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ASSESSING VERTICAL HETEROGENEITY OF SOIL PROPERTIES AND NUTRIENT AVAILABILITY IN TWO DISTINCT LANDFORMS OF DHENKANAL DISTRICT, ODISHA, INDIA

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ABSTRACT

An inventory work was carried out to evaluate the vertical distribution of available plant nutrients status at the Odapada block of Dhenkanal district located in the Mid-Central Tableland Agro-climatic Zone of Odisha. In this context, two pedons situated in two different land types (upland and lowland) were selected for studying the depth-wise vertical distribution of plant nutrients. Genetic horizon-wise soil samples were collected, processed and analyzed for different soil properties viz. textural class, bulk density, pH, electrical conductivity (EC), soil organic carbon (SOC), available nitrogen (N), phosphorus (P), potassium (K), sulphur (S), and boron (B) contents. The results indicated that there was a gradual decrease in the concentration of SOC, available N, P and K with soil depth. Whereas soil reaction (pH) and EC content increased with soil depth. Therefore, surface soils were observed to be more fertile but slightly acidic, whereas the sub-soils were of higher pH and less available nutrients. The soluble S content in all the horizons was below the critical limit (<10 mg/kg) for crop production. The soluble boron content of the surface horizon of both the pedons was above the critical limit (> 0.5 mg/kg) for crop production. Since the concentration of all the available nutrients decreased in the subsoils, 25% more than the recommended doses are recommended for growing deep-rooted crops. The findings of this study will be helpful for the scientific as well as the farming community for up taking suitable crop and land use plans for sustainable agricultural and land use management.
***Keywords*:** Catena, pedon, available nutrients, soil fertility, soil depth, land use planning, Odapada, Dhenkanal

Introduction

Soil varies from one area to another and from one horizon of a soil profile to another. Systematic description of soil characteristics holds great relevance in terms of understanding factors and processes of soil formation and grouping similar soils for mapping their extents. (Dash *et al*., 2019a, Kishore *et al*., 2020). The five factors of soil formation are climate, organisms, topography, parent material and time (Milne, 1935, Jenny, 1941), out of which, the topography is a vital cause of variation at local extents (Dash *et al*., 2022a). Toposequence or catena is a term given by Milne (1935), which refers to the variations observed due to variations in topography or relief, with all other factors of soil formation remaining the same. Vertical nutrient distributions are dominated by plant cycling relative to leaching, weathering dissolution and atmospheric deposition leading to nutrients concentrating in topsoil (Jobbagy and Jackson, 2001).

Knowing of vertical distribution of plant nutrients in the soil is very important for nutrient management and achieving sustainable crop yields. This is because the roots of most crops extend beyond the surface layer and extract a significant portion of their nutrient requirements from the subsurface layers of the soil. Without the careful use of macro and micronutrient fertilizers, crop production can't be increased further. Therefore, it is crucial to have a thorough understanding of the vertical distribution of plant nutrients in the soil to recommend the right fertilizer schedule for various crops and ensure maximum production. Nevertheless, the availability and distribution of plant nutrients both in surface soils and subsurface soils are significantly impacted by topography variations (Dorji *et al.*, 2014).

Land use planning can be done based on the physio-chemical properties and nutrient status of different horizons of soil profiles. The variability in nutrient status in the vertical distribution of soil profile has a long-term impact on the production and productivity of field crops, vegetables, orchard plantations, and agroforestry. In the recent past, several workers have studied the surface nutrient status (Dash *et al.*, 2018; Digal *et al.*, 2018; Lokya *et al.*, 2020; Sethy *et al.*, 2019; Singh *et al.*, 2021; Swain *et al.*, 2019) as well as the horizon-wise status of plant physico-chemical properties in soil profiles of different soil series of Odisha (Dash *et al.*, 2019a, Dash *et al.*, 2019b, 2022a,2022b). However, study on soil profile characteristics of soil nutrients is limited to only a very few studies (Mishra *et al.*, 2015; Dash *et al.*, 2019c; Kishore *et al.*, 2022; Pattnaik *et al.*, 2023). In this context, the present investigation studies the vertical distribution of available plant nutrients in two pedons located in two different land types of Odapada block of Dhenkanal district, Odisha, India located in the Mid-Central Tableland Agro-climatic Zone of Odisha.

