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Status of Soil Quality on Prevalent Cropping Systems in Arid Region of Northwestern Himalaya

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ABSTRACT

Background: Wide variations in the soil health indicators were observed among different cropping systems. The soil texture under various sites selected in the present study varied from sandy loam. However, sandy loam was observed as the most dominant texture both under cereal and vegetables based on cropping systems. Soil reaction across various sites under present study was neutral to slightly alkaline in arid regions.

Methods: A total of 90 surface (0-15 cm) and subsurface (15-30 cm) soil samples collected randomly from vegetable and cereal-based cropping systems. After collecting soil samples, these were air dried and analyzed for physical, chemical and biological properties. The study determined the level of availability of nutrients and knew the fertility status of studied areas.

Result: The results show that higher salt accumulation (EC) was observed under vegetable-based cropping systems as compared to those of cereal-based. Organic carbon was medium to high and the available N, P and K contents were in the low to medium category. Organic carbon and available N-P and K contents were higher under the vegetable-based cropping systems than cereal-based. DTPA Fe, Mn, Zn and Cu were observed efficiently. Microbial biomass carbon, microbial biomass nitrogen, potentially mineralizable nitrogen and soil respiration were higher in vegetable-based cropping systems. Higher soil quality index was observed under the vegetable-based cropping system as compared to the cereal based cropping system.

Key words: Arid soil, Cropping system, Soil quality.

INTRODUCTION

In India, the rice-wheat is the most extensive and traditional cropping system which has become the mainstay of cereal production in the country. Rice occupied area nearly 43.8 m ha with production 1.77 million tons. Wheat occupied 29.3 with a production of 103.6 million tons (FAOSTAT, 2022). The prominent cropping systems of India are Rice-Wheat (11 m ha), (Mandal *et al.,* 2018), Maize - Wheat (1.86 m ha), (Jat *et al.*, 2020) and Pearl millet-Wheat (2.26 m ha), (Sharma *et al*., 2021). Wheat is an important post monsoon crop of the country as India is ranking second in wheat production with an area of 30.2 million hectare having production of 93.5 million tons along with productivity of 3093 kg ha^{-1}. In Himachal Pradesh, also wheat among other cereals occupies the largest area of about 0.35 million hectares with total production of 0.68 million tons along with a productivity of 1968 kg ha^{-1}. The principal food crops grown in Himachal are Wheat, Maize, Rice and Barley occupying an area of 341.05, 294.22, 73.69 and 19.23 thousand ha, respectively (Anonymous, 2020-21).

Soil quality (SQ) refers to a set of specific soil properties responsible for sustainable agricultural production and ecosystem health (Mukherjee and Lal, 2014). It depends on how the anthropogenic factors like tillage and cropping systems, land-use and its management interact with natural soil forming processes (Vasu *et al*., 2016). To assess the soil quality, we have to consider various physical, chemical and biological attributes referred to as indicators (Elabbadi *et al*., 2024). These indicators may directly monitor the soil or monitor the outcomes that are affected by the soil.

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Soil quality indicators can also be used to evaluate sustainability of particular land-use and soil management practice in agro-ecosystems.(Thakur *et al*., 2021) Interpreting soil quality merely by monitoring changes in individual soil quality indicators may not give complete information about soil quality (Kumar *et al.,* 2023).

MATERIALS AND METHODS

The soil survey was conducted in Kinnaur district of Himachal Pradesh during 2019-2020 and analysis was done at CSK HP Krishi Vishvavidyalaya, Palampur. The study

