

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

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5 **Abstract**

6 Land use severely affects the carbon and nitrogen stock and the soil's physical, mechanical,  
7 hydraulic and chemical characteristics of the soil. This study aims to investigate the effect of land  
8 use type on some soil characteristics, including carbon stock ( $C_s$ ), nitrogen stock ( $N_s$ ), S-index,  
9 structural stability index (SSI), soil pore size distribution, soil shear strength ( $\tau$ ), internal friction  
10 angle ( $\varphi^\circ$ ), shear cohesion (C), soil water characteristic curve (SWCC), relative field capacity  
11 (RFC), available water (AW), aeration porosity (AP) and effective porosity ( $P_e$ ) in Shandiz city,  
12 Khorasan Razavi province (northeast Iran) was studied. For this purpose, 60 soil samples were  
13 taken from the surface layer (0-20 cm) in pasture and agricultural land uses. The results showed  
14 that S-Index, SSI, RFC, AW,  $P_e$ ,  $C_s$ , and  $N_s$  in pasture land use were significantly higher than  
15 agricultural land use. The values of  $\tau$ , C, and  $\varphi^\circ$  in the pasture land use were significantly ( $p < 0.01$ )  
16 less than the pasture land use. The relationship between soil organic carbon stock index and bulk  
17 density ( $r = -0.69$ ), coarse fragments ( $r = -0.73$ ), cohesion ( $r = -0.70$ ), and internal friction angle ( $r = -$   
18  $0.52$ ) were significant and negative. The amounts of carbon and nitrogen stock indices in pasture  
19 land use were 61.6 and 33.1 % greater than agricultural land use, respectively. Therefore, it can be  
20 concluded that as a result of land use change, the carbon and nitrogen stock, S-index, relative field  
21 capacity, structural stability index, available water, aeration porosity, effective porosity, and  
22 consequently, the soil quality decrease, and soil degradation increase in agricultural land use.

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

25  
26 **1. Introduction**

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

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

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

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

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

59 The slope of the characteristic curve of soil water at the inflection point (S-Index) is one of the  
60 indicators of soil physical quality (Dexter, 2004; Emami et al., 2012). The S-index is sensitive to

61 the type of land use change and also the management factors such as tillage, compaction, and  
62 cropping (Dexter and Czyz, 2007; Reynolds et al., 2009). Soil organic matter is often expressed as  
63 organic carbon of soil, and its amount is influenced by land use and management practices. Soil is  
64 the main reservoir of carbon in terrestrial ecosystems (Scharlemann et al., 2014). Human activities,  
65 land use, and management have led to a significant reduction of soil carbon. Also, the type of land  
66 use usually has long-term effects on the soil's physical, mechanical, hydraulic, biological, and  
67 chemical properties. Investigating the impact of land use on soil function is possible through  
68 changes in the soil quality indicators. The type of land use usually has long-term effects on the  
69 soil's physical, mechanical, hydraulic, biological, and chemical properties especially organic  
70 matter. Evaluating the effect of land use on soil function is one of the necessary processes to  
71 achieve sustainable soil management in agricultural ecosystems. Therefore, the objectives of this  
72 research were to I) compare the organic carbon and nitrogen stock indices in pasture and  
73 agricultural land uses and II) compare some physical and mechanical properties of soil in two land  
74 uses of pasture and agriculture in semi-arid regions in northeastern Iran.

75

## 76 2. Materials and methods

### 77 2.1. Characteristics of the study area and soil sampling

78 This research was carried out in Shandiz city, northwest of Khorasan Razavi province, with a  
79 longitude of 59° 25' 0" E and latitude of 36° 25' 0" N in two land uses of pasture (natural and virgin  
80 with little grazing) and agriculture (15 years of rainfed wheat cultivation). Plowing, irrigation, and  
81 fertilization were not made in the pasture land use because the pasture was natural and virgin, but  
82 agriculture lands are plowed by Moldboard and rainfed wheat is cultivated from 15 years ago.  
83 Nitrogen and phosphorus fertilizers are applied in agricultural lands (100 kg/ha mono ammonium  
84 Phosphate in autumn when seeds and 100 Kg/ha Urea in spring). The selected points (in each pair  
85 of sampling points for agricultural and pasture lands) had similar geology, climate, physiography,  
86 and topography conditions. Based on the soil taxonomy key, the studied soils are Aridisols (SSS,  
87 2022). The soil crops used in pasture and agricultural land were *Alhagi maurorum* and *Triticum*  
88 *aestivum*, respectively. The soil samples were randomly taken using a soil core to obtain a sample  
89 for each land use (Fig. 1). 120 soil samples were collected from agricultural and pasture land uses  
90 (60 undisturbed core samples and 60 disturbed samples of each land use) from the soil surface  
91 layer (0-20 cm).