Materials and Methods

Study Area

The study area is Odapada village of Odapada block of Dhenkanal district, Odisha located between 20°29"N to 21°11"N latitudes and 85° 58' E to 86°20"E longitudes. The study area comes under the Mid Central Tableland Agro-climatic Zone of Odisha.

Climate

The climatic condition of the study area is hot and dry sub-humid with a mean rainfall of 1421 mm per annum. The climate is generally hot with high humidity during April and May and cold during December and January. The monsoon generally onsets in June. The mean summer temperature is 38.7°C and the mean winter temperature is 14°C. The major crops of the area are paddy, groundnut, sesamum, green gram, horse gram, sugarcane, vegetables and fruits.

Soils

The region mainly consists of red and laterite soils although patches of yellow soils are also found in some parts. The red colour of the soil is primarily due to the high iron oxide content. The laterite soil has been formed by the process of lateralization because of the intense leaching of basic cations during heavy rainfall and alternate wetting-drying conditions. The alluvial soils are products of the pedogenic process of sediment deposition mostly by the river Bramhani and its tributaries. Paddy is cultivated in the *Kharif* season followed by pulses and vegetables in the *Rabi* season. The area has deciduous natural forests and grasses.

Soil sampling and analysis

Two soil profiles of approximately 1m x 1m x 1.5m dimension were exposed at two different land types (upland and lowland) of Odapada block in Dhenkanal district. Soil samples from different genetic horizons were collected using a spade during the summer season. The textural class analysis was carried out by the Bouyoucus Hydrometer method (Piper, 1950). Soil pH (1:2 w/v soil and water suspension) was determined using a glass electrode digital pH meter. Electrical conductivity (EC; 1:2 w/v soil and water suspension) was determined by an EC meter. Soil organic carbon (SOC) was determined by Walkley and Black's rapid titration method (Walkley and Black, 1934). Available nitrogen (N) was determined using the alkaline potassium permanganate method (Subbiah and Asija, 1956). Available phosphorous (P) was determined by Olsen's method (Olsen *et al.*, 1954). Available potassium (K) was determined by the neutral normal ammonium acetate extraction method using a digital flame photometer (Page *et al.*, 1982). Available boron was estimated by the hot water extraction method (John *et al.*, 1975) and available sulphur was estimated by the $CaCl_2$ turbidometric method (Chesnin and Yien, 1950).

Results and Discussion

Physical properties

Physico-chemical properties of the two pedons have been presented in Tables 1 and 2. The textural class of the soils of the two pedons varied from loam to sandy loam. The sand fraction varied from 69.4 to 78.2

per cent. The sand per cent along the depth was quite irregular or zig-zag in pedon 1. The sand fraction varied from 67.2 to 81.8 per cent and dominated the mechanical composition. However, the sand per cent gradually decreased with the soil depth in pedon 2. Contrastingly, an increasing trend of clay fractions with soil depth was noted in both pedons owing to the process of illuviation (Sharma *et al.*, 2013a). An increasing trend of silt fraction with soil depth was noted in pedon 2 while in pedon 1 it was quite irregular.

In pedon 1, the percentage of sand, silt and clay ranged from 69.4 to 78.2, 3.8 to 13.2, and 13.6 to 25.8% respectively in different horizons. The clay content, which was 15.6 per cent in the depth zone of 10-20 cm increased along the depth and reached a maximum of 25.8 per cent at the depth zone of 160-180 cm (Table 1). In pedon 2, the percentage of sand, silt and clay ranged from 67.2 to 81.8, 6.0 to 14.6, and 10.2 to 19.6 %, respectively in different horizons. The clay content was 10.2 per cent in the depth zone of 0-15 cm, which increased along the depth and reached the maximum of 19.6 per cent at 110-180 cm (Table 2).

