

# **ASSESSMENT OF VERTICAL NUTRIENT STRATIFICATION IN PADDY CULTIVATING SOILS IN VEPURIKOTA MICROWATERSHED OF ANDHRA PRADESH, INDIA**

## **ABSTRACT**

A thorough soil investigation was conducted to assess the soil's ability to supply nutrients by examining the vertical nutrient distribution pattern in the pedons of paddy growing areas in the Vepurikota microwatershed in Andhra Pradesh. The results revealed that soils were low in available nitrogen and medium to high in available  $P_2O_5$ , low to high in available  $K_2O$  and deficient to sufficient in available S. In both the surface and subsurface horizons of every pedon, the DTPA extractable Cu was revealed sufficient in the soils. All pedons in the surface and subsurface horizons had deficient to sufficient amounts of available Zn, while all pedons except pedon 4 had sufficient quantities of available Fe and Mn that were above critical levels.

Keywords: Macro and micronutrients, Organic carbon, pH, Surface horizon and sub-surface horizon.

## **INTRODUCTION**

The roots of many crops extend below the surface layer and take up some of their nutrient requirements from the beneath the surface layers, it is crucial to comprehend the vertical nutrient distribution within the soil. (Sangwan and Singh 1993). Soil degradation is progressing rapidly due to inadequate management and improper land-use practices, outpacing the natural rate of deterioration. Consequently, protecting soils from further degradation is imperative. Many crops, especially long-duration varieties and hybrids, deplete significant quantities of plant nutrients from the soil. This depletion diminishes the soil's nutrient-supplying capacity, leading to reduced crop productivity. Analyzing sub-surface soil characteristics provides valuable insights into the soil's inherent capacity to supply essential nutrients to plants. Jobbagy and Jackson (2001) investigated the nutrient distributions within the top meter of soil, highlighting that vertical nutrient distributions are predominantly influenced by plant cycling rather than by leaching, weathering dissolution, or atmospheric deposition. Intensive cropping and the imbalanced application of macro nutrient fertilizers have further exacerbated nutrient deficiencies and deteriorated the soil's physical properties, thereby impeding crop growth and development (Sivanagaraju et al., 2023). To maintain soil fertility and crop productivity, it is crucial to examine the vertical distribution of available nutrients in the soil, which aids in assessing the current fertility status. Notably, there has

been no reported case study focusing on the paddy-growing soils of the Vepurikotamicrowatershed. Considering these factors, the present study was meticulously planned and executed to address this gap.

## **MATERIAL AND METHODS**

**Details of study area:** Vepurikotamicrowatershed of Chittoor district covers an area of 1005.27 ha. The climatic condition of the investigated region is semi-arid monsoonic with a mean annual rainfall of 668.31 mm, out of which 83.54 per cent falls between the months of June to December. The mean annual temperature is 26.59°C with mean summer temperature of 30.66°C and the mean winter temperature of 23.38°C. The highest temperature was recorded in the month of April that rises to 35.49°C and while the lowest temperature 20.20°C was recorded in December. The soil temperature regime is iso-hyperthermic, and the soil moisture regime is ustic.

**Soil sampling and Taxonomic categorisation:** Four pedons were selected for assessment in the paddy cultivating areas of Vepurikotamicrowatershed during 2021-22 and Reconnaissance soil survey was conducted by traversing for selection of four pedons in the study area. The taxonomy of these four pedons viz., pedon 1: Fine loamy, mixed, isohyperthermic, Typic Natrustalfs, pedon 2 : Fine, mixed, isohyperthermic, Typic Haplustalfs, pedon 3 : Fine loamy, mixed, isohyperthermic, Typic Haplustalfs and pedon 4 : Fine, mixed, isohyperthermic, Vertic Haplustepts. Soil samples from different genetic horizons were collected by using a spade during the summer season, processed and assessed for available macro and micronutrients by adopting the standard methods as outlined by Jackson (1973). The critical limits proposed by Muhr *et al.* (1965) for available N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O, Tandon (1991) and available S (10 mg kg<sup>-1</sup>), In respect of available micronutrients, the ratings given by Lindsay and Norvell (1978) for Zn (0.6 mg kg<sup>-1</sup>), Fe (4.5 mg kg<sup>-1</sup>), Cu (0.2 mg kg<sup>-1</sup>) and Mn (2 mg kg<sup>-1</sup>) were considered for classifying profile soil samples into sufficient or deficient for paddy cultivation.