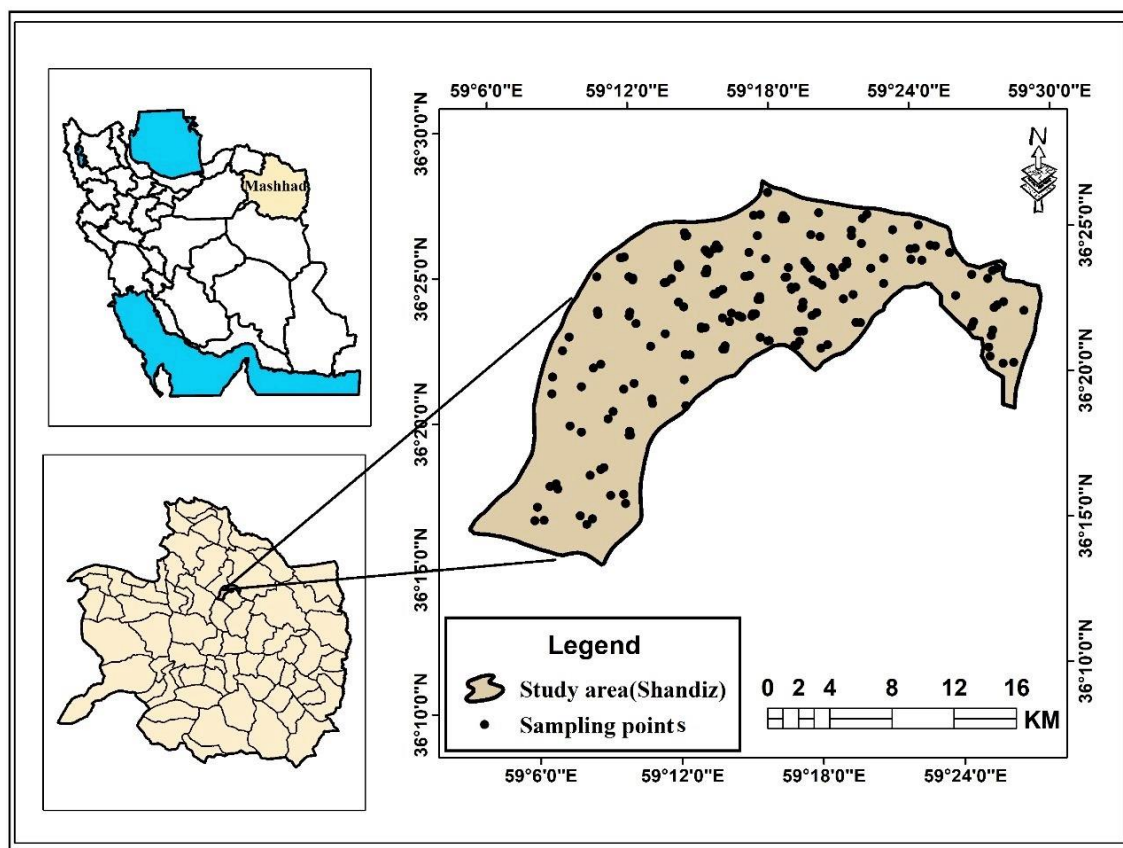


Figure 1. Location of study area.

