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Spatial distribution of nutrients in soil profile under different land use systems of cold arid region of Ladakh

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ABSTRACT

Soils of Ladakh are under active development stage and vary highly in their characteristics. The study was carried out in varied land use systems to study the soil physic-properties and nutrient status of soil profiles. All the studied profiles varied in their characteristics as land use changed. At all the profiles, a pattern of decree in available nitrogen with the increase in depth was observed. Available Phosphorus with confidential interval ranged from 7.9 to 51.09 kg/ha with a mean value of 17.59 kg/ha. The micronutrients did not follow the regular inclination in different land uses systems with some locations being deficient. While zinc content exhibited a decreasing trend in the sub-surface horizons with depth with confidential interval ranged from 0.32 to 1.04 mg/kg and with a mean value of 0.48 mg/kg. It was also noted that under the influence of weathering, depth of the soils were coarse and shallow to very shallow in depth. Soil reaction was alkaline in nature whereas a decrease in pattern of the both macro and micro nutrients was observed.

1. Introduction

Knowledge of how the physical characteristics of soil profile are altered by different land use changes and changes brought about by different land use practices may be compared with reference to the natural soil conditions that existed before any changes took place (Hursh and Hoover, 1941). Factors such as parent material, climate (including water and temperature effects), macro- and micro-organisms, topography and time create a relatively stable soil quality that has distinct physical, chemical, and biological characteristics in response to prevailing natural or non-anthropogenic factors (Karlen *et. al.* 1992; Jenny, 1941). However, humankind, the anthropogenic force was described as sixth soil forming factor in the basic model for describing a soil (SSSA, 1987), interacts with the non-anthropogenic factors and influences soil quality both negatively and positively. Soil and crop management practices imposed on land resources by humankind thus determine whether inherent soil quality will be lowered, sustained, or improved over relatively short time intervals (Doran et. al. 1990; Linn and Doran1984b). Ladakh region of the state of Jammu and Kashmir is situated between 32^0 to 36^0 North Latitude and 75^0 to 80^0 East Longitude at an altitude ranging from 2900 M to 5900 M above sea level. Being mountainous with limited precipitation at high altitude desert, the area is designated as cold desert with temperatures ranging from -13^0C to 27^0C with an annual precipitation of 80- 300 mm mostly in the form of snow. The region is confided between the great Himalayas and the Karakorum range possess harsh climate which allows agricultural practices only for 5-6 months i.e. April to September. The treeless hostile barren land where vast vertical cliffs of sand which is arranged in ways where they seem to be overlaid upon each other with upright faces towards river stream (Anonymous, 2015, Durani *et. al.* 1975).

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September. The treeless hostile barren land where vast vertical cliffs of sand which is arranged in ways where they seem to be overlaid upon each other with upright faces towards river stream (Anonymous, 2015, Durani *et. al.* 1975).

The soil characteristics of this area are completely diverse as compared to other zones due to the climatic extremes, vegetation and topography. Physiography ranges from flat valleys, dust, archaic desert, alluvial flats, rivers terraces, alluvial fans on which the Leh town is situated but agricultural practices are carried out in alluvial plains especially along the Indus river belt and its terraces. Limited rainfall, moisture and low temperature with meager natural vegetation and rocks resistant to weathering results in skeletal type rock formation with the soil profile being poorly developed leads to variations in the physico-chemical, morphological and microbiological properties but also a variation in its genetic classification can be observed. Geologically the area consists of sand stone, shale and conglomerates. Due to the lack of water action on the rock's detritus material is seen forming unweathered rock materials in the regolith. Morphologically the soils of Ladakh vary in colour, texture, structure, and permeability depending upon topography, vegetation and are shallow to very shallow in depth. The slopes can be from steep to very steep while as in low lying terraces plateau, valleys will have gentle slope. Soils are majorly structureless with pebbles, rock bits, and scree and loose in structure (Gupta and Arora, 2017; Jalali *et. al.* 2000;Talib 2000;Gupta and Tripathi 1992). Keeping in view the above facts, the study was designed, planned and carried out for two years with the objective to study and compare the soil properties and nutrient status of soil profiles under four major different land use systems namely farmer's field from Upper Tukcha, River Bed from Chushot-Gongma and lower and upper lands from Stakmo village.

