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Impact of land-use systems on fertility parameters and deterioration indices of soil in the sub humid Southern Plains of Rajasthan, India

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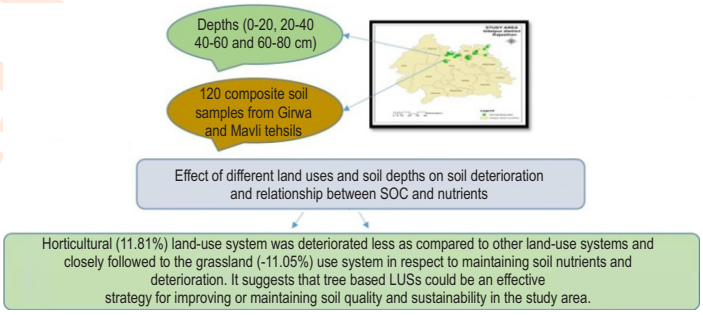
Abstract

Aim: This investigation was carried out to appraise the effect of different prevailing land-use systems (LUSs) on nutrient status along with deterioration indices of soil under sub-humid Southern Plains of Rajasthan.

Methodology: Six dominant land-use systems: barren, agricultural, agri-horticulture, horticultural, grass, and natural forest were selected in the sub-humid Southern Plains of Rajasthan. A total of 120 composite soil samples [6-LUSs, 4- soil depths (0-20, 20-40, 40-60, and 60-80 cm), and five replications] were collected for laboratory analysis. The two-way analysis of variance was used to test the effect of different LUSs and soil depths on available nutrients, essential properties with deterioration indices of soil.



Results: The results of the study showed that soil organic carbon (SOC), DTPA extractable Zn, Mn, available nitrogen, and CEC are the most degraded soil fertility parameters under studied LUSs. Barren land-use has led to the highest decline in Zn (75%), SOC (71%), N (66%), Cu (62%) and Fe (57%), followed by Agricultural land-use that has led to a decline in SOC (53%), Zn (46%), N (43%) and Mn (38%). The use of soil deterioration indices revealed that soils deteriorated slightly under grassland and horticultural LUSs (-11.05 and -11.81 %). However, moderate deterioration was observed in the agri-horticulture land-use soil (-22.51 %) while severe (-28.11%) and extremely severe deterioration (-47.50%) occurred under agricultural and barren LUSs, respectively.

Interpretation: The result of this study implies that consistent cultivation without appropriate land-use management practices in the cultivated LUS aggravates the deterioration of soil organic carbon and essential soil fertility parameters. These results suggested that restoration of barren and agricultural lands into horticultural, agri-horticulture, and grassland-uses consequently decreased soil disturbance which could be an effective strategy for improving or maintaining the soil quality and sustainability in the study area.

Key words: Deterioration indices, Land-use system, Soil depth, Soil nutrients

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Introduction

Soil is an essential source of mineral nutrients for agricultural production that is non renewable under constant cultivation due to crop removal and leaching and erosional losses if appropriate LUSs are not followed (Chandrakala *et al.,* 2018). The major ramification of indecorous LUS sare declension of soil quality and debasement of land through loss of vegetation cover, infiltration capacity, soil organic carbon, nutrients and natural regeneration capacity, which are highly critical for soil health (Moges *et al.,* 2013). Management of LUSs also affects soil properties and the process of soil erosion. Giacometti *et al.* (2021) stated that a suitable land-use with appropriate crop rotation can increase the available macro and micronutrients along with carbon stock with positive impact on soil quality. Changes in LUSs have primarily been associated with changes in soil properties. Don and Schumacher (2011) described that when tropical cropland is transformed into grassland or fallow land, the soil organic carbon stock rise by 25 and 32.2 percent within 40 cm and 20 cm soil depths, respectively. This finding indicates that land-use changes can affect soil nutrients, which has been also confirmed by Rolando *et al.* (2018). Further, agricultural LUSs may also affect the biological properties of soil through the effect of tillage practices and the use of fertilizers and agrochemicals on soil microbes.

Understanding how soil nutrients contradict by dissimilar LUSs has become an essential point of many ecological researches (Seastedt *et al.,* 1991; Wang *et al.,* 2001). Hence, characterizing special variability and distribution of soil nutrients concerning land-use changes is very important for predicting rates of soil nutrient deterioration and ecosystem processes. Soil deterioration (DI) indices reflect the variances in soil fertility parameters for different LUSs (Wang *et al.,* 2001). DI shows the percent changes (negative or positive) in soil properties under a new land-use management practice from values obtained in the natural LUS (Lemenih *et al.,* 2005; Gebresamuel *et al.,* 2020). Usually, various LUSs are recommended by researchers based on specific objectives and farmers arepracticing these alternate LUSs in their respective regions. However, the information on the impact of adopted LUSs on soil properties and their deterioration in the sub-humid Southern Plains of Rajasthan region is too scanty to recommend ideal and sustainable uses of land resources. Thus, evaluating the impact of these LUSs on soil fertility parameters and their deterioration concerning the regional conditions may provide useful information for adopting strategies for restoring soil quality and promoting the potential LUSs. This study was carried out to assess the variability in available soil nutrients along with DTPA extractable soil micronutrients and their deterioration indices under different prevailing LUSs in the sub-humid Southern Plain zone of Rajasthan.

Materials and Methods

Study area: This study was conducted in the Mavli and Girwa tehsils of Udaipur district under the sub-humid Southern Plain zone of Rajasthan in 2019-20. Udaipur district is located in the southern part of Rajasthan between 23° 50' and 25° 05' N latitude and 73°05' and 74°40'E longitude. It is mainly discontinuous hill tracts in the south (87.8%) and upland (12.2%) in the eastern part. Selected sites in the Mavli and Girwa tehsils represent the district's eastern upland and Aravalli landscape physiography, respectively. The locations of sampling sites of different LUSs are presented in Fig. 1. The climatic condition of the region is subtropical, characterized by mild winters and distinctive summers accompanied by high relative humidity, especially from July to September. The mean annual rainfall of the region varies from 630 to 800 mm, mainly during July to September. The mean maximum and minimum temperature was 35.45 and 17.41ºC. However, the last decade's mean maximum and minimum temperature was 31.33 and 17.14ºC, while the mean annual rainfall was 801.31 mm, respectively.

Selection of representative prevailing land-use systems: A preliminary survey coupled with participatory tools like field observations, transect walk, formal and informal group discussion with the farmers, and researchers from the department of agriculture was used to identify the dominant LUSs for the study. The primary data on crop cultivation, planting history, and nutrient management of identified LUSs were collected from the farmers. The selected LUSs and their description are given in Table 1.

Soil sampling and analysis: Based on the availability of LUSs, the numbers of sampling sites were determined. The soil samples were randomly collected from different 5 to 10 points as per the area and homogeneity of the LUSs and made the composite soil samples for each site. The sampling sites were considered as a replication of sampling from different LUSs. Accordingly, a total of 120 composite soil samples [6-LUSs, 4-soil depth (0-20, 20-40, 40-60, and 60-80 cm), with 5- replications] were collected for laboratory analysis in the month of October 2019. The collected soil samples from individual replications of different land-use systems were thoroughly mixed, air-dried, grind, and passed through a 2.0 mm sieve and kept in labeled polythene bags for laboratory analysis. Five replicates were analyzed from each composite soil sample in the laboratory to determine different soil parameters.

The soil samples from different LUSs were analyzed in the laboratory for various soil parameters following the standard procedures. The soil pH was determined in a 1: 2 :: soil: water suspension using an Elico-glass electrode digital pH meter (Richards, 1954) whereas electrical conductivity was measured in the supernatant liquid of 1: 2 :: soil: water suspension with the help of conductivity bridge. The calcium carbonate content was determined using the rapid titration method (Puri, 1930); soil organic carbon was measured by the wet oxidation method as outlined by Walkley and black (1934); The CEC of the soil was measured by extraction with ammonium acetate; The alkaline permanganate oxidation method was used to determine the available nitrogen through the Kjeldahl distillation unit (Subbiah and Asija, 1956). Available phosphorus in the soil was measured calorimetrically with a $SnCl_2$ blue colour reagent after extraction of

soil samples using 0.5 M $NaHCO_3$ at pH 8.5 (Olsen *et al.,* 1954). Available potassium was determined using a flame photometer after extraction of soil samples with neutral normal ammonium acetate (Jackson, 1973). The available micronutrients (Zn, Fe, Mn, and Cu) in soil were determined with the help of atomic absorption spectrophotometer after extraction of soil samples with DTPA-$CaCl_2$-TEA extracting solution (Lindsay and Norvell, 1978).

