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Vertical distribution of available nutrients in an Eastern Indian Catena

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ABSTRACT

An investigation was conducted to analyse the distribution of available plant nutrients and to examine the relationships between soil properties and available nutrient status in soil profiles of Eastern India. Three soil profiles were exposed under three different topographic positions. In all the pedons, soil pH and EC increased and soil organic carbon content decreased with increasing soil depth. The status of available N, P, K and S in surface soils ranged from 223 to 321, 11 to 36, 305 to 354 and 4.6 to 12 kg ha^{-1}, respectively. The corresponding ranges of these nutrients in the sub surface were 100 to 252, 3 to 20, 276 to 400 and 3.5 to 11 kg ha^{-1}. The status of available Fe, Mn, Cu, Zn and B in surface soils ranged from 38.5 to 48.1, 14.9 to 25.2, 0.9 to 2.9, 0.7 to 1.1 and 0.81 to 1.49 mg kg^{-1},respectively. The corresponding ranges of these nutrients in the sub surface were 5.9 to 39.8, 2.1 to 15.4, 0.2 to 1.6, 0.1 to 0.7 and 0.16 to 0.71 mg kg^{-1}. Available N, P, S, Fe, Mn, Cu, Zn and B decreased with increasing soil depth. In profiles of medium and low lands, available K status tended to increase with increasing soil depth; while reverse trend was observed in upland. Positive correlations between available Fe, Mn, Cu, Zn with soil organic carbon content and that of negative ones with soil pH were observed.

Keywords- Available nutrients, pedon, soil profile, topography

INTRODUCTION

Knowledge of vertical distribution of plant nutrients in soils is useful, as roots of most of the crops go beyond the surface layers and draw part of their nutrient requirement from the sub surface layers. Soil profile characteristics as conditioned by different processes and factors of soil formation have great influence on soil fertility and crop productivity. Detailed and scientific study of soil profiles is immensely essential for understanding the prevailing soil forming (soil genesis) factors and processes, without a knowledge of which soil characteristics cannot be clearly interpreted (Vedadri and Naidu, 2018). The crop productivity cannot be boosted further without judicious use of macro and micro nutrient fertilizers to overcome the existing deficiencies. Hence, a clear cut understanding of vertical distribution of plant nutrients in soil is highly necessary to suggest appropriate fertilizer schedule for different crops to obtain optimum yield. Variations in topography greatly influence the availability and distribution of plant nutrients, both in surface as well as sub-surface soils (Dorji *et al.,* 2014). Taking this concept into cognizance, this research work was conducted in a well-formed catena (toposequence) located in Eastern India having distinct topographic positions with an objective to study the vertical distribution of plant nutrients in different topographic positions.

MATERIALS AND METHODS

The selected study site was RRTTS (Regional Research and Technology Transfer Station) and KVK (KrishiVigyan Kendra) farm, Dhenkanal located in the Mid-Central Tableland Agro-Climatic Zone of Odisha, India. Based on slope and elevation, the study area has been divided into three major physiographic units such as gently sloping upland (332 feet above MSL, slope of 3-5%), very gently sloping medium land (308 feet above MSL, slope of 1-3%) and nearly levelled low land (295 feet above MSL, slope of 0-1%). The landform of the study area was determined through traversing thearea and taking elevation data above Mean Sea Level (MSL) at different points, using GPS instrument (Garmin make; model: 76MAPCSx). After a general traversing of the study area, three representative soil profiles located in three different topographic positions such as upland (20°37'36.26″N, 85°36'04.60″E), medium land (20°37'25.30″N, 85°36'52.83″E) and low land (20°37'11.91″N, 85°36'55.22″E) were selected and exposed. The soil profiles in upland medium land and low lands were referred as pedon 1, 2 and 3, respectively.Soil depth of pedon 1, 2 and 3 were found to be 91, 150 and 160 cm, respectively. Pedon 1 was observed with 3 distinct genetic horizons (A1, C1 and C2); pedon

2 with 7 distinct genetic horizons (Ap, Bt1, Bt21, Bt22, Bt23, BC and C) and pedon 3 with 6 distinct genetic horizons (Ap, A2, Bt1, Bt2, Bt3 and C). Soil samples from different genetic horizons were collected, processed and preserved for laboratory studies. The soil samples were analysed for textural class by Bouyoucos Hydrometer method, pH(1:2) and EC(1:2), organic carbon (Jackson, 1973), available nitrogen (Subbiah and Asija, 1956), phosphorus (Bray and Kurtz, 1945), potassium (Hanway and Heidel, 1952), sulphur (Chesnin and Yien, 1950), DTPA extractable iron, manganese, copper and zinc (Lindsay and Norvell, 1978) and hot water extractable boron (John *et al.*, 1975). Statistical correlation analyses were carried out as per methods of Gomez and Gomez (1983).