2. Materials and Methods

The study was carried out by Regional Research Station, Central Arid Zone Research Institute, Leh-Ladakh under National Mission on Sustaining Himalayan Ecosystem Task Force-6 (Himalayan Agriculture), sponsored by

Department of Science and Technology during 2017-2018 and 2018-19 consecutive for two years with the objective to study and compare the soil properties and nutrient status of soil profiles under four major different land use systems namely river side agricultural land at Chushot-Gongma (N-34002'48" North E-077038'35"East 3249 m), stream side land at Upper Stakmo village (adjoining to valley stream N34006'08" North E 077041'13" East 3620 m), barren road-side land, Lower Stakmo village (road side N 34004'09" North E 077040'09" East 3360 m), and farmer's agricultural land at Upper Tukcha (N-34009'54" North E-077034'43"East 3488 m). Before analyzing the samples, they were first air dried and then grinded with wooden mortar and pestle and passed through 2 mm sieve and stored for subsequent analysis of various physico-chemical properties using standard procedures. Soil reactions (pH) of the samples were measured in 1:2.5 soil: water suspension with a digital glass electrode pH meter (Jackson 1973). Electrical Conductivity (EC) was determined by method given by Richards (1954) and Walkley and Black's (1934) rapid titration method was used for determination of organic carbon (OC). The international society of soil science textural triangle was used for determining the textural class. N was determined by method given by Subbiah &Asija (1956), P and K was determined by method given by Jackson (1973). DTPA Zn was estimated following procedure given by Lindsay and Norvell (1978).

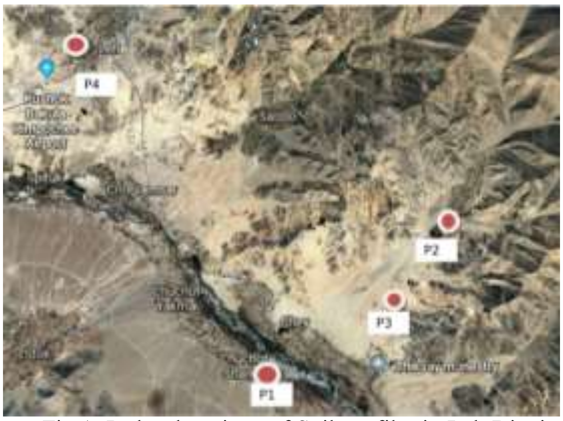

Fig.1: Pedon locations of Soil profiles in Leh District

3. Results and Discussion

Soil profile studies were carried out in four varied altitudes i.e. river side agricultural land at Chushot-Gongma, stream side land at Upper Stakmo village, barren road-side land, Lower Stakmo village, and farmer's agricultural land at Upper Tukcha (Fig.1&2).. This work was conceptualized keeping view the four locations identified (two cultivated and two non-cultivated lands) for studying the soil profiles which are generally allotted by the local development Council to the villagers as and when potential agricultural lands becomes vulnerable to any climatic hazard or natural disasters.

Vegetation of study site revealed that although natural vegetation of Ladakh region is scanty Factors responsible for sparse and reduced vegetation in the region are temperature and moisture (Kachroo *et al.*, 1997). However, farming is practiced and it consists of deciduous trees like species of Salix and Poplar and crops like wheat, barley, pea, mustard along with variety of vegetables. Although farmers have learned farming with harvesting glacier water in the lap of Himalaya has come-up as a small-scale farming system, well adapted to this unique and extreme environment. In addition, mountains, river-sides and negligible forest have some significant but with small sized alpine vegetation of highland pastures to support livestock. As the economy largely depends upon agriculture and livestock.

The collected soil samples from various soil profiles revealed (Table 1) that majority of the soils of Leh region are sandy to sandy loam in texture and medium to medium-high in organic carbon with poor water holding capacity. Soils with less than 0.5% organic C are mostly limited to desert areas like Leh where it ranged in study areas from 0.1 to 0.38%. The pH ranged from 7.79 to 8.54 as more than 90 per cent of the soils of high altitude cold desert having pH ranging between 7 and 9 making soils alkaline in nature. While electric conductivity ranged from 0.15-0.76 dS/m in Leh.

