Physicochemicalcharacteristics of soils under different cropping systems in Kashmir Himalayas

Abstract

The physicochemical characteristics of soil arefundamentally important in assessing its quality, as they govern the air and water movement within the soil profile. These processes play a significant role in the soil's ability to sustain plant growth effectively.This study was conducted to investigate the impact of dominant cropping systems on soil physicochemical properties in Kashmir Himalayas, India. Soil samples were collected from five different cropping systems, such as rice-fallow, rice-mustard, rice-oats, maize-fallow and vegetable, up to a depth of 20 cm. The findings revealed that the percent sand varied from 20.34 – 28.71%, while percent silt and clay varied from 40.80 – 46.18% and 26.38 – 36.04%, respectively.Bulk density ranged from 1.45 – 1.32Mgm^{-3} across the cropping systems. There was a variation in soil pH (7.54 – 6.46) across the examined cropping system, following a pattern: maize-fallow>vegetable> rice-mustard> rice-fallow> rice-oats. Moreover, electrical conductivity was less than 1 dSm^{-1}, indicating no salinity hazards. Understanding these variations is essential for sustainable soil management and enhancing agricultural productivity.

Introduction

The physicochemical properties of soil play a pivotal role in its quality by affecting air and water dynamics within soil layers,which in turn influence its capacity to support plant growth (Zhang et al., 2021).For instance, soil texture is a key factor in soil classification and plays a crucial role in understanding how soil properties change due to natural processes or human activities (Xu *et al*., 2013; Li *et al*., 2022). It is determined by the relative proportions of sand, silt, and clay, and defines soil categories such as sandy loam, loam, or clay (Brady & Weil, 2008). It is considered one of the most crucial physical properties due to its influence on other attributes. Soil texture influences water retention, drainage, and nutrient availability, thereby impacting soil fertility and productivity (Silva et al., 2012; Huntley, 2023). Similarly, soil pH is a critical chemical property that regulates the acidity or alkalinity of soil. It affects the chemical reactions between water and soil minerals, as well as nutrient availability to plants (Neina, 2019). Nutrient uptake, particularly of primary macronutrients like nitrogen, phosphorus, and potassium, and secondary nutrients like calcium, magnesium, and sulfur,is highly pH-dependent. These nutrients are most accessible to plants within a pH range of 5.5 to 7.9, underscoring the importance of maintaining an optimal pH for agricultural productivity (Imran et al., 2010).

Cropping systems play a critical role in shaping the physicochemical properties of soils, which are essential determinants of soil fertility, productivity, and sustainability (Yang et al., 2020). Continuous cropping, crop rotations, and monoculture system have distinct effects on soil properties due to variations in organic matter inputs, root activity, and nutrient cycling processes (Lal, 2020).Therefore, the present study was designed to evaluate the variability in soil physicochemical properties across five distinct cropping systems in the Kashmir Himalayas.

Materials and Methods

Five distinct cropping systems were selected viz. rice-fallow, rice-mustard, rice-oats, maize-fallow, and vegetable.Geo-referenced soil samples were collected from fifteen sites from a depth of 0-20cm for each cropping system.A total of seventy-five soil samples were collected from the chosen cropping systems. The properly stored soil samples were taken for further processing and study in the research laboratory of the Division of Soil Science and Agricultural Chemistry, Faculty of Agriculture Wadura.The particle size analysis was performed by hydrometric method as described by Bouyoucos (1962).Bulk density was determined by the core method as described by Blake and Hartge (1986).Soil reaction (pH) ofsamples was measured in 1:2.5 soil: water suspension with the use of glass electrode pH meter as described by Jackson (1973). The electrical conductivity was measured by Solubridge conductivity meter as described by Jackson (1973).The statistical analysis was performed using one way analysis of variance (ANOVA) to test the significance of results. All the data was analysed using R studio software.

