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Profile Distribution of Microbial Parameters, Macro and Micronutrients in Four Land Use Systems of Kular Watershed in Submontaneous Tract of Punjab

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Abstract

The research conducted revealed that forest land use system in the *Kular* watershed has significantly higher levels of macro-, micronutrients and microbial parameters conpared with remaining three land use systems. Forest land use system in the *Kular* watershed had significantly higher values of soil fertility parameters compared with pasture land use system followed by undisturbed and cultivated land use systems. Cultivated land use system has the lowest levels of soil fertility parameters due to their existance on poor textured and eroded area. Pasture land use system has higher values of soil fertility parameters than in other two land use systems due to their presence on relatively heavy textured soils. Thus forest and pasture land use systems were of better soil fertility and more productive compared to undisturbed and cultivated land use systems. Similarly, in profile both forest and pasture land use systems have higher levels of soil fertility parameters compared with undisturbed and cultivated land use systems. However, their content decreases with depth from surface to bottom. Higher levels of soil fertility parameters in profile were probably associated with higher levels of clay and organic matter in the profiles.

Key words : Micronutrient, Macronutrient, Land use system, Surface and profile distribution, Microbial parameters.

The submontaneous tract of Punjab lies in the south of *Siwalik* hills popularly known as the *kandi* zone. The total area of this belt is 0.5 million hectares constituting about 10% of the geological area of the state. Although this belt has advantage of having higher rainfall than other parts of the state, but because of erratic rainfall behavior most of the area is rainfed. As a consequence, this region is characterized by existence of distinct land use systems. Cultivated, forest, pasture and undisturbed land constitute four major land use systems in the region. These land use systems vary in their fertility and productivity status. Macronutrients (N, P and K), micronutrients (Zn, Cu, Fe and Mn), microbial parameters (PMN, MBC and MBN) and some other soil parameters (pH, EC, CEC and OC) play an important role in determination of soil fertility status. Karlen et al. (1) compared pH and EC values under three different land use systems in surface soils (0—10 cm) and suggested that cultivated system had higher pH (6.3) compared with forest system (5.9) followed by organic system (5.8). Reganold and Palmer (2) studied three land use systems based on CEC of soil in the surface layer and reported that pasture system (24.1 Cmol (+)/kg) and biovegetation (24.4 Cmol (+)/kg) system recorded almost same CEC compared to conventional vegetation system which recorded 16.9 Cmol (+)/kg CEC value. Karlen et al. (1) and Reganold and Palmer (2) observed higher levels of organic matter in pasture system (5.13%) followed by conventional vegetation system (3.06%). Carter and Rennie (3) reported that in surface soils available N, P and K were more under undisturbed system compared to cultivated system, whereas in profile, the available N, P and K levels decreased with depth and no significant change was detected in total N in both the systems. Karlen et al. (4) studied higher levels of available N, P, K and total N under undisturbed system as compared to cultivated land use system followed by deep tillage system. Hargrove et al. (5) reported greater accumulation of Mn and Zn in the surface layers of undisturbed system compared to cultivated system, whereas Franzluebbers and Hons (6) reported greater accumulation of Zn and Mn in organic land use system as compared to cultivated system in upper 5 cm layer. Rattan et al. (7) reported higher amount of available

Table 1. Surface distribution of physical, macro, micronutrients and microbial parameters in four land use systems of *Kular* watershed. CLUS-Cultivated land use system; ULUS-Undisturbed land use system; PLUS-Pasture land use system; FLUS-Forest land use system.

Parameters		CLUS	ULUS	PLUS	FLUS
Physical Parameters					
Texture	Sand (%)	75.9	77.9	66.1	65.7
	Silt (%)	15.1	9.3	16.0	16.1
	Clay (%)	9.0	12.8	17.9	18.2
pH		7.76	7.78	7.74	7.61
Electrical conductivity (EC) (ds/m)		0.23	0.22	0.27	0.26
Cation exch. capacity (me/100 g)		8.6	14.5	14.8	15.2
Organic carbon (OC) (%)		0.30	0.41	0.51	0.56
Water holding capacity (WHC) (%)		46.5	49.4	50.7	56.4
Bulk Density (Bd) (g cm^{-3})		1.57	1.56	1.55	1.52
Porosity (%)		53	54	56	62
Aggregate stability (MWD)		0.60	0.63	0.60	0.84
Macronutrient Parameters (kg/ha)					
Available nitrogen		272	284	357	362
Available phosphorus		13.4	14.8	17.3	19.8
Available potassium		328	329	369	372
Micronutrient Parameters (mg/kg)					
Available zinc		0.62	0.67	0.88	0.90
Available copper		0.28	0.28	0.52	0.54
Available iron		7.42	7.56	9.24	9.64
Available manganese		8.68	8.92	10.24	10.42
Microbial Parameters (mg/kg)					
Potentially min. nitrogen (PMN) (mg/kg/$7d^{-1}$)		7.30	7.80	8.96	9.68
Microbial biomass carbon (MBC)		84.5	86.4	97.8	122.6
Microbial biomass nitrogen (MBN)		27.6	28.9	33.8	41.6

