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Research Article

Vertical Distribution of Physico-Chemical Properties under Different Topo-sequence in Soils of Jharkhand

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ABSTRACT

Vertical distribution of physico-chemical properties and their inter-relationship were studied in twenty seven profile representing three profiles from each topo-sequence (up, medium and low land) of three agro-climatic zones of Jharkhand *viz.,* (i) central and north-eastern plateau i.e. zone-IV, (ii) western plateau i.e. zone-V and (iii) south eastern plateau i.e. zone-VI. The soil samples were analysed for various physico-chemical properties *viz*., organic carbon, pH, EC, $CaCO_3$, CEC, clay and silt content, using standard laboratory procedures. Analysis of soil pH, organic carbon and calcium carbonate revealed that soil pH and $CaCO_3$ increased with increasing soil depth of profiles. On contrary, organic carbon of the soils declined with increasing depth. Higher values of CEC in sub-surface horizons commensurate with the amount of clay. Variation of soil pH and EC was less in lowland and upland profiles, respectively whereas in case of $CaCO_3$, upland profiles show maximum variations. Correlation matrix indicated that soil pH were significantly correlated with $CaCO_3$ (r=0.72**) and organic carbon (r= -0.38**). Clay were positively and significantly correlated with CEC (r= 0.64**) and EC (r= 0.50**). Calcium Carbonate were significantly correlated EC(r= 0.35**) and organic carbon (r= -0.44**).

Key words: Vertical, Topo-sequence, Physico-chemical properties, Jharkhand

Introduction

Land degradation refers to a decline in the overall quality of soil, water or vegetation condition commonly caused by human activities. The livelihoods of people are now directly and adversely affected by land degradation. Unless the current rate of land degradation is slowed and reversed, the food security will be threatened and the ability of country to increase their wealth through improved productivity will be impeded. Land degradation is observed in all agro-climatic regions on all continents. It is estimated that out of the 328 m ha of the total geographical area in India, 173.65 m ha are degraded, producing less than 20% of its potential capacity (GOI, 1990) and out of this 89.52 m ha suffers from one or the other form of physical constraints *viz*., shallow depth, soil hardening, slow and high permeability, sub-surface compacted layer, surface crusting, temporary water logging etc. (Painuli and Yadav, 1998).

Maintaining soil health/quality is indispensable for sustaining the agricultural productivity at higher level. Soil quality includes three groups of mutually interactive attributes i.e. soil physical, chemical and biological quality, which must be restored at its optimum to sustain

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productivity. Russell (1975) expressed that yields were limited by the physical conditions of the soils rather than their nutrient status in certain situations. Hillel (1980) further stated that suitability of soil as a medium of plant growth depends on both its chemical and physical fertility. The adverse physical soil environment limits root growth and its activity and results in reduced nutrient absorption and growth of plants (Drew, 1978; Chaudhary and Sandhu, 1983 and Peterson *et al.*, 1984). The nature and extent of physical constraints are however, not static. The current scenario calls for appreciating the fact that once degraded, it is difficult to restore the soil to its good physical condition. Persistent efforts are required to arrest further aggravation of soil degradation, to alleviate soil physical constraints and also to understand the respective causal processes for the sake of holistic, safe and resilient agricultural production system.

Jharkhand state is popularly known for its coal mines, industries and metalliferous ores and having three agro-climatic zones *viz*., central and north-eastern plateau, western plateau and south eastern plateau. The Soils have been classified under the major soil orders of Entisol, Inceptisol and Alfisol. In the rapid pace of development we have inflicted serious damage to the natural resources and have given rise to a process of serious thinking to safeguard the environment and the quality of natural resources for sustainability. The present investigation was carried out on soils of different agro-climatic zones of the state with a view to study the depth-wise distribution of physico-chemical properties under different topo-sequence in soils of Jharkhand.

