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RESEARCH PAPER

Soil fertility mapping by GIS in Nilgund sub-watershed under northern dry zone of Karnataka for site specific recommendations

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Abstract: Soil samples from Nilgund 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 for each parameter. Soil fertility maps were prepared for each parameter under Geographic information system (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. Available nitrogen was low, available phosphorus was low to medium, available potassium was medium to high and sulphur was medium. Regarding available micronutrients, zinc, boron 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, P, S, Zn and Fe are important soil fertility constraints.

Key words: Geographic information system, Soil fertility constraints, Soil fertility map, Watershed

Introduction

The concept of watershed based holistic development has emerged as one of the potential approaches in rainfed areas, which can lead to higher sustainable agricultural production. It has been documented that in dry lands besides soil and water conservation, if nutrient management issues are addressed, the productivity of a watershed can be enhanced. Inadequate fertilizer application limits crop yield, results in nutrient mining and causes soil fertility depletion and also intensively cultivated soils are being depleted with available nutrients especially micronutrients. Therefore, assessment of nutrient constraints of soils that are being intensively cultivated with high yielding crops needs 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 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). Furthermore, GIS generated soil fertility maps may serve as a decision support tool for nutrient management (Iftikar *et al.,* 2010). A number of studies on soil fertility mapping have been documented. The proposed study was planned with the objective of identifying available nutrients constraints in soils of Nilgund sub-watershed in northern dry zone of Karnataka.

Material and methods

The Nilgund Subwatershed is located in Gadag taluka of Gadag district covering an area of 6478 ha (Fig. 1), falling under Northern Dry Zone of Agro climatic Zones of Karnataka. The sub watershed is located at about 20.0 km from Gadag city. The sub-watershed consists of 14 micro watersheds having undulating topography with a vast degraded open scrub area.

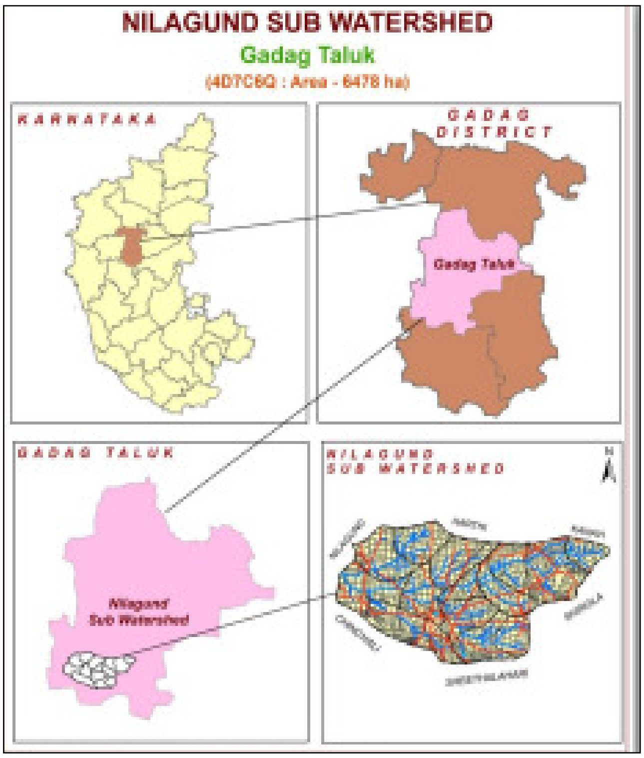

Fig.1. Location map of Nilgund sub-watershed

The Pink and grey granite and 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 monsoonic type. The maximum temperature during summer was 38.2 °C and the minimum 14.8 °C in winter. Mean maximum temperature was 32.85 °C and mean minimum temperature was 19.18 °C. The average annual rainfall is 539.8 mm. It is well distributed with southwest monsoon (June to September) bringing 315 mm and northeast monsoon about 121 mm rain during October and November months. About 88 mm of rainfall was also received during the summer months (April-May).

Surface composite soil samples were collected using a hand held GPS on grid points of 250 m interval in the study area. A total of 1035 samples were collected from the sub watershed during April, 2017. Micro watershed wise soil sample details are furnished in Table 1.

The soil samples were air-dried, grinded (< 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 measured using 0.15% calcium 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.

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

Micro watershed	Code	Area(ha)	No. of soil samples collected
1. Chinchali	4D7C6Q2c	702	112
2. Hosur 1	4D7C6Q1a	246	39
3. Hosur 2	4D7C6Q1b	755	121
4. Kanavi 1	4D7C6Q1d	409	65
5. Kanavi 2	4D7C6Q1c	415	66
6. Mulgunda East 1	4D7C6Q1h	438	70
7. Mulgunda East 2	4D7C6Q1e	223	37
8. Mulgunda East 3	4D7C6Q2f	305	49
9. Mulgunda East 4	4D7C6Q1g	436	70
10.Mulgund 1	4D7C6Q2a	546	87
11.Mulgund 2	4D7C6Q2b	451	72
12.Nilgund 1	4D7C6Q2e	535	85
13.Nilgund 2	4D7C6Q2d	452	72
14.Nilgund 3	4D7C6Q2f	564	90
Total		6478	1035

Table 2. Soil fertility ratings for available nutrients

Nutrients	Fertility rating of major nutrients		
	Low	Medium	High
Organic carbon (%)	<0.5	0.5-0.75	>0.75
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
Boron (B)	<0.5	0.5-1.0	>1.0

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 Nilgund 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 Nilgund 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 Nilgund sub-watershed and the interpolation method employed was krigging. Then map was re-classified 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 Nilgund sub-watershed were neutral to alkaline in reaction (6.84 to 9.47) with a mean pH of 8.08, standard deviation of 0.65 and coefficient of variation of 8.10 (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

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

	pH	EC dS m^{-1}	OC %	N kg ha^{-1}	P_2O_5 mg kg^{-1}	K_2O	S
RANGE	5.78-9.75	0.02-0.88	0.15-0.97	81-319	9.1-68.2	129-1018	6.5-31.1
MEAN	7.71	0.32	0.47	152.55	32.15	195.16	15.97
SD	0.65	0.07	0.16	40.94	10.59	219.22	3.51
CV	8.10	46.15	31.74	27.32	47.22	41.60	23.39

(7.3 - 7.8), Moderately alkaline (7.8 - 8.4), Strongly alkaline (8.4 - 9.0). Major proportion of the sub watershed area (Fig. 2) was moderately alkaline (56.75 %) followed by strongly alkaline (16.33 %), slightly alkaline (12.26 %) and neutral (5.16 %). 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 Prabhavati *et al.* (2015) and Patil *et al.* (2016, 2017a and b, 2018a, b and c). The EC of soils in the sub-watershed was in the range of 0.02 to 0.88 dS m^{-1} with mean value of 0.32 dS m^{-1} and standard deviation of 0.07. The CV (46.15 %) of EC values indicates 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 (Fig. 3) revealed that, 90.50 per cent of the area was non saline.

