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Variability in Some Physical Properties of Vertisols of Three Permanent Bench Mark Sites under Rice-wheat Cropping System in Jabalpur District, Madhya Pradesh, in India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The study was carried out for vertical characterization of soils at three permanent benchmark sites (Udna, Khamaria and Magarmuha) of Jabalpur district for their physical properties under the Rice-Wheat cropping system. Variability in the proportion of primary soil particles (texture), bulk density, distribution of different sized soil aggregates and mean weight diameter (MWD) of soil aggregates along the depths were studied as these influence the water and nutrients retention and release behaviour of soil. A total of 45 undisturbed soil samples were collected from selected sites at 0-20, 20-40, 40-60, 60-80 and 80-100 cm depths and brought to the laboratory for their characterization and the data thus obtained were analysed in split-plot design taking sites as main plot and depth as sub-plot treatments. Results showed that variability in the sand, silt and clay contents, bulk density, fractions of different size soil aggregate (>5.0, 5.0-2.0, 2.0-1.0, 1.0-0.5,0.5-0.25,0.25-0.1 and <0.10 mm) and mean weight diameter of soil aggregates were significant across the sites and soil depths. However, the interaction effect of sites and soil depth on the above properties was found non-

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significant except for fraction of < 0.1 mm size aggregate. It has been analysed from the study that sand, silt and clay contents, bulk density, fractions of different size aggregate and mean weight diameter of soil aggregates vary significantly (ρ=0.05) at spatially and vertically.

Keywords: Vertisols; permanent benchmark sites; soil aggregates; rice-wheat cropping system; soil depth; texture; bulk density and MWD.

1. INTRODUCTION

Physical properties of soil are equally or even more important than chemical and biological properties in the light of their direct impact on dynamics of nutrients, water and soil biota. Soil physical properties (texture, bulk density, aggregation etc.) are affected by many factors that change vertically, laterally across fields and temporally in response to climate, cultural and human activity [1,2]. Since variability in physical properties directly affects the plant growth, nutrients and water dynamics and other soil processes, in the depth knowledge of vertical changes in soil physical properties are necessary to understand the physical behaviour of soils at spatial scale [3,4]. The physical properties of soil are important since they determine how it can be used either for agricultural and non-agricultural purposes. Different interdependent soil properties, viz. infiltration rate, water-holding capacity, permeability, aeration, plasticity and nutrient-supplying ability, are influenced by the texture, density aggregation etc. of the soils [5]. It is also important to establish and define critical limits of soil properties for adapting appropriate land use and cropping/farming system [6]. To a great extent, soil properties are altered by crops and cropping system because manipulation of soil for crops with contrast edaphic requirement could alter the physical properties of soil. Spatial and vertical variability of soil properties in any field position is inherent due to geologic and pedologic soil-forming factors and physical properties of soil could vary spatially due to anthropogenic activities. Soil properties are interdependent and directly influence the availability of water and nutrients to plants and regulate crop growth and productivity. Given these facts present study was undertaken to vertically characterize the physical properties of soils under rice-wheat cropping system in three permanent benchmark sites (PBMS) of Jabalpur district, Madhya Pradesh in India.

2. MATERIALS AND METHODS

The soils of PBMS of Jabalpur are medium black belonging to Kheri series of fine montmorillonitic hyperthermic family of Typic *Haplustert.* In the study total, 45 undisturbed soil samples were collected from selected sites across three PBMS of Jabalpur district at 0-20, 20-40, 40-60, 60-80 and 80-100 cm depths and brought to the laboratory for their characterization and the data thus obtained were analysed in split-plot design taking sites as main plot and depth as sub-plot treatments. Primary soil particles (sand, silt and clay) in samples were analysed by the Bouyoucos Hydrometer method [7] to characterize the soil texture, while core method was used to determine the bulk density [8]. Proportions of different size (> 5.0, 5.0-2.0, 2.0-1.0, 1.0-0.5, 0.5-0.25, 0.25-0.1 and < 0.10 mm) aggregates in soil samples were determined by wet sieving procedure using Yoder's apparatus [9] and mean weight diameter (MWD) of soil aggregates were computed as an index of aggregation [10] using the equation given below. The data thus obtained were analysed using standard statistical procedure [11]

$$MWD = \Sigma \, W_i X_i \quad (1)$$

Where,

X_i: Arithmetic mean diameter of each size fraction (mm)
W_i: Proportion of the total sample weight occurring in each fraction