Deterioration indices of soil: Deterioration indices were determined according to Ekanade (1991) to assess the rate of deterioration of the soil properties in the investigation. The difference between mean values of individual soil parameters under the studied LUSs compared to base values of soil parameters under the reference site (Natural forest LUS) was computed and expressed as a percentage of base values of individual soil parameters. These percentage values were averaged across all the soil parameters to calculate the overall soil deterioration index under a particular LUS.

Where:

$$DI=\frac{X-Xi}{X}*100$$

X= is the mean value of soil parameters in the reference land-use (Natural forest land-use)

Xi= is the mean values of soil parameters under compared land-use

Statistical analyses: The obtained data were statistically analyzed by using SPSS 16.0. LUSs and soil depth were assumed as independent variables (factors) and different measurable soil parameters as dependent variables in the study. The significant differences in soil parameters with LUS and soil depths were tested by Two-way ANOVA. Tukey's honest significant difference (HSD) test was employed for mean separation when ANOVA showed statistically significant results ($P<0.05$). A simple correlation analysis was also employed to study the associations among different soil parameters.

Results and Discussion

The results of the study showed notable variations in the soil pH among different LUSs and the soil depths ($P \leq 0.05$) (Table 2). The highest mean soil pH was recorded in the soil of barren land (8.27), followed by agricultural (8.26), agri-horticulture (2.26) and the lowest in the grassland soil (7.74). On the whole, 5.81 to 6.85 percent reduction was noticed in soil pH under grassland soil compared to cultivated (horticulture, agriculture, and agri-horticulture) as well as barren LUSs. The soil pH ranged from 7.74 to 8.27 showing lightly alkaline conditions under all the studied LUSs. Irrespective of different LUSs, the soil pH increased with the soil depths from 7.92 in 0-20 cm soil depth to 8.27 in 60-80 cm soil depth. Reduction in soil pH under grass and cultivated land-use soil compared to barren land-use might be due to the exhaustion of base-forming cations through leaching and uptake by the plants and more microbial oxidation that releases some organic acids, which eventually reduce the soil pH to some extent (Mohammed *et al.,* 2005; Chauhan *et al.,* 2014). Soil pH was increased with the increasing soil depth under studied LUSs.

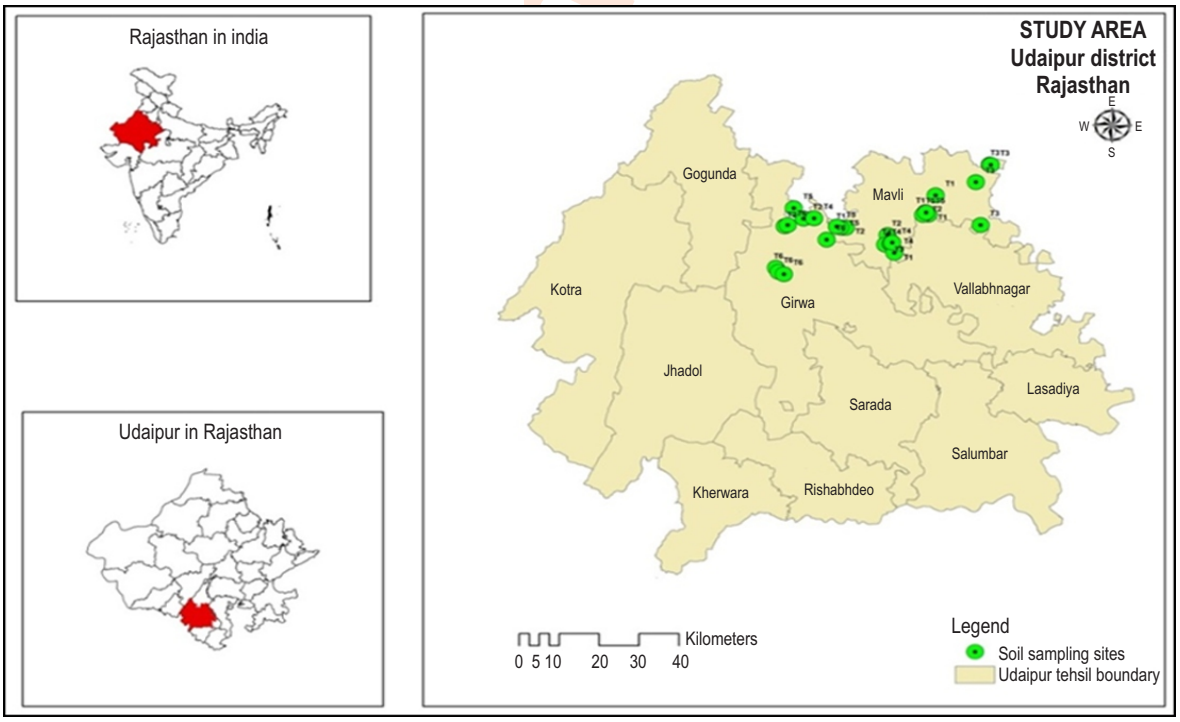

Fig.1: Location map of the study area.

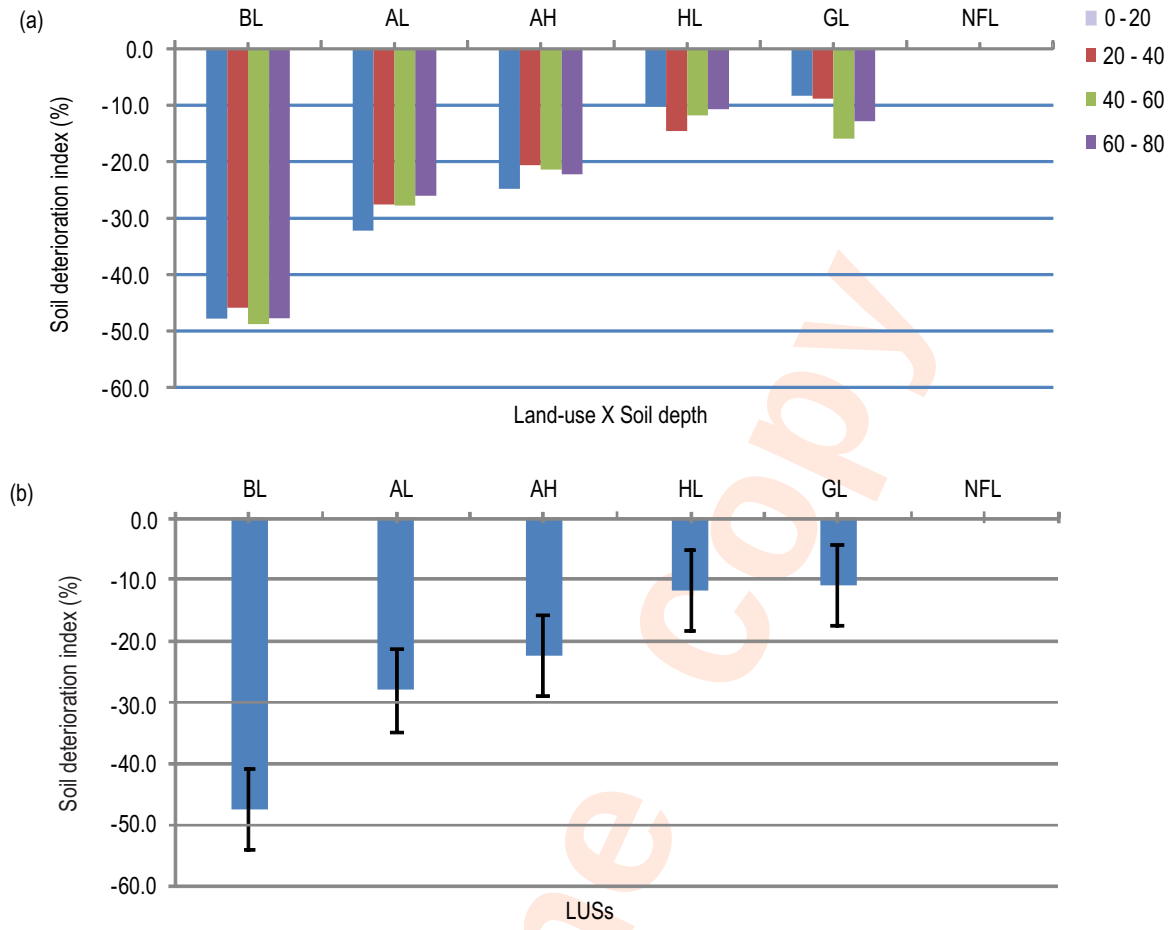

Fig. 2: Effect of different LUSs and soil depths on soil deterioration indices in the study area. Error bars show standard error. BL= Barren land, AL= Agricultural land, AH= Agri-horticulture, HL= Horticultural land, GL= Grassland, NFL= Natural forest LUSs.

