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Nutrient status of soil under different land use systems in Leh region of Himalayan cold desert

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Abstract
The present study was conducted to estimate the nutrient status of soil of seven different land use systems: agriculture; horticulture; agrisilviculture; agrihortisilviculture; silvipasture; hortisilvipasture and agrihorticulture. The study found that the soil of the area was alkaline in nature ranging from 7.43-8.01. The pH of soil of different land use systems followed the order as agriculture > horticulture > agrisilviculture > agrihorticulture > silvipasture > hortisilvipasture > agrihortisilviculture. The study further found that Nitrogen, Potassium, Phosphorus, Calcium, Magnesium and Organic Carbon were highest in agrihortisilviculture and lowest in agriculture land use system. Whereas, Electrical Conductivity and Bulk Density were found highest in agriculture and lowest in agrihortisilviculture land use system.

Keywords: Soil nutrient status, land use system, cold desert, alkaline

Introduction
Land is the most important natural resource which embodies soil, water and associated flora and fauna involving total ecosystem. Soil is a limited resource that has a crucial role in sustaining ecosystem services and human life, and ensuring environmental stability and agriculture productivity. From agricultural point of view, the soil health may be referred to as the ability of the soil to produce crops. It is conditioned by a number of physical, chemical and biological attributes and processes like soil erosion, water retention and transmission characteristics, mechanical impedance, soil temperature, soil aeration, water logging, soil salinity, alkalinity, acidity, nutrient status, organic matter content etc. Prevalence of one or more unfavourable soil conditions over time will lead to unsustainability of an agricultural system.

In India, cold desert comes under the trans Himalayan zone which is approximately 1,03,11,300 hectares of area (Gupta and Arora, 2016) [8]. These arid areas are not benefited by the south east monsoon because they lie in the rain shadow area of the Himalayan mountain system. A cold desert ecosystem refers to an area where the climate has characteristics of great extremes of being hot and cold combined with excessive dryness, scanty rainfall, massive snowfall, high wind velocity, sparse vegetation, high UV radiation, and extremely xeric conditions (Devi and Thakur, 2011) [5].

Ladakh in the erstwhile state of Jammu and Kashmir and Lahaul and Spiti in Himachal Pradesh forms most part of the cold desert in India. The Ladakh region consists of 2 districts, namely Leh and Kargil. The soil of this region is generally grey and light, characterized by low fertility status coupled with poor water retention capacity and scanty plant cover. In absence of any substantial leaching of minerals from the soil, the bases are continuously added to the soil complex, thereby rendering the pH values on alkaline side (Tundup *et al.*, 2018) [26].

There is very less information on the nutrient status of soil of different land use systems for this region. It is very important to carry out diagnosis and descriptive research prior to long-term experimental programmes in order to improve the efficiency of indigenous land use systems, as well as to assess the performance of improved technologies that ultimately will improve the sustenance of land based economy and play a pivot role in the era of global warming and climate change in the cold desert of India. The restoration of soil health is, therefore, a formidable challenge before us to ensure higher productivity, profitability and food security of this region.

Materials and Methods

Study area

The present study was carried out in two blocks i.e. Khaltse and Saspol block of Leh district of erstwhile state of Jammu and Kashmir. This region is enclosed by the Ladakh and Karakoram range in the north and Zanskar mountains and The Great Himalaya in the south. The average altitude of the region is 3200 m above mean sea level. Precipitation is very low and mainly occurs in the form of snow in the winter months.

Table 1: Locality factors of the study area

Latitude	34°10" N
Longitude	77°35" E
Altitude	2900-3500 m
Climate type	Dry temperate
Soil Texture	Coarse and sandy

(Devi and Thakur, 2011) [5]