Organic carbon

Organic carbon content of soils of Nilgund sub-watershed ranged from 0.15 to 0.97 per cent with mean and standard deviation value of 0.47 and 0.16 per cent respectively. The CV (31.74 %) for OC content indicates that, in the sub-watershed SOC varied spatially (Table 3). GIS Mapping of OC by GIS revealed that 46.26 per cent of the study area was low in organic carbon, 42.67 per cent area was medium and 1.57 per cent area was high in soil organic carbon status (Fig. 4). The values obtained in the present study are in agreement with those reported by Patil *et al.* (2011) for black soils of Malaprabha command area of Karnataka. 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 Prabhavati *et al.* (2015) for the soils of northern dry zone of Karnataka, Patil *et al.* (2017a) in Bedwatti sub-watershed under northern dry zone of Karnataka and Patil *et al.* (2018c) in Dudihal sub watershed under northern Dry Zone of Karnataka.

Available macronutrients

The available N in soils of the sub-watershed ranged from 81 to 319 kg ha^{-1} with a mean of 152.55 kg ha^{-1} and SD of 40.94. The CV value of 27.32 per cent 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. 5). 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 nitrogen deficiency. Similar nitrogen status was reported by Pulakeshi *et al.* (2012) in non-saline clay to sandy loams and calcareous soils and Patil *et al.* (2018c) in Dudihal sub-watershed under northern Dry Zone of Karnataka.

The available P_2O_5 content of the sub-watershed ranged from 9.1 to 68.2 kg ha^{-1} with average and SD value of 32.15 and 10.59 and kg ha^{-1}, respectively. The CV of 47.22 percent for available P_2O_5 distribution 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 66.21 per cent of the study area whereas, it was medium in 24.30 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, calcareousness and low organic matter content. Patil *et al.* (2011) reported for black soils of Malaprabha command area of Karnataka that available P_2O_5 status in the soils was low due to high calcium carbonate content and Patil *et al.* (2018b) in Belageri sub-watershed of Karnataka.

The available K_2O content in the sub-watershed ranged from 129 to 1018 kg ha^{-1} with mean and SD value of 195.16 and 219.22 kg ha^{-1}, respectively. The CV (41.60 %) for available 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, 85.72 per cent of the of the study area was in high category (Table 3 and Fig. 7) and 4.79 per cent of the of the study area was in medium category. It is reported that, invariably the surface soils had higher concentration of water soluble and exchangeable K in Karnataka (Somasundaram *et al.*, 2009 and 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 medium to higher content of available potassium in soils of Nilgund sub-watershed may be due to the predominance of potash rich micaceous and feldspar minerals in parent material. Similar results were observed by Pulakeshi *et al.* (2012) and Patil *et al.* (2018b).

The available sulphur content of soils of the sub-watershed varied from 6.50 to 31.10 mg kg^{-1} soil with mean and SD values of 15.97 and 3.51 mg kg^{-1} soil, respectively. The CV (23.39 %) for available S content indicates that, in the sub watershed available S varied spatially. GIS mapping of available S revealed that, the area under study was medium (90.50 %) in available sulphur status (Table 3 and Fig. 8) in sub-watershed highlighting the importance of mapping the area rather than the statistic derived from soil analysis. Medium level of available sulphur was due to lack of sulphur addition and continuous removal of S by crops (Pulakeshi *et al.* 2012, Sabyasachi Majumdar and Patil, 2016 and Patil *et al.* 2018b).

Available micro nutrients

The available iron in the sub-watershed ranged from 0.68 to 14.66 mg kg^{-1} with mean and SD value of 3.39 and 1.56 mg kg^{-1} respectively (Table 4). The CV (46.12 %) 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 83.84 per cent of the study area and sufficient in 6.67 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 observed by Pulakeshi *et al.* (2012). This type of variation may be due to the soil management practices and cropping pattern adopted by different farmers (Patil *et al.,* 2016 and 2017a and b).