Zn (6.00 mg/kg), Cu (2.33 mg/kg), Fe (30.70 mg/kg) and Mn (29.10 mg/kg) in organic system as compared with amount of Zn (3.90 mg/kg), Cu (1.42 mg/kg), Fe (2.30 mg/kg) and Mn (25.0 mg/kg) in conventional system.Katyal and Sharma (8) reported that available Zn, Fe and Mn declined with rise in pH and fall in organic matter content, whereas available Cu increased with increase in OM and clay content. However, total content of Zn, Cu, Fe and Mn increased with lime and clay content. Myrold (9) reported that potentially mineralizable nitrogen increased in forest land use systems. Powlson et al. (10) reported that MBC level increased under cultivated land use system over control. Gilley and Doran (11) reported higher levels of MBN under conserve reserve program system compared to conventional tillage system. In soil profiles MBN level decreases with depth (0—30.5 cm).

Till now not much research work has been done to monitor the distribution of macro-, micronutrients and microbial parameters under different land use systems existing in this region, because the productivity of the soil is directly related to the maintenance of soil fertility parameters. A detailed investigation of the processes leading to delineation of various soil fertility parameters of soil can help in finding ways and means to achieve sustainable high production levels in different land use systems. Keeping in view that several distinct land use systems exist in the region with different fertility status, the present investigation was carried out with the following objectives : Surface distribution of macro, micronutrients and microbial parametrs in different land use systems, and depth wise distribution of micro- and macronutrients in profiles of different land use system.

Methods

The study was carried out from 2001-2003 in Kular watershed in kandi region of Punjab adjoining the Zonal Research Station for kandi area (PAU) at Ballowal Saunkhari, Nawanshahr district of Punjab. Four land use systems identified in Kular watershed selected for study were : Cultivated land use system (CLUS); undisturbed land use system (ULUS); pasture land use system (PLUS) and forest land use system (FLUS). Cultivated land use systems are characterized by addition of chemical fertilizers and farm yard manure, whereas forest land use systems are characterized by regular addition of organic matter in the form of leaves Subabul (*Leucaena leucocephala*), kikker (*Acacia catechu*), khair (*Acacia catechu willd*), tahli (*Dalbergia sissoo*) and billi buti (*Lantana species.*) exist in the watershed. On the other hand, pasture and undisturbed land use systems are characterized by poor grass stands with wild plantation. Also, cultivated and undisturbed land use systems in Kular watershed are located on highly degraded site of the

Table 2. Profile distributon of macro-, micronutrients and microbial parameters in cultivated land use system (CLUS).

Indicators	Depth (cm) A_1 0—25	C_1 25—55	C_2 55—68	C_3 68—95	C_4 95—117	C_5 117—136
Macronutrients parameters (kg/ha)						
Available nitrogen	248	149	173	129	87	117
Available phosphorus	10.8	9.2	7.6	3.7	3.1	4.7
Available potassium	246	210	198	137	126	137
Total nitrogen (%)	0.09	0.07	0.08	0.06	0.06	0.07
Total phosphorus	70.6	64.8	43.7	32.5	38.8	36.9
Total potassium (%)	1.96	1.76	2.08	2.14	1.86	2.07
Micronutrients Parameters (mg/kg)						
Available zinc	0.60	0.38	0.32	0.44	0.22	0.30
Available copper	0.26	0.28	0.18	0.20	0.12	0.16
Available iron	7.56	5.60	5.82	5.30	5.32	5.64
Available manganese	8.42	7.86	6.90	4.36	4.76	4.82
Total zinc	66.5	58.4	72.5	63.8	70.6	68.4
Total copper	25.3	14.0	22.0	18.4	18.6	22.8
Total iron (%)	2.30	2.46	2.62	2.28	2.52	3.10
Total manganese	536	625	743	715	736	875
Microbial Parameters (mg/kg)						
Potentially min. nitrogen (mg/kg/7d)	7.28	4.59	5.26	4.10	3.97	4.21
Microbial biomass carbon	77.6	56.7	64.3	50.4	43.5	51.8
Microbial biomass nitrogen	23.7	19.6	17.4	16.7	17.9	22.3

watersheds where erosion is a severe problem.

