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Investigating the organic carbon and nitrogen stock indices and mechanical properties of soil in two land uses (northeastern Iran)

Fariba Samaei[1], and Hojat Emami[1*]

Abstract

Land use severely affects the carbon and nitrogen stock and the soil's physical, mechanical, hydraulic and chemical characteristics of the soil. This study aims to investigate the effect of land use type on some soil characteristics, including carbon stock (C_S), nitrogen stock (N_S), S-index, structural stability index (SSI), soil pore size distribution, soil shear strength (τ), internal friction angle (φ˚), shear cohesion (C), soil water characteristic curve (SWCC), relative field capacity (RFC), available water (AW), aeration porosity (AP) and effective porosity (P_e) in Shandiz city, Khorasan Razavi province (northeast Iran) was studied. For this purpose, 60 soil samples were taken from the surface layer (0-20 cm) in pasture and agricultural land uses. The results showed that S-Index, SSI, RFC, AW, P_e, C_s, and N_s in pasture land use were significantly higher than agricultural land use. The values of τ, C, and φ˚ in the pasture land use were significantly ($p<0.01$) less than the pasture land use. The relationship between soil organic carbon stock index and bulk density (r=-0.69), coarse fragments (r=-0.73), cohesion (r=-0.70), and internal friction angle (r=-0.52) were significant and negative. The amounts of carbon and nitrogen stock indices in pasture land use were 61.6 and 33.1 % greater than agricultural land use, respectively. Therefore, it can be concluded that as a result of land use change, the carbon and nitrogen stock, S-index, relative field capacity, structural stability index, available water, aeration porosity, effective porosity, and consequently, the soil quality decrease, and soil degradation increase in agricultural land use.

Keyword: S - Index, Carbon stock, Shear strength, Internal friction angle, Relative field capacity, Land use.

1. Introduction

The type of land use is one of the most important factors of land destruction, which affects the quality and quantity of soil organic carbon and is very influential on the stock or loss of soil carbon and nitrogen (Dwibedi et al., 2022; Gholoubi et al., 2019). Land use is the second leading factor

[1] Department of Soil Science, Faculty of Agriculture, Ferdowsi University of Mashhad, Mashhad, Islamic Republic of Iran.
*Corresponding author, e-mail: hemami@um.ac.ir

for carbon emissions after the combustion of fossil fuels. It significantly affects the dynamics of organic carbon and soil nitrogen and environmental pollution (Parras et al., 2013).

Soil is a fundamental source of organic carbon and nitrogen in terrestrial ecosystems. One of the most important land ecosystems for carbon stock is pastures, which make up half of the world's land and contain more than a third of the terrestrial biosphere's carbon reserves. Although the amount of carbon stock in pastures per unit area is small, due to their large size, these lands have a great ability to store carbon (Yimer et al., 2007). Poeplau and Don (2013) reported that carbon stock in pasture land use was more than agricultural land use. Breuer et al. (2006) found that the average difference of carbon and nitrogen stock in the 20 cm layer of the soil surface in pasture and agricultural lands was about 22 ton/ ha.

Soil shear strength is one property that affects the traction capacity of off-road devices and strength force against tillage tools (Zhao et al., 2009). Soil shear strength affects other inherent soil characteristics, including erodibility and machine-soil relationships. Johnson et al. (1987) found that the soil surface's shear strength controls the soil's erodibility. Yamaguchi et al., (2022) found that rill erodibility decreased with increasing shear strength and it can be represented by a linear function of shear strength. They demonstrated that shear strength measurement can be used to quickly estimate the effect of soil conditioners on rill erodibility in the field.

The soil conditions are controlled by the shear strength of the soil surface when it reaches the threshold of erosion by the furrow flow (Raus and Govers., 1988; Svoboda and McCartney., 2014). The soil's shear (mechanical) strength changes rapidly when the soil moisture varies (Bachman et al., 2006). The shear strength of the soil is related to the soil structure, and it's considered as the most important properties of soil engineering. A change in these parameters can affect the soil's resistance to agricultural machines (Zhao et al., 2009). The shear strength of soil is a function of management and land use type. Changing the dynamic properties of soil, including structure, pore size distribution, moisture, total porosity, compaction, and bulk density in agricultural land use due to tillage operations and the agricultural machinery, can change the mechanical resistance of the soil (Ouyang et al., 2018). Also, the destruction of soil structures reduces the soil's water-holding capacity. It increases the cohesion coefficient and internal friction angle, which leads to an increase in the shear strength of the soil (Amiri et al., 2018; Bachman et al., 2006).

The slope of the characteristic curve of soil water at the inflection point (S-Index) is one of the indicators of soil physical quality (Dexter, 2004; Emami et al., 2012). The S-index is sensitive to the type of land use change and also the management factors such as tillage, compaction, and cropping (Dexter and Czyz, 2007; Reynolds et al., 2009). Soil organic matter is often expressed as organic carbon of soil, and its amount is influenced by land use and management practices. Soil is the main reservoir of carbon in terrestrial ecosystems (Scharlemann et al., 2014). Human activities, land use, and management have led to a significant reduction of soil carbon. Also, the type of land use usually has long-term effects on the soil's physical, mechanical, hydraulic, biological, and chemical properties. Investigating the impact of land use on soil function is possible through changes in the soil quality indicators. The type of land use usually has long-term effects on the soil's physical, mechanical, hydraulic, biological, and chemical properties especially organic matter. Evaluating the effect of land use on soil function is one of the necessary processes to achieve sustainable soil management in agricultural ecosystems. Therefore, the objectives of this research were to I) compare the organic carbon and nitrogen stock indices in pasture and agricultural land uses and II) compare some physical and mechanical properties of soil in two land uses of pasture and agriculture in semi-arid regions in northeastern Iran.

