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IMPACT OF LAND USES ON SOIL QUALITY IN MID HILL REGION OF NORTH WESTERN HIMALAYAS

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ABSTRACT

Impact of dominant land uses on soil quality in mid hills of North Western Himalayas was studied by undertaking an field experiment during 2015 and 2016 considering five land uses as treatments namely traditional agriculture, commercial vegetable, orchard, forest and urban under randomized block design with four replications. Study indicated that dominant land uses has exerted significant impact on physical, chemical and biological properties of the soil. The soil under forest registered highest organic carbon (22.43 g kg^{-1}), microbial biomass carbon (120.40 $\mu g\ g^{-1}$) and WHC (40.61%) , whereas these were lowest under urban land use (15.33 g kg^{-1}, 29.52 $\mu g\ g^{-1}$ and 39.63%, respectively). The soils under commercial vegetable land use registered highest availability of N (381.36 kg ha^{-1}), P (37.81 kg ha^{-1}), K (199.24 kg ha^{-1}), Cu (5.89 mg kg^{-1}) and Fe (51.64 mg kg^{-1}). Soil quality index calculated through PCA and was observed that in the mid hills region soil was better under forest land use with index value of 0.78 followed by traditional agriculture (0.64), orchard (0.60), vegetable (0.60) and urban (0.59). The study indicated that urbanization, commercial fruit and vegetable farming has deteriorated the soil quality NW of Himalayas.

KEY WORDS
Traditional Agriculture
Orchard
Soil Quality Index
Urbanization
Vegetable farming

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INTRODUCTION

Soil quality refers to the capacity of specific kind of soil to function, within natural and managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water quality and support human health and habitation (Seybold *et al.,* 2001). It is an important determinant of agriculture productivity and environmental stability, the two most important challenges the world is facing today (Singh *et al.,* 2013). Maintenance of better soil quality enhances the capacity of soil to support plant, resist erosion, prevent environmental contamination and conserve water.

Soil quality index (SQI) is a tool which integrates many kinds of collected data, to arrive a single number that can be used to compare one soil to another to better understand and evaluate the process that improves or degrade soils. It is a comprehensive way to ascertain environmental quality, agronomic sustainability and socioeconomic viability of a region (Bhardwaj *et al.,* 2011). This tool helps in ascertaining whether soil quality is improving, stable or declining under different land use systems (Masto *et al.,* 2008).

Land use is defined by the purposes for which human exploit the land cover and is characterized by management practices such as logging, ranching and cropping. Land uses such as agriculture, horticulture, forest and urban areas often markedly affect soil quality through changes in biophysical environments, socioeconomic activities and cultural contexts that are associated with such systems. Land use and management are influencing not only soil properties but also its erosion processes, which may lead to deterioration of soil quality and permanent degradation in its productivity (Moges *et al.,* 2013). In agriculture land use cultivation practices have been reported to enhance the erodibility of soils making it susceptible to erosion than the soils under forests. Further, cultivation and other practices under a land use by influencing the status of soil organic matter alter physical, chemical and biological properties and ultimately affect the structure and function of an ecosystem (Celik, 2005).

Like other parts of the world, mid hills of Himachal Pradesh has undergone a tremendous transformation in land uses due to changes in agricultural cropping pattern, urbanization, industrialization, tourism and hydropower generation (Sharma *et al.,* 2014). Therefore, appraisal of soil quality index under different land uses is crucial for adopting measures to improve soil quality and to sustain the productivity in future. Since such kind of studies had not been undertaken in the region so far, therefore the present investigation was conducted with the objective to estimate the soil quality under dominant land uses in the mid hill region of North Western Himalayas.

MATERIALS AND METHODS

The field study was conducted to ascertain the impact of changing land uses on soil quality in the mid hill region at an elevation ranging between 650-1800 m above mean sea level falling in Kullu (31°58′00"N and 77°06′4"E) and Solan (30°90′59"N and 77°09′25"E) districts of Himachal Pradesh (Fig. 1). The climate of the region was mild temperate type with annual average rainfall about 1150 mm. The soils vary from sandy loam to loam in texture.