This trend of variability in pH of the soil indicated the increase in bases with the increase in soil depth that might be due to the downward movement of solutes by leaching within the soil profile. This result is in line with the findings of Malo *et al.* (2005), who concluded that soil pH increased with the soil depth, which is associated with higher carbonate levels and lower weathering rates. Electrical conductivity of soil was also significantly affected by different LUSs, soil depths, and their interaction effects ($P \leq 0.05$). The interaction effects of land-use types with soil depth revealed the highest EC at the sub-surface soil layer (60-80 cm) of barren land (0.148 dsm^{-1}) soil whereas the lowest EC was found at the surface soil layer of grassland (0.095 dsm^{-1}) soil (Table 2). Regarding soil depth effects, no definite trend was observed across the LUSs. The lowest EC in the grass LUS might be associated with the leaching of basic cations through water percolation as grassland had higher soil permeability. This result is supported with the findings of Mesele *et al.* (2006), who reported the lower EC in the grassland soils as compared to the croplands, bush lands, and bushed-grasslands. The EC ranged from 0.104 to 0.144 dsm^{-1} under the studied LUSs which showed that the concentration of soluble salts were below the critical levels at which growth and productivity of most of the cultivated crops are not affected and this indicates that the EC is not the limiting factor for plant growth and productivity of crops in the study area.

Soil organic carbon content (SOC) showed significant variations with LUSs, soil depths and their interaction effects ($P \leq 0.05$) (Table 2). The SOC content under different LUSs ranged from 1.94 to 6.58 g kg^{-1} with the highest (6.58 g kg^{-1}) in the natural forest land-use followed by grassland (5.13 g kg^{-1}) and horticultural (5.09 g kg^{-1}) LUSs, whereas the lowest (1.94 g kg^{-1}) was in the barren land-use. Further, the results showed that natural forest LUS contained two to three times more SOC than agricultural and barren land-use soils. It could be due to the higher biomass of plants at below and above ground, recalcitrance of leaf litter and plant root biomass of natural forest trees (Jha *et al.,* 2012). Among the cultivated LUSs, the greater amount of SOC in the horticultural land-use might be due to higher addition of plant biomass into the soil in the form of leaf litter residue as well as less disturbance compared to other LUSs (Mandal *et al.,* 2020). Loss of

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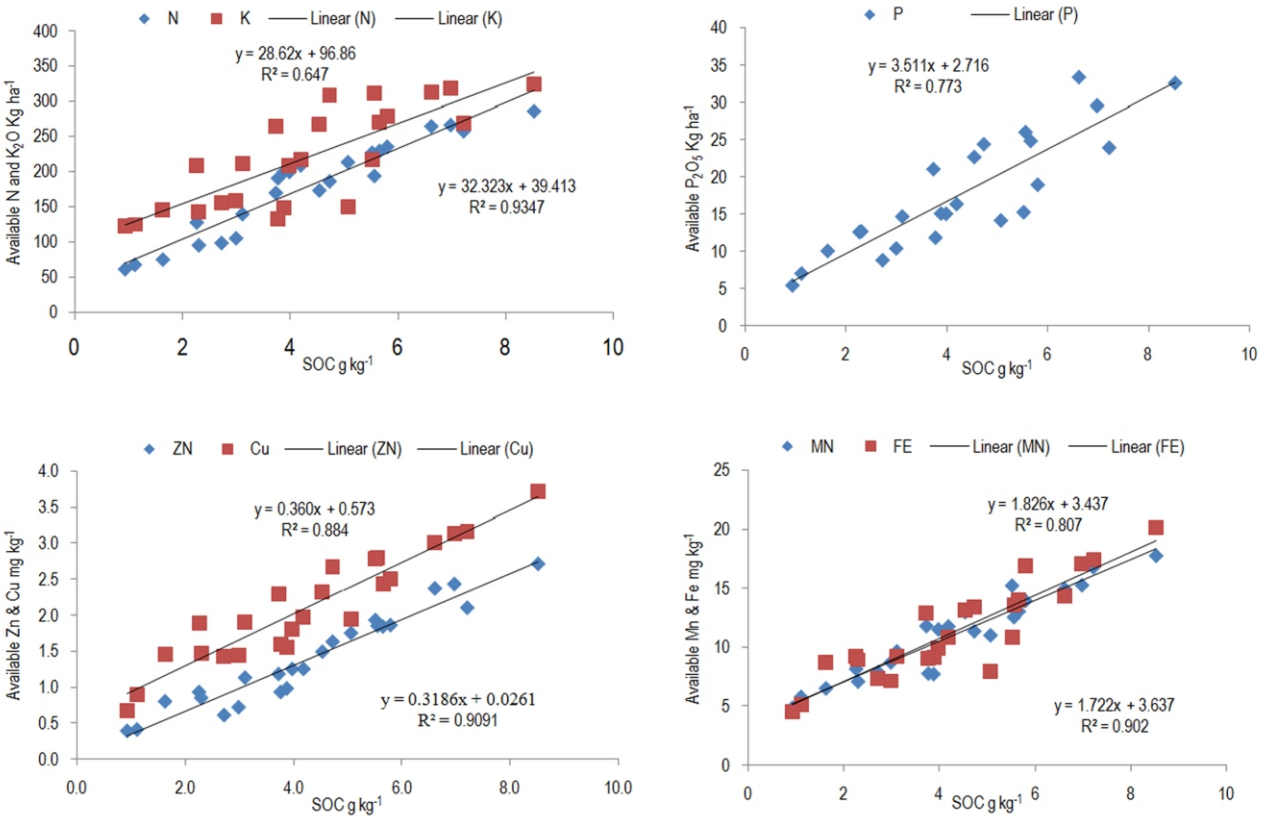

Fig. 3: Relationship between SOC and available N,P, K and micronutrints (Zn, Cu, Mn, and Fe) under different LUSs at 0-80 cm soil depth.

SOC was not remunerated by organic matter inputs from the source of crop residues in the barren and agricultural LUSs. Moreover, these SOC losses were aggravated through frequent tillage practices coupled with the removal of crop residues from the agricultural fields (Seyoum, 2016). This result is also in line with the findings of Meena *et al.* (2018). Depth effect revealed that the SOC concentration at 0-20 cm soil depth was 1.75 and 2 times higher than 40-60 cm and 60-80 cm soil depths, respectively. This signifies that the soil organic matter was adequate on the surface layers of soil where both plant and animal biomass are available to accommodate different diversities of soil organisms (Tufa *et al.,* 2019). The results illustrated that the cation exchange capacity of soil was remarkably influenced by various LUSs and soil depths (P≤ 0.05) (Table 2). The maximum mean CEC was recorded in the soils of natural forest land-use (23.36 cmol (p^+) kg^{-1}) followed by grass (19.03 cmol (p^+) kg^{-1}), and horticultural (18.40 cmol (p^+) kg^{-1}) LUSs, while the lowest CEC was observed in the barren land soil (10.80 cmol (p^+) kg^{-1}) (Table 2).

Considering the depth effect, the sub-surface soil (60-80 cm) showed significantly higher CEC (18.27 cmol (p^+) kg^{-1}) compared to surface (0-20 cm) soil (15.96 cmol (p^+) kg^{-1}). Principally, CEC of the soil is determined by the relative amount of clay content and organic carbon accumulation in the soil (Gao and Change, 1996; Meena *et al.,* 2012). Here, the increasing trend of clay content with soil depth overwhelms the influence of organic carbon on CEC and an increasing trend of CEC was observed with increasing soil depth. But in case of the main effect of LUSs, the organic carbon showed its influence on CEC as natural forest land-use soil showed higher CEC as compared to other LUSs. The higher CEC in the natural forest land-use soil might have been attributed to the presence of higher soil organic carbon while it was lower in the barren and agricultural land soils. It was also expressed by the positive and significant correlation (r= 0.656**) between CEC and SOC (Table 6).

