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Soil Fertility Mapping in Dindur Sub-Watershed of Karnataka for Site Specific Recommendations

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

Key words: Soil fertility map, GIS, watersheds, soil fertility constraints

Intensively cultivated soils are being depleted with available nutrients especially micronutrients. Therefore, assessment of nutrient constraints of soils being intensively cultivated with high yielding crops need to be carried out. 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 nutrient 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 dryland soils are not only thirsty but hungry too (Wani 2008) meaning that besides soil and water conservation, if nutrient management constraints are addressed, the productivity of a watershed will further enhanced. Some studies on soil fertility status at representative microwatershed/village level have been carried out at 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 nutrient constraints in soils of Dindur sub-watershed in northern dry zone of Karnataka.

Materials and Methods

The Dindur sub-watershed is located in Gadag taluka of Gadag district covering an area of 3124.12 ha (Fig. 1), falling under Northern Dry Agro-climatic Zone of Karnataka. The sub-watershed is located at about 20.0 km from Gadag city. It consists of eight micro-watersheds having undulating topography with a vast degraded open scrub area. The Schist parent rock covers the sub-watershed area. The predominant minerals observed in the Schist are chlorite, mica, and ferro-magnesium minerals. The climate of the area is semi-arid or hot tropical and monsoonal type. The maximum temperature during summer is 38.2 °C and

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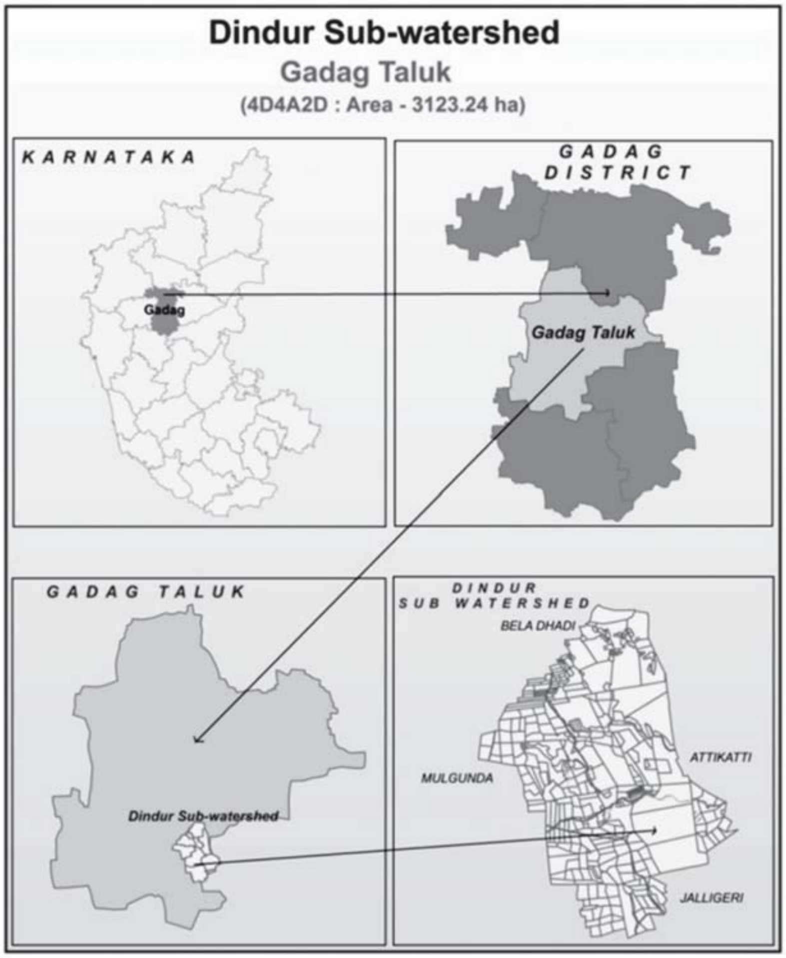

Fig.1. Location map of Dindur sub-watershed

the minimum 14.8 °C in winter. Mean maximum temperature of the area recorded 32.8 ^{0}C and mean minimum temperature 19.2 ^{0}C (Table 2). The average annual rainfall is 539.8 mm. It is well distributed with southwest monsoon (June to September) bringing 315 mm and north-east monsoon about 121 mm rain during October and November months. About 88 mm of rainfall is also received during the summer months (April-May).

Surface composite soil samples were collected using a handheld GPS on grid points of 250 m interval in the study area. A total of 499 samples were collected from the sub-watershed. Micro-watershed wise soil sample details are furnished in table 1.