2. Materials and methods

2.1. Characteristics of the study area and soil sampling

This research was carried out in Shandiz city, northwest of Khorasan Razavi province, with a longitude of 59˚ 25′ 0″ E and latitude of 36˚ 25′ 0″ N in two land uses of pasture (natural and virgin with little grazing) and agriculture (15 years of rainfed wheat cultivation). Plowing, irrigation, and fertilization were not made in the pasture land use because the pasture was natural and virgin, but agriculture lands are plowed by Moldboard and rainfed wheat is cultivated from15 years age. Nitrogen and phosphorus fertilizers are applied in agricultural lands (100 kg/ha mono ammonium Phosphate in autumn when seeds and 100 Kg/ha Urea in spring. The selected points (in each pair of sampling points for agricultural and pasture lands) had similar geology, climate, physiography, and topography conditions. Based on the soil taxonomy key, the studied soils are Aridisols (SSS, 2022). The soil crops used in pasture and agricultural land were Alhagi maurorum and Triticum aestivum, respectively. The soil samples were randomly taken using a soil core to obtain a sample for each land use (Fig. 1). 120 soil samples were collected from agricultural and pasture land uses (60 undisturbed core samples and 60 disturbed samples of each land use) from the soil surface layer (0-20 cm).

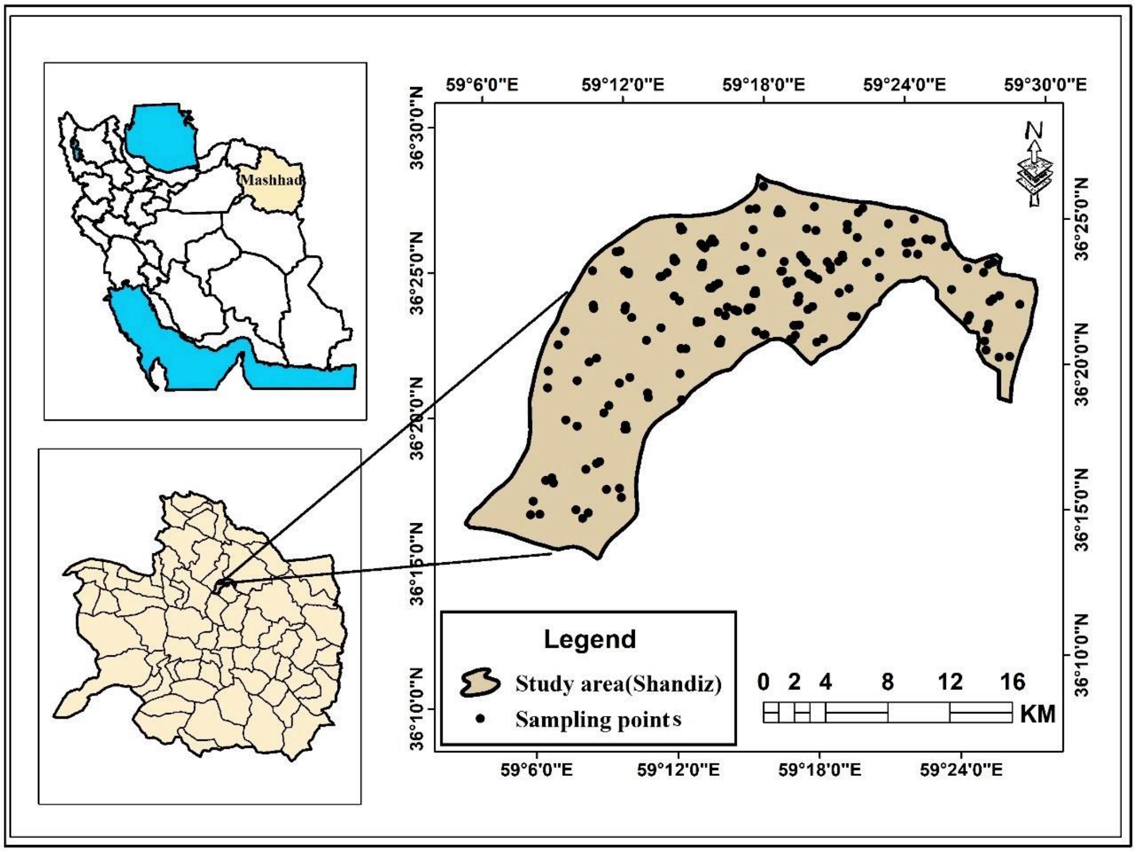

Figure 1. Location of study area.

