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Effect of different agricultural land use systems on physico-chemical properties of soil in sub-mountainous districts of Punjab, North-West India

Rajwinder Kaur and Bhat ZA

Abstract

To investigate the effect of land use systems on basic properties of surface and profile, four land use systems i.e cropland, forestry, agro-forestry and grassland were identified for each selected site in the lower Shiwalik foothills of Punjab (Takarla from District Shaheed Bhagat Singh Nagar and Mukerian from District Hoshiarpur). Soil pH of the surface layer ranged from 7.83 to 8.20 and 7.69 to 7.95 under different land-use systems at Takarla and Mukerian, respectively. Soils from cropland as well as forest land use systems at Takarla and forestry as well as grassland systems at Mukerian contained more clay and silt. Available N, P and K at Takarla and Mukerian varied from 37.78 to 234.78 and 40.48 to 264.47, 3.81 to 21.44 and 3.19 to 18.56, 15.83 to 286.67 and 6.66 to 149.17 kg ha^{-1}, respectively. Available N was significantly higher in forestry whereas, available P and K were significantly higher in cropland compared with agro-forestry and grassland. The highest (5.00 g kg^{-1}) concentration of soil organic carbon (SOC) was in the forestryat Takarla and at Mukerian, grassland possessed higher (15.88 g kg^{-1}) value followed by forestry.

Keywords: Agricultural land use, Cropland, Forestry, Agro-forestry, Grassland

1. Introduction

Pedoshere plays an important role in the global carbon cycle. The important effect of SOC on productivity and environmental quality is through its role in supplying nutrients, nutrient recycling, improving soil/plant available water reserves, increasing soil buffer capacity and stabilizing soil structure (Lal 1997) [39, 40]. Organic C has a great contribution to the chemical, physical and biological properties of soil (Franchini *et al.* 2007) [23].At different spatial and time scales, vegetation cover helps in protecting the soil from harsh climatic conditions (Deekor *et al.* 2012) [20]. Lal (1996) [38] and Shepherd *et al.* (2000) [57] experienced that land use in tropical ecosystems could cause significant modifications in soil properties. Since it is a source of energy for the microbial biomass, participates ion nutrient storage and cycling, plant available water, infiltration, aggregate formation and stability, density and soil resistance, as well as influencing cation exchange capacity (Reeves 1997) [52].

Several studies demonstrate that changes in land use and management can strongly affect soil organic matter properties; conversion from forest to croplands, combined with conventional tillage and lack of biomass return to soil, is reported to reduce the degree of soil organic matter humification (Lal and Kimble 1997; Yang *et al.* 2004) [39, 40, 70]. Factors including vegetation coverage, the amount of litter fall as well as root impact and disturbance or management regime can contribute to the significant variation of surface soil SOC across different land uses (Degryze *et al.* 2004, Chen *et al.* 2007) [21, 17]. The maize-wheat and agroforestry systems had 65-88 percent higher SOC stocks than the rice-wheat system (Benbi *et al.* 2012) [9].

Jiao *et al.* (2009) [33] investigated the effects of grassland conversion to cropland and forest on soil organic carbon (SOC) and dissolved organic carbon (DOC) in the farming-pastoral ecotone of inner Mongolia by direct field sampling. The SOC and DOC content in soil decreased after grassland were shifted to forest or cropland, in the sequence of grassland soil > forest soil > cropland soil. Wang*et al.* (2010) [69] observed that SOC concentration decreased with increasing soil depth under all land use types with significant difference across different soil depth. At the surface layer (0-5 cm), SOC was variably distributed under five land use types. The SOC of forest land was significantly different from those under other land uses except for grassland (P>0.05). This indicated that forest land and grassland are more effective in SOC accumulation than other land use types. Malhi *et al.* (2003) [41] reported that soil under hayland or permanent grass cover contained substantially higher SOC than the soil cultivated to annual grain crops.