Material and Methods

Study of soil profile: Three soil profile from each topo-sequence of three ago-climatic zones *viz.* zone (iv) i.e. central and north-eastern plateau (Baliapur), zone (v) i.e. western plateau (Bagru) and zone (vi) south eastern plateau (Moshabani) were examined. Soil taxonomy of pedons collected from Baliapur, Bagru and Mosabani were Fine, mixed, hyperthermic Aeric Endoaqualfs (order: Alfisol), Fine loamy, mixed, hyperthermic Typic Haplustepts (order: Inceptisol) and Fine loamy, mixed, hyperthermic Typic Plinthustalfs (order: Alfisol) respectively. After spot studying of some morphological characters, soil samples were collected from different depth intervals and also on the basis of diagnostic horizons.

Geology and Soils: Baliapur (zone-IV) were geologically comprised with Archean granites and gneisses. Gondwana rock formation occurs in patches.

Bagru (zone-V) were geologically comprised with Archean granites and gneisses. In the uplands considerable thickness of laterite of Pleistocene age was found in the granite in the Granite and Gneisses tracts. Alluvium of the recent to sub-recent age was found in the river valley. The most important mineral was bauxite. Other minerals were feldspar, fire clay and china clay and had less economic importance.

Mosabani (zone-VI) were geologically comprised with granites gneiss and schist. Formations of igneous, sedimentary and metamorphic rocks of Dharwarian period were found at places. Due to varied landscape, the coverage of forest was found in different proportion in different areas. Plain areas were quite productive for agriculture.

Analysis of soil samples: The soil samples were collected according to the method described by Jackson (1973). For knowing the various physico-chemicals properties, the soil samples were analysed with standard laboratory procedures. Mechanical analysis was done by the international pipette method as described by Piper (1966) and the textural class was found out from textural triangle. Soil – water suspension of 1:2.5 were used for soil reaction (pH) with a pH meter as described by Jackson (1973) and its clear supernatant solution used in electrical conductivity (EC) determination by EC meter (Chopra and Kanwar, 1982). Organic carbon was determined by Walkley and Black's (1934) chromic acid digestion rapid titration method following the procedure outlined by Jackson (1958). By leaching the soil with neutral normal ammonium acetate solution, cation exchange capacity (CEC) was determined as described by Jackson (1967). Calcium carbonate ($CaCO_3$) was determined by Piper's (1942) rapid titration method.

Results and Discussion

Soil physical and chemical properties are complex, often non-linearly related, and spatially and temporally dynamic. Vertical distribution of physico-chemical properties in different horizons of soil profiles influence the inherent capacity of soil to supply nutrients to plants (Singh *et al.* 1989). The relative mobility and availability of nutrients in the soils is primarily restricted to surface horizon.

Soil reaction: The data recorded (Table 1) of upland pedons of Baliapur (zone-IV), Bagru (zone-V) and Mosabani (zone-VI) revealed an increasing trends of soil pH with increasing depth which varied from 4.8 to 6.8, 5.3 to 6.25 and 4.74 to 5.86, respectively while in midland pedons (Table 2), pH increased from 4.4 to 7.25, 5.0 to 5.4 and 4.34 to 5.7 with increasing depth intervals, respectively. Similarly in lowland pedons (Table 3), pH increased from 6.8 to 7.6, 5.4 to 6.0 and 5.0 to 6.3 with depth intervals of zone IV (Baliapur), V(Bagru) and VI (Mosabani), respectively. Soil pH of sub-surface horizons was found to have higher pH values than surface horizons in all topo-sequence. Similar results were obtained by Kaistha and Gupta (1994). Leaching of bases under high rainfall conditions might be

Table 1. Physico-chemical properties in upland soil profiles under different agro-climatic zones of Jharkhand

Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	OC (g kg^{-1})	$CaCO_3$ (%)	CEC $cmol(p^+)kg^{-1}$	Clay (%)	Sand (%)	Silt (%)	Texture
A. Central and north-eastern plateau (zone IV)									
0-20	4.80	0.50	3.40	0.3	5.12	13.44	73.28	13.28	SL
20-40	5.50	0.25	1.20	0.45	4.90	9.44	75.28	15.28	SL
40-57	5.60	0.34	0.80	0.6	7.20	15.44	69.28	15.28	SL
57-87	5.80	0.49	0.80	0.7	10.39	25.44	52.28	22.28	SCL
87-117	6.60	0.40	0.30	0.8	8.15	17.44	57.28	25.28	SL
117+	6.80	0.32	0.50	0.81	7.90	15.44	59.28	25.28	SL
B. Western plateau (zone V)									
0-14	5.30	0.34	2.00	0.50	5.50	15.72	70.00	14.28	SL
14-47	6.24	0.37	1.40	0.70	5.90	10.72	72.00	17.28	SL
47-67	6.29	0.44	0.60	0.75	6.50	12.72	67.00	20.28	SL
67-93	6.30	0.42	0.08	0.80	5.50	14.72	75.00	10.28	LS
93-121	5.58	0.47	0.05	0.60	6.40	12.72	71.00	16.28	SL
121-165+	6.25	0.51	0.05	0.71	5.10	6.72	79.00	14.28	LS
C. South-eastern plateau (zone VI)									
0-20	4.74	0.57	3.40	0.61	7.90	14.44	65.28	20.28	SL
20-45	6.70	0.80	1.12	0.90	7.80	13.44	49.28	37.28	L
45-80	5.78	1.22	0.80	0.75	10.80	21.44	39.28	39.28	L
80-126	5.79	1.41	0.80	0.80	11.43	27.44	34.28	38.28	CL
126-144	5.61	1.17	0.80	0.58	10.90	19.44	43.28	37.28	L
144+	5.86	1.40	0.60	0.82	8.29	19.44	51.28	29.28	SL

SL- Sandy loam, SCL- Sandy clay loam, LS- Loamy sand, L-Loamy

Table 2. Physico-chemical properties in midland soil profiles under different agro-climatic zones of Jharkhand

Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	OC ($g\ kg^{-1}$)	$CaCO_3$ (%)	CEC $cmol(p^+)kg^{-1}$	Clay (%)	Sand (%)	Silt (%)	Texture
A. Central and north-eastern plateau (zone IV)									
0-15	4.40	0.49	4.70	0.4	5.32	19.72	66.72	13.56	SL
15-30	5.90	0.36	1.70	0.7	5.21	15.72	66.72	17.56	SL
30-50	6.20	0.38	0.30	0.72	7.70	20.72	67.72	11.56	SCL
50-65	6.30	0.48	0.80	0.75	5.10	8.72	76.72	14.56	SL
65-95	7.20	1.00	0.30	0.8	6.20	12.72	72.72	14.56	SL
95+	7.25	0.90	0.20	0.81	7.20	16.72	66.72	16.56	SL
B. Western plateau (zone V)									
0-13	5.00	0.32	2.10	0.40	5.82	15.00	52.70	32.30	SL
13-34	5.30	0.28	1.50	0.45	6.10	18.00	46.00	36.00	L
34-58	5.30	0.51	0.70	0.48	9.95	29.00	35.00	36.00	CL
58-121	5.90	0.51	0.50	0.70	9.96	31.00	32.00	37.00	CL
121-175	5.40	0.66	0.20	0.50	9.50	26.00	45.00	29.00	L
C. South-eastern plateau (zone VI)									
0-18	4.34	2.29	5.90	0.58	5.50	32.44	39.56	28.00	CL
18-48	6.20	1.00	2.10	0.85	6.20	31.44	34.56	34.00	CL
48-73	5.90	1.23	1.20	0.83	10.70	30.44	29.56	40.00	CL
73-98	7.30	1.51	0.80	0.91	9.78	28.44	33.56	38.00	CL
98-139	6.30	1.60	0.90	0.88	8.39	2]8.44	34.56	37.00	CL
139-174	5.70	1.13	0.50	0.74	7.36	21.44	41.28	37.28	L

SL- Sandy loam, SCL- Sandy clay loam, CL- Clay loam, L-Loamy

the primary reason for acidic soil reactions. Increase in soil pH in deeper horizons indicates accumulation of bases. Lowland profiles show very low range of variation as compared to upland and midland.