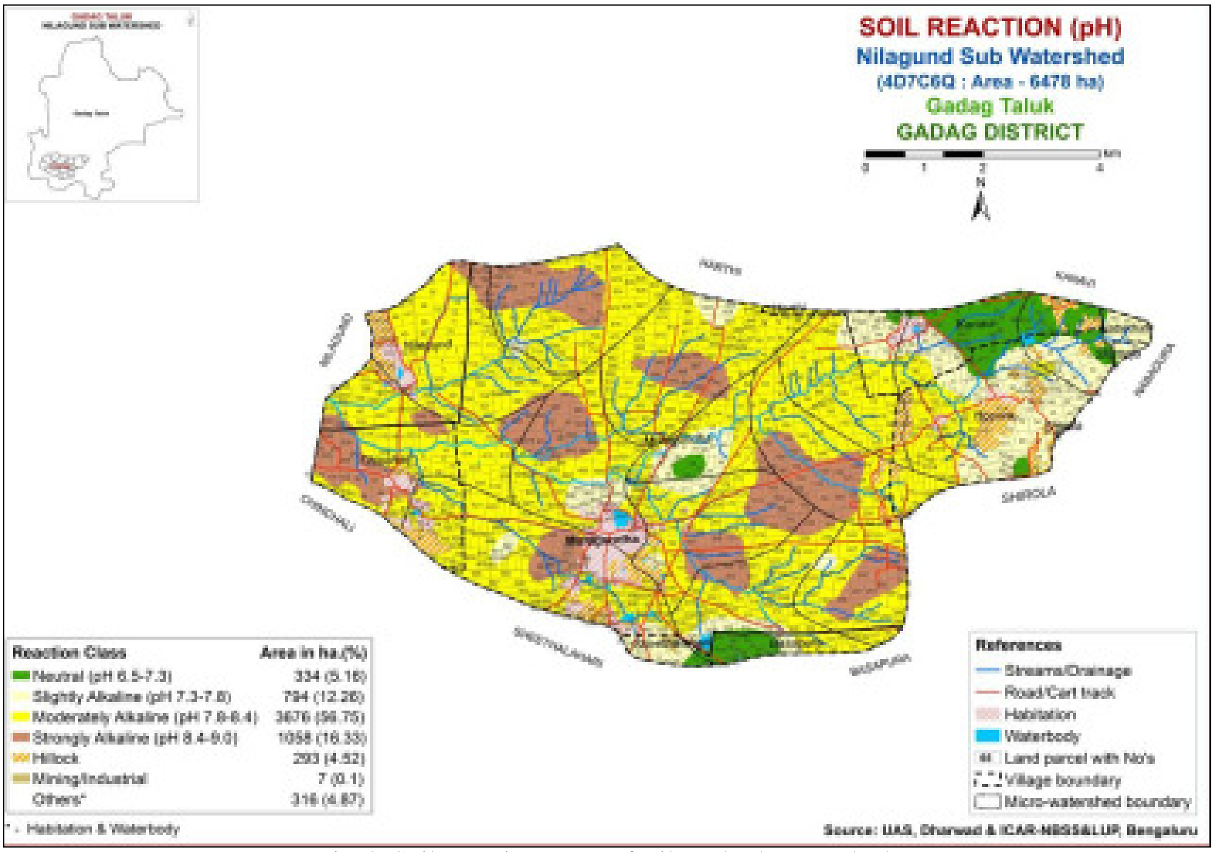

Fig. 2. Soil Reaction status of Nilgund sub-watershed

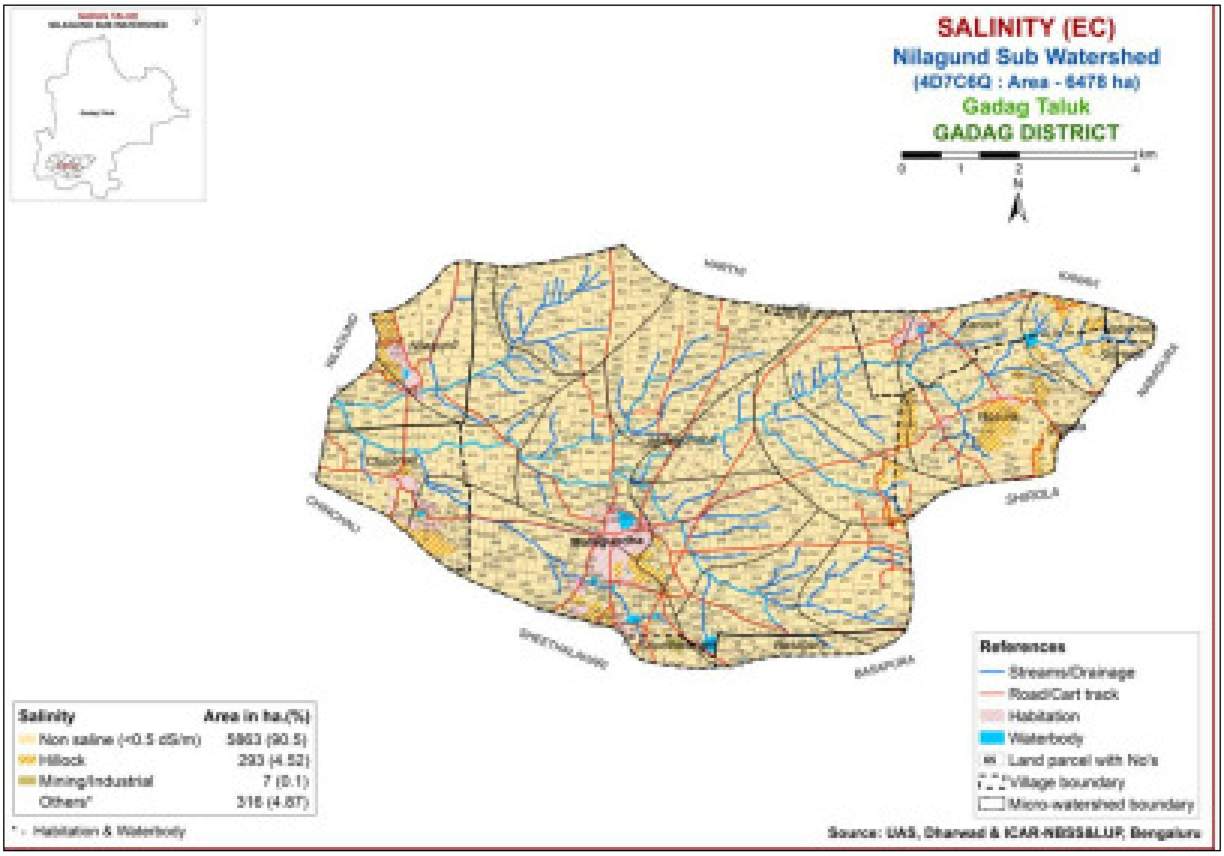

Fig.3. Salinity status of Nilgund sub-watershed

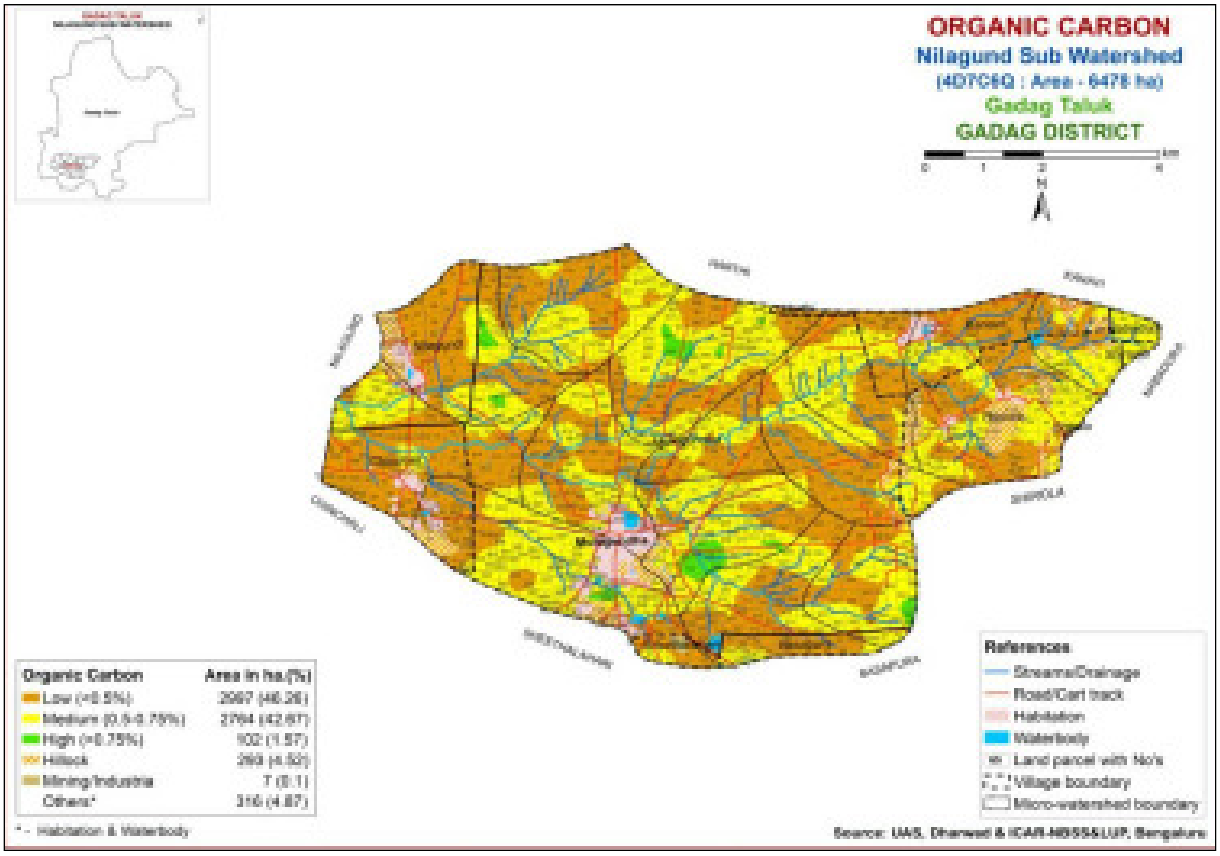

Fig.4. Soil Organic carbon status of Nilgund sub- watershed

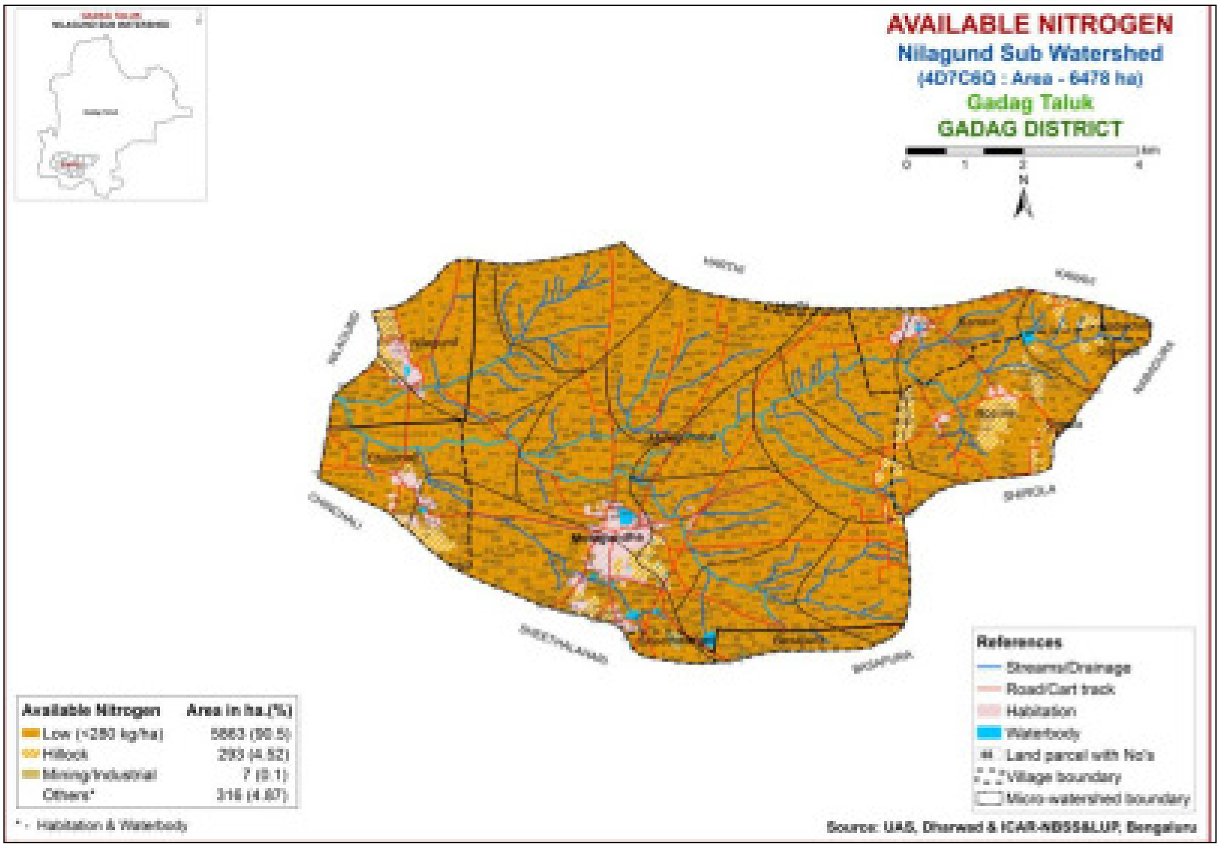

Fig. 5. Available Nitrogen status of Nilgund sub-watershed

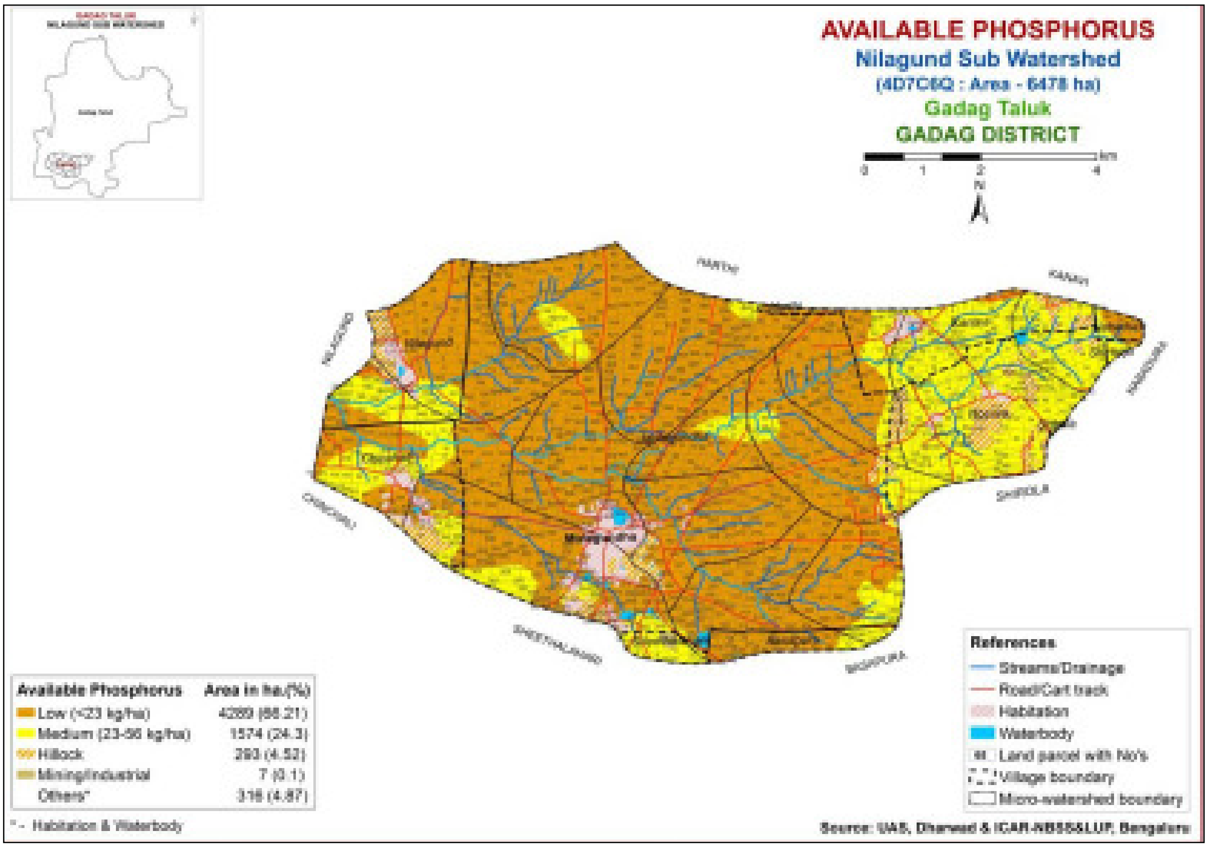

Fig. 6. Available Phosphorus status of Nilgund sub-watershed

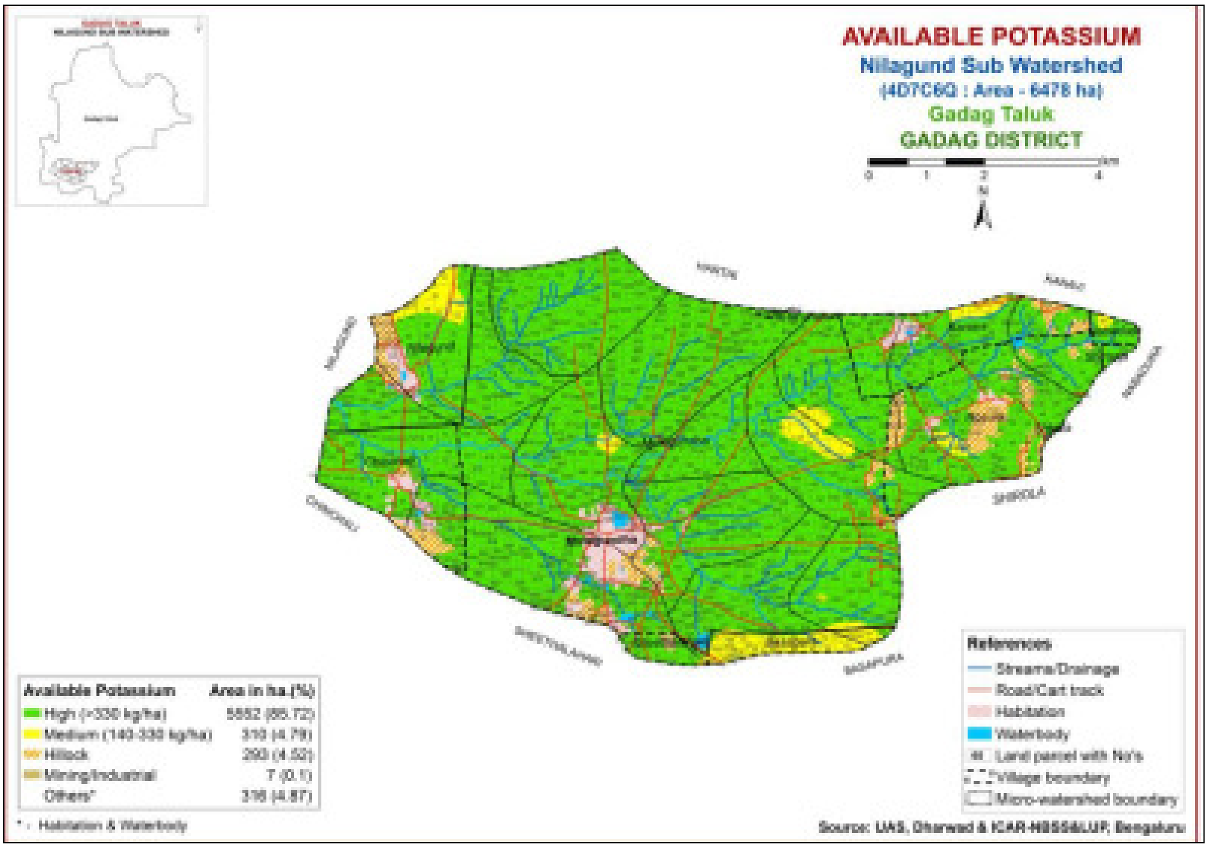

Fig. 7. Available Potassium status of Nilgund sub-watershed

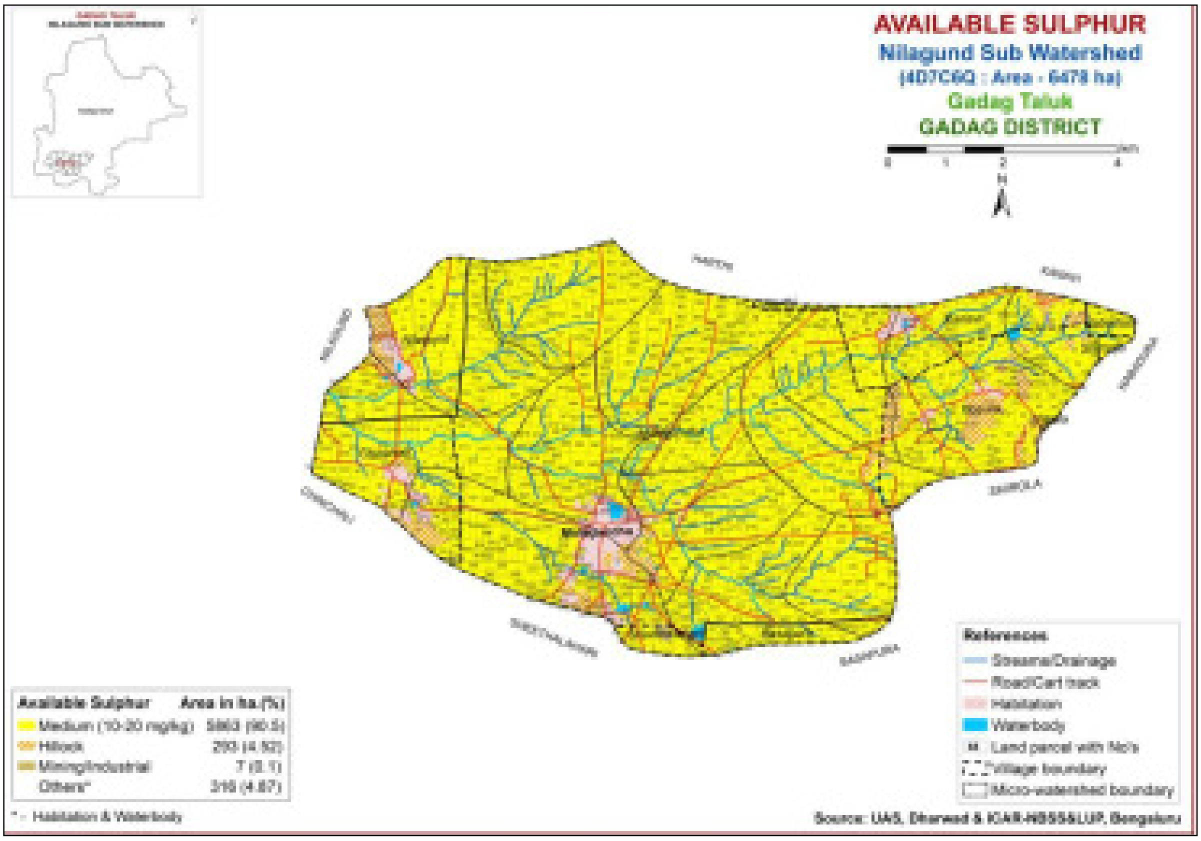

Fig. 8. Available sulphur status of Nilgund sub-watershed

