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Status and distribution of available macronutrients in relation to physico-chemical properties under different land uses of cold arid soils of Spiti valley in Himachal Pradesh

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Abstract
Global positioning system (GPS) based surface (0-15cm) and subsurface (15-30 cm) soil samples were collected randomly from cultivated and pasture lands of cold arid Spiti valley in Himachal Pradesh. These samples were analyzed for physico-chemical properties, available NPKS and exchangeable Ca and Mg. In surface soils mean available N contents (182 kg ha^{-1}) were in low category whereas, P (37 kg ha^{-1}) and K (127 kg ha^{-1}) were found in medium category under different land uses. Sand did not show significant relation with any of the physico-chemical properties studied in all the three land uses.

Key words: Cold desert, Physico-chemical properties, Macronutrients

Introduction
In India, cold desert comes under the trans Himalayan zone which is approximately 1,03,11,300 ha. These are arid areas not affected by the Indian *monsoon* because they lie in the rain shadow of the Himalayan mountain systems. Scanty rainfall, massive snowfall, high wind velocity, extreme temperature conditions from low to high, sparse vegetation, high UV radiation, intense solar radiation and extremely xeric conditions are the common features of this region (Devi and Thakur, 2011). Himachal Pradesh has been categorized into four agro-ecological situations *viz*., low hills, mid hill sub humid, high hill temperate and high hill dry temperate. High hill dry temperate zone of the state comprises of Lahaul & Spiti and Kinnaur districts and Pangi and Bharmaur divisions of Chamba district. District Lahaul & Spiti with geographical area of 9, 11,198 ha has 2, 01,087 ha (cultivated 2156 ha) in Lahaul and 7, 10,111 ha (cultivated 887 ha) in Spiti division (DAP, 2009). Spiti region is a separate geographical unit separated from Lahaul by Kunzum pass (4551 m amsl), a typical cold arid mountain much more difficult with a lowest point at 3050 m amsl. The major area is under barren and uncultivated land (77%) and pastures (22%). Major crops of the valley are Pea, Barley, Potato, Wheat, Rajmash, and Apple. The prevalent species of grasses in pasture lands commonly includes *Chrysopogon gryllus*, *Dactylis glomerta*, *Andropogon munroi* and *Themeda triandra.* With the change in climate, even the harsh cold areas of Spiti are becoming suitable for apple plantation, which is quite evident from the increase in the area under apple in recent years. Pea and apple are the two major cash crops of the valley. Cultivation is possible only in summer (April to September) under assured irrigation provided by glacial melt. Vast area lying waste can be put under cultivation if river water be used for irrigation. Due to scanty information on soil fertility (Parmar *et al.*, 1999 and Sharma and Kanwar, 2010), the present investigation was undertaken to delineate the soils of various land uses of the valley for physico-chemical characteristics and available macro nutrients.

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Material and Methods
A preliminary survey of the area was carried out for the collection of basic information regarding vegetation and physiographic locations etc. Surface (0-15 cm) and subsurface (15-30 cm) soil samples

were collected randomly from different land uses (cultivated and pasture lands) marked with the Global Positioning System co-ordinates. All the samples were collected with stainless steel auger, spade and spatula to avoid any contamination. The soil samples were air dried, ground, passed through 2 mm sieve and finally stored in cloth bags. Available nitrogen was determined by alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus by 0.5M $NaHCO_3$ (pH 8.5) extraction method (Olsen *et al.*, 1954), available potassium and exchangeable Ca and Mg by neutral normal ammonium acetate extraction method (Jackson 1967), available sulphur by turbidimetric method (Chesin and Yien, 1950), texture by international pipette method (Piper, 1950), bulk density by weighing bottle method (Lutz, J.F.. 1947), pH by 1: 2.5 (soil : water) suspension using glass electrode pH meter (Jackson, 1967), electrical conductivity by conductivity bridge method (Jackson, 1967), Organic carbon by Rapid titration method (Walkley and Black, 1934), water holding capacity by Keen's box method (Piper, 1950), cation exchange capacity by neutral normal ammonium acetate extraction method (Jackson, 1967), anoin exchange capacity by 1N ammonium phosphate (Sadana, 2007) and $CaCO_3$ by (Puri and Ashgar, 1938).