area in Kinnaur, located on the Indo-Tibetan border, is very scenic and is surrounded by Tibet on the east, Garhwal Himalaya on the south, Spiti Valley on the north and Kullu on the west. It lies between North latitude 31°35′40″ to 31°34′42″ and East longitude 77°52′38″ to 78°51′28″. The district has a total geographical area of 6,401 sq km and covers 11.5% of the state. 90 surface (0-15 cm) and subsurface (15-30 cm) soil samples were collected from the representative sites of the important cereal and vegetable-based cropping systems, *viz*. Maize-Wheat, Rice-Wheat, Wheat/ Barley-Fallow and vegetable-based cropping sequences of arid region. The soil samples collected from different locations were analysed for WHC, bulk density and aggregate analysis were determined by Yoder apparatus (Mintzer, 1961). A combined glass-calomel electrode was used to determine the pH of aqueous suspension (1:2.5 soil/solution ratio). Electrical conductivity (dsm^{-1}) was measured in the supernatant liquid of soil/ water suspension (with conductivity bridge (Jackson, 1973). Organic carbon (Walkley and Black, 1934), available nitrogen (Subbiah and Asija, 1956), available phosphorus (Olsen *et al*., 1954) and available K by 1N NH4OAc anway and Heidal, (1952) and available DTPA-extractable micronutrient cations like Fe, Zn, Cu and Mn by Lindsay and Norvell, (1978) on atomic absorption spectrophotometer. Microbial biomass carbon (MBC) determination was made by using chloro fumigation-extraction (Vance *et al*., 1987). Microbial biomass nitrogen (MBN) by Jenkinson and Ladd (1981). The potentially mineralizable nitrogen (PMN) was determined by anaerobic incubation method by Keeney, (1982) and soil respiration determined by cholorofumigation and incubation (Jenkinson, 1988).

RESULTS AND DISCUSSION

Bulk density

Bulk density of surface layer (0-0.15 m) under wheat/barley-fallow, cumin/kidney bean-fallow and vegetable based cropping systems (Table 1) ranged from 1.22 to 1.51, 1.22 to 1.44 and 1.21 to 1.32 Mg m^{-3} with mean values of 1.30, 1.29 and 1.26 Mg m^{-3}, respectively, whereas in subsurface (0.15-0.30 m) bulk density varied from 1.27 to 1.55, 1.31 to 1.48 and 1.21 to 1.31 Mg m^{-3} with mean values of 1.33, 1.35 and 1.24 Mg m^{-3}. The higher content of bulk density was found higher when compared to vegetable-based cropping systems, which might be attributed to the role of intensive

Table 1: Bulk density, Mean weight diameter and water holding capacity of soils under different cropping systems of H.P.

Cropping systems	Bulk density (Mg m^{-3})			
	0-15 cm		15-30 cm	
	Range	Mean (SD±)	Range	Mean(SD±)
Wheat/Barley-Fallow	1.22-1.51	1.30 (0.07)	1.27-1.55	1.33 (0.07)
Kalajeera-Kidneybean/Buckwheat-Fallow	1.22-1.44	1.29 (0.07)	1.31-1.48	1.35 (0.06)
Cabbage/Cauliflower/Pea+Potato-Fallow	1.21-1.32	1.26 (0.03)	1.21-1.31	1.24 (0.03)
	MWD (mm)			
Wheat/Barley-Fallow	2.35-4.36	3.41 (0.61)	2.25-4.31	3.35 (0.61)
Kalajeera-Kidneybean/Buckwheat-Fallow	2.45-4.49	3.68 (0.58)	2.25-4.39	3.46 (0.61)
Cabbage/Cauliflower/Pea+Potato-Fallow	3.24-4.88	4.13 (0.51)	3.24-4.84	4.06 (0.48)
	WHC (%)			
Wheat/Barley-Fallow	26.70-37.10	31.57(3.59)	27.70-38.10	32.66 (3.66)
Kalajeera-Kidneybean/Buckwheat-Fallow	31.10-38.10	32.53(1.83)	34.10-40.10	37.53 (2.09)
Cabbage/Cauliflower/Pea+Potato-Fallow	22.80-44.10	36.87(6.30)	23.80-45.10	38.21 (6.30)

Table 2: Soil pH, EC and OC under different cropping systems of HP.