RESULTS AND DISCUSSION

Physical and chemical characteristics

Particle size distribution: In pedon 1, a gradual decrease in clay content was observed from surface to the depth of 91 cm, which can be attributed to the absence of eluviation process. In pedon 2 and 3, clay content gradually increased with increasing depth up to 81 and 129 cm depth and then decreased up to a depth of 150 and 160 cm, respectively (Table 1).Thus, increase in clay percentage with depth might be attributed to vertical migration or translocation of clay (Mustafa *et al.,* 2011).

Soil reaction:The surface soil of pedon 1 was found to be strongly acidic with a pH value of 4.60 which was increased with soil depth up to a value of 5.95 at the lower most horizon. The surface soils of pedon 2 and 3 were moderately acidic with pH values of 5.27 and 5.44, which increased with depth up to a value of 6.15 and 6.63, respectively at the lower most horizons (Table 1). The increase in soil pH withincreasing soil depth could be attributed to leaching of basic cations from upper horizons towards the lower horizons mostly during intensive rainfall (Rajeswar and Ramulu, 2016).

Table1: Depth wise distribution of particle size, soil pH and organic carbon in representative pedons

Horizon	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	pH	EC (dSm^{-1})	OrganicCarbon(g kg^{-1})
(a) Pedon 1 (Upland)							
A1	0-18	78.0	10.8	11.2	4.60	0.028	5.1
C1	18-66	79.0	11.4	9.6	5.50	0.032	3.9
C2	67-91	83.6	11.8	4.6	5.95	0.035	1.9
(b) Pedon 2 (Medium land)							
Ap	0-15	66.4	19.6	14.0	5.27	0.046	9.06
Bt1	15-27	64.4	18.2	17.4	5.50	0.065	5.26
Bt21	27-45	62.4	16.6	21.0	5.59	0.069	4.71
Bt22	45-57	61.4	13.2	25.4	5.80	0.075	4.71
Bt23	57-81	60.4	8.6	31.0	5.97	0.079	2.35
BC	81-103	58.8	23.4	17.8	6.12	0.080	2.10
C	103-150	58.4	17.2	14.0	6.15	0.089	0.60
(c) Pedon 3 (Low land)							
Ap	0-9	66.4	19.0	14.6	5.44	0.060	12.50
A2	9-21	64.4	18.6	17.0	5.64	0.064	12.50
Bt1	21-54	62.2	10.6	27.2	6.14	0.069	6.34
Bt2	54-93	58.8	6.6	34.6	6.39	0.074	2.35
Bt3	93-129	52.2	9.6	38.2	6.62	0.084	1.08
C	129-160	60.8	17.0	22.2	6.63	0.100	0.95

Electrical conductivity:EC of all the soil profiles remained below 1 dSm^{-1}, indicatingthat it is non-saline in nature and are safe for all types of crop production. Such low electrical conductivity could be attributed to leachingandfree drainage of soluble salts duringintensive rainfall (Beeman *et al.,* 2018).

Organic carbon: The organic carbon content of the surface horizons of pedon 1, 2 and 3 ranged from 5.1, 9.06, 12.5 g kg^{-1}, respectively (Table

1). A regular trend of decrease in organic carbon with increasing soil depth was observed in all the soil profiles. Higher organic carbon content in the surface horizons of all the three pedons could be attributed to fresh accumulation and decomposition of crop residues every year in the surface horizons (Khanday *et al.*, 2018).

Distribution of available nutrients

Available nitrogen: In pedon 1, the highest amount of available N(223 kg ha^{-1}) was found in the surface horizon (0-18 cm) and the lowest (125 kg ha^{-1}) in the lower horizon (67-91 cm). In pedon 2, the highest amount of available N (271 kg ha^{-1}) was found in the surface (0-15 cm) and the lowest (100 kg ha^{-1}) in the lower horizon (103-150 cm). The highest amount of available N (321 kg ha^{-1}) in pedon 3 was found in the surface horizon and the lowest (125 kg ha^{-1}) in the lower horizon (129-160 cm) (Table 2). Available N tended to decrease with soil depth, which might be due to the confinement of falling of plant residues and debris to rhizosphere of plants and due to decreasing trend of organic carbon with increasing soil depth (Sharma *et al.,* 2013).