Five dominant land uses namely (a) Traditional agriculture, (b) Commercial vegetable farming, (c) Commercial orchard, (d) Forest and (e) Urban were selected randomly in the mid hills falling in Kullu and Solan districts of Himachal Pradesh. The field experiment was conducted by taking five land uses as treatments which were arranged under randomized block design by taking four replications in the study area. Under each replication three subsamples has been collected. The traditional agriculture land use consisted of wheat - maize cropping system which was low input based and by default as organic one and is being followed in the region for the last more than fifty years. The commercial vegetable farming system consisted of high input based system wherein commercial vegetable crops are being grown whereas, the orchard was composed of perennial temperate and stone fruit crops wherein injudicious of fertilizer and pesticides are being practiced and are being followed for last thirty years. The forest land use composed of quercus, pines and deodar trees. Urban land use was composed of human settlements, hotel, institutes and commercial centers wherein urban solid waste and domestic effluents are disposed directly in the nearby area without any treatment.

In each selected land uses 60 surface (0-15 cm) soil samples were collected in the month of October, 2015. The soil samples were air dried, ground and sieved (2mm) and stored for further laboratory examination. The bulk density of soil was determined through core method (Singh, 1980). Soil porosity was derived from bulk density using the formula: Porosity = [1-(BD/PD) x 100], where PD is particle density determined by standard pycnometer method (Nayak *et al.,* 2015).

The maximum water holding capacity was determined by equilibrating the soil with water through capillary action in a keen's box (Baruah and Barthakur, 1999). Soil pH and electrical conductivity (EC) was determined in 1: 2.5 soil: water suspension (Jackson, 1973) by using microprocessor based pH meter model 510 of EIA and conductivity meter model 1601 of EIA make. Soil organic carbon (SOC) was determined by rapid titration method (Walkley and Black, 1934). Soil

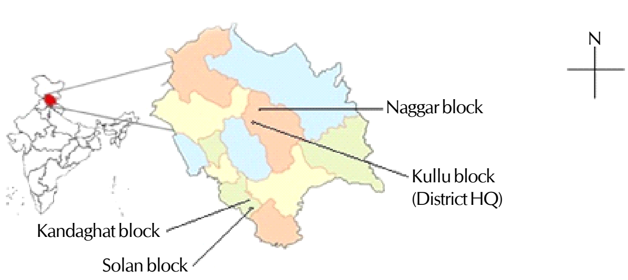

Figure 1: Map of the study area showing the selected sites in mid-hills of Himachal Pradesh

available nitrogen was determined by alkaline permanganate oxidation method (Subbiah and Asija, 1956). The available phosphorus was estimated by Olsen's method using 0.5 N $NaHCO_3$ as extractant and determined colorimetrically by stannous chloride reduced ammonium molybdate method (Olsen *et al.,* 1954). Soil available K was extracted using 1 N ammonium acetate (pH 7.0) followed by determination with flame photometer (Merwin and Peech, 1951). The DTPA-extractable soil Zn, Cu, Fe and Mn were determined by the method of Lindsay and Norvell (1978) using Inductively Coupled Plasma- Atomic Emission Spectroscopy (ICAP-6300 Duo). The chloroform fumigation–extraction method was used to estimate microbial biomass carbon (Vance *et al.,* 1987). The samples in triplicate were fumigated with $CHCl_3$ for 24 hours after that the fumigant was removed and the soil was extracted with 0.5N K_2SO_4. A non-fumigated control was extracted under the same conditions and organic carbon in the extracts was determined by dichromate digestion.