## 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,

108 330,500, 1000, 1500, 3000, 5000, 10000 and 15000 hectopascals using the sand box and the  
109 pressure plate apparatus was measured. Then S index was calculated from Equation 3.

$$110 S_{\text{Index}} = \left| -n (\theta_s - \theta_r) \left[ 1 + \frac{1}{m} \right]^{-(1+m)} \right| \quad (3)$$

111 Where S is the slope of the soil moisture characteristic curve at the inflection point,  $\theta_s$  and  $\theta_r$  are  
112 the gravimetric saturated and residual moisture, respectively. n and m are the parameters of the  
113 soil moisture curve in the Van Genuchten equation.

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

$$116 SSI = \left( \frac{OM}{\text{Clay} + \text{Silt}} \right) \times 100 \quad (4)$$

117 The pore diameter corresponding to each suction was calculated from the capillary relationship  
118 (Equation 5), then the percentages of macro-pores (MacP,  $> 75 \mu\text{m}$ ), meso-pores (MesP, 30 to 75  
119  $\mu\text{m}$ ) and micro-pores (MicP,  $< 30 \mu\text{m}$ ) were determined using the Equations, 6, 7 and 8,  
120 respectively (Danielson and Sutherland, 1986).

$$121 d = \frac{0.3}{d} \quad (5)$$

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

$$124 \text{MacP} = \left( \frac{\theta_s - \theta_{0.04}}{\theta_s} \right) \times 100 \quad (6)$$

$$125 \text{MesP} = \left( \frac{\theta_{0.04} - \theta_{0.1}}{\theta_s} \right) \times 100 \quad (7)$$

$$126 \text{MicP} = \left( \frac{\theta_{0.1} - \theta_{\infty}}{\theta_s} \right) \times 100 \quad (8)$$

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

129 A direct shear apparatus was used to measure the shear strength of the soil. The gravimetric  
130 moisture content of the samples was determined before and after the shear strength test (Blacke  
131 and Hartge, 1986). The soil samples were placed in the direct shear box (internal cross section of  
132  $6 \times 6 \text{ cm}$  and a height of 2 cm). First, a mass of 10 kg was applied to measure soil shear stress,  
133 then masses of 20 and 30 Kg were applied to measure the shear stress of the soil. The Mohr-  
134 Coulomb failure criterion (equation 9) was used to calculate shear strength parameters (Zhang et  
135 al., 2001). To find shear cohesion and the soil's internal friction angle and establish the Mohr-

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

$$138 \tau_{(\text{kPa})} = C_{(\text{kPa})} + \sigma_{(\text{kPa})} \tan \varphi(^{\circ}) \quad (9)$$

139 Where,  $\tau$  (kPa) is shear strength,  $C$  (kPa) is shear cohesion,  $\sigma$  (kPa) is the normal stress applied on  
140 the soil sample (applied load divided by the area),  $\varphi$  ( $^{\circ}$ ) is the internal friction angle and  $\tan \varphi$  is  
141 the coefficient of friction and indicates the slope of the line, which is denoted by  $\mu$ .

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

$$143 RFC = \frac{\theta_{FC}}{\theta_s} \quad (10)$$

144 Where,  $\theta_{FC}$  ( $\text{m}^3\text{m}^{-3}$ ) is the soil moisture content at the field capacity ( $h=100$  hPa) and  $\theta_s$  ( $\text{m}^3\text{m}^{-3}$ )  
145 is the saturated soil moisture ( $h=0$ ).

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

$$147 AW_{(\text{m}^3\text{m}^{-3})} = \theta_{FC} - \theta_{PWP} \quad (11)$$

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

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

$$151 A_p (\text{m}^3\text{m}^{-3}) = \theta_s - \theta_{FC} \quad (12)$$

152 Where  $\theta_s$  ( $\text{m}^3\text{m}^{-3}$ ) is the saturated soil moisture content and  $\theta_{FC}$  ( $\text{m}^3\text{m}^{-3}$ ) is the soil moisture content  
153 at the field capacity ( $h=100$  hPa).

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

$$155 P_e = P_t - \theta_{FC} \quad (13)$$

156 Where  $P_t$  (%) is total porosity,  $\theta_{FC}$  ( $\text{m}^3\text{m}^{-3}$ ) is the soil moisture content at the field capacity ( $h=$   
157  $100$  hPa),  $BD$  ( $\text{g}/\text{cm}^3$ ) is bulk density, and  $DP$  ( $2.65$   $\text{g}/\text{cm}^3$ ) is particle density.