This result corroborates with the findings of Yitbarek *et al.* (2013) and Nigussie and Kissi (2012). The depletion of organic matter content might be due to repeated intense tillage practices which decreased the CEC in the agricultural land-use soil. This trend was in line with the results of Seyoum (2016) who stated that continual cultivation reduces soil organic carbon and appeared a reduction in CEC under cultivated land-use soil than virgin land. The soil calcium carbonate ($CaCO_3$) varied from 3.12 to 3.30 percent under different LUSs with a non-significant difference. An increasing trend of $CaCO_3$ was observed with soil depth across the LUSs. The presence of higher $CaCO_3$ in lower soil depths might be associated with the precipitation of dissolved

Table 1: Detail of dominant land-use systems with a brief description

Land-use system	Description
Barren land	The land lying unutilized for the last 25 to 30 years is considered as barren land. This land is not suitable for cultivation due to root restriction and other soil-related problems.
Agricultural land	The agricultural system is dominated by maize, bajra, sorghum, black gram and green gram in the Kharif season, whereas wheat, mustard, and chickpea in the rabi season. These crops have continuously cultivated for more than 25 years in the area. 200-250 kg ha^{-1} Nitrogen and100-150 kg ha^{-1} phosphorus was applied to these fields annually through chemical fertilizers. The FYM was used at the rate of 8-10 t ha^{-1} once in a three years cycle.
Agri-horticulture	Soils were sampled from aonla + wheat, citrus + guar, and citrus + wheat systems. All these systems were established 17 to 18 years back on cultivated fields. The intercrops of wheat and guar were grown with recommended fertilizers. FYM was applied 8-10 t ha-1 once every three-year cycle.
Horticultural land	Guava (*Psidium guajava*), citrus (*Citrus limon*), and sapota (*Manikara zapota*) are the most commonly cultivated species in the studied area. All the considered orchards were established 17 to 18 years back. The fertilizers applied at the rate of 500 g Urea, 250 g DAP, and 15 kg FYM $plant^{-1}$ yr^{-1}.
Grassland	Grassland is composed of short-height grasses and usually situated within protected areas. There is no history of plowing in all the grassland areas.
Natural forest land	Forest LUS is less disturbed, which is used as a reference for comparison with the other LUSsin the study. The dominant species are *Acacia Nilotica*, *Terminalia arjuna*, *Anogeissus pendula*, *Terminalia tomentosa*, *Albizia lebbeck* and *Prosopis julliflora*. The forest area is generally protected by the government and restricted from farming and grazing.

carbonates in lower layers of soil (Pal *et al.,* 2000; Meena *et al.,* 2011). The highest (4.90%) and the lowest (1.84%) $CaCO_3$ were observed at sub-surface (60-80 cm) and surface soil layers (0-20 cm) of grassland soils, respectively (Table 2) which could be associated with the leaching of dissolved carbonates from upper layers to lower depths through water percolation as grassland had higher permeability compared to other LUSs. (Srivastava *et al.*, 2002; Pal *et al.*, 2016). The available nitrogen was significantly affected by different LUSs and soil depths ($P<0.05$). The available nitrogen varied from the lowest in the barren land-use (83.23 kg ha^{-1}) to the highest in the natural forest land-use (245.74 kg ha^{-1}) (Table 3). Among cultivated LUSs, the horticultural land-use was superior over barren, agriculture, and agri-horticulture land-uses by 170.94, 61.52, and 49.83 percent, respectively.

The depth effect indicated a dwindling trend of available nitrogen with soil depth across the LUSs, as it declined from 216.83 kg ha^{-1} in 0-20 cm soil depth to 139.23 kg ha^{-1} in the 60-80 cm soil depth. Significantly higher available-N content in the natural forest, grassland, and horticultural land-use soils than barren, agricultural, and agri-horticulture LUSs because these LUSs have higher organic matter input by leaf litter fall and root biomass deposition that enhanced the nitrogen mineralization. While, in agricultural land-use, intense tillage practices accelerate the oxidation of soil organic matter, reducing nitrogen availability (Emiru and Gebrekidan, 2013). Besides, less vegetation cover in the barren, agricultural, and agri-horticulture land-uses than natural forest and horticultural LUSs expedite leaching loss of nitrogen through irrigation and rainfall. (Pal *et al.*, 2013; Kaur and Bhat, 2017; Mandal *et al.,* 2018). A decreasing trend of available-N with the soil depth under different LUSs might be due to immobilization of nitrogen as well as lower soil organic carbon in the lower soil depths (Chen *et al.,* 2016). The available phosphorus was significantly ($P\leq 0.05$) influenced by LUSs, soil depths and their interaction effects (Table 3). The main effects of LUSs and soil depths revealed that the horticultural LUS and surface soil layer (0-20 cm) showed the highest available-P (22.04; 26.04 kg ha^{-1} and the lowest was shown by barren land and sub-surface soil layer (60-80 cm) to the tune of 7.86 and 11.50 kg ha^{-1} (Table 3). Relatively higher available-P recorded in the horticultural LUS might be due to carry over effects from the continuous application of phosphoric fertilizers as well as good content of soil organic matter which results the release of organic phosphorus thus improved available-P in the soil (Selassie and Ayanna, 2013; Dhaliwal and Singh, 2013). The available potassium of soil was influenced significantly ($P\leq 0.05$) by different LUSs, soil depth, and their interaction effects (Table 3).

The results revealed that the available-K content varied from 140.05 to 239.89 kg ha^{-1}, with the highest mean value in the natural forest land-use followed by horticultural (237.42 kg ha^{-1}), and grassland (234.67 kg ha^{-1}), while least in the barren land-use. Moreover, the study conceded that the natural forest land-use was significantly superior to barren land, agricultural, and agri-horticulture land-uses by 71.29, 3.46, and 2.93 percent, respectively. Among cultivated LUSs, the horticultural land-use showed a non-significant difference from the agricultural and agri-horticulture land-uses, while significantly higher available-K than the barren land-use by 69.53 percent. A decreasing trend in available-K content with soil depth was noticed under all the studied LUSs. These results are similar to Waken's (2001) who demonstrated that the surface soils contained higher available-K and declined gradually with the soil depth. Relatively higher available-K in natural forest and horticultural LUSs could be due to higher amount of organic matter in the form of leaf litter fall and root biomass deposition, which helps in the liberation of bounded-K and solubilizing of insoluble forms of potassium in the soil. The lower amount of available-K in the barren land-use might be due to leaching losses and soil degradation (Mandal *et al.* 2018; Moges *et al.,* 2013). The DTPA extractable soil

Table 2: Basic soil properties (soil pH, EC, SOC, CEC and $CaCO_3$) in relation to land-use systems and soil depth effects (mean ± standard error of the mean)