Shrestha *et al.* (2004) observed that the Soil Organic Carbon stock, mean ± SE, kg C m^{-2} in the topsoil (0-10 cm) was higher in grazing land soil (3.4 ± 0.1) compared to forest soil (1.4 ± 0.2) and cultivated soil (1.4 ± 0.2). The estimated depth wise distribution of SOC stock for 1 m soil depth in the entire watershed was 28, 22, 28 and 22 percent in the 0-10, 10-20, 20-40 and 40 cm soil depths respectively.

Information on effect on different land use systems on physico-chemical properties of soil in sub-montaneous districts of Punjab is lacking, so the present study was undertaken to demonstrate the effect of four land-use systems onphysico-chemical properties soil properties viz; pH, EC, Bulk density, Soilorganic carbon, Available N, Available P, Available K and CEC.

Materials and Methods

Study site

The study were conducted in soils of sub-montaneous districts of Punjab", two sites were selected in '*lowerShiwaliks foothills of Punjab locally known as Kandi area'*i.e Village Takarla, Tehsil Balachaur, District Shaheed Bhagat Singh Nagar and Villages Rajwaal, Shri Pandyan and ChakPandyan, Tehsil Mukerian, District Hoshiarpur. At Takarla site, four land use sytems were located at 31º06'45.2"N and 76º22'39.7"E with height of 339 meter above mean sea level and at Mukerian site, four land use sytems were located at 31º56'29.50"N and 75º51'39.76"E with height of 365 meter above mean sea level.

Land uses

For an evaluation of soil health indicator, four land use sytem: cropland, forestry, agro-forestry and grassland were selected. Cropland systems are characterized by addition of chemical fertilizer and farm yard manure. Soil samples were collected under Maize-Wheat system. Forest land use systems were characterized by regular addition of organic matter in the form of falling leaves including those of treespecies (Beri, Neem, Bamboo, Sarinh, Kikar, Tahli, Lantana and Subabul) in both sites whereas, Agro-forestry was characterized by Poplar-fodder (Bajra, Baru)/Wheat and Sagwaan/Toon, Bahera, Sarihn – Wheat/Barseem. On the other hand, Grassland was characterized by grass stands. AtTakarla, grassland is 25 years and at Mukerian, itis>50 years old.

Soil sampling and Soil analysis

Three spots were randomly selected from selected sites under each land use system. Soil samples were taken with the help of spade from 0-15, 15-30, 30-60 and 60-90 cm depths, with replication, in each land use system. All the samples were brought to the laboratory and air-dried. Soil samples were passed through a set of 5 and 8 mm sieves and the soil fraction retained on the 5 mm sieve was used for analysis of aggregate size distribution. The soil fraction that passed rough 2 mm size sieve was used for determining soil texture, pH and Carbon fractions. The soil pH was determined in 1:2 soil-water suspensions using an Elico-glass electrode pH meter (Jackson 1967) [31, 32]. The electrical conductivity of the soil samples was determined in 1:2 soil-water suspension equilibrated after 24 hours using a conductivity bridge (Richard 1954) [55]. Particle size distribution was determined by International Pipette method (Gee and Bauder 1986) [26]. Bulk density of undisturbed natural soil aggregates, the clod saturation method (Prihar and Hundal 1971) [49] was used. The oven-dried aggregate was weighed and allowed to saturate completely on a sand bath kept in tray containing water. It was then weighed again Volume (V_{wa}) was considered as the total pore space. The bulk colume (V_b) of the aggregate was obtained by

$$V_b = W_s/D_p+V_{wa}$$

Where Ws is the weight of dry clod and D_p is particle density. Bulk density express as g cm^{-3}.

The available nitrogen (kg ha^{-1}) in soil samples was determined by the method of Subbiah and Asija (1956) [66]. The available phosphorus (kg ha^{-1}) in soil samples was determined by following the procedure of Olsen *et al.* (1954) [45]. Available potassium (kg ha^{-1}) content in soil was estimated by extraction with neutral normalammonium acetate and determined on a Flame Photometer (Merwin and Peech 1950). CEC was determined by using 1N ammonium acetate by the method by Jackson 1967 [31, 32]. Soil organic carbon was determined by Walkey and Black's (1934) [68] rapid titration method.