P-1: River side agricultural land at Chushot-Gongma	P-2: Stream side land at Upper Stakmo village	P-3: Barren road-side land, Lower Stakmo village	P-4: Farmer's agricultural land at Upper Tukcha

Fig.2: Different soil profiles of Leh region

Table 1. Physico-Chemical properties of different soil profiles

Sl	Pedon Locations (Depth)	Horizon	Land use	Parent material	Depth of soil	pH	EC dSm-1	OC (%)
P1	River side agricultural land at Chushot-Gongma	Ap	Cultivated to wheat, barley & vegetables	Alluvium	15cm	7.79	0.76	0.10
		Bw1			2 feet	8.06	0.51	0.25
P2	Stream side land at Upper Stakmo village	A	Barren	Moraine	15cm	8.21	0.18	0.23
		1C			1 feet	8.15	0.78	0.25
		2C			2 feet	8.35	0.17	0.18
P3	Barren road-side land, Lower Stakmo village	A	Barren	Moraine	15cm	8.54	0.15	0.67
		C1			1feet	8.59	0.17	0.33
		C2			2 feet	8.13	0.46	0.37
P4	Farmer's agricultural land at Upper Tukcha	Ap	Cultivated for crop and vegetables	Alluvium	15cm	8.05	0.34	0.38
		Bw1			1 feet	8.18	0.15	0.31
		Bw2			2 feet	8.34	0.14	0.26
		2C			3 feet	8.35	0.08	0.20

Study showed the soil fertility exhibits the grading of different soils with regard to the quantity and availability of nutrients essential for plant growth. Scrutiny of data in Table 2 revealed that in macro nutrients, the available nitrogen in studied area ranged from 52.38 to 184.59 kg/ha with a mean value of 78.26 kg/ha. At all the sites, a pattern of decree in available nitrogen with the increase in depth was observed. The available N found to be maximum in surface horizons and decreased regularly with depth which is due to decreasing trend of organic carbon with depth with the cultivation of crops being mainly confined to the rhizosphere (Kumar *et.al.,* 2012; Naidu and Sireesha, 2013; and Khanday *et. al.,* 2018).

Available Phosphorus with confidential interval ranged from 7.9 to 51.09 kg/ha with a mean value of 17.59 kg/ha. Available Phosphorus decreases with the increase in depth. The highest available P was observed in the surface horizons. It might be due to the internment of crop cultivation to the rhizosphere and supplementing the depleted P by external sources i.e. fertilizers and presence of free iron oxide and exchangeable $Al3+$ in reduced quantities (Naidu and Sireesha, 2013; and Khanday *et. al.,* 2018; Singh and Mishra, 2012). The lower phosphorus content in sub-surface horizons in these profiles could be credited to the fixation of P by clay minerals and oxides of iron and aluminium (Thangasamy *et. al.,* 2005; Khanday *et. al.,* 2013). Available potassium also showed a regular decrease with the depth. The confidential interval ranged from 0.47 to 209.55 kg ha-1 with a mean value of 48.49 kg/ha. The highest available K being observed in the surface horizons showed a more or less a decreasing trend with depth. This might be attributed to more intense weathering, release of liable K from organic residues, application of K fertilizers and upward translocation of K from lower depths (Naidu and Sireesha, 2013; Sharma and Kumar,2003; Kirmani, 2004).

The micronutrients did not follow the regular inclination in different land uses systems with some locations being deficient. The data in Table-2 divulges that in all the profiles of the study area zinc content exhibited a decreasing trend in the sub-surface horizons with depth with confidential interval ranged from 0.32 to 1.04 mg/kg and with a mean value of 0.48 mg/kg. Vertical distribution of Zn exhibited little variation with depth. Considering 0.6 mg/kg as critical level (Lindsay and Norvell, 1978) except for few locations these soils were sufficient Zn. The low available Zn was possibly due to high soil pH values which might be resulted in the formation of insoluble compounds of Zn or insoluble calcium zincate (Prasad *et.al.,* 2009). Trivial decrease in the zinc content was noted with the increase in soil depth, which may be credited to their positive and significant correlation with organic carbon. Similar findings were observed by (Khanday *et. al.,* 2018; Khanday *et. al.,* 2013, Ganai *et. al.,* 1999; Devi *et.al.,* 2015). The DTPA-extractable Fe in accordance to critical limit of 4.5 mg/kg of Lindsay and Norvell, 1978 Fe was found low rhizosphere in all the locations. The confidential interval ranged from 0.94 to 5.82 mg kg-1 with a mean value of 2.39 mg/kg. The available Fe distribution in all the pedons decreased with the increase in depth which might be attributed to the reduction of organic carbon in the sub surface horizons. Surface horizons had higher concentration of DTPA-extractable Fe due to relatively higher organic carbon in surface horizons.