158

### 159 2.3. Statistical analysis of data

160 Before the statistical analysis, the Kolmogorov-Smirnov test checked the data's normality. The  
161 independent-sample t-test evaluated soil characteristics in pasture and agricultural land uses.

162 Statistical analyses were performed using JMP version 8 software. The graphs were plotted using  
163 Excel software.

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### 166 3. Results and discussion

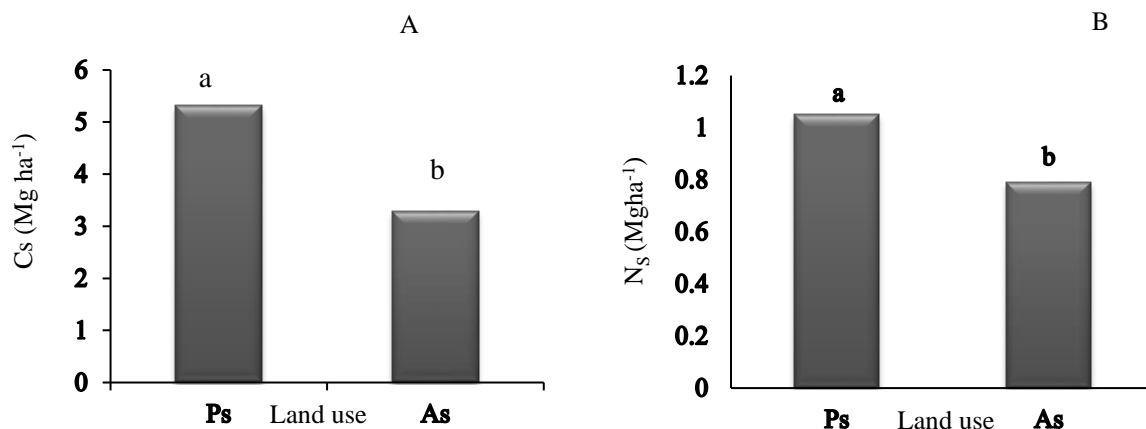
#### 167 3.1. Carbon and nitrogen stock indices

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

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

193 There was a positive and significant correlation between the carbon and nitrogen stock indices  
194 with soil porosity. However, there is a significant negative correlation between the soil's organic  
195 carbon and nitrogen stock indices and the bulk density. Land use often determines the amount of  
196 carbon input to the soil. The soil's organic carbon and nitrogen stocks are variable due to the net

197 balance between input and output by carbon emission dioxide, dissolved organic matter, and  
 198 carbon loss through soil erosion. Management practices such as tillage and plowing, cause to break  
 199 down the soil aggregates and expose organic matter to microbial decomposition. Because the  
 200 aeration of agricultural soils is more than that of pasture soils, which accelerates the oxidation of  
 201 organic matter and increases and consequently reduces soil carbon and nitrogen stock (Don et al.,  
 202 2011). Zach et al., (2006) found that soil carbon decreased by 35% to 56% after 3-5 years of  
 203 agriculture practices. Therefore, land use and management practices can prevent the destruction of  
 204 soil structure and increase the ability to stock organic carbon and nitrogen in the soil. Also, one of  
 205 the valuable to estimate the amount of organic carbon stock in the soil as the main source of carbon  
 206 stock in the terrestrial ecosystem is to study the amount and distribution of soil organic carbon  
 207 stocks in different regions using various methods because soil organic carbon has a high temporal  
 208 and spatial variability (Francaviglia et al., 2017).  
 209 The crop cover is one of the important and main factors of carbon and nitrogen inputs into the soil  
 210 and increases soil carbon and nitrogen stocks in the long term. Also, the presence of crop cover  
 211 improves the soil quality (physical, hydraulic, biological and chemical properties) by reducing the  
 212 erosion of fine soil particles and the compaction of compacted soil (Samaei et al., 2024; Derner  
 213 and Schuman, 2007). In arid and semi-arid regions, due to the low content of the plant residues  
 214 and their oxidation in agricultural lands, the amount of soil organic carbon and nitrogen stock is  
 215 generally low (Wang, et al., 2012).



