International Journal of Plant & Soil Science

Volume 35, Issue 24, Page 131-146, 2023; Article no.IJPSS.100727
ISSN: 2320-7035

Soil Quality Index for Different Cropping Systems in Northwestern Himalaya Region of India

Ravinder Kumar [a*], Sukhdev Singh Paliyal [b++], Sanjay Kumar Sharma [a++] and Sandeep Sharma [c#]

[a] Department of Soil Science, CSK HPKV, Palampur, 176062 (H.P.), India.
[b] Department of Soil Science, CSK HPKV, HAREC, Dhaulakuan 173001 (H.P.), India.
[c] Department of Soil Science, Punjab Agriculture University, Ludhiana, Punjab, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2023/v35i244305

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/100727

Original Research Article

Received: 02/04/2023
Accepted: 06/06/2023
Published: 27/12/2023

ABSTRACT

Background: A study was conducted to examine the impact of soil quality under different cropping systems in Mid hill conditions of Himachal Pradesh". The study was carried out to ascertain the physical, chemical and biological properties of soils under prevalent cropping systems maize-wheat, rice- wheat and vegetable based in different in mid hill conditions of northwestern Himachal Pradesh.
Methods: On the basis of representative 90 soil samples from two depths i.e. 0-0.15 m and 0.15-0.30 m were collected. Soil samples were analyzed for their physical, chemical and biological properties and key indicators were identified using multivariate statistical analysis for computing the soil quality index.

[++]*Principal Scientist;*
[#]*Soil Chemist;*
**Corresponding author: E-mail: singotraravi786@gmail.com;*

Results: Soil reaction across various sites under present study was 5.30-6.70. 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 available N, P and K contents were in low to medium range. DTPA Fe, Mn, Zn and Cu were observed sufficient, whereas total Fe, Mn, Zn and Cu were recorded higher in cereal and vegetable based cropping system. Microbial biomass carbon, microbial biomass nitrogen, potentially mineralizable nitrogen and soil respiration were low to medium in all cropping systems.
Conclusion: Soil quality index was 1.00 under vegetable based cropping system as compared to the cereal based cropping systems.

Keywords: Assessment soil quality; cropping systems; mid hill; India.

1. INTRODUCTION

Himachal Pradesh, is a mountainous region spread over an area of 55,673 km² with elevation ranging from 350 to 6,500 meters above mean sea level noticeably increased from west to east and south to north. The State categorized into four agro-climatic situations viz. low hills, mid hills sub humid, high hills temperate and high hills dry temperate. Mid hill zone extends from 65 to 1,800 meters above mean sea level. This zone occupies about 8% of the total geographical area and about 37% of the cultivated area of the state mainly having brown soils [1].

In India, the rice – wheat is the most extensive and traditional cropping system which has become the mainstay of cereal production in the country. It occupies an area of about 737.91 lakh hectare [2]. The prominent cropping systems of India are Rice - Wheat (11 m ha), [3], Maize - Wheat (1.86 m ha) [28], and Pearl millet -Wheat (2.26 m ha), [4]. In India, maize is cultivated in an area of 8.69 million hectare having production of 21.81 million tonnes with a productivity of 2509 kg ha^{-1}. Maize is the major crop of Himachal Pradesh. The production of maize, which was cultivated on an area 0.30 million hectare having production 0.67 million tonnes with a productivity of 2270 kg ha^{-1}. 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 tonnes along with productivity of 3093 kg ha^{-1}.

Soil quality has been defined as “the capacity of specific kind of soil to function within ecosystem and land use boundaries to sustain biological productivity, maintain environmental quality and sustain plant, animal and human health” [5]. To assess the soil quality have to consider various physical, chemical and biological attributes referred to as indicators. Soil quality indicators can also be used to evaluate sustainability of particular land-use and soil management practice in agro-ecosystems [6]. Therefore, to assess management-induced changes in soil quality over time, a minimum number of soil quality indicators (minimum data set, MDS) need to be identified from a large data set. Further, combining these indicators in a meaningful way into a single index may help assess soil quality more precisely [7,8]. A valid SQI would also help in interpretation of data from different soil measurements and show whether management and land use are having desired results for productivity, environmental protection and health.

2. MATERIALS AND METHODS

The study fields were located in Mandi District, Himachal State, India. The study site is situated at 31043’19 N latitude and 76058’31” E longitude at an elevation of 880-950 m above mean sea level of Mandi District of Himachal Pradesh. The region receives on an average 1239.98 mm rainfall. Soil sampling was done up to a depth of 0-0.15 m to 0.15 – 0.30m. A total of 90 representative surface (0-0.15 m) and subsurface (0.15-0.30 m) soil samples were collected randomly from different cropping systems falling under different agro-climatic zones of the state from 45 sites (15 samples from each cropping system). Soil samples were air dried and ground to pass through a 2-mm sieve. Soil texture was determined by International pipette [9], while WHC, bulk density and Aggregate analysis were determined by Yoder apparatus [10]. A combined glass–calomel electrode was used to determine the pH of aqueous suspensions (1:2.5 soil⁄solution ratio). Electrical conductivity (dS m^{-1}) was measured in the supernatant liquid of soil⁄water suspension (1:2) with conductivity bridge [11]. Soil organic carbon (OC) was determined using the wet digestion method 20 ml (98% concentrate H_2SO_4) [12]. Available nitrogen (N) was measured by the alkaline permanganate method as described [13]. Available phosphorus (P) was determined by the Bray II method [14]. Available potassium of soil was determined as per the procedure outlined [11]. Whereas total Nitrogen and Phosphrous determined by wet and digestion method [15]. Available micronutrient content copper (Cu),manganese (Mn), iron (Fe), and zinc (Zn) were determined by diethylenetriaminepentaacetic acid (DTPA) extraction [16], followed by atomicabsorption spectrophotometry. Total micronutrients determined by triacid method [11]. Microbial biomass carbon (MBC) determinations were made by using chloroform fumigation method [17]. Microbial biomass nitrogen (MBN) determination was made by using the Chloroform fumigation method [18]. The Potential minealizable nitrogen (PNM) was determined by anaerobic incubation method [19] and soils respiration determined by chloroform fumigation ad incubation [20].

After selection of physical, chemical and biological indicators, each of parameters was scored on the basis of the performance of soil function, considering variation of values within variables. Each variable was transformed or standardized to a value between 0 (least favourable soil function) and 1 (most favourable soil function) scoring functions [21]. Principal components (PCs) for a data set are defined as linear combinations of variables that account for maximum variance within the set by describing vectors of closet fit to the ‘n’ observation in p-dimensional space, subject to being orthogonal to one another. The principal components receiving high eigen values and variables with high factor loading were assumed as the variables that best represent system attributes [22]. Therefore, only the PCs with eigen values 1 or greater, which explained at least 5% of the variation in the data were examined [23]. Within each principal component only highly weighted factors (*i.e.*, those with absolute values within 10% of the highest factor loading or $r \geq 0.40$) were retained for the minimum data set (MDS). To reduce redundancy and to rule out spurious groupings among the highly weighted variables within PCs, multivariate correlation matrix were used to determine the strength of the relationships among variables [21]. If the highly weighted factors were not correlated (correlation coefficient <0.60), then each was considered important and thus retained in the MDS. As a check of how well the MDS represented the management system goals, multiple regressions were run by using the final MDS indicators as independent variables representing management goal as dependent variables.