2.2. Laboratory analyses

Soil organic carbon was determined through the Walkley-Black method (Nelson and Summers, 1982). Soil bulk density was determined using undisturbed core samples (Blacke and Hartge, 1986). The coarse fraction (>2 mm) was determined by passing through a 2 mm sieve (Wiesmeier et al., 2012; Simon et al., 2018). Total soil nitrogen was determined using Kjeldahl (Page et al., 1982). The carbon stock (C_S) and the nitrogen stock (N_S) indices were calculated using Equations 1 and 2, respectively (Simon et al., 2018):

$$C_s\ (Mg\ ha^{-1}) = (SOC\ (\%))(BD\ (g\ cm^{-3}))(1 - CF)(D\ (cm)) \quad (1)$$

$$N_s\ (Mg\ ha^{-1}) = (N\ (\%))\ (BD\ (g\ cm^{-3}))\ (1 - FC)\ (D\ (cm)) \quad (2)$$

Where, CF is coarse fraction, D is soil depth (0 – 20 cm), BD is bulk density, N and SOC are total nitrogen and soil organic carbon percentage, respectively (Simon et al., 2018).

To determine the S-index, the Van Genuchten equation was fitted to the laboratory data of the water characteristic curve using the software program (RETC) (Dexter, 2004). In order to measure the water characteristic curve, the amount of moisture in the matric suctions of 0,20,40,60, 80 100, 330,500, 1000, 1500, 3000, 5000, 10000 and 15000 hectopascals using the sand box and the pressure plate apparatus was measured. Then S index was calculated from Equation 3.

$$S_{\text{Index}} = \left| -n\,(\theta_s - \theta_r)\left[1 + \frac{1}{m}\right]^{-(1+m)} \right| \quad (3)$$

Where S is the slope of the soil moisture characteristic curve at the inflection point, θ_s and θ_r are the gravimetric saturated and residual moisture, respectively. n and m are the parameters of the soil moisture curve in the Van Genuchten equation.

The stability index of the soil structure (SSI) was calculated using the values of organic matter, silt and clay as bellow (Pieri, 1992).

$$SSI = \left(\frac{OM}{\text{Clay} + \text{Silt}}\right) \times 100 \quad (4)$$

The pore diameter corresponding to each suction was calculated from the capillary relationship (Equation 5), then the percentages of macro-pores (MacP, > 75 µm), meso-pores (MesP, 30 to 75 µm) and micro-pores (MicP, < 30 µm) were determined using the Equations, 6, 7 and 8, respectively (Danielson and Sutherland, 1986).

$$\text{d} = \frac{0.3}{\text{d}} \quad (5)$$

Where, h (cm) is the applied suction and d (cm) is the diameter of the pore corresponding to each suction.

$$\text{MacP} = \left(\frac{\theta_S - \theta_{0.04}}{\theta_S}\right) \times 100 \quad (6)$$

$$\text{MesP} = \left(\frac{\theta_{0.04} - \theta_{0.1}}{\theta_S}\right) \times 100 \quad (7)$$

$$\text{MicP} = \left(\frac{\theta_{0.1} - \theta_{\infty}}{\theta_S}\right) \times 100 \quad (8)$$

Where, θ_s ($m^3\ m^{-3}$) is saturated moisture, $\theta_{0.04}$, $\theta_{0.1}$ and θ_{∞} ($m^3\ m^{-3}$) are the moisture contents at the suction of 40 hPa, 100 hPa, and the infinity suction ($\theta_{\infty} = 0$), (Danielson and Sutherland, 1986).

A direct shear apparatus was used to measure the shear strength of the soil. The gravimetric moisture content of the samples was determined before and after the shear strength test (Blacke and Hartge, 1986). The soil samples were placed in the direct shear box (internal cross section of 6 × 6 cm and a height of 2 cm). First, a mass of 10 kg was applied to measure soil shear stress, then masses of 20 and 30 Kg were applied to measure the shear stress of the soil. The Mohr-Coulomb failure criterion (equation 9) was used to calculate shear strength parameters (Zhang et al., 2001). To find shear cohesion and the soil's internal friction angle and establish the Mohr-

Coulomb linear failure criterion, shear stress was plotted as a function of normal stress (at loads of 10, 20, and 30 kg).

$$\tau_{(\mathrm{kPa})} = \mathrm{C}_{(\mathrm{kPa})} + \sigma_{(\mathrm{kPa})} \tan \varphi_{(°)} \quad (9)$$

Where, τ (kPa) is shear strength, C (kPa) is shear cohesion, σ (kPa) is the normal stress applied on the soil sample (applied load divided by the area), φ (˚) is the internal friction angle and tan φ is the coefficient of friction and indicates the slope of the line, which is denoted by μ.

Relative field capacity (RFC) was calculated using Equation 10 (Reynolds and Topp, 2008).

$$RFC = \frac{\theta_{FC}}{\theta_S} \quad (10)$$

Where, θ_{FC} (m^3m^{-3}) is the soil moisture content at the field capacity (h =100 hPa) and θ_s (m^3 m^{-3}) is the saturated soil moisture (h = 0).

Available water (AW) was calculated using Equation 11 (White, 2006).

$$AW_{(m^3m^{-3})} = \theta_{FC} - \theta_{PWP} \quad (11)$$

Where θ_{FC} (m^3m^{-3}) is the soil moisture at the field capacity (h =100 hPa) and θ_{PWP} (m^3 m^{-3}) is the soil moisture at the permanent wilting point (h= 15000 hPa).