The soil samples were air-dried, ground (< 2 mm) 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 using the 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

Table 1. Details of soil sampling in Dindur sub-watershed

Micro-watershed	Code	Area (ha)	No. of samples
1.Nabhapura Tanda 2	4D4A2D1a	292.86	49
2.Nabhapura Tanda 1	4D4A2D1b	361.95	59
3.Beladadi Tanda 2	4D4A2D1c	376.52	61
4.Beladadi Tanda 1	4D4A2D1d	282.37	44
5.Kabulayakatti Tanda 3	4D4A2D1e	313.63	49
6.Kabulayakatti Tanda 2	4D4A2D1g	508.63	82
7.Dindur Tanda	4D4A2D1h	452.48	70
8.Attikatti 5	4D4A2D2a	535.68	85
Total		**3124.12**	**499**

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) (mg kg^{-1})	<10	10-20	>20
Micronutrients (mg kg^{-1})	Deficient	Sufficient	Excess
Zinc (Zn)	<0.6	0.6-1.5	>1.5
Iron (Fe)	<2.5	2.5-4.5	>4.5
Copper (Cu)	<0.2	0.2-5.0	>5.0
Manganese (Mn)	<2.0	2-4	>4.0

measured using 0.15% calcium chloride ($CaCl_2$) as an extractant (Tabatabai 1996). Micronutrients (Fe, Zn, Cu and Mn) were extracted by DTPA 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 (Zn), iron (Fe), copper (Cu) and manganese (Mn) 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 Dindur 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 Dindur 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 Dindur sub-watershed and the interpolation method employed was kriging. 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 Dindur sub-watershed were neutral to alkaline in reaction (6.84 to 9.47) with a mean pH of 7.71, standard deviation of 0.52 and coefficient of variation of 6.78 per cent (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 four soil reaction classes (Fig. 2). They are, neutral (6.5–7.3), slightly alkaline (7.3–7.8), moderately alkaline (7.8–8.4) and strongly alkaline (8.4–9.0). Major proportion of the sub-watershed area (Fig. 2) was slightly alkaline (65.2%) followed by moderately alkaline (20.1%), neutral (4.8%) and strongly alkaline (1.0%). The higher pH of soils could be attributed to low intensity of leaching and accumulation of bases. The results are in agreement with those reported for northern dry zone soils by Ravikumar *et al.* (2007a), Vinay (2007) and Prabhavati *et al.* (2015). The EC of soils in the sub-watershed was in the range of 0.05 to 0.97 dS m^{-1} with mean value of 0.32 and standard deviation of 0.24. The CV (74.1%) of EC values indicates that salt content in the sub-watershed varied spatially. Slightly higher level of soluble salts in the study area is due to semi-arid climatic condition. Soluble salt content in the sub-watershed revealed that, the area was non saline.

Organic carbon

Soil organic carbon (OC) content of Dindur sub-watershed ranged from 0.3 to 12.1 g kg^{-1} with mean and standard deviation value of 4.7 and 2.4, respectively. The CV of 51.0 per cent for OC content indicates that, in the sub-watershed OC varied spatially (Table 3). Mapping of OC by GIS revealed that 71.3 per cent of the study area was low in OC and 25.8 per cent area was medium in soil OC status (Fig. 3). The values obtained in the present study are in agreement with those reported by Ravikumar *et al.*

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

Statistics	pH	EC (dS m^{-1})	OC (g kg^{-1})	N	P_2O_5 (kg ha^{-1})	K_2O	S (mg kg^{-1})
Range	6.84-9.47	0.05-0.97	0.3-12.1	63-280	3.1-61.8	30-720	1.9-82.5
Average	7.71	0.32	4.7	152.5	32.1	195.1	15.9
SD	0.52	0.24	2.4	39.9	13.5	80.5	12.1
CV (%)	6.78	74.1	51.0	26.1	42.2	41.2	75.7