The Bulk density of Pedon 1 ranged from 1.48-1.52 g/cc with a mean value of 1.49 g/cc (Table 1). The bulk density of the pedon 1 gradually increased down the depth of the soil. In Pedon 2 the bulk density ranged from 1.35-1.42 g/cc with a mean value of 1.38 g/cc (Table 2). The bulk density of the pedon 2 along depth was quite irregular. The higher bulk density in the lower depth of both the pedons could be due to the influence of gravel content in this zone. The lower zone mainly consists of weathered parent materials. Therefore, the compact weathered mass of residuum of biotite-genesis and shallow content of organic matter in the zones might have led to a higher bulk density on the bottom horizons. Similar findings have been observed by Mishra (2005).In contrast, the lower bulk densities in the surface horizons could be attributed to the effect of the higher content of organic matter including plant roots, besides that of regular ploughing.

Chemical properties

In pedons 1 and 2, the pH of the surface horizon was observed to be 7.21 (neutral) and 6.24 (slightly acidic), respectively. In pedon 1, pH increased along with depth from 7.21 to 8.10. In pedon 2 pH increased along with depth from 6.24 to 8.17. Such an increase in pH can be attributed to the movement of the bases from the upper to the lower horizons during intense rainfall. A similar result was also found by (Sharma *et al.* (2013b) and Dash *et al.* (2019a). EC ranged from 0.010 to 0.065 dSm^{-1} in both of the pedons. Such low EC could be attributed to the high intensity of rainfall prevalent in the study area. The low EC indicates their safety for the production of all the crops. Similar results have been found by Mishra (2005). In pedon 1 (upland), the SOC varied from 0.33 to 0.86 %, whereas the same in pedon 2 varied from 0.17 to 1.36 % (Table 3). Higher SOC content in the low-land topographic position can be attributed to higher cropping intensity in the low-land region because of higher soil moisture status (Dash *et al.*, 2019a). In both the pedons, the decrease of organic carbon along depth was irregular or zigzag, which can be attributed to the effect of surficial erosion by water runoff and largely to the addition of colluvial materials. Dash *et al.* (2022a) also reported that SOC content followed a zigzag pattern in the soils of Keonjhar district owing to the fluvial nature of the soils.

Available nutrient status

Available N was observed in the low range in both the pedons. However, the available N status decreased irregularly with soil depth in both up and lowlands. The sub-soils were observed to be in the low range with respect to available N. The irregular declining pattern of the available N can correspond to the irregularity of the soil organic carbon contents in these layers (Tables 3 and 4). The available P content in pedon 1 decreased from 17.46 kg/ha in the surface horizon to 6.76 kg/ha at the depth zone of 160-180cm (Table 3). Similarly, the available P content in pedon 2 decreased from 12.39 kg/ha in the surface horizon to 3.94 kg/ha at the depth zone of 110-180cm. Nevertheless, the higher P concentration in the surface layers could be because of the addition of large quantities of P fertilizers in the surface layers for paddy cultivation. This result conforms with the observations made by Dash *et al.*, 2019c.

In pedon 1, the available K decreased from 196.22 kg/ha in the surface horizon along soil depth to 98.11 kg/ha at the depth zone of 130-180cm (Table 3). This decrease in available K content with soil depth can be due to the addition of potassic fertilizers and the incorporation of paddy stubbles and straw in the surface layers after the harvest of paddy crops by the farmers. A similar result was also found by Sharma *et al.* (2013b) and Mishra (2005). In pedon 2, the available K decreased from 243.26 kg/ha in the surface horizon along soil depth to 130.37 kg/ha at the depth zone of 110-180 cm (Table 4). However, in pedon 2, the decrease of the available K along soil depth was quite irregular, which can be because of the irregular content of clay (Kishore *et al.*, 2020).

The soluble S content in all the horizons was below the critical limit (<10 mg/kg) for crop production, which could be attributed to the lower content of organic carbon in these horizons (Tables 3 and 4). The soluble boron content of the surface horizon of both the pedons was above the critical limit (> 0.5) for crop production. An irregular pattern of available S and B could be because of the zigzag pattern observed for the soil organic carbon.

Conclusion

Clay content in general increased with soil depth and along the slope. The soils of the study area were observed to be safe in terms of soil salinity. Soil pH increased with soil depth. The soil reaction in low land was alkaline, whereas the same was slightly acidic in pedon 1. To maintain the soil quality, application of organic matter is required. Surface soils were in general low in available N, medium in P and K, low in S, and sufficient in B. Therefore, 25 % more nitrogenous and sulphatic fertilizers are recommended. Recommended doses of phosphatic and potassic fertilizers should be applied for shallow-rooted crops. Since the concentration of all the available nutrients decreased in the subsoils, 25% more than the recommended doses are recommended for growing deep-rooted crops.