	Soil depth (cm)				
LUS	**0-20**	**20-40**	**40-60**	**60-80**	**Mean**
			Soil pH (1:2.5)		
Barren Land	8.13±0.04^{bcdef}	8.26±0.03^{abcde}	8.31±0.04^{abcde}	8.38±0.04^{abc}	8.27±0.03^{a}
Agriculture	8.11±0.09^{bcdef}	8.17±0.03^{abcde}	8.33±0.05^{abcd}	8.45±0.05^{ab}	8.26±0.04^{a}
Agri-horticulture	8.04±0.04^{cdef}	8.16±0.12^{abcde}	8.35±0.16^{abcd}	8.49±0.15^{a}	8.26±0.07^{a}
Horticulture	8.06±0.09^{cdef}	8.2±0.04^{abcde}	8.22±0.04^{abcde}	8.26±0.05^{abcde}	8.19±0.03^{a}
Grass land	7.56±0.05^{h}	7.61±0.05^{gh}	7.77±0.05^{fgh}	8.01±0.06^{def}	7.74±0.05^{c}
Natural forest	7.63±0.06^{gh}	7.96±0.06^{efg}	8.03±0.06^{cdef}	8.06±0.06^{cdef}	7.92±0.05^{b}
Mean	7.92±0.04^{c}	8.06±0.05^{bc}	8.17±0.06^{b}	8.27±0.04^{a}	
			EC (dS m^{-1})		
Barren Land	0.097±0.008^{b}	0.113±0.033^{ab}	0.142±0.051^{ab}	0.148±0.051^{ab}	0.125±0.019^{ab}
Agriculture	0.191±0.002^{a}	0.144±0.001^{ab}	0.135±0.003^{ab}	0.108±0.001^{ab}	0.144±0.007^{a}
Agri-horticulture	0.171±0.001^{ab}	0.131±0.003^{ab}	0.115±0.003^{ab}	0.117±0.001^{ab}	0.134±0.005^{ab}
Horticulture	0.102±0.006^{b}	0.099±0.002^{b}	0.114±0.004^{ab}	0.127±0.003^{ab}	0.111±0.003^{b}
Grass land	0.095±0^{b}	0.110±0.001^{ab}	0.097±0.0002^{b}	0.114±0.005^{ab}	0.104±0.002^{b}
Natural forest	0.104±0.002^{ab}	0.110±0.002^{ab}	0.106±0.001^{ab}	0.100±0.001^{b}	0.105±0.001^{b}
Mean	0.127±0.007^{a}	0.118±0.006^{a}	0.118±0.008^{a}	0.119±0.008^{a}	
			OC (g kg^{-1})		
Barren Land	2.99±0.04^{jk}	2.72±0.03^{k}	1.11±0^{n}	0.93±0.02^{n}	1.94±0.21^{e}
Agriculture	4.73±0.11^{ef}	3.73±0.05^{i}	2.26±0.02^{l}	1.63±0.01^{m}	3.09±0.28^{d}
Agri-horticulture	5.56±0.13^{d}	4.54±0.06^{fg}	3.11±0.03^{j}	2.3±0.01^{l}	3.88±0.29^{c}
Horticulture	6.62±0.56^{c}	5.66±0.19^{d}	4.19±0.23^{gh}	3.88±0.06^{hi}	5.09±0.26^{b}
Grass land	6.98±0.03^{bc}	5.8±0.13^{d}	3.98±0.05^{hi}	3.77±0.02^{i}	5.13±0.31^{b}
Natural forest	8.53±0.04^{a}	7.22±0.17^{b}	5.52±0.05^{d}	5.07±0.06^{e}	6.58±0.32^{a}
Mean	5.90±0.33^{a}	4.94±0.28^{b}	3.36±0.26^{c}	2.93±0.27^{d}	
			CEC (cmol (p+) kg^{-1})		
Barren Land	9.99±0.19^{m}	11.46±0.35^{lm}	10.67±0.23^{lm}	11.07±0.03^{lm}	10.8±0.16^{e}
Agriculture	13.21±0.3^{kl}	14.47±0.48^{ijk}	15.54±0.59^{ijk}	16.4±0.31^{hij}	14.91±0.34^{d}
Agri-horticulture	15.95±0.43^{hij}	16.74±0.48^{ghij}	17.56±0.25^{efghi}	17.14±0.64^{fghi}	16.85±0.24^{c}
Horticulture	16.93±1.34^{ijk}	17.28±0.32^{ghij}	19.17±1.04^{cdefg}	20.2±0.9^{cd}	18.40±0.53^{b}
Grass land	18.12±0.55^{defgh}	19.38±0.37^{cdef}	18.55±0.47^{defgh}	20.07±0.46^{cde}	19.03±0.28^{b}
Natural forest	21.57±0.77^{bc}	23.01±0.48^{ab}	24.09±0.48^{ab}	24.76±0.87^{a}	23.36±0.41^{a}
Mean	15.96±0.7^{c}	17.06±0.69^{b}	17.6±0.77^{ab}	18.27±0.81^{a}	
			$CaCO_3$ (%)		
Barren Land	2.71±0.13^{ghi}	2.87±0.07^{efghi}	2.92±0.24^{defghi}	4.26±0.31^{abc}	3.19±0.17^{a}
Agriculture	2.48±0.03^{hij}	3.10±0.22^{efghi}	3.46±0.13^{defgh}	4.17±0.12^{bcd}	3.30±0.15^{a}
Agri-horticulture	2.03±0.17^{ij}	2.67±0.09^{fghi}	3.63±0.18^{bcdef}	4.36±0.28^{ab}	3.17±0.22^{a}
Horticulture	1.99±0.34^{ij}	3.40±0.25^{cdefg}	3.50±0.14^{cdefg}	3.71±0.18^{bcdefg}	3.15±0.16^{a}
Grass land	1.84±0.18^{ij}	1.98 ±0.22^{ij}	3.77±0.14^{bcd}	4.90±0.17^{a}	3.12±0.3^{a}
Natural forest	2.20±0.21^{ij}	2.25±0.19^{ij}	3.52±0.37^{fghi}	4.59±0.23^{bcde}	3.14±0.26^{a}
Mean	2.20±0.09^{d}	2.71±0.13^{c}	3.47±0.11^{b}	4.33±0.12^{a}	

Mean followed by the same letter are not significantly different based on Tukey's HSD ($P<0.05$). Overall means within rows and columns are represented land-use systemand soil depth effects, respectively

micronutrients (Fe, Mn, Zn and Cu) were significantly influenced by different LUSs,soil depths, and their interaction effects ($P \leq 0.05$) (Table 4). According to the main effects of LUSs and soil depths, significantly highest micronutrients (Fe, Mn, Zn, and Cu) content was found in the soil of natural forest land-use (2.13, 2.90, 15.20 and 14.06 mg Kg^{-1} Zn, Cu, Mn, and Fe, respectively) as compared to other LUSsand lowest was observed in the soil of barren land (0.53, 1.10, 6.83 and 6.02 mg Kg^{-1} Zn, Cu, Mn, and Fe, respectively). The greater amount of micronutrients in the natural forest, grass, and horticultural land-use soils might have contributed due to regular addition of higher organic matter in the form of leaf litter fall in the surface soil and higher root biomass in the lower soil layers which encourages the soil microbial activity that enables the availability of nutrients compared to barren, agriculture and agri-horticulture LUSs (Dhaliwal and Singh, 2013). Higher amount of micronutrients was observed under

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Table 3: Available nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) in relation to land-use systemsand soil depth effects (mean ± standard error of the mean)

	Soil depth (cm)				
LUS	**0-20**	**20-40**	**40-60**	**60-80**	**Mean**
			Avail-N (kg ha^{-1})		
Barren Land	105.37±2.67^{l}	98.57±2.77^{l}	67.67±5^{m}	61.31±4.22^{m}	83.23±4.7^{e}
Agriculture	186.11±2.62^{hij}	169.63±1.47^{j}	127.74±1.12^{k}	74.97±2.69^{m}	139.61±9.9^{d}
Agri-horticulture	193.73±1^{fgh}	173.16±1.68^{ij}	139.64±1.52^{k}	95.48±2.18^{l}	150.5±8.56^{c}
Horticulture	264.21±13.37^{b}	229.45±6.87^{cd}	208.72±4.38^{efg}	199.62±2.45^{fgh}	225.5±5.91^{b}
Grass land	266.02±1.82^{ab}	235.22±1.75^{c}	199.46±1.52^{fgh}	190.62±3.07^{ghi}	222.83±6.95^{b}
Natural forest	285.56±7.09^{a}	257.31±10.86^{b}	226.73±6.47^{cde}	213.38±4.9^{def}	245.74±7.31^{a}
Mean	216.83±11.65^{a}	193.89±10.08^{b}	161.66±10.36^{c}	139.23±11.79^{d}	
			Avail-P_2O_5 (kg ha^{-1})		
Barren Land	10.35±0.49^{ijk}	8.76±0.62^{jkl}	6.97±0.61^{kl}	5.36±0.5^{l}	7.86±0.5^{d}
Agriculture	24.41±0.68^{cd}	21.05±0.67^{de}	12.56±0.63^{ghij}	10.01±0.67^{ijk}	17.01±1.39^{c}
Agri-horticulture	26.03±1.7^{bc}	22.69±1.33^{cde}	14.65±0.53^{gh}	12.66±0.53^{ghij}	19.01±1.37^{b}
Horticulture	33.33±3.19^{a}	24.85±1.33^{cd}	16.34±1.65^{fg}	15.07±1.12^{fgh}	22.4±1.78^{a}
Grass land	29.56±0.92^{ab}	18.95±0.66^{ef}	15.03±0.4^{fgh}	11.79±0.38^{hij}	18.83±1.56^{b}
Natural forest	32.56±0.92^{a}	23.95±0.66^{cd}	15.24±0.4^{fgh}	14.12±0.38^{ghi}	21.47±1.73^{a}
Mean	26.04±1.48^{a}	20.04±1.05^{b}	13.47±0.66^{c}	11.5±0.64d	
			Avail-K_2O (kg ha^{-1})		
Barren Land	158.23±2.47^{d}	155.75±2.53^{d}	124.2±5.05^{fg}	122.02±4.94^{g}	140.05±4.3^{c}
Agriculture	308.04±5.12^{a}	265.02±3.69^{b}	208.9±5.75^{c}	145.49±3.89^{def}	231.87±14.16^{b}
Agri-horticulture	311.52±3.34^{a}	267.3±3.39^{b}	211.62±2.66^{c}	141.86±3.48^{defg}	233.07±14.63^{b}
Horticulture	312.85±36.93^{a}	271.02±9.42^{b}	217.3±10.15^{c}	148.49±14.94^{de}	237.42±14.28^{a}
Grass land	318.15±1.44^{a}	278.96±3.26^{b}	208.91±2.13^{c}	132.68±7.25^{efg}	234.67±16.33^{a}
Natural forest	323.71±2.58^{a}	269.17±3.95^{b}	217.02±5.71^{c}	149.66±6.51^{de}	239.89±14.93^{a}
Mean	288.75±10.94^{a}	251.2±8.12^{b}	197.99±6.37^{c}	140.03±2.7^{d}	