Statistical analysis

All the data were analyzed statistically using analysis of variance for Completely Randomized Design (CRD).

Results and Discussion

Soil pH and EC

Soil pH of the surface layer ranged between 7.83 and 8.20 under different land-use systems at Takarla (Table 1). A perusal of table shows that the soils under different land-use systems at Takarla varied from slightly alkaline to moderate alkaline. Grassland soils had the highest pH (8.2), whereas cropland had a lowest value (7.83) at the surface soils. Similar trend was observed in lower depths. At Mukerian site, under same land-use systems, highest pH (7.95) was observed in grassland, but lower pH (7.69) in forestry. Soil pH slightly increases with soil depth in cultivated lands, similar results observed by Kizilkaya and Dengiz (2010) [36] due to accumulation of basic cations in cultivated lands. Benbi and Brar (2009) [8] observed that long-term intensive cultivation of rice-wheat provide favorable pH environment by decreasing the pH of alkaline soils, leading to increased nutrient availability in soils and reclamation of the alkaline soils.

Table 1: Effect of different land-use systems on pH and EC (dSm^{-1}) at variable depths at Takarla and Mukerian.

Site	Soil pH and EC (dSm^{-1})	Depth (cm)	Cropland	Forestry	Agro-forestry	Grassland	CD (0.05)
Takarla	pH	0-15	7.83	7.90	8.07	8.20	0.146
		15-30	7.77	8.13	8.27	8.42	0.208
		30-60	7.97	7.81	8.12	8.28	NS
		60-90	7.95	7.84	7.97	8.23	NS
	EC (dSm^{-1})	0-15	0.22	0.14	0.18	0.13	0.037
		15-30	0.20	0.12	0.16	0.12	0.030
		30-60	0.15	0.12	0.14	0.11	NS
		60-90	0.14	0.11	0.12	0.10	NS

Mukerian	pH	0-15	7.75	7.69	7.83	7.95	0.079
		15-30	8.02	7.88	8.07	8.31	0.249
		30-60	7.97	7.81	8.12	8.28	NS
		60-90	7.95	7.84	7.97	8.23	NS
	EC (dSm^{-1})	0-15	0.20	0.14	0.17	0.13	0.020
		15-30	0.19	0.12	0.15	0.12	0.019
		30-60	0.18	0.12	0.14	0.11	0.041
		60-90	\0.16	0.11	0.12	0.10	NS

Electrical conductivity showed a range with minimum value of 0.13 dSm^{-1} in grassland to a maximum value of 0.22 dSm^{-1} in the cropland at Takarla. At Mukerian, the highest EC values was observed in the cropland probably because of addition of various salts through fertilizers and lowest value in grassland followed by forestry. Surface soil had higher EC values as compared to sub-surface soils, in general, for all the land uses of both sites, which is possibly due to the slow mobility of salts of various ions towards lower horizons (Sondhi 1992 and Nazir 1993) [64, 44].

Soil Texture

Soils from cropland and forest land use systems at Takarla contained more clay and silt as compared to those in the other two systems (Table 2). However, the differences were not significant if cropland system was compared with agro-forest land-use system, but other systems were significantly different from each other. Grassland had the highest sand percentage. No specific pattern in sand and clay was observed with depth. The higher silt content in the lowest depth can be taken as illuvation. These observations are similar to those obtained by Gilley and Doran (1997) [27, 28] and Singh *et al.* (2005) [59] for texture. The sand content in the agro-forestry system was less as compared to grassland across the profile, due to dwarf roots of grasses in lower depths. Gupta and Verma (1992) [29] have reported similar results in Shiwalik foothills of Jammu and Kashmir.

Table 2: Effect of different land-use systems on soil texture and bulk density (g cm^{-3}) at variable depths at Takarla.