3. RESULTS AND DISCUSSION

3.1 Soil Texture

Results of the study revealed that proportions of primary particles (sand, silt and clay) in soils were significantly (ρ=0.05) variable across the sites and depths (Table 1). Further, it was noted that the texture of the soil samples was Clay. It is evident from the data that proportion of sand (36.50%) in soil of Udna, Magarmuha (37.25%) were significantly (p=0.05) higher than that of Khamaria (31.02%), while silt content in soil of Khamaria was statistically at par with Magarmuha but significantly (p=0.05) higher than Udna (19.85%) soil. Whereas, variability in clay content in soils across the three sites was found non-significant with highest (46.91%) and lowest (41.30%) clay contents at Khamaria and Magarmuha sites, respectively. It may be because of elluvisiation of clay particles within the depth and variable management practices responsible for textural alteration across sites of PBMS. Data further indicated that variability in sand, silt and clay contents of soil across the soil depths was significant. It was also noted that proportions of sand and silt were decreased with soil depth, while a progressive non-significant increase in clay content with soil depth was obtained. The findings are well supported by those reported in the literature indicating that clay content increased with depth and across different sites [12,13]. However, the interaction effect of sites and soil depths on variability in proportions of primary soil particles was found non-significant.

3.2 Distribution of Soil Aggregates

Data about variability in the fraction of different size soil aggregates across soil depths (0-20, 0-40, 40-60, 60-80 and 80-100 cm) over three PBMS of Jabalpur district are given in Table 2 and Table 3. It is evident from the data (Table 2) that effect of sites and soil depth on distribution of different size water-stable aggregate (>5.0, 5.0-2.0, 2.0-1.0, 1.0-0.5, 0.5-0.25, 0.25-0.1 and <0.1 mm) was significant (p=0.05) but the interaction effect was found significant only for soil aggregates of size < 0.1 mm. Data further showed that fraction of >1.0 mm size aggregates was highest at Udna (35.2%) followed by Magarmuha and lowest (32.0%) at Khamaria, while the fraction of <1.0 mm size aggregates were highest at Magarmuha (68.1%) followed Khamaria by and lowest (64.9%) at Udna. It was also found that proportion of larger size (>1.0 mm) water-stable aggregates were maximum (49.5%) in 0-20 cm depth followed by 20-40, 40-60, 60-80 and minimum (17.9%) in 80-100 cm depth, whereas smaller size (<1.0 mm) aggregates were highest (82.1%) in 80-100 cm depth and lowest (50.5%) in 0-20 cm depth. Similar kind of findings are also cited in the literature indicated that larger size aggregates were found more in surface (0-15 cm) soil as compared to sub-surface (15-30 cm) soil [14]. The results also revealed that the interaction effect of sites and soil depths on the fraction of < 0.1 mm size water-stable soil aggregate was significant. It might be due to variable cementing agents like organic carbon across the sites and depths. Data indicated that water-stable soil aggregate of size < 0.1 mm in soils of Magarmuha (Mean-12.3%) was significantly (ρ=0.05) higher than Udna and Khamaria sites. While across the depths soil aggregates of size < 0.1 mm were lowest (8.1%) in 0-20 cm that increased significantly (ρ=0.05) with depth and found highest (mean-17.0%) in 80-100 cm depth.

Table 1. Spatial and vertical changes in proportions of primary particles in soils of permanent benchmark sites of Jabalpur district

Main plot (Benchmark sites)	**The proportion of soil particles (%)**			**Textural class**
	Sand	**Silt**	**Clay**	
S_1:Udna	36.50	19.85	43.65	Clayey
S_2:Magarmuhan	37.25	21.45	41.30	Clayey
S_3:Khamariya	31.02	22.07	46.91	Clayey
SEm±	1.775	0.712	1.962	
CD (*p=0.05*)	5.106	2.015	NS	
Sub-plot (Soil depth)				
D1: 0-20 cm	36.47	21.19	42.34	Clayey
D2: 20-40 cm	35.20	21.32	43.47	Clayey
D3: 40-60 cm	34.62	21.13	44.26	Clayey
D4:60-80 cm	34.41	21.03	44.56	Clayey
D5: 80-100 cm	33.93	20.94	45.13	Clayey
SEm ±	0.403	0.347	0.247	
CD (*p=0.05*)	1.150	0.990	0.705	
Main x Sub treatment				
SEm±	0.81	0.81	0.87	
CD (p=0.05)	NS	NS	NS	

CD = Critical difference; P = 0.05; NS = non-significant

Table 2. Spatial and vertical changes in water-stable aggregates of soil at permanent benchmark sites of Jabalpur district

