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RESEARCH PAPER

Identification of soil nutrient constraints by GIS technique in Belageri sub watershed of Karnataka for site specific recommendations

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Abstract: Soil samples from Belageri sub-watershed in northern dry zone of Karnataka were drawn at 250 m grid interval and analysed for their fertility parameters. Analytical data was interpreted with different statistical tools like range, mean, standard deviation and coefficient of variation for each parameter. Soil fertility maps were prepared for each parameter under GIS environment using Arc GIS v 10.4. Soils were neutral to very strongly alkaline in reaction with non saline to slight salinity. Soil organic carbon content was low to medium with low available nitrogen, low to medium available phosphorus, medium to high available potassium and low to medium available sulphur. Regarding available micronutrients, zin and iron were deficient in about half of the sub watershed area whereas, copper and manganese were sufficient in the soils. The mapping of nutrients by GIS technique in the sub watershed revealed that, available N, S, Zn and Fe are important soil fertility constraints.

Key words: Nutrients, Soil fertility map, Soil fertility constraints, Watershed

Introduction

Soil testing is usually followed by collecting composite soil samples in the fields without geographic reference. The results of such soil testing are not useful for site specific recommendations and subsequent monitoring. Soil available nutrients constraints of an area using Global Positioning System (GPS) will help in formulating site specific balanced fertilizer recommendation and to understand the status of soil fertility spatially and temporally. Geographic information system (GIS) is a powerful tool which helps to integrate many types of spatial information such as agro-climatic zone, land use, soil management, *etc*. to derive useful information (Adornado and Yoshida, 2008). It has been documented very well that dry land soils are not only thirsty but hungry too, meaning that besides soil and water conservation, if nutrient management issues are addressed, the productivity of a watershed is further enhanced. Some studies on soil fertility status at representative micro-watershed/village level have been carried out at the University of Agricultural Sciences, Dharwad for a few agro ecological zones. Such information is not available for contiguous micro watersheds or for a sub watershed in Karnataka and is essential in planning soil fertility management on a sub watershed area basis. The proposed study was planned with the objective of identifying available nutrients constraints in soils of Belageri sub watershed in northern dry zone of Karnataka.

Material and methods

The Belageri sub-watershed is located in Yelburga taluka of Koppal district covering an area of 5564.15 ha (Fig.1), falling under Northern Dry Zone of Karnataka. The sub watershed is located at about 30 km from Koppal city, bounded by Jarakunti, Guddagha, Thallura village on the north, Malakasamudra, Kudarikotagi is on west, Chikkamyageri, Huligudda on the east and Boodhagumpi, Kudagunti villages on the south. The sub-watershed consists of eleven micro watersheds having undulating topography with a vast degraded open scrub area. The peninsular gneiss covers the sub-watershed area. The predominant minerals observed in the peninsular gneiss are oligoclase and orthoclase feldspar. The climate of the area is semi-arid or hot tropical and monsoonic type. The maximum temperature during summer is 42.7 °C and the minimum 16.1 °C in winter. Mean maximum temperature was 36.56^{0}C and mean minimum temperature was 20.43 °C (Table 2). The average annual rainfall is 580.7 mm. It is well distributed with southwest monsoon (June to September) bringing 365 mm and northeast monsoon about 200 mm rain during October and November months.

Surface composite soil samples were collected during April 2017on grid points of 250 m interval in the study area and the sample location was recorded by GPS. A total of 884 samples were collected from the sub watershed. Micro watershed wise soil sample details are furnished in Table 1.

The soil samples were processed and analyzed for chemical and fertility parameters. The pH (1:2.5)and electrical conductivity (EC) (1:2.5) of soils were measured using standard procedures as described by Jackson (1973). Organic carbon (OC) was determined by Walkley-Black method (Nelson and Sommers, 1996). Available nitrogen (N) was estimated by modified alkaline permanganate method (Sahrawat and Burford, 1982). Available phosphorus (Olsen P) was measured using sodium bicarbonate ($NaHCO_3$) as an extractant (Olsen and Sommers, 1982). Available potassium (K) was determined using the ammonium acetate method (Helmke and Sparks, 1996). Available sulphur (S) was measured using 0.15 per cent calcium

