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Vertical Distribution of Available Plant Nutrients in Soils of Mid-Central Tableland Agro-Climatic Zone of Odisha, India

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ABSTRACT

Study on the vertical distribution of plant nutrients is very essential for improving crop production and productivity rather than studying the nutrient characteristics of the surface soil only. It is because many plants absorb nutrients from the subsoil. Moreover, the vertical distribution of nutrients is much more complex because of the many simultaneous processes going on in the soils such as recycling of the plant residues, leaching of nutrients, and weathering of parent materials. In this context, two pedons located in pedons in two different land types(upland and low land) of Dhenkanal district of the Mid-Central Tableland argo-climatic zone of Odisha 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 (sand, silt, clay), pH, electrical conductivity (EC), soil organic carbon (SOC), available nitrogen (N), phosphorus (P), potassium (K), sulfur (S) and boron (B) content. The results indicated that there was a gradual decrease in the concentration of SOC, available N, P and S with soil depth. Whereas soil reaction (pH), EC and available K content increased with soil depth. Therefore, surface soils were observed to be more fertile but acidic, whereas the sub-soils were of higher pH. The findings of this study will be helpful for the scientific as well as the farming community for suggesting and uptaking suitable crop and land use plans for sustainable agricultural and land use management.

Keywords Soil horizons, Profile, Dhenkanal, Nutrient distribution, Crop productivity, Land use management.

INTRODUCTION

Knowledge of the vertical distribution of plant nutrients in the soil is useful as the roots of many crop plants go beyond the surface layer and draw part of their nutrient requirements from the sub-surface

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layers of the soil (Sangwan and Singh 1993). Paddy and groundnut are the most important crops in Odisha. The study of Singh *et al.* (1997) showed that more than 30% of the roots of paddy and groundnut crops were present at a depth of 25-40 cm, which are normally considered surface feeders. Brar and Sekhon (1987), Pal and Mukhopadhyay (1992) observed that the vertical distribution of potassium is of considerable importance as many deep-rooted crops are known to absorb potassium from the sub-surface layers. Studying sub-surface soil characteristics is also helpful in understanding the inherent capacity of the soil to supply essential nutrients to plants. To understand the importance of plants in structuring the vertical distributions of plant nutrients, Jobbagy and Jackson (2001) explored nutrient distributions in the top 1 meter of soil and observed that vertical nutrient distributions are dominated by plant cycling relative to leaching, weathering dissolution, and atmospheric deposition.

As the interface between the atmosphere, biosphere and lithosphere, soil undergoes an intense vertical exchange of materials resulting in steep chemical and physical gradients from surface to bedrock. Soil stratification is the most visible result of this exchange, and its extensive observation and synthesis form the basis of pedogenetic and taxonomic study (Hilgard 1906, Jenny 1941, Soil Survey Staff 1975, Buol *et al.* 1989). The type, thickness, and position of horizons can yield information about soil-forming factors such as climate, topography and vegetation type (Jenny 1941, Marion *et al.* 1985, Honeycutt *et al.* 1990). Likewise, the vertical distribution of plant nutrients should yield similar insights into nutrient inputs, outputs and cycling processes (Smeck 1973, Kirby 1985). Most knowledge about the role of plant cycling in the distribution of nutrients comes from studies on horizontal nutrient patterns (Noy-Meir 1973). According to Patil and Patel (1983) in the present strategy of high yielding and intensive cropping system, fertilizer application based on soil tests assume great significance for fertilizer recommendation. Generally, the soil samples are collected from the surface (0-15 cm) layer. But, the sub-surface fertility status of soil also needs to be evaluated while making fertilizer recommendations for different crops (Dash *et al.* 2022c).

Land use planning can be done based on the physico-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, Mishra *et al.* 2014, Pattanayak 2016, 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 characteristic of soil nutrients is limited to only a very few studies (Dash *et al.* 2019c, Kishore *et al.* 2022, Mishra *et al.* 2015). In this context, the present investigation studies the vertical distribution of available plant nutrients in two pedons located in two different land types of the Mid-central tableland Agro-climatic Zone of Odisha.

MATERIALS AND METHODS

Study area

The study is Pandua block of Dhenkanal district located between longitudes 85°58’ E to 86°20”E and between latitudes 20’29” N to 21°11”N. 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 in 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 district has 8 numbers of administrative blocks consisting of 1215 numbers of villages covering a total area of 4,452 km^2 (Mishra *et al.* 2014). The major crops of the district are paddy, groundnut, sesamum, green gram, horse gram, sugarcane, vegetable and fruits.