Cropping system	pH			
	0-0.15 m		0.15-0.30 m	
	Range	Mean (SD±)	Range	Mean (SD±)
Wheat/barley-Fallow	7.20-7.80	7.51 (0.23)	7.20-7.70	7.43 (0.19)
Kalajeera-Kidneybean/Buckwheat-Fallow	7.20-7.80	7.53 (0.21)	7.10-7.70	7.42 (0.19)
Cabbage/Cauliflower/Pea+Potato-Fallow	7.20-7.80	7.59 (0.15)	7.20-7.70	7.45 (0.14)
	EC (dSm^{-1})			
Wheat/barley- Fallow	0.49-0.68	0.62 (0.06)	0.48-0.66	0.61 (0.06)
Kalajeera-Kidneybean/Buckwheat-Fallow	0.49-0.68	0.62 (0.06)	0.47-0.67	0.61 (0.06)
Cabbage/Cauliflower/Pea+Potato-Fallow	0.45-0.65	0.58 (0.06)	0.44-0.63	0.56 (0.06)
	OC (g kg^{-1})			
Wheat/barley- Fallow	10.1-14.6	11.8 (1.4)	10.1-14.4	11.7 (1.4)
Kalajeera-Kidneybean/Buckwheat-Fallow	9.2-14.5	11.7(1.7)	9.1-14.4	11.6 (1.8)
Cabbage/Cauliflower/Pea+Potato-Fallow	10.3-16.1	12.8 (1.8)	10.1-16.1	12.7 (1.8)

management tillage operations and frequent applications of higher amounts of organic manure and fertilizers. Mahajan *et al*. (2007); Thu and Quang, (2023).

Mean weight diameter

The mean weight diameter of surface layer (0-0.15 m) under the cereal and vegetable based cropping systems ranged from 2.35 to 4.36, 2.45 to 4.49 and 3.24 to 4.88 mm with mean values of 3.41, 3.68 and 4.13 whereas, of subsurface layer (0.15-0.30 m) it varied from 2.25 to 4.31, 2.25 to 4.39 and 3.24 to 4.84 mm with mean values of 3.35, 3.46 and 4.06, respectively. Slightly higher values of MWD in vegetable-based cropping systems soils may be attributed to a high amount of organic matter responsible for more aggregation in soils (Kanwar, 2016).

Water holding capacity

Water holding capacity of surface layer (0-15 cm) under cereals and vegetable-based cropping systems ranged from 26.70 to 37.10, 31.10 to 38.10 and 22.80 to 44.10 per cent with mean values of 31.57, 32.53 and 36.87 per cent, whereas in subsurface (15-30 cm) water holding capacity varied from 27.70 to 38.10, 34.10 to 40.10 and 23.80 to 45.10 per cent with mean values of 32.66, 37.53 and 38.21 per cent, respectively. Higher WHC of subsurface and surface soil in vegetable-based cropping systems as compared to that of cereal-based may be due to less bulk density and more organic matter content. (Khongjee, 2012 and Kyndiah, 2012).

Soil pH

Soil pH of surface layer (0-0.15 m) under cereals and vegetable-based cropping systems Table 2 ranged from 7.20 to 7.80, 7.20 to 7.80 and 7.20 to 7.80 with mean values of 7.51, 7.53 and 7.59 respectively, whereas in subsurface (0.15-0.30 m) soil pH varied from 7.20 to 7.70, 7.10 to 7.70 and 7.20 to 7.70 with mean value of 7.43, 7.42 and 7.45, respectively. pH values were found to increase in sub soil depth possibly due to leaching of bases. Sharma and Kanwar (2010) and Magota, (2015).

Electrical conductivity (EC)

Electrical conductivity of surface layer (0-0.15 m) under cereals and vegetable-based cropping systems ranged from 0.49 to 0.68, 0.49 to 0.68 and 0.45 to 0.65 dS/m^{-1} with mean values of 0.62, 0.62 and 0.58, respectively, whereas in subsurface layer (0.15-0.30 m), it ranged from 0.48 to 0.66, 0.47 to 0.67 and 0.44 to 0.63 dS/m^{-1} with mean values of 0.61, 0.61 and 0.56 dS/m^{-1}, respectively. The EC values, in general, decreased in the sub-surface soils which may be attributed to relatively higher concentrations of mineral nutrients in the surface layers (Kumar, 1996).

