**POC** *g kg^{-1}*	**MOC** *g kg^{-1}*	**TOC** *g kg^{-1}*	**CMI** **%**
L1R1	4.67	9.35	14.02	56.08
L1R2	4.87	9.75	14.62	58.48
L1R3	4.78	9.57	14.35	57.41
L1R4	4.92	9.84	14.76	59.04
L2R1	1.85	3.75	5.61	22.44
L2R2	1.75	3.51	5.26	21.04
L2R3	1.71	3.42	5.13	20.52
L2R4	1.78	3.56	5.34	21.36
L3R1	3.77	7.54	11.31	45.24
L3R2	3.51	7.02	10.53	42.12
L3R3	3.88	7.76	11.64	46.56
L3R4	3.43	6.86	10.29	41.16
L4R1	2.77	5.54	8.31	33.24

L4R2	2.08	4.16	6.24	24.96
L4R3	2.38	4.76	7.14	28.56
L4R4	2.16	4.32	6.48	25.2
L.S.D.	0.0136	0.752	0.931	1.0524

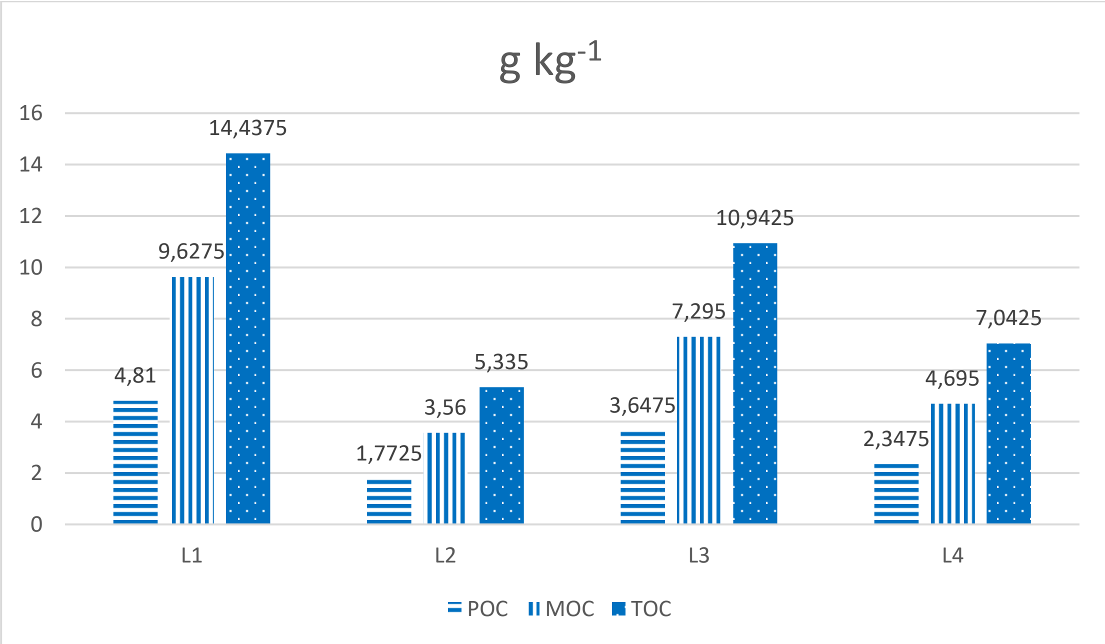

Figure 2. carbon parts index

Carbon Management Index (CMI)

As shown in Table 2 and Figure 3, the Carbon Management Index (CMI) was highest in area L1, which was planted with vegetables, while it was lowest in area L2, which was unused. For other areas, the CMI was highest in L3 and lowest in L4. In this study, the CMI was adopted as a reference type for land use assessment. CMI was highest in L1 (57.75%), followed by L3 with 43.77% and L4 with 27.99%, compared to unused L2, which was 21.34% at a depth of 0-15 cm.
Carbon Management Index (CMI)

The highest values were recorded for L1, L3, and L4 (Table 2 and Figure 3). This is because L2 provides a less oxidizing environment for organic matter, which exposes the soil to degradation. In contrast, in agriculturally exploited soils, the values were higher due to the dense canopy and protective structure of large aggregates and reduced susceptibility to erosion, which allows POC accumulation. These results are consistent with those of Blair (1996), who showed that reduced disturbance in native grasslands contributes to higher levels of total organic carbon.