Highly weighted variables which got higher factor loading under Principal component analysis (PCA) or minimum data set (MDS) for assessment of soil quality under cereal and vegetable based cropping systems. Whereas, other variables did not get enough loading to qualify for MDS. All the factor loadings under PCs discarded for MDS formation because 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 $\geq$ 1 were examined and considered for MDS (minimum data set) preparation. PCA was performed using XLSTAT (version 2018.6, Excel 12.0.4518 32 bit) for variables with significant differences. The main objective of PCA was to reduce the dimension of data while minimising the loss of information [24]. Highly weighted variables under PC1 included available copper and available zinc, under PC2- EC and total Mn. Whereas, other variables did not get enough loading to qualify for MDS. The only variable which got higher factor loading under PC3 were available MWD and PMN and WHC and available nitrogen under PC4.

3. RESULTS AND DISCUSSION

Sand content of surface layer (0-0.15 m) under rice-wheat, maize-wheat and vegetable based systems varied from 57.10 to 67.10, 58.50 to 69.50 and 56.00 to 68.00 per cent with mean values of 63.09, 65.94 and 62.02 per cent, respectively. Whereas in sub-surface layer (0.15-0.30 m) of respective cropping systems in same zone, sand content varied from 58.30 to 66.00, 55.50 to 67.50 and 55.10 to 64.80 per cent with mean values of 61.98, 64.01 and 59.95 per cent, respectively. Sand contents were found a little higher in cereal based cropping systems than vegetable based cropping systems and lower in subsurface of all the three cropping systems of the zone. More content of coarse sand in all the soils under study could be explained due to presence of sandy type of rocks *viz.*, sand stones, silt stones, granites etc. prevailed in the area [25].

Silt content of surface layer (0-0.15 m) under rice-wheat, maize-wheat and vegetable based cropping systems in mid hills humid zone ranged from 15.40 to 18.10, 15.50 to 25.00 and 16.00 to 26.00 per cent with mean values of 17.37, 18.20

and 21.40 per cent, respectively, whereas in subsurface (0.15-0.30 m) silt content varied from 16.20 to 18.80, 13.00 to 22.00 and 15.00 to 25.00 per cent with mean values of 17.50, 16.13 and 20.07 per cent, respectively. Data with respect to the depth and cropping systems revealed that silt content is high in surface under vegetable based cropping systems which might be due to the regularly frequent irrigations resulting in movement of clay to lower layers. The results are in accordance with the findings of Gupta et al. [26].

Clay content of surface layer (0-0.15 m) in mid hills humid zone under rice-wheat, maize-wheat and vegetable based cropping system ranged from 15.00 to 18.50, 15.80 to 17.50 and 16.00 to 19.20 per cent, with mean values of 16. 53, 16.77 and 17.32 per cent, respectively, whereas in subsurface (0.15 –0.30 m) clay content varied from 16.10 to 22.20, 17.10 to 20.15 and 16.40 to 20.20 per cent with mean values of 18.93, 18.49 and 18.44 per cent, respectively. Clay content, in general, increased in the sub-surface in comparison to surface layer which may have resulted due to movement of clay from upper to lower horizon. Minhas et al. [27]. Soil texture under different sites varied from sandy loam to clay loam.

Bulk density (Table 2) of surface soil (0-0.15 m) under rice-wheat, maize-wheat and vegetable based cropping systems ranged from 1.22 to 1.37, 1.14 to 1.28 and 1.20 to 1.27 Mg m^{-3} with mean value of 1.27, 1.22 and 1.21 Mg m^{-3} respectively, whereas in sub-surface (0.15-0.30 m) bulk density values varied from 1.26 to 1.39, 1.19 to 1.31 and 1.21 to 1.29 Mg m^{-3} with mean value of 1.30, 1.25 and 1.24 Mg m^{-3}, respectively. Bulk density generally increased with depths which were obvious because of decreasing trend of organic carbon [28]. The result indicated that as BD increases, OC decreases, and vice-versa.

MWD values under rice-wheat, maize-wheat and vegetable based cropping systems surface layer (0-0.15 m) ranged from 2.03 to 2.86, 2.03 to 2.88 and 2.03 to 2.88 mm with mean values of 2.45, 2.43 and 2.43, respectively, whereas in subsurface layer (0.15 to 0.30 m), it varied from 2.02 to 2.85, 1.07 to 2.71 and 1.02 to 2.79 mm with mean values of 2.43, 1.78 and 1.82 mm, respectively. Irrespective of the depth, higher values of MWD were observed in vegetable based cropping systems than cereal based which decreased in subsurface soil depth. The slightly higher values of MWD in vegetable based cropping systems soils may be attributed to high amount of organic matter responsible for more aggregation in soils [29]. Soil aggregate are consequently stabilized naturally by the accumulation of organic matter produced by microorganisms such as fungi, whose hyphae hold soil particles together and generate a glycoprotein (glomalin) cementing agents that helps bound primary soil particles.

Water holding capacity in surface soils (0-0.15 m) under rice-wheat, maize-wheat and vegetable based cropping system ranged from 38.10 to 53.30, 38.10 to 51.40 and 40.30 to 55.20 per cent, with mean value of 47.41, 44.17 and 50.82 per cent whereas, in subsurface (0.15-0.30 m) water holding capacity varied from 40.10 to 58.30, 40.30 to 52.40 and 50.40 to 58.30 per cent with a mean value of 50.81, 46.84 and 54.55 per cent, respectively. Higher WHC of subsurface and surface soil in vegetable based cropping systems as compared to that of cereal based cropping system may be due to less bulk density and more organic matter content coupled with higher percentage of clay in subsoil and vegetable based cropping system which enhanced the available water [30].

A perusal of data in Table 3 soil pH in the surface (0-0.15 m) layer ranged from 5.30 to 6.70, 5.40 to 6.60 and 5.90 to 6.70 with mean values of 5.80, 6.11 and 6.51 under rice-wheat, maize-wheat and vegetable based cropping system, respectively, whereas in subsurface layer (0.15 - 0.30 m), it varied from 5.20 to 6.60, 5.10 to 6.50 and 5.70 to 6.60 with mean values of 5.70, 5.87 and 6.38 respectively.The soil pH was found to decrease in the sub soil depth and higher pH values were observed in vegetable based cropping systems. This might be due to reduction in leaching of bases and moderating effect of organic matter as it decreases the activity of exchangeable Al^{3+} ions in soil solution due to chelation effect of organic molecules and formation of alumino-phosphate complexes, respectively [31].

Electrical conductivity for surface soils (0–0.15 m) of rice-wheat, maize-wheat and vegetable based cropping systems ranged from 0.14 to 0.49, 0.22 to 0.44 and 0.32 to 0.44 dS m^{-1} with mean values of 0.31, 0.36 and 0.39 dS m^{-1}, respectively. Likewise, for sub-surface soil (0.15-0.30 m), EC varied from 0.14 to 0.47, 0.21 to 0.43 and 0.31 to 0.42 dS $m^{-1}$with mean value of 0.30, 0.34 and 0.37 dS m^{-1}, respectively.

Comparatively a little higher salt accumulation, as evidenced by EC values, under vegetable based cropping system was observed, might be the consequence of frequent applications of fertilizers, composted animal manures and high evaporation conditions coupled with restricted leaching [32].

Organic carbon contents for surface soils (0–0.15 m) under rice-wheat, maize-wheat and vegetable based cropping system ranged from 6.0 to 10.8, 6.0 to 14.0 and 6.5 to 13.0 g kg^{-1} with mean values of 8.3, 8.3 and 10.1g kg^{-1}, respectively, whereas, in subsurface layer (0.15-0.30 m), organic carbon varied from 6.0 to 10.7, 6.0 to 14.0 and 6.1 to 12.9 g kg^{-1} with mean values of 7.6, 8.1 and 9.3g kg^{-1}, respectively. Organic carbon contents were decreased in the subsurface, irrespective of the cropping systems though the organic carbon contents were higher under the vegetable based cropping systems under study. Accumulation of organic matter in the surface layers might be due to incorporation of FYM, leaf litter and addition of decayed roots in the upper layers and their further decomposition might have resulted in accumulation of organic carbon in the surface layers [33].

