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Evaluating Soil Quality in High Altitude Region: A Case Study of Miyar Valley (Lahaul & Spiti) in Himachal Pradesh

Shikha Acharya*, Muskaan Kashyap, Kanika Baghla and N.K. Sankhyan
Department of Soil Science, CSK HPKV, Palampur (Himachal Pradesh), India.

(Corresponding author: Shikha Acharya)*
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ABSTRACT: Miyar valley is a vital agricultural region following various land use systems in Lahaul valley within the trans-Himalayan region of Himachal Pradesh. There is limited information on the nutrient status across these systems. This region faces challenges like fluctuating temperatures, unpredictable conditions and limited human activity. Soil samples were collected from prevalent land use systems: cultivated lands (annual crops), cultivated lands (perennial crops), forests, orchards, pasture lands, seabuckthorn plantations, polyhouses and floriculture. The soils were found sandy loam to sandy clay loam in texture. Microbial biomass carbon was highest in forests and lowest in floriculture. Soil moisture content varied from 9.2 to 21.23 per cent and was higher in cultivated lands. Available N, P and K ranged from 120 to 340, 8 to 44 and 107 to 452 kg ha^{-1}. In case of micronutrients *i.e*. Fe, Mn, Zn, Cu the range was 1.19 to 15.04, 0.14 to 4.80, 0.15 to 2.10 and 0.02 to 3.81 mg kg^{-1} respectively. Nutrient index for nitrogen was low in all land use systems except orchards and seabuckthorn plantation where it was medium, while phosphorus was medium in forests, orchards, seabuckthorn plantation, polyhouses, pasture lands but low in cultivated lands and floriculture and potassium was medium in all other systems except floriculture.

Keywords: Soil quality, high altitude, seabuckthorn, Miyar valley.

INTRODUCTION

In India, the cold desert region falls within the Trans-Himalayan zone covering an area of approximately 10.3 million hectares. Himachal Pradesh accounts for 10.4% of the Indian Himalayan Region (Sidhu and Surya 2014). The high-altitude areas in the Trans-Himalayan zone of Himachal Pradesh are characterized by extreme and unpredictable environmental conditions, including fluctuating temperatures, unexplored micro-flora and minimal human interference. The majority of India's cold desert lies in regions like Ladakh in Jammu and Kashmir, Lahaul and Spiti, Chamba in H.P.

Miyar valley is situated within the Western Himalayan division in the Lahaul and Spiti district of Himachal Pradesh. Over half of the valley's total area (568 km² out of 975.7 km²) is covered by glaciers. The seasonal cycle of heavy snow accumulation, followed by repeated thawing and freezing, creates challenging conditions for agriculture (Joshi et al. 2017). These severe climatic variations, combined with the rough topography of the Himalayas, have a profound impact on the soil's physical and chemical properties. Despite the challenges posed by harsh climatic conditions and a short growing season (typically lasting from April to October or May to September, as heavy snowfall blankets the area throughout the winter months), Miyar valley holds significant agricultural value. This valley provides a distinctive setting for soil quality assessment due to its varied land use systems and unique climatic conditions. The high-altitude environment, marked by a cold desert climate, supports a range of ecological niches that foster diverse agricultural practices, pastoral activities and natural vegetation.

Soil quality plays a vital role in sustainable land management as it determines the soil's ability to function effectively within an ecosystem. It includes physical, chemical and biological properties of soil that collectively support productivity, environmental stability and the health of both plants and animals. There is very limited information n nutrient status of this region. Therefore evaluating soil quality in Miyar valley under different land use systems is essential for developing a base map for future land management strategies and before implementing any experimental interventions, as it will help optimize the efficiency of indigenous land use practices and evaluate the effectiveness of modern technologies.