216  
 217 **Figure 2.** The effect of land use type on carbon stock index (C<sub>S</sub>) (A) and nitrogen stock index (N<sub>S</sub>)  
 218 (B) in pasture land use (P<sub>s</sub>) and agricultural land use (A<sub>s</sub>).  
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 220



### 221 3.2. Physical and hydraulic properties of soil

222 The results of statistical analysis showed that the values S-index, effective porosity, structural  
223 stability index, and available water in agricultural land use were significantly ( $p < 0.001$ ) lower  
224 than the pasture land use (Table 1). The value of S-index, effective porosity, structural stability  
225 index and available water in pasture land use were 40%, 19.4 %, 52.7 % and 15.3 % higher than  
226 the agricultural land use, respectively. The higher values of S-index, Pe, SSI and AW in pasture  
227 land use compared to agricultural land use can be due to the high percentage of soil porosity in  
228 pasture land use (Table 1). Because the S-Index, effective porosity, and available water are directly  
229 related to soil porosity and soil moisture curve, the soil structure stability index is indirectly  
230 associated with soil pore volume through the amount of organic carbon and soil texture (Dexter,  
231 2004; Reynolds et al., 2009, Farahani et al., 2022). Small structural pores mainly cause the S-  
232 index, which directly affects many critical soil characteristics. Physical quality in soils with  
233 dominant textural pores is very weak; therefore, the presence of structural pores and, as a result,  
234 large amounts of S are necessary for proper soil quality. Using the S-index as an index of physical  
235 soil quality allows for direct comparison of different soils and the impacts of different treatments  
236 and management conditions (Dexter, 2004). Also, the amount of organic matter and soil porosity  
237 were correlated positively. There was a positive significant correlation (Table 3) between soil  
238 organic carbon, nitrogen stock indices and soil porosity ( $r = 0.68, p < 0.01$  and  $r = 0.70, p < 0.01$ ).  
239 During the time, organic compounds (containing low density) decay, and mineral materials with a  
240 high density remain, which changes the soil porosity. The S-index and total porosity had a  
241 significant positive correlation ( $r = 0.37$ ). Also, the total porosity of the soil in pasture land use was  
242 higher (15.1 %) than in agricultural land use. In soils under cultivation, due to the agricultural  
243 practices and traffic of agricultural machines on the soil surface, the soil structure is destroyed,  
244 and the soil porosity is reduced.

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251 **Table 1.** Statistical description of some soil characteristics in pasture and agriculture land uses at  
 252 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 <sup>3</sup>	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 <sub>t</sub>	%	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 <sub>m</sub>	%	6.10	6.74**	7.50	0.54	8.34	5.50	5.60**	5.70	0.08	1.43

253 \*\*: Significant at the 1% probability level, \*: significant at the 5% probability level, BD: bulk density, SOC: soil  
 254 organic carbon, FC: coarse fraction, P<sub>t</sub>: soil total porosity, N: soil total nitrogen, θ<sub>m</sub>: gravimetric water content, Min:  
 255 minimum, Max: maximum, SD: standard deviation, CV: coefficient of variation.

256  
 257 On the other hand, coarse aggregates are broken, turn into smaller aggregates and fill the pore  
 258 space, as a result, the number of air-filled pores and the S-index decrease. In pasture soils, stable,  
 259 coarse and developed soil aggregates, due to the plant residues, higher organic matter and lower  
 260 traffic, the structural porosity of the soil and the S-index increase. The results of this study  
 261 confirmed that the S- **index** differentiates the effect of land use and soil management systems. **S-**  
 262 **Index is especially useful for evaluating and monitoring land use and management systems' impact**  
 263 **on soil structure destruction and recovery and soil quality (Imaz et al., 2010). Soils with coarse**  
 264 **aggregates and interconnected pores generally have a higher S-index than soils with small**  
 265 **individual pores (Tormena et al., 2008). Celik (2005) has shown that the density caused by**  
 266 **cultivation in agricultural lands increases bulk density and decreases porosity compared to pasture**  
 267 **lands.**

