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Vertical distribution of available nutrients in soils of Brahmanakotkur watershed of Kurnool district in Andhra Pradesh

S Satish, MVS Naidu and KV Ramana

Abstract
The detailed soil survey was carried out in Brahmanakotkur watershed of Kurnool district in the year 2018 using toposheet (1:50,000) and LISS IV image as base map. For this, six pedons viz., Brahmanakotkur (P1 to P4), Paipalem (P5) and Diguvapadu (P6) were studied. The soils were analysed for macro and micro nutrients status by adopting standard analytical procedures. The study revealed that the soils were shallow to very deep with profile development of A-Bw-C, A-Bss-C and A-C in Plains, Lowlands and Uplands, respectively. The Organic carbon content was more in surface horizons than in sub-surface horizons. However, the available nitrogen was low, available phosphorus, potassium and sulphur was low to high status. DTPA extractable micronutrient Zn was found to be sufficient in surface horizons and deficient in sub-surface horizons excepting in pedons 3 and 5 wherein it was found to be sufficient in pedon 3 and deficient in pedon 5. The DTPA extractable Fe and Zn was found to be deficient to sufficient whereas DTPA extractable Cu and Mn were found to be sufficient. The available macro and micronutrients were decreased with increasing depth in all the pedons.

Keywords: Detailed soil survey, macro nutrients, micro nutrients, watershed and Kurnool district

Introduction

Soils in general are degrading due to poor management and faulty land use at a rate faster than their natural degeneration, it becomes imperative to protect them from further degradation; as there is a concomitant decline in soil quality to produce healthy crops. Many crops are long duration and heavy feeder of nutrients, it uptakes considerable amount of plant nutrients from soil. As a result, the nutrient ability of soil to supply plant nutrients is declining day by day which leads to decline in productivity of crops till recently. Further, intensive cropping and imbalanced use of essential plant nutrients have rendered the soils to be poor in organic carbon content and deterioration in physical properties (Speir *et al*., 2004) [17] lead to restricted growth and development of the crop. The major and micronutrients govern the fertility of the soils and control the yields of the crops. In the recent past, concept of watershed based holistic development has emerged as one of the potential approaches in rainfed areas, which can lead to higher productivity and sustainability in agricultural production. Although the wide spread deficiencies of major and micronutrients in Kurnool district had been reported by Sireesha and Naidu (2013) [15]. However, the research work on detailed soil resource inventory of Brahmanakotkur watershed in particular and in Kurnool district of Andhra Pradesh in general is very much lacking. Hence, the present investigation was planned and carried out.

Material and methods

The present investigation involves detailed soil resource inventory of Brahmanakotkur watershed in Kurnool district of Andhra Pradesh using remote sensing and GIS. The Brahmanakotkur watershed lies in between 15o.46' to 15o.50' of North latitudes and 78o.09' to 78o.13' of East longitudes. It has a total geographical area of 2,931 ha and comprises of four villages namely Gargeyapuram, Diguvapadu, Paipalem and Damagatla. Before starting fieldwork, preliminary traverse of the entire watershed was carried out using 1:10,000 base map (Fig.1) and satellite imagery (Fig.2). The study area was confined to semi-arid monsoonic climate with receives a mean annual rainfall of 543.73 mm and mean annual temperature was 28.92^{o}C and mean maximum and minimum temperatures were 34.86^{o}C and 22.98^{o}C, respectively. The area has ustic moisture regime and isohyperthermic temperature regime.

During the traverse based on geology, drainage pattern, surface features, slope characteristics and land use, landforms and physiographic divisions were identified. After delineating the landform on the satellite image, intensive traversing of the each landform was undertaken to select the representative areas for transect study. Later, horizon-wise soil samples were collected (Table 1) and analysed for their physical and physico-chemical properties and available macro and micro nutrient status using standard procedures and classified according to Soil Taxonomy (Soil Survey Staff, 2014) [16].

Available nitrogen was estimated by alkaline permanganate method as given by Subbiah and Asija (1956) [18]. The available phosphorus was extracted by Olsen's Extractant (0.5 N NaHCO3 at pH 8.5), available potassium was extracted by 1N ammonium acetate at pH 7 and then determined with the help of flame photometer using K-filter (Jackson, 1973) [3] and available sulphur (S) was measured using 0.15 per cent calcium chloride ($CaCl_2.2H_2O$) as an extractant (Williams and Steinbergs, 1959) [22]. The micronutrient estimation was done by using the method outlined by Lindsay and Norvell (1978) [5] The soil samples were classified into low, medium and high categories as per limits suggested by Muhr *et al.*, (1965) [7] for available N, P and K. Available sulphur was rated based on the limits proposed by Tandon (1991) [19]. In respect of available micronutrients, the ratings given by Lindsay and Norvell (1978) [5] were followed.

Results and discussion

The depth of different pedons studied from watershed area found to have shallow to very deep solum. Soils are neutral to strongly alkaline in reaction, non- saline in nature and low to medium in organic carbon. Low organic carbon content in soils might be attributed to the prevalence of tropical conditions, where the degradation of organic matter occurs at a faster rate coupled with low vegetation cover, thereby leaving less organic carbon in the soils. The wide variation in soil characteristics is mostly associated with variation in slope, vegetation cover, parent material and slop, aspect. The soils are mostly subjected to slight to moderate erosion and sub-soil the slickensides were formed mainly due to the differences between the horizontal stress and vertical stress (Wilding and Tessier, 1988) [21].