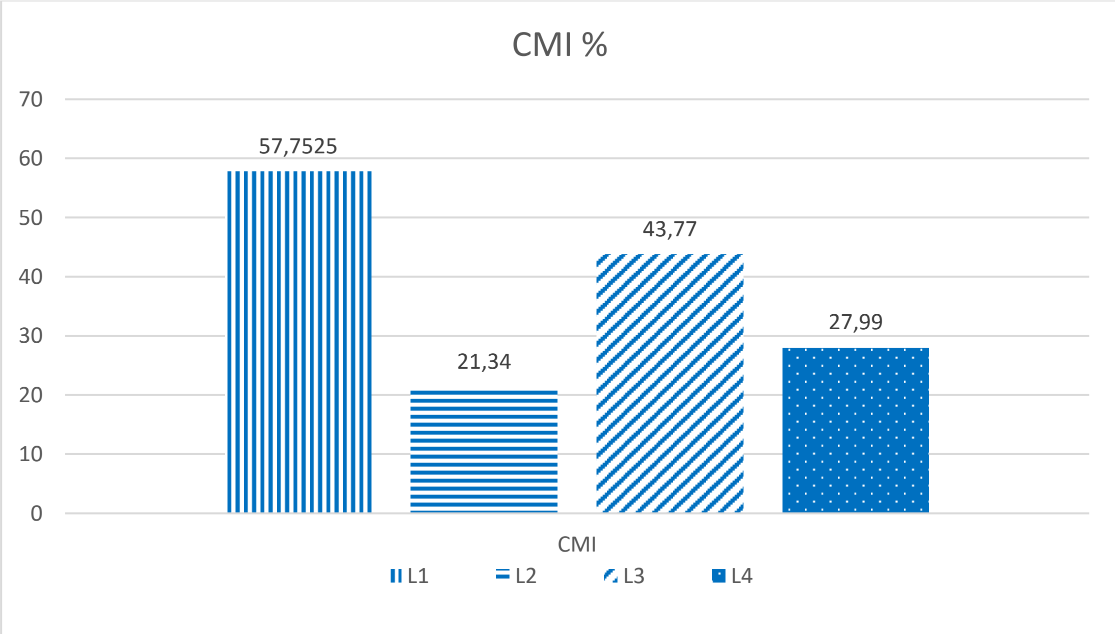

Figure 3. carbon management index

CMI values in cultivated land (AG) may be related to fertilizer use on farms, as studies have shown that nitrogen fertilizers promote biomass and increase soil organic matter content. These results are consistent with Farhan et al. (2022), who showed that barley cultivation systems with the addition of fertilizers and straw improve soil carbon retention and increase CMI.

In organic-rich soils, overgrazing has been observed to reduce carbon (C) content, attributed to a decrease in grass root biomass, leading to a decrease in CMI of grasslands (Liu, 2014). It should be noted that the CMI standard depends on the local land use in the area, with Blair (1996) suggesting that high CMI values indicate carbon rehabilitation, while low values indicate carbon content degradation. Furthermore, Benbi (2015) explained that land use with higher CMI values provides better opportunities for carbon sequestration.

CONCLUSION

This study shows that different land use patterns affect soil organic carbon pools and, consequently, the carbon management index (CMI). It is noted that the variable fraction of carbon, represented by POC, remains low across all land use types and soil depths. However, shrublands recorded the highest POC values, which is attributed to higher organic matter inputs and less disturbance compared to other areas, as shown in Tables 1 and 2. POC levels are related to fertilizer amount, crop type, gypsum amount, and moisture, so they were higher in grasslands. Unexpectedly, low POC levels are associated with high levels of overgrazing, which leads to low grass litter input, and vehicle traffic has led to soil degradation when not used for agriculture. MOC levels were higher than POC levels, due to their stability and lack of susceptibility to soil management practices.