Organic carbon (OC)

Organic carbon of surface layer (0-0.15 m) under cereals and vegetable-based cropping systems ranged from 10.1 to 14.6, 9.2 to 14.5 and 10.3 to 16.1 g kg^{-1} with mean values of 11.8, 11.7 and 12.8 respectively, whereas in subsurface layer (0.15-0.30 m), organic carbon ranged from 10.1 to 14.4, 9.1 to 14.4 and 10.1 to 16.1 g kg^{-1} with mean values of 11.7, 11.6 and 12.7 g kg^{-1}, respectively. Comparatively, higher average organic carbon under the vegetable-based system might be due to frequent additions of the FYM in the vegetable cultivation system and more biomass addition from intensive cropping. (Coskan *et al*., 2012) and Nguyen *et al*. (2024).

Available nitrogen

Available nitrogen content of surface layer (0-0.15 m) under cereals and vegetable-based cropping systems (Table 3) ranged from 287 to 419, 297 to 426 and 297 to 476 kg ha^{-1} with mean values of 313.93, 371.73 and 430.80 kg ha^{-1}, respectively, whereas in subsurface layer (0.15-0.30 m), it ranged from 286 to 418, 295 to 424 and 296 to 475 kg ha^{-1} with mean values of 312.53, 369.53 and 428.47 kg ha^{-1}, respectively. As such, available nitrogen was low to medium under all the cropping systems. The low to medium levels of N may be due to the cultivation of high-nutrient-requirement (Chakrabarti *et al*., 2019).

Table 3: Available nitrogen, phosphorous and potassium content of soils under different cropping systems of HP.

Cropping system	Available N (kg ha^{-1})			
	0-0.15 m		0.15-0.30 m	
	Range	Mean (SD±)	Range	Mean (SD±)
Wheat/Barley-Fallow	287-419	313.93 (40.47)	286-418	312.53 (40.57)
Kalajeera-Kidneybean/Buckwheat-Fallow	297-426	371.73 (37.07)	295-424	369.53 (37.08)
Cabbage/cauliflower/pea+potato-Fallow	297-476	430.80 (47.47)	296-475	428.47 (46.97)
	Available P (kg ha^{-1})			
Wheat/barley-Fallow	18.90-55.10	43.52 (11.27)	18.90-54.10	42.65 (11.02)
Kalajeera-Kidneybean/Buckwheat-Fallow	29.40-57.10	42.21 (9.05)	21.40-56.40	38.89 (9.70)
Cabbage/cauliflower/Pea+Potato	30.80-64.90	50.43 (9.82)	30.10-63.90	49.38 (9.83)
	Available K (kg ha^{-1})			
Wheat/Barley-Fallow	137-351	286.33 (66.65)	136-342	279.73 (64.73)
Kalajeera-Kidneybean/Buckwheat-Fallow	187-350	291.60 (56.41)	167-343	271.00 (58.91)
Cabbage/Cauliflower/Pea+Potato-Fallow	220-360	301.93 (47.98)	210-360	295.13 (46.36)

Available phosphorus

Available phosphorus of surface layer (0-0.15 m) in cereals and vegetable-based cropping systems ranged from 18.90 to 55.10, 29.40 to 57.10 and 30.80 to 64.90 kg ha^{-1}, with mean values of 43.52,42.21 and 50.43 kg ha^{-1}, respectively, whereas in subsurface layer (0.15-0.30 m) it ranged from 18.90 to 54.10, 21.40 to 56.40 and 30.10 to 63.90 kg ha^{-1} with mean values of 42.65, 38.89 and 49.38 kg ha^{-1}, respectively. Higher available P status in vegetable-based cropping systems might be due to frequent application of organic manures and fertilizers (Reddy *et al*., 2006) and (Bajpai *et al*., 2006).