Available nitrogen (Table 4) of surface soils (0–0.15 m) under rice-wheat, maize-wheat and vegetable based cropping systems ranged from 205 to 347, 201 to 379 and 238 to 467 $kgha^{-1}$ with mean values of 258.80, 279.87 and 332.87 $kgha^{-1}$, respectively, whereas in subsurface layer (0.15-0.30 m), it varied from 204 to 346, 198 to 369 and 219 to 457 $kgha^{-1}$ with mean values of 257.27, 270.40 and 319.93 $kgha^{-1}$, respectively. Low to medium available nitrogen was observed in all the cropping system. Available nitrogen decreased in sub-soil depth and higher nitrogen content were observed in vegetable based cropping systems as compared to cereals based systems which might be due to addition of organic matter and frequent application of nitrogenous fertilizers. Content of available phosphorus in surface layer (0-0.15 m) varied between 15.30 to 26.40, 17.60 to 29.50 and 17.40 to 38.30 $kgha^{-1}$ with mean values of 20.20, 23.97 and 29.90 $kgha^{-1}$, whereas in subsurface layer (0.15-0.30 m), it varied from 13.60 to 25.40, 16.60 and 27.50 and 17.10 to 37.30 $kgha^{-1}$ with mean values of 18.93, 22.31 and 28.68 $kgha^{-1}$, respectively. Irrespective of the depth, available P content in soils of vegetable based cropping systems was higher in comparison to that of cereals and its values decreased in the subsurface, irrespective of the cropping systems. Higher P content in the surface horizons of cultivated soils might be due to the confinement of crop cultivation to this layer and supplementation of the depleted phosphorus through additional phosphatic fertilizers [34].

The content available potassium under rice-wheat, maize-wheat and vegetable based cropping systems, available potassium in surface layer (0-0.15 m) varied between 124 to 201, 145 to 223 and 158 to 243 $kgha^{-1}$ with mean values of 154.87, 165.27 and 196.00 $kgha^{-1}$, whereas in subsurface layer (0.15-0.30 m) varied from 114 to 199, 136 to 221 and 154 to 241 $kgha^{-1}$ with mean values of 145.67, 160.60 and 191.67 $kgha^{-1}$, respectively. The overall status of available potassium was found to be high in the vegetable based cropping systems, irrespective of the depth of soil [35].

Available Fe of surface layer (0-0.15 m) under rice-wheat, maize-wheat and vegetable based cropping system ranged from 10.30 to 19.40, 10.40 to 19.40 and 13.40 to 24.20 mg kg^{-1} with the mean values of 14.72, 14.40 and 17.89 mg kg^{-1}, respectively. Whereas in subsurface layer (0.15-0.30 m), varied between 9.30 to 18.40, 9.40 to 18.40 and 12.40 to 21.20 mg kg^{-1} with mean values of 13.59, 12.67 and 16.15 mg kg^{-1}, respectively. Available Fe was found decreased in subsurface in all the cropping systems. Among different cropping systems, the higher mean extractable Fe was recorded under vegetable cropping systems, might be due to higher organic carbon content under vegetable based cropping systems. Iron oxide minerals play an important role in the preservation of OC by binding mechanisms involving adsorption, co-precipitation, aggregate formation, and occlusion. Similar results were also observed by Sidhu and Shrama [36] for the soils of Himachal Pradesh.

Available Mn of surface layer (0-0.15 m) under rice-wheat, maize-wheat and vegetable based cropping systems varied between 8.20 to 12.10, 8.40 to 12.30 and 10.30 to 14.50 mg kg^{-1} with mean values of 9.70, 10.37 and 12.70 mg kg^{-1}, respectively. Whereas in subsurface layer (0.15-0.30 m), it varied from 7.40 to 11.10, 7.40 to 11.30 and 9.20 to 13.50 mg kg^{-1} with mean values of 8.89, 9.33 and 11.62 mg kg^{-1}, respectively. Among different cropping systems, higher Mn contents were observed in vegetable based cropping systems which found decreased in subsurface, irrespective of the cropping systems. These results are in conformity with the findings of Gupta et al. [37].

Available Zn in surface layer (0-0.15 m) under rice-wheat, maize-wheat and vegetable based cropping systems varied from 1.5 to 4.1, 1.4 to 4.1 and 1.5 to 5.2 mg kg^{-1} with mean values of 2.51, 2.39 and 3.02 mg kg^{-1}, respectively, whereas in subsurface layer (0.15-0.30 m), it ranged from 1.2 to 3.7, 1.2 to 4.7 and 1.4 to 5.1 mg kg^{-1} with mean values of 2.18, 2.29 and 2.79 mg kg^{-1}, respectively. Irrespective of cropping systems, available Zn was found decreased in sub surface soil depth, though recorded higher in vegetable based cropping systems when compared to cereal based cropping systems. High content of available Zn in surface layers might be due to variable intensity of pedogenic processes and more complexing with organic matter that provides chelating agents for complexation of added or soluble Zn and reduces adsorption and precipitation. These results are in conformity with the findings of Mahajan [25].

Content of available Cu of surface layer (0-0.15 m) under rice-wheat, maize-wheat and vegetable based cropping systems varied from 0.11to 0.24, 0.18 to 0.26 and 0.28 to 0.34 mg kg^{-1} with mean values of 0.19, 0.24 and 0.30 mg kg^{-1}, respectively. Likewise in subsurface layer (0.15-0.30 m), it ranged from 0.11 to 0.21, 0.12 to 0.26 and 0.18 to 0.31 mg kg^{-1} with mean values of 0.17, 0.19 and 0.25 mg kg^{-1}, respectively. Cu decreased with the increase in depth and higher contents were observed in vegetable based cropping systems. The results are in conformity with the earlier findings of Dhale and Prasad [34].

Microbial biomass carbon in surface soil (0-0.15 m) under rice-wheat, maize-wheat and vegetable based cropping systems varied from 145.40 to 352.10, 234.50 to 342.20 and 309.40 to 432.20 µg g^{-1} with mean values of 251.52, 271.73 and 365.45 µg g^{-1}, whereas in sub surface layer (0.15-0.30 m), it ranged between 135.40 to 342.10, 215.20 to 322.20 and 307.40 to 431.20µg g^{-1} with mean values of 239.45, 257.47 and 352.65 µg g^{-1}, respectively. Higher microbial biomass carbon contents were observed in vegetable based cropping than cereal based cropping systems. Higher microbial biomass carbon in vegetable based cropping systems may be due to production of more leaf litter and more root volume allowing more microbial activities. Similar findings were reported by Sharma et al. [38].

Microbial biomass of nitrogen (0-0.15 m) surface layer under rice-wheat, maize-wheat and vegetable based cropping systems ranged from 9.40 to 20.20, 11.40 to 23.70 and 14.20 to 26.30 µg g^{-1} with mean values of 15.15, 17.56 and 20.30 µg g^{-1}, whereas in subsurface layer (0.15-0.30 m), it varied from 9.30 to 19.20, 10.40 to 22.70 and 12.20 to 24.30 µg g^{-1} with mean values of 14.77, 16.23 and 18.43 µg g^{-1}, respectively. Higher microbial biomass nitrogen was recorded under vegetable based cropping systems as compared to the cereal based cropping systems. This might be attributed to the high soil organic carbon content, more root proliferation and additional supply of N by FYM along with fertilizers. These results are in agreement with the findings of Mishra et al. [27].