Soil quality index was worked out by considering critical soil quality indicators as detailed by Bhardwaj *et al.* (2011). A total of 15 physical, chemical and biological parameters were considered as indicators for SQI estimation as depicted in fig. 2 which were reduced to minimum data set (MDS) using Principal Component Analysis (PCA) through a series of univariate and multivariate statistical methods. One way Analysis of Variances (ANOVA) was used to identify indicators with significant treatment differences. Only variables with significant difference among treatments ($P < 0.05$) were chosen for next step in MDS formation. After that standardized PCA was performed for each statistically significant variable. Principal components receiving high Eigenvalues of greater than one best represents the high factor loading, which refers to an absolute value within 10% of the highest factor loading (Brejda *et al.,* 2000), was selected and subjected to varimax rotation to maximize correlation between PCs and the measured attributes. Within each PC only components with high factor loading were initially retained for SQI. However, when more than one variable was retained under a particular PC, Pearson's correlation matrix was used to determine the correlation coefficients between the parameters. Significantly correlated parameters having $p < 0.05$ and highest loading factor were retained in the MDS and all others were eliminated to avoid redundancy as suggested by Mukherjee and Lal (2014). After selection of MDS, each observed value of indicator is transformed using linear scoring function into unit less values ranging between 0-1. The unit less values referred as indicator scores (S) were calculated by ranking them in ascending or descending order depending upon its beneficial or detrimental value. For 'higher is better' indicators, each observation value was divided by highest observed value which received the score 1. For 'lower is better' indicators, the lowest observed value was divided by each observation which received a score of 1. For those indicators where neither higher is better nor lower is better, observations were scored as 'higher is better' up to a threshold and then scored as 'lower is better' above the threshold value (Liebig *et al.,* 2001).

Since, some indicators have great influence than others on soil quality; therefore, the scores were multiplied by a weighing factor before taking their averages. The MDS variables for each observation were weighted using PCA results. The percent variation of each PC was divided by total percentage of variation explained by all PCs with Eigenvectors >1.0 to obtain weighted factor (W) for variables chosen under a given PC. The scored indicators for each observation were summed by the following equation given by Bhardwaj *et al.* (2011).

$$SQI = \sum_{i=1}^{n} (Wi\ Si)$$

Where,

S was the score of the indicator, and W the weighted factor derived through PCA. Higher scores were assumed to give the best soil quality. The calculated SQI values were tested for their significance at $p<0.05$ by ANOVA.

The selection of MDS and the PCA for SQI development was conducted using SPSS version 21 (SPSS, 2014). All the parameters were tested using a one-way analysis of variance (ANOVA). Correlation analysis was conducted to identify relationships between the measured parameters. All tests were performed at the 0.01 and 0.05 significance level.

RESULTS AND DISCUSSION

Land use impact on soil parameters

Dominant land uses of mid hills have exerted a significant impact on most of the physical, chemical and biological properties of the soil (Table 1). The soil bulk density varied significantly under different land uses and was in the range of 1.20- 1.42 mg m^{-3}. The forest land use registered lowest bulk density of 1.20 mg m^{-3} which was followed by orchard (1.24 mg m^{-3}), vegetable (1.31 mg m^{-3}), traditional agriculture (1.34 mg^{-3}) and urban (1.42 mg m^{-3}). Similar results were observed by Nayak *et al.* (2015). The lowest bulk density under forest land use may be ascribed to addition of relatively higher organic matter through litterfall and further it's less decomposition. Under forest land use soil is generally not disturbed as in case of agriculture based land uses wherein cultivation practices are responsible for increased loss of organic matter. Relatively higher bulk density observed under traditional agriculture, vegetable and orchard land use may probably be due to soil compaction caused by regular and intensive tillage operations which ultimately might have resulted in loss of organic matter through increased decomposition (Mandal *et al.,* 2011).

The soils under forest land use have registered significantly higher water holding capacity of 40.61% which was followed by vegetable (36.25%), orchard (36.21%), traditional agriculture (35.93%) and urban (31.01%). The WHC of soils under forest land use may be ascribed to its higher organic matter content. Results are in line with the findings of Hazarika *et al.* (2014), who have also observed significant reduction in water holding capacity under systems wherein cultivation is practiced. The present results are in conformity with findings of Weil and Magdoff (2004), Allen *et al.* (2011).