MATERIALS AND METHODS

There are only 2 panchayats (Chimret and Tingret) in Miyar valley. A total of 133 surface soil samples were collected from these panchayats. Samples were gathered from eight prevalent land use systems: cultivated lands (annual crops), cultivated lands (perennial crops), forests, orchards, pasture lands, seabuckthorn plantations, polyhouses and floriculture. The sampling was proportionate to the area covered by

each land use system, resulting in 49 samples from cultivated lands (annual crops), 23 from cultivated lands (perennial crops), 12 from forests, 11 from orchards, 12 from pasture lands, 16 from seabuckthorn plantations, 6 from polyhouses and 4 from floriculture. To avoid contamination, all samples were collected using auger and stainless steel spatula. Soil moisture content (SMC) was determined at the time of sampling (w/w basis). Samples were analysed for microbial biomass carbon, soil texture, available N, P, K, Fe, Mn, Zn and Cu using standard methods.

Nutrient Index was calculated by Parker's index method (Parker *et al.*, 1951) as per the following equation:

Nutrient index= Nl+2Nm+3Nh
Nt

where

Nl = number of samples in low category of available nutrients

Nm = number of samples in medium category of available nutrients

Nh = number of samples in high category of available nutrients

Nt = total number of samples

The nutrient index classes were categorized into low, medium and high by comparing the calculated value of nutrient index (NI) with the recommended levels as per the following standard classes:

Low	<1.5
Medium	1.5-2.5
High	>2.5

RESULTS AND DISCUSSION

Soil texture. The proportion of mechanical soil separates of different land use systems is shown in Table 1. The mean values corresponding to cultivated lands (annual crops), cultivated lands (perennial crops), forests, orchards, pasture lands, seabuckthorn plantation, polyhouses and floriculture land use of sand were 50, 48, 57, 51, 54, 62, 53 and 64, of silt 30, 32, 28, 31, 28, 24, 30 and 23, of clay 20, 20, 14, 18, 18, 14, 17 and 13 % respectively. The soil texture of Miyar valley was found to be sandy loam, loam and sandy clay loam. According to the work reported by Verma (1979) the dominant parent materials of the soils of dry temperate zone were granite, quartzite, gneiss, shale and schist, which might have resulted into coarse texture of these soils. Similar findings have been reported by Sharma and Kanwar (2010) for cold desert soils.

Soil moisture content. Soil moisture content ranged from 9.2 to 35.7% under different land use systems as shown in Table 1. Cultivated annuals were found to have highest soil moisture content *i.e.* 21.23%. Pasture lands showed a higher SMC (20.92%) which might be attributed to the continuous grass mating on the surface thereby reducing evaporation and increasing water infiltration.

Table 1: Range and mean values of biological and physical properties under different land use systems in Miyar valley.

	Mechanical separates (%)			Soil moisture content (%)	MBC ($\mu g\ g^{-1}$)
	Sand	Silt	Clay		
Cultivated lands (annual crops)					
Range	38-69	26 -37	3-25	10.1-35.7	150-352
Mean	50	30	19	21.23	236
SD	±4.78	±1.75	±3.99	±7.06	±53.19
Cultivated lands (perennial crops)					
Range	44-54	28-35	14-23	9.2-31.9	200-354
Mean	48	32	19	19.65	267
SD	±2.73	±2.01	±2.06	±6.06	±44.85
Polyhouses					
Range	50-56	26-32	15-17	13.7-25.3	152-274
Mean	53	30	16	18.43	225
SD	±2.02	±2.09	±0.96	±4.68	±45.30
Floriculture					
Range	54-70	19-28	10-17	11.0-18.0	135-212
Mean	64	23	13	13.63	188
SD	±6.73	±3.81	±3.00	±3.04	±36.02
Orchards					
Range	40-62	25-36	10-23	16.5-24.7	217-352
Mean	51	31	17	20.40	286
SD	±6.31	±3.61	±3.50	±2.70	±39.52
Forests					
Range	50-73	19-32	5-17	10.1-23.4	312-540
Mean	57	28	13	15.62	439
SD	±6.31	±3.68	±3.85	±4.51	±75.55
Pasture lands					
Range	45-68	18-34	10-23	11.4-28.7	202-512
Mean	54	28	16	20.92	382
SD	±7.91	±5.09	±4.48	±5.36	±78.81
Seabuckthorn plantation					
Range	55-79	13-29	4-16	11.1-24.3	254-415
Mean	62	24	11	16.36	339
SD	±6.71	±3.85	±3.65	±3.82	±48.26

