The Pharma Innovation Journal 2023; SP-12(10): 107-111

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; SP-12(10): 107-111

www.thepharmajournal.com
Received: 25-07-2023
Accepted: 29-08-2023

Charishma DS
Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, Dharwad, Karnataka, India

VB Kuligod
Professor and Head, Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, Dharwad, Karnataka, India

SS Gundlur
Professor, Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, Dharwad, Karnataka, India

MB Doddamani
Professor, Department of Crop Physiology, University of Agricultural Sciences, Dharwad, Karnataka, India

MP Potdar
Chief Scientist, AICRP on Dryland Agriculture, RARS, Vijayapur, Karnataka, India

Corresponding Author:
Charishma DS
Ph.D. Scholar, Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, Dharwad, Karnataka, India

Comparative analysis of physical and chemical properties and available nutrient status in *Vertisols*, *Ultisols*, and *Alfisols* of northern Karnataka

Charishma DS, VB Kuligod, SS Gundlur, MB Doddamani and MP Potdar

Abstract
This study presents a detailed comparative analysis of *Vertisols*, *Ultisols*, and *Alfisols*, the three dominant soil orders in northern Karnataka, India. Each soil type exhibits distinct physical characteristics within the 0-15 cm depth range. *Vertisols* are fine-textured with high clay content, showcasing higher water-holding capacity. *Ultisols*, conversely, feature coarser texture, lower water-holding capacity, and reduced nutrient availability, likely due to intensified weathering. *Alfisols* exhibits a balance, with well-structured soils with effective root penetration. Physico-chemically, *Vertisols* demonstrate slightly alkaline pH, elevated cation exchange capacity, and substantial base saturation. *Ultisols* showcase a acidic pH range, lower organic carbon content, and decreased nutrient availability, indicative of more intense weathering. *Alfisols* maintain slightly alkaline conditions with intermediate nutrient availability. In terms of available nutrients, *Vertisols* exhibited significant variability in both macro and micronutrients on other hand, *Ultisols* had higher nitrogen content but notable variability in phosphorus and potassium, while *Alfisols* maintain relatively consistent nitrogen levels. These findings highlight the importance of understanding soil variability for informed agricultural practices. Adopting the strategies to the unique attributes of each soil type is essential for optimizing agricultural productivity and ensuring long-term soil health in northern Karnataka. This comparative analysis provides valuable insights for implementing effective soil management practices, ultimately contributing to sustainable agriculture in the region.

Keywords: *Vertisol*, *Ultisol*, *Alfisol*, variability, physical

Introduction
The physical, chemical, morphological properties of soils are vital factors that influence their suitability for various agricultural and non-agricultural utilization. The state of Karnataka shares 5.83 per cent (19.18 m ha) of the country’s geographical area (328.8 m ha). Karnataka being under a semi-arid, arid, and humid tropical monsoon climate, has several soil types and varied topography with diverse climates. Therefore, soils are bound to change spatially and depth-wise. Among the different soil orders, *Vertisols*, *Ultisols*, and *Alfisols* are particularly significant due to their widespread distribution and ecological importance. Understanding their unique properties is crucial for optimizing land use and implementing effective soil management strategies. The soil properties of *Vertisols*, *Ultisols*, and *Alfisols* play crucial roles in determining their fertility, water-holding capacity, and overall suitability for various agricultural practices.

Material and Methods
Study area and site characteristics
Three agricultural sites of northern Karnataka in Belavadi Microwatershed (MWS) (15° 54’ N 74° 48’ E) of Belagavi district, Hotanhalli Microwatershed (MWS) (14° 33’ N 74° 10’ E) of Uttara Kannada district, and Bailmadhpura Microwatershed (MWS) (15°10’ N 75° 35’ E) of Gadag district were chosen for this study (Fig 1). The soils were classified according to Keys to Soil Taxonomy (Soil Survey Staff, 2014) as *Vertisols* in Belavadi MWS, *Ultisols* in Hotanhalli MWS, and *Alfisols* in Bailmadapura MWS region.