Available potassium

Available potassium content of surface layer (0-0.15 m) under cereals and vegetable-based cropping systems ranged from 137 to 351, 187 to 350 and 220 to 360 kg ha^{-1} with mean values of 286.33, 291.60 and 301.93 kg ha^{-1}, respectively, whereas in subsurface layer (0.15-0.30 m), it ranged from 136 to 342, 167 to 343 and 210 to 360 kg ha^{-1} with mean values of 279.73, 271.00 and 295.13 kg ha^{-1}, respectively. The available potassium was found decreased in subsurface soil depth (Shekhar, 2009).

Available Fe

Available Fe of surface layer (0-0.15 m) under cereals and vegetable-based cropping systems (Table 4) ranged from 5.64 to 16.32, 8.18 to 16.32, 10.18 to 18.42 mg kg^{-1} with the mean values of 10.61, 11.68 and 13.21 mg kg^{-1}, respectively. Whereas in subsurface layer (0.15-0.30 m) it varied from 5.54 to16.22, 8.14 to 16.22 and 10.12 to 16.43 mg kg^{-1} with the mean values of 10.21, 11.59 and 12.21 mg kg^{-1}, respectively. Available Fe was found decreasing in subsoil depth in all the cropping systems.

Available Mn

Available Mn of surface layer (0-0.15 m) under cereals and vegetable-based cropping systems ranged from 1.12 to 3.11, 1.21 to 3.41 and 2.11 to 4.21 mg kg^{-1} with mean values of 2.12, 2.40 and 2.93 mg kg^{-1}, respectively. Whereas, in subsurface layer (0.15-0.30 m) it varied from 1.11 to 3.01, 1.11 to 3.21 and 2.01 to 4.09 mg kg^{-1} with mean values of 2.03, 2.25 and 2.84 mg kg^{-1}, respectively.

Available Zn

Available Zn in surface soil (0-0.15 m) under cereal vegetable-based cropping systems ranged from 1.23 to 4.64, 1.23 to 3.55 and 1.05 to 5.78 mg kg^{-1} with mean values of 2.75, 2.51 and 2.96 mg kg^{-1}, respectively. Likewise, in the subsurface layer (0.15-0.30 m), it ranged from 1.13 to 4.01, 1.23 to 3.15 and 1.05 to 5.72 mg kg^{-1} with mean values of 2.52, 2.36 and 2.93 mg kg^{-1}, respectively.

Available Cu

Available content of surface layer (0-0.15 m) under cereals and vegetable-based cropping systems ranged from 0.18 to 2.77, 0.54 to 2.33 and 0.22 to 2.55 mg kg^{-1} with mean values of 1.06, 1.10 and 1.27 mg kg^{-1}, respectively, whereas in subsurface layer (0.15-0.30 m) it ranged from 0.17 to 2.67, 0.24 to 2.23 and 0.21 to 2.45 mg kg^{-1} with the mean values of 1.00, 1.00 and 1.23 mg kg^{-1}, respectively. Higher content of micronutrients was observed in a vegetable-based cropping system, which may be explained on the basis of higher organic carbon (Chandel *et al*., 2017).

Microbial biomass carbon

Microbial biomass carbon in surface layer (0-0.15 m) under cereals and vegetable-based cropping systems (Table 5) ranged from 223.30 to 558.40, 234.30 to 567.30 and 302.10

Table 4: Available iron, manganese, zinc and copper content of soilsunder different cropping systems of HP.