Microbial biomass carbon. The highest value for MBC (439 µg g^{-1}) was found in forests Lepcha and Devi (2020); Sharma *et al.* (2022) which might be due to higher organic matter, efficient nutrient cycling and lowest (188 µg g^{-1}) in floriculture which might be due to its recent adoption and the limited addition of organic matter and fertilizers in this land use system. Additionally, floriculture is typically practiced on a small scale in areas adjacent to cultivated lands.

Available Nitrogen. In general available N was low in the study area which might be due to low temperature for more than 6 months in a year and low rate of decomposition of organic matter Sharma and Kanwar (2010); Sharma and Tripathi (2002). Seabuckthorn plantation showed highest nitrogen content *i.e.* 287 kg ha^{-1} (Table 2) which may be attributed to the nitrogen fixing capabilities of *Frankia* (Actinomycetes) in seabuckthorn (*Hippophae* sp.) communities. Jike and Xiaoming (1992) have reported the ability of seabuckthorn to fix 180 kg N ha^{-1} $year^{-1}$. Similar findings were reported by Rana *et al.* (2019). In cultivated lands (annual crops) and polyhouses heavy-feeding crops like potatoes, vegetables and rajmash resulted in higher nitrogen uptake.

Available phosphorus. Overall, the availability of P in soil is highly pH dependent with maximum availability near neutral soil pH which may corroborate the higher values of P in the study area (Sharma and Kanwar 2010). Highest mean available P content was 29 kg ha^{-1}, followed by 24 kg ha^{-1} in both seabuckthorn plantation and forests. One hundred and six phosphorus-solubilizing bacteria were isolated from the rhizosphere and root endosphere of seabuckthorn in Lahaul and Spiti indicating that its root exudates selectively promote specific rhizobacteria which might be the reason for higher availability of P in this land use system (Kumar *et al.*, 2015).

Table 2: Range and mean values of available nutrients under different land use systems in Miyar valley.

	N	P	K	Fe	Mn	Zn	Cu
Cultivated lands (annual crops)							
Range	120-310	10-36	108-324	2.12-13.55	0.44-4.10	0.22-2.04	0.02-3.00
Mean	184	19	208	5.40	1.43	0.73	0.81
SD	±36.02	±6.09	±63.97	±2.61	±0.80	±0.37	±0.76
Cultivated lands (perennial crops)							
Range	185-340	16-44	128-372	1.78-9.56	0.14-2.87	0.21-1.45	0.22-3.81
Mean	251	29	234	5.19	1.24	0.61	1.02
SD	±33.86	±7.60	±77.77	±2.52	±0.66	±0.35	±0.74
Polyhouses							
Range	165-224	8-27	149-248	3.25-6.94	0.88-2.63	0.15-0.75	0.64-1.44
Mean	192	17	211	4.83	1.50	0.47	1.02
SD	±22.87	±7.27	±32.80	±1.36	±0.67	±0.26	±0.30
Floriculture							
Range	125-178	12-20	129-218	3.21-5.22	0.85-1.72	0.26-0.69	0.36-1.03
Mean	152	16	185	4.25	1.41	0.42	0.71
SD	±22.20	±3.27	±38.96	±0.83	±0.38	±0.19	±0.34
Orchards							
Range	168-326	14-28	107-330	3.58-6.20	0.56-3.20	0.22-0.86	0.54-2.40
Mean	271	22	195	4.83	1.44	0.54	1.05
SD	±48.66	±5.01	±88.92	±1.01	±0.92	±0.22	±0.50
Forests							
Range	154-320	15-32	214-452	1.19-11.92	0.98-4.80	0.38-1.40	0.64-2.47
Mean	223	24	327	6.31	2.71	0.96	1.29
SD	±56.00	±5.44	±84.83	±3.25	±1.22	±0.29	±0.51
Pasture lands							
Range	178-268	9-27	148-440	3.20-14.16	1.13-3.06	0.20-1.10	0.36-1.42
Mean	217	20	228	8.15	1.74	0.58	0.82
SD	±26.21	±6.53	±83.06	±3.46	±0.60	±0.38	±0.32
Seabuckthorn plantation							
Range	224-330	15-33	122-322	2.04-15.04	1.12-4.13	0.42-2.10	0.14-2.69
Mean	287	24	214	8.17	2.48	0.88	1.23
SD	±30.45	±6.30	±64.87	±4.04	±0.83	±0.40	±0.76