Available Macronutrients

The available nitrogen (Table 2) in the studied area was rated as low and the range of available nitrogen varied from 45.16 to 163.07 kg ha-1 throughout the depth with a mean value of 110.07 kg ha^{-1}. All the profiles showed that the available nitrogen decreases with the increase in depth. Increasing trend of Nitrogen increased with the altitude. Soil fertility exhibits the status of different soils with regard to the amount and availability of nutrients essential for plant growth. However, the available nitrogen was found to be maximum in the surface horizons and decreased more or less with depth of the pedons, which might be due to the decreasing trend in organic carbon with depth. The available nitrogen was found higher in high altitude compared to mid and low altitude. This can be attributed to the high organic carbon/matter in high altitude soils. (Satish Kumar and Naidu, 2012 and Sireesha and Naidu, 2013) [11, 15].

The available phosphorus in the pedons varied from 2.29 to 151.51 kg ha-1 with a mean value of 47.53 kg ha^{-1} (Table 2) and was rated as low to high. The higher available phosphorus was observed in the surface horizons and decreased with depth regularly. The higher phosphorus in the surface horizons might possibly be due to confinement of crop cultivation to the rhizosphere and supplementing the depleted phosphorus by external sources i.e. fertilizers and also due to presence of small amount of free iron oxide and exchangeable Al+3 (Singh and Mishra, 2012) [14]. The low phosphorus content could be attributed to the fixation of released phosphorus by clay minerals and oxides of iron and aluminium. (Thangasamy *et al.*, 2005) [20]. However, the data depicted that the available phosphorus was slightly high in low altitude soils which might be due to the continuous use of Phosphatic fertilizers resulted in the built up of phosphorus in intensity cultivated low altitude soils (Sharma *et al.*, 2008) [12]

Available potassium was medium in surface horizons and showed a regular decrease with the depth. The available potassium ranged from 88.17 to 395.00 $kgha^{-1}$ with a mean value of 205.85 kg ha^{-1} (Table 2) and was rated as low to high. The highest available potassium was observed in the surface horizons and showed more or less a decreasing trend with depth (Sireesha and Naidu, 2013) [15]. Slow weathering of mica and fixation of released potassium might have resulted in low exchangeable potassium status (Ramprakash and Seshagiri Rao, 2002) [9]. The higher potassium could be attributed to more intense weathering, release of liable K from organic residues, application of K fertilizers and upward translocation of potassium from lower depths along with capillary raise of ground water. Amount and type of clay, organic carbon, soil pH and CEC significantly affected the soil K-availability.

It is known that chemical characteristics of a soil can vary with depth down the soil profile. The vertical variation in nitrogen, phosphorus and potassium is the result of profile distribution of the parent materials from which they derive or soil aggregations or concretions. Changes in soil management may also alter the vertical distribution of nutrients. The depth of accumulation and the amount of nutrients that accumulates also depends on rainfall and leaching. The graphical representation of distribution of N, P_2O_5 and K_2O nutrients was depicted in fig. 3.

The available sulphur in the soils varied from 1.87 to 18.75 mg kg^{-1} with a mean value of 8.80 mg kg^{-1} (Table 2) and was rated as low to high. The trend variation may also be attributed to the root distributional patterns of principle crops in soil profiles. Similar results were reported by Devi *et al.*, (2015) [1]. Surface layers contained almost 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 (Farida, 1997) [2].

Available Micronutrients

The study of the data on micronutrients of the soils presented in table 3 revealed that DTPA extractable zinc, copper, iron and manganese varied in their levels of sufficiency and deficiency. All the micronutrients in the study area show the decreasing trend with depth. The DTPA extractable zinc varied from 0.20 to 1.62 mg kg^{-1} soil with a mean value of 0.67 mg kg^{-1} soil (Table 3). Vertical distribution of zinc exhibited decreasing trend with depth. Considering 0.6 mg kg^{-1} soil as critical level (Lindsay and Norvell, 1978) [5] for available zinc, these soils were sufficient in surface horizons and deficient in sub-surface horizons in all the pedons except in pedons 3 and 5 wherein it was found to be sufficient in pedon 3 and deficient in pedon 5. The relatively higher values of available Zn may be attributed to variable intensity of pedogenic processes and more complexing with organic matter which resulted in chelating of Zn. 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) [4]. Less available zinc in some deeper layers was due to low amount of organic carbon in these deeper layers.

All the pedons were found to be sufficient in available copper (0.20 to 1.73 mg kg^{-1} soil with mean value of 0.98 mg kg^{-1} soil) (Table 3).as all the values were well above critical limit of 0.2 mg kg^{-1} soil as suggested by Lindsay and Norvell (1978) [5]. Accumulation of copper in surface horizons of all the soils may be due to its turnover by plant residues.

The available iron ranged from 1.76 to 6.48 mg kg^{-1} soil with mean value of 4.63 mg kg^{-1} soil (Table 3). According to the critical limit (4.5 mg kg^{-1} soil) of Lindsay and Norvell (1978) [5], the soils were deficient to sufficient in available iron content. The distribution of available iron in all the pedons show a decreasing trend with depth. The surface horizons contain more Fe than sub-surface horizons. It might be due to accumulation of organic carbon in the surface horizons. The organic carbon due to its affinity to influence the solubility and availability of iron by chelation effect might have protected the iron from oxidation and precipitation, which consequently increased the availability of iron (Prasad and Sakal, 1991) [8]. These results were further supported by significant and positive correlation of available iron with organic carbon (r = +0.477**) and negative and significant correlation with pH (r = -0.345**). These findings were in good agreement with those of Sarkar *et al*. (2000) [10].

According to critical limit of 1.0 mg kg^{-1} of Lindsay and Norvell (1978) [5], the soils were sufficient in available Mn. The available Mn in soils of watershed ranged from 2.44 to 15.46 mg kg^{-1} with a mean value of 7.23 mg kg^{-1} (Table 3) and all the pedons decreasing trend with depth which might be due to higher biological activity and organic carbon in the surface horizons, the higher content of available Mn in surface soils was attributed to the chelating of organic compounds released during the decomposition of organic matter left after harvesting of crop. The graphical representation of distribution of Zn, Fe, Cu and Mn nutrients was depicted in fig. 4.