Soil Sampling and Analysis

Four land use systems were selected in Kular watershed. Around 10 to 15 spots were randomly selected from each land use system in the watershed. Soil samples from 0—15 cm depth were collected from each spot. One profile was exposed in each of the four land use systems to assess the depth wise distribution of various soil fertility parameters. These surface and profile soil samples were analyzed in the laboratory using standard procedures. Available nitrogen, phosphorus and potassium were determined by the methods described by Subbiah and Asija (12), Olsen et al. (13) and Merwin and Peech (14) respectively. The total N and total phosphorus contents of the soil were determined by the methods of Dalal et al. (15) nd Jackson (16) respectively. The available and total Zn, Cu, Fe, and Mn were assessed by the method of Lindsay and Norvell (17). Total K and total Zn, Cu, Fe and Mn were determined by the method described by Page et al. (18). The potentially mineralizable nitrogen (PMN), microbial biomass carbon (MBC) and microbial biomass nitrogen (MBN) in the soil were estimated following the method described by Keeney (19), Anderson and Domsch (20) and Keeney and Nelson (21) respectively.

Statistical Analysis

The statistical analysis was carried out for probability associated with Student's *t*-test (22) to compare different macro-, micronutrients and microbial parameters of soil fertility within different land use systems.

Results and Discussion

The effect of different land use systems on macro, micronutrients and microbial parameters and their distribution in surface as well as profile has been de-

Table 3. Profile distribution of macro, micronutrients and microbial parameters in undisturbed land use system (ULUS).

Indicators	Depth (cm) A_1 0–15	C_1 15–28	C_2 28–51	C_3 51–75	C_4 75–116
Macronutrients Parameters (kg/ha)					
Available nitrogen	263	146	132	**164**	120
Available phosphorus	13.6	12.5	7.6	**3.9**	1.8
Available potassium	296	268	237	**271**	196
Total nitrogen (%)	0.12	0.10	0.09	**0.10**	0.06
Total phosphorus	67.4	55.9	46.8	**33.2**	21.8
Total potassium (%)	1.98	1.64	1.36	**1.54**	1.14
Micronutrients Parameters (mg/kg)					
Available zinc	0.64	0.30	0.18	**0.27**	0.14
Available copper	0.30	0.18	0.16	**0.18**	0.12
Available iron	6.72	5.86	4.46	**5.10**	4.80
Available manganese	8.92	9.70	8.14	**10.12**	6.10
Total zinc	71.6	54.3	86.2	**104.2**	88.6
Total copper	23.4	18.3	22.6	**28.6**	20.5
Total iron (%)	2.03	2.16	2.62	**2.76**	2.48
Total manganese	578	547	694	**726**	593
Microbial Parameters (mg/kg)					
Potentially min. nitrogen (mg/kg/7d)	7.74	2.82	2.17	**2.34**	1.47
Microbial biomass carbon (mg/kg)	78.6	38.6	26.7	**29.6**	18.1
Microbial biomass nitrogen (mg/kg)	25.1	12.8	9.8	**10.4**	6.5

Table 4. Profile distribution of macro-, micronutrients and microbial parameters in pasture land use system (PLUS).

Indicators	Depth (cm) A_1 0–8	C_1 8–20	C_2 20–50	C_3 50–90	C_4 90–111
Macronutrients Parameters (kg/ha)					
Available nitrogen	318	237	223	140	**193**
Available phosphorus	16.7	7.3	3.5	2.8	**1.93**
Available potassium	394	292	274	281	**304**
Total nitrogen (%)	0.19	0.14	0.12	0.10	**0.13**
Total phosphorus	96.4	76.5	26.4	28.6	**31.5**
Total potassium (%)	2.18	1.93	1.92	1.70	**1.95**
Micronutrients Prarameters (mg/kg)					
Available zinc	0.78	0.64	0.48	0.26	**0.28**
Available copper	0.48	0.24	0.22	0.18	**0.24**
Available iron	8.92	7.36	8.52	6.16	**7.14**
Available manganese	10.06	10.42	11.16	8.27	**9.82**
Total zinc	86.9	68.4	40.6	71.8	**84.3**
Total copper	23.6	22.5	18.7	23.8	**24.7**
Total iron (%)	3.42	3.50	2.94	3.76	**3.81**
Total manganese	665	736	676	718	**758**
Microbial Parameters (mg/kg)					
Potentially min. nitrogen (mg/kg/7d)	8.90	7.63	6.33	4.35	**5.10**
Microbial biomass carbon	96.5	57.4	23.8	43.6	**52.6**
Microbial biomass nitrogen	34.6	27.6	23.8	19.8	**23.9**

scribed in the following sections.