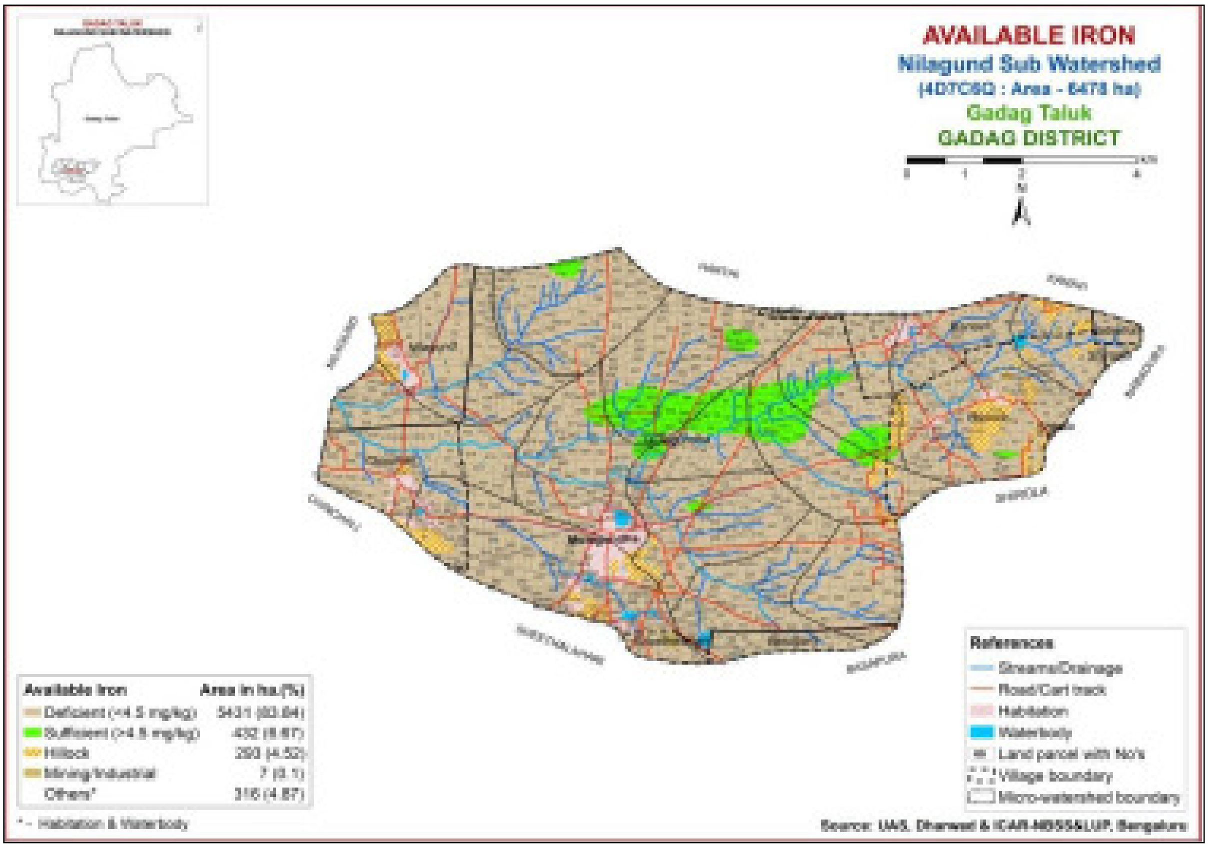

Fig. 9. Available iron status of Nilgund sub-watershed

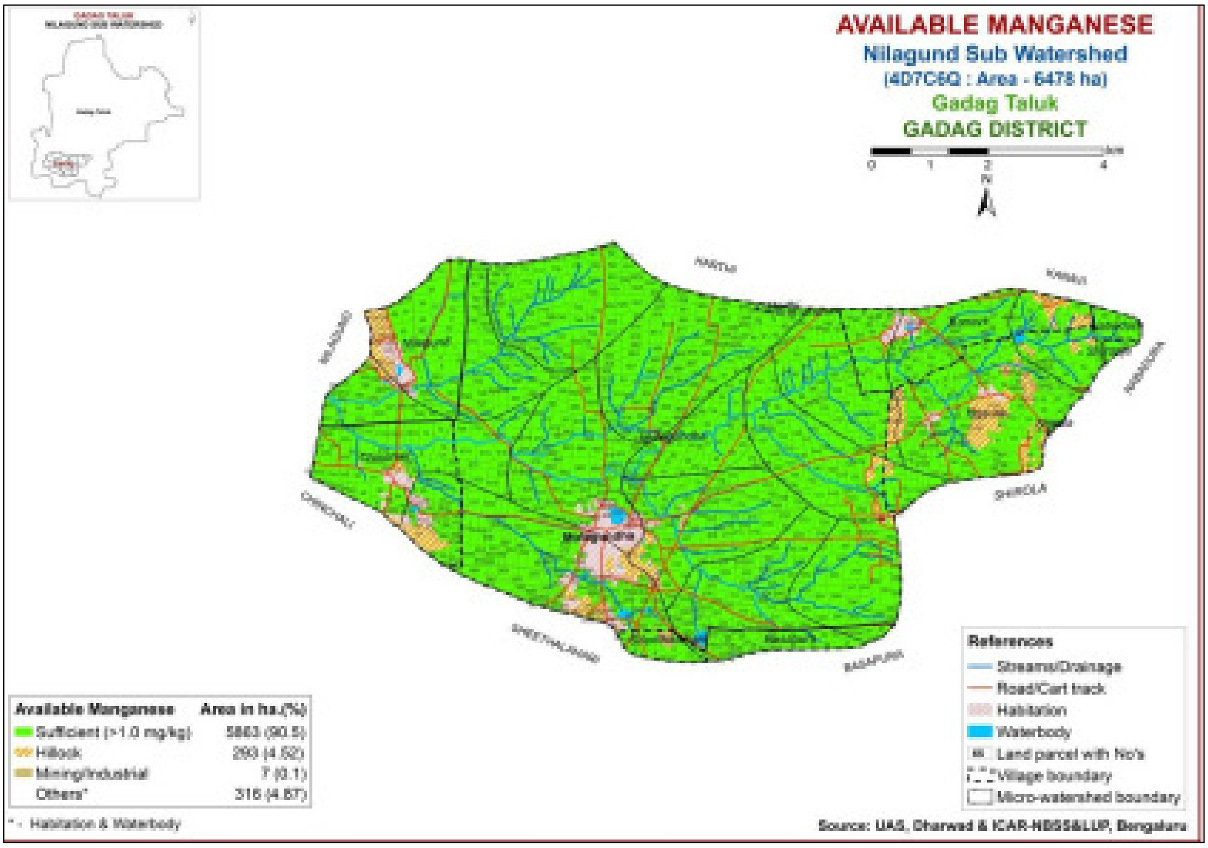

Fig.10. Available manganese status of Nilgund sub-watershed

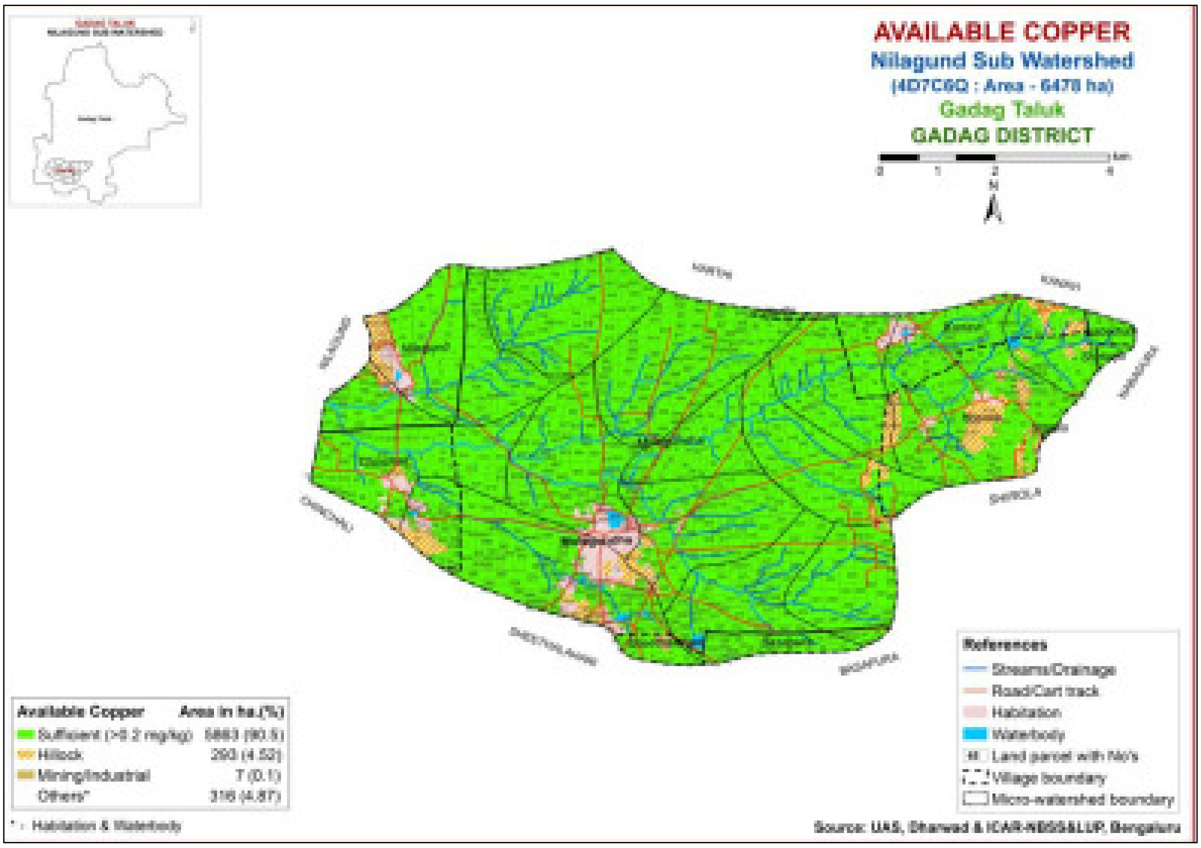

Fig.11. Available copper status of Nilgund sub-watershed

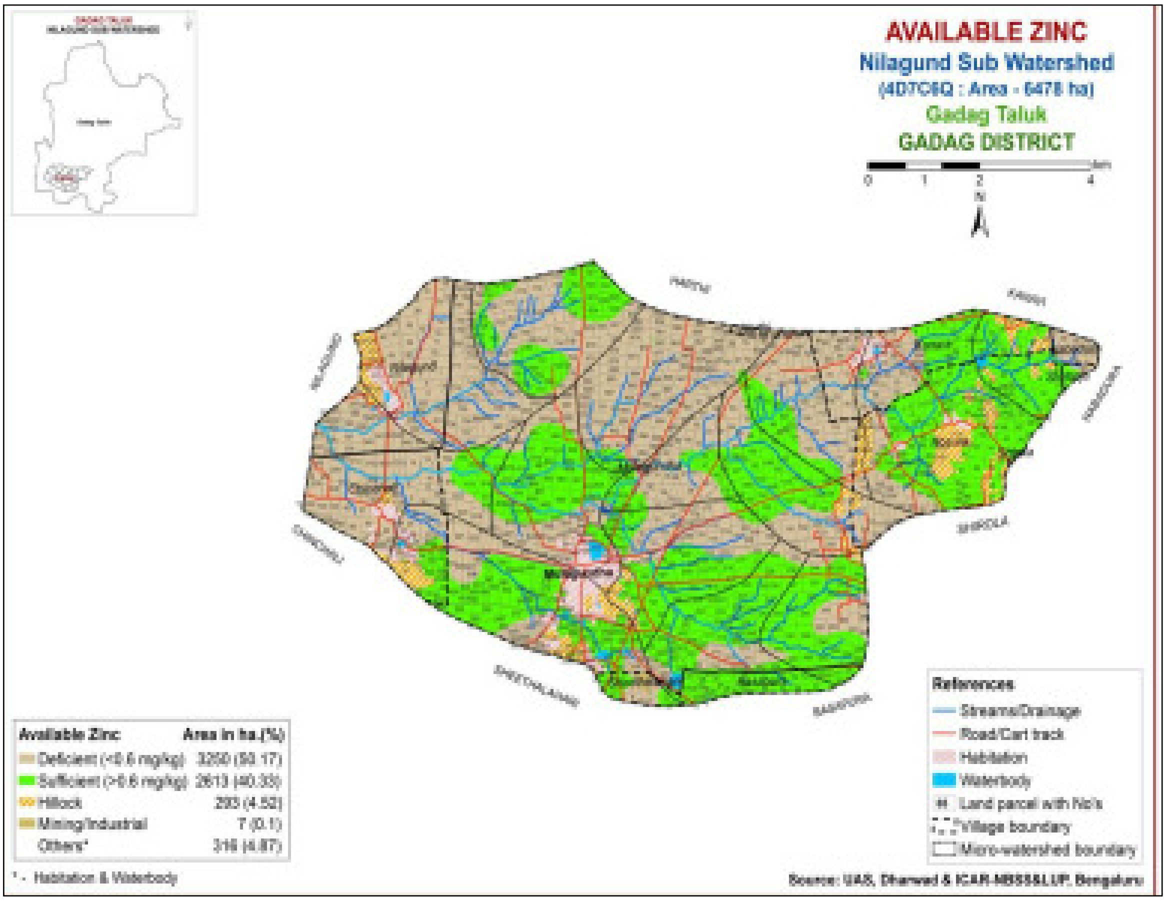

Fig. 12. Available zinc status of Nilgund sub-watershed

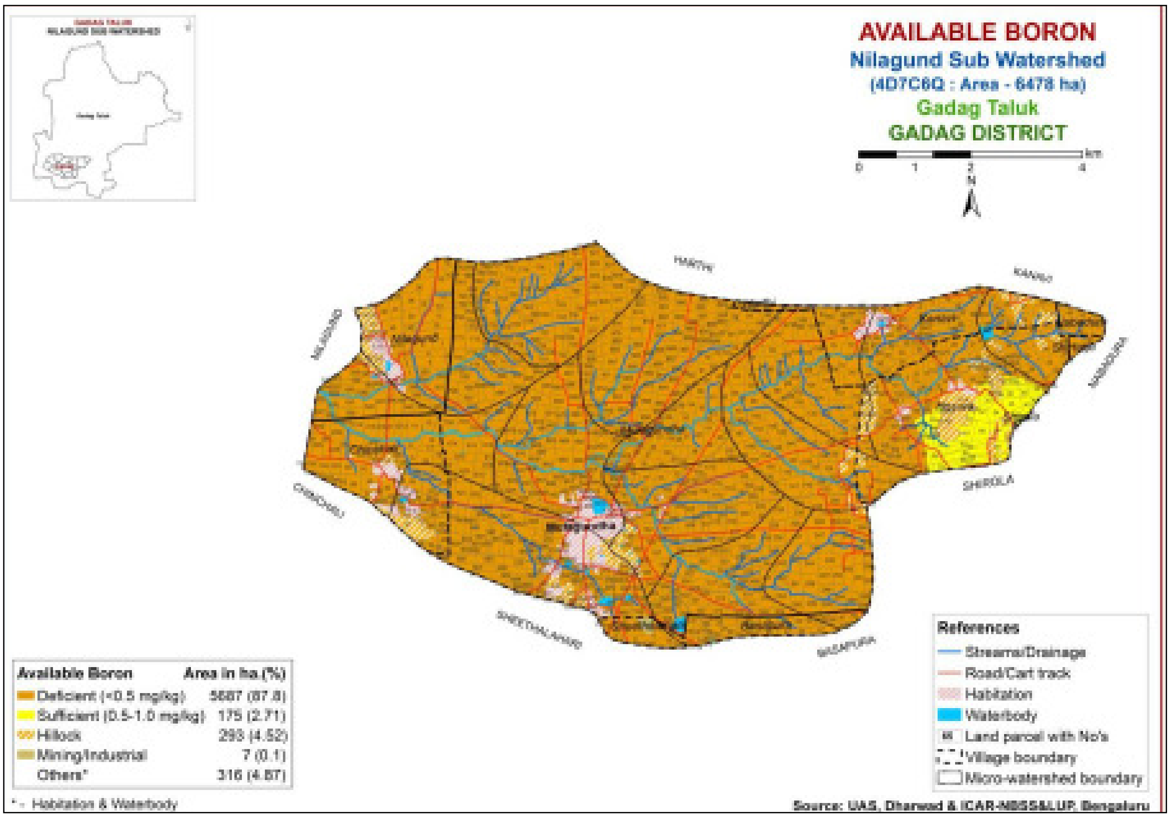

Fig. 13. Available boron status of Nilgund sub-watershed

Table 4. Available micro nutrients status in Nilgund sub-watershed

	Fe	Mn	Cu mg kg^{-1}	Zn	B
RANGE	0.68-14.66	0.70-15.48	0.06-4.20	0.06-3.94	0.10-1.00
MEAN	3.39	4.18	1.19	0.59	0.38