Location of the study area

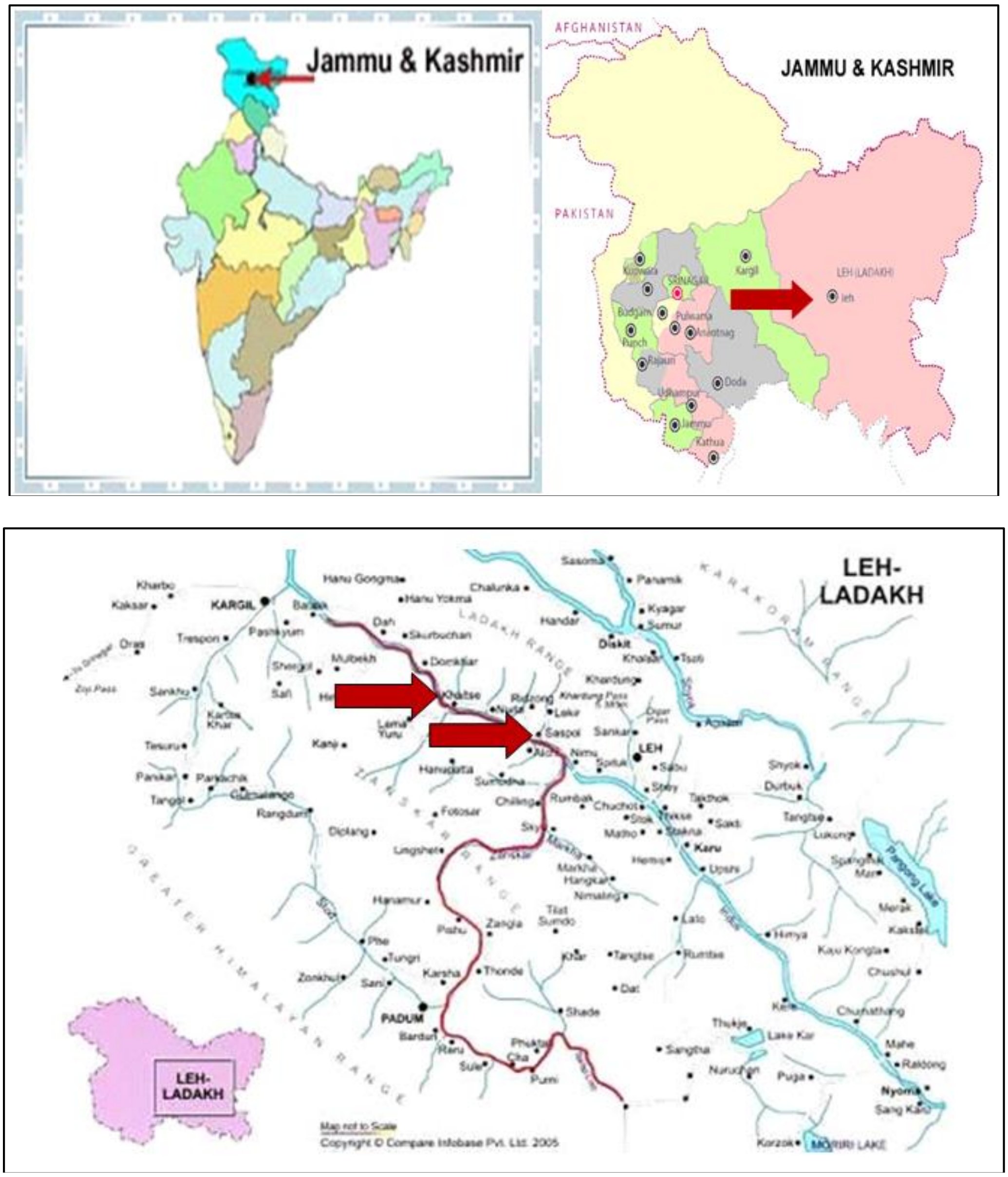

Fig 1: Location map of the study area

Selection of study sites

The study sites were selected through multi stage random sampling technique. Leh district consisted of 16 blocks and out of all the blocks, Khaltse and Saspol block were selected for the study. From each block 36 households were selected and a total of 72 households were selected from both the blocks for the study.

Table 2: Multi-stage random sampling method for choosing the study sites

Sr. no.	Block	Panchayat	Village	Farmer (9 farmers from each village according to their land holding)
1.	Khaltse	Khaltse	• Khaltse • Skindiyang •	• Three marginal farmer(<1 hectare) • Three small farmer (1-2 hectare) • Three medium farmer (2-5 hectare)
		Tingmosgang	• Tingmosgang • Nurla •	• Three marginal farmer(<1 hectare) • Three small farmer (1-2 hectare) • Three medium farmer (2-5 hectare)
2.	Saspol	Saspol	• Saspol • Saspochey	• Three marginal farmer(<1 hectare) • Three small farmer (1-2 hectare) • Three medium farmer (2-5 hectare)
		Gera	• Gera • Alchi	• Three marginal farmer(<1 hectare) • Three small farmer (1-2 hectare) • Three medium farmer (2-5 hectare)

Treatment details
Treatments: 7 (Land use systems)
Replications: 4 (villages)
Statistical design: Randomised Block Design (RBD)

Experimental methodology
Soil samples were collected at 0-30 cm depth from different land use systems in the study area. The soil samples were collected separately from all the 8 villages and the samples from the same land use system of same block were then mixed thoroughly and the bulk was then reduced by using quartering method so that about 500 gram of composite soil sample was retained for each land use system. The Samples were then air dried in shade, grinded and allowed to pass through 2 mm sieve and further was brought to the lab for physico-chemical analysis.