`Table 1. Sand, silt and clay content of soils under different cropping systems of HP

Cropping system	Sand (%)			
	0-0.15 m		0.15-0.30 m	
	Range	Mean(SD+)	Range	Mean(SD+)
Rice –Wheat	57.10-67.10	63.09 (3.21)	58.30-66.00	61.98 (2.32)
Maize-Wheat	58.50-69.50	65.94 (3.19)	55.50-67.50	64.01 (3.16)
Vegetable based**	56.00-68.00	62.02 (4.06)	55.10-64.80	59.95 (3.21)
Silt (%)				
Rice –Wheat	15.40-18.10	17.37 (0.73)	16.20-18.80	17.50 (0.82)
Maize-Wheat	15.50-25.00	18.20 (2.75)	13.00-22.00	16.13 (2.72)
Vegetable based**	16.00-26.00	21.40 (2.97)	15.00-25.00	20.07 (3.03)
Clay (%)				
Rice –Wheat	15.00-18.50	16.53 (1.25)	16.10-22.20	18.93 (1.69)
Maize-Wheat	15.80-17.50	16.77 (0.64)	17.10-20.15	18.49 (0.99)
Vegetable based**	16.00-19.20	17.32 (1.01)	16.40-20.20	18.44 (1.16)

***1.Capsicum/Tomato/Chilli-Cauliflower/Cabbage/Knolkhol/Broccoli-Capsicum/Tomato/Chilli, 2.Cucumber/Bottlegourd/Bittergourd- Radish/Turnip/early Pea, 3. Okra/Brinjal/Green onion-Radish/Turnip/Spinach- Okra/Brinjal*

Table 2. Bulk density, Mean weight diameter (MWD) and Water holding capacity (WHC) of soils under different cropping systems of HP

Cropping system	Bulk density (Mg m^{-3})			
	0-0.15 m		0.15-0.30 m	
	Range	Mean(SD±)	Range	Mean(SD±)
Rice –Wheat	1.22-1.37	1.27 (0.04)	1.26-1.39	1.30 (0.04)
Maize-Wheat	1.14-1.28	1.22 (0.04)	1.19-1.31	1.25 (0.04)
Vegetable based	1.20-1.27	1.21 (0.02)	1.21-1.29	1.24 (0.02)
MWD (mm)				
Rice –Wheat	2.03-2.86	2.45 (0.32)	2.02-2.85	2.43 (0.31)
Maize-Wheat	2.03-2.88	2.43 (0.27)	1.01-2.71	1.78 (0.47)
Vegetable based	2.03-2.88	2.43 (0.27)	1.02-2.79	1.82 (0.47)
WHC (%)				
Rice –Wheat	38.10-53.30	47.41 (5.30)	40.10-58.30	50.81 (5.14)
Maize-Wheat	38.10-51.40	44.17 (4.61)	40.30-52.40	46.84 (4.22)
Vegetable based	40.30-55.20	50.82 (3.34)	50.40-58.30	54.55 (2.75)

Table 3. 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±)
Rice –Wheat	5.30-6.70	5.80 (0.46)	5.20-6.60	5.70 (0.46)
Maize-Wheat	5.40-6.60	6.11 (0.48)	5.10-6.50	5.87 (0.53)
Vegetable based	5.90-6.70	6.51(0.24)	5.70-6.60	6.38 (0.25)
EC (dSm^{-1})				
Rice –Wheat	0.14-0.49	0.31 (0.10)	0.14-0.47	0.30 (0.10)
Maize-Wheat	0.22-0.44	0.36 (0.06)	0.21-0.43	0.34 (0.06)
Vegetable based	0.32-0.44	0.39 (0.04)	0.31-0.42	0.37 (0.04)
OC (g kg^{-1})				
Rice –Wheat	6.0-10.8	8.3 (1.3)	6.0-10.7	7.6 (1.3)
Maize-Wheat	6.0-14.0	8.3 (2.1)	6.0-14.0	8.1 (2.1)
Vegetable based	6.5-13.0	10.1 (1.9)	6.1-12.9	9.3 (1.7)

Table 4. Available nitrogen, phosphorus and potassium content of soils under different cropping systems of HP

Cropping system	Available N (kgha^{-1})			
	0-0.15 m		0.15-0.30 m	
	Range	Mean(SD±)	Range	Mean(SD±)
Rice –Wheat	205-347	258.80 (47.73)	204-346	257.27 (47.91)
Maize-Wheat	201-379	279.87 (44.43)	198-369	270.40 (44.19)
Vegetable based	238-467	332.87 (69.17)	219-457	319.93 (73.54)
Available P (kgha^{-1})				
Rice –Wheat	15.30-26.40	20.20 (3.92)	13.60-25.40	18.93 (3.92)
Maize-Wheat	17.60-29.50	23.97 (3.94)	16.60-27.50	22.31 (3.50)
Vegetable based	17.40-38.30	29.90 (6.65)	17.10-37.30	28.68 (6.47)
Available K (kgha^{-1})				
Rice –Wheat	124-201	154.87 (199.4)	114-199	145.67 (22.22)
Maize-Wheat	145-223	165.27 (20.63)	136-221	160.60 (21.66)
Vegetable based	158-243	196 .00 (28.36)	154-241	191.67 (29.43)

Table 5. Available iron, manganese, zinc and copper content of soils under 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±)
Rice –Wheat	10.30-19.40	14.72 (2.95)	9.30-18.40	13.59 (2.79)
Maize-Wheat	10.40-19.40	14.40 (1.00)	9.40-18.40	12.67 (2.33)
Vegetable based	13.40-24.20	17.89 (3.25)	12.40-21.20	16.15 (2.97)
Available Mn (mg kg^{-1})				
Rice –Wheat	8.20-12.10	9.70 (1.07)	7.40-11.10	8.89 (1.13)
Maize-Wheat	8.40-12.30	10.37 (1.37)	7.40-11.30	9.33 (1.25)
Vegetable based	10.30-14.50	12.70 (1.18)	9.20-13.50	11.62 (1.19)
Available Zn (mg kg^{-1})				
Rice –Wheat	1.5-4.1	2.51 (0.69)	1.2-3.7	2.18 (0.59)
Maize-Wheat	1.4-4.1	2.39 (0.72)	1.2-4.7	2.29 (0.79)
Vegetable based	1.5-5.2	3.02 (1.00)	1.4-5.1	2.79 (0.96)
Available Cu (mg kg^{-1})				
Rice –Wheat	0.11-0.24	0.19 (0.04)	0.11-0.21	0.17 (0.04)
Maize-Wheat	0.18-0.26	0.24 (0.03)	0.12-0.26	0.19 (0.04)
Vegetable based	0.28-0.34	0.30 (0.02)	0.18-0.31	0.25 (0.05)

Table 6. Microbial biomass carbon, microbial biomass nitrogen, potential minearlizable 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±)
Rice –Wheat	145.40-352.10	251.52 (59.29)	135.40-342.10	239.45 (56.25)
Maize-Wheat	234.50-342.20	271.73 (35.07)	215.20-322.20	257.47 (35.58)
Vegetable based	309.40-432.20	365.45 (31.01)	307.40-431.20	352.65 (39.91)
MBN (µg g^{-1})				
Rice –Wheat	9.40-20.20	15.15 (3.39)	9.30-19.20	14.77 (3.19)
Maize-Wheat	11.40-23.70	17.56 (3.79)	10.40-22.70	16.23 (3.85)
Vegetable based	14.20-26.30	20.30 (3.20)	12.20-24.30	18.43 (3.60)
PMN (µg g^{-1})				
Rice –Wheat	10.40-20.40	15.03 (2.89)	10.20-20.10	14.61 (2.94)
Maize-Wheat	10.40-23.30	16.18 (3.32)	10.20-21.30	14.63 (2.95)
Vegetable based	11.40-22.90	17.02 (3.63)	10.40-21.90	15.95 (3.69)
Soil respiration (µg CO_2 g^{-1} soil per 24 hrs)				
Rice –Wheat	46.40-176.40	90.05 (33.09)	42.40-172.40	87.19 (34.21)
Maize-Wheat	78.30-123.40	100.70 (15.50)	77.30-122.40	98.61 (14.70)
Vegetable based	69.90-207.30	115.87 (39.83)	68.90-206.30	68.90 (113.53)