Results and Discussion

Particle size distribution

The perusal of data in Table1 depicts that the mean values of sand percent in soils ranged from 20.34 – 28.71% across the studied cropping systems. The maximum value was recorded in maize-fallow (28.71%) and minimum was recorded in rice-fallow system (20.34%), following a pattern: maize-fallow> rice-oats> rice-mustard> vegetable> rice-fallow. The values for confidence interval (95% CI) varied from 19.78 – 20.89, 25.44 – 27.80, 26.95 – 29.10, 28.12 – 29.30, and 20.03 – 22.15 percent in rice-fallow, rice-mustard, rice-oats, maize-fallow and vegetable cropping system, respectively. Coefficient of variation (CV) ranged from 3.69 – 9.05 percent across the studied cropping systems.

The mean content of silt percent in the appraised cropping systems ranged from 40.80 – 46.18% where rice-mustard exhibited a maximum value (46.18%), while lowest was recorded in maize-fallow cropping system (40.80%), following a trend: rice-mustard> rice-oats> vegetable> rice-fallow> maize-fallow (Table2). Confidence interval (95 % CI) ranged from 41.45 – 45.77 percent in rice-fallow, 44.55 – 47.82 percent in rice-mustard, 43.43 – 47.72 percent in rice-oats, 39.56 – 42.04 percent in maize-fallow, and 43.63 – 46.57 percent in vegetable cropping system. CV ranged from 5.46 – 8.94 percent across the studied cropping systems.

The mean values of clay percent in the studied cropping systems exhibited a variation of 26.38 – 36.04%. The mean values of clay were 36.04, 27.19, 26.38, 30.47 and 33.69 percent in rice-fallow, rice-mustard, rice-oats, maize-fallow and vegetable soils, respectively with minimum values under rice-oats cropping system (26.38%) and maximum under rice-fallow system (36.04%), following a pattern: rice-fallow> vegetable> maize-fallow> rice-mustard> rice-oats (Table3). The values for confidence interval (95% CI) varied from 33.96 – 38.12, 26.09 – 28.28, 25.21 – 27.55, 29.45 – 31.49, and 32.54 – 34.84 percent in rice-fallow, rice-mustard, rice-oats, maize-fallow and vegetable cropping system, respectively. CV ranged from 6.00 – 10.40 percent across the studied cropping systems.

The overall comparison of particle size distribution and textural classesrevealed adifference between under different cropping systems. Therefore, based on particle size distribution, the texture of all the soils across the studied cropping systems varied from loam to clay loam (Table 7). This could be attributed to the variation in soil texture in plains, which range from loam to sandy loam, and tend to have higher clay content than upland soils,due to the deposition of finer particles from higher areas(Kumar et al., 2002). A similar pattern in soil particle size fractions was observed by Bangroo (2010) in his study of benchmark soils in Kashmir'stoposequence.Similarly, Maqbool et al., (2017), also categorized the soils as clay loam, silt loam, sandy loam in the district Ganderbal. This is further verified by observations of Shrestha et al. (2007), Wani et al. (2010) and Mir et al., (2024).

Bulk density

The mean values of bulk density under different cropping systems are presented in Table 4.The mean values for bulk density under different cropping systems varied from 1.32 – 1.45 Mgm^{-3}. The mean values of bulk density were 1.32, 1.38, 1.38, 1.45, and 1.41 Mgm^{-3} in rice-fallow, rice-mustard, rice-oats, maize-fallow, vegetable cropping system, respectively. Among the examined cropping systems, rice-fallow system exhibited the minimum value (1.32 $Mg\ m^{-3}$) while maize-fallow exhibited the highest value(1.45 $Mg\ m^{-3}$), following a pattern: maize-fallow> vegetable> rice-mustard= rice-oats> rice-fallow (Table 4).The 95% C.I values under examined cropping systems ranged from 1.30 – 1.33 in rice-fallow, 1.37 – 1.40 in rice-mustard, 1.37 – 1.39 in rice-oats, 1.43 – 1.47 in maize-fallow, and 1.40 – 1.42 percentin vegetable cropping system. CV ranged from 0.71 – 2.07 percent across the studied cropping systems (Table 4). When the studied cropping systems were compared using one way ANOVA with respect to bulk density, a statistical ($p < 0.05$) difference was observed between rice-based and non-rice-based cropping systems (Table 7). The results of the present study show that the modalities of cropping systems are significantly different in terms of soil bulk density. A lower organic matter content and reduced aggregation can contribute to an increase in soil bulk density in maize-fallow cropping system (Subedi *et al.,* 2020). Similar dependence has been put forward by Koueloet *al.*,(2020).