Table 2. Macro- and micro-nutrient status of different soil profile

S.No	Pedon Locations	Horizon	Depth	N	P	K	Zn	Cu	Fe	Mn
				Kg/ha			Mg/kg			
P1	River side agricultural land at Chushot-Gongma	Ap	15 cm	56.12	27.96	209.55	0.54	1.74	0.94	16.98
		Bw1	2 feet	53.63	12.81	37.96	0.48	1.23	1.75	2.23
P2	Stream side land at Upper Stakmo village	A	15cm	57.37	8.12	46.48	0.33	0.39	2.09	0.62
		1C	1 feet	67.35	7.97	0.82	0.43	1.78	2.35	1.37
		2C	2 feet	52.38	9.84	22.64	0.40	0.35	2.17	0.65
P3	Barren road-side land, Lower Stakmo village	A	15cm	62.36	10.47	41.19	0.33	0.06	1.02	0.21
		C1	1feet	56.12	13.28	77.75	0.36	0.09	1.15	0.22
		C2	2 feet	54.88	22.03	0.49	0.56	1.05	1.59	1.31
P4	Farmer's agricultural land at Upper Tukcha	Ap	15cm	184.59	51.09	74.84	1.04	0.32	2.65	0.90
		Bw1	1 feet	63.61	12.50	42.88	0.49	0.27	3.69	1.33
		Bw2	2 feet	119.73	20.62	26.78	0.46	0.48	3.51	0.58
		2C	3 feet	111.00	14.37	0.47	0.32	0.49	5.82	0.48

Rendering to the critical limit of 1.0 mg/kg of Lindsay and Norvell (1978) the soils were sufficient in available Mn in almost all the locations. The confidential interval ranged from 0.21 to 16.98 mg/kg with a mean value of 2.24 mg/kg and almost decreased with depth which might be due to higher biological commotion and organic carbon in the surface horizons, the higher content of available Mn in surface soils was attributed to the chelating of organic compounds released during the breakdown of organic matter left after harvesting of crop. All the surface horizons were found to be sufficient in available Cu as all the values were well above the critical limit of 0.20 mg/kg soil as suggested by Lindsay and Norvell (1978) with confidential interval ranged from 0.06 to 1.78 mg/kg with a mean value of 0.69 mg/kg. The distinction in Cu content with the depth may also be attributed to the positive relation with organic carbon, clay content and cation exchange capacity of the soils (Yadav and Meena, 2009).

4. Conclusion

Soils of Ladakh are under active development stage and vary highly in their characteristics at different soil profile environment and varied in their characteristics as land use changed. The soils of Ladakh region are generally skeletal with A~C profile due to the effect of topography. The profiles in the visited areas exhibited the weak structural horizons which appear to be the result of in situ weathering. At all the profiles, a pattern of decree in available nitrogen with the increase in depth was observed. Available Phosphorus with confidential interval ranged from 7.9 to 51.09 kg/ha with a mean value of 17.59 kg/ha. The micronutrients did not follow the regular inclination in different land uses systems with some locations being deficient. While zinc content exhibited a decreasing trend in the sub-surface horizons with depth with confidential interval ranged from 0.32 to 1.04 mg/kg and with a mean value of 0.48 mg/kg. It was also noted that under the influence of weathering, depth of the soils were coarse and shallow to very shallow in depth. Soil reaction was alkaline in nature whereas a decrease in pattern of the both macro and micro nutrients was observed. In addition P-1 (River side agricultural land at Chushot-Gongma) and P-4 (Farmer's agricultural land at Upper Tukcha) are well-suited for staple crops and vegetables including alfalfa. While P-2: Stream side land at Upper Stakmo village, P-3: Barren road-side land, Lower Stakmo village are suitable for taking of seabuckthorn and tree plantation. Since the topography of Ladakh region is rugged, undulated and prone to soil erosion during summer and snow melt as observed. On the other hand, due to non-application of fertilizer and deficiency of organic matter, nutrients are on deficient side in all the soil profiles visited. Hence, it becomes necessary to apply all the micronutrients regularly, especially in deficient areas. There is a need to design suitable intervention for soil and water management measures of such cold desert soils with micro-nutrient application to enhance the livelihood options of resource poor farmers.

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