Potential mineralizable nitrogen (PMN) surface layer (0-0.15 m) under rice-wheat, maize-wheat and vegetable based cropping systems ranged from 10.40 to 20.40, 10.40 to 23.30 and 11.40 to 22.90 µg g^{-1} with the mean values of 15.03, 16.18 and 17.02 µg g^{-1}, respectively. Likewise in subsurface layer (0.15-0.30 m) under respective cropping systems, it varied from 10.20 to 20.10, 10.20 to 21.30 and 10.40 to 21.90 µg g^{-1}, with mean values of14.61, 14.63 and 15.95 µg g^{-1}, respectively. Potentially mineralizable nitrogen relates to organic carbon content. Therefore, under vegetable based cropping system, higher organic carbon owing to more production as well comparatively higher additions of organics might have contributed towards higher PMN. PMN was found more in surface than subsurface and in vegetable based cropping systems than cereals based [39].

Soil respiration rate in surface soil (0-0.15 m) under rice-wheat, maize-wheat and vegetable based cropping systems ranged from 46.40 to 176.40, 78.30 to 123.40 and 69.90 to 207.30 µg CO_2 g^{-1}soil with mean values of 90.05, 100.70 and 115.87 µg CO_2 g^{-1} soil, respectively.

Likewise in subsurface layer (0.15-0.30 m), it ranged from 42.40 to 172.40, 77.30 to 122.40 and 68.90 to 206.30 µg CO_2 g^{-1} soil with the mean values of 87.19, 98.61 and 68.90 µg CO_2 g^{-1} soil, respectively. Soil respiration rate was found decreased in sub soil depth in all the cropping systems [40-44]. Higher respiration rate was observed in vegetable based cropping

Table 7. Selected indicators of soil quality under different cropping systems of HP

Available. Cu (mgkg^{-1})	Available Mn (mgkg^{-1})	EC (dSm^{-1})	MWD (mm)	PMN (µg g^{-1})	Available N(kgha^{-1})	WHC (%)
			Rice- Wheat			
0.11	8.6	0.36	2.23	15.3	210	40.1
0.22	9.5	0.45	2.03	10.4	205	45.8
0.17	10.3	0.3	2.64	12.3	210	53.4
0.21	10.3	0.49	2.64	19.3	209	50.3
0.24	11.2	0.4	2.75	20.4	288	49.5
0.24	9.3	0.33	2.12	16.3	254	49.5
0.15	10.3	0.25	2.24	15.3	205	52.1
0.16	8.5	0.28	2.16	11.3	265	56.6
0.22	9.1	0.37	2.81	15.3	209	50.4
0.23	8.5	0.14	2.68	12.3	312	42.4
0.22	9.3	0.19	2.57	16.4	280	49.5
0.21	8.4	0.28	2.83	14.3	347	58.3
0.19	10.3	0.19	2.09	16.6	290	53.5
0.11	12.1	0.39	2.07	12.4	309	57.3
0.21	9.8	0.24	2.86	17.5	289	53.4
			Maize-Wheat			
0.25	8.6	0.26	2.67	12.1	201	51.2
0.26	11.5	0.41	2.12	10.4	234	50.2
0.22	10.3	0.31	2.11	13.7	288	50.1
0.26	12.3	0.4	2.03	18.3	345	52.4
0.26	11.2	0.22	2.63	23.3	379	49.3
0.25	9.3	0.36	2.18	18.1	307	50.5
0.22	10.3	0.36	2.55	17.2	245	42.1
0.19	11.5	0.42	2.69	14.3	252	40.3
0.24	12.1	0.38	2.17	18.1	306	41.3
0.26	8.5	0.4	2.88	13.1	285	45.3
0.25	9.3	0.31	2.81	18.2	301	46.2
0.25	8.4	0.37	2.44	17.1	259	45.4
0.22	10.3	0.39	2.34	15.9	267	52.1
0.18	12.1	0.44	2.41	13.6	254	42.1
0.23	9.8	0.41	2.36	19.3	275	44.1
			Vegetable based			
0.29	13.6	0.43	2.67	18.5	467	50.4
0.28	12.5	0.43	2.12	11.4	349	56.3
0.32	14.3	0.44	2.11	14.4	268	54.1
0.31	12.3	0.42	2.03	20.4	238	55.2
0.29	11.2	0.36	2.63	22.9	257	51.2
0.34	13.3	0.38	2.18	18.8	310	56.7
0.28	10.3	0.37	2.55	22.4	404	58.3
0.28	11.5	0.41	2.69	13.4	296	53.4
0.29	12.1	0.44	2.17	19.9	435	55.6
0.32	14.5	0.34	2.88	12.3	250	51.3
0.32	13.3	0.32	2.81	16.4	369	56.2
0.34	12.4	0.38	2.44	14.3	328	50.5
0.29	13.3	0.42	2.34	18.9	289	53.5
0.28	12.1	0.35	2.41	13.8	365	58.3
0.32	13.8	0.39	2.36	17.5	368	57.3

Table 8. Indicators score under cereal and vegetable based cropping systems HP

Available Cu (mg kg^{-1})	Available Mn (mg kg^{-1})	EC (dSm^{-1})	MWD (mm)	PMN (µg g^{-1})	Available N ($kgha^{-1}$)	WHC (%)
			Rice- Wheat			
1.00	0.98	0.39	0.78	0.75	0.61	0.69
0.50	0.88	0.31	0.71	0.51	0.59	0.79
0.65	0.82	0.47	0.92	0.60	0.61	0.92
0.52	0.82	0.29	0.92	0.95	0.60	0.86
0.46	0.75	0.35	0.96	1.00	0.83	0.85
0.46	0.90	0.42	0.74	0.80	0.73	0.85
0.73	0.82	0.56	0.78	0.75	0.59	0.89
0.69	0.99	0.50	0.76	0.55	0.76	0.97
0.50	0.92	0.38	0.98	0.75	0.60	0.86
0.48	0.99	1.00	0.94	0.60	0.90	0.73
0.50	0.90	0.74	0.90	0.80	0.81	0.85
0.52	1.00	0.50	0.99	0.70	1.00	1.00
0.58	0.82	0.74	0.73	0.81	0.84	0.92
1.00	0.69	0.36	0.72	0.61	0.89	0.98
0.52	0.86	0.58	1.00	0.86	0.83	0.92
			Maize-Wheat			
0.72	0.98	0.85	0.93	0.52	0.53	0.98
0.69	0.73	0.54	0.74	0.45	0.62	0.96
0.82	0.82	0.71	0.73	0.59	0.76	0.96
0.69	0.68	0.55	0.70	0.79	0.91	1.00
0.69	0.75	1.00	0.91	1.00	1.00	0.94
0.72	0.90	0.61	0.76	0.78	0.81	0.96
0.82	0.82	0.61	0.89	0.74	0.65	0.80
0.95	0.73	0.52	0.93	0.61	0.66	0.77
0.75	0.69	0.58	0.75	0.78	0.81	0.79
0.69	0.99	0.55	1.00	0.56	0.75	0.86
0.72	0.90	0.71	0.98	0.78	0.79	0.88
0.72	1.00	0.59	0.85	0.73	0.68	0.87
0.82	0.82	0.56	0.81	0.68	0.70	0.99
1.00	0.69	0.50	0.84	0.58	0.67	0.80
0.78	0.86	0.54	0.82	0.83	0.73	0.84
			Vegetable based			
0.97	0.76	0.74	0.93	0.81	1.00	0.86
1.00	0.82	0.74	0.74	0.50	0.75	0.97
0.88	0.72	0.73	0.73	0.63	0.57	0.93
0.90	0.84	0.76	0.70	0.89	0.51	0.95
0.97	0.92	0.89	0.91	1.00	0.55	0.88
0.82	0.77	0.84	0.76	0.82	0.66	0.97
1.00	1.00	0.86	0.89	0.98	0.87	1.00
1.00	0.90	0.78	0.93	0.59	0.63	0.92
0.97	0.85	0.73	0.75	0.87	0.93	0.95
0.88	0.71	0.94	1.00	0.54	0.54	0.88
0.88	0.77	1.00	0.98	0.72	0.79	0.96
0.82	0.83	0.84	0.85	0.62	0.70	0.87
0.97	0.77	0.76	0.81	0.83	0.62	0.92
1.00	0.85	0.91	0.84	0.60	0.78	1.00
0.88	0.75	0.82	0.82	0.76	0.79	0.98

