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ASSESSMENT OF SOIL QUALITY PARAMETERS UNDER DIFFERENT LAND USES IN SER BANERA-SER CHIRAG WATERSHED IN SOLAN DISTRICT OF HIMACHAL PRADESH, INDIA

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ABSTRACT

This study investigated the impact of different land use systems on soil quality in Ser Banera-Ser Chirag watershed in Solan district of Himachal Pradesh. Results of this study based on the observations recorded in respect to relatively important morphological, physico-chemical and biological properties of soils of both, project and non project area of watershed. Forest land was found best in respect to physical properties such as porosity (46.24%), Maximum water holding capacity (46.19%) and infiltration characteristics (9.4 cm hr^{-1}), chemical properties such as cation exchange capacity (16.62 cmol(p^+) kg^{-1}), exchangeable cations such as potassium (0.50 cmol(p^+) kg^{-1}), calcium (4.18 cmol(p^+) kg^{-1}), and magnesium (1.72cmol(p^+) kg^{-1}), available micronutrients such as zinc(4.00 mg kg^{-1}), iron (16.56 mg kg^{-1}), copper (0.75 mg kg^{-1}) and manganese (4.69 mg kg^{-1}) and biological properties such as bacterial count (320.88 cfu g^{-1}), fungal count (3.66 cfu g^{-1}) and actinomycetes count (16.08 cfu g^{-1}) with higher soil quality index values 0.74 and 0.69 both in project and non project area respectively. Based on findings it can be concluded that overall soil quality of land uses can be enhanced, properly through scientific soil and water conservation measures.

INTRODUCTION

Soil is an important natural resource for all land based activities to meet the requirements of food, fuel, fodder etc. and mankind, and to manage this resource on sustain basis is one of the vital issue in the current scenario, when the pressure on the soil is increasing day by day. Soil and water loss is one of the worldwide environmental issues threatening sustainable land use. Soil erosion is one the most significant forms of land degradation and is greatly influenced by land use and watershed management (Erskin and Saynor, 1996). Water shed management facilitates the harmonious use of the prevailing climate, soils, water, locally available materials and human resource towards steeping up crop yields. Under standing the effects of land use and land cover changes on soil properties have implications for devising land management strategies for sustainable land use. Generally, a sound understanding of land use effects on soil properties provides an opportunity to evaluate sustainability of land use systems (Bewket and Stroosnijder, 2003)..

Soil quality is the "capacity of a specific soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation" (Karlen *et al.* ,1997). It is a dynamic interaction between various physical, chemical and biological soil properties, which are influenced by many external factors such as land use systems, land management practice, environment and socio-economic priorities.

An appropriate land use system plays an important role in improving soil quality through the addition of leaf litter, binding of soil through root system, checking runoff, soil and nutrient losses, *etc.* Therefore, the effects of different land uses on soil quality have become an integral component of watershed management practices. Land use systems such as forest land, grass land, agriculture land and scrub land *etc.*, provide stability and sustainability to the farming systems. Therefore, the maintenance and improvement of soil quality in continuous cropping systems are very important to sustain agriculture productivity for future. These systems not only help the farming community in providing assured income in the events of droughts but also protect the land from degradation and enhance the soil quality.

The practice of mulching impart manifold beneficial effect, like stabilization of soil temperature, reduced water loss through evaporation resulting in more stored soil moisture , maintenance of soil fertility (Kumar V. 2014), suppression of weed growth, improvement in growth and yield , reduces erosion by wind or water, checks surface run-off and suppress the weed growth (Bakshi *et al.,* 2015)

A systematic method of soil quality assessment is required to be developed in mountainous watershed of mid-Himalayas in India. The paper deals with the study of soil quality characteristics under different land use system for appropriate land use system in relation to soil quality characteristics.

MATERIALS AND METHODS

Study region

The study was conducted in the mid-hill zone of Himachal Pradesh (INDIA) at Ser Banera-Ser Chirag , having an elevation of 1238m above mean sea level. It lies between 30º 52′ 533" N latitudes and 77º 11′947" E longitudes. The area encompasses many land uses and dominant land uses were agriculture land, forest land, grassland and scrub land.