Mean followed by the same letter are not significantly different based on Tukey's HSD (P<0.05). Overall means within rows and columns are represented by land-use systemand soil depth effects, respectively

agricultural and agri-horticultural lands than barren land, due to the regular addition of crop residues and fertilizers/manures. While the lesser amount of soil micronutrients in the barren land could be due to erosional loss, poor soil aggregation, and low organic carbon content (Dhaliwal *et al.,* 2008; Chaudhury *et al.,* 2021). On the other hand, regular crop harvest, exhaustive cultivation, and consistent disturbances during various soil management practices are the reason behind the lesser content of soil micronutrients in the agricultural and agri-horticulture land-uses than forest, grass, and horticultural LUSs.

Table 5 shows the deterioration indices under different LUSs which reflect the percent changes in soil nutrients and soil properties from their values under natural forest LUS (reference site); it can be regarded as an indication of degree of soil deterioration/improvement under studied LUSs. The results of this study show that SOC, DTPA extractable Zn,Mn, available-N, and CEC are the most degraded soil properties under studied LUSs (Table 5). The overall soil deterioration index (DI) was expressed by averaging values of the percent changes in all the soil parameters under a particular LUS (Fig. 2). The deterioration index between-5 to-15 percent assumes the light deterioration in the soil, whereas moderate deterioration ranges from -15 to -25 percent and severe deterioration less than-25 percent. The overall soil deterioration indices varied between -11.05 and -47.50 percent (Fig. 2) revealing that the soils under different LUSs had deteriorated from light to severe category. The overall soil deterioration under grassland and horticultural LUSs was less than 15 percent (-11.05 and -11.81 %), indicating slight decline. In contrast, agri-horticulture land-use (-22.51 %) observed moderate deterioration whereas, severe to very severe deterioration (-28.11 and -47.50%) occurred under agricultural and barren land-uses, respectively. Soil deterioration indices appropriately and truly reflected the differences in soil quality for different LUSs. The natural forest, grassland, and horticultural land-uses had higher content of SOC and available primary and micronutrients compared to barren and agricultural LUSs which reflected in the form of better deterioration indices. The superior fertility status was noticed in the horticultural land-use among cultivated LUSs, and its deterioration index was -11.81 percent which indicated superior soil quality compared to agri-horticulture (-22.51 %) and agricultural (-28.11%) land soils. It suggests that the horticultural LUS is a better land-use practice in sub-humid southern plans of Rajasthan.

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Table 4: DTPA extractable soil micronutrients (Zn, Cu, Mn, and Fe) in relation to land-use systems and soil depth effects (mean ± standard error of the mean)

	Soil depth (CM)				
LUS	**0-20**	**20-40**	**40-60**	**60-80**	**Mean**
			Zn (mg kg^{-1})		
Barren Land	0.72±0.02^{kl}	0.61±0.01^{l}	0.41±0^{m}	0.39±0^{m}	0.53±0.03^{e}
Agriculture	1.63±0.04^{f}	1.18±0.03^{h}	0.93±0.01^{ij}	0.80±0.01^{k}	1.14±0.07^{d}
Agri-horticulture	1.85±0.01^{de}	1.49±0.03^{g}	1.13±0.01^{h}	0.85±0.01^{jk}	1.33±0.09^{c}
Horticulture	2.37±0.27^{b}	1.84±0.11^{de}	1.25±0.13^{h}	0.98±0.08^{i}	1.61±0.12^{b}
Grass land	2.43±0.02^{b}	1.86±0.01^{de}	1.25±0.03^{h}	0.93±0.01^{ij}	1.62±0.14^{b}
Natural forest	2.71±0.03^{a}	2.1±0.04^{c}	1.93±0.04^{d}	1.75±0.02^{ef}	2.13±0.08^{a}
Mean	1.95±0.12^{a}	1.52±0.09^{b}	1.15±0.08^{c}	0.95±0.08^{d}	
			Cu (mg kg^{-1})		
Barren Land	1.44±0.05^{i}	1.42±0.06^{i}	0.89±0.04^{j}	0.67±0.02^{j}	1.1±0.08^{d}
Agriculture	2.67±0.06^{cde}	2.29±0.05^{ef}	1.89±0.07^{fgh}	1.45±0.03^{i}	2.08±0.11^{c}
Agri-horticulture	2.8±0.1^{bcd}	2.32±0.1^{ef}	1.9±0.09^{fgh}	1.47±0.05^{hi}	2.12±0.12^{bc}
Horticulture	3.01±0.3^{bc}	2.43±0.08^{de}	1.97±0.07^{fg}	1.55±0.06^{ghi}	2.24±0.13^{bc}
Grass land	3.15±0.15^{b}	2.51±0.06^{de}	1.8±0.06^{ghi}	1.59±0.04^{ghi}	2.26±0.15^{b}
Natural forest	3.71±0.08^{a}	3.17±0.11^{b}	2.78±0.28^{bcd}	1.94±0.07^{fg}	2.9±0.16^{a}
Mean	2.8±0.13^{a}	2.36±0.1^{b}	1.87±0.11^{c}	1.44±0.07^{d}	
			Mn (mg kg^{-1})		
Barren Land	8.73±0.23^{ijkl}	7.9±0.07^{jklm}	5.81±0.13^{mn}	4.89±0.15^{n}	6.83±0.36^{d}
Agriculture	11.37±0.48^{fgh}	11.81±0.28^{efg}	8.17±1.36^{hijk}	6.53±0.21^{lmn}	9.47±0.59^{c}
Agri-horticulture	12.57±0.46^{def}	12.98±0.52^{cdef}	9.66±0.39^{ghij}	7.11±0.33^{klmn}	10.58±0.58^{c}
Horticulture	14.95±1.47^{bcd}	13.05±0.24^{cdef}	11.78±0.31^{efgh}	7.73±0.71^{jklm}	11.88±0.63^{b}
Grass land	15.27±0.47^{bc}	13.96±0.6^{cde}	11.53±0.61^{fgh}	7.79±0.43^{jklm}	12.14±0.7^{b}
Natural forest	17.76±0.36^{a}	16.78±0.38^{ab}	15.23±0.47^{bc}	11.03±0.49^{fghi}	15.2±0.62^{a}
Mean	13.44±0.56^{a}	12.75±0.52^{a}	10.36±0.59^{b}	7.51±0.37^{c}	
			Fe (mg kg^{-1})		
Barren Land	7.12±0.37^{h}	7.35±0.42^{gh}	5.08±0.07^{i}	4.52±0.16^{i}	6.02±0.31^{e}
Agriculture	13.36±0.42^{c}	12.9±0.18^{c}	9.2±0.49^{def}	8.71±0.2^{fgh}	11.04±0.51^{d}
Agri-horticulture	13.56±0.27^{c}	13.1±0.47^{c}	9.25±0.44^{def}	8.91±0.38^{fg}	11.20±0.52^{d}
Horticulture	14.34±1.01^{c}	13.95±0.11^{c}	10.82±0.74^{d}	9.13±0.43^{ef}	12.06±0.51^{c}
Grass land	17.04±0.46^{b}	16.85±0.39^{b}	9.87±0.44^{def}	9.03±0.16^{fg}	13.2±0.88^{b}
Natural forest	20.12±0.23^{a}	17.42±0.27^{b}	10.8±0.22^{de}	7.89±0.31^{def}	14.06±1^{a}
Mean	14.26±0.75^{a}	13.6±0.62^{b}	9.17±0.38^{c}	8.03±0.34^{d}	