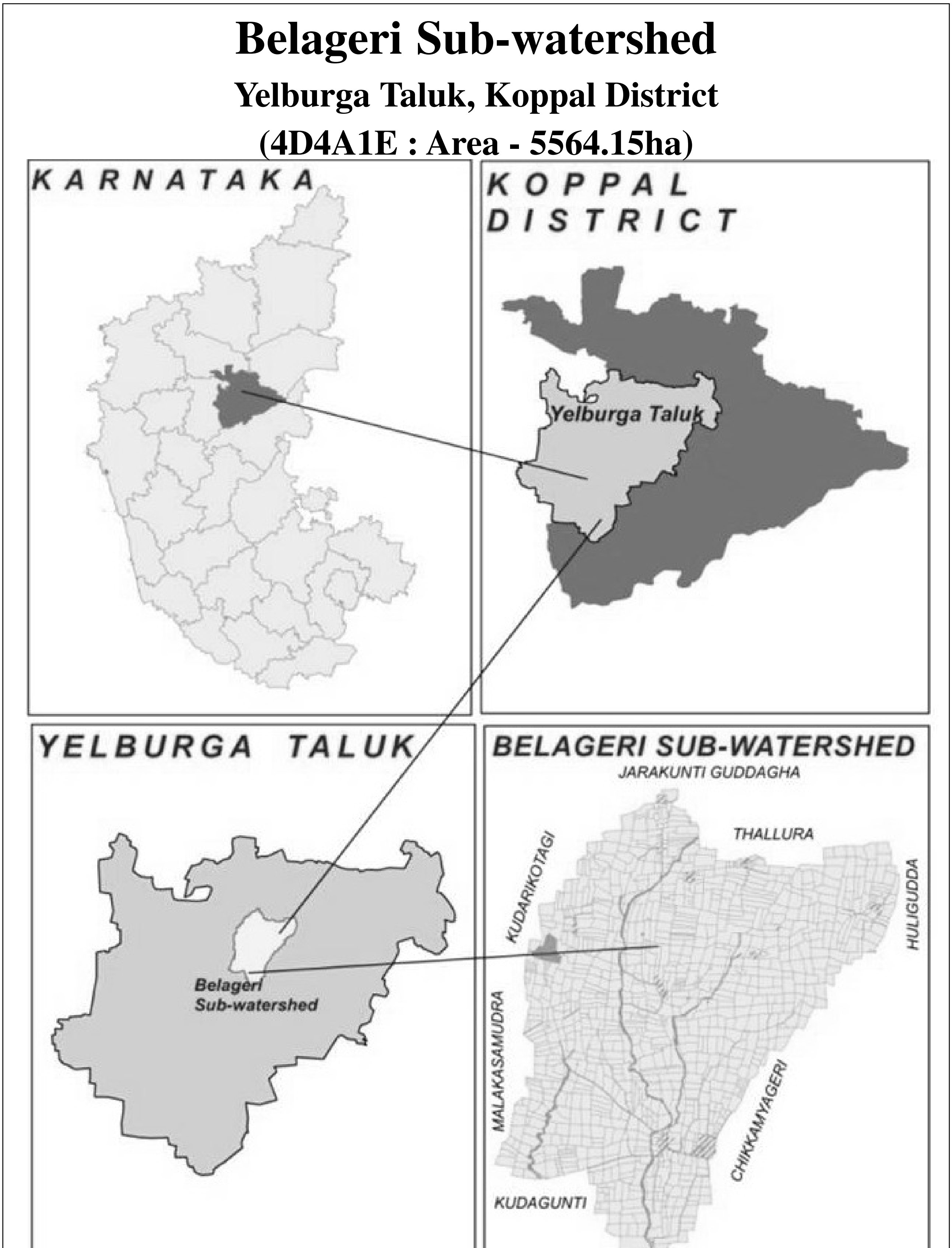

Fig.1. Location map of Belageri sub watershed

Table1. Details of soil sampling in Belageri sub watershed

Name of MWS	MWS Code	Area (ha)	No.of Grids
Godgeri-1	4D4A1E2d	707.17	113
Godgeri-2	4D4A1E2e	454.91	75
Gudgunti-1	4D4A1E2f	508.46	83
Gudgunti-2	4D4A1E2g	393.60	59
Gudgunti-3	4D4A1E2h	388.11	58
Madlur	4D4A1E1e	647.84	105
Talur Tanda-1	4D4A1E2c	452.35	70
Talur Tanda-2	4D4A1E2b	669.33	107
Wirapur	4D4A1E1f	421.22	65
Wirapur-1	4D4A1E3b	448.32	74
Wirapur-2	4D4A1E3 c	472.50	75
	Total	5564.15	884

Table 2. Soil fertility ratings for available nutrients

Nutrients	Fertility rating major nutrients		
	Low	Medium	High
Organic carbon (g kg^{-1})	<5	5-7.5	>7.5
Macronutrients (kg ha^{-1})			
Nitrogen (N)	<280	280-560	>560
Phosphorus(P_2O_5)	<22.5	22.5-55	>55
Potassium (K_2O)	<140	140-330	>330
Sulphur (S) (ppm or mg kg^{-1})	<10	10-20	>20
Micronutrients (ppm or mg kg^{-1})	Deficient	Sufficient	
Zinc (Zn)	<0.6	>0.6	
Iron (Fe)	<2.5	>2.5	
Copper (Cu)	<0.2	>0.2	
Manganese (Mn)	<2.0	>2	

chloride ($CaCl_2$) as an extractant (Tabatabai 1996). Micronutrients (Fe, Zn, Cu and Mn) were extracted by DTPA reagent using the procedure outlined by Lindsay and Norvell (1978). Variability of data was assessed using mean standard deviation and coefficient of variation for each set of data. Availability of N, P, K and S in soils are interpreted as low, medium and high and that of available zinc, iron, copper and manganese interpreted as deficient and sufficient by following the criteria given in Table 2.

A *dbf* file consisting of data for X and Y co-ordinates in respect of sampling site location was created. A shape file (Vector data) showing the outline of Belageri sub watershed area was created in *Arc GIS* 10.4.

The *dbf* file was opened in the project window and in X-field, “longitudes“ and in Y-field, “latitudes“ were selected. The Z field was used for different nutrients. The Belageri sub watershed file was also opened and from the “Surface menu“ of Arc GIS geo-statistical Analyst, “geo statistical wizard“ option was selected. On the output “grid specification dialogue”, output grid extend chosen was same as Belageri sub-watershed and the interpolation method employed was krigging. Then map was reclassified based on ratings of the respective nutrients (Table 2) and area for each category of nutrient was calculated.

Results and discussion

Soil reaction and electrical conductivity

Soils of the Belageri sub-watershed were neutral to alkaline in reaction (6.39 to 9.54) with a mean pH of 7.78, standard deviation of 0.83and coefficient of variation of 10.67 (Table 3). Higher soil reaction in the sub watershed is mainly because of calcareousness nature and sodicity of the soils. The coefficient of variation of soil pH indicates that, spatially it did not vary. Mapping of soil pH by GIS technique resulted in six soil reaction classes (Fig. 2). They are; Slightly acidic (pH 6.0-6.5), Neutral (pH 6.5 - 7.3), Slightly alkaline (pH 7.3-7.8), Moderately alkaline (pH 7.8-8.4), Strongly alkaline (pH 8.4 -9.0), Very strongly alkaline (pH > 9.0). Major proportion of the sub watershed area (Fig. 2) was slightly alkaline (26.36%)followed by neutral (24.88%), moderately alkaline (23.91%) and strongly alkaline (19.42%). The higher pH of soils could be attributed to low intensity of leaching and accumulation of bases. (Ravikumar *et al.,* 2007a, Prabhavati *et al.,* 2015, Patil *et al.,* 2016, 2017a and 2017b). The EC of soils in the sub-watershed was in the range of 0.10 to 0.95 dSm^{-1} with mean value of 0.23 $dSm^{-1}$and standard deviation of 0.14. The CV (60.87) of EC values indicate that salt content in the sub watershed varied spatially. Higher level of soluble salts in the study area is due to arid climatic condition. GIS Mapping of soluble salt content in the sub watershed revealed that, 96 per cent of the area was non saline whereas,very less area was slightly saline and marginally saline. Patil *et al.,* (2017a) also reported that, Soils of Bedwatti sub watershed of Koppal district were non saline and soluble salt content varied spatially.