Soil sampling and analysis

Based on the detailed survey and area under different land use classes, random sampling technique was followed for the selection of sampling sites. Accordingly, four representative soil samples from the depths of 0.0-0.15 m were collected in the month of June 2012 from watershed project area having four dominant land uses *viz*., grassland, agriculture land, forest land and scrub land. In addition four soil samples also collected from the depths of 0.0-0.15 m were also collected from non project area of watershed from representative land uses *viz*., grassland, agriculture land, forest land and scrub land. Each sample was air dried and divided into two equal parts. One part was processed *i.e.* properly grind in pestle and mortar and passed through 2 mm sieve, to analyze the soils for different morphological (Soil colour) composite soil samples was taken from each land use to assess soil colour, physico-chemical (bulk density, particle density, available nutrients, pH, EC, CEC, MWHC, porosity, soil texture, *etc*.) and biological properties (total microbial count, *etc*). Remaining part was kept unprocessed and unsieved for the determination of aggregate size distribution.

Morpohological and physical properties of soil

Soil colour

Composite soil samples were taken from each land use to assess soil colour. Soil colour was determined in the laboratory by Munsell colour chart.

Mechanical composition

Particle size fractionation was carried out by the International Pipette Method as described by Piper (1966). The texture of the soil was determined by relative distribution of sand, silt and clay in the sample and textural classification was made using ISSS equilateral triangle.

Bulk density (BD)

Bulk density of disturbed soil was determined in the laboratory by Pycnometer method and calculated by using the formula:

$$BD(gcm^{-3}) = \frac{(\text{Wt. of pycnometer} + \text{Soil}) - (\text{Wt.of empty pycnometer})}{\text{Volume of water filled in pycometer}}$$

Particle density (PD)

Particle density of disturbed soils was determined in the laboratory by standard Pycnometer method and was calculated using the formula:

$$PG(gcm^{-3}) = \frac{10}{W_{pw} + 10 - W_{psw}}$$

Where,

W_{pw} = Weight of water filled in pycnometer

W_{psw} = Weight of pycnometer + water + soil

Porosity

Porosity was determined by using bulk density and particle density with the help of empirical formula:

$$\text{Porosity} = 1 - \frac{BD}{PD} \times 100$$

Where,

BD = Bulk density (g cm^{-3})

PD = Particle density (g cm^{-3})

Maximum water holding capacity (MWHC)

Maximum water holding capacity (MWHC) was determined by Keen Raczkowski (K. R.) Box method (Piper, 1966).

Aggregate Size distribution and mean weight diameter (MWD)

Aggregate size distribution was determined by following the standard wet sieving method outlined by Yoder (1936). From this data, water stable aggregates (WSA), > 0.25 and < 0.25 mm in diameter were worked out. Mean weight diameter (MWD) was calculated according to the formula of Yonker and Mc Guiness (1957) as under:

$$MWD = \sum_{i=1}^{n} diWi$$

Where,

d_i = Mean diameter of each size fraction

W_i = Proportion of sample size

Infiltration characteristics

Infiltration rate of soil was determined in the field. Infiltration studies were carried out under each land use by using double ring infiltrometers. The infiltrometers were installed in duplicate at three different sites under each land use. Water was added slowly to avoid dispersion of soil at the surface. Constant head of water was maintained inside the infiltrometer. The volume of water required to replenish the quantity of water that infiltered in the soil was recorded as a function of time. Experiment was run up to 300 minutes. Both infiltration rate (cm hr^{-1}) and cumulative infiltration (cm) were plotted against time for each replicate separately. The curves were drawn through the data obtained from the replicates. These averaged out curves were plotted to represent the average infiltration rate and cumulative infiltration under each land use.

Chemical properties

Various soil chemical properties were determined in the laboratory by using standard methods (Table 1).

Biological properties

Total microbial count (bacteria, fungi and actinomycetes count in soil)

The serial dilution and plating techniques suggested by Rao (1999) was employed for isolation and identification of viable bacteria, actinomycetes and fungi count.

Scoring functions and soil quality evaluation indicators selection criteria

Scoring technique

First of all the most relevant indicators representing various functions were selected (Table 3). Unit less standard scores (0-1 scale) were given to the indicators according to their importance. For example 'more is better' concept was used in case of organic carbon, infiltration rate etc. On the other hand, in case of bulk density and particle density, 'lower is better' concept was followed for ranking. The critical limits of various parameters were used for ranking. The associated score of 1 represented the highest potential function for that system. Weight was calculated by following the procedure outlined by Andrews *et al.,* 2002 (Table 2).