Available Potassium. The available potassium content ranged from 107 to 452 kg ha^{-1}. Higher range of available potassium in soils of this area is due to the presence of feldspar and quartz as the sedentary parent material (Verma, 1979) which is rich source of potassium. Similar observations for available potassium content were reported by Sharma and Kanwar (2012) in the soils of dry temperate zone of Himachal Pradesh.

Available micronutrient cations (Fe, Mn, Zn, Cu). Seabuckthorn plantation exhibited the highest Fe content *i.e.* 8.17 mg kg^{-1} (Table 2) content which might be due to its deep-rooted system, which accesses subsurface soil layers for nutrients (Acharya *et al.*, 2010) followed by pasture lands, forests, cultivated lands (annual crops) and cultivated lands (perennial crops). Highest mean Mn, Cu, Zn content were present in forests followed by seabuckthorn plantation and

other land use systems. The decomposition of leaf litter and dead roots within the soil enhances mineralization, contributing to higher nutrient levels and increasing Fe content (Dar *et al*., 2012; He *et al*., 2016; Sharma and Singh 2017).

Nutrient index. As observed in Table 3 nutrient index of available nitrogen was low in cultivated lands (annual crops), cultivated lands (perennial crops), forests, pasture lands, polyhouses and floriculture.

Table 3: Nutrient index of soil samples under different land use systems in Miyar valley.

Land use systems	N	P	K
Cultivated lands (annual crops)	1.12 (l)	1.02 (l)	1.52 (m)
Cultivated lands (perennial crops)	1.08 (l)	1.10 (l)	2.10 (m)
Forests	1.08 (l)	2.20 (m)	2.38 (m)
Orchards	1.63 (m)	2.27 (m)	2.27 (m)
Pasture lands	1.00 (l)	1.91 (m)	2.08 (m)
Seabuckthorn plantation	1.75 (m)	2.30 (m)	2.18 (m)
Polyhouses	1.00 (l)	2.00 (m)	1.88 (m)
Floriculture	0.90 (l)	1.45 (l)	1.23 (l)

*(l) - low status; ** (m) - medium status

whereas it was medium in orchards and seabuckthorn plantation. The status of available phosphorus was medium in forests, orchards, seabuckthorn plantation, polyhouses, pasture lands and was low in cultivated lands (annual crops), cultivated lands (perennial crops) and floriculture. Available potassium status was low in floriculture and medium for other land use systems.

CONCLUSIONS

Soils were sandy loam, with highest moisture content in cultivated annuals. Forests had the highest K, Zn, Mn, and Cu while seabuckthorn plantations showed the highest N however, highest P was recorded in perennial crops. Microbial biomass carbon was highest in forest soils. Soils with seabuckthorn plantations demonstrated highest N and higher levels of P, K, Fe, Mn, Zn, and Cu indicating that seabuckthorn plays a vital role in maintaining soil fertility in Miyar region. Nutrient index for nitrogen was low in most land use systems except for orchards and seabuckthorn plantation where it was medium while phosphorus was medium in forests, orchards, seabuckthorn plantation, polyhouses, pasture lands but low in cultivated lands and floriculture. Potassium was medium in all other systems except floriculture. Overall soil was low in N, medium in P, K and DTPA extractable Fe, Mn, Zn, Cu were in sufficient range.

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