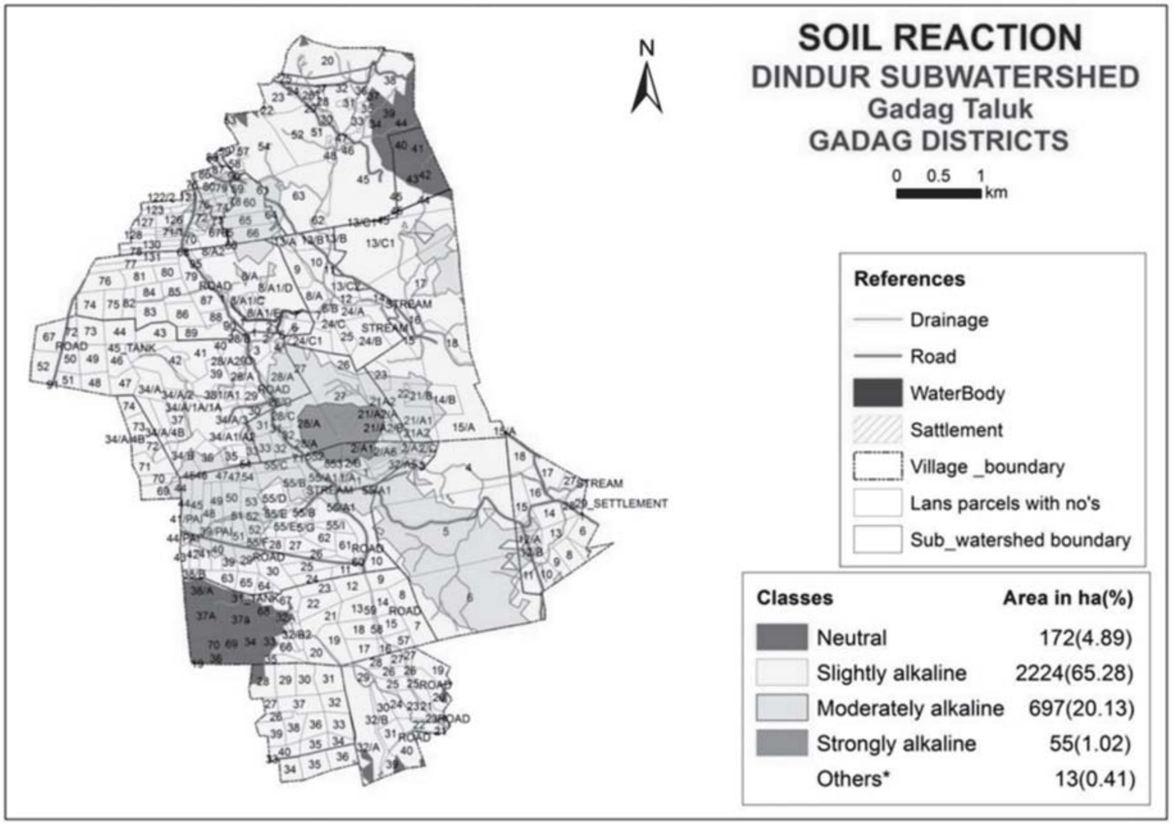

Fig. 2. Soil reaction status of Dindur sub-watershed

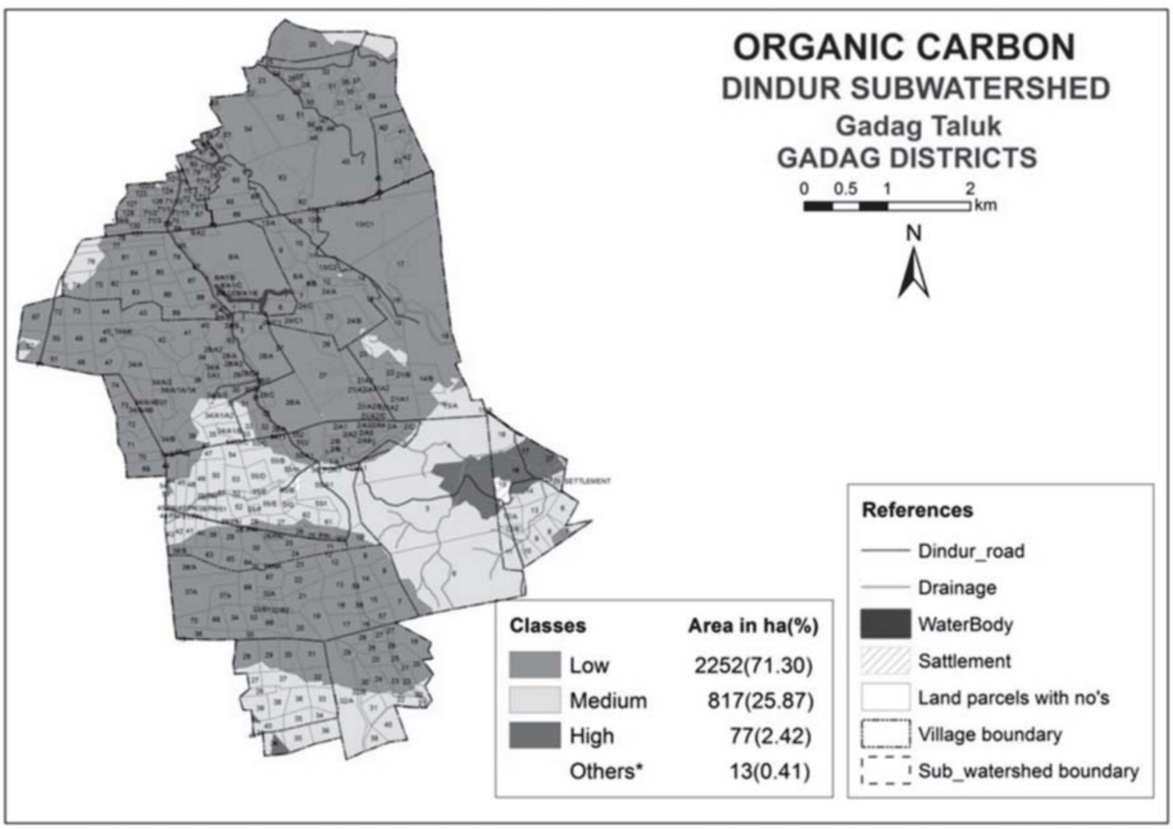

Fig. 3. Soil organic carbon status of Dindur sub-watershed

(2007a) for black soils of Malaprabha command area of Karnataka. The reason for low OC content in these soils may be attributed to the prevalence of semi 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 OC content. The similar results were also reported by Prabhavati *et al*. (2015) for the soils of northern dry zone of Karnataka.

Available macronutrients

The available N in soils of the sub-watershed ranged from 63 to 280 kg ha^{-1} with a mean of 152.5 and SD of 39.9. The CV value of 26.1 per cent indicates that available N in soils varied spatially. The study revealed that, the entire sub-watershed was low in the available N (Table 3). The low N content could be attributed 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 N deficiency. Similar N status was reported by Basavaraju *et al.* (2005), Thangasamy *et al.* (2005) and Shankaraiah *et al.* (2006) in non-saline clay to sandy loams and calcareous soils.

The available P content of the sub-watershed ranged from 3.08 to 61.8 kg P_2O_5 ha^{-1} with average and SD value of 32.1 and 13.5, respectively. The CV of 42.2 per cent for available P distribution in the sub-watershed indicates that, it varied spatially. Mapping of available P by GIS revealed that, it was low in 19.7 per cent of the study area, whereas medium in 79.8 per cent area (Table 3 and Fig. 4). Low P availability in these soils is related to their high pH, calcareousness and low organic matter content. Ravikumar *et al.* (2007a) reported for black soils of Malaprabha command area of Karnataka that available P status in the soils was low due to high calcium carbonate content. The present findings are in line with those of Bopathi and Sharma (2006) and Shiva Prasad *et al*. (1998) who reported that majority of the soils in Karnataka were medium in P content.

The available K content in the sub-watershed ranged from 30 to 720 kg K_2O ha^{-1} with mean and SD value of 195.1 and 80.5, respectively. The CV of 41.2 per cent for available K content indicates that, it varied spatially in the sub-watershed. Mapping of available K content in the sub-watershed by GIS