All chemical indicators like pH, organic carbon, available NPK, Cu and Fe were significantly influenced by land uses except available Zn and Mn. Soil pH among different land uses ranged from 6.23 to 7.45 (Table 1). Under all land uses pH was in

Table 1: Soil properties used for the minimum data set (MDS) selection process for different land uses

Land use	BD(mg m^{-3})	WHC (%)	Porosity (%)	Erodibility	pH	EC(μg cm^{-1})	OC(g kg^{-1})	N(kg ha^{-1})	P(kg ha^{-1})	K(kg ha^{-1})	Cu (mg kg^{-1})	Fe (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})	MB (μg g^{-1})
Agriculture	1.34	35.93	40.22	0.50	6.81	287.50	17.61	317.35	18.95	126.51	3.66	36.02	8.09	6.90	85.69
Vegetable	1.31	36.25	43.77	0.50	6.23	377.50	19.04	381.36	37.81	199.24	5.89	51.64	10.86	14.79	77.57
Orchard	1.24	36.21	46.19	0.51	6.52	295.00	19.18	340.75	32.01	169.49	3.93	36.51	11.67	8.46	68.43
Forest	1.20	40.61	44.09	0.45	6.52	222.50	22.43	341.82	7.60	135.80	1.20	28.36	4.63	9.17	120.40
Urban	1.42	31.01	39.63	0.52	7.45	425.00	15.33	255.22	26.12	103.29	1.82	13.19	7.69	4.65	29.52
$P<á^b$	0.00	0.03	0.11	0.12	0.00	0.04	0.04	0.04	0.00	0.04	0.00	0.04	0.20	0.23	0.00

BD- Bulk density; WHC- Water holding capacity; EC- Electrical conductivity; OC- Organic carbon; N- Available nitrogen; P- Available phosphorus; K- Available potassium; Cu- Available copper; Fe- Available iron; Zn- Available zinc; Mn- Available manganese; MB- Soil microbial biomass carbon

Table 2: Factor loading/ eigenvectors of significant soil quality indicators

Factor loading/ Eigenvectors Soil parameters	PC1	PC2	PC3
Bulk density	-0.748[a]	0.017	-0.055
Water Holding Capacity	0.757[a]	0.18	0.171
Soil pH	-0.089	0.087	-0.895[a]
Electrical conductivity	-0.087	0.724	-0.19
Organic Carbon	0.820[a]	0.239	-0.209
Available Nitrogen	0.48	0.31	0.464
Available Phosphorus	0.003	0.848[a]	0.037
Available Potassium	0.396	0.651	0.169
Available Copper	0.236	0.748	0.347
Available Iron	-0.006	0.11	0.882[a]
Soil microbial biomass carbon	0.68	-0.44	0.229
Statistical parameters			
Eigenvalues	3.500	2.214	1.727
% of Variance	31.817	20.131	15.696
Cumulative %	31.817	51.948	67.644

Extraction Method: Principal Component Analysis; Factor loadings are considered highly weighted when within 10% of variation of the absolute values of the highest factor loading in each PC

Table 3: Pearson's correlation matrix among soil properties under different land uses in mid hills of Himachal Pradesh

Variables	Bulk density	Water Holding Capacity	Soil pH	Electrical conductivity	Organic Carbon	Available Nitrogen	Available Phosphorus	Available Potassium	Available Copper	Available Iron	Soil microbial biomass carbon
Bulk density	1.00										
Water Holding Capacity	-0.42**	1.00									
Soil pH	0.17	-0.16	1.00								
Electrical conductivity	0.04	-0.04	0.21	1.00							
Organic Carbon	-0.53**	0.60**	0.12	0.05	1.00						
Nitrogen	-0.32*	0.41**	-0.31	0.22	0.25	1.00					
Phosphorus	-0.02	0.14	0.00	0.43**	0.26*	0.18	1.00				
Potassium	-0.18	0.43**	-0.19	0.38**	0.35**	0.46**	0.46**	1.00			
Copper	-0.21	0.33**	-0.25	0.34**	0.34**	0.40**	0.63**	0.53**	1.00		
Iron	-0.06	0.23	-0.67**	-0.08	-0.06	0.37**	0.13	0.10	0.37**	1.00	
Soil microbial biomass carbon	-0.40**	0.340**	-.315*	-0.27*	0.36**	0.35**	-0.35**	0.08	-0.10	0.08	1.00

**Correlation is significant at the 0.01 level * Correlation is significant at the 0.05 level

Table 4: Land use wise categorization of soil quality index in mid hills of Himachal Pradesh