Aeration porosity (AP) was calculated using Equation 12 (White, 2006).

$$A_P\ (m^3m^{-3}) = \theta_S - \theta_{FC} \quad (12)$$

Where θs (m^3 m^{-3}) is the saturated soil moisture content and θ_{FC} (m^3m^{-3}) is the soil moisture content at the field capacity (h = 100 hPa).

The effective porosity (Pe) was calculated using Equation 13 (White, 2006).

$$P_e = P_t - \theta_{FC} \quad (13)$$

Where P_t (%) is total porosity, θ_{FC} (m^3m^{-3}) is the soil moisture content at the field capacity (h = 100 hPa), BD (g/cm^3) is bulk density, and DP (2.65 g/cm^3) is particle density.

2.3. Statistical analysis of data

Before the statistical analysis, the Kolmogorov-Smirnov test checked the data's normality. The independent-sample t-test evaluated soil characteristics in pasture and agricultural land uses. Statistical analyses were performed using JMP version 8 software. The graphs were plotted using Excel software.

3. Results and discussion

3.1. Carbon and nitrogen stock indices

The type of land use had a significant effect ($p< 0.001$) on the carbon and nitrogen stock indices. The carbon and nitrogen stock indices in pasture land use were significantly greater than the agricultural land use (Fig 2), so that these indices in pasture land use were 61.6 % and 33.1% more in compared to the agriculture land use, respectively. The lower carbon and nitrogen stock indices in agricultural land use can be due to the low content organic carbon and harvesting of plant residues in agricultural land use, total soil nitrogen, and more coarse fragments compared to the pasture land use (Table 1). The value of organic carbon and total nitrogen in agricultural land use was 31.8% and 14.3% lower than pasture land use, respectively, and coarse fragments in agricultural land use was 34.8% higher than the pasture land use (Table 1).

Agricultural operations, massive cultivation and removal of plant residues from the soil surface in agricultural land use increase soil degradation and erosion, and decrease soil organic matter due to runoff and erosion, as a result, the amount of soil organic carbon and soil total nitrogen decreases (Deneve and Hofman., 2000). Carbon and nitrogen stock indices in soil are affected by land use, soil organic matter, soil texture, soil structure, soil porosity, and bulk density. An increase in organic matter improves the structure and porosity of the soil and reduces the bulk density, which reduces runoff and erosion and increases the storage of carbon and nitrogen in the soil (Gebeyehu and Soromessa, 2018). The stock of organic carbon and soil nitrogen directly affects soils' physical, mechanical, chemical, and biological characteristics. Also, the self-restoration capacity of the soil significantly depends on the amount and quality of soil organic carbon (Martin et al., 2016). In general the stabilization mechanisms of SOC are three key ways: 1) occlusion of organic carbon within soil aggregates (Six et al. 2002); 2) interaction of SOC with the soil mineral particles particularly clay and silt (Mikutta et al., 2007); 3) molecular structure of organic carbon influenced by environmental factors, which in turn, affects the relative resistance to decomposition (Assunção et al., 2019). The increased amount of soil aggregates facilitates the physical protection of SOC from microbial decomposition and mineralization (Razafimbelo et al., 2008).

There was a positive and significant correlation between the carbon and nitrogen stock indices with soil porosity. However, there is a significant negative correlation between the soil's organic carbon and nitrogen stock indices and the bulk density. Land use often determines the amount of carbon input to the soil. The soil's organic carbon and nitrogen stocks are variable due to the net balance between input and output by carbon emission dioxide, dissolved organic matter, and carbon loss through soil erosion. Management practices such as tillage and plowing, cause to break down the soil aggregates and expose organic matter to microbial decomposition. Because the aeration of agricultural soils is more than that of pasture soils, which accelerates the oxidation of organic matter and increases and consequently reduces soil carbon and nitrogen stock (Don et al., 2011). Zach et al., (2006) found that soil carbon decreased by 35% to 56% after 3-5 years of agriculture practices. Therefore, land use and management practices can prevent the destruction of soil structure and increase the ability to stock organic carbon and nitrogen in the soil. Also, one of the valuable to estimate the amount of organic carbon stock in the soil as the main source of carbon stock in the terrestrial ecosystem is to study the amount and distribution of soil organic carbon stocks in different regions using various methods because soil organic carbon has a high temporal and spatial variability (Francaviglia et al., 2017).

The crop cover is one of the important and main factors of carbon and nitrogen inputs into the soil and increases soil carbon and nitrogen stocks in the long term. Also, the presence of crop cover improves the soil quality (physical, hydraulic, biological and chemical properties) by reducing the erosion of fine soil particles and the compaction of compacted soil (Samaei et al., 2024; Derner and Schuman, 2007). In arid and semi-arid regions, due to the low content of the plant residues and their oxidation in agricultural lands, the amount of soil organic carbon and nitrogen stock is generally low (Wang, et al., 2012).