Electrical conductivity: Electrical conductivity has generally been associated with determining soil salinity; however, EC also can serve as a measure of soluble nutrients (Smith and Doran, 1996) for both cations and anions and is useful in monitoring the mineralization of organic matter in soil (De Neve et al., 2000). EC of upland pedons of Baliapur (zone IV), Bagru (zone V) and Mosabani (zone VI) varied from 0.32 to 0.50, 0.34 to 0.51 and 0.57 to 1.40 dSm^{-1}; in midland pedons 0.49 to 1.00, 0.32 to 0.66 and 1.60 to 2.29 dSm^{-1} while in lowland pedons, 0.60 to 1.49, 0.30 to 0.60 and 0.71 to 1.27 dSm^{-1} vary, respectively (Tables 1,2,3). Electrical conductivity varies with depth and its range of variation was less in upland profile, probably occurred due to slope of land surface, high permeability and high rainfall, responsible to leach out alkali and alkaline bases. Similar results were found by Dutta and Ram (1993).

Organic carbon: Organic carbon of upland pedons of Baliapur (zone-IV), Bagru (zone-V) and Mosabani (zone-VI) varied from 3.4 to 0.5, 2 to 0.05 and 3.4 to 0.6 gkg^{-1}, in midland pedons 4.7 to 0.2, 2.1 to 0.2 and 5.9 to 0.5 gkg^{-1} and similarly in lowland pedons 7.4 to 0.2, 5.3 to 0.1 and 5.0 to 0.1 gkg^{-1}, respectively. Organic carbon decreases with depth in soil profiles and results were matched with the findings of Tripathi *et al.* (1994) and Kumar *et al*. (2002). Soil texture has a strong influence on soils' ability to store and

Table 3. Physico-chemical properties in lowland soil profiles under different agro-climatic zones of Jharkhand

Depth (cm)	pH (1:2.5)	EC (dSm^{-1})	OC ($g\ kg^{-1}$)	$CaCO_3$ (%)	CEC $cmol(p^+)kg^{-1}$	Clay (%)	Sand (%)	Silt (%)	Texture
A. Central and north-eastern plateau (zone IV)									
0-15	6.80	1.49	7.40	0.60	5.60	26.44	51.56	22.00	SCL
15-30	7.60	1.02	2.60	0.88	9.60	17.44	52.56	30.00	SL
30-45	7.50	1.10	0.90	0.84	4.41	15.44	68.56	16.00	SL
45-75	7.60	0.70	0.20	0.88	3.60	5.44	92.56	2.00	S
75-100	6.84	0.55	0.20	0.70	2.67	5.44	92.56	2.00	S
100+	6.90	0.60	0.20	0.75	3.29	5.44	85.56	9.00	LS
B. Western plateau (zone V)									
0-20	5.40	0.30	5.30	0.45	5.64	19.44	60.28	20.28	SL
20-46	5.50	0.40	3.10	0.50	6.50	18.44	51.28	30.28	SL
46-75	5.60	0.53	0.50	0.55	8.10	20.44	47.28	32.28	L
75-121	5.90	0.55	0.20	0.70	9.00	26.44	36.28	37.28	L
121-153+	6.00	0.60	0.10	0.80	9.12	25.44	35.28	39.28	L
C. South-eastern plateau (zone VI)									
0-15	5.20	1.27	5.00	0.70	6.80	24.44	50.28	25.28	SCL
15-35	5.00	0.63	1.60	0.59	6.20	11.44	74.28	14.28	SL
35-60	5.66	0.53	0.80	0.73	6.21	11.44	67.28	21.28	SL
60-93	6.30	0.45	0.70	0.87	5.80	7.44	79.28	13.28	SL
93-133	5.20	0.55	0.80	0.71	7.37	11.44	65.28	23.28	SL
133-158	5.80	0.69	0.80	0.85	8.01	17.44	58.56	24.00	SL
158+	5.70	0.71	0.10	0.74	7.70	9.44	77.28	13.28	SL

SL- Sandy loam, SCL- Sandy clay loam, LS- Loamy sand, L-Loamy, S- Sandy

accrue soil organic carbon (Gili *et al*., 2010) but its distribution reflects a combination of soil physical properties, biomass inputs as well as decomposition rates which are a function of climatic conditions (Angers and Eriksen-Hamel, 2008).