The variation observed in available micronutrients within and among the profiles might be the result of variable intensity of different pedogenic processes taking place during soil development. Organic matter has been reported to play an important role in controlling the availability of micronutrients in soils. Decomposition of organic matter releases micronutrients and also reduces pH of soil locally, which helps in increasing solubility of micronutrient cations from soil. The availability of these ions (Zn, Cu, Fe and Mn) increased with increase in organic matter because organic matter acts as a chelating agent for complexation of these micronutrients which reduces their adsorption, oxidation and precipitation into unavailable forms. Similar kind of relationship between Zn and organic carbon was also reported by Mahesh Kumar *et al*. (2011) [6] and Sharma *et al*. (2003) [13].

Table 1: Details of Pedons

Pedon No.& village	Location	Elevation above msl (m)	Horizon	Horizon thickness (m)
1 (Brahmanakotkur)	15º49′00.9″ N 78º09′51.9″ E	328	Ap	0.00 – 0.20
			Bw	0.20 – 0.51
			Bss1	0.51 – 0.92
			Bss2	0.92 – 1.20
			Cr	1.20
2 (Brahmanakotkur)	15º48′46.7″ N 78º10′11.3″ E	324	Ap	0.00 – 0.21
			Bw	0.21 – 0.52
			Bss1	0.52 – 0.91
			Bss2	0.91 – 1.23
			Bss3	1.23 – 1.50+
4 (Brahmanakotkur)	15º49′14.7″ N 78º11′20.1″ E	315	Ap	0.00-0.22
			Bw	0.22-0.50
			R	0.50
13 (Brahmanakotkur)	15º49′32.4″ N 78º11′56.9″ E	293	Ap	0.00 – 0.20
			Bw	0.20 – 0.53
			Bss1k	0.53 – 0.80
			Bss2k	0.80 – 1.14
			Bss3	1.14- 1.50
			R	1.50
18 (Paipalem)	15º48′11.6″ N 78º12′56.7″ E	308	Ap	0.00 – 0.30
			Bw	0.30 – 0.62
			Bss1	0.62 – 0.90
			Bss2k	0.90 – 1.20
			Bss3k	1.20- 1.60+
21 (Diguvapadu)	15º46′56.3″ N 78º11′44.9″ E	330	Ap	0.00 – 0.18
			A2	0.18 – 0.35
			R	0.35

Table 2: Available macronutrient content of the soils

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 – 0.20	163.07	76.94	308.18	11.25
Bw	0.20 – 0.51	137.98	51.30	219.07	5.00
Bss1	0.51 – 0.92	127.98	11.72	192.06	4.37
Bss2	0.92 – 1.20	125.44	2.61	191.79	1.87
Cr	1.20				
Mean		138.62	35.64	227.78	5.62
Pedon 2					
Ap	0.00 – 0.21	163.07	151.51	203.08	18.75
Bw	0.21 – 0.52	137.98	46.17	153.08	7.50
Bss1	0.52 – 0.91	137.98	9.43	140.45	6.87
Bss2	0.91 – 1.23	124.44	4.90	130.50	4.62
Bss3	1.23- 1.50+	87.80	2.29	99.72	4.37
Mean		130.25	42.86	145.36	8.42
Pedon 3					
Ap	0.00-0.22	150.52	123.11	395.00	14.37
Bw	0.22-0.50	148.52	24.55	363.96	10.62
R	0.50				
Mean		149.52	73.83	379.48	12.50
Pedon 4					
Ap	0.00 – 0.20	150.17	65.77	151.20	13.75
Bw	0.20 – 0.53	85.26	65.04	146.23	12.50
Bss1k	0.53 – 0.80	72.24	42.87	131.71	7.50
Bss2k	0.80 – 1.14	62.72	34.26	120.54	4.25
Bss3	1.14- 1.50	50.17	14.11	90.67	3.12
R	1.50				
Mean		84.11	44.41	128.07	8.22
Pedon 5					
Ap	0.00 – 0.30	150.17	115.60	195.01	12.5
Bw	0.30 – 0.62	112.89	64.67	122.30	8.75
Bss1	0.62 – 0.90	112.89	56.79	113.70	8.75
Bss2k	0.90 – 1.20	75.26	33.53	95.42	7.37
Bss3k	1.20- 1.60+	62.72	5.13	88.17	3.75
Mean	102.79	55.14	122.92	8.22	102.79
Pedon 6					
Ap	0.0 -0.18	65.12	35.84	294.66	11.03
A2	0.18 – 0.35	45.16	30.73	168.26	8.56
R	0.35				
Mean		55.14	33.29	231.46	9.80
Total mean		110.07	47.53	205.85	8.80

Table 3: Available micronutrient status (mg kg^{-1}) of the soils

Pedon No. & Horizon	Depth (m)	Available micronutrients			
		Cu	Fe	Mn	Zn
Pedon 1					
Ap	0.00 – 0.20	1.70	6.48	15.46	0.97
Bw	0.20 – 0.51	1.43	6.38	11.96	0.84
Bss1	0.51 – 0.92	1.29	6.25	11.93	0.57
Bss2	0.92 – 1.20	1.25	6.13	8.92	0.45
Cr	1.20				
Mean		1.42	6.31	12.07	0.71
Pedon 2					
Ap	0.00 – 0.21	1.73	5.80	11.47	0.73
Bw	0.21 – 0.52	1.33	5.26	8.01	0.60
Bss1	0.52 – 0.91	1.18	5.14	7.45	0.59
Bss2	0.91 – 1.23	1.12	4.63	6.70	0.59
Bss3	1.23- 1.50+	0.96	3.27	5.95	0.37
Mean		1.26	4.82	7.92	0.58
Pedon 3					
Ap	0.00-0.22	1.44	4.90	11.82	1.62
Bw	0.22-0.50	1.39	4.42	11.61	0.85
R	0.50				
Mean		1.42	4.66	11.72	1.24
Pedon 4					