Soil Texture and Bulk density (g cm^{-3}) at different depths (cm)			Cropland	Forestry	Agro-forestry	Grassland	CD (0.05)
Site Takarla	Sand (percent)	0-15	68.12	64.88	71.17	80.38	1.961
		15-30	62.03	64.35	69.67	77.38	4.974
		30-60	62.10	61.63	69.85	73.60	7.017
		60-90	64.17	57.18	68.10	76.42	2.988
	Silt (percent)	0-15	17.55	19.75	17.23	12.88	1.852
		15-30	25.57	21.52	20.03	17.22	5.579
		30-60	24.27	25.87	18.35	19.90	NS
		60-90	21.27	28.29	20.37	16.98	4.083
	Clay (percent)	0-15	14.33	15.37	11.60	6.73	0.573
		15-30	12.40	14.13	10.30	5.40	3.171
		30-60	13.63	12.50	11.80	6.50	1.797
		60-90	14.57	14.53	11.53	6.60	2.648
	Bulk density (g cm^{-3})	0-15	1.67	1.17	1.38	1.51	0.014
		15-30	1.68	1.24	1.49	1.57	0.069
		30-60	1.72	1.38	1.55	1.61	0.068
		60-90	1.82	1.44	1.57	1.67	0.110

At Mukeriansite, data presented in Table 3 reveals that soils in agro-forestry and cropland possessed significantly higher levels of sand content compared with forest and grassland. The differences were not significant if forest land-use system was compared with cropland. The difference were significant if forest land-use system was compared with other two. Silt and clay content was higher in grassland and forestry. Clay content significantly differed in all land-use systems. Soils having more clay content, retain more water, organic matter, exchangeable cations and micronutrients. Clay and organic molecules interact in a complex manner in soils. These organo-clay complexes in the soil act as microhabitats for microorganisms. The activity of microbial life is certainly concentrated in these regions containing clay and organic molecules (Brookers *et al.* 1985) [13].Most of the SOC originates from plant residue additions and during decomposition, plant debris becomes intimately associated with inorganic soil particles and stabilized within soil organo-mineral complexes (Post and Kwon, 2000) [47]. Organo-mineral complexes are predominantly found in association with clay and silt-sized fractions that may limit microbial access to plant C when organo-minerals complex as soil aggregates (Post and Kwon 2000; Bossuyt *et al.* 2002; Six *et al.*2002) [47, 11, 11]. A significant trend between aggregate stability and organic C content was noted in the highly aggregated forest (r = 0.75; $P < 0.05$) and pasture soils (r = 0.80; $P < 0.05$), but the aggregate-C trend was not evident in the cropped soil (r = 0.64). The rate of SOC cycling has been linked to aggregate formation (Beare *et al.* 1994; Six *et al.* 2001) [7, 62], and the low aggregate stability in the cropped soil supports previous research showing that organic C and aggregate stability are greatly impacted by tillage-based cropping systems (Biederbeck *et al.*1994; Bremer *et al.*1994) [10, 12].

Soil Bulk Density

At Takarla, thesoil bulk values observed in the cropland and grassland were 1.66 and 1.51 g cm^{-3} respectively. These are high as compared to other systems because of impact of machinery in the cropland.

Table 3: Effect of different land-use systems on soil texture and bulk density (g cm $^{-3}$) at variable depths at Mukerian.

Soil Texture and Bulk density (g cm $^{-3}$) at different depths (cm)			Cropland	Forestry	Agro-forestry	Grassland	CD (0.05)
Site Mukerian	Sand (percent)	0-15	68.48	67.70	75.73	64.88	1.977
		15-30	67.17	63.03	76.03	64.35	2.432
		30-60	68.07	65.43	71.62	61.63	2.757
		60-90	65.60	63.10	73.97	57.18	2.019
	Silt (percent)	0-15	17.75	17.50	14.47	19.75	1.940
		15-30	22.53	23.03	18.03	21.52	NS
		30-60	20.85	21.70	21.88	25.87	3.152
		60-90	22.87	22.10	19.10	28.29	3.381
	Clay (percent)	0-15	13.77	14.80	9.80	15.37	0.538
		15-30	10.30	13.93	5.93	14.13	3.530
		30-60	11.80	14.40	6.50	12.50	1.816
		60-90	11.53	14.80	6.93	14.53	2.690
	Bulk density (g cm $^{-3}$)	0-15	1.62	1.32	1.47	1.56	0.023
		15-30	1.67	1.36	1.48	1.57	0.053
		30-60	1.74	1.44	1.54	1.57	0.083
		60-90	1.86	1.55	1.57	1.59	0.027