Results and Discussion

Available nitrogen

The available nitrogen content of surface soils (Table 1) of Spiti valley under cultivated lands (annual crops), cultivated lands (apple plantation) and pasture lands ranged from 109 to 407, 188 to 256 and 125 to 250 kg ha^{-1}, respectively. However, in the sub-surface layers, its values varied from 78 to 376 for cultivated lands (annual crops), 188 to 256 for cultivated lands (apple plantation) and104 to 334 kg ha^{-1} for pasture lands (Table 2). As such available nitrogen was low to medium under all the three land uses. The surface soils were having comparatively higher nitrogen content than the subsurface soils and the cultivated land (apple plantation) have more available nitrogen in comparison to cultivated lands (annual crops) and pasture lands which might be due to continuous addition of organic matter and frequent applications of nitrogenous fertilizers in orchards. These results authenticated the earlier findings of Singh, 2012 who have also reported higher available N content at the surface and a decreasing trend with depth.

Available phosphorus

Available phosphorus content ranged from 4 to 82, 20 to 53 and 13 to 80 kg ha^{-1} for the surface soils under cultivated lands (annual crops), cultivated lands (apple plantation) and pasture lands, respectively. In subsurface soils the corresponding values were 8 to 89, 20 to 53 and 17 to 31 kg ha^{-1} under respective land uses. Average available P content was almost similar in all land uses in valley. Similar were the findings of (Parmar *et al.*, 1999 and Sharma and Kanwar , 2010).

Available potassium

Data (Table 1) indicated that the values of available potassium in surface horizons under cultivated lands (annual crop), cultivated lands (apple plantation) and pasture lands were 22 to 260, 41 to 108 and 94 to 238 kg ha^{-1}, respectively whereas, in the sub-surface layers these values (Table 2) varied from 79 to 287, 41 to 108 and 98 to 260 kg ha^{-1} for corresponding land uses. As such, the soils under study were low to medium with respect to available potassium status. High potassium in the pasture lands is due to the presence of yellow to brown coloured cretaceous age sand stone containing glauconite which is a potash rich mineral (Sharma and Singh, 1991).

Available Sulphur

Available sulphur varied from 8.4 to 58.8, 16.8 to 42.0 and 29 to 58.8 kg ha^{-1} in surface and 8.4 to 58.8, 14 to 50.4 and 12.6 to 50.4 kg ha^{-1} in subsurface soils under cultivated lands (annual crops), cultivated lands (apple plantation) and pasture lands, respectively. The status of available sulphur was almost equivalent under all the three land uses studied and values are surprisingly high. Unlike available N contents, available sulphur increased with increase in soil depth certainly because of deposits of gypsum in the area associated with Lipak limestone in thick bands (Sharma and Singh, 1991). Comparatively lower content in the surface horizons may be due to the over exploitation by crops and grasses.

Exchangeable calcium

Exchangeable Ca content of soils ranged between 7.5 to 15.8, 10.7 to 12.27 and 9.5 to 15.45 cmol (p^+) kg^{-1} in the surface layers of cultivated lands (annual crop), cultivated lands (apple plantation) and pasture lands, respectively and values in subsurface layers of respective land uses were 7.4 to 16.67, 10.82 to 12.55 and 1.57 to 15.05 cmol (p^+) kg^{-1}. The contents of exchangeable Ca under all land uses were found to decrease in the subsurface. Higher exchangeable Ca in the surface soils may be due to higher organic carbon, $CaCO_3$ and clay in the surface layer. (Nair and Chamuah, 1988) have also reported higher exchangeable Ca in surface horizons in soils of Meghalaya.

Exchangeable magnesium

Exchangeable Mg content in surface soils of cultivated lands (annual crops), cultivated lands (apple plantation) and pasture lands varied from 1.16 to 3.77, 1.94 to 3.38 and 1.24 to 2.95 cmol (p^+) kg^{-1}, respectively and the corresponding values in subsurface soils ranged from1.27 to 3.34, 1.94 to3.38 and 1.34 to 3.31cmol (p^+) kg^{-1}, respectively. Exchangeable Mg content in the surface soils was found high which might be due to the higher organic matter and decreased with depth owing to decrease in OC and clay in the subsurface soils. (Singh and Raman, 1982) reported a decreasing order of exchangeable Mg in sub surface soils of North-Eastern Himalaya.