Integration

The converted values on 0 to 1 scale were multiplied by the respective weight assigned to them. The aggregate of all the weighted parameters of soil functions defined the state of soil functions (Q).

$Q = q_{bd}w_{bd} + q_{pd}\, w_{pd}$ ....

Where;

Q : Soil condition

q_{bd} : Rating for bulk density

w_{bd} : Weight factor for bulk density

q_{pd} : Rating for particle density

w_{pd} : Weight factor for particle density

Soil quality index

Soil quality index was calculated by following the procedure outlined by Jha *et al.* (2009) and Mandal *et al.* (2010).

Soil quality index (SQI) = $\Sigma_{Wi\,Si}$

Where;

Wi: Weighted factor derived from principle component analysis

S_i : Score for the subscripted variable soil quality index was grouped in to three categories:

Low (Q < 0.33)

Medium (Q 0.33 - 0.66)

High (Q > 0.66)

RESULTS AND DISCUSSION

Table 4 and 5 showed the score and mean values of the physico-chemical and biological parameters of soil quality in different land uses under both project and non project area of watershed, respectively.In mechanical fractions of the soils of different land uses (Table 6), sand contribution was in majority compared to silt and clay ranged from 42.40-58.78 per cent in both project and non project area of watershed. Total sand content was found highest in scrub lands 57.96 and 58.78 per cent and lowest in forest lands 42.40 and 44.22 per cent under project and non project area of watershed, respectively. The clay content was found highest in forest land with mean value of 23.15 per cent under project area 22.33 per cent under non project area of watershed, whereas, lowest clay content was recorded in scrub land soils with a mean values of 16.83 and 16.00 per cent under project and non project area of watershed, respectively. Both forest and grass land soil was loam, where as, agricultural and scrub land soils was sandy loam and gravely sandy loam in texture, under project and non project area of watershed, respectively. Kumar (2005) also reported higher clay content under forest soils might be due to lesser raindrop impact and reduced velocity of runoff water and also due to higher infiltration rate.

Bulk density of soils under different land uses varied from 1.30-1.61 g cm^{-3}. Grass land soil had lower bulk density (1.30 g cm^{-3}) due to less biotic interference which consequently led to less compaction of soils. Similar results have also reported by Gupta *et al*. (2010).

The particle density of soils under different land uses varied from 2.34- 2.70 g cm^{-3}, highest being under scrub land soils (2.70 g cm^{-3}) and grassland soils (2.34 g cm^{-3}) being lowest. This may be due to comparatively higher organic matter content. These results are in accordance with the findings of Kumar *et al*. (2002).

Highest porosity was observed under forest land soils (46.24 %) followed by grassland (44.46 %), agriculture land

Table 1: Soil chemical properties and methods

Sr. No.	Parameters	Method	Reference(s)
i)	Soil pH (1:2)	Potentiometric	Jackson (1973)
ii)	Electrical conductivity (dSm^{-1})	Wheat stone bridge circuit method	Jackson (1973)
iii)	Organic carbon (OC) (g kg^{-1})	Rapid titration method	Walkley and Black (1934)
iv)	Available N (kg ha^{-1})	Alkaline potassium permanganate method	Subbiah and Asija (1956)
v)	Available P (kg ha^{-1})	Olsen's method	Olsen *et al*.(1954)
vi)	Available K (kg ha^{-1})	Flame photometric method (1N NH_4OAC extractable)	Merwin and Peech (1951)
vii)	Total nitrogen (%)	Microkjeldahl distillation	Jackson (1973)
viii)	Cation exchange capacity (CEC) (cmol(p^+) kg^{-1})	Centrifuge method	Bower *et al*. (1952)
ix)	Exchangeable calcium (cmol(p^+) kg^{-1})	Centrifuge method	Bower *et al*. (1952)
x)	Exchangeable magnesium(cmol(p^+) kg^{-1})	Centrifuge method	Bower *et al*. (1952)
xi)	Exchangeable potassium (cmol(p^+) kg^{-1})	Centrifuge method	Bower *et al*. (1952)
xii)	Exchangeable sodium (cmol(p^+) kg^{-1})	Centrifuge method	Bower *et al*. (1952)
xiii)	Available micronutrients (mg kg^{-1}) zinc, iron, manganese, copper	DTPA method	Lindsay and Norvell, (1978)