Distribution of Various Parameters in Surface Soil

Table 1. shows that soils in forest and pature land use systems possessed significantly higher levels of electrical conductivity, cation exchange capacity and organic carbon as compared to in undisturbed and cultivated land use system. Forest land use system, exhibited the highest organic carbon and the lowest pH levels compared to remaining three land use systems. In this watershed, the increase in OC and CEC and decrease in pH were attributed to regular addition of organic matter in forest land use system, whereas an increase in electrical conductivity, cation exchange capacity and organic matter in pasture land use system was due to addition of animal manure. A significant coefficient of correlation between organic carbon and pH (.38**) was observed in pasture land use system. Both undisturbed and cultivated land use systems existed on highly eroded and degraded area of the watershed. Similar results were reported by Karlen et al. (1). Both available and total N, P and K levels were significantly higher (Table 1) in forest and pasture land use systems compared with undisturbed and cultivated land use systems. The differences pertaining to available and total N, P and K were not significant if forest land use system was compared with pasture land use system and undisturbed land use system was compared with cultivated land use system. Also the results were not significant if same land use system was compared for two different periods. A significant coefficient of correlation between organic carbon and available N (0.44**) was observed in forest land use system. Higher levels of

Table 5. Profile distribution of macro-, micronutrients and microbial parameters in forest land use system (FLUS).

Indicators	Depth (cm) A_1 0—7	C_1 7—23	C_2 23—38	C_3 38—61	C_4 61—79	C_5 79—104
Macronutrients Parameters (kg/ha)						
Available nitrogen	329	290	283	310	**261**	246
Available phosphorus	18.7	14.6	13.9	8.7	**7.5**	6.4
Available potassium	396	364	296	312	**248**	210
Total nitrogen (%)	0.23	0.18	0.12	0.16	**0.10**	0.08
Total phosphorus	90.8	80.4	47.6	37.8	**30.6**	28.9
Total potassium (%)	2.18	2.10	1.98	2.36	**2.10**	1.64
Micronutrients Parameters (mg/kg)						
Available zinc	0.92	0.84	0.64	0.72	**0.46**	0.34
Available copper	0.64	0.68	0.40	0.38	**0.28**	0.22
Available iron	9.48	8.10	6.42	7.45	**6.20**	5.86
Available manganese	10.18	11.86	10.80	11.35	**9.32**	8.14
Total zinc	86.4	72.3	76.8	80.1	**70.3**	52.8
Total copper	27.3	18.9	13.6	17.8	**16.5**	13.6
Total iron (%)	3.49	2.84	2.95	3.10	**3.36**	2.86
Total manganese	693	676	600	755	**725**	622
Microbial Parameters (mg/kg)						
Potentially min. nitrogen (mg/kg.7d)	12.07	8.51	3.50	4.70	**4.25**	3.10
Microbial biomass carbon	126.8	104.3	78.6	57.9	**48.6**	32.2
Microbial biomass nitrogen	38.6	32.1	14.4	21.5	**16.8**	17.9

available and total N, P and K in forest and pasture land use systems were possibly due to addition of leaves of leguminous tree species (subabul, kiker, tahli, khair and billi buti) and animal manure. The data on available and total N, P and K showed that forest and pasture land use systems had better soil fertility and remunerative for grass production compared to undisturbed and cultivated land use systems. These results are in accordance with those of Reganold and Plamer (2) and Gilley et al. (23). Both forest and pasture land use systems had significantly higher levels of available and total Zn, Cu, Fe and Mn (Table 1) compared to cultivated and undisturbed land use systems. Both cultivated and undisturbed land use systems had lower levels of available and total Zn, Cu, Fe and Mn. Significant coefficients of correlation between available Zn and OC (0.37*) and available Mn and OC (0.57**) were observed in pasture land use system. Undisturbed and cultivated land use systems existed on highly eroded and degraded site of the watershed. The results pertaining to available Zn, Cu, Fe and Mn showed that forest and pasture land use system possessed better soil quality compared to cultivated and undisturbed land use systems. These results are in agreement with those obtained by Bellaki and Badanur (24) and Rattan et al. (7).