Organic carbon

Organic carbon content of soils of Belageri sub watershed was ranged from 0.08 to 1.09 per cent with mean and standard deviation value of 0.51 and 0.2 per cent respectively. The CV (39.22) for OC content indicates that, in the sub watershed SOC varied spatially (Table 3). GIS Mapping of OC by GIS revealed that 52.52 per cent of the study area was low in organic carbon and 39.82 per cent area was mediumin soil organic carbon status (Fig. 3). The values obtained in the present study are in agreement with those reported by for Bedwatti sub watershed area of Yalburga taluka, Koppal district of Karnataka (Patil *et al.,* 2017a). The reason for low organic carbon content in these soils may be attributed to the prevalence of arid condition, where the degradation of organic matter occur at a faster rate coupled with little or no addition of organic manures and low vegetative cover on the fields, thereby leaving less chances of accumulation of organic carbon in the soils. Intensive cropping is also one of the reasons for low organic carbon content. The similar results were also reported by Srikant *et al.* (2008),

Table 3. Chemical properties and available major nutrients status in Belageri sub watershed

	pH	EC	OC	N	P_2O_5	K_2O	S
		(dS m^{-1})	(%)		(kg ha^{-1})		(mg kg^{-1})
Minimum	6.39	0.10	0.08	48	7.4	107	2.3
Maximum	9.54	0.95	1.09	407	69.6	977	25.8
Mean	7.78	0.23	0.51	204	28.4	406	9.2
S.D.	0.83	0.14	0.20	63	10.9	147	3.7
C.V. (%)	10.67	60.87	39.22	30.88	38.38	36.21	40.22

Prabhavati *et al.* (2015) and Patil *et al.* (2016 and 2017a, 2017b, 2018a,and 2018b) for the soils of northern dry zone of Karnataka. Organic carbon status of soils is to be enhanced by crop residue management for improving physical, chemical and biological properties and fertility status.

Available macro nutrients

The available N in soils of the sub watershed ranged from 48 to 407 kg ha^{-1} with amean of 204 kg ha^{-1} and SD of 63. The CV value of 30.88 indicates that available N in soils varied spatially. GIS mapping revealed that, the entire sub watershed was low in the available nitrogen (Table 3 and Fig. 4). The low N content could beattributed to soil management, varied application of FYM and fertilizer to previous crops. Nitrogen is the most limiting nutrient in black soils as its availability decreases due to fixation and volatilization losses. Another possible reason may also be due to low organic matter content in these areas due to low rainfall and high temperature which facilitate faster degradation and removal of organic matter leading to nitrogen deficiency. Similar nitrogen status was reported by Srikant *et al.* (2008), Pulakeshi *et al.* (2012) and Patil *et al.* (2016 and 2017a, 2017b, 2018a and 2018b) in non-saline clay to sandy loams and calcareous soils of northern Karnataka. Since, the soils of the entire sub watershed area was low in available nitrogen status,crops are to be supplied with 25 per cent more than the recommended dose of N. Use of bio fertilizers for seed treatment may be popularised for increasing N supply to the crops. In wider row spacing crops sunhemp may be grown and incorporated at flowering stage.

The available P_2O_5 content of the sub watershed was ranged from 7.4 to 69.6 kg ha^{-1} with average and SD value of 28.4 and 10.9 kg ha^{-1} respectively. The CV for available P_2O_5 distribution (38.38) in the sub watershed indicates that, it was varied spatially. Mapping of available P_2O_5 by GIS revealed that, available P_2O_5 was low in 13.22 per cent of the study area whereas, it was medium in 82.75 per cent of the study area (Table 3 and Fig. 6). Low P_2O_5 availability in these soils is related to their high pH, calcareous nature and low organic matter content. Mapping of available P_2O_5 by GIS revealed that, available P_2O_5 was low to medium in the sub watershed (Table 3 and Fig. 5). Low to Medium P_2O_5 availability in these soils is related to their high pH, calcareousness and low organic matter content. The present findings are in line with those of Srikant *et al.* (2008) and Pati *et al.* (2016, 2017a, 2017b, 2018a and 2018b) who reported that majority of the soils in northern dry zone Karnataka were low to medium in phosphorus content. Use of P solubilizers may be popularized for enhancing P availability to crops.

The available K_2O content in the sub watershed was ranged from 107 to 977 kg ha^{-1} with mean and SD value of 406 and 147 kg ha^{-1} respectively. The CV (36.21) foravailable K_2O content indicates that, it varied spatially in the sub watershed. Mapping of available K_2O content in the sub watershed by GIS revealed that, 16.59 per cent of the of the study area was in medium category (Table 3 and Fig. 6) and 79.38 per cent of the of the study area was in high category. It is reported that, invariably the surface soils had higher concentration of water soluble and exchangeable K in Karnataka (Patil *et al.,* 2011). Soils are able to maintain a sufficient or even high level of exchangeable K and provide a good supply of K to plants for many years. The higher content of available potassium in soils of Belageri sub watershed may be due to the predominance of potash rich micaceous and feldspar minerals in parent material. Similar results were observed by Srikant *et al.* (2008) in Banapur micro watershed of Koppal district.

The available sulphur content of soils of the sub watershed varied from 2.3 to 25.8 mg kg^{-1} soil with mean and SD values of 9.7 and 3.7 mg kg^{-1} soil, respectively. The CV (40.22) for available Scontent indicates that, in the sub watershed available S varied spatially. GIS mapping of available S revealed that, the area under study was low to medium in available sulphur status with 63.2and 32.8 per cent of the study area respectively (Table 3 and Fig. 7). The sulphur deficient area is separated clearly from sufficient area in sub-watershed highlighting the importance of mapping the area rather than the statistic derived from soil analysis. The low S is partly due to gypsiferrous nature of S which is non-available in black soils. Low and medium level variation of available sulphur was due to lack of sulphur addition and continuous removal of S by crops. Similar results were also observed by Patil *et al.* (2016, 2017a, 2017b, 2018a and 2018b) for soils of Gadag, Koppal and Vijayapur districts in northern dry zone of Karnataka.

Available micro nutrients

The available zinc in the sub watershed was ranged from 0.13 to 3.88 mg kg^{-1} with mean and SD value of 0.57 and 0.35 mg kg^{-1} respectively (Table 4). The CV (61.4) for available Zn content indicates that, it varied spatially in the sub watershed. Mapping of available Zn by GIS revealed that, it was deficient in the 62.1 per cent of the study area and sufficient in 33.9 per cent of the area (Fig 8). The content of Zn increases with low pH and high organic carbon content but decreases with increase in pH. Since, the soils under study are alkaline, low in OC and dominated by $CaCO_3$, zinc may be precipitated as hydroxides and carbonates, as a result, their solubility and mobility might have decreased and reduced the availability. Similar results were reported by Ravikumar *et al.* (2007b) and Patil *et al.* (2006) and for the soils of Malaprabha command in Karnataka, Pulakeshi *et al.* (2012) for black soils of Northern transition zone of Karnataka and Patil *et al.* (2016, 2017a, 2017b, 2018a and 2018b) for soils of Gadag, Koppal and Vijayapur districts in northern dry zone of Karnataka.