Table 3: Soil chemical analysis methods

Chemical Characteristics	Method employed
• Soil pH	1:2.5 soil: water suspension, with the help of digital pH meter (Jackson,1973)
• EC (dSm^{-1})	1:2.5 soil: water suspension, with the help of digital EC meter (Jackson,1973)
• Bulk density ($g\ cm^{-3}$)	Specific gravity method (Singh,1980)
• Organic carbon (%)	Walkley and Black method (1934)
• Available nitrogen ($kg\ ha^{-1}$)	Alkaline potassium permanganate method of Subbijah and Asija (1956)
• Available phosphorus ($kg\ ha^{-1}$)	(Olsen *et al.*1954)
• Available potassium ($kg\ ha^{-1}$)	Merwin and Peech (1951) Determined on Flame photometer

Statistical analysis
The data obtained were subjected to statistical analysis as per the procedure suggested by Gomez and Gomez (1984). Wherever, the effects exhibited significance at 5 per cent level of probability, the critical difference (CD) was calculated. Analysis was carried out on computer using "OPSTAT".

Result and Discussion
Soil pH
The pH was highest (8.01) in agriculture land use system and lowest (7.43) in agrihortisilviculture land use system. The amount of organic matter present in the soil significantly affects the pH of the soil and the decomposition of this organic matter produces acids such as follic acid and humic acid thereby lowering the pH of the soil. As the agriculture land use system contains less organic matter therefore, its pH is highest among all the land use systems.
The higher value of pH in agriculture land use system may be because of absence of trees as they add more organic matter into the soil and lowers the pH. Berhe *et al.*, (2013) [2] reported higher soil pH outside the tree canopy of *Ficusthonningii* as compared to that of soil pH under tree canopy. This was attributed to several mechanisms that releases H^+ ions such as soil base cation uptake, decomposition of organic matter to organic acids and CO_2, root respiration and nitrification. Nakayama (1969) [16] reported that under vegetation cover, the respiring roots raise the CO_2 concentration in soil atmosphere, which on dissolution in water produces carbonic acid (HCO_3). This acid would reduce the pH of the soil under vegetative cover. The alkaline nature of the soil of Ladakh region has also been reported by Dwivedi *et al.*, (2005) [6], Sharma *et al.*, (2006) [19], Tundup *et al.*, (2016) [25] and Tundup *et al.*, (2018) [26].

Bulk Density ($g\ cm^{-3}$)
The bulk density was recorded highest (0.86 $g\ cm^{-3}$) in agriculture land use system and lowest (0.64 $g\ cm^{-3}$) in agrihortisilviculture land use system.

Table 4: pH, bulk density and electrical conductivity of soil of various land use systems of the study area

Land use Systems	pH			Bulk density ($g\ cm^{-3}$)			Electrical conductivity ($d\ S\ m^{-1}$)		
	Khaltse block	Saspol block	Mean	Khaltse block	Saspol block	Mean	Khaltse block	Saspol block	Mean
Agriculture	8.05	7.98	8.01	0.88	0.83	0.86	0.98	0.96	0.97
Horticulture	7.9	7.87	7.89	0.81	0.76	0.79	0.91	0.84	0.88
Agrisilviculture	7.79	7.73	7.76	0.79	0.75	0.77	0.85	0.80	0.83
Agrihortisilviculture	7.44	7.41	7.43	0.67	0.61	0.64	0.64	0.60	0.62
Silvipasture	7.5	7.45	7.48	0.72	0.67	0.70	0.67	0.63	0.65
Hortisilvipasture	7.49	7.44	7.46	0.71	0.66	0.68	0.71	0.68	0.70