Soil reaction (pH)

Data pertaining to the mean values of pH under different cropping systems are presented in Table5. Soil reaction under different cropping systems was slightly acidic to slightly alkaline. The mean values of pH were 7.17, 7.33, 6.46, 7.54 and 7.48 in rice-fallow, rice-mustard, rice-oats, maize-fallow and vegetable, respectively. The lowest values of pH were recorded under rice-oat system and highest values under maize-fallow system, following a pattern: maize-fallow> vegetable> rice-mustard> rice-fallow> rice-oats (Table5). The 95% C.I values under studied cropping system ranged from 6.89 – 7.46, 7.23 – 7.44, 6.25 – 6.66, 7.34 – 7.74 and 7.35 – 7.60 percent in in rice-fallow, rice-mustard, rice-oats, maize-fallow and vegetable cropping system, respectively. CV ranged from 2.45 – 7.11 percent across the studied cropping systems (Table5). When the studied cropping systems were compared using one way ANOVA with respect to pH, a statistical ($p < 0.05$) difference was observed between rice-based and non-rice-based cropping systems (Table7). The lower pH levels in soils under rice cultivation, relative to other cropping systems, may be due to the combination of waterlogging during the rice growing season and elevated organic carbon content. Studies by

Sharma *et al*., (2020) and Chhibba*et al*., (2007) observed that soil pH was lower in rice-based cropping systems compared to cotton-wheat systems.

Electrical conductivity (EC)

Data pertaining to the mean values of EC under different cropping systems are presented in Table6. The observed mean values for EC under examined cropping systems ranged from 0.05 – 0.16 dS m^{-1}, possessing a mean value of 0.06 dS m^{-1} in rice-fallow, 0.09 dS m^{-1} in rice-mustard, 0.05 dS m^{-1} in rice-oats, 0.16 dS m^{-1} in maize-fallow, and 0.14 dS m^{-1} in vegetable cropping system (Table6). C.I values (95%) under the respective cropping systems ranged from 0.05 – 0.08, 0.07 – 0.12, 0.03 – 0.07, 0.13 – 0.18, and 0.11 – 0.16 percentin rice-fallow, rice-mustard, rice-oats, maize-fallow and vegetable cropping system, respectively. CV ranged from 25.00 – 60.00 percent across the studied cropping systems (Table6). When the studied cropping systems were compared using one way ANOVA with respect to EC, a statistical ($p < 0.05$) difference was observed between rice-based and non-rice-based cropping systems (Table7). All the examined cropping systems have EC values below 1 dSm^{-1} indicating that there is no salinity hazard. Sheikh (2006) and Wani et al. (2009) also reported the normal range of EC while studying the soils of Kashmir valley. Singh and Benbi (2021), and Sharma *et al*., (2020) also reported lower EC under rice-wheat than cotton-wheat cropping system.

Sand (%)						
Cropping Systems / Locations		RF	RM	RO	MF	V
L1		21.39	25.82	26.46	29.31	23.55
L2		20.16	25.86	30.49	27.62	21.36
L3		20.59	24.00	26.08	30.06	22.18
L4		20.30	29.86	27.49	28.08	18.59
L5		19.26	27.57	29.64	28.51	19.80
Mean ± SE		**20.34 ± 0.25**	**26.62 ± 0.54**	**28.03 ± 0.50**	**28.71 ± 0.27**	**21.09 ± 0.49**
Min		18.81	23.38	25.03	27.06	17.88
Max		22.15	30.13	31.89	31.19	24.12
95% C.I	LL	19.78	25.44	26.95	28.12	20.03
	UL	20.89	27.80	29.10	29.30	22.15
CV (%)		**4.91**	**7.96**	**6.92**	**3.69**	**9.05**