## **RESULTS AND DISCUSSION**

### **Physico-chemical properties**

The Paddy growing soils were slightly acidic to very strongly alkaline in their reactivity (6.03-9.27) (Table 1) and significant pH variation was associated with the source material's that is parent material composition, leaching, the presence of salts of calcium

carbonate, exchangeable sodium, and the release of organic acids by the breakdown of organic materials. Similar results were noticed by Leelavathy and Naidu (2020). The parent material's type, in situ weathering, topographic location, and clay translocation were the main causes of the paddy growing soils' broader textural variety from sandy clay loam to clay loam (Selvaraj *et al.*, 2012). The EC in paddy growing soils was ranged from 0.03 to 1.20 dSm<sup>-1</sup> indicating their non-saline nature in the soil electrical conductivity (Table 1). The low Electrical Conductivity of paddy growing soils was due to free drainage nature which promoted the removal of released bases by the processes of percolation and drainage (Mohan *et al.*, 2020). The organic carbon content of the paddy growing soils was low to medium (0.01 to 0.60 per cent), which is due to the predominance of tropical conditions, where organic matter degrades more quickly and there is less vegetative cover, the OC content of the paddy cultivating soils was ranged from low to medium thereby leaving less organic carbon in the soils as reported by Supriya *et al.*, 2019.

### **Macronutrients:**

The available nitrogen content varied from 62.72 - 225.79 kg ha<sup>-1</sup> in pedons of paddy cultivating areas with a mean of 137.98 kg ha<sup>-1</sup> of nitrogen (Table 2a). Considering 280 kg ha<sup>-1</sup> as critical limit, the available N status was low in both the horizons and a decreasing pattern with depth was observed in all the pedons except pedon 1. The region's predominant semiarid conditions could have contributed to the low levels of accessible nitrogen (N) in the soils by restricting the amount of organic matter that may accumulate and encouraging quick oxidation, resulting in the release of NO<sub>3</sub>-N, which is readily leached and subsequently lost from the soil. Similar findings were documented by Sharma *et al.* (2013) and Borse *et al.* (2018).

The available P<sub>2</sub>O<sub>5</sub> content varied from 46.19-217.41 kg ha<sup>-1</sup> in all the pedons of paddy producing areas with a mean of 75.69 kg ha<sup>-1</sup> as indicated in table 2a. Considering 22.8 kg ha<sup>-1</sup> as critical limit, the available P<sub>2</sub>O<sub>5</sub> status was medium to high in both the horizons and in the pedons 2 and 3, the available P<sub>2</sub>O<sub>5</sub> content decreased with depth, which might possibly be due to the confinement of crop cultivation up to the rhizosphere zone and supplementing the depleted Phosphorus by external sources *i.e.*, fertilizers to the surface soil (Nazir *et al.*, 2021). The extent of phosphorus fixation with Fe and other cations in the soil, as well as the degree of soil disturbance, might be related to variations in the readily available P levels in the remaining pedons. (Osujieket *et al.*, 2018).

The available  $K_2O$  content of paddy growing soils varied from 73.25-381.70  $kg\ ha^{-1}$  with a mean value 157.36  $kg\ ha^{-1}$  (Table 2a). Taking 129.6  $kg\ ha^{-1}$  as a critical limit, in all of these pedons, the surface horizons had the highest available  $K_2O$  content, which decreased with depth. This might be attributed to increased weathering of the minerals containing potassium, the use of fertilisers containing potassium, the upward translocation of potassium from deeper levels, and groundwater capillary movement could all be contributing factors to this (Vedadri and Naidu, 2018).

The available S in paddy producing soils varied from 5.29 - 45.25  $mg\ kg^{-1}$  with a mean of 19.27  $mg\ kg^{-1}$  (Table 2a). Using 10  $mg\ S\ kg^{-1}$  soil as the critical value, all surface horizons showed sufficient quantities of available S, and all pedons showed a pattern of decreasing S with depth. More available Sulphur was found in the surface horizons of the pedons of paddy growing areas than in the subsurface horizons, possibly as a result of the surface layers having more organic matter than the deeper layers. The identical results were reported by Thangasamy *et al.* (2005) and Raghuet *et al.* (2022).