Agrihorticulture	7.59	7.55	7.57	0.73	0.69	0.71	0.76	0.73	0.75
Mean	7.68	7.63		0.76	0.71		0.79	0.75	
C.D.(0.05)	System NS			System NS			System NS		
	Block NS			Block NS			Block NS		
	(SXB) NS			(SXB) NS			(SXB) NS		

From the finding it was observed that the land use system which is intensively managed had higher bulk density and it declined as the intensity of land management system reduced. The higher value of bulk density can also be ascribed to lower soil organic carbon content. The agriculture crops such as Wheat, Barley and vegetables are uprooted during harvesting season and the land is kept bare for the whole winter season. This results in lower addition of organic carbon in this land uses as there is no material left for decomposition. These results are in the line with findings of Karan *et al.,* (1991) [10] and Senneh (2007) [18], who reported higher values of bulk density in cultivated soil in comparison to grasslands. Similar results were also found by Toppo (2012) [24].

EC (d S m^{-1})

The EC was highest (0.97 d S m^{-1}) in agriculture land use system and lowest (0.62 d S m^{-1}) in agrihortisilviculture land use system.

The higher value of EC in agriculture land use system might be because of continuous addition of fertilizers which might have added salts. Berhe *et al.,* (2013) [2] reported lower soil electrical conductivity under tree canopy and it is higher in area outside tree canopy. The results of EC are in line with the findings of Dwivedi *et al.,* (2005) [6], Sharma *et al.,* (2006) [19], Tundup *et al.,* (2016) [25] and Tundup *et al.,* (2018) [26].

Organic carbon (%)

The organic carbon content was highest (0.61%) in agrihortisilviculture land use system and lowest (0.41%) in agriculture land use system (Table 5).

The increased organic carbon content in soils under tree based system may be ascribed to more leaf litter deposition and root turnover from trees (Zegeye, 1999) [28]. Soil organic carbon is formed by the decomposition of plant and animal residues, root exudates (Lal 1989; Blevins and Frye, 1993) [13, 3]. The similar range of soil organic carbon was found by Dwivedi *et al.,* (2005) [6], Tundup *et al.,* (2016) [25] and Sharma *et al.,* (2006) [19].

Table 5: Organic carbon, calcium and magnesium content in soils of various land use systems of the study area

	Organic carbon (%)			**Calcium (C mol (P$^+$) Kg^{-1})**			**Magnesium (C mol (P$^+$) Kg^{-1})**		
Land use system	**Khaltse block**	**Saspol block**	**Mean**	**Khaltse block**	**Saspol block**	**Mean**	**Khaltse block**	**Saspol block**	**Mean**
Agriculture	0.44	0.38	0.41	1.10	0.99	1.04	0.09	0.07	0.08
Horticulture	0.49	0.43	0.46	1.14	0.96	1.05	0.13	0.10	0.12
Agrisilviculture	0.54	0.49	0.51	1.15	0.99	1.07	0.14	0.11	0.13
Agrihortisilviculture	0.63	0.6	0.61	1.21	1.08	1.15	0.23	0.32	0.27
Silvipasture	0.56	0.53	0.54	1.16	1.07	1.12	0.16	0.14	0.15
Hortisilvipasture	0.60	0.54	0.57	1.16	1.09	1.13	0.19	0.16	0.17
Agrihorticulture	0.52	0.48	0.50	1.14	1.08	1.08	0.15	0.13	0.14
Mean	0.54	0.49		1.15	1.03		0.16	0.15	
C.D.(0.05)	System NS			System NS			System NS		
	Block NS			Block NS			Block NS		
	(S X B) NS			(S X B) NS			(S X B) NS		

Magnesium and Calcium

The calcium content of agrihortisilviculture was highest (1.15 C mol (P$^+$) kg^{-1}). Similarly magnesium in the same system was highest (0.27 C mol (P$^+$) kg^{-1}). The minimum value of calcium and magnesium were 1.04 C mol (P$^+$) kg^{-1} and 0.08 C mol (P$^+$) kg^{-1}respectively in agriculture land use system.

Nair (1989) [15] suggested that agroforestry and other trees based land use systems are commonly credited with more efficient nutrient cycling and in turn, a greater potential to improve soil fertility than many other systems because of the presence of woody perennials in the system. Kellman (1979) [11] revealed that in addition to translocation of nutrients from soil layers beyond the reach of annual crops, enhancement of nutrient status beneath tree canopies is attributed to canopy capture of precipitation.