Soils

The district mainly consists of red and laterite soils although patches of yellow soils are also found in some parts of the district. River Bramhani, the second biggest river in Odisha flows through this district and alluvial soils are found on the riverbanks, which are very suitable for vegetable cultivation during summer. As per the USDA soil taxonomy, soils of the study area have been classified as *Alfisols*, *Inceptisols* and *Entisols* (Sahu and Mishra 2005). The red color 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. The alluvial soils are products of the pedogenic process of sediment deposition mostly by the river Bramhani and its tributaries. The relief of the district consists of high hills and valleys with dense forests. The pedogenic process of colluviation has also taken place in these types of topographies. The colluvial deposits are found in the foot slope of most of the hills, which are mostly used for the cultivation of paddy 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

A detailed soil survey of the area was conducted by using the soil survey manual of USDA (Soil Survey Staff 1995) and guidelines for soil profile description by the Food and Agriculture Organization (Food and Agriculture Organization 1977). Two soil profiles of approximately 2 m × 1.5 m × 1.5 m dimension were opened at two different land types (upland and lowland) of Pandua block in Dhenkanal district. Soil samples from different genetic horizons were collected by using a spade during the summer season. The textural class analysis was carried out by the Bouyoucus Hydrometer method (Piper 1950). The pH of 1:2 (w/v) soil and water suspension was determined using a glass electrode digital pH meter. EC at 1:2 (w/v) soil and water suspension was determined by an EC meter. Soil organic carbon was determined by Walkley and Black's rapid titration method (Jackson 1973). Available phosphorus was determined by Olsen's method (Olsen *et al.* 1954). Available nitrogen was determined using the alkaline potassium permanganate method (Subbiah and Asija 1956). Available potassium was determined by the neutral normal ammonium acetate extraction method using a digital flame photometer (Page *et al.* 1982). Available boron was done by hot water extraction method (John *et al.*1975) and available Sulfur was done by 0.15% $CaCl_2$ method (Chesnin and Yien 1950).

RESULTS AND DISCUSSION

Physico-chemical properties of the twopedons have been presented in Tables 1–2. The textural class of the soils of the two pedons varied from clay to sandy loam. The sand fraction varied from 55.0 to 76.0% and dominated the mechanical composition. However, the sand per cent gradually decreased with the soil depth in both the pedons. Contrastingly, an increasing trend of silt and clay fractions with soil depth was noted in both pedons owing to the process of illuviation Sharma *et al.* (2013a).

In pedon 1, the percentage of sand, silt and clay ranged from 58.0 to 76.0, 7.4 to 10.6, and 16.4 to 32.4%, respectively in different horizons. The clay content, which was 16.4% in the depth zone of 10-20 cm increased along the depth and reached a maximum of 32.4% at the depth zone of 85–130 cm (Table 1). In pedon 2, the percentage of sand, silt and clay ranged from 55.0 to 75.2, 7.4 to 15.4 and 16.4 to 32.8% respectively in different horizons. The clay content which was 16.4% in the depth zone of 15-25 cm increased along the depth and reached the maximum of 32.8% at 140–180 cm (Table 2).

In pedons 1 and 2, the pH of the surface horizon was observed to be 5.36 (strongly acidic) and 6.08 (slightly acidic), respectively. In pedon 1, pH increased along with depth from 5.36 to 6.56. 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), Dash *et al.* (2019a),In pedon 2, the soil was strongly acidic to medium acidic in all the layers of the depth zone of 15 – 110 cm but in the depth zone of 110-180 cm, it was slightly acidic (Table 3). This was because of the leaching down of bases in the laterite soils to the lower horizons.

Table 1. Physical properties of pedon-1(upland).

Sl. No.	Depth (cm)	Horizon	Sand	Silt %	Clay	Textural class
1	0-10	Ap	76.0	7.4	16.6	Sandy loam
2	10-20	A	76.0	7.6	16.4	Sandy loam
3	20-35	AB	66.0	10.6	23.4	Clay loam
4	35-60	E	65.0	7.6	27.4	Clay loam
5	60-85	BE	61.0	8.6	30.4	Clay loam
6	85-110	Bt_1	58.0	9.6	32.4	Clay
7	110-130	Bt_2	60.0	7.6	32.4	Clay
8	130-150	BC	62.0	9.6	28.4	Clay loam

Table 2. Physical properties of pedon -2 (lowland).