Ap	0.00 – 0.20	0.96	5.06	6.18	0.67
Bw	0.20 – 0.53	0.90	4.82	6.16	0.65
Bss1k	0.53 – 0.80	0.89	4.10	5.93	0.65
Bss2k	0.80 – 1.14	0.81	4.02	4.09	0.58
Bss3	1.14- 1.50	0.72	3.54	3.86	0.43
R	1.50				
Mean		0.86	4.31	5.24	0.60
Pedon 5					
Ap	0.00 – 0.30	1.02	3.63	4.33	0.34
Bw	0.30 – 0.62	0.68	3.55	3.56	0.34
Bss1	0.62 – 0.90	0.66	3.46	3.47	0.33
Bss2k	0.90 – 1.20	0.62	2.47	2.59	0.26
Bss3k	1.20- 1.60+	0.61	1.76	2.56	0.20
Mean		0.72	2.97	3.30	0.29
Pedon 6					
Ap	0.0 -0.18	0.21	5.16	3.88	0.64
A2	0.18 - 0.35	0.20	4.25	2.44	0.58
R	0.35				
Mean		0.21	4.71	3.16	0.61
Total mean		0.98	4.63	7.23	0.67

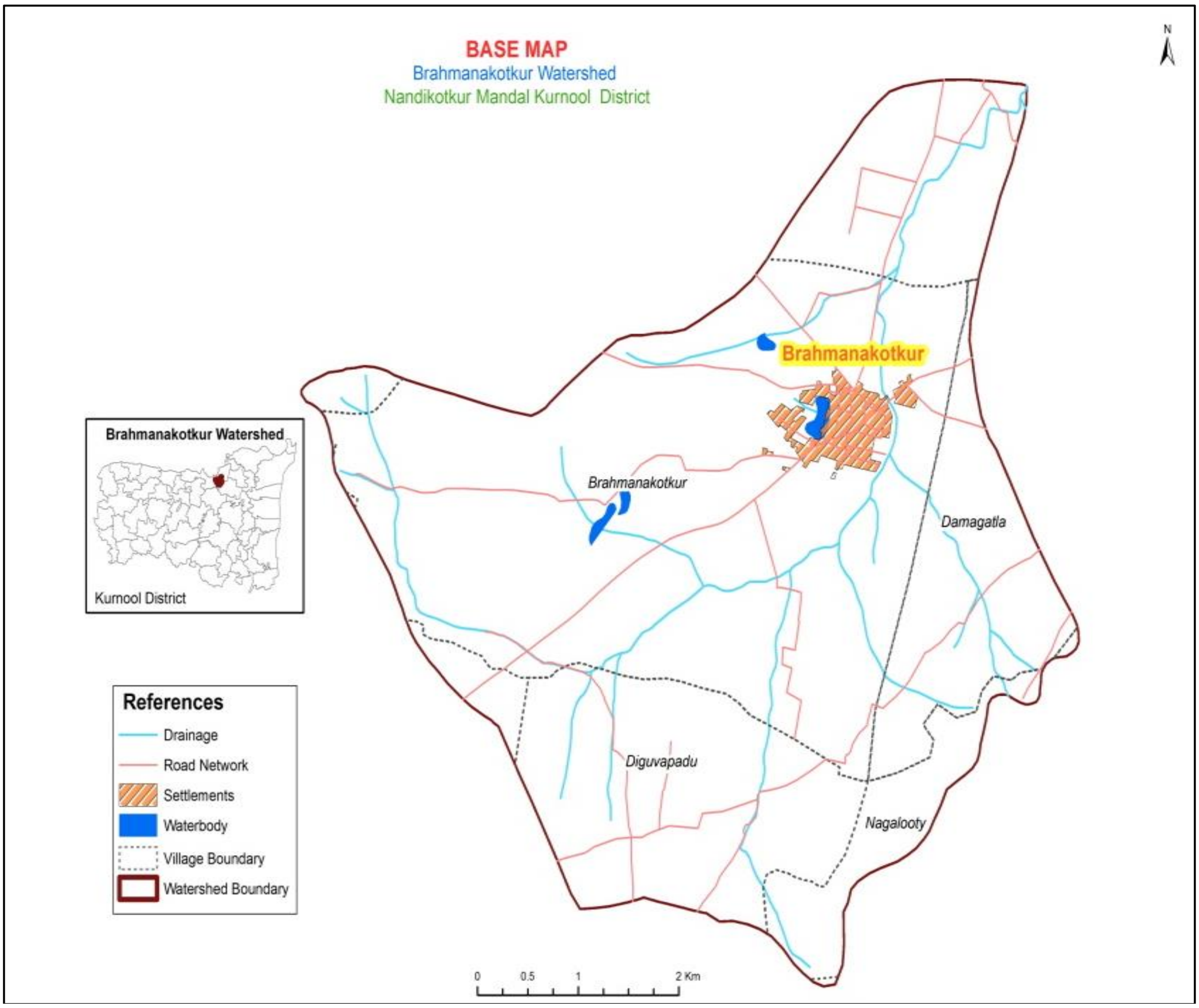


Fig 1: Base map of Brahmanakotkur watershed

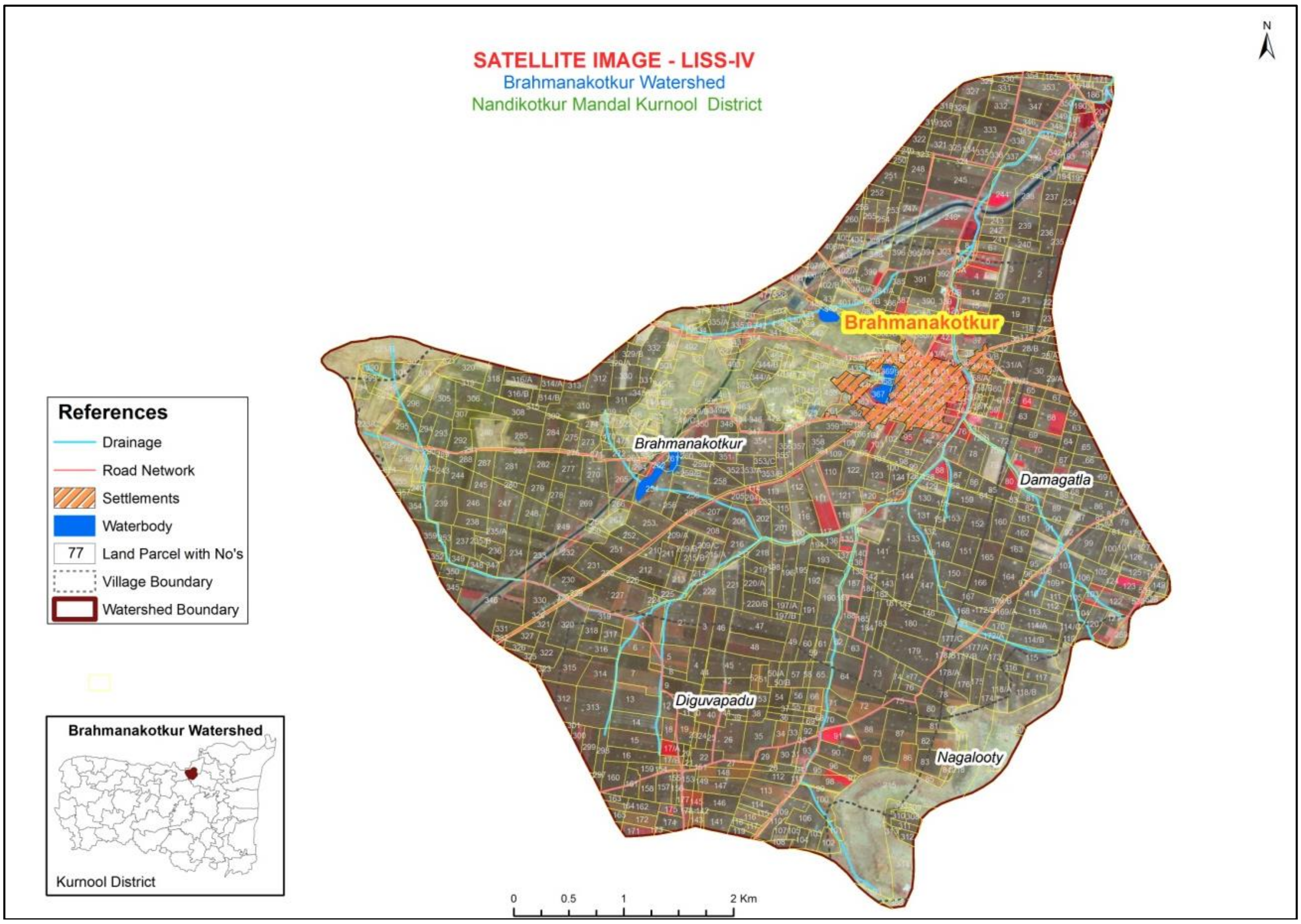
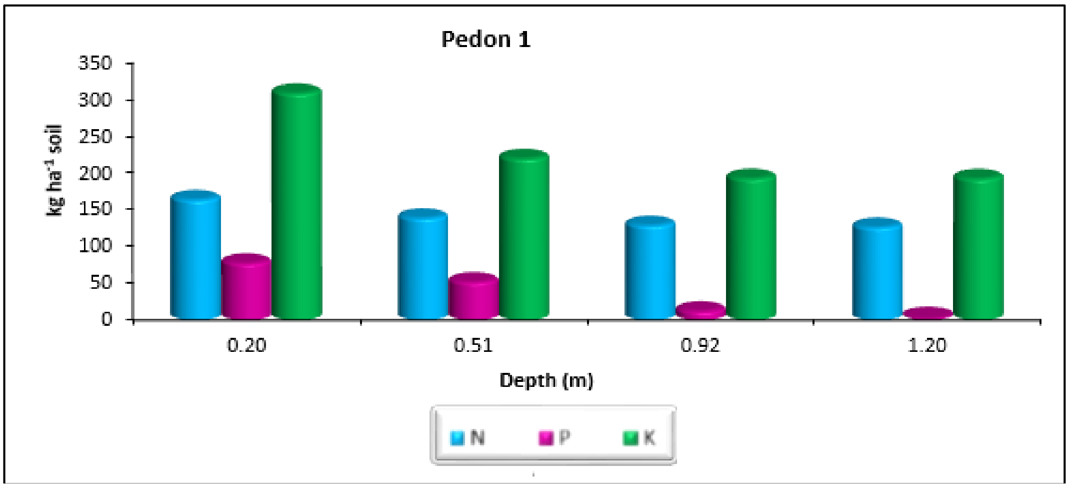
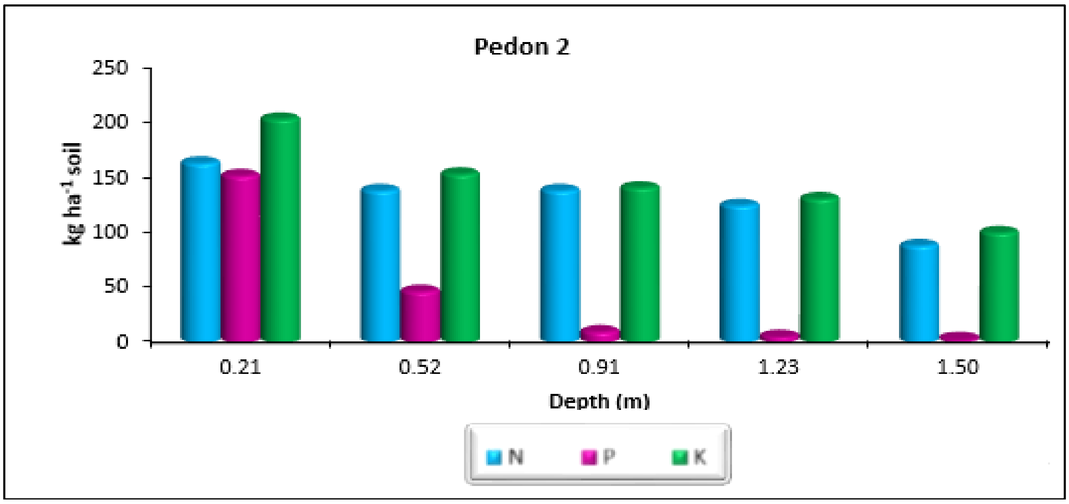