Soil sampling and laboratory analysis
Sampling was carried out on selected plots at a grid interval of 320x 320m in 2022 March-May. 30 surface soil samples at a depth (0-15 cm) were collected representing the three locations of *Vertisol*, *Ultisol*, and *Alfisol*. Altogether 90 samples were taken. Samples collected were air-dried, ground, and sieved (≤2 mm) and thoroughly mixed before analysing in the

laboratory, the soil samples were analysed for physical, chemical and fertility parameters using standard analytical procedures outlined by (Jackson, 1979 and Piper, 2002) [5, 6]. Descriptive statistics was done for all the soil properties across the soil types in excel as outlined by (Gomez and Gomez 1984) [4]. The samples were collected in collaboration with WDPD (Watershed Development to Prevent Drought Program) project, Bengaluru, Karnataka. The primary aim of this study is to conduct a comprehensive analysis of the physical, physico-chemical, and available nutrient properties of *Vertisols*, *Ultisols*, and *Alfisols* at the surface level (0-15 cm).

Results and Discussion

Vertisols, *Ultisols*, and *Alfisols*, each present distinctive physical characteristics within the 0-15 cm depth range are presented in table 1. *Vertisols* are predominantly fine-textured, with (20.85%) sand, (17.29%) silt, and a dominant (61.86%) clay content. They exhibit a bulk density of (1.48 Mg m^{-3}), along with remarkable water-holding capacity (46.48%) and substantial pore space (30.61%). The skewness and kurtosis values underscore their unique textural variation, with positively skewed sand, silt, and clay content, indicating sharp distribution peaks. *Vertisols*, rich in clay content and pore space, exhibit high water-holding capacity and structural stability, characteristic of seasonally waterlogged environments.

Ultisols, in contrast, feature notably higher sand content (69.09%), indicating a coarser texture. They exhibit lower silt and clay fractions compared to *Vertisols*, emphasizing their coarse nature. With a bulk density of (1.35 Mg m^{-3}), *Ultisols* are looser in texture, accompanied by lower water-holding capacity (21.60%) and pore space (19.43%). The high CV for clay content (18.65%) highlights significant variability in this component. *Ultisols*, with coarser texture and lower water retention, likely result from intensified weathering processes.

Alfisols exhibited a balance with mean sand content (65.72%), silt content (13.95%), and clay content (20.35%). They possess a moderate bulk density of (1.47 Mg m^{-3}), coupled with a good water-holding capacity (33.58%) and substantial pore space (29.12%). The skewness values, approaching zero for sand, silt, and clay content, indicate a balanced texture. Kurtosis values suggest flatter distributions, emphasizing the well-balanced textural variation. The CV values reveal lower variability in sand, silt, and clay content compared to other soil types, indicating a more consistent composition within *Alfisols*. *Alfisols*, exhibiting a balanced texture, reflect a combination of weathering and paedogenic processes, resulting in well-structured soils with effective root penetration. The observed variability within each soil order is influenced by local factors such as topography, climate, and parent material. (Raja *et al*., 2018) [8].

Physico- chemical properties

The physico-chemical properties of *Vertisols*, *Ultisols*, and *Alfisols* within the 0-15 cm depth range are presented in table 2. *Vertisols* display a pH range of 6.73 to 8.72, with an average pH of 7.99. Electrical conductivity (EC) levels are relatively low, varying from (0.03 to 0.16 dS m^{-1}) suggesting a low concentration of salts in the soil (Pulakeshi *et al*., 2014) [7]. The organic carbon content spans from (1.01 to 10.2 g kg^{-1}) with a mean of 5.70 g kg^{-1}. In terms of exchangeable cations, *Vertisols* show higher concentrations of Ex.Ca, Ex.Mg and Ex.K compared to *Ultisols* and *Alfisols*. The cation exchange capacity (CEC) is relatively high, averaging 45.63 c mol (p+) kg^{-1}. Base saturation is substantial, averaging (86.82%).The data indicates moderate variability with coefficients of variation (CV) ranging from 6.80% (Ex. Na) to 43.79% (CEC). The pH exhibits a slightly negatively skewed distribution, suggesting a tendency towards higher pH values. Kurtosis values indicate distributions generally within normal limits.