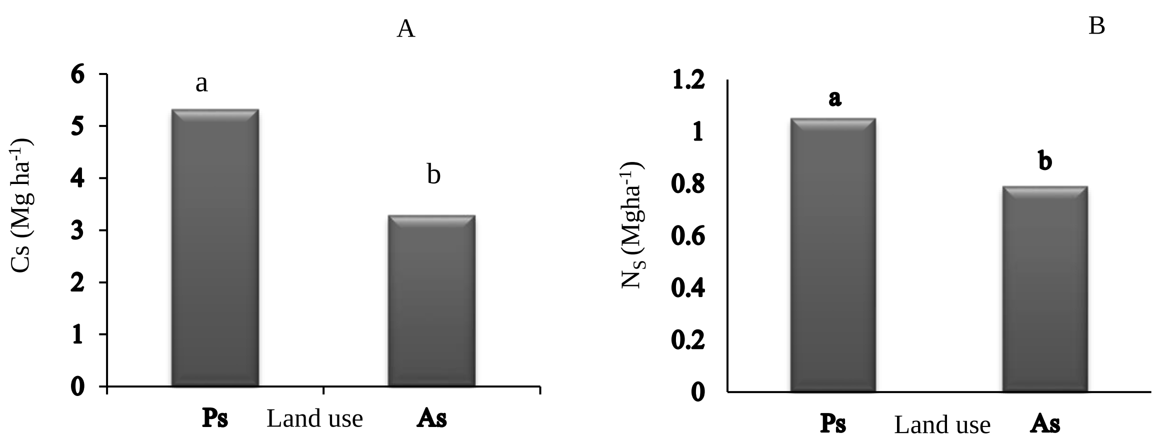

Figure 2. The effect of land use type on carbon stock index (C_S) (A) and nitrogen stock index (N_S) (B) in pasture land use (P_s) and agricultural land use (A_s).

3.2. Physical and hydraulic properties of soil

The results of statistical analysis showed that the values S-index, effective porosity, structural stability index, and available water in agricultural land use were significantly ($p < 0.001$) lower than the pasture land use (Table 1). The value of S-index, effective porosity, structural stability index and available water in pasture land use were 40%, 19.4 %, 52.7 % and 15.3 % higher than the agricultural land use, respectively. The higher values of S-index, Pe, SSI and AW in pasture land use compared to agricultural land use can be due to the high percentage of soil porosity in pasture land use (Table 1). Because the S-Index, effective porosity, and available water are directly related to soil porosity and soil moisture curve, the soil structure stability index is indirectly associated with soil pore volume through the amount of organic carbon and soil texture (Dexter, 2004; Reynolds et al., 2009, Farahani et al., 2022). Small structural pores mainly cause the S-index, which directly affects many critical soil characteristics. Physical quality in soils with dominant textural pores is very weak; therefore, the presence of structural pores and, as a result, large amounts of S are necessary for proper soil quality. Using the S-index as an index of physical soil quality allows for direct comparison of different soils and the impacts of different treatments and management conditions (Dexter, 2004). Also, the amount of organic matter and soil porosity were correlated positively. There was a positive significant correlation (Table 3) between soil organic carbon, nitrogen stock indices and soil porosity ($r = 0.68$, $p < 0.01$ and $r = 0.70$, $p < 0.01$). During the time, organic compounds (containing low density) decay, and mineral materials with a high density remain, which changes the soil porosity. The S-index and total porosity had a significant positive correlation ($r = 0.37$). Also, the total porosity of the soil in pasture land use was higher (15.1 %) than in agricultural land use. In soils under cultivation, due to the agricultural practices and traffic of agricultural machines on the soil surface, the soil structure is destroyed, and the soil porosity is reduced.

Table 1. Statistical description of some soil characteristics in pasture and agriculture land uses at a depth of 0-20 cm.

Soil Characteristics	Unit	Pasture land use					Agricultural land use				
		Min	Mean	Max	SD	CV(%)	Min	Mean	Max	SD	CV(%)
Clay	%	17.50	19.69*	22.86	1.57	7.97	15.55	18.73*	21.58	1.66	8.86
Silt	%	30.32	34.71**	39.52	2.11	6.09	25.48	31.96**	38.77	2.91	9.08
Sand	%	37.62	45.59**	50.04	2.98	6.54	41.69	49.31**	57.73	3.75	7.60
BD	g/cm^3	1.31	1.39**	1.47	0.04	2.88	1.44	1.52**	1.65	0.05	3.28
SOC	g/kg	1.76	2.67**	3.9	0.47	17.60	0.98	1.82**	2.53	0.36	19.78
FC	%	26.70	34.70**	43.16	4.17	12.01	39.81	46.78**	59.25	5.24	11.20
P_t	%	44.41	47.16**	48.76	1.25	2.65	38.34	40.99**	43.55	1.51	3.68
N	ppm	525	556.96**	595	18.81	3.37	441	477.40**	511	18.05	3.78
θ_m	%	6.10	6.74**	7.50	0.54	8.34	5.50	5.60**	5.70	0.08	1.43

**: Significant at the 1% probability level, *: significant at the 5% probability level, BD: bulk density, SOC: soil organic carbon, FC: coarse fraction, P_t: soil total porosity, N: soil total nitrogen, Θ_m: gravimetric water content, Min: minimum, Max: maximum, SD: standard deviation, CV: coefficient of variation.

