J. Farm Sci., 33(2): (220-229) 2020

RESEARCH PAPER

Identification of soil fertility constraints by GIS in Kadadi sub-watershed under northern dry zone of Karnataka for site specific recommendations

P. L. PATIL, K. SUNILKUMAR, G. P. GEETHA, BASAVASHREE YADAWAD, MALLAPPA KALLAPUR, V. B. KULIGOD, S. S. GUNDLUR AND G. S. DASOG

Sujala-III Project, Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dharwad
University of Agricultural Sciences, Dharwad - 580 005, Karnataka, India
E-mail: patilpl@uasd.in

(Received: January, 2020 ; Accepted: May, 2020)

Abstract: Soil samples from Kadadi sub-watershed in northern dry zone of Karnataka were drawn at 320 m grid intervals and assessed their fertility. Analytical data was interpreted and statistical parameters like range, mean standard deviation, coefficient of variation, kurtosis and skewness were calculated for each parameter. Soil fertility maps were prepared for each nutrient using Arc GIS v 10.4. Soils were moderately alkaline to strongly alkaline with non saline to slight salinity. Majority of area in micro-watershed had low to medium in soil organic carbon, nitrogen was low, available phosphorous was low to medium, available potassium was high, available boron and sulphur was low to medium. Regarding available micronutrients, zinc and iron were deficient in more than half of the sub watershed area, whereas copper and manganese were sufficient in these 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: Nutrients, Soil fertility constrains, Soil fertility map, Watershed

Introduction

Intensively cultivated soils are being depleted with available nutrients especially micronutrients. Therefore, assessment of nutrient constraints in the 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. Such soil testing results 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 both 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 meaning that besides soil and water conservation, if nutrient management issues are addressed, the productivity of a watershed could be further enhanced. Some studies on soil fertility status at representative micro-watershed/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 nutrients constraints in soils of Kadadi sub watershed in northern dry zone of Karnataka.

Material and methods

The Kadadi sub-watershed is located in Gadag taluka of Gadag district covering an area of 6632.47ha (Fig. 1), falling under northern dry zone of agro climatic zones of Karnataka. The sub-watershed consists of thirteen micro-watersheds with undulating topography under forest cover. The peninsular gneiss covers the sub-watershed area with the predominance of oligoclase and orthoclase feldspar minerals. The climate of the area is semi-arid or hot tropical and monsoonal type. The

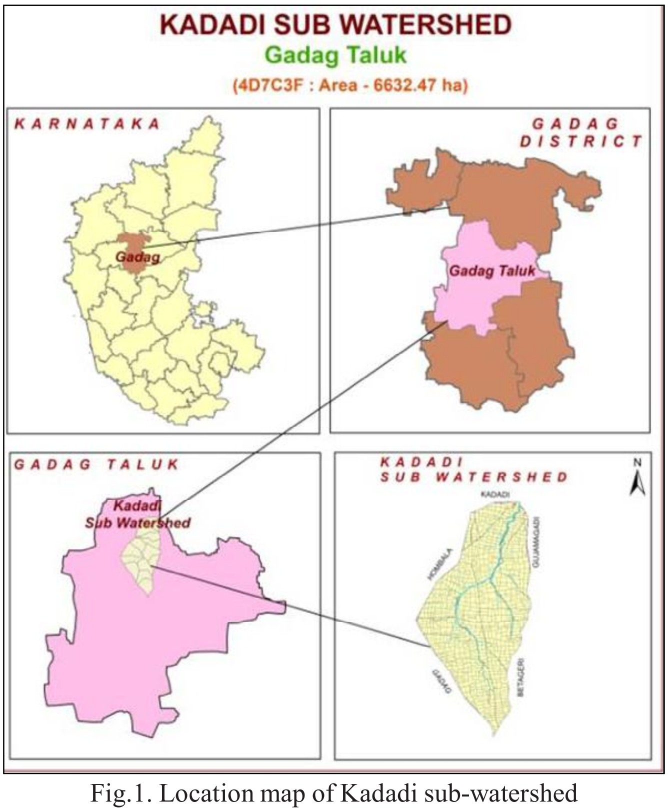

Fig.1. Location map of Kadadi sub-watershed

maximum temperature during summer is 42.7 °C and the minimum of 16.1 °C in winter. Mean maximum temperature was 36.56 °C and mean minimum temperature was 20.43 °C. The average annual rainfall is 580.7 mm and it is well distributed with southwest monsoon (June to September) bringing 365 mm and northeast monsoon (October and November) bringing about 200 mm rain.