Table 1: Physical properties of Pedon 1(upland)

Sl. No.	Depth (cm)	Horizon	Sand %	Silt %	Clay %	Bulk density (g/cc)	Textural Class
1	0-10	Ap	70.2	13.2	16.6	1.49	Loam
2	10–20	A	71.2	13.2	15.6	1.48	Loam
3	20-35	AB	71.2	12.2	16.6	1.48	Loam
4	35-60	B	70.2	12.2	17.6	1.49	Loam
5	60-90	Bw_1	78.2	8.2	13.6	1.48	Sandy Loam
6	90-130	Bw_2	75.2	8.2	16.6	1.50	Sandy Loam
7	130-160	BC	72.4	3.8	23.8	1.52	Sandy Clay Loam
8	160-180	C	69.4	4.8	25.8	1.52	Sandy Clay Loam

Table 2 : Physical properties of pedon-2 (low land)

Sl No	Depth (cm)	Horizon	Sand %	Silt %	Clay %	Bulk density (g/cc)	Textural Class
1	0-15	Ap	81.8	8.0	10.2	1.38	Sandy Loam
2	15-25	A	81.8	7.6	10.6	1.42	Sandy Loam
3	25-40	AB	78.8	6.0	15.2	1.42	Sandy Loam
4	40-60	Bt_1	70.8	12.0	17.2	1.38	Loam
5	60-80	Bt_2	69.8	12.0	18.2	1.36	Loam
6	80-95	B_2	73.8	11.6	14.6	1.35	Sandy Loam
7	95-110	BC	70.2	14.6	15.2	1.37	Loam
8	110-180	C	67.2	13.2	19.6	1.37	Loam

Table 3 : Chemical properties and available nutrient status of different horizons of pedon 1 (upland)

Sl No	Depth (cm)	Horizon	PH (1:2)	EC (dsm^{-1})	OC (%)	Avail Nutrients (kg/ha)			S (mg/kg)	B (mg/kg)
						N	P_2O_5	K_2O		
1	0-10	Ap	7.21	0.065	0.86	167.50	17.46	196.22	1.13	0.66
2	10–20	A	7.37	0.060	0.60	181.25	14.08	193.54	2.96	0.48
3	20-35	AB	7.40	0.061	0.43	135.00	12.39	141.12	1.39	0.24
4	35-60	B	7.68	0.061	0.45	121.25	10.70	115.58	0.70	0.42
5	60-90	Bw_1	7.64	0.010	0.45	122.50	9.57	114.24	1.13	0.12
6	90-130	Bw_2	7.93	0.010	0.45	151.25	9.57	120.96	0.52	0.60
7	130-160	BC	8.04	0.010	0.41	126.25	9.01	98.11	1.22	0.96
8	160-180	C	8.10	0.100	0.33	90.00	6.76	98.11	1.22	0.36

Table 4 : Chemical properties and available nutrient status of different horizons of pedon 1 (low land)

Sl No	Depth (cm)	Horizon	PH (1:2)	EC (dSm^{-1})	OC (%)	Avail Nutrients (kg/ha)			S (mg/kg)	B (mg/kg)
						N	P	K		
1	0-15	Ap	6.24	0.055	1.36	228.75	12.39	243.26	1.74	1.62
2	15-25	A	6.48	0.055	0.69	207.50	9.57	122.30	2.18	0.48
3	25-40	AB	6.85	0.056	0.28	116.25	8.45	133.06	1.57	1.32
4	40-60	Bt_1	7.43	0.057	0.32	98.75	7.88	135.74	3.74	1.62
5	60-80	Bt_2	7.66	0.063	0.35	101.25	7.88	131.71	2.00	0.78
6	80-95	B_2	7.59	0.064	0.30	75.00	6.76	130.37	1.83	0.54
7	95-110	BC	7.99	0.061	0.22	67.50	5.63	147.84	1.57	0.66
8	110-180	C	8.17	0.064	0.17	68.75	3.94	130.37	1.31	0.90

Competing interests

The authors have declared that no competing interests exist.

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