Table 2: Depth wise distribution of available nutrients in pedons

Horizon	Depth (cm)	N	P	K	S	Fe	Mn	Cu	Zn	B
		<-------- kg ha^{-1}------->				<---------mg kg^{-1}-------->				
Pedon-1 (Upland)										
A1	0-18	223	11	305	4.6	38.5	14.9	0.9	0.7	0.81
C1	18-67	220	9	284	3.9	35.9	9.3	0.7	0.5	0.65
C2	67-91	125	5	276	3.5	25.8	5.4	0.4	0.3	0.45
Pedon-2 (Medium land)										
Ap	0-15	271	18	348	9.8	42.8	20.5	1.7	0.9	0.85
Bt1	15-27	220	14	356	8.6	39.8	15.4	1.6	0.7	0.71
Bt21	27-45	198	12	364	7.8	28.9	12.1	1.5	0.6	0.69
Bt22	45-57	195	10	372	7.8	22.1	8.6	1.3	0.6	0.50
Bt23	57-81	125	4	372	5.6	15.9	5.9	1.2	0.5	0.45
BC	81-103	113	4	389	5.4	10.8	4.2	1.1	0.3	0.35
C	103-150	100	3	389	4.8	9.6	2.2	1.1	0.3	0.30
Pedon-3 (Low land)										
Ap	0-9	321	36	352	10	48.1	25.2	2.9	1.1	1.49
A3	9-21	297	35	354	12	39.1	22.8	1.9	1.0	1.19
B1t	21-54	252	20	378	11	16.0	9.5	1.3	0.3	0.62
B2t	54-93	221	14	382	9	8.9	6.9	0.8	0.2	0.39
B3t	93-129	196	11	400	4	5.9	2.2	0.4	0.1	0.27
C	129-160	125	9	362	4	5.9	2.1	0.2	0.1	0.16

Available phosphorous: In pedon 1, the highest amount of available phosphorus (11 kg ha^{-1}) was found in the surface horizon (0-18 cm) and the lowest (5 kg ha^{-1}) in the lower most horizon (67-91 cm). In pedon 2, the maximum(18 kg ha^{-1}) and minimum (3 kg ha^{-1}) amounts of available P were noted in surface horizon and the lowest in the lower horizon (103-150 cm), respectively. In pedon 3, the highest amount of available phosphorous (36 kg ha^{-1}) was found in the surface horizon (0-9 cm) and the lowest (9 kg ha^{-1}) in the lower most horizon (129-160 cm) (Table 2). The low phosphorus content could be attributed to the fixation of released phosphorus by clay minerals and oxides of iron and aluminium.

Available potassium: In pedon 1, the highest amount of available potassium (305 kg ha^{-1}) was found in the surface horizon (0-18 cm) and the lowest (276 kg ha^{-1}) in the lower horizon (67-91 cm). Inpedon 2, the highest amount of available K (389 kg ha^{-1}) was found in the lower horizons (81-150 cm) and the lowest (348 kg ha^{-1}) in the surface horizon (0-15 cm). In pedon 3, the highest amount of available K (400 kg ha^{-1}) was found in the B3t horizon (93-129 cm) and the lowest (352 kg ha^{-1}) in the surface horizon (0-9 cm). In pedon 1, available K was decreased with increase in soil depth, which can be attributed to decreasing trend of clay content (Saini and Grewal, 2014). This result was further supported by the significant positive correlation of available K with percentage clay content