On the other hand, coarse aggregates are broken, turn into smaller aggregates and fill the pore space, as a result, the number of air-filled pores and the S-index decrease. In pasture soils, stable, coarse and developed soil aggregates, due to the plant residues, higher organic matter and lower traffic, the structural porosity of the soil and the S-index increase. The results of this study confirmed that the S- index differentiates the effect of land use and soil management systems. S-Index is especially useful for evaluating and monitoring land use and management systems' impact on soil structure destruction and recovery and soil quality (Imaz et al., 2010). Soils with coarse aggregates and interconnected pores generally have a higher S-index than soils with small individual pores (Tormena et al., 2008). Celik (2005) has shown that the density caused by cultivation in agricultural lands increases bulk density and decreases porosity compared to pasture lands.

Dexter (2004) has divided the soils into 3 classes based on the soil physical quality index (S-index): 1- $S < 0.02$ very weak and no root growth, 2- $0.02 \leq S \leq 0.035$ weak and root growth is low, 3- $S > 0.035$ is good and the root grows sufficiently. According to the classification of Dexter (2004) and the obtained results (Table 1), the studied soils of both pasture and agricultural land use have good physical quality. The SSI values in different soils vary from zero to infinity (0-∞), while SSI > 9% indicates stable soil structure. One of the most important factors of soil structure stability is organic carbon. According to the results, the amount of organic carbon in pasture land use was higher than that in agricultural land use. Therefore, the stability of soil structure in pasture land use was higher than that in agricultural land use (Table 1). There was a positive, significant correlation between soil organic carbon and S-Index (r = 0.48), soil stability index (r = 0.77), and total porosity (r = 0.90). Also, SOC shows the critical role of SOM in soil physical quality (Table 3). It has been demonstrated that the soils with proper structure have more available water in conditions with the same texture compared to the soils with weak structure (Asgarzadeh et al., 2010; Farahani et al., 2020). According to the amount of AW, the soils are classified into three groups: 1- dry or weak AW< 0.10 m3 m-3, 2- limited 0.10 ≤ AW < 0.15 m3 m-3, and 3- good 0.15 ≤ AW < 0.2 m3 m-3 (White, 2006). According to the results, the AW in the pasture soils was more significant than 0.15 m3 m-3. Therefore, they have no limitation of AW, while agricultural soils are limited for AW value.

Table 2. Mean comparisons of soil characteristics in pasture and agriculture land uses at a depth of 0-20 cm.

Soil Characteristics	Unit	Pasture land use				Agricultural land use			
		Min	Mean	Max	SD	Min	Mean	Max	SD
S-Index	-	0.04	0.07^a	0.13	0.02	0.03	0.05^b	0.08	0.01
Pe	%	12.11	22.97^a	29.60	3.46	14.66	19.24^b	24.35	2.70
SSI	%	0.61	0.86^a	1.22	0.12	0.22	0.56^b	0.80	0.11
AP	m^3m^{-3}	7.27	10.97	16.46	2.85	7.32	10.11	13.56	1. 56
MacP	%	7.43	14.94	24.34	5.25	10.21	15.97	27.94	4.48
MesP	%	10.18	16.13	23.94	3.80	10.29	15.88	22.66	3.56
MicP	%	57.26	68. 91	80.52	7.16	54.38	68.13	77.06	4.74
RFC	-	0.57	0.69	0.81	0.07	0.54	0.68	0.77	0.04
AW	m^3m^{-3}	0.12	0.15^a	0.22	0.02	0.09	0.13^b	0.16	0.01

S-Index: is the slope of the soil moisture curve at the inflection point, Pe: is effective porosity, SSI: is structure stability index, AP: is aeration porosity, MacP: is macro pores, MesP: is meso pores, MicP: is micro pores, RFC: relative field capacity, AW: Available water, Min: Minimum, Max: Maximum, SD: standard deviation, Different letters in each column represent the significant differences between pasture and agriculture land uses.

Table 3. Correlation coefficient between soil organic carbon stock index (C_S) and some physical and mechanical soil parameters.

Variables	BD	SOC	SII	S-Index	C	φ	θ_m	P_t	N_S
SOC	-0.769**								
SII	-0.620**	0.765**							
S-Index	-0. 317*	0.481**	0.486**						
C	0. 687**	-0.851**	-0.669**	-0.409**					
φ	0.626**	-0.734**	0.469**	-0.227	0.572**				
θ_m	-0.742**	0.824**	0.641**	0.343**	-0.801**	-0.630**			
P_t	-0.726**	0.895**	0.647**	0.371**	-0.774**	-0.704**	0.773^{*8}		
N_S	-0.702**	0.797**	0.605**	0.398**	-0.743**	0.703**	0.630**	0.704**	
C_S	-0.699**	0.826**	0.846**	0.557**	-0.702**	-0.521**	0.632**	0.684**	0.780**

**: Significant at the 1% probability level, *: significant at the 5% probability level, BD: bulk density, SOC: soil organic carbon, P_t: soil total porosity, Ɵm: gravimetric water content, S-Index: is the slope of the soil moisture curve at the inflection point, SSI: is structure stability index, C: is shear cohesion, φ: is the internal friction angle, N_S: nitrogen stock index, C_S: carbon stock index.