Land use	Mean	Std. Deviation	Std. Error	Soil quality classification
Agriculture	0.64	0.10	0.03	Medium
Vegetable	0.60	0.08	0.02	Medium
Orchard	0.60	0.09	0.02	Medium
Forest	0.78	0.11	0.03	High
Urban	0.59	0.07	0.02	Medium
Total	0.64	0.11	0.01	Medium
P<á[b]	0.00			

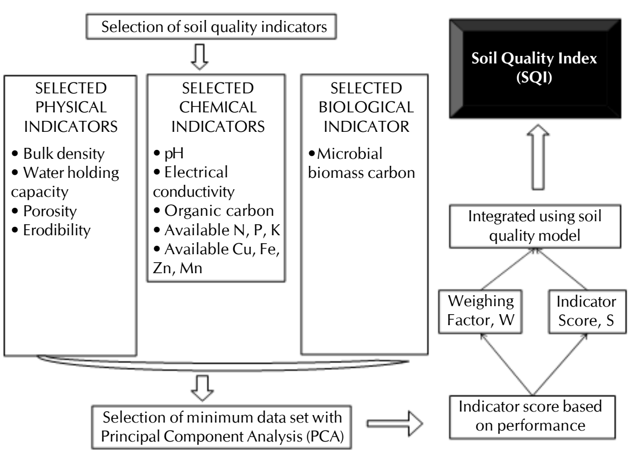

Figure 2: Conceptual framework for soil quality index

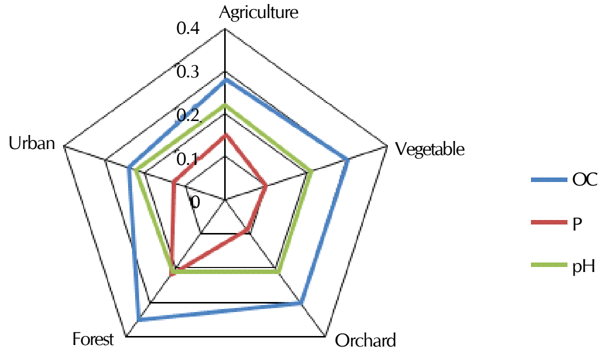

Figure 3: Relative contribution of selected indicators to soil quality index under different land uses of mid hills

normal range except vegetable, wherein it was slightly acidic in reaction which may be ascribed to regular application of acid forming fertilizers like urea under this system. The results are in line with the findings of Kumar *et al.* (2015), Loria *et al.* (2016) who have also noticed slightly acidic pH under vegetable farming in low hills of Himachal Pradesh as a result of continuous use of acid forming fertilizers. The results also corroborate the findings of Babbu *et al.* (2015) who have also noticed soil acidification due to long-term application of urea. Soil EC was found to be in normal range under all selected land uses of the region. Relatively higher EC observed in urban land use (425 μg cm^{-1}) may be probably due to disposal of municipal solid waste and effluents in the nearby soils in the region.

The soil organic carbon under selected land uses of the region was in the range of 15.33- 22.43 g kg^{-1} (Table 1). Land use wise trend of soil organic carbon was: forest (22.43 g kg^{-1}) > orchard (19.18 g kg^{-1}) > vegetable (19.04 g kg^{-1}) > traditional agriculture (17.61 g kg^{-1}) > urban (15.33 g kg^{-1}). In mid hills of Himachal Pradesh the soil organic carbon was found to be in slightly higher range under all land uses which may be due to less decomposition of organic matter because of low temperature. Significantly higher soil organic carbon status of forest land use may be ascribed to more addition of organic matter and less decomposition as compared to other systems wherein regular tilling operations resulted in loss of organic matter because of increased decomposition. The results are in line with the findings of Mandal *et al.* (2011), Bhardwaj *et al.* (2012), Yurembam *et al.* (2015).