SD	1.56	1.74	0.54	0.44	0.15
CV	46.12	41.70	45.69	73.79	38.64

The available Manganese in the sub-watershed ranged from 0.70 to 15.48 mg kg^{-1} with mean and SD value of 4.18 and 1.74 mg kg^{-1}, respectively (Table 4). The CV (41.70 %) 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 (Fig. 10). Sufficient content of manganese was observed by Pulakeshi *et al*.(2012) in the soils of northern transition zone of Karnataka derived from chlorite schist and Patil *et al.* (2018b) in Belageri sub-watershed of Karnataka.

The available copper in the entire sub-watershed was sufficient and ranged from 0.06 to 4.20 mg kg^{-1} with mean and SD value of 1.19 and 0.54 mg kg^{-1}, respectively (Table 4). The CV (45.69 %) 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 (Fig, 11). Pulakeshi *et al.*(2012) in the soils of northern transition zone of Karnataka derived from chlorite schist and Patil *et al.* (2018b) in Belageri sub-watershed of Karnataka.

The available zinc in the sub-watershed was ranged from 0.06 to 3.94 mg kg^{-1} with mean and SD value of 0.59 and 0.44 mg kg^{-1}, respectively (Table 4). The CV (73.79 %) 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 50.17 per cent of the study area and sufficient in 40.33 per cent of the area (Fig. 12). The content of Zn increases with low pH and high organic carbon content but decreases with increase in pH as also reported by Pulakeshi *et al.,* 2012 and Patil *et al.,* 2017b and 2018c). Since, most of the soils 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.

The available boron in the sub-watershed ranged from 0.10-1.00 mg kg^{-1} with mean and SD value of 0.38 and 0.15 mg kg^{-1} respectively (Table 4). The CV (38.64 %) for available B content indicates that, it varied spatially in the sub-watershed. Mapping of available boron revealed that 5687 ha (87.8 %) area of the sub-watershed is found to be low and 175 ha (2.71 %) to be medium (Fig. 13). The content of B increases with organic carbon content. Since, most of the soils are low in OC, it might have decreased and reduced the boron availability.

From the study, it can be concluded that, soils of Nilgund 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. Available nitrogen was low, available phosphorus was low to medium, available potassium was medium to high and sulphur was medium. Regarding available micronutrients, zinc, iron and B 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, P, Zn, Fe and B are important soil fertility constraints indicating their immediate attention for sustained crop production. The deficient micronutrient may be replenished to avoid the crops suffering from their deficiency and for optimum utilization of other nutrients.

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