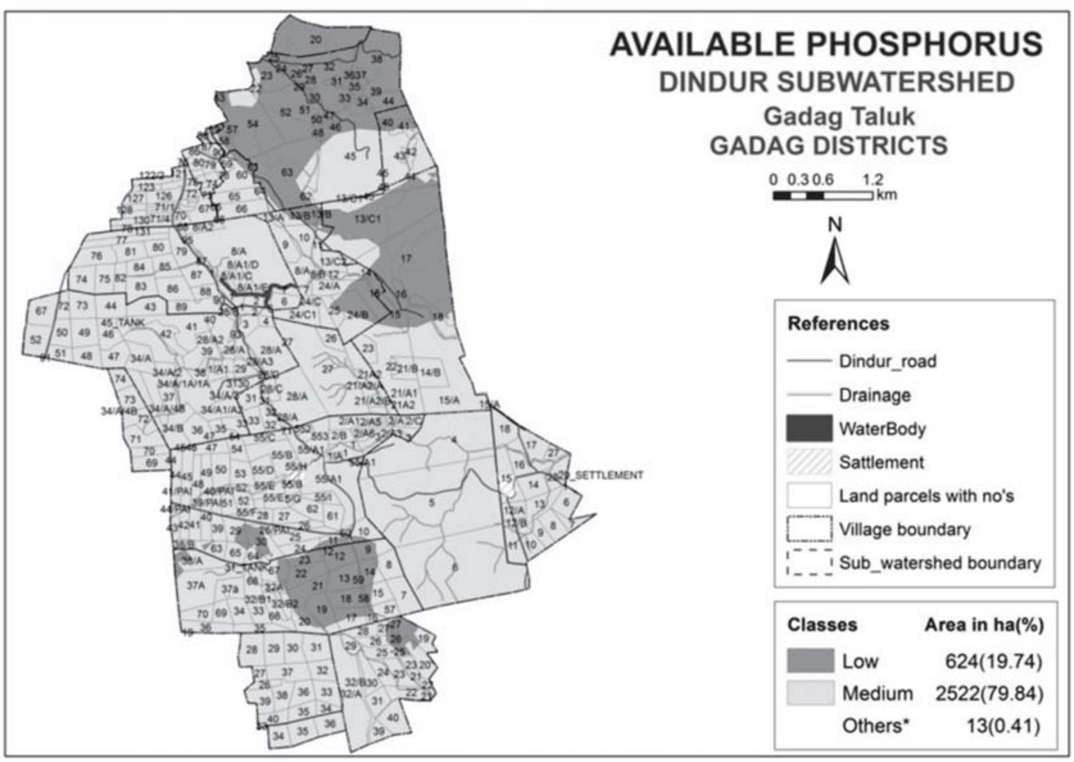

Fig. 4. Available phosphorus status of Dindur sub-watershed

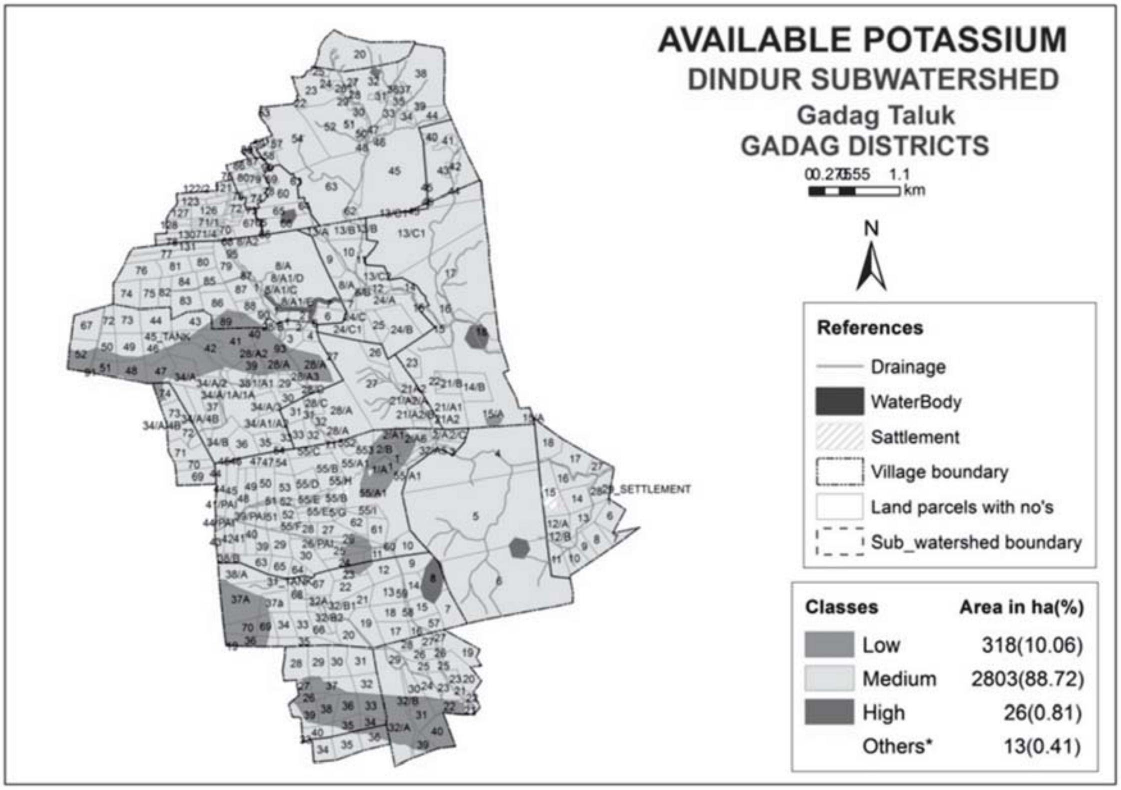

Fig. 5. Available potassium status of Dindur sub-watershed

revealed that, 88.7 per cent of the study area was in medium category (Table 3 and Fig. 5) and 10.0 per cent in low category. It is reported that, invariably the surface soils had higher concentration of water soluble and exchangeable K in Karnataka (Basavaraju *et al.* 2005; Somasundaram *et al.* 2009). 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 medium to higher content of available K in soils of Dindur sub-watershed may be due to the predominance of K-rich micaceous and feldspar minerals in parent material. Similar results were observed by Vara Prasad Rao *et al*. (2008) and Srikant *et al.* (2008).

