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Assessment of Vertical Nutrient Stratification in Paddy Cultivating Soils in Vepurikota Microwatershed of Andhra Pradesh, India

G. Sivanagaraju [a++*], M.V.S. Naidu [b#], B.P. Bhaskar [c†], K.V. Naga Madhuri [d†], V. Ramamurthy [c‡] and SK. Nafeez Umar [e++]

[a] Department of Agricultural and Horticultural Sciences, Vignan Foundation for Science, Technology and Research, Vadlamudi-522213, India.
[b] Department of Soil Science and Agricultural Chemistry, S.V. Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati– 517 502, India.
[c] ICAR- NBSS&LUP, Regional Centre, Hebbal, Bangalore – 560024, India.
[d] Institute of Frontier Technology, RARS, Tirupati- 517502, India.
[e] Department of Statistics and Computer Applications, S.V. Agricultural College, Acharya N.G. Ranga Agricultural University, Tirupati– 517 502, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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[++] *Assistant Professor;*
[#] *Professor & Head;*
[†] *Principal Scientist (Soil Science);*
[‡] *Principal Scientist & Head (Agronomy);*
**Corresponding author: E-mail: sivanagaraju093@gmail.com;*

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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; micronutrients; organic carbon; pH; surface horizon; sub-surface horizon.

1. 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 [1]. 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 [2] 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 [3]. 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 Vepurikota microwatershed. Considering these factors, the present study was meticulously planned and executed to address this gap.

2. MATERIALS AND METHODS

2.1 Details of Study Area

Vepurikota microwatershed 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.

2.2 Soil Sampling and Taxonomic Categorisation

Four pedons were selected for asessment in the paddy cultivating areas of Vepurikota microwatershed 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 [4]. The critical limits proposed by Muhr et al*.* [5] for available N, P_2O_5 and K_2O, Tandon [6] and available S (10 mg kg^{-1}), In respect of available micronutrients, the ratings given by Lindsay and Norvell [7] for Zn (0.6 mg kg^{-1}), Fe (4.5 mg kg^{-1}), Cu (0.2 mg kg^{-1}) and Mn (2 mg kg^{-1}) were considered for classifying profile soil samples into sufficient or deficient for paddy cultivation.

3. RESULTS AND DISCUSSION

3.1 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 [8]. 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 [9]. The EC in paddy growing soils was ranged from 0.03 to 1.20 dSm^{-1} 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 [10]. 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*.* [11].

3.2 Macronutrients

The available nitrogen content varied from 62.72 - 225.79 kg ha^{-1} in pedons of paddy cultivating areas with a mean of 137.98 kg ha^{-1} of nitrogen (Table 2a). Considering 280 kg ha^{-1} 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 NO3-N, which is readily leached and subsequently lost from the soil. Similar findings were documented by Sharma et al*.* [12] and Borse et al*.* [13].

The available P_2O_5 content varied from 46.19-217.41 kg ha^{-1} in all the pedons of paddy producing areas with a mean of 75.69 kg ha^{-1} as indicated in Table 2a. Considering 22.8 kg ha^{-1} as critical limit, the available P_2O_5 status was medium to high in both the horizons and in the pedons 2 and 3, the available P_2O_5 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 [14]. 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 (Osujieke 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 acribed for 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 [15].

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*.* [16] and Raghu et al*.* [17].

Table 1. Physico–chemical properties of soils

Pedon No. & Horizon	Depth (m)	Organic carbon (%)	$CaCO_3$ (%)	pH 1:2.5		EC(dS m^{-1})
				H_2O	*1N* KCl	
Pedon 1						
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
Btn1	0.56-0.79	0.04	11.5	8.12	6.63	0.18
Btn2	0.79-1.15	0.01	11.5	8.13	6.63	0.21
Cr	1.15	Weathered gneiss				
Pedon 2						
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
Bt1	0.50-0.80	0.10	12.0	8.02	6.66	0.19
Bt2	0.80-1.16	0.07	12.5	7.92	6.27	0.20
Bt3	1.16-1.60	0.04	13.5	8.01	6.56	0.20
Cr	1.60	Weathered gneiss				
Pedon 3						
Ap	0.00-0.25	0.39	15.5	6.56	4.72	0.14
Bt1	0.25-0.45	0.27	14.0	6.03	4.31	0.03
Bt2	0.45-0.70	0.06	14.0	7.00	5.24	0.09
Pedon 4						
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 Vepurikota microwatershed of Chittoor district

Pedon No. & Horizon	Depth (m)	Available macronutrients			
		N	P_2O_5	K_2O	S
			(Kg ha^{-1})		(mg kg^{-1})
Pedon 1					
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
Btn1	0.56-0.79	150.53	62.47	147.17	9.15
Btn2	0.79-1.15	125.44	62.68	106.18	7.28
Cr	1.15	Weathered gneiss			
Pedon 2					
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
Bt1	0.50-0.80	125.44	52.04	181.44	6.20
Bt2	0.80-1.16	125.44	48.63	158.59	6.01
Bt3	1.16-1.60	112.90	46.39	149.18	5.29
Cr	1.60	Weathered gneiss			
Pedon 3					
Ap	0.00-0.25	225.79	86.44	114.64	35.24
Bt1	0.25-0.45	150.53	86.06	74.19	21.45
Bt2	0.45-0.70	150.53	75.15	73.25	11.25
Cr	0.70	Weathered gneiss			
Pedon 4					
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			
Mean		137.98	75.69	157.36	19.27
Range		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 Vepurikota microwatershed of Chittoor district

Pedon No. & Horizon	Depth (m)	Available macronutrients			
		Zn	Cu	Fe	Mn
		(mg kg^{-1})			
Pedon 1					
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			
Pedon 2					
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			
Pedon 3					
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			
Pedon 4					
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

3.3 Micronutrients

The available zinc content in pedons of paddy cultivating areas was varied from 0.12 mg kg^{-1} to 0.95 mg kg^{-1} with a mean value of 0.33 mg kg^{-1} (Table 2b). Considering 0.6 mg Zn kg^{-1} 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*.* [18] and Satish et al*.* (2018) in Nagalwadi microwatershed 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^{-1} soil with a mean of 14.97 mg kg^{-1} soil (Table 2b). Considering the critical limit of 4.5 mg kg^{-1} 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, [19] and Satish et al*.* (2018).

Available Cu in the pedons ranged from 0.25 to 1.83 mg kg^{-1} with an average value of 0.93 mg kg^{-1} (Table 2b). Considering 0.2 mg Cu kg^{-1} 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*.* [20].

The available Mn content in paddy growing soils varied from 1.27 to 33.45 mg kg^{-1} with a mean of 16.16 mg kg^{-1} (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^{-1} 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*.* [21].

4. CONCLUSIONS

Paddy producing areas of Vepurikota microwatershed were classified into Inceptisols (Vertic Haplustepts) 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.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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