Main plot (Benchmark sites)	Fractions of different size aggregates in soil (%)						
	> 5.0 mm	5.0-2.0 mm	2.0-1.0 mm	1.0-0.5 mm	0.5-0.25 mm	0.25-0.10 mm	< 0.10 mm
S_1:Udna	5.6	11.8	17.8	17.0	14.0	23.2	10.6
S_2:Magarmuhan	5.5	10.7	15.8	17.6	14.3	23.9	12.2
S_3:Khamariya	6.0	11.5	17.4	17.3	13.7	23.2	10.9
SEm ±	0.07	0.21	0.43	0.10	0.13	0.06	0.14
CD (*p=0.05*)	0.18	0.60	1.27	0.29	0.38	0.17	0.40
Sub-plot (Soil depth)							
D1: 0-20 cm	8.2	17.8	23.5	14.6	10.4	17.4	8.1
D2: 20-40 cm	7.3	15.5	19.8	16.4	11.4	20.2	9.3
D3: 40-60 cm	5.6	14.1	17.4	15.9	12.7	23.9	10.5
D4:60-80 cm	4.4	5.5	13.1	21.1	17.4	27.0	11.5
D5: 80-100 cm	2.9	3.7	11.2	18.4	17.9	28.8	17.0
SEm ±	0.14	0.23	0.34	0.31	0.27	0.34	0.23
CD (*p=0.05*)	0.40	0.64	0.96	0.88	0.78	0.96	0.65
Main x Sub treatment	NS	NS	NS	NS	NS	NS	S

S = significant

Table 3. Spatial and vertical variability in the fraction (%) of <0.1 mm size aggregates in soils of permanent benchmark sites of Jabalpur districts

Soil depth (cm) → / Benchmark sites ↓	0-20 cm	20-40 cm	40-60 cm	60-80 cm	80-100 cm	Mean
S_1:Udna	6.8	8.9	9.1	11.1	17.5	10.7
S_2:Magarmuhan	9.5	11.1	11.6	12.8	16.5	12.3
S_3:Khamariya	8.0	8.1	8.8	12.4	16.9	10.8
Mean	8.1	9.3	9.8	12.1	17.0	11.3
Comparison of main plot (Benchmark sites) treatments					SEm ±	0.14
					CD (*p=0.05*)	0.40
Comparison of sub-plot (Soil depth) treatments					SEm ±	0.23
					CD (*p=0.05*)	0.65
Comparison of main plots at the same level of sub-plot treatments					SEm ±	0.37
					CD (*p=0.05*)	1.12
Comparison of sub-plot plot at the same or different levels of main treatments					SEm ±	0.41
					CD (*p=0.05*)	1.16

Table 4. Spatial and vertical variability in mean weight diameter and bulk density of soil at permanent benchmark sites of Jabalpur districts

Main plot (Benchmark sites)	MWD (mm)	Bulk density (Mg m^{-3})
S_1:Udna	1.14	1.40
S_2:Magarmuhan	1.06	1.42
S_3:Khamariya	1.14	1.36
SEm±	0.011	0.005
CD(*p=0.05*)	0.032	0.014
Sub-plot (Soil depth)		
D1: 0-20 cm	1.57	1.35
D2: 20-40 cm	1.38	1.38
D3: 40-60 cm	1.21	1.39
D4:60-80 cm	0.78	1.41
D5: 80-100 cm	0.61	1.43
SEm ±	0.107	0.004
CD(*p=0.05*)	0.307	0.011
Main x Sub treatment	NS	NS

MWD= mean weight diameter

3.3 Bulk Density

Data about variability in bulk density of soil under rice-wheat cropping system as affected by sites and depths are presented in Table 4. Data clearly showed that bulk density o soils varied significantly (ρ=0.05) across sites and soil depths but the interaction effect was found non-significant. Data further indicated that bulk density soil across different sites varied from 1.36 to 1.42 Mg m^{-3} with the highest value at Magarmuha and lowest at Khamaria. Whereas, over the depth, it varied from 1.35 to 1.43 Mg m^{-3} with the minimum value in 0-20 cm that increased with depth up to 100 cm. It might be because of variation in sand content with sites and depths as obtained in the present study. Similar findings showing an increased bulk density with depth and sites have been reported which were attributed to variable compaction, organic carbon and aggregation [15].