Ultisols exhibit a narrower pH range compared to *Vertisols*, ranging from 4.30 to 6.98, with a mean of 5.41. EC values are less to those of *Vertisols*, ranging from 0.03 to 0.20 dS m^{-1}. *Ultisols* have notably lower organic carbon content compared to *Vertisols*, with a mean of 7.10 g kg^{-1}. Exchangeable cation concentrations are significantly lower in *Ultisols*, indicating lower nutrient availability compared to *Vertisols.* CEC and base saturation are also lower, with mean values of 6.73 c mol (p+) kg^{-1} and 36.98 per cent, respectively. The data shows higher variability, particularly in Ex.Mg and Ex.Na, with CVs above 29 per cent. This indicates a greater degree of heterogeneity within *Ultisols.* The kurtosis values suggest distributions with heavier tails, particularly in Ex.Mg and Ex.Na, indicating some degree of non-normality. Skewness values are generally positive, indicating a slight rightward skew in the distributions.

Alfisols showcase a pH range between 7.14 (minimum) and 9.15 (maximum), with a mean pH of 8.11. EC values range from 0.16 dS m^{-1} (minimum) to 0.58 dS m^{-1} (maximum). Organic carbon content in *Alfisols* falls between that of *Vertisols* and *Ultisols*, with a mean of 6.30 g kg^{-1}. Exchangeable cation concentrations are intermediate, indicating moderate nutrient availability. CEC is higher compared to *Ultisols*, with a mean of 11.35 c mol (p+) kg^{-1}, reflecting the higher nutrient-holding capacity of *Alfisols*. Base saturation is also relatively high, averaging at 58.99 per cent. The data shows lower variability compared to *Ultisols*, with CV values generally below 10 per cent. Kurtosis values suggest distributions that are generally within normal limits. However, Ex.Mg and Ex.Na exhibit higher kurtosis, indicating heavier tails. The differences in exchangeable cation concentrations and CEC highlight the nutrient-holding capacities of these soil types. *Vertisols* have the highest nutrient-holding capacity, followed by *Alfisols*, and then *Ultisols*. This reflects the influence of parent material, climate, and vegetation cover on soil development. (Basavaraju *et al*., 2004) [1].

Available nutrient status

Vertisols exhibit a wide range of available nitrogen content, ranging from 42.00 to 182.00 kg ha^{-1}. The mean nitrogen content is 87.03 kg ha^{-1} with coefficient of variation (CV) of 33.31per cent suggests a significant degree of variability in nitrogen levels. Available phosphorus levels in *Vertisols* range from 11.45 to 100.19 kg ha^{-1}, indicating substantial variability. The mean phosphorus content is 51.62 kg ha^{-1}. The high CV of 50.14 per cent indicates that phosphorus levels are not uniformly distributed across *Vertisols*. Available Potassium levels exhibit a broad range from 288.00 to 972.00 kg ha^{-1}, with a mean of 628.00 kg ha^{-1} with CV of 32.80 per cent indicates significant variability. Sulphur content ranges from 8.75 to 36.88 kg ha^{-1}, with a mean of 21.78 kg ha^{-1}. The CV of 26.27 per cent indicates moderate variability. N, P_2O_5, S, Fe, Cu, and B show positive skewness, indicating a rightward skew. N, S, Mn, Cu, and Zn have positive kurtosis, suggesting heavier tails and a sharper peak indicating a more concentrated distribution Micronutrients like Iron (Fe), Manganese (Mn), Copper (Cu), and Zinc (Zn) show substantial variation. This variability may be influenced by factors like soil pH, organic matter content, and redox potential. Factors such as organic matter content, microbial activity, and historical land use practices also affect the nutrient availability in *Vertisols*.