Table1: Sand percentage under different cropping systems

Table2: Silt percentage under different cropping systems

Silt (%)						
Cropping Systems / Locations		RF	RM	RO	MF	V
L1		43.50	46.83	48.06	37.32	42.92
L2		50.03	45.54	40.15	42.89	42.44
L3		40.08	51.07	50.20	39.92	46.53
L4		39.96	44.80	46.88	40.80	45.89
L5		44.49	42.70	42.64	43.11	48.26
Mean ± SE		**43.61 ± 1.00**	**46.18 ± 0.76**	**45.58 ± 1.00**	**40.80 ± 0.57**	**45.20 ± 0.64**
Min		38.63	42.17	39.54	36.88	41.09
Max		51.16	52.27	50.78	43.62	48.63
95% C.I	LL	41.45	44.55	43.43	39.56	43.83
	UL	45.77	47.82	47.72	42.04	46.57
CV (%)		**8.94**	**6.38**	**8.49**	**5.49**	**5.46**

Table3: Clay percentage under different cropping systems

Clay (%)						
Cropping Systems / Locations		RF	RM	RO	MF	V
L1		35.11	27.35	25.47	33.36	33.53
L2		29.81	28.60	29.36	29.50	36.20
L3		39.32	24.93	23.73	30.02	31.29
L4		39.74	25.34	25.63	31.12	35.52
L5		36.25	29.73	27.73	28.38	31.95
Mean ± SE		**36.04 ± 0.96**	**27.19 ± 0.51**	**26.38 ± 0.54**	**30.47 ± 0.47**	**33.69 ± 0.53**
Min		28.95	24.35	23.18	27.86	30.26
Max		40.15	30.24	30.42	33.97	36.92
95% C.I	LL	33.96	26.09	25.21	29.45	32.54
	UL	38.12	28.28	27.55	31.49	34.84
CV (%)		**10.40**	**7.28**	**8.04**	**6.00**	**6.14**

Table 4: Bulk density under different cropping systems

Bulk Density (Mg m^{-3})						
Cropping Systems / Locations		RF	RM	RO	MF	V
L1		1.34	1.39	1.37	1.47	1.41
L2		1.33	1.38	1.40	1.44	1.42
L3		1.32	1.36	1.37	1.41	1.43
L4		1.30	1.40	1.39	1.50	1.41
L5		1.31	1.41	1.38	1.47	1.40
Mean ± SE		**1.32 ± 0.006**	**1.38 ± 0.006**	**1.38 ± 0.005**	**1.45 ± 0.009**	**1.41 ± 0.004**
Min		1.28	1.34	1.35	1.39	1.38
Max		1.36	1.42	1.42	1.51	1.45
95% C.I	LL	1.30	1.37	1.37	1.43	1.40
	UL	1.33	1.40	1.39	1.47	1.42
CV (%)		**1.51**	**1.45**	**1.45**	**2.07**	**0.71**

Table 5: Soil reaction under different cropping systems

Soil reaction (pH)						
Cropping Systems / Locations		RF	RM	RO	MF	V
L1		7.72	7.46	5.88	7.77	7.28
L2		7.72	7.46	6.75	7.69	7.75
L3		7.09	7.39	6.40	7.76	7.46
L4		6.66	7.18	6.68	7.58	7.61
L5		6.69	7.20	6.60	6.93	7.30
Mean ± SE		**7.17 ± 0.13**	**7.33 ± 0.04**	**6.46 ± 0.09**	**7.54 ± 0.09**	**7.48 ± 0.05**
Min		6.37	6.91	5.80	6.59	7.02
Max		7.86	7.57	6.85	7.85	7.93
95% C.I	LL	6.89	7.23	6.25	7.34	7.35
	UL	7.46	7.44	6.66	7.74	7.60
CV (%)		**7.11**	**2.45**	**5.72**	**4.64**	**2.94**

Table 6: Electrical conductivity under different cropping systems

Electrical Conductivity (dS m^{-1})					
Cropping Systems / Locations	RF	RM	RO	MF	V
L1	0.06	0.06	0.02	0.19	0.08
L2	0.06	0.09	0.05	0.16	0.13
L3	0.07	0.09	0.06	0.21	0.15
L4	0.10	0.12	0.07	0.11	0.13
L5	0.06	0.15	0.08	0.14	0.21
Mean ± SE	**0.06 ± 0.006**	**0.09 ± 0.01**	**0.05 ± 0.008**	**0.16 ± 0.01**	**0.14 ± 0.01**
Min	0.03	0.03	0.01	0.08	0.06