Cropping system	Available Fe (mg kg^{-1})			
	0-0.15 m		0.15-0.30 m	
	Range	Mean (SD±)	Range	Mean (SD±)
Wheat/Barley-Fallow	5.64-16.32	10.61 (2.91)	5.54-16.22	10.21 (2.56)
Kalajeera-Kidneybean/Buckwheat-Fallow	8.18-16.32	11.68 (2.29)	8.14-16.22	11.59 (2.29)
Cabbage/Cauliflower/Pea+Potato-Fallow	10.18-18.43	13.21 (2.56)	10.12-16.43	12.21 (1.93)
Available Mn (mg kg^{-1})				
Wheat/Barley-Fallow	1.12-3.11	2.12 (0.60)	1.11-3.01	2.03 (0.56)
Kalajeera-Kidneybean/Buckwheat-Fallow	1.21-3.41	2.40 (0.74)	1.11-3.21	2.25 (0.72)
Cabbage/Cauliflower/Pea+Potato-Fallow	2.11-4.21	2.93 (0.66)	2.01-4.09	2.84 (0.65)
Available Zn (mg kg^{-1})				
Wheat/Barley-Fallow	1.23-4.64	2.75 (1.06)	1.13-4.01	2.52 (0.95)
Kalajeera-Kidneybean/ Buckwheat-Fallow	1.23-3.55	2.51 (0.62)	1.23-3.15	2.36 (0.62)
Cabbage/Cauliflower/Pea+Potato-Fallow	1.05-5.78	2.96 (1.42)	1.05-5.72	2.93 (1.39)
Available Cu (mg kg^{-1})				
Wheat/Barley-Fallow	0.18-2.77	1.06 (0.81)	0.17-2.67	1.00 (0.80)
Kalajeera-Kidneybean/Buckwheat-Fallow	0.54-2.33	1.10 (0.47)	0.24-2.23	1.00 (0.52)
Cabbage/Cauliflower/Pea+Potato-Fallow	0.22-2.55	1.27 (0.81)	0.21-2.45	1.23 (0.78)

to 798.80 µg g^{-1} with mean values of 315.81, 353.68 and 400.39 µg g^{-1}, whereas in subsurface layer (0.15-0.30 m), it ranged from 221.30 to 557.40, 231.30 to 560.30 and 301.10 to 794.80 µg g^{-1} with mean values of 314.28, 348.75 and 398.05 µg g^{-1}, respectively. Higher MBC was observed by vegetable-based cropping systems.

Microbial biomass carbon

The MBN of surface layer (0-0.15 m) under cereal and vegetable-based cropping systems ranged from 11.20 to 34.30, 10.20 to 30.20 and 17.20 to 25.90 µg g^{-1} with mean values of 17.47,19.03 and 21.56 µg g^{-1}, respectively. Whereas in the subsurface layer (0.15-0.30 m), it ranged from 10.20 to 24.30, 10.20 to 28.20 and 16.20 to 31.20 µg g^{-1} with mean values of 15.87, 16.56 and 24.43 µg g^{-1}, respectively. Comparatively, higher microbial biomass nitrogen was recorded in the subtropical zone. This might be due to variation in temperature (Padalia *et al*., 2018).

Potentially mineralizable nitraogen

The PMN of surface layer (0-0.15 m) under cereal and vegetable-based cropping systems ranged between 11.10 to 30.10, 14.40 to 31.20 and 14.40 to 37.20 µg g^{-1} with mean values of 19.16, 21.37 and 22.47 µg g^{-1}, respectively. Likewise, in the subsurface layer (0.15-0.30 m) under the respective cropping systems, it varied from 11.10 to 28.10, 13.80 to 28.20 and 13.40 to 35.20 µg g^{-1} with mean values of 17.63, 19.23 and 22.27 µg g^{-1}, respectively. Higher

Table 5: Microbial biomass carbon, microbial biomass of nitrogen, Potential mineralizable of nitrogen and soil respiration of soils under different cropping systems of HP.