268 Dexter (2004) has divided the soils into 3 classes based on the soil physical quality index (S-index):  
 269 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-  $S$   
 270  $> 0.035$  is good and the root grows sufficiently. According to the classification of Dexter (2004)  
 271 and the obtained results (Table 1), **the studied soils of both pasture and agricultural land use have**  
 272 **good physical quality. The SSI values in different soils vary from zero to infinity (0-∞), while SSI**  
 273 **> 9% indicates stable soil structure. One of the most important factors of soil structure stability is**  
 274 **organic carbon. According to** the results, the amount of organic carbon in pasture land use was  
 275 higher than that in agricultural land use. **Therefore, the stability of soil structure in pasture land**  
 276 **use was higher than that in agricultural land use (Table 1). There was a positive, significant**

277 correlation between soil organic carbon and S-Index ( $r = 0.48$ ), soil stability index ( $r = 0.77$ ), and  
 278 total porosity ( $r = 0.90$ ). Also, SOC shows the critical role of SOM in soil physical quality (Table  
 279 3). It has been demonstrated that the soils with proper structure have more available water in  
 280 conditions with the same texture compared to the soils with weak structure (Asgarzadeh et al.,  
 281 2010; Farahani et al., 2020). According to the amount of AW, the soils are classified into three  
 282 groups: 1- dry or weak  $AW < 0.10 \text{ m}^3 \text{ m}^{-3}$ , 2- limited  $0.10 \leq AW < 0.15 \text{ m}^3 \text{ m}^{-3}$ , and 3- good  $0.15$   
 283  $\leq AW < 0.2 \text{ m}^3 \text{ m}^{-3}$  (White, 2006). According to the results, the AW in the pasture soils was more  
 284 significant than  $0.15 \text{ m}^3 \text{ m}^{-3}$ . Therefore, they have no limitation of AW, while agricultural soils  
 285 are limited for AW value.

286  
 287 **Table 2.** Mean comparisons of soil characteristics in pasture and agriculture land uses at a depth  
 288 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 <sup>a</sup>	0.13	0.02	0.03	0.05 <sup>b</sup>	0.08	0.01
Pe	%	12.11	22.97 <sup>a</sup>	29.60	3.46	14.66	19.24 <sup>b</sup>	24.35	2.70
SSI	%	0.61	0.86 <sup>a</sup>	1.22	0.12	0.22	0.56 <sup>b</sup>	0.80	0.11
AP	$\text{m}^3 \text{m}^{-3}$	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	$\text{m}^3 \text{m}^{-3}$	0.12	0.15 <sup>a</sup>	0.22	0.02	0.09	0.13 <sup>b</sup>	0.16	0.01

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

293  
 294 **Table 3.** Correlation coefficient between soil organic carbon stock index ( $C_s$ ) and some physical  
 295 and mechanical soil parameters.

Variables	BD	SOC	SII	S-Index	C	$\varphi$	$\theta_m$	$P_t$	$N_s$
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**					
$\varphi$	0.626**	-0.734**	0.469**	-0.227	0.572**				
$\theta_m$	-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* <sup>8</sup>		
$N_s$	-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**

296 \*\*: Significant at the 1% probability level, \*: significant at the 5% probability level, BD: bulk density, SOC: soil  
 297 organic carbon,  $P_t$ : soil total porosity,  $\theta_m$ : gravimetric water content, S-Index: is the slope of the soil moisture curve  
 298 at the inflection point, SSI: is structure stability index, C: is shear cohesion,  $\varphi$ : is the internal friction angle,  $N_s$ :  
 299 nitrogen stock index,  $C_s$ : carbon stock index.