Mean followed by the same letter are not significantly different based on Tukey's HSD (P<0.05). Overall means within rows and columns are represented by land-use systemand soil depth effects, respectively

The SOC content has often been used as a universal indicator of soil quality. The agricultural LUS decreases total soil carbon: nitrogen ratios (C: N), which usually range from 14 to 18, as labile SOC is lost (Meena *et al.,* 2018). Irrespective of different LUSs and soil depths, available N,P, K, and micronutrients of soil were found significantly well correlated (Table 6) with SOC (P=0.01). The available nitrogen showed highest positive correlation with SOC (r= 0.965, P= 0.01) followed by Zn (r=0.942,P= 0.01) and available potassium exhibited least (r= 0.825, P= 0.01). Except for Zn, all the remaining soil micronutrients (Cu, Fe, Mn) showed more or less similar level of correlation with SOC under studied LUSs. The highest negative significant correlation of SOC was showed with soil pH (r= - 0.564, P= 0.01) followed by $CaCO_3$ (r= - 0.513, P= 0.01) and least was exhibited by EC (r= - 0.256, P= 0.05). In all six LUSs, available N, P, K, and micronutrients (Zn, Cu, Mn, and Fe) exhibited a positive linear relationship with SOC (Fig. 3). The regression analysis showed a trend of nitrogen (R^2= 0.9347)> Zn (R^2= 0.9091) >Fe (R^2= 0.9326)> Cu (R^2= 0.884) >Mn (R^2= 0.8076) >P (R^2= 0.7739)> K (R^2= 0.6475) regarding their relationship with SOC under different LUSs. Aggradation of SOC under different LUSs is reflected by increasing the concentration of all soil nutrients.

The agricultural LUS had reduced the SOC concentration by oxidation of labile fraction of organic matter due to intensive tillage practices and soil disturbances (Purakayastha *et al.,* 2008; Mandal *et al.,* 2020). A higher correlation among SOC and nitrogen and other soil nutrients suggested that the production and concentration of these nutrients were principally determined by the amount and quality of soil organic matter under different

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Table 5: Deterioration of various soil properties (%) under different land-use systems*

Soil properties	Barren Land	Agriculture	Agri-horticulture	Horticulture	Grass land
pH	-4.42	-4.29	-4.29	-3.41	2.27
CaCO3	-1.59	-5.10	-0.96	-0.32	0.64
EC	-19.05	-37.14	-27.62	-5.71	0.95
SOC	70.52	53.04	41.03	22.64	22.04
Zn	75.12	46.48	37.56	24.41	23.94
Cu	62.01	28.43	26.81	22.73	21.96
Mn	55.07	37.70	30.39	21.84	20.13
Fe	57.30	21.70	20.57	14.47	6.12
N	66.13	43.18	38.75	8.22	9.31
K	41.62	3.35	2.85	1.03	2.18
P	63.39	20.77	11.46	-4.33	12.30
CEC	53.77	36.17	27.87	21.23	18.54

*Negative values for soil pH, EC, and $CaCO_3$ and positive values for other soil properties show degradation under different LUSs

Table 6: Person's correlation matrix between different soil parameters as affected by different LUSs at various soil depths

Parameters	pH	OC	Zn	Cu	Mn	Fe	N	K	P	CEC	$CaCO_3$
pH	1										
OC	-0.564**	1									
Zn	-0.502**	0.942**	1								
Cu	-0.437**	0.914**	0.936**	1							
Mn	-0.584**	0.910**	0.893**	0.861**	1						
Fe	-0.568**	0.911**	0.898**	0.877**	0.865**	1					
N	-0.579**	0.965**	0.936**	0.873**	0.907**	0.874**	1				
K	-0.410**	0.825**	0.871**	0.866**	0.750**	0.883**	0.812**	1			
P	-0.342**	0.848**	0.879**	0.854**	0.748**	0.842**	0.807**	0.918**	1		
CEC	-0.424**	0.656**	0.641**	0.638**	0.740**	0.582**	0.725**	0.410**	0.394**	1	
CaCO3	0.372**	-0.513**	-0.506**	-0.488**	-0.376**	-0.542**	-0.375**	-0.530**	-0.502**	0.033	1
EC	0.293**	-0.256*	-0.188	-0.054	-0.279**	-0.109	-0.304**	0.156	0.002	-0.33**	-0.102

**Correlation is significant at 0.01 level (2-tailed). *Correlation is significant at 0.05 level (2-tailed).

LUSs (Meena *et al.,* 2018). Similarly, Wang *et al.* (2016) also reported that the land-use changes from cultivated to forest LUSs enhance the SOC and total nitrogen stocks in the long term.

This study revealed that the natural forest land-use maintained superior soil properties followed by grassland and horticultural LUSs. The minimum soil disturbance through minimum tillage or zero-till like conditions in the horticultural LUS improves all vital properties of soil and reduces the SOC losses. Whereas consistent cultivation without appropriate land management practices in the agricultural fields aggravates the deterioration of physico-chemical properties of soil and SOC. Thus, the horticulture LUS is superior to the agriculture land-use for maintaining soil health. Besides, the horticulture LUS has a great potential to achieve land degradation neutrality, nutritional and livelihood security. Irrespective of LUSs, suitable scientific land-use management is essential for improving or maintaining soil health.Further, these results also suggest that restoration of barren and agricultural lands to horticultural, agri-horticulture, and grassland-uses consequently decreased soil disturbances which could be an effective strategy for improving or maintaining fertility and deterrent the soil deterioration in the study area.

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samples for different soil properties. **M.A. Alam, D.C. Meena:** Performed the statistical analysis of data; **P. Kumar, G. L. Meena:** Helped in manuscript writing and editing, **M. Nogiya, R.L. Meena:** Assisted in the preliminary survey for selection and finalization of prevailing LUSs, sampling sites and prepared location map of the study area.

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References

Chandrakala, M., M. Ramesh, K. Sujatha, R. Hegde and S.K. Singh: Soil fertility evaluation under different land-use system in tropical humid region of Kerala, India. *Int. J. Plant Soil Sci.,* **24**,1-13 (2018).

Chauhan, R.P., K.K. Pand and S. Thakur: Soil properties affected by LUSs in Western Chitwan, Nepal. *Int. J. Bioass.,* **2**, 398-402 (2014).

Chen, F., L. Hou, M. Liu, Y. Zheng, G. Yin, X. Lin, X. Li, H. Zong, F. Deng, J. Gao and X. Jiang: Net anthropogenic nitrogen inputs (NANI) into the Yangtze River basin and the relationship with riverine nitrogen export. *J. Geophys. Res. Biogeosci.,* **121**, 451–465 (2016).

Chaudhury, B.U., M.A. Ansari, M. Chakraborty and T.T. Meetei: Effect of land-use change along altitudinal gradients on soil micronutrients in the mountain ecosystem of Indian (Eastern) Himalaya. *Sci. Rep.,* **11**, 14279 (2021).

Dhaliwal, S.S. and B. Singh: Depth wise distribution of macronutrients, micronutrients and microbial populations under different land-use systems. *Asian J. Soil Sci.,* **8**, 404-411 (2013).

Dhaliwal, S.S., B.D. Sharma, B. Singh and K.L. Khera: Profile distribution of chemical, physical and microbial indicators in four LUSs of Sadh Di Khad watershed in sub-mountainous tract of Punjab. *Asian J. Soil Sci.,* **3**, 316-322 (2008).

Don, A. and F.A. Schumacher: Impact of tropical land-use change on soil organic carbon stocks: Meta analysis. *Glob. Chang. Biol.,* **17**, 1658-1670 (2011).

Ekanade, O.: The nature of soil properties under mature forest and plantations of fruiting and exotic trees in the tropical rainforest fringes of South-western Nigeria. *J. World For. Res. Manage.,* **5**, 101-114 (1991).