Sl. No.	Depth (cm)	Horizon	Sand	Silt %	Clay	Textural class
1	1−15	Ap	61.2	7.4	31.4	Clay
2	15-25	A	75.2	8.4	16.4	Sandy loam
3	25-45	AB	70.2	7.4	22.4	Sandy clay loam
4	45-60	E	63.2	8.4	28.4	Clay loam
5	60-75	Bt_1	59.2	15.4	25.4	Clay loam
6	75-110	Bt_2	61.2	8.4	30.4	Clay loam
7	110-140	Bt_3	59.0	12.2	28.8	Clay loam
8	140-180	BC	55.0	12.2	32.8	Clay

Table 3. Available nutrient status of different horizons of pedon-1 (upland).

Sl. No.	Depth (cm)	Horizon	pH (1:2)	EC (dSm^{-1})	SOC (%)	Avail nutrients (kg/ha) N	P	K	S (mg/kg)	B (mg/kg)
1	0-10	Ap	5.36	0.020	0.48	302.50	24.23	184.13	2.26	0.78
2	10-20	A	5.56	0.023	0.40	202.50	21.41	150.53	0.78	0.60
3	20-35	AB	5.66	0.022	0.54	220.00	9.01	120.96	2.52	0.24
4	35-60	E	5.95	0.019	0.34	220.00	7.88	106.18	2.87	0.24
5	60-85	BE	6.11	0.019	0.33	266.25	7.88	115.58	2.70	0.24
6	85-110	Bt_1	6.34	0.020	0.38	275.00	7.32	124.99	2.70	0.36
7	110-130	Bt_2	6.42	0.020	0.48	277.50	7.32	143.81	3.74	0.24
8	130-150	BC	6.56	0.019	0.56	263.75	6.19	96.77	4.87	0.18

Table 4. Available nutrient status of different horizons of pedon-2 (lowland).

Sl. No.	Depth (cm)	Horizon	pH (1:2)	EC (dSm^{-1})	SOC (%)	Avail nutrients (kg/ha) N	P	K	S (mg/kg)	B (mg/kg)
1	1−15	Ap	6.08	0.019	0.46	272.50	47.89	98.11	2.09	0.18
2	15-25	A	5.11	0.019	0.65	216.25	17.46	131.71	3.13	0.30
3	25-45	AB	5.31	0.019	0.57	263.75	14.65	193.54	3.22	0.54
4	45-60	E	5.83	0.019	0.57	302.50	12.39	108.86	3.13	0.78
5	60-75	Bt_1	5.45	0.020	0.50	297.50	9.58	272.83	4.44	0.30
6	75-110	Bt_2	5.97	0.020	0.65	322.50	8.45	122.30	2.44	0.36
7	110-140	Bt_3	6.19	0.018	0.57	363.75	8.45	201.60	2.26	0.18
8	140-180	BC	6.32	0.018	0.41	408.75	7.88	168.00	2.00	0.54

EC ranged from 0.018 to 0.023 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), Mishra *et al.* (2009). In pedon 1 (upland), the SOC varied from 0.33 to 0.56 %, whereas the same in pedon 2 varied from 0.46 to 0.65% (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 N was observed in the medium range in both pedons. However, the available N status decreased irregularly with soil depth in both up and low lands. 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 3–4).

The available P content in pedon 1 decreased from 24.23 kg/ha in the surface horizon to 6.19 kg/ha at the depth zone of 130-150 cm (Table 3). Similarly, the available P content in pedon 2 decreased from 47.89 kg/ha in the surface horizon to 7.88 kg/ha at the depth zone of 140-180 cm. It indicates that overall P content was higher in the low land, which could be because of the higher SOC status in the low-land region (Dash *et al.* 2022a). 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 Mehta and Patel (1963), Bhan and Shanker (1973), and Das *et al.* (1993).

In pedon 1, the available K decreased from 184.13 kg/ha in the surface horizon along soil depth to 96.77 kg/ha at the depth zone of 130-150 cm (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). But in pedon 2, the decrease of the available Kalong soil depth was quite irregular, which can be because of the irregular content of clay Kishore *et al.* (2020). Nevertheless, except for the low status of available K in the surface horizon of pedon 2, available K content was in the medium range in all the horizons of both of the pedons.

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 3–4). The soluble boron content of the surface horizon of pedon 1 was above the critical limit (> 0.5) for crop production while it was below the critical limit (<0.5 mg/kg) in the case of pedon 2. A more or less zigzag 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. While the surface soils were observed to be more acidic in nature, the subsoils were less acidic. Hence, suitable liming materials should be applied. To maintain the soil quality, liberal application of organic matter is required. It can be concluded that 25 % more nitrogenous and phosphatic fertilizers should be applied for growing deep-rooted crops. Since the soils were observed to be deficient in available sulfur and boron, additional sources of sulfur and boron fertilizers should be applied.

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