300

### 301 3.3. Shear strength of the soil

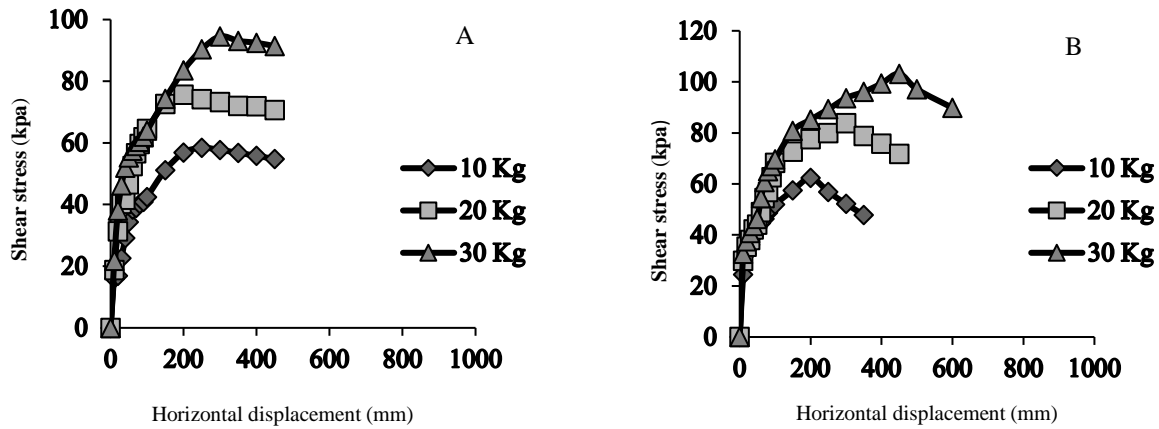
302 An example of the variation for the horizontal displacement due to the strain stress in two land  
303 uses has been shown in Figure 3. Due to the compression of the soil, the curve has a specific  
304 breaking point and after that the amount of shear stress decreases. According to this figure,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

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

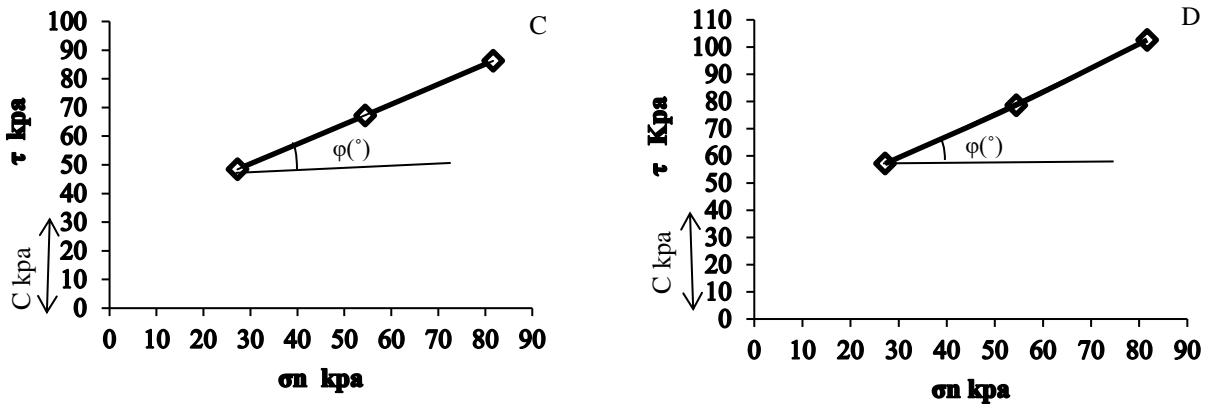
322 The shear cohesion of the soil depends on the molecular resistance of water and the amount of  
323 water between the soil particles. The texture of the studied soils is loamy, and in loamy soils, water  
324 molecules reduce the cohesion and internal friction angle, but in clay and sandy soils, water  
325 molecules increase the indices of shear strength (Komandi, 1992; Tabari et al., 2019). Increasing  
326 shear cohesion with decreasing the water content can create stronger bonds between the mineral  
327 particles of the soil. On the other hand, when the soil water content increases, the frictional  
328 resistance between soil particles decreases. Greater total porosity in pasture land use (15.1 %)  
329 compared to agricultural land use can be another reason for the lower internal friction angle in  
330 pasture land use, because the internal friction angle decreases when total soil porosity increases  
331 (Terzaghi, 1959; Mun et al., 2016). Figure 4 shows an example of maximum shear cohesion versus