Calcium carbonate: Calcium carbonate of upland pedons of Baliapur (zone-IV), Bagru (zone-V) and Mosabani (zone-VI) increased from 0.3 to 0.81, 0.5 to 0.71 and 0.61 to 0.82 %; in midland pedons 0.4 to 0.81, 0.4 to 0.7 and 0.58 to 0.91 % and in lowland pedons 0.6 to 0.88, 0.45 to 0.8 and 0.7 to 0.87 %, respectively. Higher amount of calcium carbonate was assigned with depth, which was indicated by the process of leaching of calcium and subsequently precipitated as carbonate at a lower depth. Similar results were also registered by Gupta *et al.* (2003). Leaching of $CaCO_3$ might be due to high permeability and high rainfall. Due to soluble nature of $CaCO_3$, variation of its amount in profile was more in upland in comparison to midland and lowland.

Cation exchange capacity: Cation exchange capacity of upland pedons of Baliapur (zone-IV), Bagru (zone-V) and Mosabani (zone-VI) varied from 5.12 to 10.39, 5.5 to 6.5 and 7.9 to 11.43 $Cmol(P^+)kg^{-1}$; in midland pedons 5.32 to 7.77, 5.82 to 9.96 and 5.5 to 10.7 $Cmol(P^+)kg^{-1}$ and similarly in lowland pedons 2.67 to 9.6, 5.64 to 9.12 and 6.8 to 8.01 $Cmol(P^+)kg^{-1}$, respectively. Higher values of CEC in sub-surface horizons correspond with the amount of clay. The CEC in these soils might be attributed to clay content as the organic carbon content was very low in lower layers. Similar results were observed by Sahu and Mishra (1994).

Table 4. Correlation coefficient (r) between physico-chemical properties of soil profile

	pH	EC	OC	$CaCO_3$	CEC	Clay	Sand
EC	0.11	1					
OC	-0.38**	0.30	1				
$CaCO_3$	0.72**	0.35**	-0.44**	1			
CEC	-0.08	0.28*	-0.21	0.20	1		
Clay	-0.23	0.50**	0.29*	-0.04	0.64**	1	
Sand	0.19	-0.48**	-0.13	-0.06	-0.76**	-0.90**	1
Silt	-0.16	0.40**	0.01	0.09	0.76**	0.73**	0.95**

*Significant at 5% level of significance

**Significant at 1% level of significance

Relationship among physico-chemical properties: Inter-correlation studies between physic-chemical properties (Table 4) revealed that soil pH were significantly correlated with $CaCO_3$ (r=0.72**) and organic carbon (r=-0.38**). Electrical conductivity were positively and significantly correlated with $CaCO_3$ (r=0.35**) and clay (r=0.50**). Organic carbon and $CaCO_3$ were positively and significantly correlated (r=0.44**). CEC was positively and significantly correlated with clay (r=0.64**).

Conclusions

Thus profile study showed an increase of soil pH and $CaCO_3$ with increasing depth of profiles. On contrary, organic carbon of the soils declined with increasing depth. Higher values of CEC in sub-surface horizons commensurate with the amount of clay. Correlation matrix indicated that soil pH were significantly correlated with $CaCO_3$ (r=0.72**) and organic carbon (r=-0.38**). Clay were positively and significantly correlated with CEC (r= 0.64**) and EC (r=0.50**). $CaCO_3$ were significantly correlated EC(r= 0.36**) and Organic carbon (r=-0.44**). Lowland profiles show very low range of variation of soil pH as compared to upland and midland whereas upland profiles show more variation of $CaCO_3$ and less variation of electrical conductivity.

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