The available iron in the sub watershed was ranged from 0.24 to 9.06 mg kg^{-1} with mean and SD value of 6.63 and 4.22 mg kg^{-1} respectively (Table 4). The CV (63.65) for available

Table 4. Available micro nutrients status in Belageri sub watershed

	Zn	Fe	Mn	Cu
	mg kg^{-1}			
Minimum	0.13	0.24	0.41	0.20
Maximum	3.88	9.06	14.37	4.30
Mean	0.57	6.63	5.48	0.80
S.D.	0.35	4.22	2.89	0.54
C.V. (%)	61.4	63.65	52.74	67.5

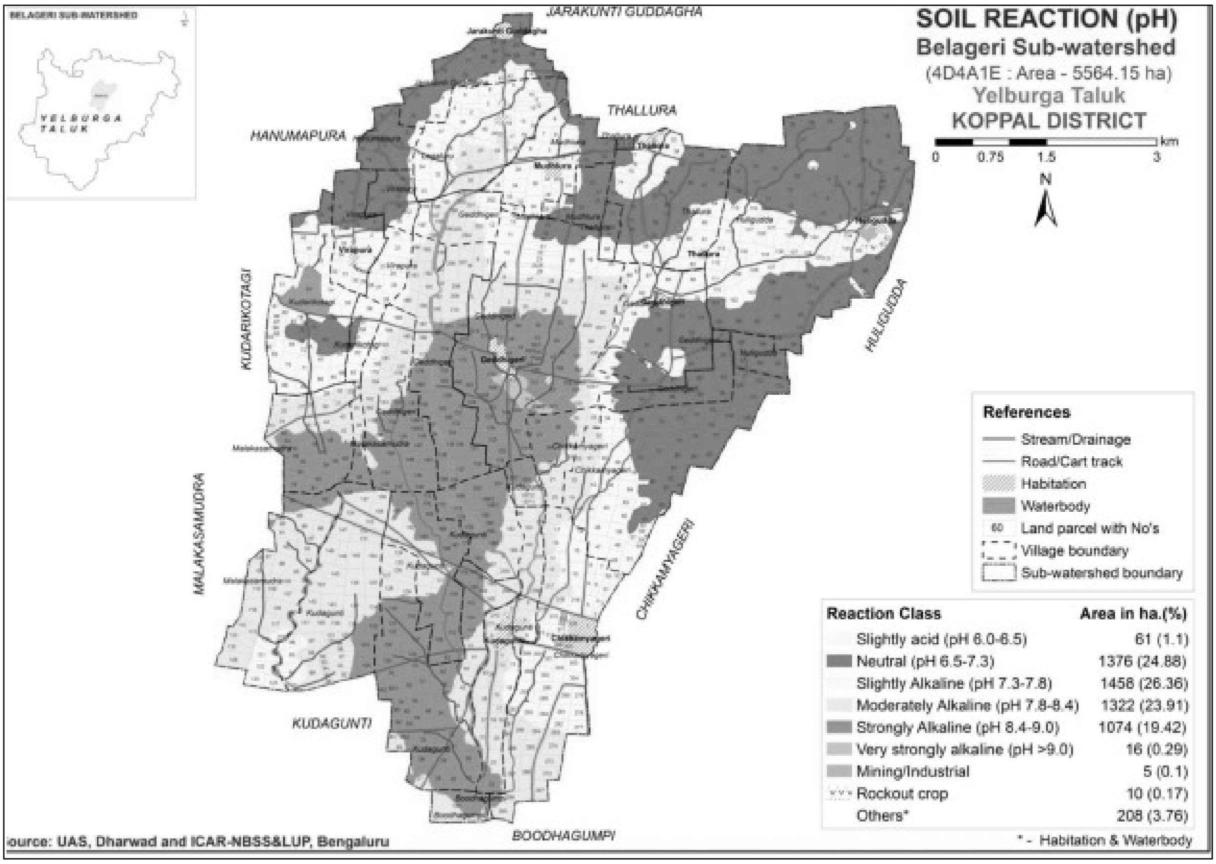

Fig. 2. Soil reaction status of Belageri sub watershed

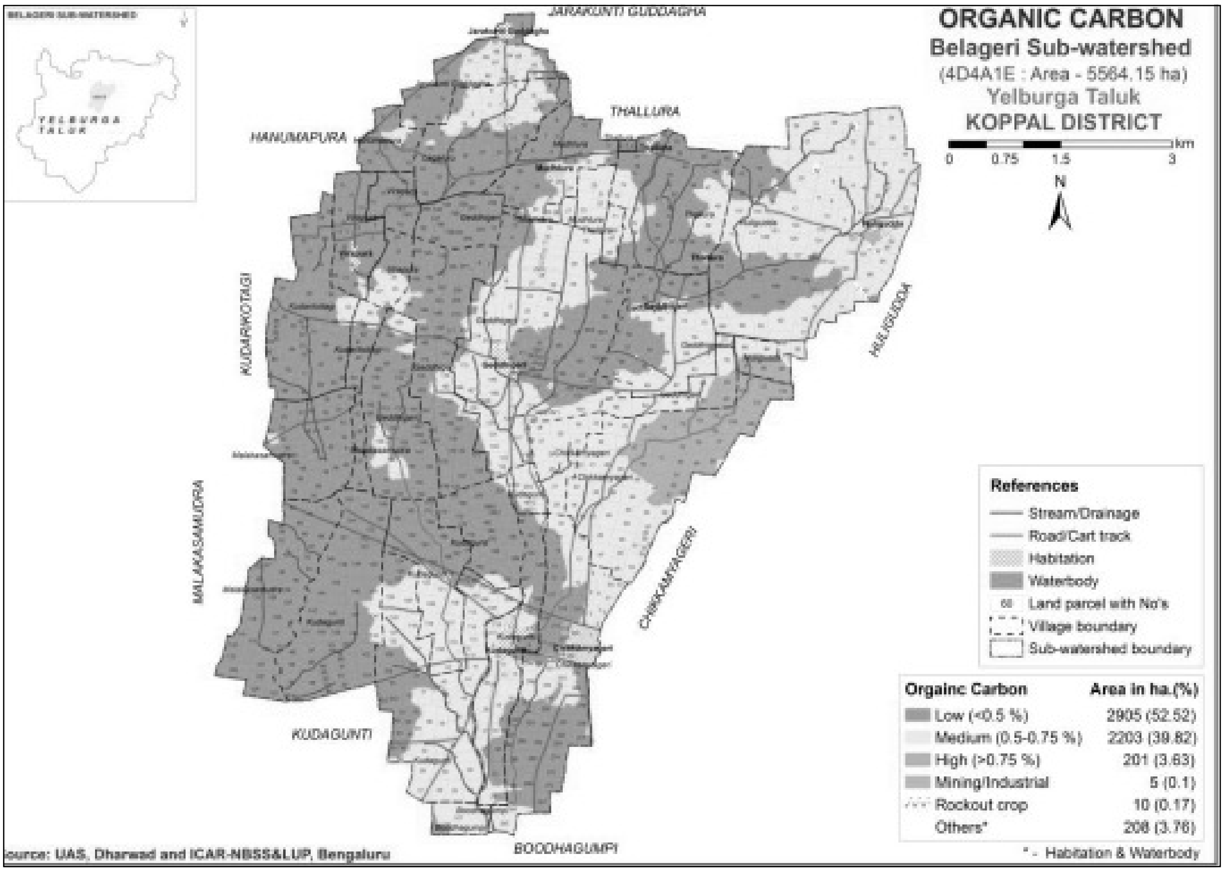

Fig.3. Soil organic carbon status of Belageri sub watershed

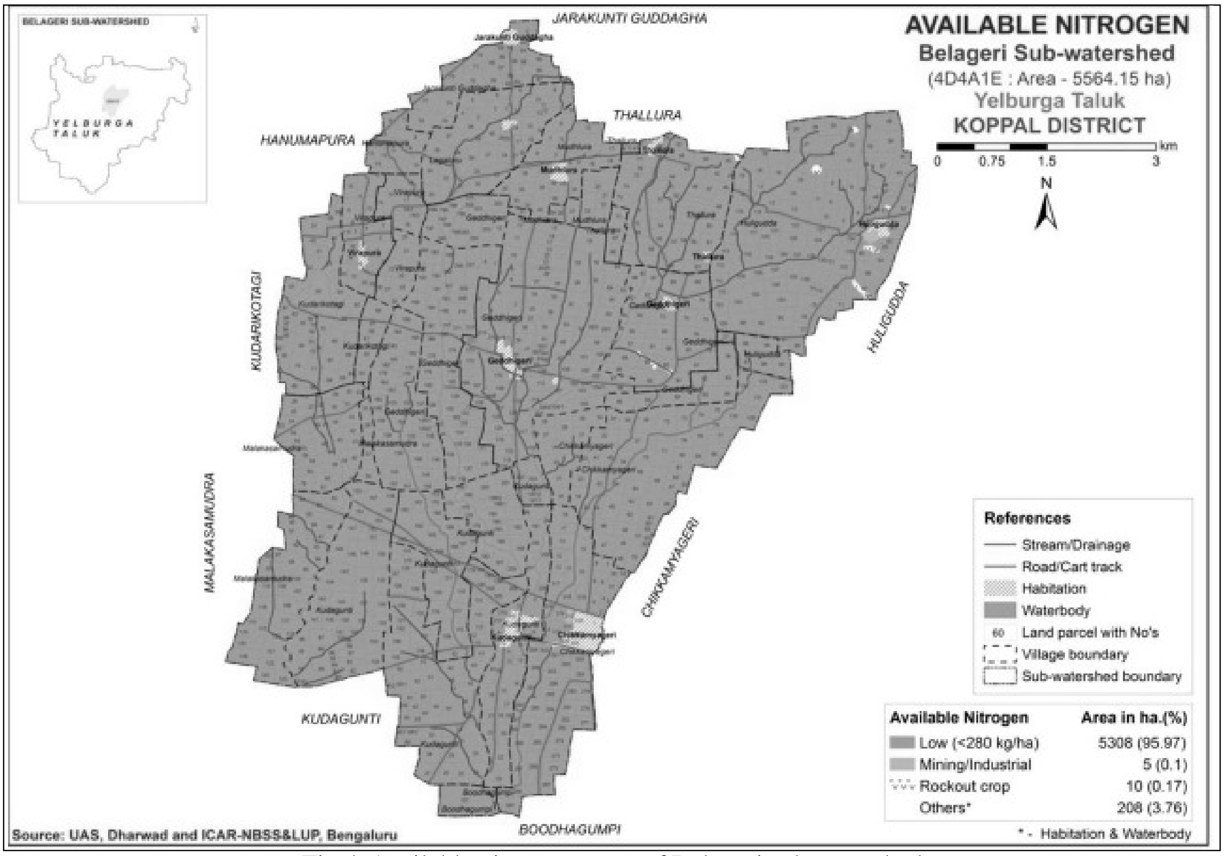

Fig.4. Available nitrogen status of Belageri sub watershed

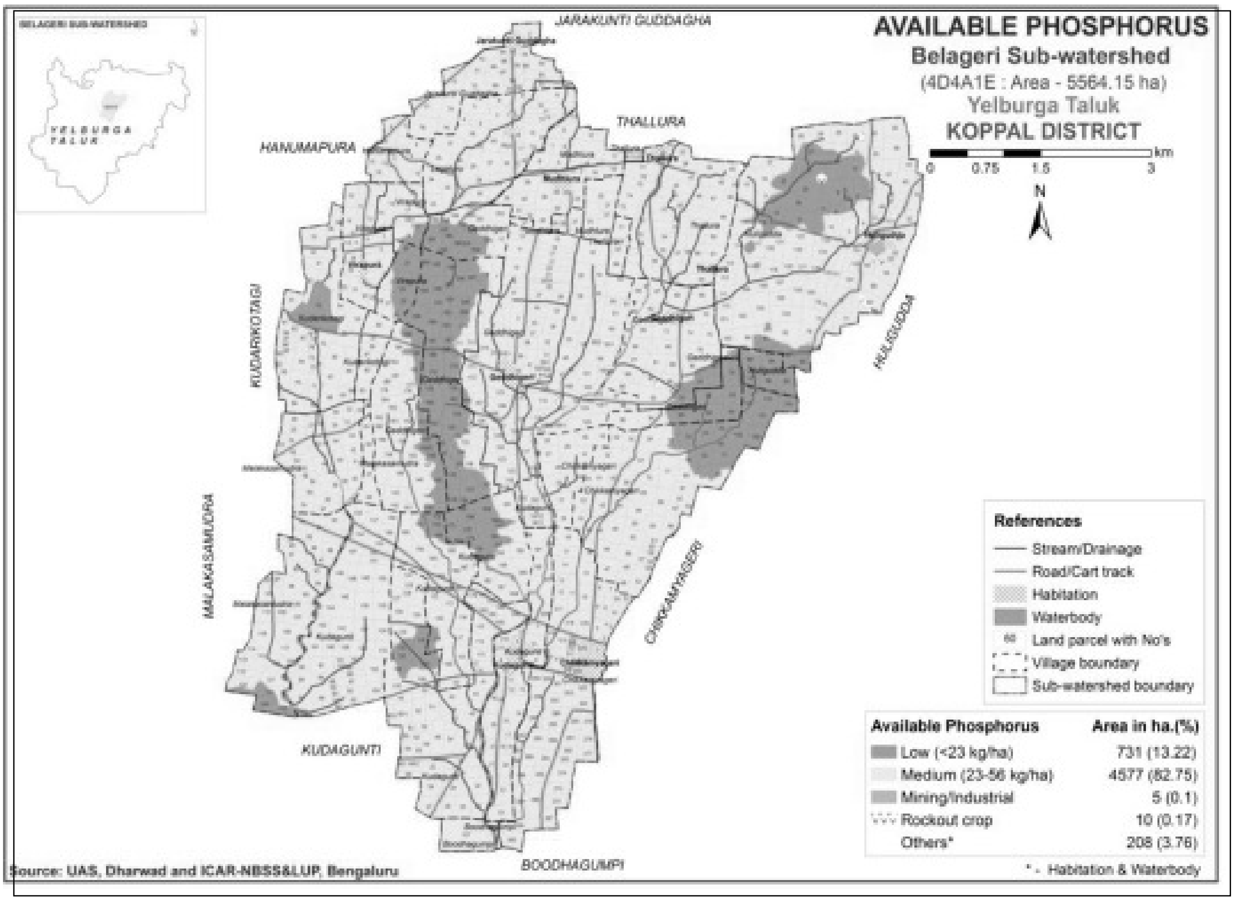

Fig. 5. Available phosphorus status of Belageri sub watershed

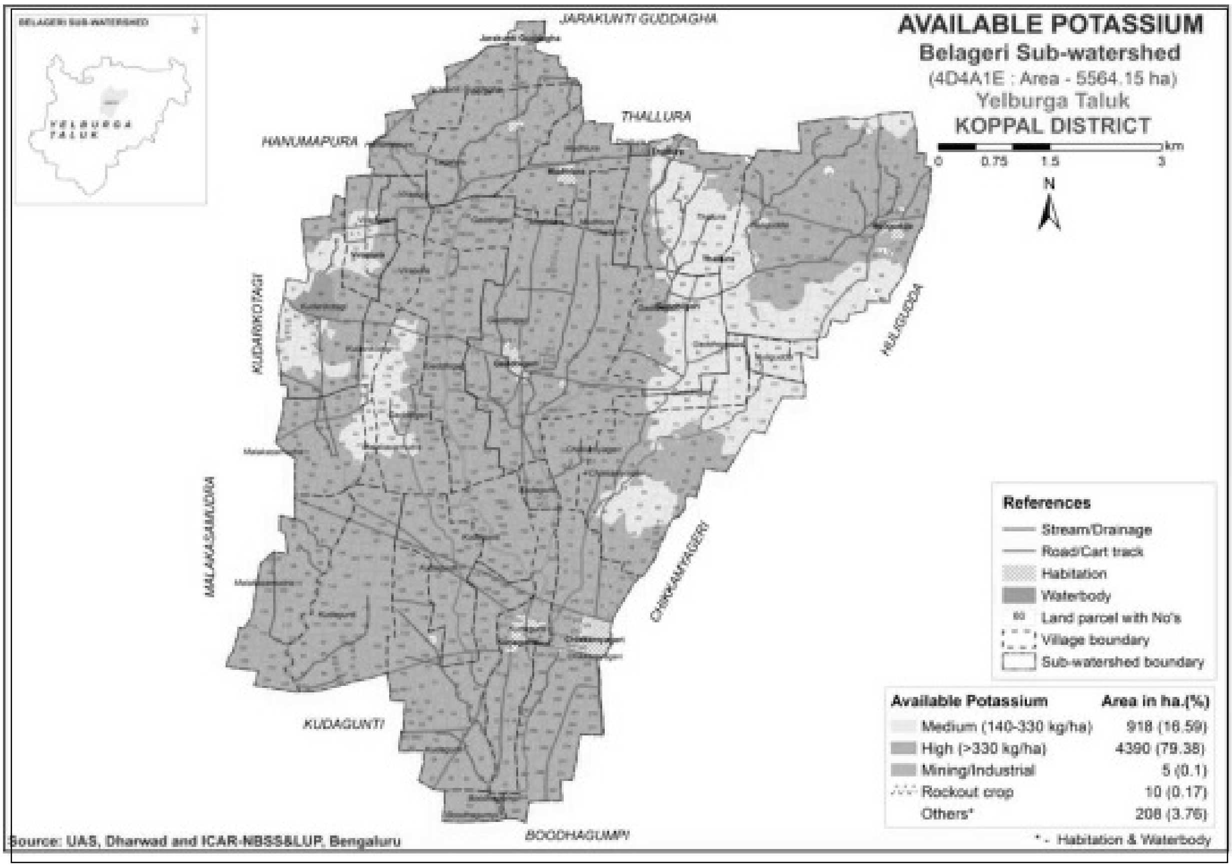