Fig 2: LIISS-IV image of Brahmanakotkur watershed





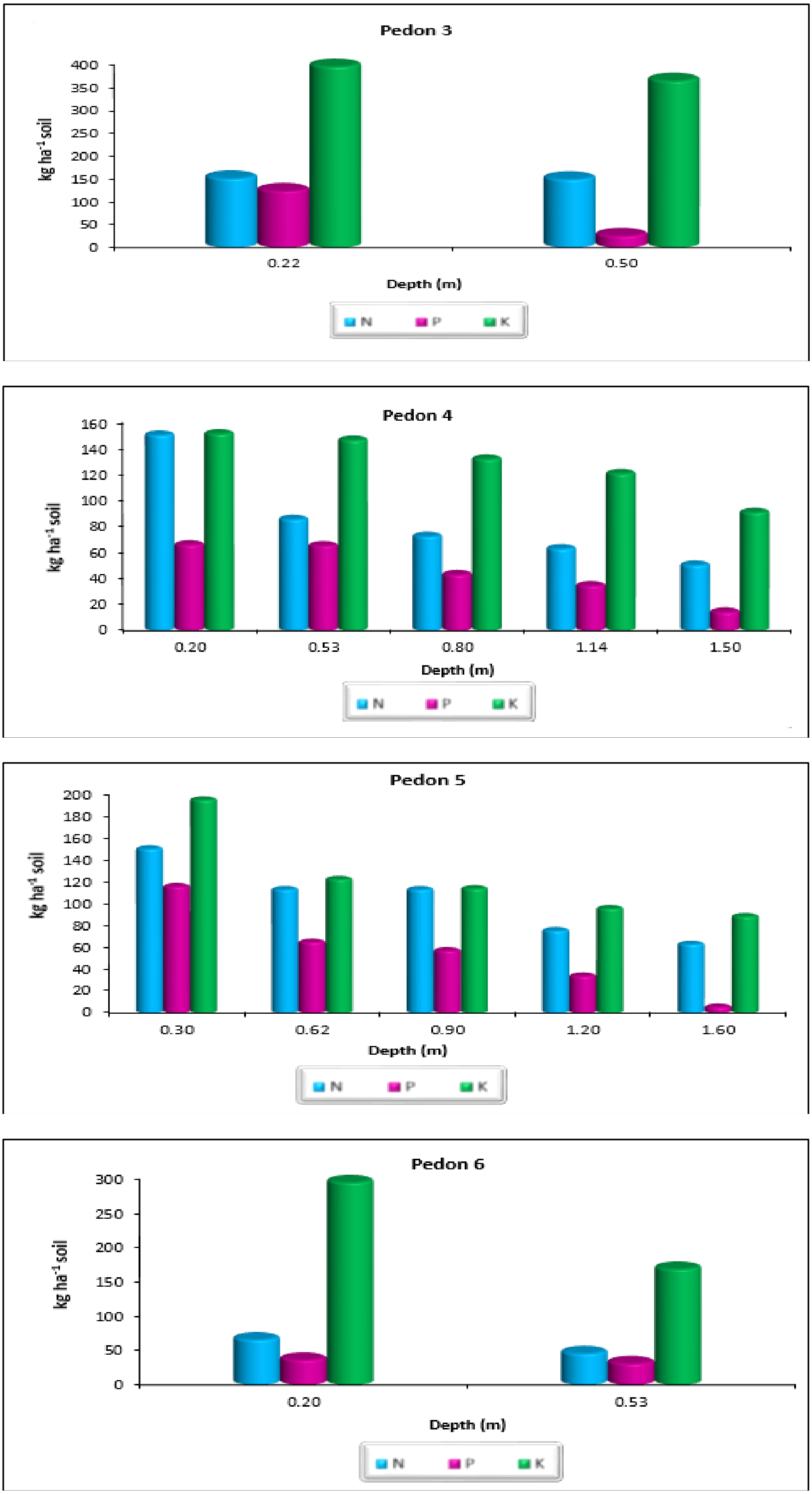
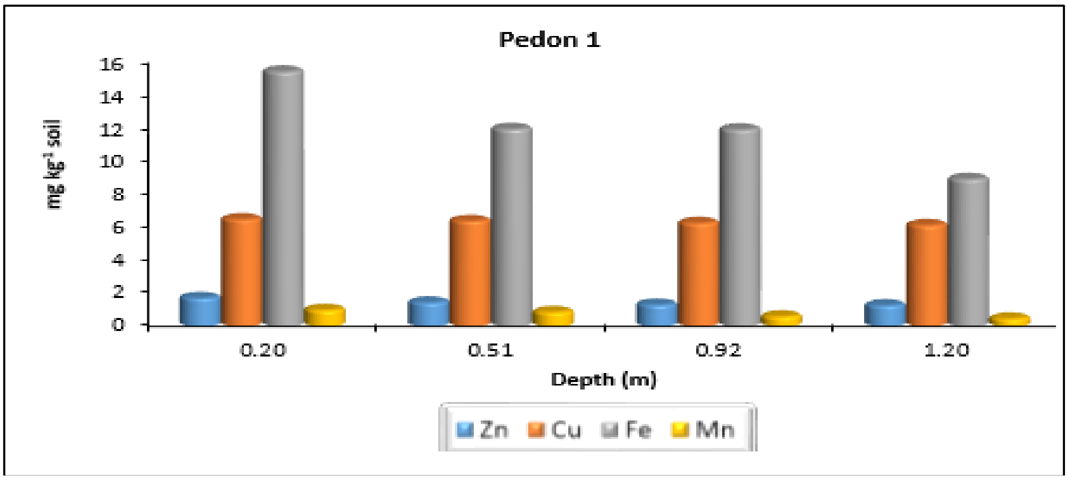