Table 2 : Weight of physico-chemical and biological parameters under different land uses

Parameters	Component			
	1	2	3	4
Bulk density	-0.980	-0.001	-0.164	-0.033
Particle density	-0.987	-0.044	-0.071	0.054
Porosity	0.862	-0.123	0.383	0.251
MWD	0.992	0.116	0.010	0.023
WSA >0.25	0.994	-0.067	-0.049	0.027
WSA <0.25	-0.656	0.066	0.049	-0.027
MWHC	0.956	-0.120	0.397	0.253
Infiltration rate	0.176	0.193	0.525	-0.711
pH	-0.701	0.594	-0.248	0.062
Electrical conductivity	-0.913	0.146	0.324	-0.042
Organic carbon	0.990	0.045	-0.094	-0.075
CEC	-0.403	0.863	0.072	-0.396
Total nitrogen	0.977	-0.040	0.059	-0.118
Available nitrogen	0.965	-0.101	-0.144	-0.155
Available phosphorus	0.967	-0.215	0.080	-0.025
Available potassium	0.988	0.037	0.056	-0.067
Bacterial count	0.564	-0.071	0.707	0.315
Fungal count	0.163	-0.518	0.786	-0.190
Actinomycetes count	0.723	0.584	-0.129	0.196

Table 3 : Categorical ranking of soil characteristics used to convert into unit less score of 0 to 1

Soil attribute	Categorical ranking					
		1	2	3	4	5
Bulk density (g cm^{-3})	Range	<1.40	1.40-1.47	1.48-1.55	1.56-1.60	>1.60
	Score	1.0	0.8	0.5	0.3	0.2
Particle density (g cm^{-3})	Range	<2.40	2.40-2.47	2.48-2.55	2.56-2.60	>2.60
	Score	1.0	0.8	0.5	0.3	0.2
Porosity (%)	Range	>45.0	42-45	38-42	35-38	<35.0
	Score	1.0	0.8	0.5	0.3	0.2
MWD (mm)	Range	>4.0	3.5-4.0	3.0-3.5	2.5-3.0	<2.5
	Score	1.0	0.8	0.5	0.3	0.2
WSA >0.25 (mm)	Range	>50.0	45-50	40-45	35-40	<35.0
	Score	1.0	0.8	0.5	0.3	0.2
WSA <0.25 (mm)	Range	<45	45-50	50-55	55-60	>60.0
	Score	1.0	0.8	0.5	0.3	0.2
MWH (%)	Range	>45.0	42-45	38-42	35-38	<35.0
	Score	1.0	0.8	0.5	0.3	0.2
Infiltration rate (cm hr^{-1})	Range	>5.0	3.5-5.0	2.5-3.5	1.0-2.5	0.5-1.0
	Score	1.0	0.8	0.5	0.3	0.2
pH (1:2)	Range	>7.0	6.5-7.0	6.0-6.5	5.0-6.0	<5.0
	Score	1.0	0.8	0.5	0.3	0.2
EC (dS m^{-1})	Range	0.1-0.5	0.5-0.8	0.8-1.6	1.6- 2.5	>2.5
	Score	1.0	0.8	0.5	0.3	0.2
Organic carbon (g kg^{-1})	Range	>15.0	10-15	7.5-10	5.0-7.5	<5.0
	Score	1.0	0.8	0.5	0.3	0.2
CEC (cmol (p^+) kg^{-1})	Range	>15.0	10.0-15.0	7.0-10.0	4.0-7.0	<4.0
	Score	1.0	0.8	0.5	0.3	0.2
Total nitrogen (%)	Range	>0.5	0.2-0.5	0.07-0.1	0.03-0.06	<0.03
	Score	1.0	0.8	0.5	0.3	0.2
Available N (kg ha^{-1})	Range	>560	460-560	370- 460	280-370	<280
	Score	1.0	0.8	0.5	0.3	0.2
Available P (kg ha^{-1})	Range	>25	20-25	15-20	10-15	<10
	Score	1.0	0.8	0.5	0.3	0.2
Available K (kg ha^{-1})	Range	>280	220-280	160-220	98.6-160	<98.6
	Score	1.0	0.8	0.5	0.3	0.2
Total microbial count (cfu g^{-1})	Range	>300	210-300	125-210	30-125	<30
	Score	1.0	0.8	0.5	0.3	0.2

(43.55 %) and scrub land soils (40.60 %). Highest porosity in forest and grassland soils may be due to more organic matter content. These results are in accordance with the findings of Khan *et al.* (1998).