3.4 Mean Weight Diameter (MWD) of Soil Aggregates

Data presented in Table 4 indicated that MWD of water-stable aggregates in the soil of Magarmuha (1.06 mm) was significantly (ρ=0.05) lower than those at Udna and Khamaria sites which may be attributed to lower organic carbon and poor aggregation. Data also revealed that the mean weight diameter of soil aggregates was significantly (ρ=0.05) affected by soil depths with highest (1.57 mm) in 0-20 cm and lowest (0.61 mm) in 80-100 cm depth. Interaction effect of sites and soil depth on MWD of soil aggregate was statistically non-significant. MWD is a cumulative effect of the distribution of the different size of soil aggregates, hence variability in the proportion of aggregates may be the basic cause for change in MWD across te sites and depths. Higher MWD of soil aggregates in surface soils as compared to sub-surface soil have been reported which were attributed to a higher proportion of smaller aggregates in lower depth [16].

4. CONCLUSION

The present study concludes that physical properties of soil like texture (proportions of sand, silt and clay) bulk density, proportions of different size aggregates and mean weight diameter of soil aggregates in Vertisols under rice-wheat cropping system could vary significantly (ρ=0.05) at vertical and spatial levels. Therefore, greater attention to understanding these physical properties of Vertisols under rice-wheat cropping system is needed for potential agronomic management practices to enhance the inputs use efficiency.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Macedo SD, Grimaldi M, Medina CC, Cunha JE, Guimaraes MDF, Tavares FJ. Physical properties of soil structures identified by the profile cultural under two soil management systems. Rev Bras Cienc Solo. 2017;41.
2. Suryawanshi A, Rai HK, Mitra NG, Upadhyay SD. Studies on physico-chemical properties of a Vertisol as influenced by land use practices. International Journal of Chemical Studies. 2018;6(2):450-453.
3. Chouhan B, Rai HK, Suryawanshi A. Mandloi S, Pandey R. Characterization of physical properties of a vertisol under long-term fertilizer experiment in soybean-wheat cropping system. Journal of Pharm-acognosy and Phytochemistry. 2018;7(2): 596-601.
4. Wang, ZM, Song KS, Zhang. Spatial variability and affecting factors of soil nutrients in croplands of northeast China. Plant, Soil and Environment. 2009; 55(3):110–120.
5. Rai HK, Sharma A, Sindhu J. Das DK, Kalra N. Pedo-transfer functions for assessing soil moisture constants and nitrogen availability in Indian soils. SAARC J. of Agriculture. 2003;127-140.
6. Lal R, Steward BA. Research and development priorities for soil restoration. Advances in Soil Science. 17th ed. Springer-Verlag New York; 1992.
7. Bouyoucos GJ. The hydrometer as a new method for the mechanical analysis of soils. Soil Science. 1927;23:343-353.

8. Richards LA. Diagnosis and improvement of saline and alkali soils. USDA Agric. Handbook 60. Washington, D. C; 1954.
9. Yoder RE. A direct method of aggregate analysis of soils and a study of the physical nature of soil erosion J. Am. Soc. Agron. 1936;28:337-351.
10. Kemper WD, Rosenau RC. Physical and Mineralogical Methods, 2nd edition, American Society of Agronomy, Madison, WI; 1986.
11. Gomez AA, Gomez KA. Statistical procedures for agricultural research. 2nd edition. John wiley and sons, New York; 2018.
12. Giday O, Gibrekidan H, Berhe T. Soil fertility characterization in vertisols of Southern Tigray, Ethiopia. Advances in Plants and Agriculture Research. 2015; 2(1):00-34.
13. Tripathi PN, Mishra US, Tiwari RK, Sirothia P, Dwivedi BS, Pandey R, Singh M. Characterization and classification of some typical soils of village Madava, district Shahdol, Madhya Pradesh. International Journal of Agriculture sciences. 2018; 10(14):6657-6659.
14. Suman J, Dwivedi BS, Dwivedi AK, Pandey SK. Forms of sulphur and their relationship with soil physical properties in Vertisol. International Journal of Chemical Studies. 2018;6(1):975-980.
15. Leelavathi GP, Naidu MVS, Ramavatharam N, Karuna Sagar G. Studies on genesis, classification and evaluation of soils for sustainable land use planning in Yerpedu Mandal of Chittoor district, Andhra Pradesh. J. Indian Soc. Soil Sci. 2009;57(2):109-120.
16. Suryawanshi A, Rai HK, Mitra NG, Upadhyay SD. Appraisal of changes in bulk density and nitrogen content of a Vertisol as affected by land use practices and depth. Journal of Pharmacognosy and Phytochemistry. 2018;7(2):2080-2083.

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