3.3. Shear strength of the soil

An example of the variation for the horizontal displacement due to the strain stress in two land uses has been shown in Figure 3. Due to the compression of the soil, the curve has a specific breaking point and after that the amount of shear stress decreases. According to this figure, the value of shear stress reduction in agricultural land use after the breaking point is faster than pasture land use, which may be due to greater compaction of the soil (higher bulk density (9.4 %) than pasture land use). However, in pasture land use, shear stress reduction occurs after at a slow speed after the breaking point. An increase in the applied normal load from 10 to 30 kg increases the soil's compaction and thus density, which leads to an increase in particle interaction as a result of an increase in shear stress (Fig. 3). If a soil sample is subjected to shear displacement, the role of displacement in shear strength measurements strongly depends on the state of soil compaction (Komandi, 1992; Tabari et al., 2019).

The results of this research showed that there was a significant difference ($p < 0.001$) between the values of shear cohesion (C), internal friction angle (φ) and gravimetric water content (θ_m) in two land uses (pasture and agriculture). The results of mean comparison showed that shear cohesion (C) and internal friction angle (φ) in agricultural land use were 42.1 and 11.5 % higher than pasture land use, respectively (Fig. 5). Therefore, the shear stress in the pasture land use is lower than the agricultural land use. By reducing the shear stress of the soil, the force and power required to perform tillage operations are reduced (Yokoi, 1968). Lower soil moisture in agricultural land use can be the reason for the higher indices of soil shear strength, shear cohesion and internal friction angle, compared to pasture land use (Table 1).

The shear cohesion of the soil depends on the molecular resistance of water and the amount of water between the soil particles. The texture of the studied soils is loamy, and in loamy soils, water molecules reduce the cohesion and internal friction angle, but in clay and sandy soils, water molecules increase the indices of shear strength (Komandi, 1992; Tabari et al., 2019). Increasing shear cohesion with decreasing the water content can create stronger bonds between the mineral particles of the soil. On the other hand, when thes oil water content increases, the frictional resistance between soil particles decreases. Greater total porosity in pasture land use (15.1 %) compared to agricultural land use can be another reason for the lower internal friction angle in pasture land use, because the internal friction angle decreases when total soil porosity increases (Terzaghi, 1959; Mun et al., 2016). Figure 4 shows an example of maximum shear cohesion versus vertical loads. Shear cohesion is the intercept on the y-axis of the Mohr-Coulomb shear strength line. Shear cohesion is the shear resistance when the compressive stresses are equal to zero. Shear cohesion in pasture land use was lower than agricultural land use (Fig. 5). The results showed that there was a significant negative correlation (Table 3) between gravimetric water content and shear cohesion (r = - 0.80) and internal friction angle (r = - 0.63). Also, a significant negative correlation was found between total porosity and shear stress (r= -0.77) and internal friction angle (r= -0.70). Zhao et al (2009) found that clay particles swell and disperse more easily when soil moisture increases, thereby shear stress between soil particles reduces. Also, swelling the clay particles with increasing moisture content reduces the internal friction (cohesion forces between the particles), and as a result, the shear strength of the soil decreases. As soil moisture increases, water acts as a lubricant between the soil particles, prevents from contacting the soil particles and reduces the internal friction angle. Some researchers, such as Zhao et al (2009), Amiri et al (2018) and Bachman et al (2006) found that when soil moisture increases, shear strength and internal friction angle decrease. Another factor that affects the internal friction angle of soil is compaction (the degree of soil particles compaction), which is represented by bulk density. According to the results of this research, the value of bulk density in agricultural land use was 9.4% higher than the pasture land use (Table 1). when the bulk density of the soil increases, the compaction and then the internal friction angle of the soil particles increases (Maruf, 2012). A positive and significant correlation (Table 3) was found between bulk density and shear stress (r = 0.69) and internal friction angle (r = 0.63). The pasture land use had the higher more moisture content, higher total porosity, and lower bulk density than the agricultural land use. As a result, the shear cohesion and internal friction angle in this land use were lower than in the agricultural land use (Fig. 4), and the shear strength in pasture land use was less than agricultural land use.

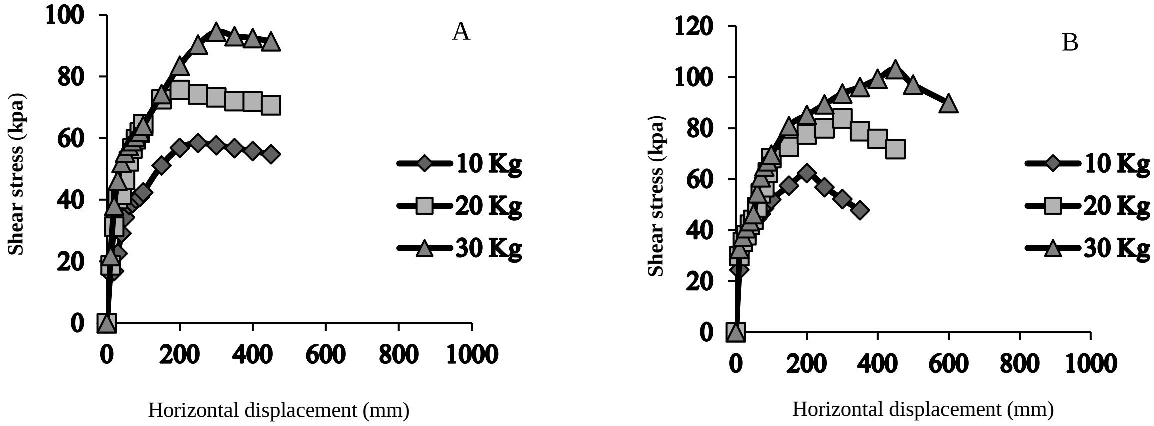

Figure 3. An example of the variation of horizontal displacement due to the strain stress. A: pasture land use, B: agricultural land use.