The Water stable aggregates > 0.25 of soils under different land uses varied from 43.25 to 57.05 mm, highest under grassland soils (57.05 mm) and lowest under scrub land soils (43.25 mm). The WSA < 0.25, highest in scrub land soils

Table 4 : Mean values and scores of soil attributes in different land uses under watershed project area

Parameters	WPA	GL	AL	FL	SL
Bulk density (g cm^{-3})	Mean	1.26	1.45	1.33	1.59
	Score	1	0.8	1	0.3
Particle density (g cm^{-3})	Mean	2.33	2.59	2.5	2.69
	Score	1	0.3	0.5	0.2
Porosity (%)	Mean	45.82	43.97	46.8	41.02
	Score	1	0.8	1	0.5
MWD (mm)	Mean	4.7	3.17	4.37	2.41
	Score	1	0.5	1	0.2
WSA > 0.25 (mm)	Mean	57.28	47.34	56.02	43.76
	Score	1	0.8	1	0.5
WSA < 0.25 (mm)	Mean	42.62	52.66	43.98	56.24
	Score	1	0.5	1	0.3
MWHC (%)	Mean	45.78	43.91	46.77	40.99
	Score	1	0.8	1	0.5
Infiltration rate (cm hr $^{-1}$)	Mean	7.4	6.9	9.4	3
	Score	1	1	1	0.5
pH(1:2)	Mean	6.67	6.8	6.57	6.91
	Score	0.8	0.8	0.8	0.8
EC (dS m^{-1})	Mean	0.15	0.26	0.16	0.29
	Score	1	1	1	1
Organic carbon (g kg $^{-1}$)	Mean	18.51	10.06	11.47	7.58
	Score	1	0.8	0.8	0.5
CEC (cmol(p^{+})kg $^{-1}$)	Mean	10.91	11.45	17.95	8.7
	Score	0.8	0.8	1	0.5
Total nitrogen (%)	Mean	1.33	1.01	1.15	0.89
	Score	1	1	1	1
Available N (kg ha^{-1})	Mean	373.48	281.12	318.12	189.47
	Score	0.5	0.3	0.3	0.2
Available P (kg ha^{-1})	Mean	49.41	69.35	50.75	53.47
	Score	1	1	1	1
Available K (kg ha^{-1})	Mean	272.63	234.36	264.79	201.14
	Score	0.8	0.8	0.8	0.5
Total microbial count (cfu g^{-1})	Mean	327.68	304.96	407.45	151.9
	Score	1	1	1	0.5

WPA : Watershed Project Area

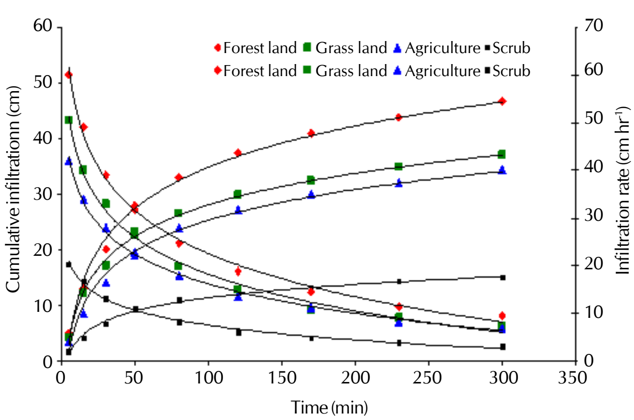

Figure1: Cumulative infiltration rate characteristic under watershade project area

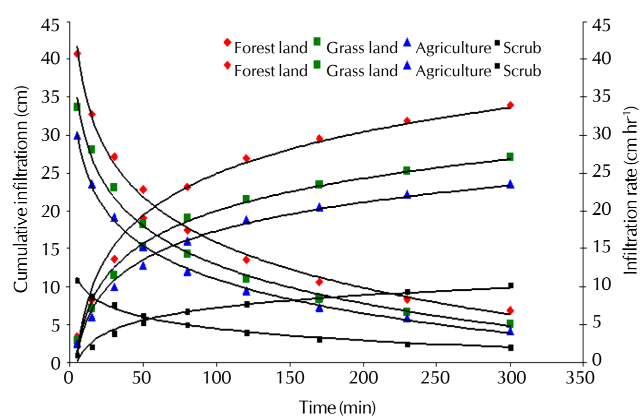

Figure2 : Cumulative infiltration and infiltration rate characteristics under nonproject area of water shed