The land uses of mid hill region have also been found to exert significant influence on available NPK contents of soil. Under all land uses the available nitrogen was in the range of 255.22 – 381.36 kg ha^{-1} which was in medium range except urban system where it was in lower range. The trend of available nitrogen was: vegetable (381.36 kg ha^{-1}) > forest (341.82 kg ha^{-1}) > orchard (340.75 kg ha^{-1}) > traditional agriculture (317.35 kg ha^{-1}) > urban (255.22 kg ha^{-1}) land use (Table 1). Comparatively higher available nutrient contents in soils under vegetable farming may be attributed to regular additions of nitrogenous fertilizers and organic manures. Degryze *et al.* (2004) have also reported increase in available nitrogen in soils under vegetable farming system due to continuous fertilization. Similarly, the soils under vegetable land use have registered significantly higher available phosphorus of 37.81 kg ha^{-1} followed by orchard (32.01 kg ha^{-1}), urban (26.12 kg ha^{-1}), traditional agriculture (18.95 kg ha^{-1}). However, minimum available phosphorus (7.60 kg ha^{-1}) was noticed under forest land use. Increase in the available fraction of soil phosphorus due to long-term phosphorus fertilization has been reported by Brady and Weil (2010) and Havlin *et al.* (2009). Available potassium among different land uses was in the range of 103.29- 199.24 kg ha^{-1} (Table 1). The vegetable land use registered highest available potassium of 199.24 kg ha^{-1} which was followed by orchard (169.49 kg ha^{-1}), forest (135.80 kg ha^{-1}), traditional agriculture (126.51 kg ha^{-1}) and urban (103.29 kg ha^{-1}). The results are in agreement with those of Somasundaram *et al.* (2009) and Sigdel *et al.* (2015).

The dominant land uses of mid hills have also exerted significant influence on the availability of micronutrients like available Cu and Fe except Zn and Mn. Under different land uses the soil available Cu and Fe ranged from 1.20 to 5.89 and 13.19 to 51.64 mg kg^{-1}, respectively. The land use wise trend of available Cu and Fe was: vegetable (5.89 mg kg^{-1}) > orchard (3.93 mg kg^{-1}) > traditional agriculture (3.66 mg kg^{-1}) > urban (1.82 mg kg^{-1}) > forest (1.20 mg kg^{-1}) and vegetable (51.64 mg kg^{-1}) > orchard (36.51 mg kg^{-1}) > traditional agriculture (36.02 mg kg^{-1}) > forest (28.36 mg kg^{-1}) > urban (13.19 mg kg^{-1}), respectively. The relatively higher availability of Cu and Fe under vegetable land use may be ascribed to long term application of pesticides and fertilizers. The results are in line with the findings of Hazarika *et al.* (2014) and Yurembam *et al.* (2015).

The land uses of mid hills have also resulted in significant variation in the soil microbial biomass carbon which ranged from 29.52– 120.40 $\mu g\ g^{-1}$. Significantly higher soil microbial biomass carbon of 120.40 $\mu g\ g^{-1}$ was observed in forest land use followed by traditional agriculture (85.69 $\mu g\ g^{-1}$), vegetable (77.57 $\mu g\ g^{-1}$), orchard (68.43 $\mu g\ g^{-1}$) and urban (29.52 $\mu g\ g^{-1}$). The richness of soil microbial biomass carbon status under forest land use may be due to higher status of soil organic carbon (Table 1) as compared to other systems. The results are in line with Ford *et al.* (2007), Quinones *et al.* (2011). The sensitiveness of soil microbial biomass to land use practices like pesticide and fertilizer application and its contribution towards low soil microbial biomass carbon under vegetable and orchard farming systems and has also been reported by Hussain *et al.* (2009), Divya *et al.* (2012) and Ullah *et al.* (2013).

Selection of minimum data set

Interestingly, no significant changes in the properties like soil porosity, erodibility, available Zn and Mn was noticed under dominant land uses and hence all four variables were dropped and not considered for further PCA analysis. However the remaining eleven indicators with significant differences were selected for PCA (Table 2). In the PCA using these indicators, three PCs had Eigenvalues > 1 and explained 68% of the variance in data (Table 2). The highly weighted variables under PC1, falling within 10% of highest weight of factor loading, were available organic carbon, water holding capacity and bulk density. The rotated factor loadings of soil organic carbon, water holding capacity and bulk density were 0.820, 0.757 and 0.748 respectively. All these indicators were found to be significantly correlated with each other (Table 3), therefore in order to avoid redundancy in indicator selection only organic carbon was selected on the basis of its higher factor loading. In PC2, only available phosphorus showed highest weighted value and hence was selected for MDS. Soil pH and available Fe registered 0.895 and 0.882 weighted values respectively in PC3. However soil pH was found to be highly correlated with available Fe, therefore only soil pH was retained for MDS (Table 2). Accordingly, the final MDS was composed of organic carbon, available phosphorus and pH.