Fig. 6. Available potassium status of Belageri sub watershed

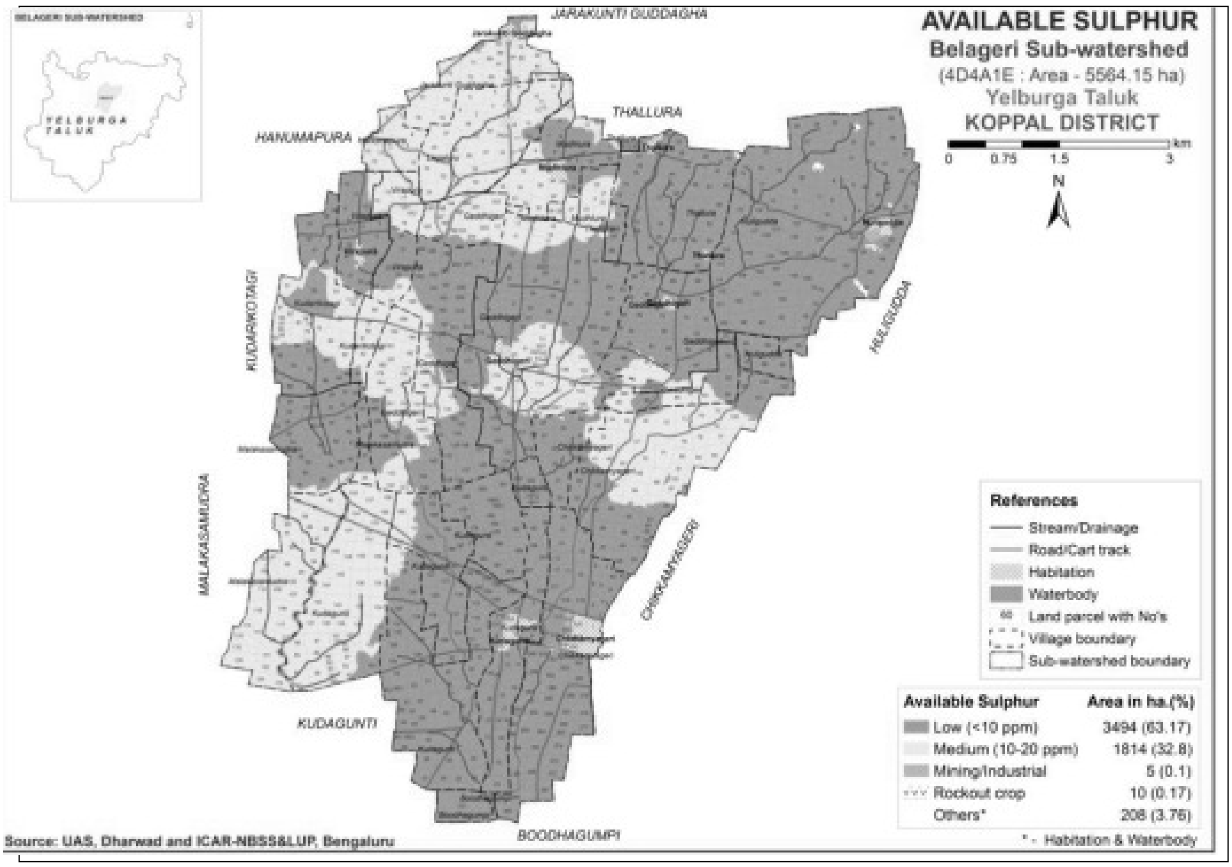

Fig. 7. Available sulphur status of Belageri sub watershed

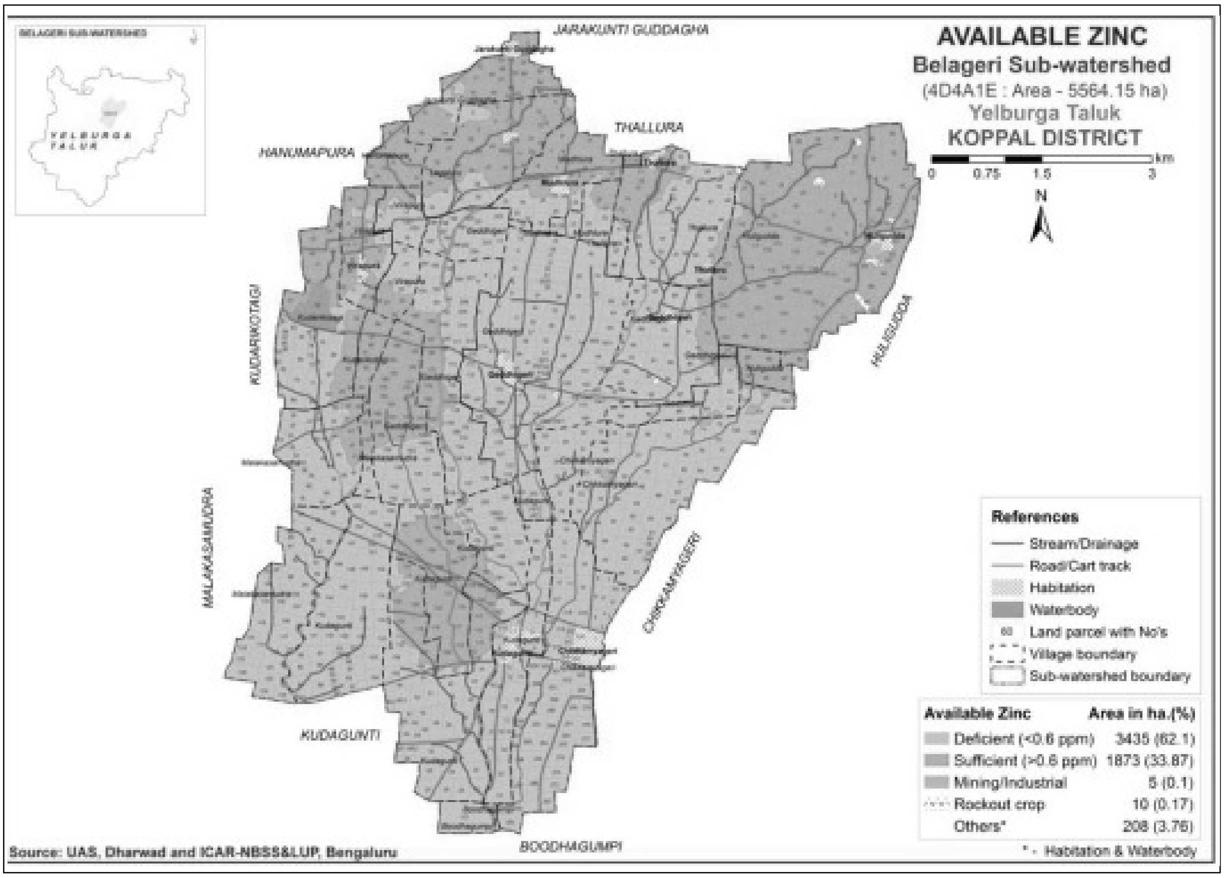

Fig. 8. Available zinc status of Belageri sub watershed

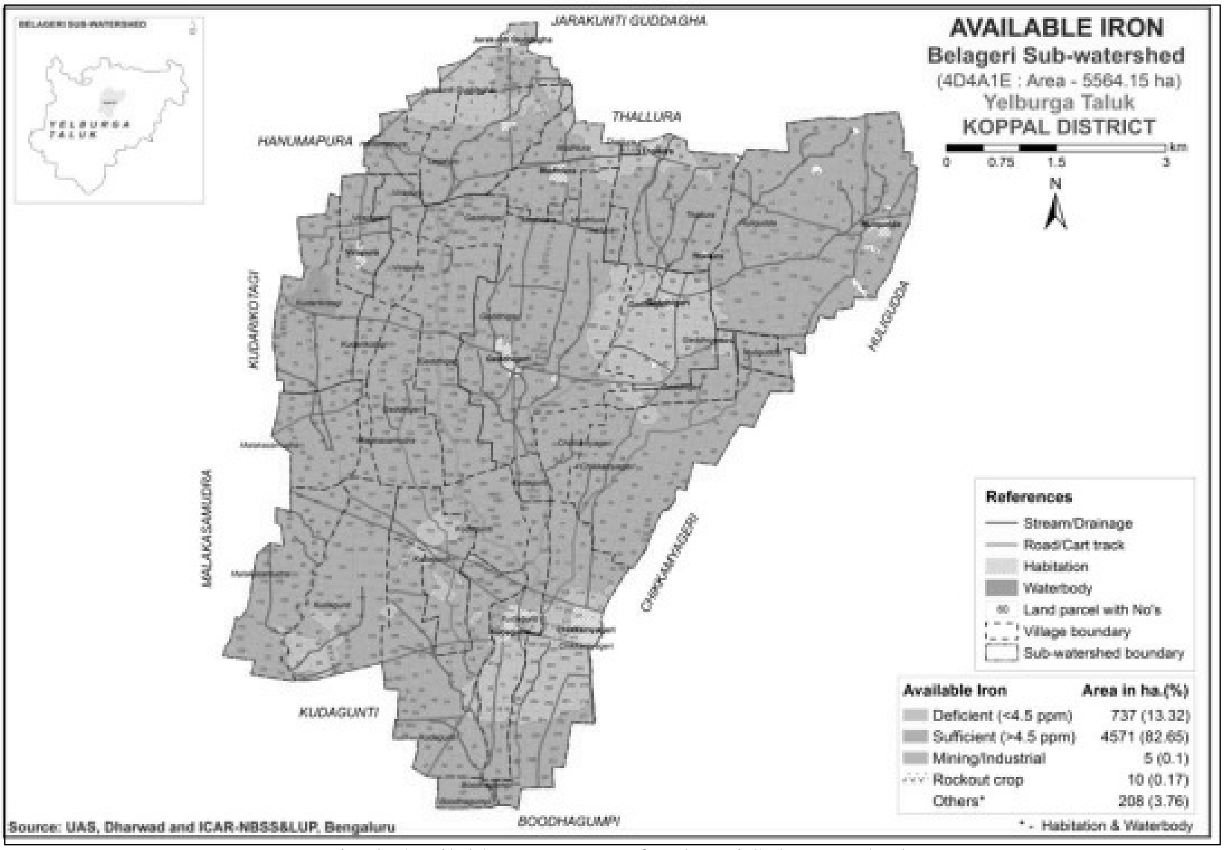

Fig. 9. Available Iron status of Belageri Sub watershed

Fe content indicates that, it varied spatially in the sub watershed. Mapping of available Fe by GIS revealed that, it was deficient in the 59.7 per cent of the study area and sufficient in 38.8 per cent of the area (Fig. 9). The low Fe content may be due to precipitation of Fe by $CaCO_3$ and decreased its availability. Similar results were also obtained by Ravikumar *et al.* (2007b) and Patil *et al.