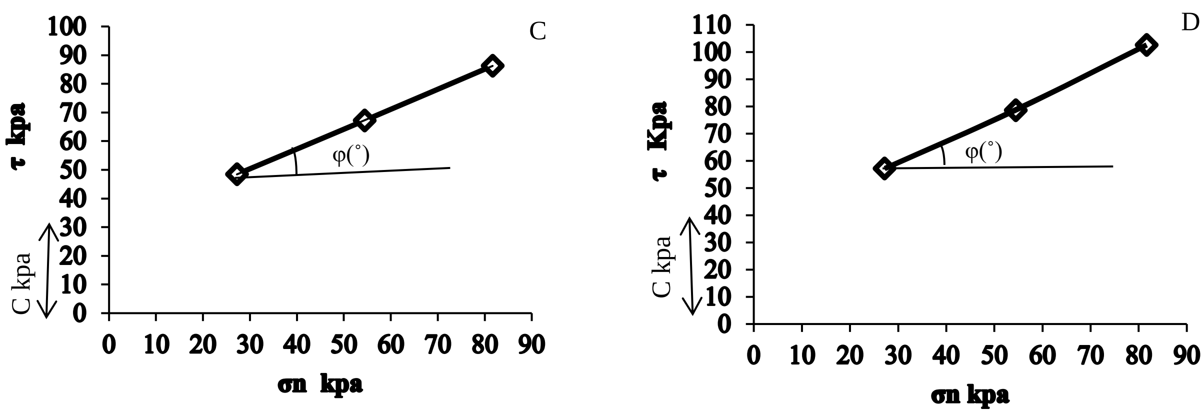

Figure 4. Example of Mohr-Columb failure envelope in two land uses, C pasture land use, D: agricultural land use.

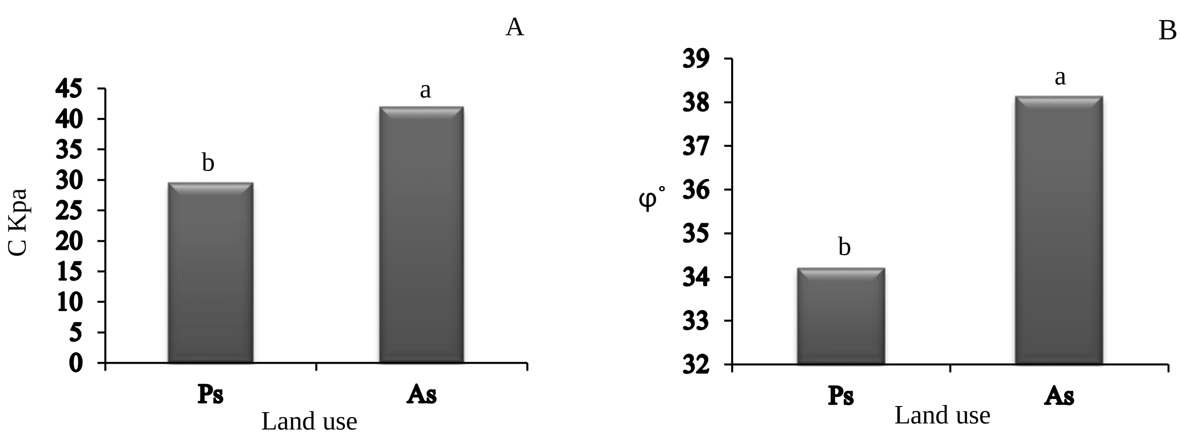

Figure 5. Effect of land use type on shear cohesion (A) and internal friction angle (B).

4. Conclusions

The findings of this research showed that land use type can change soil attributes including soil carbon stock (C_S), nitrogen stock (N_S) contents, and indices of soil strength, so that in agricultural land use due to tillage operations, reduction of vegetation and soil organic matter, the values of the carbon and nitrogen stock indices, soil structure stability index, effective porosity, available water, S-index were lower than pasture land use. Also, due to the higher moisture content, higher total porosity, and lower bulk density, the shear cohesion and internal friction angle in the pasture land use were lower than agricultural land use. The indices of shear strength, organic carbon and nitrogen stock indices are strongly influenced by land use and management practices. The type of land use that does not consider its effects on soil quality can destroy the environment quality. Unfortunately, land exploitation systems have often been used without recognizing their impact on soil conservation and environmental quality. As a result, they have faced a severe decrease in soil quality worldwide. Therefore, considering the impact of land use on soil properties as one of the critical and essential resources for human life, we should pay more attention to the type of land use and management in order to prevent soil degradation.

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