system than that of cereals, might be due to high amount of organic matter. The above results are in the same line with that of Law et al. [45]. Respiration temporarily increases as a result of aeration (similar effect as tilling) by increasing the amount of oxygen available to break down organic matter more rapidly [46-49].

The data in (Table 10) with regard to soil health indices show better soils quality index (SQI) in vegetable based cropping systems of mid hill humid conditions of Himachal Pradesh than cereal based cropping systems. It can be summarized that health status of soil under vegetable based cropping system is at higher level as compared to cereal based cropping system [50-57]. This may be attributed to proper adoption of crop rotation, which increases or maintain the quantity and quality of soil organic matter, and improve soil chemical and physical properties [58-61]. Adequate application of fertilizers combined with farmyard manure may increase soil nutrients and soil organic carbon content [62-68]. Similar results were reported by Chaudhury et al. [69] for rice-wheat cropping system in Indo-Gangetic plains of the country.

Table 9. Results from the principal components analysis of soil quality indicators cereals and vegetable based cropping systems of HP

Principal components:	**P C 1**	**P C 2**	**P C 3**	**P C 4**
Eigen value	7.576	2.547	2.203	1.606
Variability (%)	28.060	9.435	8.160	5.949
Cumulative %	28.060	37.495	45.655	51.604
Weight	0.540	0.182	0.158	0.115
Eigen vectors				
p H	0.237	-0.078	0.132	0.010
EC	0.160	***0.286***	-0.095	-0.194
BD	-0.203	-0.273	-0.153	-0.050
MWD	-0.019	-0.142	***0.419***	-0.052
WHC	0.147	-0.121	-0.145	***0.395***
OC	0.183	-0.139	-0.167	-0.131
Available N	0.205	-0.188	0.003	***0.313***
Available P	0.230	0.116	0.050	-0.199
Available K	0.223	0.125	-0.246	-0.072
Available Cu	***0.303***	-0.016	0.155	0.020
Available Fe	0.164	-0.243	-0.104	0.255
Available Mn	***0.286***	0.144	-0.072	0.046
Available Zn	0.134	-0.283	0.238	-0.017
MBC	0.259	0.098	-0.059	-0.119
MBN	0.244	-0.179	0.032	0.004
PMN	0.099	-0.077	***0.390***	0.100
Soil respiration	0.123	0.240	0.304	-0.171

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

Table 10. Score, weight and soil quality index (SQI) values of selected minimum data set (MDS) variable under different cropping systems of HP

Available Cu ($mgkg^{-1}$)		**Mn ($mg\ kg^{-1}$)**		**MWD (mm)**		**WHC (%)**		$SQI = \sum_{i=1}^{n} WiXSi$
Score (S)	**Weight (W)**	**Score (S)**	**Weight (W)**	**Score (S)**	**Weight (w)**	**Score (s)**	**Weight (w)**	
Rice- Wheat								
1.00	0.54	0.65	0.18	0.78	0.16	0.69	0.12	0.73
0.50	0.54	0.90	0.18	0.71	0.16	0.79	0.12	0.72
0.65	0.54	1.00	0.18	0.92	0.16	0.92	0.12	0.87
0.52	0.54	0.95	0.18	0.92	0.16	0.86	0.12	0.81
0.46	0.54	0.57	0.18	0.96	0.16	0.85	0.12	0.71
0.46	0.54	0.53	0.18	0.74	0.16	0.85	0.12	0.64
0.73	0.54	0.94	0.18	0.78	0.16	0.89	0.12	0.83
0.69	0.54	0.74	0.18	0.76	0.16	0.97	0.12	0.78
0.50	0.54	0.47	0.18	0.98	0.16	0.86	0.12	0.7
0.48	0.54	0.75	0.18	0.94	0.16	0.73	0.12	0.72

Available Cu ($mgkg^{-1}$)		Mn ($mg\ kg^{-1}$)		MWD (mm)		WHC (%)		$SQI = \sum_{i=1}^{n} WiXSi$
Score (S)	**Weight (W)**	**Score (S)**	**Weight (W)**	**Score (S)**	**Weight (w)**	**Score (s)**	**Weight (w)**	
0.50	0.54	0.55	0.18	0.90	0.16	0.85	0.12	0.7
0.52	0.54	0.96	0.18	0.99	0.16	1.00	0.12	0.86
0.58	0.54	0.94	0.18	0.73	0.16	0.92	0.12	0.79
1.00	0.54	0.93	0.18	0.72	0.16	0.98	0.12	0.9
0.52	0.54	0.75	0.18	1.00	0.16	0.92	0.12	0.79
Maize-Wheat								
0.72	0.54	0.87	0.18	0.93	0.16	0.98	0.12	0.87
0.69	0.54	0.90	0.18	0.74	0.16	0.96	0.12	0.82
0.82	0.54	0.99	0.18	0.73	0.16	0.96	0.12	0.87
0.69	0.54	0.88	0.18	0.70	0.16	1.00	0.12	0.82
0.69	0.54	0.72	0.18	0.91	0.16	0.94	0.12	0.81
0.72	0.54	0.60	0.18	0.76	0.16	0.96	0.12	0.76
0.82	0.54	0.70	0.18	0.89	0.16	0.80	0.12	0.80
0.95	0.54	0.85	0.18	0.93	0.16	0.77	0.12	0.87
0.75	0.54	1.00	0.18	0.75	0.16	0.79	0.12	0.82
0.69	0.54	0.67	0.18	1.00	0.16	0.86	0.12	0.80
0.72	0.54	0.47	0.18	0.98	0.16	0.88	0.12	0.76
0.72	0.54	0.88	0.18	0.85	0.16	0.87	0.12	0.83
0.82	0.54	0.59	0.18	0.81	0.16	0.99	0.12	0.80
1.00	0.54	0.81	0.18	0.84	0.16	0.80	0.12	0.86
0.78	0.54	0.44	0.18	0.82	0.16	0.84	0.12	0.72
Vegetable based								
0.97	0.54	0.94	0.18	0.93	0.16	0.86	0.12	0.92
1.00	0.54	0.96	0.18	0.74	0.16	0.97	0.12	0.91
0.88	0.54	0.94	0.18	0.73	0.16	0.93	0.12	0.86
0.90	0.54	0.98	0.18	0.70	0.16	0.95	0.12	0.87
0.97	0.54	0.94	0.18	0.91	0.16	0.88	0.12	0.92
0.82	0.54	0.98	0.18	0.76	0.16	0.97	0.12	0.87
1.00	0.54	1.00	0.18	0.89	0.16	1.00	0.12	**1.00**
1.00	0.54	0.97	0.18	0.93	0.16	0.92	0.12	**1.00**
0.97	0.54	0.96	0.18	0.75	0.16	0.95	0.12	0.90
0.88	0.54	0.95	0.18	1.00	0.16	0.88	0.12	0.92
0.88	0.54	0.95	0.18	0.98	0.16	0.96	0.12	**1.00**
0.82	0.54	0.96	0.18	0.85	0.16	0.87	0.12	0.87
0.97	0.54	0.98	0.18	0.81	0.16	0.92	0.12	0.92
1.00	0.54	0.98	0.18	0.84	0.16	1.00	0.12	**1.00**
0.88	0.54	1.00	0.18	0.82	0.16	0.98	0.12	0.91