* (2006) for the soils of Malaprabha command in Karnataka and and Patil *et al*. (2016, 2017a, 2017b, 2018a and 2018b) for soils of Gadag, Koppaland Vijayapur districts in northern dry zone of Karnataka. This type of variation may be due to the soil management practices and cropping pattern adopted by different farmers.

The available Manganese in the sub watershed was ranged from 0.41to 14.37 mg kg^{-1} with mean and SD value of 5.48 and 2.89 mg kg^{-1} respectively (Table 4). The CV (52.74) for available Mn content indicates that, it varied spatially in the sub watershed. Mapping of available Mn by GIS revealed that, it was sufficient in the entire study area. Sufficient content of manganese was observed by Ravikumar *et al.* (2007b) in Vertisols of Malaprabha command area, Pulakeshi *et al*. (2012) in the soils of northern transition zone of Karnataka derived from chlorite schist and Patil *et al*. (2016, 2017a, 2017b, 2018a and 2018b) for soils of Gadag, Koppal and Vijayapur districts in northern dry zone of Karnataka.

The available copper in the entire sub watershed was sufficient and ranged from 0.20 to 4.3 mg kg^{-1} with mean and SD value of 0.80 and 0.54 mg kg^{-1} respectively (Table 4). The CV (67.5) for available Cu content indicates that,it varied spatially in the sub watershed. Mapping of available Cu by GIS revealed that, it was sufficient in the entire study area. Ravikumar *et al.* (2007b), Pulakeshi *et al.* (2012) and Patil *et al.* (2016, 2017a, 2017b, 2018a and 2018b) also observed sufficient status of available copper in soils of north Karnataka.

Conclusion

From the study, it can be concluded that, soils of Belageri sub-watershed in northern dry zone of Karnataka are neutral to very strongly alkaline with non saline to slight salinity. Alkaline soils in the study area need immediate attention for their management to arrest further degradation. Soil organic carbon content was low to medium. Available nitrogen was low, available phosphorus was low to medium, available potassium was medium to high and sulphur was low to medium. Regarding available micro nutrients, zinc and iron were deficient in about half of the sub watershed area whereas, copper and manganese were sufficient in the soils. The mapping of nutrients by GIS techniquein the sub watershed revealed that major portion of the study area was deficient in available N, S, Zn and Fe are important soil fertility constraints indicating their immediate attention for sustained crop production. The deficient micro nutrient may be replenished to avoid the crops suffering from their deficiency and for optimum utilization of other nutrients.

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