Nitrogen content in *Ultisols* ranges from 105.00 to 224.00 kg ha^{-1}, indicating relatively higher content compared to *Vertisols*. The mean nitrogen content is 157.50 kg ha^{-1}. The moderate CV of 19.80 per cent suggests relatively less variability compared to *Vertisols*. This may be attributed to differences in organic matter decomposition rates and vegetation cover, influencing nitrogen dynamics in *Ultisols*. Available phosphorus levels vary from 11.45 to 65.84 kg ha^{-1}, showcasing substantial variability. The mean phosphorus content is 28.34 kg ha^{-1}. The high CV of 48.14 per cent indicates significant variability. This variability may be influenced by factors such as soil parent material and historical land use practices, necessitating tailored phosphorus management strategies. Available potassium ranges from 38.28 to 685.08 kg ha^{-1}, indicating a wide range of availability within the soil. The mean potassium content is 280.30 kg ha^{-1}. The CV of 68.03 per cent indicates considerable variability. Sulphur content varies from 5.00 to 40.63 kg ha^{-1}, indicating notable differences in sulphur content. The mean sulphur content is 19.88 kg ha^{-1}. The CV of 46.01per cent indicates significant variability. N, P_2O_5, K_2O, S, Fe, Mn, Cu, and Zn exhibit positive skewness, indicating rightward skewness with similar trend as of *Vertisols*. P_2O_5, K_2O, S, Fe, Mn, Cu, and Zn exhibit positive kurtosis, indicating heavier tails and a sharper peak with more concentrated distribution. Micronutrients: (Fe, Mn, Cu and Zn) exhibit substantial variation in *Ultisols.*

Nitrogen content in *Alfisols* ranges from 140.00 to 196.00 kg ha^{-1}, indicating a more consistent nitrogen status compared to the other soil types. The mean nitrogen content is 163.33 kg ha^{-1}. The low CV of 7.72 per cent indicates relatively consistent nitrogen levels within this soil type. This may be attributed to the moderate nutrient-holding capacity and typically good drainage characteristics of *Alfisols*. Available phosphorus levels vary from 8.59 to 37.21 kg ha^{-1}, The mean phosphorus content is 18.42 kg ha^{-1}. The CV of 44.08 per cent indicates moderate variability. Available potassium ranges from 216.96 to 467.76 kg ha^{-1}, indicating a moderate range of availability within the soil. The mean Potassium content is 332.00 kg ha^{-1}. The CV of 15.35per cent indicates a moderate range of variability. Sulphur content varies from 10.63 to 20.00 kg ha^{-1}, indicating relatively stable Sulphur content. The mean Sulphur content is 14.57 kg ha^{-1}. The CV of 18.33 per cent indicates relatively stable sulphur content. N, P_2O_5, K_2O, S, Fe, Mn, Cu, and Zn also show positive skewness, indicating rightward skewness. S and Zn have negative kurtosis, indicating lighter tails and a flatter peak with a broader distribution. Micronutrients: Iron (Fe), Manganese (Mn), Copper (Cu), and Zinc (Zn) also exhibit relatively lower variability compared to *Vertisols* and *Ultisols.* Variability in soil micronutrient levels arises from diverse factors including geological parent material, weathering processes, and biological activity. Soil pH, redox potential, and organic matter content further impact micronutrient availability. Land use history, drainage, and climate also play crucial roles in determining micronutrient availability in soils, emphasizing the complexity of nutrient dynamics. (Rekwar and Ahmed 2022) [9].