Table 1. Range & mean values of available macronutrients in surface soils (0-15 cm) under different land uses in Spiti valley

	Available (kg ha^{-1})				Exchangeable (cmol p^+) kg^{-1}	
	N	**P**	**K**	**S**	**Ca**	**Mg**
Cultivated lands (annual crops)						
Range	109-407	4-82	22-260	8.4-58.8	7.55-36.4	1.16-3.77
Mean	182	37	127	39.13	12.92	2.50
SD±	50.99	21.64	39.95	15.43	3.77	1.57
Cultivated lands (apple plantation)						
Range	188-256	20-53	41-108	16.8-42.0	10.7-12.27	1.94-3.38
Mean	228	35	80	32.67	11.48	2.62
SD±	29.17	13.57	28.70	11.27	0.64	0.59
Pasture lands						
Range	125-250	13-80	94-238	29-58.8	9.5-15.45	1.24-2.95
Mean	196	39	166	45.46	13.07	2.15
SD±	44.80	29.73	59.92	11.32	2.59	0.64

Table 2. Range and mean values of available macronutrients in subsurface soils (15-30 cm) under different land uses in Spiti valley

	Available (kg ha^{-1})				Exchangeable [cmol (p^+) kg^{-1}]	
	N	**P**	**K**	**S**	**Ca**	**Mg**
Cultivated lands (annual crops)						
Range	78-376	8-89	79-287	8.4-58.8	7.4-16.67	1.27-3.34
Mean	155	27	134	40.39	12.49	2.40
SD±	50.16	16.25	43.62	12.47	2.10	0.59
Cultivated lands (apple plantation)						
Range	188-256	20-53	41-108	14-50.4	10.82-12.55	1.94-3.38
Mean	228	35	80	32.66	11.48	2.62
SD±	35.72	16.62	35.16	13.81	0.78	0.72
Pasture lands						
Range	104-334	17-31	98-260	12.6-50.4	1.57-15.5	1.34-3.31
Mean	213	24	188	43.86	12.63	2.12
SD±	93.95	5.00	58.92	5.21	1.36	0.76

Texture

In present study, a little variation in clay and almost no variation in sand and silt contents was observed (Table 3, 4 and 5) in Spiti soils of high altitude cold desert which have been originated from weathered rocks. They are immature and have large proportion of sand, gravel and stone in them (Dwivedi *et al.*, 2005) indicating the dominance of sand forming minerals in parent materials. Hence, our findings indicated that the cold arid soils are dominated by sand alike the hot arid soils, and this relative high proportions of sand in these soil fragments is causing sandy loam textural class in this region. Sand fraction varied from 39 to 65 per cent in surface and 40 to 64 per cent in subsurface horizons of cultivated lands (annual crops), 38 to 60 per cent in surface and 42 to 65 per cent in subsurface layers of cultivated lands (apple plantation) and 44 to 56 in surface and 43 to 62 per cent in subsurface horizons of pasture lands of Spiti valley (Table 4 and 5). Silt content in surface soils of cultivated lands (annual crop), cultivated lands (apple plantation) and pasture lands varied from 19 to 45, 24 to 40 and 22 to 35 per cent, respectively whereas, in the sub-surface soils it ranged from 17 to 43, 25 to 30 and 16 to 31 per cent in respective land uses. Under cultivated lands (annual crop), cultivated lands (apple plantation) and pasture lands the clay content ranged from 8 to 26, 10 to 21 and 15 to 20 per cent, respectively in surface soils whereas, in subsurface soils it ranged from 7 to 22, 7 to 16 and 14 to 23 in respective land uses. The texture of soils of Spiti valley was found to be sandy loam, loam and sandy clay loam. Similar were the earlier reports by Parmar *et al.,* (1999) and Sharma and Kanwar, (2010) for cold desert soils of Spiti.

Water holding capacity (WHC)

Data (Table 4 and 5) opined that WHC varied from 18.7 to 35.1, 20.1 to 32.3 and 10 to 33.7 in surface and 18.7 to 39.9, 19.3 to 29.1 and 8 to 28.9 per cent in subsurface layers of cultivated lands (annual crop), cultivated lands (apple plantation) and pasture lands, respectively. These results are in line with the findings of Babhulkar *et al.,* 2000, Selvi *et al.,* 2005. Pature lands were found to have comparatively lower WHC as compared to cultivated lands (annual crops) because of higher clay and organic matter content in cultivated lands (annual crops).