Soil quality index

In order to calculate SQI, first, the selected MDS variables were transformed into scores ranging from 0 to 1. Out of three significant indicators selected for MDS, soil organic carbon was considered as 'higher is better', whereas other two indicators, available phosphorus and soil pH were considered as 'higher is better' up to a threshold and then scored as 'lower is better' in case they exceeded the threshold value. The second component of SQI is weighted factors. Weighted factors were derived from the PCA. The percent variation in the data set explained by the PC that contributed toward the indicated variable was divided by the total percentage of variation explained by all PCs with Eigenvector >1 as per data presented in table 2, to derive the coefficient of weighing factor. Accordingly, the weighing factor for organic carbon in PC1 was 0.472, whereas for phosphorus in PC2 and for soil pH in PC3 was 0.296 and 0.231 respectively.

Soil indicator values were transformed into scores and finally SQI rating for different land uses was developed on the scale of 0 to 1 using weighing factors derived from the PCA and data is presented in table 4. The data indicated that selected land uses of mid hills of Himachal Pradesh have exerted significant influence on the soil quality. The SQI for different land uses ranged from 0.59 to 0.78. The forest land use registered the highest SQI of 0.78 followed by traditional agriculture (0.64), orchard (0.60), vegetable (0.60) and urban (0.59). The results indicated that urban land use resulted in poor SQI which was statistically at par with vegetable, orchard and traditional land uses. The soil quality of forest land use was found to be high in quality rating (SQI >0.75), while those under agriculture, orchard, vegetable and urban were in medium category (0.50<SQI<0.75) as per the classification of Xu *et al.* (2006). Injudicious application of fertilizers and pesticides in commercial vegetable and orchard and improper disposal of municipal solid wastes and effluents in the region might have resulted in deterioration of soil quality in the said land uses as compared to forest.

Percent contribution of the three indicators namely organic carbon, available phosphorus and soil pH towards SQI is depicted through radar plot (Fig. 3). Among various indicators selected through PCA, organic carbon came out to be the strongest indicator of soil quality with highest factor loading followed by phosphorus and pH. The results are in aggrement with the findings of Liu *et al.* (2006), Shukla *et al.* (2006) and Singh *et al.* (2013) who have also observed soil organic carbon, available phosphorus and pH as the indicators contributing towards SQI. The data presented in figure 3 indicated that the percent contribution of soil organic carbon towards SQI was highest in all land uses and followed the order: forest > orchard > vegetable > traditional agriculture > urban. Contribution of soil organic in improving soil physical, chemical and biological properties and sustaining soil productivity has also been repoted by Rao (2012). In the present study the higher SQI in forest land use may be attributed to its significantly higher soil organic carbon status. Further, land uses also affect structural stability of soil which has been reported to be positively associated with soil organic carbon and ultimately with better SQI (Caravaca *et al.,* 2004). The studies indicated thereby that for sustainable management of soil quality under these land uses, emphasis should be laid to maintain soil organic carbon in higher range, whereas available phosphorus and pH should be maintained at optimum level.

The study indicated that dominant land uses of mid hills of North Western Himalayas have significantly influenced the quality of soils. Parameters such as soil organic carbon, phosphorus and soil pH have been identified as the key indicators of SQI in the region. Urban land use has influenced the soil quality adversely followed by vegetable and orchard farming system in the region. Therefore in order to maintain soil quality in the region eco friendly practices and technologies need to be adopted in the urban land use, whereas in case of commercial vegetable and orchard faming systems the chemical inputs should be used scientifically. Under such farming systems combination of organic and chemical fertilizers may be a viable option to increase yield, improve nutrient availability, soil health and productivity in mid hills of North West Himalayan region in India.

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