Emiru, N. and H. Gebrekidan: Effect of land-use changes and soil depth on soil organic matter, total nitrogen and available phosphorus contents of soils in Senbat Watershed, Western Ethiopia. *J. Agric. Biol. Sci.,* **8**, 206-12 (2013).

Gao, G. and C. Change: Changes in cation exchange capacity and particle size distribution of soil as associated with long term annual application of cattle feed lot manure. *Soil Sci.,* **161**, 115–120 (1996).

Gebresamuel, G., B. Molla, K. Teka, E. Negash, M. Haile and C.C. Okolo: Changes in soil organic carbon stock and nutrient status after conversion of pasture land to cultivated land in semi-arid areas of northern Ethiopia. *Arch. Agron. Soil Sci.,* **68**, 44-60 (2020).

Giacometti, C., M.Mazzon, L. Cavani, L. Triberti, G. Baldoni, C. Ciavatta and C. Marzadori: Rotation and fertilization effects on soil quality and yields in a long term field experiment. *Agronomy*, **11**, 636 (2021).

Jackson, M.L.: Soil Chemical Analysis. Prentice Hall of India Private Limited, New Delhi, 485 pages (1973).

Jha, P. and K.P. Mohapatra: Developing soil quality index for ravenous ustfluents of the semi-arid region of India. *J. Indian Soci. Soil Sci.,* **60**,116-124 (2012).

Kaur, R. and Z.A. Bhat: Effect of different agricultural LUSs on physico-chemical properties of soil in sub-mountainous districts of Punjab, North-west India. *J. Pharm. Phyto.,* **6**, 226-233 (2017).

Lemenih, M., E. Karltun and M. Olsson: Assessing soil chemical and physical property responses to deforestation and subsequent cultivation in smallholders farming system in Ethiopia. *Agric. Ecosyst. Environ.,* **105**, 373-386 (2005).

Lindsay, W.L. and W.A. Norvel: Development of DTPA soil test for Zn, Fe, Mn and Cu. *Soil Sci. Soc. American J.,* **42**, 421-428 (1978).

Malo, D.D., T.E. Schumacher and J.J. Doolittle: Long-term cultivation impacts on selected soil properties in the Northern Great Plains. *Soil Till. Res.,* **81**, 277-291 (2005).

Mandal, A., A.S. Toor and S.S. Dhaliwal: Assessment of sequestered organic carbon and its pools under different agricultural land-uses in the semi-arid soils of south-western Punjab India. *J. Soil Sci. Plant Nutri.,* **20**, 259-273 (2020).

Mandal, A., A.S. Toor and S.S. Dhaliwal: Effect of land-uses on physico-chemical properties and nutrient status of surface (0-15 cm) and sub-surface (15-30 cm) layers in soils of South-western Punjab, India. *Int. J. Curr. Microbiol. Appl. Sci.,* **7**, 2659-2671(2018).

Meena, R.H., J.D. Giri, S.R. Chaudhary and R.L. Syampura: Characterization and classification of the soils of Malwa plateau in Banswara district of Rajasthan. *J. Soil Crops*, **22**, 216-225 (2012).

Meena, R.B., S.S. Balpande, V.P. Babhulkar and G.M. Madhumita: Characteristics and classification of waterlogged soils in upper Wardha command area of Maharashtra. *J. Soils Crops,* **21**, 90-94 (2011).

Meena, V.S., T. Mondal, B.M. Pandey, A. Mukherjee, R.P Yadav, M. Choudhary, S. Singh, J.K.Bisht and A. Pattanayak: Land-use changes: Strategies to improve soil carbon and nitrogen storage pattern in the mid-Himalaya ecosystem, India. *Geoderma*, **321**, 69-78 (2018).

Mesele, S., H. Gebrekidan, L. Gizachew and C. Layne: Changes in land cover and soil conditions for the Yabelo district of the Borana plateau, 1973-2003. Global Livestock Collaborative Research Support Program. University of California, Davis. 4 (2006).

Moges, A., M. Dagnachew and F. Yimer: Land-use effects on soil quality indicators: A case study of Abo-Wonsho Southern Ethiopia. *Appl. Environ. Soil Sci.,* **2013**, 784989 (2013).

Mohammed, A.P., A.L. le Roux, C.H. Barker and G. Heluf: Soils of Jelo micro-catchment in the chercher highlands of Eastern Ethiopia: I. Morphological and physiochemical properties. *Ethiopian J. Natu. Reso.,* **7**, 55-81 (2005).

Nigussie, A. and E. Kissi: Physicochemical characterization of nitisol in South-western Ethiopia and its fertilizer recommendation using NuMaSS. *Glob. Ad. Res. J. Agric. Sci.,* **1**, 66-73 (2012).

Olsen, S.R., C.V. Cole, S.W. Frank and L.A. Dean: Estimation of available phosphorus by extraction with sodium bicarbonate. United States Development of Agriculture Circular number, 939 (1954).

Pal, D.K., G.S. Dasog, S. Vadivelu, R.L. Ahuja and T. Bhattacharyya: Secondary calcium carbonate in soils of arid and semi-arid regions of India. In: Global Climate Change and Pedogenic Carbonates

(Eds.: R. Lal, J. M. Kimble, B. A. Stewart and H. Eswaran). Lewis Publishers, USA, pp. 149–185 (2000).

Pal, D.K., T. Bhattacharyya, K.L. Sahrawat and S.P Wani: Natural chemical degradation of soils in the Indian semi-arid tropics and remedial measures. *Curr. Sci.,* **110**, 1675-1682 (2016).

Pal, S., P. Panwar and D.R. Bhardwaj: Soil quality under forest compared to other land-uses in acid soil of North-western Himalaya, India. *Ann. Fore. Res.,* **56**, 187-198 (2013).

Purakayastha, T.J., D.R. Huggins and J.L. Smith: Carbon sequestration in native prairie, perennial grass, no-till and cultivated Palouse silt loam. *Soil Sci. Soc. American J.,* **72**, 534–540 (2008).

Puri, A.N.: A new method for estimating total carbonates in soils. Imperial Agricultural Research Pusa Bulletin, 7 (1930)

Richards, L.A.: Diagnosis and Improvement of saline-alkali soils. Agriculture Handbook No. 60, USDA, Washington (1954).

Rolando, J.L., J. Dubeux, D. Ramirez and M.R. Moreno: Land-use effects on soil fertility and nutrient cycling in the Peruvian High-Andean Puna grasslands. *Soil Sci. Soc. American J.,* **82**, 463-474 (2018).

Seastedt, T.R., J.M. Briggs and D.J. Gibson: Controls of nitrogen limitation in tallgrass prairie. *Oecologia*, **87**, 72-79 (1991).

Selassie, Y.G. and G. Ayanna: Effects of different land-use systems on selected physico-chemical properties of soils in North-western Ethiopia. *J. Agric. Sci.,* **5**, 112-120 (2013).

Seyoum, B.: Assessment of soil fertility status of vertisols under selected three land-uses in Girar Jarso District of North Shoa Zone, Oromia National Regional State Ethiopia. *Environ. Syst. Res.,* **5**, 1-16 (2016).

Srivastava, P., T. Bhattacharyya and D.K. Pal: Significance of the formation of calcium carbonate minerals in the pedogenesis and management of cracking clay soils (vertisols) of India. *Clays Clay Miner.,* **50**, 111-126 (2002).

Subbiah, B.V. and G.L. Asija: A rapid procedure for determination of available nitrogen in soil. *Curr. Sci.,* **25**, 259-260 (1956).

Tufa, M., A. Melese and W. Tena: Effects of land-use types on selected soil physical and chemical properties: The case of Kuyu District, Ethiopia. *Eurasian J. Soil Sci.,* **8**, 94 -109 (2019).

Walkley, A.J. and I.A. Black: Estimation of soil organic carbon by chromic acid titration method. *Soil Sci.,* **37**, 29-38 (1934).

Wang, J., B. Fu, Y. Qiu and L. Chen: Soil nutrients in relation to land-use and landscape position in the semi-arid small catchment on the loess plateau in China. *J. Arid. Environ.,* **48**, 537-550 (2001).

Yitbarek, T., H. Gebrekidan, K. Kibret and S. Beyene: Impacts of land-use on selected physico-chemical properties of soils of Abobo Area, Western Ethiopia. *Agric. For. Fish.,* **2**, 177-183 (2013).

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