Bulk density

Bulk density in the surface soils under cultivated lands (annual crops), cultivated lands (apple plantation) and pasture lands varied from 1.20 to 1.37, 1.25 to 1.28 and 1.23 to 1.38 Mgm^{-3}, whereas, in the subsurface layers, it varied from 1.20 to 1.55, 1.23 to 1.28 and 1.17 to 1.26 Mgm^{-3}, respectively. Parmar *et al.,* (1999) and Sharma and Kanwar, (2010) have also reported similar results for Spiti soils of Himachal Pradesh.

Soil pH

Soil pH in surface soils varied from 7.2 to 8.3, 7.7 to 7.9 and 7.6 to 8.1 in surface and 7.1 to 8.1, 7.5 to 7.8 and 7.5 to 7.9 in subsurface under cultivated lands (annual crops), cultivated lands (apple plantation) and pasture lands, respectively. Majority of soils were moderately alkaline in reaction. The pH of cultivated lands (annual crops) was observed tending towards neutrality and comparatively low as compared to pasture lands because of amelioration effect due to regular addition of FYM to annual crops. Similar findings have also been reported by Parmar *et al.,* (1999) for the soils of cold desert area in district Lahaul and Spiti of Himachal Pradesh.

Electrical conductivity (EC)

Data indicated that the values of EC ranged from 0.19 to 0.50, 0.23 to 0.44 and 0.17 to 0.44 in surface and 0.18 to 0.74, 0.23 to 0.44 and 0.34 to 0.45 in subsurface under cultivated lands (annual crop), cultivated lands (apple plantation) and pasture lands, respectively. Similar results were reported by Sharma and Singh, (1991) for Spiti catchment soils in Himachal Pradesh.

Organic carbon (OC)

Organic carbon content in surface soils under cultivated lands (annual crops), cultivated lands (apple plantation) and pasture lands varied from 10.1 to 21.2, 8.9 to 18.3 and 12.2 to 19.8 $g\ kg^{-1}$, respectively, whereas, in the subsurface layers it varied from 9.9 to 20.1, 7.8 to 17.1 and 11.1 to 19.8 in respective land uses. The organic carbon content of cultivated lands (annual crops) was higher in comparison to cultivated lands (apple plantation) and pasture land soils certainly due to continuous addition of organic matter as FYM and decomposition of crop residues under tilling conditions. Similar vertical distribution pattern of organic carbon have been reported by Parmar *et al.,* (1999) and Krishnan *et al.,* (2004) in HP soils.

Table 3. Range and mean values of physico-chemical properties in surface (0-15 cm) soils under different land uses in Spiti valley

	Mechanical separates (%)			BD (Mgm^{-3}) (w/w)	WHC (%)	pH	EC(dSm^{-1})	OC ($g\ kg^{-1}$)	CEC [cmol (p^+) kg^{-1}]	AEC [cmol (p^-) kg^{-1}]	$CaCO_3$ (%)
	Sand	Silt	Clay								
Cultivated lands (annual crops)											
Range	39-65	19-45	8-26	1.20-1.37	18.7-35.1	7.2-8.3	0.19-0.50	10.1-21.2	16.3-25.1	0.21-0.62	3.2-16.2
Mean	49	29	19	1.27	27.27	7.69	0.35	16.8	20.1	0.40	9.77
SD±	5.2	5.7	3.9	0.05	4.09	0.17	0.10	2.35	2.07	0.11	3.07
Cultivated lands (apple plantation)											
Range	38-60	24-40	10-21	1.25-1.28	20.1-32.3	7.7-7.9	0.23-0.44	8.9-18.3	18.6-22.0	0.28-0.61	3.7-8.7
Mean	51	28	14	1.27	26.47	7.77	0.36	13.22	20.0	0.43	5.65
SD±	10.2	7.8	4.9	0.02	5.6	0.09	0.10	4.01	1.60	0.15	2.2
Pasture lands											
Range	44-56	22-35	15-20	1.23-1.38	10-33.7	7.6-8.1	0.17-0.44	12.2-19.8	16.5-20.3	0.24-0.54	7.8-15.2
Mean	50	30	17	1.29	21.35	7.75	0.29	16.58	18.25	0.35	11.95
SD±	4.8	4.9	1.8	0.05	10.02	0.18	0.12	2.90	1.40	0.11	2.87

Table 4. Range & mean values of physico-chemical properties in subsurface soils (15-30 cm) under different land uses in Spiti valley