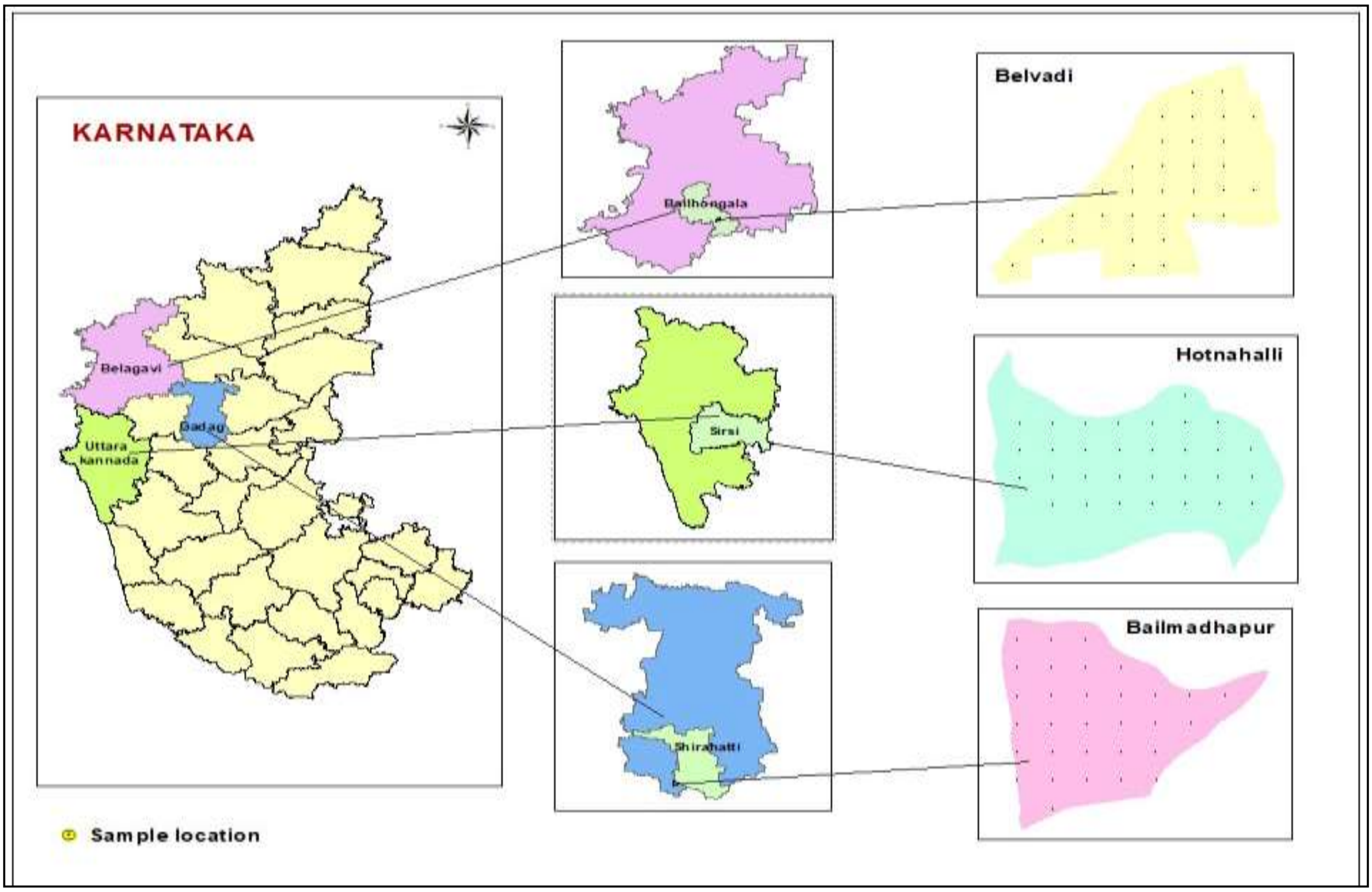

Fig 1: Location of study area

Table 1: Physical properties of *Vertisols, Ultisols* and *Alfisols* (Surface 0-15 cm).

	Sand	Silt	Clay	BD	WHC	Porespace
		(%)		($Mg\ m^{-3}$)	(%)	(%)
Vertisols						
Minimum	26.30	19.60	65.10	1.53	52.40	42.23
Maximum	18.50	14.40	58.10	1.41	41.20	22.80
Mean	20.85	17.29	61.86	1.48	46.48	30.61
S.Em±	0.32	0.25	0.30	0.01	0.48	1.12
Kurtosis	1.74	-0.55	-0.07	0.32	-0.13	-1.19
Skewness	1.22	-0.35	-0.28	-0.21	0.24	0.31
CV(%)	8.49	7.77	2.67	1.90	5.61	20.13
Ultisols						
Minimum	78.31	7.43	33.50	1.44	27.23	29.30
Maximum	61.20	4.98	15.26	1.31	16.23	10.23
Mean	69.09	5.63	25.29	1.35	21.60	19.43
S.Em±	0.84	0.10	0.88	0.01	0.53	0.43
Kurtosis	-0.38	3.15	-0.33	-0.75	-0.61	-0.10
Skewness	0.31	1.63	-0.35	0.72	0.45	-0.32
CV(%)	6.52	9.62	18.65	3.03	13.33	5.02
Alfisols						
Minimum	70.00	17.00	25.80	1.51	48.70	36.80
Maximum	60.00	12.50	17.40	1.42	28.20	22.80
Mean	65.72	13.95	20.35	1.47	33.58	29.12
S.Em±	0.52	0.23	0.41	0.01	1.22	0.89
Kurtosis	-0.80	0.91	0.06	-1.30	0.81	-1.65
Skewness	-0.38	0.98	0.70	-0.05	1.47	0.21
CV(%)	2.80	1.21	2.21	0.03	6.55	4.81