Max		0.12	0.17	0.12	0.24	0.23
95% C.I	LL	0.05	0.07	0.03	0.13	0.11
	UL	0.08	0.12	0.07	0.18	0.16
CV (%)		**33.33**	**44.44**	**60.00**	**25.00**	**28.57**

Table 7: Overall properties of soils under different cropping systems

Cropping Systems	Sand (%)	Silt (%)	Clay (%)	Textural Class	BD	pH	EC
Rice-Fallow	20.341^{c}	43.613^{b}	36.047^{a}	Clay Loam	1.321^{d}	7.178^{b}	0.069^{c}
Rice-Mustard	26.623^{b}	46.187^{a}	27.190^{d}	Clay Loam	1.387^{c}	7.339^{ab}	0.099^{b}
Rice-Oats	28.031^{a}	45.585^{ab}	26.385^{d}	Loam	1.384^{c}	6.462^{c}	0.057^{c}
Maize Fallow	28.717^{a}	40.807^{c}	30.476^{c}	Clay Loam	1.458^{a}	7.545^{a}	0.161^{a}
Vegetables	21.096^{c}	45.206^{ab}	33.698^{b}	Clay Loam	1.415^{b}	7.483^{a}	0.140^{a}
CD ($p < 0.05$)	**1.223**	**2.306**	**1.790**		**0.018**	**0.255**	**0.028**

pH = soil reaction; EC = electrical conductivity; BD = bulk density.Mean values possessing different letters are statistically significantly different.

Conclusion

- This study concluded that different cropping systems have varying degree of influence on soil physicochemical characteristics.
- All the soils across the studied cropping were fine textured (loam to clay loam).
- Bulk density varied significantly between rice-based and other cropping systems.
- Soil reaction was slightly acidic to slightly alkaline with more values under maize-fallow and lowest under rice-based cropping systems.
- No salinity hazard was found across the examined cropping system.
- Therefore, understanding the various properties of soil is crucial for assessing its ability to perform essential functions.

References

Bangroo, S. A. 2010. Kotassium Releasing and Fixing Capacity of Rainfed Maize Growing Soils of District Ganderbal. M.Sc. (Agri.) Thesis, Submitted to Sher-e-Kashmir. University of Agricultural Sciences and Technology of Kashmir, Srinagar. India, pp. 1-150.

Blake, G. R., Hartge, K. H. 1986. Bulk Density. In: Klute A (editor). Methods of Soil Structure and Migration of Colloidal Materials Soils. Madison, WI, USA: *Soil Science Society of America* pp. 297-300.

Bouyoucos, G. J. 1962. Hydrometer Method improved for Making Particle Size Analysis of Soils. *Agronomy Journal***54**: 464- 465.

Brady, N. C., Weil, R. R., & Weil, R. R. (2008). *The nature and properties of soils* (Vol. 13, pp. 662-710). Upper Saddle River, NJ: Prentice Hall.

Chhibba, I. M., Brar, J. S. and Saini, S. P. 2007. Impact of cropping system on soil nutrient status in ustochreptic camborthids in Punjab.

Huntley, B.J. (2023). Soil, Water and Nutrients. In: Ecology of Angola. Springer, Cham. https://doi.org/10.1007/978-3-031-18923-4_6

Imran, M., Khan, A., Hassan, A., Kanwal, F., Liviu, M., Amir, M. and Iqbal, M.A. (2010), Evaluation of physico-chemical characteristics of soil samples collected from Harrapa-Sahiwal (Pakistan). Asian Journal of Chemistry, 22(6): 4823-4830.

Jackson, M. L. 1973. Soil Chemical Analysis. Prentice Hall of India Private Limited, New Delhi.

Kouelo, A. F., Mathieu, A. F., Julien, A., Moriaque, A. T., Lambert, A., Socrate, A. M. ... and Aliou, S. 2020. Variation of Physical and Chemical Properties of Soils under Different Cropping Systems in the Watershed of Kpocomey, Southern Benin. *Open Journal of Soil Science* **10**(11): 501-517.