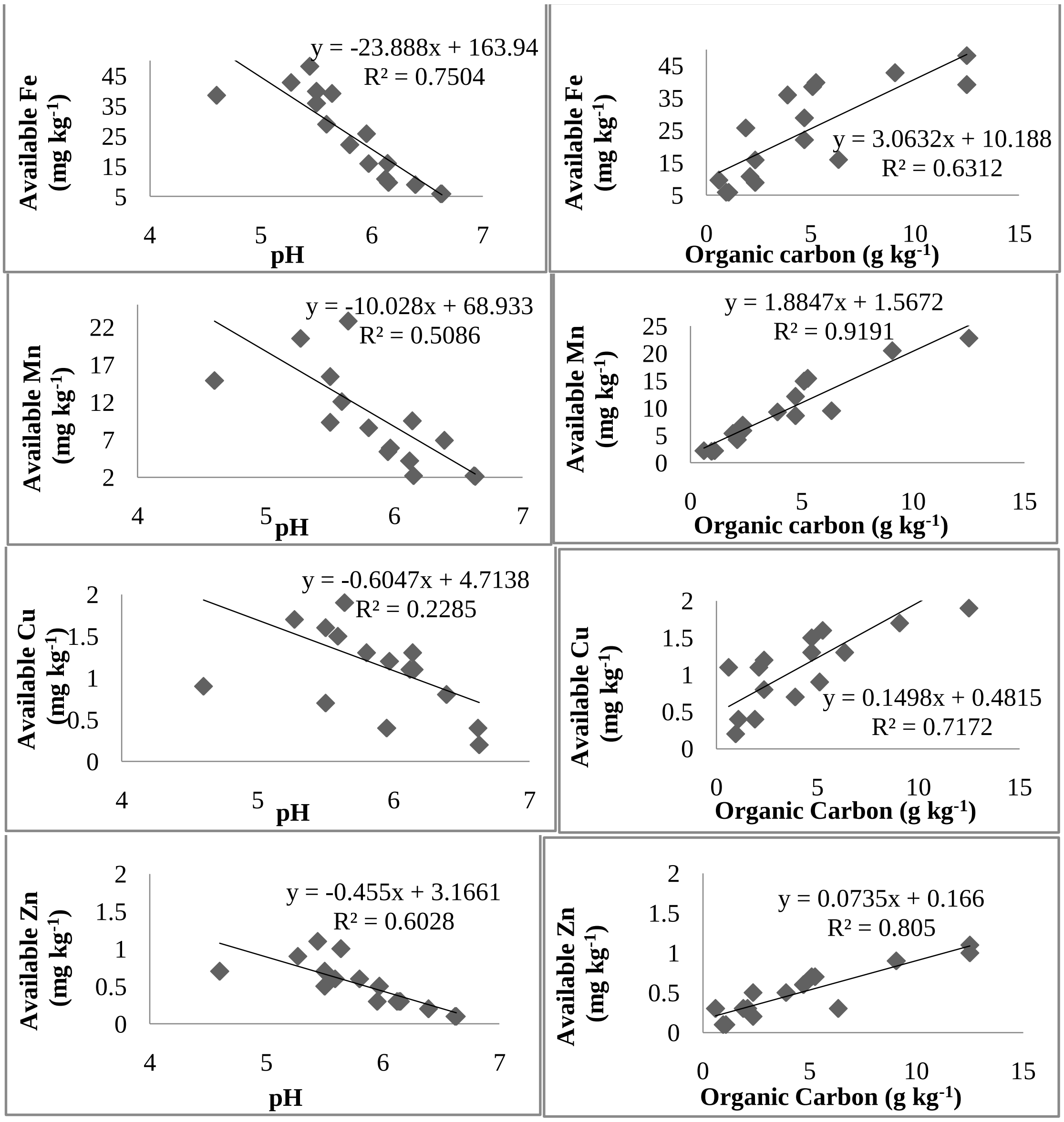

Fig. 1: Relationships between available micronutrients and soil properties

(r=0.75**). But, the increasing trend of available potassium with increase in soil depth was observed in pedon 2 and 3 (Table 2), which could be due to development of the soil from the residual parent materials mostly consisting of feldspars and micas, which are mostly potash bearing minerals (Mishra *et al.,* 2015) and also due to the effect of potassium depletion by the crops from the surface horizons (Saini and Grewal, 2014).

Available sulphur: In pedon 1, the highest amount of available sulphur (4.6 kg ha^{-1}) was found in the surface horizon (0-18 cm) and the lowest (3.5 kg ha^{-1}) in the lower horizon (67-91 cm). In pedon 2, the highest amount of available S (9.8 kg ha^{-1}) was found in the surface horizon (0-15 cm) and the lowest (4.8 kg ha^{-1}) in the lower horizon (103-150 cm). In pedon 3, the highest amount of available S (12 kg ha^{-1}) was found in the A3 horizon (9-21 cm) and the lowest (4 kg ha^{-1}) in the lower horizons (93-160 cm). Surface layers contained more available sulphur than sub-surface layers, which could be due to higher amount of organic matter in surface layers than in deeper layers and varying land use and parent material (Srinivasan*et al.,* 2013)

Available iron:The status of available Fe in surface and sub-surface soils ranged from 38.5 to 48.1 and 5.9 to 39.8, mg kg^{-1}, respectively.In pedon 1, the highest amount of available iron