There is lower content of organic matter in the grassland system due to which bulk density is high. Similar observations were reported by Lal (1989) [37] and Rawat *et al.* (1998) [51]. At Mukerian, bulk density values of cropland and grassland 1.62 and 1.56 g cm $^{-3}$. An increase in bulk density with depth has also been observed by different workers under different soil types (Franzluebbers and Stuedemann 2005; Aumtong *et al.* 2009; Barreto *et al.* 2010 and Singh *et al.* 2011) [24, 3, 5, 60]. Stockfisch *et al.* (1999) [65] have observed that bulk density increase with depth due to compaction. The increase is largely because of decreasing organic matter content and reduced aggregation with depth. At both sites higher bulk density in grassland is due to compaction effect of grazing by animals year after year and less soil disturbance. These observations are similar to that obtained by Chaudhary *et al.* (1985) [18] and Reganold and Palmer (1995) [53]. Singh *et al.* (2011) [60] observed that the bulk density increased with soil depth and it had a negative relationship with soil organic C.

Available N, P and K

Available nitrogen (N) was significantly higher in forestry whereas, available phosphorus (P) andpotassium (K) were significantly higher in cropland compared with agro-forestry and grassland (Table 4) in Balachour.

Table 4: Effect of different land-use systems on available N, P and K (kg ha $^{-1}$) and CEC (Cmol kg $^{-1}$) at variable depths at Takarla.

Available NPK and CEC (Cmol kg $^{-1}$) at different depths (cm)			Cropland	Forestry	Agro-forestry	Grassland	CD (0.05)
Site Takarla	Available N (kg ha $^{-1}$)	0-15	132.23	234.78	153.82	89.06	17.606
		15-30	107.95	210.50	121.44	70.17	16.468
		30-60	83.66	194.30	97.15	51.27	19.684
		60-90	75.56	178.11	59.37	37.78	15.247
	Available P (kg ha $^{-1}$)	0-15	21.44	13.45	15.86	11.23	1.618
		15-30	16.43	11.67	12.93	8.68	1.239
		30-60	8.42	4.90	7.86	6.00	1.165
		60-90	4.40	4.00	4.34	3.81	NS
	Available K (kg ha $^{-1}$)	0-15	286.67	79.17	55.83	39.17	115.208
		15-30	164.17	70.00	46.67	35.00	10.440
		30-60	80.00	65.00	40.83	20.00	5.924
		60-90	42.50	58.33	36.67	15.83	8.155
	CEC (Cmol kg $^{-1}$)	0-15	10.83	10.22	9.42	7.43	0.981
		15-30	11.16	9.82	9.60	6.88	0.73
		30-60	10.51	10.00	9.71	7.14	0.340
		60-90	10.54	9.93	10.33	6.63	0.65

Table 5: Effect of different land-use systems on available N, P and K (kg ha $^{-1}$) and CEC (Cmol kg $^{-1}$) at variable depths at Mukerian.