	Mechanical separates (%)			BD ($Mg\ m^{-3}$) (w/w)	WHC (%)	pH	EC ($dS\ m^{-1}$)	OC ($g\ kg^{-1}$)	CEC [cmol (p^+)kg^{-1}]	AEC [cmol(p^-) kg^{-1}]	Ca CO3 (%)
	Sand	Silt	Clay								
Cultivated lands (annual crops)											
Range	40-64	17-43	7-22	1.20-1.55	18.7-39.9	7.1-8.1	0.18-0.74	9.9-20.1	16.1-26.1	0.23-0.58	4.1-14.7
Mean	54	28	15	1.27	27.62	7.6	0.36	16.15	20.24	0.38	9.45
SD±	5.73	5.79	4.42	0.06	4.66	0.16	0.12	2.40	2.24	0.09	2.87
Cultivated lands (apple plantation)											
Range	42-65	25-30	7-16	1.23-1.28	19.3-29.1	7.5-7.8	0.23-0.44	7.8-17.1	21.3-24.9	0.4-0.57	3.9-7.7
Mean	57	28	10	1.25	23.02	7.7	0.34	12.05	23.0	0.49	6.0
SD±	10.42	2.16	4.04	0.02	4.24	0.14	0.12	4.05	1.63	0.09	1.89
Pasture lands											
Range	43-62	16-31	14-23	1.17-1.26	8-28.9	7.5-7.9	0.34-0.45	11.1-19.8	16.8-24.1	0.21-0.47	9.9-15.7
Mean	54	25	19	1.27	17.93	7.7	0.41	16.53	20.56	0.37	11.91
SD±	7.06	5.77	3.34	0.07	8.25	0.17	0.52	3.44	2.83	0.09	2.01

Table 5. Correlation between physico-chemical properties and macronutrients in different land uses in Spiti valley

Physico-chemical properties	Available Macronutrients					
	N	P	K	S	Ca	Mg
Cultivated lands (annual crops)						
Sand	0.113	0.134	0.166	-0.016	0.092	0.002
Silt	0.137	0.166	0.149	0.128	-0.128	-0.030
Clay	0.089	0.020	0.020	0.036	0.036	0.050
Bulk density	-0.105	-0.140	0.068	-0.005	0.001	0.129
WHC	0.106	-0.092	0.063	-0.107	0.197*	0.142
pH	0.097	-0.161	0.157	-0.059	0.197*	0.018
EC	0.063	0.142	0.136	0.030	0.110	0.077
OC	0.018	0.187	0.182	0.137	0.137	0.116
CEC	0.106	0.142	0.206*	-0.144	0.244*	0.210*
AEC	0.097	0.052	-0.066	0.066	-0.137	-0.041
$CaCO_3$	0.164	0.051	0.054	0.307	0.026	0.117
Cultivated lands (apple plantation)						
Sand	-0.223	0.189	0.199	-0.201	0.099	0.158
Silt	-0.671	-0.122	0.804*	0.410	0.011	0.814*
Clay	0.158	0.439	0.774*	0.153	0.535*	0.866*
Bulk density	-0.471	-0.122	0.304	-0.410	0.011	0.214
WHC	0.142	0.686*	0.927*	-0.440	0.762*	0.874*
pH	-0.307	-0.399	-0.377	-0.585*	0.860*	0.096
EC	-0.307	-0.189	0.977*	0.585*	0.869*	0.696*
OC	0.998*	0.782*	0.451	0.931*	0.708*	0.988*
CEC	-0.625*	-0.062	0.660*	-0.355	0.649*	0.778*
AEC	0.634*	0.650*	0.262	0.648*	0.160	0.403
$CaCO_3$	0.272	0.197	0.938*	0.330	0.999*	0.618*
Pasture lands						
Sand	-0.248	0.067	0.248	0.214	0.214	-0.274
Silt	-0.223	0.353	0.724*	-0.160	0.334	0.783*
Clay	0.166	0.820*	0.014	0.643*	0.591*	0.687*
Bulk density	-0.160	-0.009	0.204	-0.338	0.311	0.373
WHC	0.297	0.238	0.275	-0.117	0.513*	0.511*
pH	0.007	-0.712	0.202	0.336	0.606*	0.621*
EC	-0.065	0.230	0.645*	0.024	0.665*	0.710*
OC	0.327	0.802*	0.649*	0.315	0.661*	0.094
CEC	0.202	-0.378	0.583*	0.004	0.656*	0.772*
AEC	0.549*	0.579*	-0.331	0.616*	-0.313	-0.177
$CaCO_3$	0.594	0.181	0.089	0.278	0.670*	0.622*

Cation exchange capacity (CEC)