4. CONCLUSION

The study conclusively indicated that vegetable based cropping system with balanced fertilization along with manures, maintained soil quality as well the productivity. Therefore farmers are advised to adopt cropping systems comprised of vegetables and cereals crops with integrated nutrient management practices.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Bhagat RM, Singh Sarda, Kumar Virender. Aroecological zonation of Himachal Pradesh agricultural systems in formation development at microlevel. Report. CSK Himachal Pradesh. 2006;94.
2. Anonymous. Annual report of department of soil science, Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh. 2019-2020;77.
3. Mandal T, Chandra S, Singh G. Productivity and economics of rice-wheat cropping system under irrigation, nutrient

and tillage practices in a silty clay loam soil. International Journal of Current Microbiology and Applied Sciences. 2018;7:823-831.
4. Sharma MP, Bali SV, Gupta DK. Soil fertility and productivity of rice (*Oryza sativa*)-wheat (*Triticum aestivum*) cropping system in an inceptisol as influenced by integrated nutrient management. Indian Journal of Agricultural Sciences. 2001;71:82–86.
5. Dhaliwal SS, Singh B, Sharma BD, Khera KL. Soil quality and yield trends of different crops in low productive submontane tract and highly productive area in Punjab, India. Indian Journal of Dryland Agriculture Research and Development. 2009;24:39–45.
6. Shukla MK, Lai R, Ebinger M. Determining soil quality indicators by factor analysis. Soil and Tillage Research. 2006;87:194-204.
7. Jaenicke EC, Lengnick LL. A soil-quality index and its relationship to efficiency and productivity growth measures: Two decompositions. American Journal of Agricultural Economics. 1999;81:881-893.
8. Bucher E. Soil quality characterization and remediation in relation to soil management. PhD Thesis, p 206. Department of Crop and Soil Sciences, Pennsylvania State University, USA; 2002.
9. Piper CD. Soil and Plant Analysis. Inc. Sci. Pub. INC, New York; 1950.
10. Mintzer. Methods of Soil Analysis. Part II. American Society of Agronomy, Madison, Wisconsin, USA; 1961.
Mishra B, Sharma A, Singh SK, Prasad J and Singh BP. Influence of continuous application of amendments to maize-wheat cropping system on dynamics of soil microbial biomass in Alfisol of Jharkhand. Journal of the Indian Society of Soil Science. 2008;56:71-75.
11. Jackson ML. Soil chemical analysis, Prentice Hall of India Pvt. Ltd., New Delhi; 1973.
Jackson ML. Soil chemical analysis. New Delhi: Prentice Hall; 1967.
12. Verma Karan, Bindra AD, Singh Janar dan, Negi SC, Datt Naveen, Rana Usha, Manuja Sandeep. Effect of integrated nutrient management on growth, yield attributes and yield of maize and wheat in maize-wheat cropping system in mid hills of Himachal Pradesh. Int. J. Pure App. Biosci. 2018;6(3):282-301.
13. Subbiah BV, Asija GL. A rapid procedure for assessment of available nitrogen in soils. Current Science. 1956;25:259–60.
14. Olsen SR, Cole CU, Watanabe FS, Deen LA. Estimation of available Phosphorous in soil by extracting with sodium bicarbonate. USDA Cire. US Gov. Print, Office, Washington DC. 1954;939.
15. Dalal RC, Sahrawat KL, Myers RK. Inclusion of nitrate nitrite in the Kjeldahal nitrogen determination of soils and plant materials llsing sodium thiosulphate. Communication in Soil Science and Plant Analysis. 1984;15:1453-61.
16. Lindsay WL, Norvell WA. Development of a DTPA soil test for zinc, iron, manganese and copper. Soil Science Society of America Journal. 1978;42:421–28.
17. Bruulsema TW, Duxbury JM. Simultaneous measurement of soil microbial nitrogen, carbon, and carbon isotope ratio. Soil Science Society of America Journal. 1996 Nov;60(6):1787-91.
18. Jenkinson DS, Ladd JN. Microbial biomass in soil, measurement and turn over. In: Soil Biochemistry, (ed. Paul EA, Ladd JN). Marcel Dekker, New York. 1981;5:415-471.
19. Kennedy AC, Pappendick RI. Microbial characteristics of soil quality. Journal of Soil and Water Conservation. 1995;50:243-248.
20. Jenikinson DS. The nitrogen in the Broadbalk wheat Experiment: A model for the turnover of nitrogen through the soil microbial biomass. Soil Biol Biochem. 1988;21(4):535-41.
21. Andrews SS, Karlen DL, Mitchell JP. A comparison of soil quality indexing methods for vegetable production systems in Northern California. Agriculture, Ecosystems & Environment. 2002;90:25-45.
22. Brejda JJ, Moorman TB, Karlen DL, Dao TH. Identification of regional soil quality factors and indicators. I. Central and Southern high plains. Soil Science Society of America Journal. 2000;64: 2115-2124.
23. Wander MM, Bollero GA. Soil quality assessment of tillage impacts on Illinois. Soil Science Society of America Journal. 1999;63:961-971.
24. Armenise E, Redmile-Gordon MA, Stellacci AM, Ciccarese A, Rubino. P Developing a soil quality index to compare soil fitness for agricultural use under different managements in the Mediterranean