Nitrogen

Among the different land use systems, nitrogen content was highest (352.08 kg ha^{-1}) in agrihortisilviculture land use system which was statistically at par with hortisilvipasture land use system. The minimum (330.84 kg ha^{-1}) nitrogen content was found in agriculture land use system.

The maximum nitrogen content in agrihortisilviculture land use system could be because of presence of nitrogen fixing agriculture crop such as Pea, Bean and Rajmash. The variation in available nitrogen may be attributed to variation in soil organic matter and total nitrogen contents (Korikanthmath, 1994) [12]. Atta *et al.,* (2013) [1] also reported higher available nitrogen under tree canopy of *Acacia* species as compared to that of available nitrogen outside the tree canopy. The value range of nitrogen content in the study area is also in line with the findings of Tundup *et al.,* (2018) [26].

Phosphorus

The mean phosphorus (8.25 kg ha^{-1}) content in soil of khaltse block was higher than mean phosphorus (7.77 kg ha^{-1}) content of Saspol block. The phosphorus content of agrihortisilviculture was highest (9.99 kg ha^{-1}) among all the land use systems and the minimum (7.28 kg ha^{-1}) was recorded in agriculture land use system.

Tanga *et al.,* (2014) [23] also reported higher available phosphorus under tree canopy to that of available phosphorus outside the tree canopy. This was ascribed to leaf litter deposition and release at mineralization, higher microbial population stimulated by organic matter input. The range of the result of phosphorus content in the soils of this region is at par with the results of Dwivedi *et al.*, (2005) [6] and Sharma *et al.*, (2006) [19].

Potassium

The potassium content of agrihortisilviculture was highest (360.81 kg ha^{-1}) among all the land use systems and the minimum (344.30 kg ha^{-1}) was recorded in agriculture land use system.

Table 6: Nitrogen, Potassium and Phosphorus content in soils of various land use systems of the study area

	Nitrogen (Kg ha^{-1})			Potassium (Kg ha^{-1})			Phosphorus (Kg ha^{-1})		
Land use system	**Khaltse block**	**Saspol block**	**Mean**	**Khaltse block**	**Saspol block**	**Mean**	**Khaltse block**	**Saspol block**	**Mean**
Agriculture	331.55	330.12	330.84	345.1	343.51	344.30	7.51	7.23	7.28
Horticulture	338.09	336.59	337.34	351.64	350.03	350.83	7.52	7.05	7.37
Agrisilviculture	343.72	341.88	342.8	354.44	352.64	353.54	7.58	7.19	7.38
Agrihortisilviculture	353.01	351.15	352.08	361.78	359.85	360.81	10.34	9.65	9.99
Silvipasture	347.37	345.88	346.63	357.76	356.11	356.93	8.18	7.8	7.99
Hortisilvipasture	351.62	349.74	350.68	358.9	357.1	358.00	8.76	8.31	8.53
Agrihorticulture	344.66	343.46	344.06	356.89	355.3	356.09	7.84	7.17	7.5
Mean	344.29	342.69		355.21	353.51		8.25	7.77	
	System 1.48			System 0.68			System 0.15		
	Block 0.79			Block 0.37			Block NS		
	(SXB) NS			(S X B) NS			(SXB) NS		

The higher potassium contents in agroforestry systems as compared to agriculture can be ascribed to leaf litter deposition and release at mineralization, higher microbial population stimulated by organic matter input. Atta *et al.*, (2013) [1] also reported higher available potassium under tree canopy of *Acacia* species as compared to that of outside the tree canopy. Tanga *et al.*, (2014) [23] also reported higher available potassium under tree canopy to that of available potassium outside the tree canopy and available potassium decreased with increasing distance from tree trunk. Sileshi (2016) [20] reported increased potassium under the tree canopy as compared to that outside the tree canopy. The results are also in line with the findings of Dwivedi *et al.*, (2005) [6] and Sharma *et al.*, (2006) [19].

Conclusion

The pH of the study area was alkaline in nature. The highest pH was recorded in agriculture land use system and lowest in agrihortisilviculture land use system. Electrical conductivity and bulk density were again recorded highest in agriculture land use system and lowest in agrihortisilviculture land use system. Nitrogen, phosphorus, potassium, calcium, magnesium and organic carbon were recorded highest in agrihortisilviculture land use system and lowest in agriculture land use system.

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