(56.75 mm) and lowest under grass land soils (42.88 mm). The slightly higher values of WSA > 0.25 of grassland soils may be attributed due to high amount of organic carbon might be responsible for more aggregation in those soils. Similar results were observed by Sharma and Qaher (1989).

Maximum water holding capacity was highest under forest lands (46.19 %) followed by grassland (44.39 %), agriculture land (43.34 %) and scrub land soils (40.33 %). MWHC in

forest land soils may be due to more organic carbon content coupled with higher percentage of clay in forest lands which enhanced the available water. These results are in accordance with the findings of Kumar *et al.* (2002).

Table 5 : Mean values and scores of soil attributes in different land uses under non project area of watershed

Parameters	NPA	GL	AL	FL	SL
Bulk density (g cm^{-3})	Mean	1.34	1.49	1.37	1.63
	Score	1	0.5	1	0.2
Particle density (g cm^{-3})	Mean	2.36	2.62	2.52	2.73
	Score	1	0.2	0.5	0.2
Porosity (%)	Mean	43.09	42.87	45.69	40.18
	Score	0.8	0.8	1	0.5
MWD (mm)	Mean	4.62	3.13	4.26	2.33
	Score	1	0.5	1	0.2
WSA> 0.25 (mm)	Mean	56.83	46.71	54.21	42.73
	Score	1	0.8	1	0.5
WSA< 0.25 (mm)	Mean	43.15	53.20	45.79	57.27
	Score	1	0.5	1	0.3
MWHC (%)	Mean	43	42.76	45.62	39.67
	Score	0.8	0.8	1	0.5
Infiltration rate (cm hr^{-1})	Mean	5.4	4.7	6.8	2
	Score	1	0.8	1	0.3
pH (1:2)	Mean	6.65	6.71	6.5	6.84
	Score	0.8	0.8	0.8	0.8
EC (d Sm^{-1})	Mean	0.18	0.3	0.19	0.33
	Score	1	1	1	1
Organic carbon (g kg^{-1})	Mean	13.25	9.19	10.5	5.95
	Score	0.8	0.5	0.8	0.3
CEC (cmol(p^+)kg^{-1})	Mean	9.06	9.93	15.3	7.92
	Score	0.5	0.5	1	0.5
Total nitrogen (%)	Mean	1.15	0.94	1.12	0.79
	Score	1	1	1	1
Available N (kg ha^{-1})	Mean	290.74	194.65	217.72	169.93
	Score	0.3	0.2	0.2	0.2
Available P (kg ha^{-1})	Mean	44.4	54.83	45.35	47.76
	Score	1	1	1	1
Available K (kg ha^{-1})	Mean	205.86	144.3	187.95	135.71
	Score	0.5	0.3	0.5	0.3
Total microbial count (cfug^{-1})	Mean	245.88	215.31	273.77	121.58
	Score	0.8	0.8	0.8	0.3

NPA: Non Project Area of Watershed

Table 6: Effect of different land uses on mechanical composition (%) and soil texture

Land Uses		Coarse sand	Fine sand	Total sand	Silt	Clay	Textural class
Grassland	WPANPA	19.8922.50	28.1927.85	48.0850.35	30.3330.00	21.5019.50	ll
Agriculture	WPANPA	20.1023.09	33.9332.85	54.0355.94	26.6025.50	19.3318.09	slsl
Forest	WPANPA	16.0518.11	26.3526.11	42.4044.22	34.0033.00	23.1522.33	ll
Scrub	WPANPA	36.3238.50	21.6420.28	57.9658.78	25.1725.00	16.8316.00	gslgsl

WPA : Watershed Project Area ; NPA : Non Project Area of Watershed

Table 7 : Soil quality index of different land uses under project and non project area of watershed