**Table 1. Physico-chemical properties of soils**

Pedon No. & Horizon	Depth (m)	Organic carbon (%)	CaCO <sub>3</sub> (%)	pH 1:2.5		EC(dS m <sup>-1</sup> )
				H <sub>2</sub> O	1N KCl	
<b>Pedon 1</b>						
Ap	0.00-0.26	0.60	11.5	7.89	7.02	0.25
A/B	0.26-0.56	0.24	7.5	8.08	6.69	0.19
Bt <sub>n1</sub>	0.56-0.79	0.04	11.5	8.12	6.63	0.18
Bt <sub>n2</sub>	0.79-1.15	0.01	11.5	8.13	6.63	0.21
Cr	1.15	Weathered gneiss				
<b>Pedon 2</b>						
Ap	0.00-0.28	0.18	12.5	8.54	7.10	0.31
B/A	0.28-0.50	0.13	12.5	8.13	6.61	0.24
Bt <sub>1</sub>	0.50-0.80	0.10	12.0	8.02	6.66	0.19
Bt <sub>2</sub>	0.80-1.16	0.07	12.5	7.92	6.27	0.20
Bt <sub>3</sub>	1.16-1.60	0.04	13.5	8.01	6.56	0.20
Cr	1.60	Weathered gneiss				
<b>Pedon 3</b>						
Ap	0.00-0.25	0.39	15.5	6.56	4.72	0.14
Bt <sub>1</sub>	0.25-0.45	0.27	14.0	6.03	4.31	0.03
Bt <sub>2</sub>	0.45-0.70	0.06	14.0	7.00	5.24	0.09
<b>Pedon 4</b>						
Ap	0.00-0.30	0.16	18.0	8.96	7.14	1.20
Bw	0.30-0.60	0.07	24.5	9.15	7.29	1.06
BC	0.60-0.90	0.06	15.5	9.27	7.33	0.69
Cr	0.90	Weathered gneiss				
Mean		0.16	13.76	7.98	6.41	0.34
Range		0.01-0.60	7.5-24.5	6.03-9.27	4.31-7.33	0.03-1.20

**Table 2(a). Macronutrient status of paddy growing soils of Vepurikotamicrowatershed of Chittoor district**

Pedon No. & Horizon	Depth (m)	Available macronutrients			
		N	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O	S
		(Kg ha <sup>-1</sup> )			(mg kg <sup>-1</sup> )
<b>Pedon 1</b>					
Ap	0.00-0.26	175.62	217.41	381.70	38.31
A/B	0.26-0.56	125.44	60.82	195.55	15.20
Bt <sub>n1</sub>	0.56-0.79	150.53	62.47	147.17	9.15
Bt <sub>n2</sub>	0.79-1.15	125.44	62.68	106.18	7.28
Cr	1.15	Weathered gneiss			
<b>Pedon 2</b>					
Ap	0.00-0.28	200.70	80.51	189.50	25.20
B/A	0.28-0.50	150.53	74.46	188.16	16.58
Bt <sub>1</sub>	0.50-0.80	125.44	52.04	181.44	6.20
Bt <sub>2</sub>	0.80-1.16	125.44	48.63	158.59	6.01
Bt <sub>3</sub>	1.16-1.60	112.90	46.39	149.18	5.29
Cr	1.60	Weathered gneiss			
<b>Pedon 3</b>					
Ap	0.00-0.25	225.79	86.44	114.64	35.24
Bt <sub>1</sub>	0.25-0.45	150.53	86.06	74.19	21.45
Bt <sub>2</sub>	0.45-0.70	150.53	75.15	73.25	11.25
Cr	0.70	Weathered gneiss			
<b>Pedon 4</b>					
Ap	0.00-0.30	112.90	58.87	135.21	45.25
Bw	0.30-0.60	75.26	77.28	133.32	24.56
BC	0.60-0.90	62.72	46.19	132.38	22.15
Cr	0.90	Weathered gneiss			
<b>Mean</b>		137.98	75.69	157.36	19.27
<b>Range</b>		62.72-225.79	46.19-217.41	73.25-381.70	5.29-45.25

**Table 2(b). Micronutrient status of paddy growing soils of Vepurikotamicrowatershed of Chittoor district**

Pedon No. & Horizon	Depth (m)	Available macronutrients			
		Zn	Cu	Fe	Mn
		(mg kg <sup>-1</sup> )			
<b>Pedon 1</b>					
Ap	0.00-0.26	0.95	1.83	46.57	13.39
A/B	0.26-0.56	0.29	0.53	10.68	20.19
Btn1	0.56-0.79	0.32	0.30	12.47	33.45
Btn2	0.79-1.15	0.35	0.25	7.77	15.20
Cr	1.15	Weathered gneiss			
<b>Pedon 2</b>					
Ap	0.00-0.28	0.37	1.74	19.78	6.55
B/A	0.28-0.50	0.26	1.37	9.95	11.75
Bt1	0.50-0.80	0.22	1.52	9.54	23.10
Bt2	0.80-1.16	0.21	1.11	8.99	21.64
Bt3	1.16-1.60	0.16	1.35	8.04	22.49
Cr	1.60	Weathered gneiss			
<b>Pedon 3</b>					
Ap	0.00-0.25	0.74	1.58	30.24	14.77
Bt1	0.25-0.45	0.31	0.74	42.29	30.14
Bt2	0.45-0.70	0.28	0.41	11.38	22.25
Cr	0.70	Weathered gneiss			
<b>Pedon 4</b>					
Ap	0.00-0.30	0.33	0.48	3.09	4.21
Bw	0.30-0.60	0.12	0.35	2.15	2.02
BC	0.60-0.90	0.06	0.32	1.61	1.27
Cr	0.90	Weathered gneiss			
Mean		0.33	0.93	14.97	16.16
Range		0.12-0.95	0.25-1.83	2.15-46.57	1.27-33.45