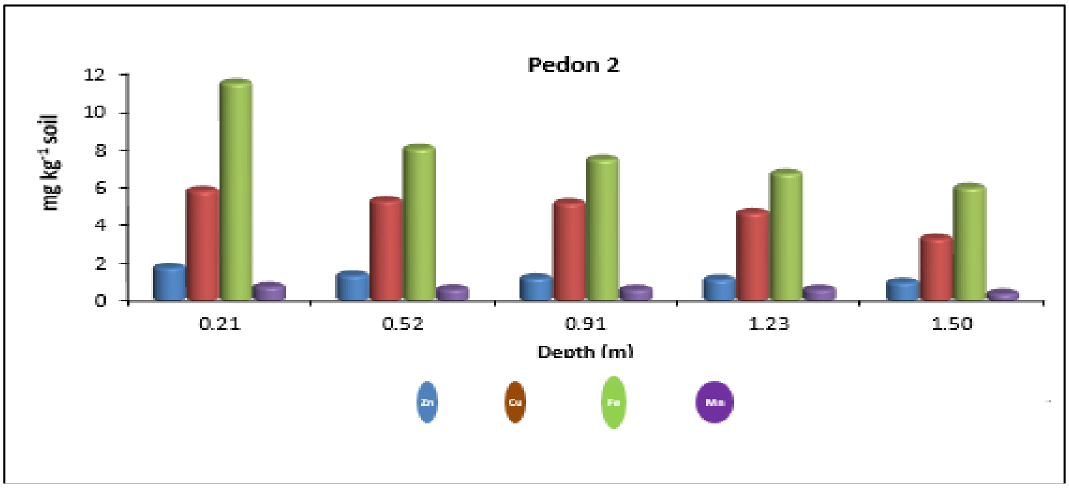
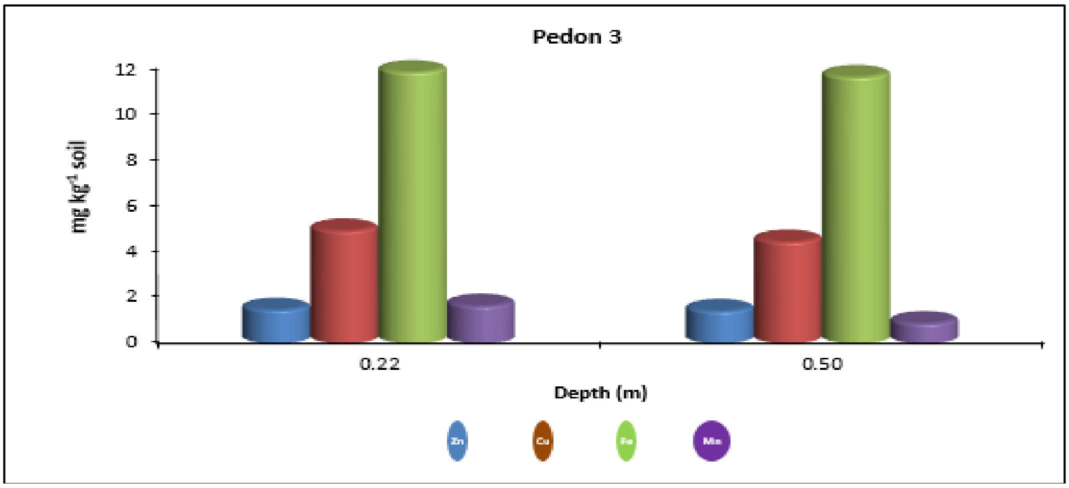
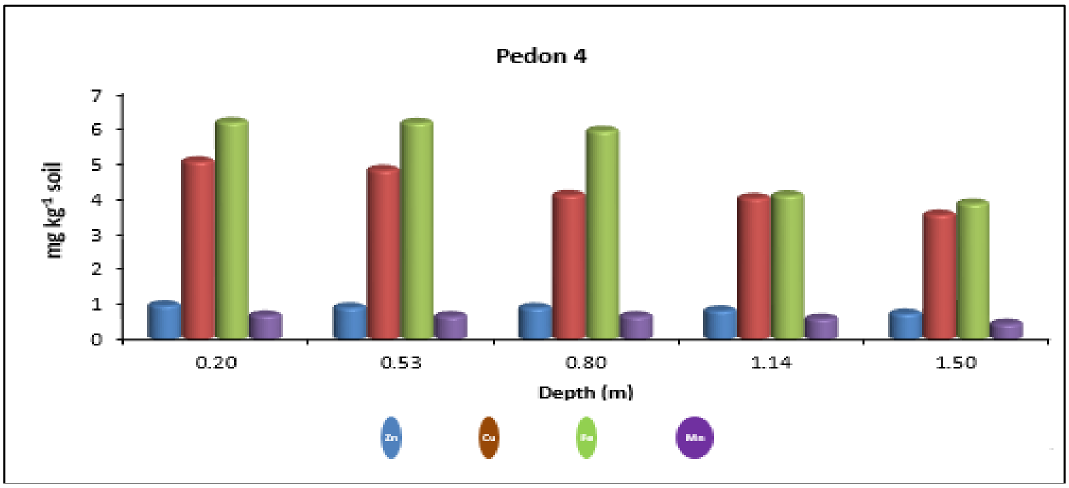