Available NPK and CEC (Cmol kg $^{-1}$) at different depths			Cropland	Forestry	Agro-forestry	Grassland	CD (0.05)
Site Mukerian	Available N (kg ha $^{-1}$)	0-15	124.14	199.70	97.15	264.47	17.046
		15-30	102.55	148.43	75.56	232.09	13.918
		30-60	89.06	105.25	80.96	137.63	18.673
		60-90	75.56	78.26	40.48	89.06	16.469
	Available P (kg ha $^{-1}$)	0-15	18.56	10.89	9.40	13.10	1.204
		15-30	14.00	8.71	7.28	10.13	1.122
		30-60	8.84	7.06	5.03	7.12	0.897
		60-90	4.62	3.53	3.19	3.35	0.704
	Available K	0-15	149.17	72.50	87.50	56.67	8.703

	(kg ha^{-1})	15-30	85.00	64.17	73.33	42.50	10.171
		30-60	63.33	48.33	61.67	37.50	6.658
		60-90	53.33	35.00	50.00	30.00	8.596
	CEC (Cmol kg^{-1})	0-15	12.54	12.65	10.14	9.78	0.647
		15-30	11.56	10.65	9.09	9.96	0.759
		30-60	10.98	10.91	9.64	9.46	0.980
		60-90	11.63	11.45	10.25	9.67	0.885

Higher levels of available N value was observed in the forestry which is expected, as it has highest organic matter content and greater mineralization. Both values for available P and K in cropland probably due to addition of fertilizersand build-up. In forest use system, recycling of nutrients due to falling leaves of tree species was the possible reason for high available N, P and K value. The data (Table 4) on available N, P and K showed that forest and cultivated land use systems had better soil quality compared with grassland. These results are in accordance with those of Bauer *et al.* (1987) [6], Arshad and Coen (1992) [2] and Aune and Lal (1995) [4]. In Mukerian, available N levels were significantly higher (Table 5) in grassland and available P and K in cropland followed by forestry and agro-forestry. Irrespective of land-use systems, available N, P and K content were decreased with depth. Similar observations were reported by Reganold*et al.* (1993) [54], Doran and Parkin (1994) [22], Karlen *et al.* (1994) [35], Reganold and Palmer (1995) [53] and Gilley *et al.* (1997) [27, 28].

Cation exchange capacity (CEC)

At Takarla, CEC of cropland and forest land-use systems possessed higher value as compared to agro-forestry and grassland. Cropland had significantly higher CEC as compared to agro-forestry and grassland. But, forestry possessed significantly higher value as compared to only grassland. At Mukerian, CEC of forest soils significantly higher than agro-forestry and grassland, but insignificantly than cropland, as forest soils have highest organic matter content. CECishighest in cropland due to addition of crop residues and farm yard manure and in forestry due to regular addition of organic matter and high clay content. Similar observation were made by Powell (1986) [48] and Reganold and Palmer (1995) [53]. Deekor *et al.* (2012) [20] opined that both clay and organic matter serve as potential sources of nutrients by attracting cations; as such, soils with large amounts of clay or organic matter have higher exchange capacities than sandy soils, which are usually low in organic matter. Organic carbon and clay play a major role in controlling the CEC (Chandrans *et al.* 2009).

Soil organic carbon

At Takarla, soil organic carbon (SOC) concentration ranged from 2.95 to 5.00 g kg^{-1} soil in the 0-15 cm soil depth (Table 4.8). The highest concentration of SOC was in the forestry (5.00 g kg^{-1}) followed by agro-forestry (4.32 g kg^{-1}), grassland (3.14 g kg^{-1}) and cropland (2.95 g kg^{-1}). Irrespective of the land-use, SOC concentration decreased with depth and ranged from 1.05 to 2.91 g kg^{-1} in 15-30 cm. 0.33 to 2.06 g kg^{-1} in 30-60 cmand 0.36 to 2.00g kg^{-1} in60-90 cm depth (Table 6). The SOC content in grassland soils sharply decreased as compared to other land-use systems. The higher SOC concentration under agro-sforestry may be attributed to input of C through litter fall that occurs at the beginning of winter season and greater root biomass compared to sole annual crops. Poplar trees, grown in the region, add 2.9-3.3 t ha^{-1} of litter fall every year (Tandon *et al.* 1991 and Ralhan *et al.* (1996) [67, 50] and supply 2.3 t C ha^{-1} y^{-1} through roots and leaves (Chauhan *et al.* 2011) [16]. The lowest soil organic carbon in cultivated fields could be due to low organic matter inputs coupled by reduced physical protection of SOC as a result of tillage and oxidation of soil organic matter. This was in agreement with John *et al.* (2005) [34] who reported an increasing SOC concentration in the A horizons in the order arable soils < grassland soils < forest soils. The results of the present study are also in confirmity with the findings of many other authors (Dawit *et al.* 2002; Celik 2005; Merino *et al.* 2004; Heluf and Wakene 2006 and Gebeyaw 2007) [19, 14, 42, 30, 25] elsewhere.