332 vertical loads. Shear cohesion is the intercept on the y-axis of the Mohr-Coulomb shear strength  
333 line. Shear cohesion is the shear resistance when the compressive stresses are equal to zero. Shear  
334 cohesion in pasture land use was lower than agricultural land use (Fig. 5). The results showed that  
335 there was a significant negative correlation (Table 3) between gravimetric water content and shear  
336 cohesion ( $r = -0.80$ ) and internal friction angle ( $r = -0.63$ ). Also, a significant negative correlation  
337 was found between total porosity and shear stress ( $r = -0.77$ ) and internal friction angle ( $r = -0.70$ ).  
338 Zhao et al (2009) found that clay particles swell and disperse more easily when soil moisture  
339 increases, thereby shear stress between soil particles reduces. Also, swelling the clay particles with  
340 increasing moisture content reduces the internal friction (cohesion forces between the particles),  
341 and as a result, the shear strength of the soil decreases. As soil moisture increases, water acts as a  
342 lubricant between the soil particles, prevents from contacting the soil particles and reduces the  
343 internal friction angle. Some researchers, such as Zhao et al (2009), Amiri et al (2018) and  
344 Bachman et al (2006) found that when soil moisture increases, shear strength and internal friction  
345 angle decrease. Another factor that affects the internal friction angle of soil is compaction (the  
346 degree of soil particles compaction), which is represented by bulk density. According to the results  
347 of this research, the value of bulk density in agricultural land use was 9.4% higher than the pasture  
348 land use (Table 1). when the bulk density of the soil increases, the compaction and then the internal  
349 friction angle of the soil particles increases (Maruf, 2012). A positive and significant correlation  
350 (Table 3) was found between bulk density and shear stress ( $r = 0.69$ ) and internal friction angle ( $r$   
351  $= 0.63$ ). The pasture land use had the higher more moisture content, higher total porosity, and  
352 lower bulk density than the agricultural land use. As a result, the shear cohesion and internal  
353 friction angle in this land use were lower than in the agricultural land use (Fig. 4), and the shear  
354 strength in pasture land use was less than agricultural land use.

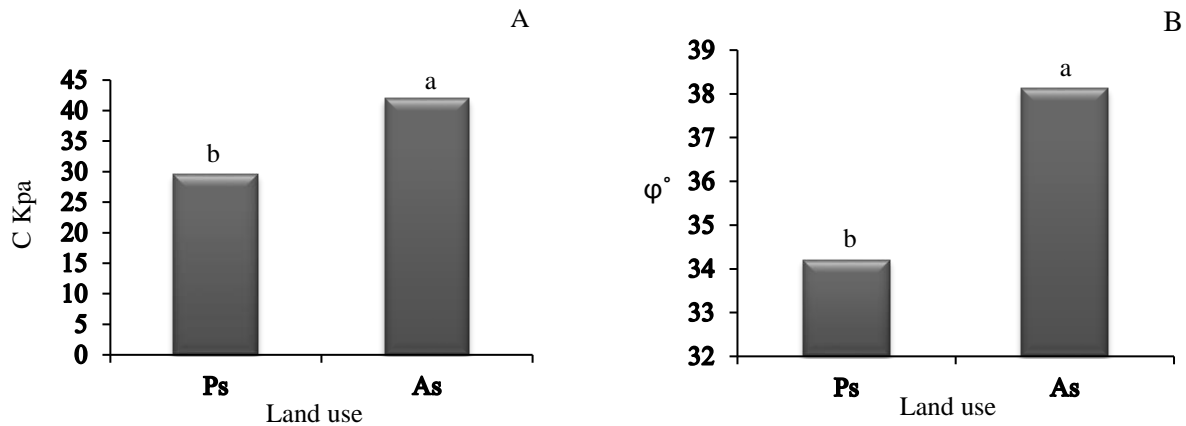
355



356  
 357 **Figure 3.** An example of the variation of horizontal displacement due to the strain stress. A: pasture  
 358 land use, B: agricultural land use.  
 359



360  
 361 **Figure 4.** Example of Mohr-Coulomb failure envelope in two land uses, C pasture land use, D:  
 362 agricultural land use.  
 363



364  
 365 **Figure 5.** Effect of land use type on shear cohesion (A) and internal friction angle (B).  
 366  
 367

368 **4. Conclusions**

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

383  
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387  
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