### **Micronutrients:**

The available zinc content in pedons of paddy cultivating areas was varied from 0.12 mg kg<sup>-1</sup> to 0.95 mg kg<sup>-1</sup> with a mean value of 0.33 mg kg<sup>-1</sup> (Table 2b). Considering 0.6 mg Zn kg<sup>-1</sup> soil as critical limit, Both the surface and subsurface horizons in pedons 2 and 4 were below the critical limit and revealed lower values than the critical limit, while the surface horizons in pedons 1 and 3 were more than the critical limit. The low available zinc was possibly due to high soil pH values which might have resulted in the formation of insoluble compounds of zinc or insoluble calcium zincate (Jagdish Prasad *et al.*, 2009). This was supported by significant and positively correlation ( $r = +0.880^*$ ) of Zn with organic carbon. Similar findings were reported by Sadanshiv *et al.* (2017) and Satish *et al.* (2018) in Nagalwadimicrowatershed and Brahmanakotkur watershed, respectively.

The available iron content in all the pedons was found to be varied from 2.15 and 46.57 mg kg<sup>-1</sup> soil with a mean of 14.97 mg kg<sup>-1</sup> soil (Table 2b). Considering the critical limit of 4.5 mg kg<sup>-1</sup> soil, the paddy cultivating soils were sufficient in available Fe content except pedon 4. The pattern of available iron in all the pedons showed a decreasing trend with depth. The high iron content might be due to accumulation of organic carbon in the surface horizons and affinity to influence the availability by chelation effect. Similar results were reported by Prasad and Sakal, (1991) and Satish *et al.* (2018).

Available Cu in the pedons ranged from 0.25 to 1.83 mg kg<sup>-1</sup> with an average value of 0.93 mg kg<sup>-1</sup> (Table 2b). Considering 0.2 mg Cu kg<sup>-1</sup> soil as a critical limit the available Cu in paddy producing areas was sufficient in both the horizons of four pedons. Accumulation of more amount of organic carbon might have fixed more copper which is proved by a positive correlation ( $r = +0.557^*$ ) with organic carbon. Similar observations were also reported by Choudhury *et al.* (2019).

The available Mn content in paddy growing soils varied from 1.27 to 33.45 mg kg<sup>-1</sup> with a mean of 16.16 mg kg<sup>-1</sup> (Table 2b). The available manganese in all the pedons was found to be adequate except pedon 4 considering the critical limit of 2.0 mg Mn kg<sup>-1</sup> soil. In general, the increased Mn in surface horizons might be the result of both chelating organic chemicals released during the decomposition of organic materials left over after crop harvest

and substantially higher biological activity. It is possible that the parent material is the source of the greater Mn (above the critical limit) observed in subsurface horizons. A positive correlation ( $r = +0.153^{**}$ ) among available manganese and organic carbon further supports it. Similar findings were made by Dinesh *et al.* (2020).

## CONCLUSIONS

Paddy producing areas of Vepurikotamicrowatershed were classified into Inceptisols (VerticHaplustepts) and Alfisols (Typic Natrustalfs and Typic Haplustalfs). These soils were slightly acidic to strongly alkaline, non-saline and low in organic carbon. They were low in available nitrogen and medium to high in available  $P_2O_5$ , low to high in available  $K_2O$  and deficient to sufficient in available sulphur. The DTPA extractable Cu was found to be sufficient in both the horizons of all the pedons. The available zinc content was deficient to sufficient in all four pedons and the available Fe and Mn were found to be sufficient and above the critical limits except pedon 4. Land-use planning in the study area should be based on the soil's physico-chemical properties and nutrient status. Enhancing soil health and sustaining production can be achieved by supplementing deficient nutrients with organic materials in combination with inorganic fertilizers.

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