(38.5 mg kg^{-1}) was observed in the surface horizon (0-18 cm) and the lowest (25.8 mg kg^{-1}) in the lower horizon (67-91 cm). In pedon 2, the highest amount of available Fe (42.8 mg kg^{-1}) was found in the surface horizon (0-15 cm) and the lowest (9.6 mg kg^{-1}) in the lower horizon (103-150 cm). In pedon 3, the highest amount of available Fe (48.1 mg kg^{-1}) was noted in the surface horizon (0-9 cm) and the lowest (5.9 mg kg^{-1}) in the lower horizons (93-160 cm) (Table 2). The decreasing trend of available Fe with soil depth might be due to higher biological activity and organic carbon in the surface soils.These results were further supported by the positive correlation of available Fe (r= 0.87**) with organic carbon and a negative correlation (r=-0.79**) with soil pH (Ravi*et al.,* 2014, Bungla *et al.* 2019).

Available manganese:The status of available Mn in surface and sub-surface soils ranged from 14.9 to 25.2 and 2.1 to 15.4mg kg^{-1}, respectively.The decreasing trend of available Mn with soil depth might be due to accumulation of humic materials in the surface layers. The higher content of available Mn in surface soils can be attributed to the chelating of organic compounds released during the decomposition of organic matter left after harvesting of crop (Satish*et al.,* 2018). These results were supported by positive correlation of available Mn (r=0.95**) with organic carbon and a negative correlation (r=-0.71**) with soil pH (Bungla *et al.* 2019).

Available copper: In pedon 1, the maximum(0.9 mg kg^{-1}) and minimum (0.4 mg kg^{-1}) amounts of available copper were noted in surface (0-18 cm) and lower horizon (67-91 cm), respectively.. In pedon 2, the highest amount of available Cu (1.7 mg kg^{-1}) was found in the surface horizon (0-15 cm) and the lowest (1.1 mg kg^{-1}) in the lower two horizons (81-150 cm). In pedon 3, the highest amount of available Cu (2.9 mg kg^{-1}) was found in the surface (0-9 cm) and the lowest (0.2 mg kg^{-1}) in the lower most horizon (129-160 cm). Available Cu decreased with increasing soil depth (Table 2),which can be attributed to its positive correlation (r=0.84**) with organic carbon and a negative correlation (r= -0.47) with soil pH (Giri *et al.,*2017).

Available zinc:The status of available Zn in surface and sub-surface soils ranged from 0.7 to 1.1 and 0.1 to 0.7 mg kg^{-1},respectively.Available Zn decreasedwith increasing soil depth(Table 2), which can be attributed to low amount of organic carbon in the deeper layers (Satish *et al.,* 2018). The availability of Zn increased with increase in organic matter because organic matter acts as a chelating agent for complexation of which reduces its adsorption, oxidation and precipitation into unavailable forms as evident with the positive correlation (r=0.89**) with organic carbon and a negative one (r=-0.77**) with soil pH (Bungla *et al.* 2019).

Available boron:The status of available B in surface and sub-surface soils ranged from 0.81 to 1.49 and 0.16 to 0.71 mg kg^{-1},respectively. In pedon 1, the highest amount of available boron (0.81 mg kg^{-1}) was found in the surface horizon (0-18 cm) and the lowest (0.45 mg kg^{-1}) in the lower most horizon (67-91 cm). In pedon 2, the highest amount of available B (0.85 mg kg^{-1}) was found in the surface horizon (0-15 cm) and the lowest (0.30 mg kg^{-1}) in the lower most horizon (103-150 cm). In pedon 3, the highest amount of available B (1.49 mg kg^{-1}) was found in the surface (0-9 cm) and the lowest amount (0.16 mg kg^{-1}) in the lower most horizons (93-160 cm). Available B was also found to be showing decreasing trend increasing soil depth which can be attributed to the decreasing trend of organic carbon with soil depth (Mishra, 2015).

The status of available N, P, K and S in soils ranged from 100 to 321, 3 to 36, 276 to 400 and 3.5 to 12 kg ha^{-1}, respectively. Available Fe, Mn, Cu, Zn and B ranged from 5.9 to 48.1, 2.1 to 25.2, 0.2 to 2.9, 0.1 to 1.1 and 0.16 to 1.49 mg kg^{-1},respectively. In all the pedons, availability of these nutrients decreased with increasing soil depth.Available K decreased in upland with increase in soil depth; whereas reverse trend was observed in medium and low lands.

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