The available S content of soils of the sub-watershed varied from 1.93 to 82.5 mg kg^{-1} soil with mean and SD values of 15.9 and 12.1, respectively. The CV of 75.7 per cent for available S content indicates that, in the sub-watershed available S varied spatially. The GIS mapping of available S revealed that, the area under study was low to medium in available S in 48.2 and 27.3 per cent, respectively (Table 3 and Fig. 6). It was observed that the area is divided almost equally between the high and medium status in sub-watershed highlighting the importance of mapping the area rather than the statistics derived from soil analysis. The low S is partly due to gypsiferous nature of S which is non-available in black soils. Low and medium level of available S was due to lack of sulphur addition and continuous removal of S by crops (Venkatesh and Satynarayana 1999).

Available micronutrients

The available Fe in the sub-watershed ranged from 0.43 to 19.1 mg kg^{-1} with mean and SD value of 5.19 and 3.93, respectively (Table 4). The CV of 132.1 per cent for available Fe content indicates that, it varied spatially in the sub-watershed. Mapping of available Fe by GIS revealed that, it was deficient in the 29.6 per cent and sufficient in 69.9 per cent of the area (Fig. 7). The low Fe content may be due to precipitation of Fe by $CaCO_3$ which decreased its availability. Similar results were also observed by Patil *et al*. (2006) and Ravikumar *et al.* (2007b). The available iron in surface soils has no regular pattern of distribution as also reported by Nayak *et al.* (2002). This type of variation may be due to the soil management practices and cropping pattern adopted by different farmers.

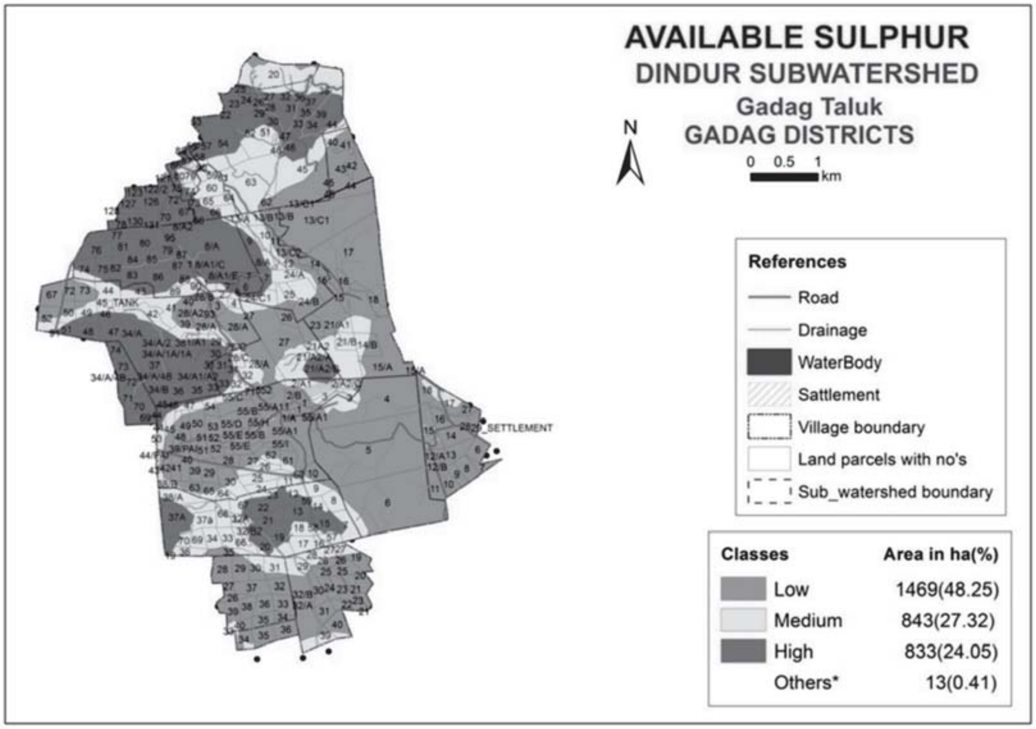

Fig. 6. Available sulphur status of Dindur sub-watershed

Table 4. Available micronutrients status in Dindur sub-watershed

Statistic	Fe	Mn	Cu	Zn
	(mg kg^{-1})			
Range	0.43-19.1	0.17-25.3	0.25-10.6	0.04-3.6
Average	5.19	5.31	1.89	0.60
SD	3.93	4.23	1.57	0.43
CV (%)	132.1	125.3	120.2	140.9