To evaluate the sensitivity of **POC** relative to **TOC**, the **CMI** indicated that soil degradation was most severe in **L2**, followed by **L4**. These findings suggest that enhancing soil organic matter (SOM) across all land-use types can improve soil quality and help reverse degradation in agricultural soils. The study recommends immediate implementation of agricultural management practices that limit the harvesting of above-ground biomass to promote the accumulation of soil organic carbon (SOC). Furthermore, targeted soil management strategies should be adopted in agricultural areas to increase labile carbon fractions, thereby enhancing soil fertility over the long term.This study shows that different types of land use have an impact on soil organic carbon pools and, consequently, on the CMI index. The CMI index can be used as an indicator of soil degradation or improvement in response to land use and land cover changes.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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The authors have no acknowledgments to declare.

REFERENCES

Alatawi, M., Alhajoj, Y. A. A., & Abdullah, R. M. (2024). Evaluation of the performance of several cultivars of bean (Vicia faba L.) for yield and its components under three different cultivation distances. *Tikrit Journal for Agricultural Sciences*, *24*(3), 256-266.

Al-Duliami, A. A. K., Altai, S. H., & Ismaeal, A. S. (2020). Impact study of slope aspect in the boilogical crust properties of some gypsiferous soils using remote sensing and GIS. Plant Archives (09725210), 20(2).

Altai, S. H. M., & Yousif, H. M. (2024). Evaluation of the Biological and Chemical Properties of Compost Prepared from Different Plants Sources Taken from the University of Tikrit. In IOP Conference Series: Earth and Environmental Science (Vol. 1371, No. 9, p. 092002). IOP Publishing.

Altai, S. H., AL-Hamandi, H. M., Khairo, A. M., Ali, O. N., & Ortas, I. (2025). Effect of Mycorrhizal fungi inoculation on the water consumptive use, growth, and yield of barley (Hordeum Vulgare L.) under drought stress in Gypsifereous soil. *Tikrit Journal for Agricultural Sciences*, *25*(2), 177-190.

Araújo, L. G., de Sousa, D. M. G., de Figueiredo, C. C., Rein, T. A., de Souza Nunes, R., dos Santos, J. D. D. G., & Malaquias, J. V. (2019). How does gypsum increase the organic carbon stock of an Oxisol profile under sugarcane?. *Geoderma*, *343*, 196-204.

Benbi, D. K., Brar, K., Toor, A. S., & Singh, P. (2015). Total and labile pools of soil organic carbon in cultivated and undisturbed soils in northern India. *Geoderma*, *237*, 149-158.

Blair, G. J., Lefroy, R. D., & Lisle, L. (1995). Soil carbon fractions based on their degree of oxidation, and the development of a carbon management index for agricultural systems. *Australian journal of agricultural research*, *46*(7), 1459-1466.

Cao, H., Zhao, X., Wang, S., Zhao, L., Duan, J., Zhang, Z., ... & Zhu, X. (2015). Grazing intensifies degradation of a Tibetan Plateau alpine meadow through plant–pest interaction. *Ecology and Evolution*, *5*(12), 2478-2486.

de Carvalho, M., Ciarkowska, K., & Miechówka, A. (2023). Storage of persistent organic matter in temperate gypsum soils–Relevance of the parent material and vegetation cover. *Geoderma*, *435*, 116522.

Farhan, M. J., Khalefah, K. M., Altai, S. H. M., & Alsajri, F. A. (2022). The Impact of Inoculation with Azotobacter and Azospirillum Bacteria and Chemical Fertilizer on Barley Growth (Hordeum Vulgare L.). In IOP Conference

Series: Earth and Environmental Science (Vol. 1060, No. 1, p. 012001). IOP Publishing.

Franzluebbers, A. J., Stuedemann, J. A., Schomberg, H. H., & Wilkinson, S. R. (2000). Soil organic C and N pools under long-term pasture management in the Southern Piedmont USA. *Soil Biology and Biochemistry*, *32*(4), 469-478.

Gelaw, A. M., Singh, B. R., & Lal, R. (2015). Organic carbon and nitrogen associated with soil aggregates and particle sizes under different land uses in Tigray, Northern Ethiopia. *Land Degradation & Development*, *26*(7), 690-700.