Table 2: Physico -chemical properties of *Vertisols, Ultisols* and *Alfisols* (Surface 0-15 cm).

	pH (1:2.5)	EC (1:2.5)	OC	Ex.Ca	Ex.Mg	Ex.Na	Ex.K	CEC	Base saturation	ESP
		($dS\ m^{-1}$)	($g\ kg^{-1}$)			(c mol (p+) kg^{-1})				(%)
Vertisols										
Minimum	6.73	0.03	10.2	21.47	9.21	2.01	0.16	41.73	85.62	4.09
Maximum	8.72	0.16	1.01	29.40	12.67	3.08	1.32	49.35	87.84	6.81
Mean	7.99	0.08	5.70	25.78	10.88	2.26	0.71	45.63	86.82	4.98
S.Em±	0.07	0.01	0.04	0.38	0.14	0.04	0.06	0.40	0.12	0.11
Kurtosis	2.13	1.40	-0.63	-0.55	0.77	6.60	-0.81	-0.96	-0.93	2.76
Skewness	-1.03	0.79	0.22	-0.07	0.36	2.22	0.18	0.02	-0.13	1.43
CV(%)	10.14	36.88	42.46	8.13	6.80	9.61	43.79	4.77	0.73	12.08
Ultisols										
Minimum	4.30	0.03	0.19	1.12	0.18	0.03	0.04	6.09	30.54	0.44
Maximum	6.98	0.20	1.34	1.83	1.24	1.01	0.43	8.07	47.58	12.52
Mean	5.41	0.08	7.10	1.42	0.80	0.10	0.18	6.73	36.98	1.39
S.Em±	0.12	0.01	0.06	0.03	0.04	0.03	0.01	0.07	0.60	0.39
Kurtosis	-0.38	1.77	-0.48	0.09	0.95	28.17	2.00	5.14	2.89	27.56
Skewness	0.54	1.25	0.33	0.24	-0.32	5.24	0.97	1.44	0.78	5.16
CV(%)	11.09	48.72	42.75	11.84	29.45	76.28	43.63	5.47	8.83	154.02
Alfisols										
Minimum	7.14	0.16	0.38	3.01	1.23	0.09	1.09	10.35	55.07	0.77
Maximum	9.15	0.58	0.88	3.93	1.87	0.64	1.54	11.78	60.53	5.43
Mean	8.11	0.26	6.30	3.67	1.56	0.19	1.27	11.35	58.99	1.71
S.Em±	0.11	0.01	0.02	0.04	0.02	0.02	0.02	0.05	0.21	0.16
Kurtosis	-1.18	11.92	-0.83	2.39	11.26	11.23	0.02	4.70	5.51	9.84
Skewness	0.06	2.85	0.02	-1.66	-0.54	2.84	0.51	-1.79	-2.02	2.63
CV(%)	7.75	29.13	19.75	6.23	5.79	54.69	9.10	2.67	1.95	53.28

Table 3: Available nutrient status of *Vertisols*, *Ultisols* and *Alfisols* (Surface 0-15 cm).