The available Mn in the sub-watershed was sufficient and ranged from 0.17 to 25.3 mg kg^{-1} with mean and SD value of 5.31 and 4.23, respectively (Table 4). The CV of 125.3 per cent for available Mn content indicates that, it varied spatially in the sub-watershed. Sufficient content of Mn was also observed by Ravikumar *et al*. (2007b) in Vertisols of Malaprabha command area, Pulakeshi (2010) in the soils of northern transition zone of Karnataka derived from chlorite schist and Manojkumar (2011) in the soils of northern transition zone of Karnataka derived from basalt.

The available Cu in the entire sub-watershed was sufficient and ranged from 0.25 to 10.62 mg kg^{-1} with mean and SD value of 1.89 and 1.57, respectively (Table 4). The CV of 120.2 per cent for available Cu content indicates that, it varied spatially in the sub-watershed. Ravikumar *et al*. (2007b), Pulakeshi (2010) and Manojkumar (2011) also observed sufficient status of available Cu in soils of north Karnataka.

The available Zn in the sub-watershed ranged from 0.04 to 3.66 mg kg^{-1} with mean and SD value of 0.6 and 0.43, respectively (Table 4). The CV of 140.9 per cent 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 53.8 per cent and sufficient in 45.7 per cent of the study area (Fig. 8). The content of Zn increased with decrease in pH and increase in OC content. Satyavathi and Suryanarayana Reddy (2004) also reported that Zn content in soils decreased with increase in pH. Since, most of the soils are alkaline, low in OC and dominated by $CaCO_3$, Zn might have been precipitated as hydroxides and carbonates as a result, and their decreased solubility and mobility might have reduced the availability (Patil *et al*. 2006).

From the study, it can be concluded that, soils of Dindur 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 N was low, available P was low to medium, available K was