Soils in pasture and forest land use systems possessed significantly higher levels of water holding capacity (WHC), porosity, aggregate stability and clay as compared to undisturbed and cultivated land use systems. A significant coefficient of correlation between water holding capacity and organic carbon (0.58**) was observed in forest land use system. These results showed that forest and pasture land use systems had better fertility soils as compared to cultivated and undisturbed land use systems. Similar observations were reported by Gilley and Doran (23), for texture and water holding capacity, Campbell et al. (25) for porosity and water holding capacity and Maddonni et al. (26). The PMM, MBC and MBN possessed significantly higher levels in forest and pasture land use systems as compared to cultivated and undisturbed land use system (Table 1). The results were not significant if forest land use system was

Table 6. Variation of different soil fertility parameters in surface and profile of Kular watershed. CLUS—Cultivated land use system; ULUS—Undisturbed land use system; PLUS—Pasture land use system; FLUS—Forest land use system.

Parameter	CLUS	ULUS	PLUS	FLUS
Distribution in the Surface				
Clay (%)	9.0	12.8	17.9	18.2
pH	7.76	7.78	7.74	7.61
Electrical conductivity (EC) (ds/m)	0.23	0.22	0.27	0.26
Cation exchange capacity (CEC) (me/100 g)	8.6	14.5	14.8	15.2
Organic carbon (OC) (%)	0.30	0.41	0.51	0.56
Distribution in the Profile				
Depth (cm) in profile	117–136	51–75	90–111	61–79
Clay (%)	18.6	14.8	17.3	22.8
pH	7.85	7.81	7.86	7.90
Electrical conductivity (EC) (ds/m)	0.23	0.21	0.23	0.24
Cation exchange capacity (CEC) (me/100 g)	13.9	11.6	12.6	12.7
Organic carbon (OC) (%)	0.18	0.16	0.14	0.23

compared with pasture land use systems and cultivated land use system was compared with undisturbed land use system. Significant coefficients of correlation were observed between PMN and OC (0.49**) and MBC and OC (0.51**) in forest and pasture land use systems respectively. The data for microbial indicators of soil quality reveal that forest and pasture land use systems were better in soil fertility and more productive as compared to cultivated land undisturbed land use systems. This may be attributed to more organic matter addition and higher microbial activity. Similar results were reported by Gilley and Doran (23) and Keeney and Nelson (21).

Distribution of Various Parameters in Profile

The data pertaining to different soil fertility parameters in the profiles of cultivated (Table 2), undisturbed (Table 3), pasture (Table 4) and forest (Table 5) land use systems depicted that soil fertility (micro- and macronutrients) and microbial parameters showed a lot variation in the profiles of Kular watershed. Various macro-, micronutrients and microbial parameters of soil productivity were more prominently expressed in the surface horizon of each land use system and these parameters showed either increase or decrease within the land use system (Table 1), However, the magnitude of each soil parameter generally decreased with depth in all the four land use systems. Increased levels of soil fertility and productivity parameters were also reported at different depths on profiles of different land use systems. These depths in profiles which reported increased levels of soil quality indicators after decrease were 117—136 cm (CLUS), 51—75 cm (ULUS), 90—111 cm (PLUS) and 61—79 cm (FLUS). These depths in profiles of different land use systems were associated with higher levels of clay, organic matter, clectrical conductivity and cation exchange capacity and low pH values (Table 6).

The results on the soil fertility parameters in profiles of different land use systems revealed that forest land use system (Table 5) had higher levels at different depths as compared to pasture (Table 4) land use system followed by profiles of cultivated (Table 2) and undisturbed (Table 3) land use systems. This showed that soils lying under forest and pasture land use systems were of better quality compared to soils of cultivated and undisturbed land use systems. Similar results were reported for these land use systems at the surface (Table 6). Both cultivated and undisturbed land use systems reported lower levels of soil fertility parameters due to their existence on marginally poor textured soils with undulating topography. The higher levels of soil fertility parameters in forest and pasture land use systems were attributed to addition of organic matter by animals (pasture) and falling leaves of plants (forest) which also caused higher microbial activity. Carter and Rennie (3), Stockfisch et al. (27) and Maddonni et al. (26) also reported similar observations.

Conclusion

Both the forest and pasture land use systems were found to be fertile and more productive. The higher levels of macro-, micronutrients and microbial parameters in cultivated land use system were due to addition of fertilizers and farm yard manure, whereas higher levels of microbial parameters in forest land use system were due to the regular addition of organic matter in the form of leaf litter. Cultivated and

undisturbed land use systems exhibited low magnitude of soil fertility parameters and thus were less productive. Also the soil samples drawn from profiles of pasture and forest land use systems in the Kular watershed has higher levels of soil fertility parameters compared with the remaining two land use systems. Higher levels of sol fertility parameters in profile were associated with higher content of clay and organic matter. The magnitude of soil fertility parameters generally decreased with depth in profile.

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