Cropping system	MBC (µg g^{-1})			
	0-0.15 m		0.15-0.30 m	
	Range	Mean (SD±)	Range	Mean (SD±)
Wheat/Barley-Fallow	223.30-558.40	315.81 (83.21)	221.30-557.40	314.28 (83.06)
Kalajeera-Kidneybean/Buckwheat-Fallow	234.30-567.30	353.68 (78.03)	231.30-560.30	348.75 (77.99)
Cabbage/Cauliflower/Pea+Potato-Fallow	302.10-798.80	400.39 (127.66)	301.10-794.80	398.05 (127.13)
	MBN (µg g^{-1})			
Wheat/Barley- Fallow	11.20-34.30	17.47 (5.78)	10.20-24.30	15.87 (4.01)
Kalajeera-Kidneybean/Buckwheat-Fallow	10.20-30.20	19.03 (4.96)	10.20-28.20	16.56 (5.18)
Cabbage/Cauliflower/Pea+Potato-Fallow	17.20-25.90	21.56 (2.64)	17.20-24.90	20.69 (2.14)
	PMN (µg g^{-1})			
Wheat/Barley-Fallow	11.80-30.10	19.16 (4.77)	11.10-28.10	17.63 (4.79)
Kalajeera-Kidneybean/Buckwheat-Fallow	14.40-31.20	21.37 (4.34)	13.80-28.20	19.23 (3.99)
Cabbage/Cauliflower/Pea+Potato-Fallow	14.40-37.20	22.47 (5.72)	13.40-35.20	22.27 (5.48)
	Soil respiration (µg CO_2 g^{-1} soil per 24 hrs)			
Wheat/Barley-Fallow	32.30-62.10	42.27 (7.89)	31.30-61.10	39.21 (7.96)
Kalajeera-Kidneybean/Buckwheat-Fallow	29.60-67.80	44.32 (12.03)	31.10-65.10	46.77 (9.37)
Cabbage/Cauliflower/Pea+Potato-Fallow	32.10-67.10	48.30 (9.58)	32.4-60.1	47.10 (6.76)

Table 6: Selected average indicators of soil quality under cereal and vegetable based cropping systems in arid Zone of HP.

Available N (kg ha^{-1})	PMN (µg g^{-1})	Available K (kg ha^{-1})	Available Mn (kg ha^{-1})
	Wheat/Barley-Fallow		
0.75	0.64	0.81	0.58
	***Kalajeera*-Kidneybean/Buckwheat-Fallow**		
371.73	21.37	291.60	2.40
	Vegetable based		
451	25.1	286	2.61

Table 7: Indicators average score under cereal and vegetable based cropping systems in arid zone of HP.

Available N (kg ha^{-1})	PMN (µg g^{-1})	Available K (kg ha^{-1})	Available Mn (mg kg^{-1})
	Wheat/Barley- Fallow		
0.75	0.64	0.81	0.58
	***Kalajeera*-Kidneybean/Buckwheat- Fallow**		
0.87	0.68	0.83	0.57
	Vegetable based		
0.90	0.60	0.84	0.75

potentially mineralizable nitrogen was recorded under the vegetable-based cropping system as compared to the cereal based cropping system.

Soil respiration

Soil respiration rate in surface soil (0-0.15 m) under cereals and vegetable based cropping systems ranged between 32.3 to 62.10, 29.60 to 67.80 and 32.10 to 67.10 µg CO_2 g^{-1} soil with mean values of 42.27, 44.32 and 83.40 µg CO_2 g^{-1} soil whereas in subsurface layer (0.15-0.30 m), it ranged between 31.30 to 61.10, 31.10 to 65.10 and 32.40 to 60.10 µg CO_2 g^{-1} soil with mean values of 39.21, 46.77 and 47.10 µg CO_2 g^{-1} soil, respectively. Among different cropping systems, higher biological parameters properties were observed in vegetable-based cropping systems. This may be due to the higher application of organics that increased levels of carbon in surface soil associated with increased levels of microbial biomass (Nath *et al*., 2012).

On the basis of factor loading value and contribution percentage value, different soil quality indicators were selected (Table 6) the identified average indicators were PMN, available potassium and Mn. Whereas, indicators which were not observed with significant difference between them under cereal and vegetable based cropping systems, were discarded for the next step of MDS preparation. In principal component analysis (PCA), these non-significant variables were dropped and the variables having significant difference within production systems were used further for preparation of MDS. After scoring and weighting, the values were fed in to the additive model and finally aggregate score indicating state of soil quality was determined and the numerical value of soil quality (SQI) was obtained for each parameter of the site. On the basis of factor loading value and contribution percentage value, different soil quality indicators were selected in different agro-climatic zones for soil quality assessment under cereal and vegetable based cropping systems. Whereas, indicators which were not observed with significant difference between them under cereal and vegetable based cropping systems, were discarded for the next step of MDS preparation. In principal component analysis (PCA), these non-significant variables were dropped and the variables having significant difference within production systems were used further for preparation of MDS. After scoring and weighting (Table 7) the values were fed in to the additive model and finally aggregate score indicating state of soil quality was determined and the numerical value of soil quality (SQI) was obtained for each parameter of the site.