	N	P_2O_5	K_2O	S	Fe	Mn	Cu	Zn	B
Vertisols									
	(kg ha^{-1})				(mg kg^{-1})				
Minimum	42.00	11.45	288.00	8.75	8.20	7.27	1.00	0.27	0.30
Maximum	182.00	100.19	972.00	36.88	20.80	16.80	3.61	1.30	1.00
Mean	87.03	51.62	628.00	21.78	13.25	12.42	1.62	0.62	0.71
S.Em±	5.29	4.73	37.61	1.04	0.60	0.54	0.10	0.05	0.04
Kurtosis	2.66	-1.01	-1.19	1.14	0.18	-1.00	4.99	-0.46	-1.16
Skewness	1.21	0.13	0.27	-0.11	0.82	-0.23	1.88	0.77	-0.11
CV(%)	33.31	50.14	32.80	26.27	24.89	24.01	33.66	45.68	31.24
Ultisols									
Minimum	105.00	11.45	38.28	5.00	17.26	10.82	1.33	0.53	0.20
Maximum	224.00	65.84	685.08	40.63	54.42	28.92	9.13	3.77	0.50
Mean	157.50	28.34	280.30	19.88	35.63	23.74	2.70	1.14	0.29
S.Em±	5.69	2.49	34.81	1.67	1.85	0.84	0.28	0.14	0.02
Kurtosis	-0.14	1.16	-0.82	-0.18	-0.80	1.23	11.27	4.98	-0.17
Skewness	0.63	1.34	0.60	0.29	0.01	-1.24	3.04	2.28	0.77
CV (%)	19.80	48.14	68.03	46.01	28.43	19.32	55.88	66.74	31.82
Alfisols									
Minimum	140.00	8.59	216.96	10.63	3.49	9.29	0.65	0.21	0.10
Maximum	196.00	37.21	467.76	20.00	19.33	27.82	2.50	1.36	0.40
Mean	163.33	18.42	332.00	14.57	9.29	21.51	1.51	0.53	0.21
S.Em±	2.28	1.48	10.27	0.49	0.84	0.87	0.08	0.05	0.02
Kurtosis	0.19	0.06	0.05	-1.13	-0.45	0.35	-0.09	1.86	-0.69
Skewness	0.47	0.77	0.39	0.25	0.72	-0.85	0.22	1.16	0.60
CV (%)	7.72	44.08	15.35	18.33	50.00	22.24	26.68	48.57	48.84

Conclusion
In comparing *Vertisols*, *Ultisols*, and *Alfisols* within the 0-15 cm depth range, distinct physical and physico-chemical characteristics emerge. *Vertisols* are fine-textured with high clay content, exhibiting superior water-holding capacity. *Ultisols* present a coarser texture, lower water-holding capacity, and reduced nutrient availability. *Alfisols* showed a balance with a moderate texture, with well-structured soils. *Vertisols* have a slightly alkaline pH, higher cation exchange capacity, and substantial base saturation. *Ultisols* display a narrower pH range, lower organic carbon content, and decreased nutrient availability. *Alfisols* present moderately alkaline conditions with intermediate nutrient availability. In terms of available nutrients, *Vertisols* demonstrate significant variability, *Ultisols* exhibit higher nitrogen content but notable variability in phosphorus and potassium, while *Alfisols* maintain relatively consistent nitrogen levels.

Acknowledgment
The author is thankful to ‘The Karnataka Science and Technology Promotion Society (KSTEPS), Department of Science and Technology, Govt. of Karnataka with grant no AGR-13:2022-23/981 for providing financial assistance in the form of a stipend during the course of the investigation.

References
1. Basavaraju D, Naidu MVS, Ramavatharam N, Venkaiah K, Ramarao G, Reddy KS. Characterization and evaluation of soils in Chandragiri mandal of Chittoor district, Andhra Pradesh. Agropedology. 2005;15:55-62.
2. Chaudhari PR, Ahire DV, Ahire VD. Correlation between Physico-chemical properties and available nutrients in sandy loam soils of Haridwar. Journal of Chemical Biological and Physical Sciences. 2012;2(3):1493-1500.
3. Gangopadhyay SK, Battacharjee T, Sarkar. Soil resource information for land evaluation: A case study with selected soils from South Tripura district of North- east India. Journal of Indian Society of Soil Science. 2008;56(1):14-23.
4. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. An International Rice Research Institute Book, Wiley- Inter Science Publication, New York, USA, 1984, p. 680.
5. Jackson ML. Soil chemical analysis, Advanced course 2nd edition. University of Wisconsin, Madison, WI, USA; c1979.
6. Piper CS. Soil and Plant Analysis, Han’s publication, Bombay, India. 2002, p. 56-64.
7. Pulakeshi HBP. Patil PL and Dasog GS. Characterization and classification of soil resources derived from chlorite schist in northern transition zone of Karnataka. Karnataka Journal of Agricultural Sciences. 2014;27(1):212-219.
8. Raja P, Bhaskar BP, Surendran U, Rajan K, Sarkar SK, Malpe DB, *et al*. Pedogenesis of spatially associated red and black soils in Purna valley from semi-arid region of central India. Chemical Geology. 2018;48:174-190.
9. Rekwar RK, Ahmed N. Characterization and classification of soils under different land use systems in the upper Brahmaputra valley of Assam. Annals of Plant and Soil Research. 2022;24(1):23-28.