environment. Soil and Tillage Research. 2013;130:91–98.
25. Mahajan A. Characterization of Balh valley soils of District Mandi. M Sc Thesis, Department of Soil Science, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India. 2001;133.
26. Gupta RD, Arora S, Gupta GD, Sumberia NM. Soil physical variability in relation to soil erodibility under different land uses in foothills of Shiwalik in North West India. Tropical Ecology. 1981;51(2):183-190.
27. Minhas RS, Minhas HK, Verma SD. Soil characterization in relation to forest vegetation in the wet temperate zone of Himachal Pradesh. Journal of the Indian Society of Soil Science. 1997;45(2):146-15.
28. Mahajan S, Kanwar SS, Sharma SP. Long-term effect of mineral fertilizers and amendments on microbial dynamics in an Inceptisol of Western Himalayas. Indian Journal of Microbiology. 2007;47:86-89.
29. Sharma PD, Qaher AQ. Characterization of some outer Himalayan protected and eroded forest soils. Journal of the Indian Society of Soil Science. 1989;37:113-120.
30. Khongjee S. Runoff and nutrient losses under different land uses in Ga3a microwatershed of Giri river in Solan district of Himachal Pradesh. M.Sc. Thesis, Dr. Y S Parmar University of Horticulture and Forestry, Nauni, Solan. 2012;1-79.
31. Chandel S, Tripathi D, Kakar R. Soil health assessment under protected cultivation of vegetable crops in North-West Himalayas. Journal of environmental Biology. 2017;38:97-103.
32. Shi J, Singh RK, Ali S, Sethy BK, Singh D, Lakaria BL, Chaudhary RS, Singh RK, Sinha NK. Soil aggregates and other properties as inflenced by different long term land uses under table landscape topography of Chambal region, Rajasthan, India. 2009;40:212- 217.
33. Krishan DL, Mausbach JW, Doran JW, Cline RG, Harris RF, Schuman GE. Soil quality: A concept, definition and framework for evaluation. Soil Science Society of America Journal. 2004;6:4–10.
34. Dhale SA, Prasad Jagdish. Characterization and classification of sweet orange growing soils of Jalna district Maharashtra. Journal of the Indian Society of Soil Science. 2009;57(1):11- 17.
35. Tripathi S, Kumari S, Chakraborty A, Gupta A, Chakrabarti K, Bandyapadhyay BK. Microbial biomass and its activities in salt-affected coastal soils. BiolFertil Soils. 2007;42:273–277.
36. Sidhu GS, Sharma BD. Diethylenetriaminepentaacetic acid-extractable micronutrients status in soil under a rice-wheat system and their relationship with soil properties in different agroclimatic zones of Indo-Gangetic Plains of India. Communication in Soil Science and Plant Analysis. 2010;41:29–51.
37. Gupta RD, Arora S, Gupta GD, Sumberia NM. Soil physical variability in relation to soil erodibility under different land uses in foothills of Shiwalik in North West India. Tropical Ecology. 2010;51(2):183-190.
38. Sharma VK, Sharma PD, Sharma SP, Acharya CL, Sood RK. Cultivated soils of Neogal watershed in North-West Himalayas and their suitability for major crops. Journal of the Indian Society of Soil Science. 2004;52:63-68.
39. Jin XT, Kou CL, Christie P, Dou ZX, Zhang FS. Changes in the soil environment from excessive application of fertilizers and manures to two contrasting intensive cropping systems on the North China Plain. Environmental Pollution. 2008;145: 497–506.
40. Singh MJ, Khera KL, Priyabrata S. Selection of soil physical quality indicators in relation to soil erodibility. Archieves of Agronomy and Soil Science. 2011;1–16.
41. Tesfahunegn GB. Soil quality assessment strategies for evaluating soil degradation in northern Ethiopia. Applied and Environmental Soil Science; 2014.
42. Vance ED, Brookes PC, Jenkinson DS. An extraction method for measuring soil microbial biomass carbon. Soil Biology and Biochemistry. 1987;19:703–07.
43. Varvel ED, Jenkinson DS. An extraction method for measuring soil microbial biomass carbon. Soil Biology and Biochemistry. 2001;19(6):703-707.
44. Walkley A, Black IA. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Science. 1934;37:29–38.
45. Law S, Mathur BS, Sinha K. Effect of long-term fertilization, manuring and liming of an Alfisol on maize, wheat and soil properties-III. Forms of potassium. Journal of the Indian Society of Soil Science. 2001; 38(1):21-26.

46. Ammari TG, Tahhan R, Sulebi NA, Tahboub A, Taany RA, Abubaker S. Impact of intensive greenhouse production system on soil quality. Pedosphere. 2015;25(2):282-293.
47. Andrews SS, Karlen, DL Mitchell JP. A comparison of soil quality indexing methods for vegetable production systems in Northern California. Agriculture, Ecosystem and Environment. 20090:25–45.
48. Bhardwaja AK, Jasrotia P, Hamiltona SK, Robertsona GP. Ecological management of intensively cropped agro-ecosystems improves soil quality with sustained productivity. Agriculture, Ecosystems & Environment. 2011;140:419–29.
49. Dadhwal KS, Mandal D, Shrimali SS. Soil quality index for different land use systems in North-Western hilly region of India. Journal of Indian Society of Soil Science. 2011;59:169–76.
50. Raiesi F, Kabiri V. Identification of soil quality indicators for assessing the effect of different tillage practices through a soil quality index in a semi-arid environment. Ecological Indicators. 2016;71:198–207.
51. Reganold JP, Palmer A S. Lockhart JC, Macgregor AN. Soil quality and profitability of biodynamic and conventional farming systems: A review. American Journal of Alternative Agriculture. 2009; 10:36-45.
52. Rezaei SA, Giles RJ, Andrew SS. A minimum data set for assessing soil quality in rangeland. Geoderma. 2006;126:229–34.
53. Sharma S, Chander G, Verma TS. Soil microbiological and chemical changes in rice-wheat cropping system at Palampur (Himachal Pradesh) after twelve years of *Lantana camara* L. residue incorporation. Journal of Tropical Agriculture. 2010;48(1-2):64-67.
54. Sharma U, Bhandari AR. Survey of the nutrient status of apple orchards in Himachal Pradesh. Indian Journal of Horticulture. 1992;49(3):234-241.
55. Singh K. Nature of soil K reserves as related to important pedogenic factors in Himachal Pradesh. Ph.D Thesis, HPKV, Palampur. 1987;1-59.
56. Singh AK, Bordoloi LJ, Kumar MH, Parmar B. Land use impact on soil quality in eastern Himalayan region of India. Environmental Monitoring and Assessment. 2013;185:314–25.
57. Singh AK, Bordoloi LJ, Kumar MH, Parmar B. Land use impact on soil quality in eastern Himalayan region of India. Environmental Monitoring and Assessment. 2013;185:314–25.
58. Doran JW, Parkin TB. Defining and assessing soil quality. In: Defining Soil Quality for a Sustainable Environment (JW Doran; et al., eds.). Soil Science Society of America,Madison, WI, Special Publication. 1994;35:3-22.
59. Erkossa TF, Itanna F, Stahr K. Indexing quality: A new paradigm in soil science research. Australian Journal of Soil Research. 2007;45:129–37.
60. Ezeaku PI. Evaluation of agro-ecological approach to soil quality assessment for sustainable land use and management system. Scientific Research and Essays. 2015;10:501–12.
61. Garcha S, Katyal P, Sharma V. Microbial diversity in soil under different land use systems in submountaineous zone of Punjab. Journal of Indian Society of Soil Science. 2016;64:271–75.
62. Gupta RD, Verma SD. Characterization and classification of some soils of Kandi belt in Jammu Siwalik hills. J Indian Soc. Soil Sci. 1992.;40:809-815.
63. Heise J. Soil quality: An indicator of sustainable land management. Applied Soil Ecology. 1971;15:75–83.
64. Herrick JE. Soil quality: an indicator of sustainable land management? Applied Soil Ecology. 2000;15:75-83.
65. Kalu S, Koirala M, Khadka UR, Anup KC. Soil quality assessment for different land use in the Panchase area of western Nepal. International Journal of Environmental Protection. 2015;5:38–43.
66. Karlen DL, Eash NS, Unger PW. Effect of chemical fertilizer on Nitrate content in vegetables. Journal of Human Agricultural university. 1994;32:165-170.
67. Mandal UK, Ramchandran K, Sharma KL, Satyam B, Venkanna, K Bhanu MU, et al. Assessing soil quality in a semiarid tropical watershed using a geographical information system. Soil Science Society of America Journal. 2011;75:1144–60.
68. Raiesi HM. Determination of plant-available soil manganese. In Graham, RD, Hannam RJ and Uren NC. (eds.) Manganese in Soils and Plants. Kluwer Academic, Dordrecht, The Netherlands. 2017;87–98.

69. Chaudhury J, Mandal UK, Sharma KL, Ghosh H, Mandal B. Assessing soil quality under long-term rice-based cropping system. Communications in Soil Science and PlantAnalysis. 2005;36:1141-1161.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/100727