Gerritse, R. G., & Van Driel, W. (1984). *The relationship between adsorption of trace metals, organic matter, and pH in temperate soils* (Vol. 13, No. 2, pp. 197-204). American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

Jackson, R. B., Canadell, J., Ehleringer, J. R., Mooney, H. A., Sala, O. E., & Schulze, E. D. (1996). A global analysis of root distributions for terrestrial biomes. *Oecologia*, *108*(3), 389-411.

Jobbágy, E. G., & Jackson, R. B. (2000). The vertical distribution of soil organic carbon and its relation to climate and vegetation. *Ecological applications*, *10*(2), 423-436.

Khalaf, A. A., Ismaeal, A. S., & Altai, S. H. (2021). Evaluation and Biological properties maps of Gypsiferous Soil using Geomatic techniques, Tikrit city, Salahaldin, Iraq. In *IOP Conference Series: Earth and Environmental Science* (Vol. 735, No. 1, p. 012067). IOP Publishing.

Lal, R. (2004). Soil carbon sequestration impacts on global climate change and food security. *science*, *304*(5677), 1623-1627.

Lal, R. (2008). Carbon sequestration. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *363*(1492), 815-830.

Lalitha, M., & Kumar, P. (2016). Soil carbon fractions influenced by temperature sensitivity and land use management. Agroforestry Systems, 90(6), 961-964

Liu, J. B., Zhang, Y. Q., Wu, B., Qin, S. G., & Lai, Z. R. (2014). Changes in soil organic carbon and its density fractions after shrub—planting for desertification control. *Polish Journal of Ecology*, *62*(2), 205-216.

Maina, J. G. (2013). Mainstreaming sustainable land management in agropastoral production systems of Kenya: Dadaab district baseline survey report.

Mganga, K. Z., Musimba, N. K., Nyariki, D. M., Nyangito, M. M., Ekaya, W. N., Muiru, W. M., & Mwang'ombe, A. W. (2011). Different land use types in the semi-arid rangelands of Kenya influence soil properties.

Page, A. L. (Ed.). (1982). *Methods of soil analysis. Part 2. Chemical and microbiological properties* (pp. 1159-pp).

Plante, A. F., Conant, R. T., Stewart, C. E., Paustian, K., & Six, J. (2006). Impact of soil texture on the distribution of soil organic matter in physical and chemical fractions. *Soil Science Society of America Journal*, *70*(1), 287-296.

Richards, L. A. (Ed.). (1954). *Diagnosis and improvement of saline and alkali soils* (No. 60). US Government Printing Office.

Rumpel, C., & Kögel-Knabner, I. (2011). Deep soil organic matter—a key but poorly understood component of terrestrial C cycle. *Plant and soil*, *338*(1), 143-158.

Sainepo, B. M., Gachene, C. K., & Karuma, A. (2018). Assessment of soil organic carbon fractions and carbon management index under different land use types in Olesharo Catchment, Narok County, Kenya. *Carbon balance and management*, *13*(1), 4.

Singh, P., Sharma, S., Nisar, S., & Choudhary, O. P. (2023). Structural stability and organic matter stabilization in soils: Differential impacts of soil salinity and sodicity. *Journal of Soil Science and Plant Nutrition*, *23*(2), 1751-1773.

Tandon, A., Bannykh, S., Kowalchyk, J. A., Banerjee, A., Martin, T. F., & Balch, W. E. (1998). Differential regulation of exocytosis by calcium and CAPS in semi-intact synaptosomes. *Neuron*, *21*(1), 147-154.

Wang, Q., Zhang, L., Li, L., Bai, Y., Cao, J., & Han, X. (2009). Changes in carbon and nitrogen of Chernozem soil along a cultivation chronosequence in a semi-arid grassland. *European Journal of Soil Science*, *60*(6), 916-923.

Were, K., Bui, D. T., Dick, Ø. B., & Singh, B. R. (2015). A comparative assessment of support vector regression, artificial neural networks, and random forests for predicting and mapping soil organic carbon stocks across an Afromontane landscape. *Ecological Indicators*, *52*, 394-403.