Soil quality index

Highly weighted variables Table 8 and 9 (MDS) for assessment of soil quality were available N, P, Mn and PMN. Highly weighted variables which got higher factor loading under Principal component analysis (PCA) or

Table 8: Results from the principal components analysis of soil quality indicators under cereal and vegetable based cropping systems in arid zone of HP.

Principal components	PC1	PC2	PC3	PC4
Eigen value	4.861	3.307	2.359	2.056
Variability (%)	18.002	12.250	8.738	7.614
Cumulative %	18.002	30.252	38.990	46.604
weight	0.386	0.262	0.180	0.163
Eigen vectors				
Available N	*0.355*	-0.119	0.094	-0.021
Available K	0.070	-0.180	-0.339	0.385
Available Mn	0.205	-0.083	-0.329	0.243
PMN	0.100	0.417	0.068	-0.079

Bold italic factor loadings are considered highly weighted;while bold italic underlined factor loadings were retained in MDS.

Table 9: Score, weight and soil quality index (SQI) values of selected minimum data set (MDS) variable under different cropping systems of Himachal Pradesh.

Available N (kg ha^{-1})		PMN		Available K (kg ha^{-1}) Wheat/Barley- Fallow		Available Mn (kg/ha^{-1})		$SQI = \sum_{I=1}^{n} Wixsi$
Score	Weight	Score	Weight	Score	Weight	Score	Weight	
(S)	(W)	(S)	(w)	(s)	(w)	(s)	(w)	
0.75	0.39	0.64	0.26	0.82	0.18	0.58	0.18	0.72
				***Kalajeera*-Kidney bean/Buckwheat-Fallow**				
0.87	0.39	0.68	0.26	0.83	0.18	0.57	0.18	0.76
				Vegetable based				
0.91	0.39	0.60	0.26	0.84	0.18	0.75	0.18	0.79

Table 10: Overall soil quality Index of soils under different cropping systems of HP.

Cropping systems	Soil quality index		
	Range	Mean	SD±
Wheat/Barley-fallow	0.59-1.00	0.72	0.09
Kalajeera-Kidneybean/Buckwheat-fallow	0.59-1.00	0.71	0.09
Vegetable based	0.69-1.00	0.79	0.07

minimum data set (MDS) for assessment of soil quality under cereal and vegetable-based cropping systems. All the factor loadings on PCs were discarded for MDS formation because the eigen value was less than 1 and it is assumed that PCs receiving higher eigen value are only the best to represent the variation between the systems. Therefore, only the PCs with eigen values >1 were examined and considered for MDS (minimum data set) preparation (Kaiser, 1960). The higher value of the index implies that soil quality under that cropping system is better compared to others. In the present investigation, we have observed better SQ under vegetable-based cropping systems. This indicates that in vegetable-based cropping systems, soil generally does not deteriorate the physical, chemical and biological soil quality indicator, whereas the poorest SQ observed in this study was found under cereal based cropping systems.

The higher value of index (Table 10) implied that SQ under that cropping system is better compared to other. Better soil quality was observed under vegetable based cropping systems. This indicates that in vegetable based cropping systems soil generally does not deteriorate the physical, chemical and biological SQ indicator. The poorest SQ observed in this study was found under cereal based cropping systems.

CONCLUSION

The soil quality index (SQI) values the highest under vegetable-based cultivation as compared to cereal-based cultivation.

Conflict of interest

All authors declare that there are no any potential conflicts of interest related to the publication of their work. This includes any financial or personal relationships that could have potentially have appeared to influence the content of the publication.

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