Kumar, S., Sharma, J. C. and Sharma, I. P. 2002. Water Retention Characteristics and Erodability Indices of Some soils under Different land uses in NorthWest Himalayas. *Indian Journal of Soil Conservation***30**(1): 29-35.

Lal, R. (2020). Regenerative agriculture for food and climate. *Journal of soil and water conservation*, *75*(5), 123A-124A.

Li, J., Bao, Y., Wei, J., He, X., Tang, Q., Wu, S., ... and Wang, M. 2022. Scaling properties of particle-size distributions of purple soils in a small agricultural watershed: A multifractal analysis. *Catena* **215**: 106326.

Maqbool, M., Rasool, R. and Ramzan, S. 2017. Soil Physico-Chemical Properties as Impacted by Different Land Use Systems in District Ganderbal, Jammu and xxi Kashmir: India. *International Journal of Chemical Studies***5**(4): 832-840.

MIR, Y. H., Ganie, M. A., Baba, Z. A., MIR, S., Bhat, M. A., Bhat, J. A. ... and KURIQI, A. 2024. Assessing the Impact of Land use Change on Carbon and Soil Quality in Kashmir Himalayas. *Turkish Journal of Agriculture and Forestry* **48**(5): 658-676.

Neina, D. (2019). The role of soil pH in plant nutrition and soil remediation. *Applied and Environmental Soil Science*, *2019*, 5794869

Sharma, S., Singh, P. and Sodhi, G. P. S. 2020. Soil Organic Carbon and Biological Indicators of Uncultivated Vis-a-Vis Intensively Cultivated Soils under Rice–Wheat and Cotton–

Wheat Cropping Systems in South-Western Punjab. *Carbon Management* **11**(6): 681-695.

Sheikh, A. M. 2006. Studies on Micro-nutrient Cation in Paddy Growing Soils of District Kupwara. M.Sc. Thesis Submitted to SKUAST-Kashmir Srinagar pp. 59-65.

Shrestha, B. M., Singh, B. R., Sitaula, B. K., Lal, R. and Bajracharya, R.M. 2007. Soil Aggregateand Particle-Associated Organic Carbon under Different Land uses in Nepal. *Soil Science Society America Journal***71**: 1194-1203.

Silva, M. Poly, F. Guillaumaud, N. van Elsas, J. D., Salles, J. F. (2012). Fluctuations in ammonia oxidizing communities across agricultural soils are driven by soil structure and pH. *Frontiers in Microbiology, 3*, 77.

Singh, P., Benbi, D. K. 2021. Physical and Chemical Stabilization of Soil Organic Matter in Cropland Ecosystems under Rice-Wheat, Maize-Wheat and Cotton-Wheat Cropping Systems in North-Western India. *Carbon Management*. **12**:603–621.

Subedi, A., Badal, D., Mandal, R. A. and Yadab, B. K. 2020. Carbon Stock of Tree Species and its Biodiversity in Community Forests of Dang, Nepal. *Concepts of Dairy and Veterinary Sciences* **4**(1): 378-385.

Wani, M. A., Mushtaq, Z. and Nazir, S. 2010. Mapping of Micronutrients of the Submerged Rice soils of Kashmir. *Research Journal of Agricultural Sciences***1**(4): 458-462.

Wani, M. H., Baba, S. H. and Yousef, S. 2009. Land use Dynamics in Jammu and Kashmir. Agricultural Economics Research Review **22**: 145-154.

Xu, G., Li, Z. and Li, P. 2013. Fractal features of soil particle-size distribution and total soil nitrogen distribution in a typical watershed in the source area of the middle Dan River, China. *Catena* **101**: 17-23.

Yang, T., Siddique, K. H., & Liu, K. (2020). Cropping systems in agriculture and their impact on soil health-A review. *Global Ecology and Conservation*, *23*, e01118.

Zhang, Y., Wang, J., & Feng, Y. (2021). The effects of biochar addition on soil physicochemical properties: A review. *Catena*, *202*, 105284.