The data on cation exchange capacity for the three land uses under study (Table 4 and 5) indicated that the values of CEC ranged from 16.3 to 25.1 cmol (p^+) kg^{-1} for cultivated lands (annual crops), 18.6 to 22.0 cmol (p^+) kg^{-1} for cultivated lands (apple plantation) and 16.5 to 20.3 cmol (p^+) kg^{-1} for pasture lands in the surface and 16.1 to 26.1, 21.3 to 24.9 and 16.8 to 24.1cmol(p^+) kg^{-1} for respective land uses in subsurface soils. The wide variation in the CEC of soils was also supported by wide variation in $CaCO_3$ content in the soils due to sedimentary parent material. Similar findings have also been reported by Sharma and Kanwar, (2010).

Anion exchange capacity (AEC)

The AEC in the surface soils under cultivated lands (annual crops), cultivated lands (apple plantation) and pasture lands varied from 0.21 to 0.62, 0.28 to 0.61 and 0.24 to 0.54 cmol (p^-) kg^{-1}, respectively whereas, in the subsurface layers, it varied from 0.23 to 0.58 in cultivated lands (annual crops), 0.4 to 0.57 in cultivated lands (apple plantation) and 0.21 to 0.47 cmol (p^-) kg^{-1} in pasture lands. The similar findings were reported by Toner *et al.,* (1989) in middle Atlantic soils.

Calcium carbonate ($CaCO_3$)

Data indicated that the values of $CaCO_3$ ranged from 3.2 to 16.2 per cent under cultivated lands (annual crops), 3.7 to 8.7 per cent under cultivated lands (apple plantation) and 7.8 to 15.2 per cent under pasture lands in surface soils and it ranged from 4.1 to 14.7, 3.9 to 7.7 and 9.9 to 15.7 per cent under respective land uses in subsurface soils. The similar findings were reported by Parmar et al., (1999) and Sharma and Kanwar, (2010) in cold desert area of Himachal Pradesh.

Correlation:Correlation of physico- chemical propertries was worked out with available macronutrients of different land uses (Table 5). In cultivated lands (annual crops), sand, silt and clay did not show any significant relationship with N, P, K, S, Ca and Mg. WHC and pH showed the positive and significant relation with Ca only, whereas, CEC and $CaCO_3$ showed significantly positive relationship with K. Gupta and Dabas, (1980) have reported almost similar results in saline soils. In cultivated lands (apple plantation), silt and clay showed the significant positive with K and Mg. WHC was found to have positive and significant relationship with P, K, Ca and Mg. A positive and significant correlation of pH was found with Ca only and significantly negative with S only. EC showed the positive and significant relationship with K, S, Ca and Mg. OC showed the positive and significant relationship with N, P, S, Ca and Mg. The correlation of CEC was found positive and significant with K, Ca and Mg , whereas it showed significantly negative with N. AEC showed the positive and significant relationship with N, P and S, whereas, $CaCO_3$ showed positive and significant with K, Ca and Mg. In pasture lands, silt showed positive and significant relationship with K and Mg only. Clay showed positive relationship with all macronutrients but significant with P, S, Ca and Mg only, whereas bulk density did not show any significant relationship with macro and secondary nutrients. A positive and significant relationship was observed for WHC, $CaCO_3$ and pH with Ca and Mg only. A positive and significant relationship of OC was observed with P, K and Ca. CEC showed positive and significant relationship with K, Ca and Mg. AEC was found positively and significantly correlated with available N, P and S nutrients.

Conclusion

The soils of Spiti valley were found low in available N, low to medium in available K, medium to high in available P and high in available Ca and sulphur. Exchangeable Mg content in the surface soils was found high. The soils were moderately alkaline in reaction, medium to high in organic carbon and have high values of CEC. Surface soils were high in organic carbon than subsurface soils. Available Nitrogen was low to medium under all the three land uses and potassium was high in the pasture lands. Available sulphur was high in subsurface soils. Macronutrients decreased in the sub-surface soils. Clay was found below 20 percent and silt near and above 30 per cent. Soils were found sandy loam to sandy clay loam in texture. Bulk density was highly variable ranging from 1.2 to 1.67 Mgm^{-3}.Sand did not show significant relation with any of the physico-chemical properties studied in all the three land uses, whereas silt showed positive and significant relationship with WHC and EC. WHC was below 30 per cent. EC, CEC, AEC and calcium carbonate contents were in safe and required limits.

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