Land uses	WPA			NPA		
	SQI	Group	Level	SQI	Group	Level
Grassland	0.73	3	High	0.64	2	Medium
Agriculture	0.68	3	High	0.54	2	Medium
Forest land	0.74	3	High	0.69	3	High
Scrub land	0.49	2	Medium	0.40	2	Medium

Among four different land uses, infiltration rate was recorded highest under forest land as 9.4 and 6.8 cm hr^{-1}, whereas, scrub land being lowest 3.0 and 2.0 cm hr^{-1} under project and non project area of watershed (Fig. 1 and2), respectively. The higher infiltration rate in forest land soils could be ascribed to the more vegetative cover and good soil aggregation, high organic matter content. Ambegaonkar *et al*. (1984) have also advocated the role of vegetation in improving the infiltration characteristics.

The highest soil pH (6.87) was recorded under scrub land followed by the agriculture (6.76), grassland (6.66) and forest land (6.53) being lowest, respectively. The electrical conductivity was found very well safe and normal in the range of (0.16-0.31 d Sm^{-1}). It was highest under scrub land (0.31 d Sm^{-1}) and lowest (0.16 d Sm^{-1}) in grassland soils. The soil organic carbon content different land uses ranged from 6.77-15.88 g kg^{-1}, highest under grassland soils (15.88 g kg^{-1}) followed by forest land (10.98 g kg^{-1}), agricultural land (9.62 g

kg^{-1}) and scrub land (6.77 g kg^{-1}) being lowest. The significantly higher OC value in grassland soils is probably because of a more rapid turnover and recycling of organic matter of the natural vegetation, less erosion and slower oxidation of the new organic material (Mandal *et al*., 2010).

The cation exchange capacity in soils of different land uses ranged from 8.31– 16.62 cmol(p^+) kg^{-1}, highest under forest land soils (16.62 cmol(p^+)kg^{-1}) whereas lowest under scrub land (8.31 cmol(p^+) kg^{-1}). This may be due to comparatively higher organic carbon contents coupled with higher clay in forest soils. The results are in agreement with the findings of Swaranam *et al*. (2004) also observed for the soils of Solan district of Himachal Pradesh.

Of the various land uses, total nitrogen content varied from 0.84 – 1.24 %. Grassland soil had significantly higher total nitrogen than that of other land uses. The grassland contained more total nitrogen (1.24%) than that of other land uses because of its higher organic carbon status.

Available N was higher in grassland soils (332.11 kg ha^{-1}) and lowest under scrub land soils (179.70 kg ha^{-1}). Higher organic matter in grassland soils may be ascribed to the higher available N in grassland, since organic matter is the sole source of available N in the soils. These results are in agreement with the findings of Singh and Dutta (1988).

Highest available phosphorus contents were recorded in the soils under agricultural land (62.09 kg ha^{-1}) because of frequent application of phosphatic fertilizers under intensive cropping system. These results are in accordance with the findings of Dadhwal *et al*. (2011).

Highest available potassium contents were recorded in the soils under grassland soils (239.24 kg ha^{-1}) followed by forest land (226.37 kg ha^{-1}), agriculture land (189.33 kg ha^{-1}) and scrub land (168.43 kg ha^{-1}) being lowest. In general, potassium decreased in agriculture land due to the lower application rates and crop uptake.

The microbial count in forest land soil was higher for bacteria, fungi and actinomycetes which was about (320.88 cfu g^{-1}), (3.66 cfu g^{-1}), (16.08 cfu g^{-1}), respectively. This may be due to higher pore space and organic material added to the soil through leaf litter which serves as a source of energy for microbial population. Similar results were also observed by Joshi and Yadav (2005).

Soil quality index

The following systems *viz*., Grassland, Agriculture land, Forest land and Scrub land were assessed for soil quality, out of which, the forest land was found to be best with respect to physical, chemical and biological properties followed by grassland, agriculture land and scrub land. Forest land soils showed higher overall soil quality (0.74 and 0.69) under both project and non project area of water shed, respectively, followed by grassland and agriculture land (Table 7). Where as, scrub land reported lowest soil quality (0.49 and 0.40) under both project and non project area of watershed, respectively. Higher soil quality index for forest land might be due to higher values of most of the soil attributes, used for calculating soil quality index. Dadhwal *et al*. (2011) also reported higher soil quality index for forest soils. Similar results were also reported by Michael *et al*. (2007).

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