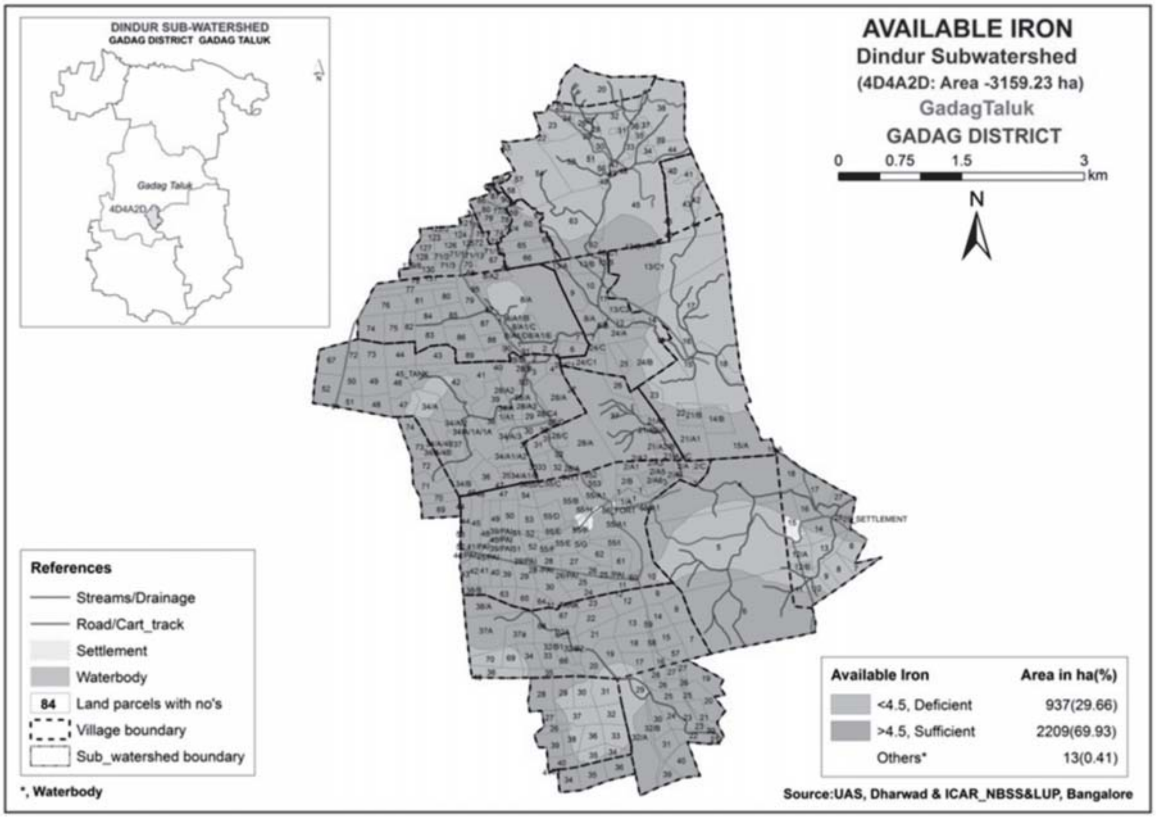

Fig.7. Available iron status of Dindur sub-watershed

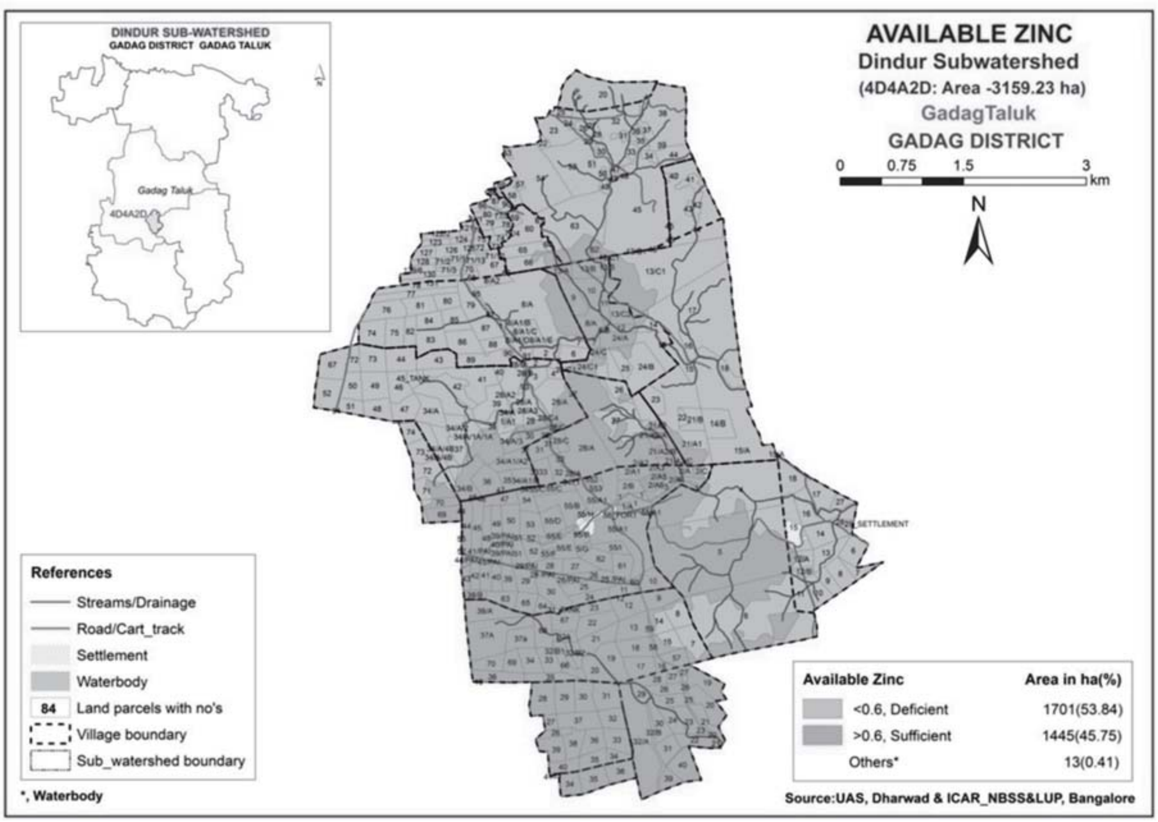

Fig. 8. Available zinc status of Dindur sub-watershed

medium to high and S was low to medium. Regarding available micronutrients, Zn and Fe were deficient in about half of the sub-watershed area, whereas Cu and Mn were sufficient in the soils. The mapping of nutrients by GIS technique in the sub-watershed revealed that, major portion of the study area was deficient in available N, P, S, Zn and Fe which are important soil fertility constraints indicating their immediate attention for sustained crop production. The deficient micronutrients need to be replenished to avoid the crops suffering from their deficiency and for optimum utilization of other nutrients.

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