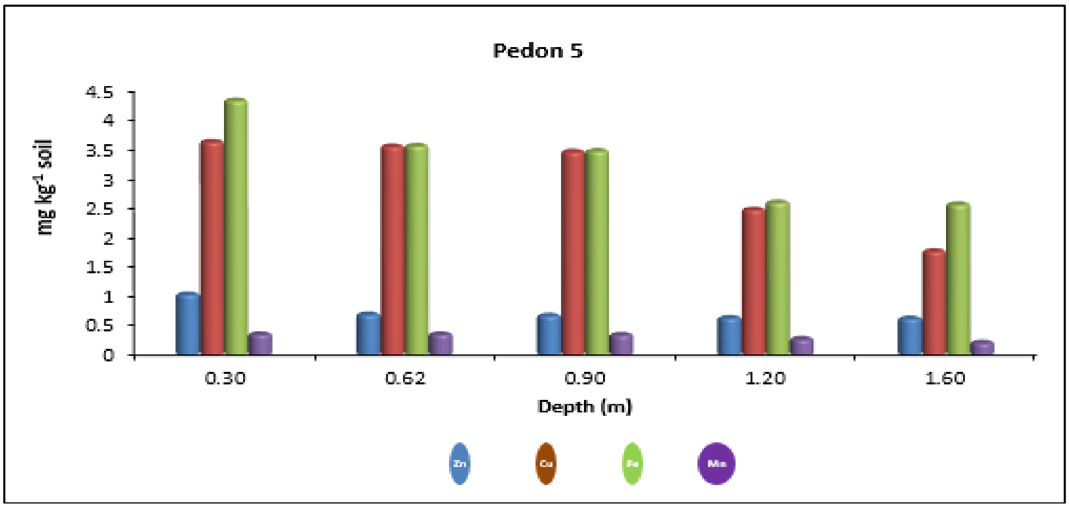
Fig 3: Vertical distribution of N, P and K in soils of Brahmanakotkur watershed


Pedon 1
16
14
12
10
8
6
4
2
0
mg kg-1 soil
0.20
0.51
0.92
1.20
Depth (m)
Zn
Cu
Fe
Mn


Pedon 2
12
10
8
6
4
2
0
mg kg-1 soil
0.21
0.52
0.91
1.23
1.50
Depth (m)


Pedon 3
12
10
8
6
4
2
0
mg kg-1 soil
0.22
0.50
Depth (m)


Pedon 4
7
6
5
4
3
2
1
0
mg kg-1 soil
0.20
0.53
0.80
1.14
1.50
Depth (m)



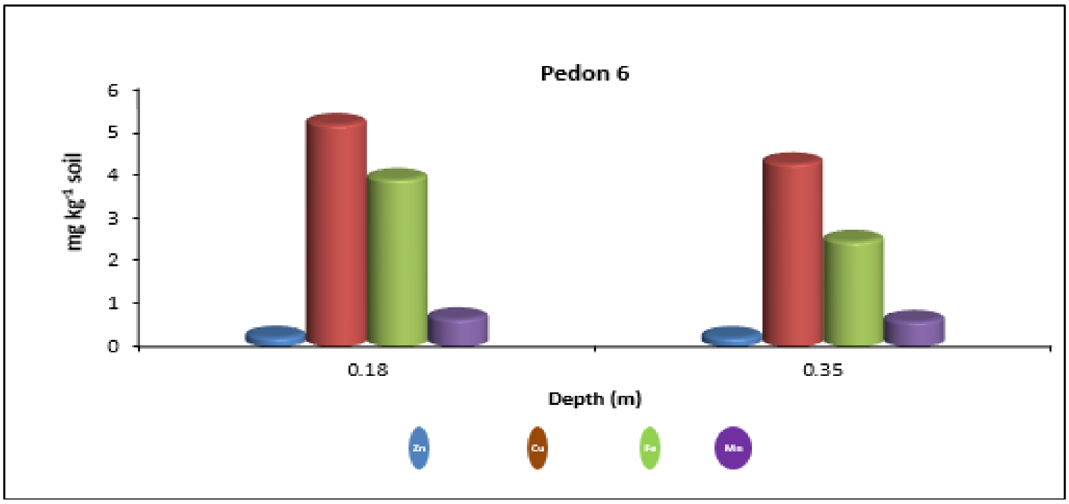


Fig 4: Vertical distribution of micronutrients of soils of Brahmanakotkur watershed

Conclusion

The vertical distribution of available macro and micronutrients status of soils of Brahmanakotkur watershed in Kurnool district of Andhra Pradesh as discussed above indicated that soils were low in available N, low to high in available P, K and S. With regard to DTPA extractable micronutrients the soil samples were deficient to sufficient in available Zn and Fe and sufficient with Cu and Mn. However, the available Zn was sufficient in surface horizons and deficient in sub-surface horizons in all the pedons except in pedons 3 and 5 wherein it was found to be sufficient in pedon 3 and deficient in pedon 5. Land use

planning should be done on the basis of physico-chemical properties and nutrient status of different horizons of upland and lowland soil of the study area. Supplementing the deficient nutrients through organics in combination with inorganic fertilizers not only improves the soil health but also sustains production of different crops like tobacco, bengalgram chillies etc. in these soils.

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