The SOC of virgin forestlands were higher than the virgin grasslands most probably because of differences in management practices between the two-land use systems. Soils of the forest sites were well protected, with little disturbance but that of the virgin grassland were heavily overgrazed, and mostly they were susceptible to surface erosion and poor texture. In addition to this, cow dung is largely used as fuel sources rather than enriching SOC of grassland sites (Abera and Belachew 2011) [1]. In Mukerian, Soil organic carbon (SOC) concentration ranged from 8.97 to 15.88 g kg^{-1} soil in the 0-15 cm soil depth (Table 6). The highest concentration of SOC was in the grassland (15.88 g kg^{-1}) followed by forestry (14.50 g kg^{-1}), cropland (11.76 g kg^{-1}) and agro-forestry (8.97 g kg^{-1}). Irrespective of the land-use, SOC concentration decreased with depth and ranged from 5.04 to 7.57 g kg^{-1} in 15-30 cm, 3.54 to 6.16 g kg^{-1} in 30-60 cmand 2.85 to 5.83g kg^{-1} in60-90 cm depth. Wang *et al.* (2010) [69] observed that SOC concentration decreased with increasing soil depth under all land use types with significant difference across different soil depth. However, the forest lands had significantly higher SOC in lower depths than other land uses. At both sites, SOC content in grassland soils sharply decreased as compared to other land-use systems. Smith and Paul (1990) [63], comparing three different systems, reported that biomass increased in the order: cultivated soils < forest soils < grassland soils. The higher SOC concentration in grassland soils is attributed to the chemical stabilization of organic C in the soil matrix (Percival *et al.* 2000) [46]. Schnurer *et al.* (1985) [56] observed a close relationship between contents of biomass and soil organic carbon, usually considered the most important substrate for soil microorganisms.

Table 6: Soil organic C (g kg^{-1}) in relation to different land-use systems in variable soil depths at Takarla and Mukerian.

Site	Depths (cm)	Cropland	Forestry	Agro-forestry	Grassland	CD (0.05)
Takarla	0-15	2.95	5.00	4.32	3.14	1.119
	15-30	2.49	1.38	2.91	1.05	0.711
	30-60	1.67	0.33	2.06	0.36	0.512
	60-90	1.38	0.36	2.00	0.46	0.459

Mukerian	0-15	11.76	14.97	8.97	15.88	2.265
	15-30	6.32	7.57	5.04	6.52	NS
	30-60	6.16	5.40	5.14	3.54	1.089
	60-90	2.85	5.83	3.47	2.36	1.861

Conclusion

The study was conducted to investigate the impact of agricultural landuse systems on soil physico-chemical properties. The magnitude of soil quality parameters decreased with depth in all landuse systems falling under two sites. Bulk density increased with depth due to compaction and decreasing organic matter content and reduced aggregation with depth.At both sites, availability of N, P, K and CEC possessed high value at surface soil which is associated with clay and organic matter. The higher SOC concentration under forestry and agroforestry may be attributed to input of C through litter fall that occurs at the beginning of winter season and greater root biomass compared to sole annual crops. Permanent grass cover contained substantially higher SOC than the soil cultivated to annual grain crops.At both sites, SOC content in grassland soils sharply decreased as compared to other land-use systems. The lowest soil organic carbon in cultivated fields could be due to low organic matter inputs coupled with reduced physical protection of SOC as a result of tillage and oxidation of soil organic matter.Studies have shown that an increase in SOC levels is directly related to the amount of organic residues added to the soil and fertilizer as well as manure application.

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