Surface composite soil samples were collected during April 2016 by following grid points at320 m intervals in thestudy area and the sample location was recorded using GPS. A total of 502 samples were collected from the sub-watershed. Micro watershed wise soil sample details are furnished in Table 1.

The soilsamples were air-dried, ground (<2 mm) and analyzedfor 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 Sommers1982). 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 eachset of data. Availability of N, P, K, S and Bin 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 as 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 Kadadi 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 Kadadi 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 Kadadi sub-watershed and the interpolation method employed was krigging. Then the map was reclassified based on ratings of the respective nutrients (Table 2) andthe area for each category of nutrient was calculated.

Table1. Details of soil sampling in Kadadi sub watershed

Micro watershed	Code	Area (ha)	No. of Samples
Ali Halla-1	4D7C3F2b	636.83	42
Ali Halla-2	4D7C3F2a	354.74	25
Ali Halla-3	4D7C3F2c	417.08	29
Hombal East-1	4D7C3F1d	547.33	42
Hombal East-2	4D7C3F1g	468.30	35
Hombal East-3	4D7C3F1b	466.59	35
Hombal East-4	4D7C3F1e	458.67	35
Hombal East-5	4D7C3F1a	564.37	45
Hombal East-6	4D7C3F1f	645.05	53
Hombal East-7	4D7C3F1c	499.17	39
Kadadi-1	4D7C3F2e	655.92	53
Kadadi-1	4D7C3F2f	509.64	37
Kadadi-3	4D7C3F2d	408.76	32
Total		6632.47	502

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

Results and discussion

Soil reaction and electrical conductivity

Soils of the Kadadi sub-watershed were moderately alkaline tostrongly alkaline in reaction (7.34 to 9.63) with a mean pH of 8.55, standard deviation of 0.33 and coefficient of variation of 3.80 (Table 3). The coefficient of variation of soil pH indicates that, it does not vary spatially. Mapping of soil pH by GIS technique resulted in three soil reaction classes (Fig. 2). They are Slightly alkaline (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 (20.07 %) followed by strongly alkaline (77.59 %). The higher pH of soils could be attributed to low intensity of leaching and accumulation of bases. (Ravikumar *et al.,* 2007a, and Prabhavati *et al.,* 2015). The EC of soils in the sub-watershed was in the range of 0.07 to 1.12dSm^{-1} with mean value of 0.29dS$m^{-1}$and standard deviation of 0.19. The CV (64.59) 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 the existing arid climatic condition in the study area. GIS Mapping of soluble salt content in the sub-watershed (Fig. 3) revealed that, 93.3 per cent of the area was non saline whereas 4.36 per cent of the area was slightly saline.

Organic carbon

Organic carbon content of soils of Kadadi sub-watershed ranged from 0.12 to 0.86 g kg^{-1} with the mean and standard deviation value of 0.43 and 0.15 g kg^{-1}, respectively. The CV (34.76) for OC content indicates that SOC varied spatially in the sub-watershed (Table 3). GIS Mapping of OC revealed that 73.68 per cent of the study area was low in organic carbon and

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

	pH	EC	OC	N	P_2O_5	K_2O	S
		(dS m^{-1})	(g kg^{-1})		(kg ha^{-1})		(mg kg^{-1})
Average	8.55	0.29	0.43	156	29	604	13.0
SD	0.33	0.19	0.15	34.46	12.17	149.72	4.56
Range	7.34-9.64	0.07-1.12	0.12-0.86	87-302	9.0-70.3	154-1095	3.1-37.2
CV	3.80	64.59	34.76	22.13	42.32	24.78	35.06

23.98 per cent area was mediumin soil organic carbon status (Fig. 4). The values obtained in the present study are in agreement with those reported by Ravikumar *et al.* (2007a) and 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 high temperature under 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 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.

Available macronutrients

The available N in soils of the sub-watershed ranged from 87 to 302 kg ha^{-1} with amean of 156 kg ha^{-1} and SD of 34.46. The CV value of 22.13 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 beattributed to the varied soil management practices such as 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 be due to low organic matter content in these areas due to low rainfall and high temperaturewhich 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.

The available P_2O_5 content in the soils of sub-watershed ranged from 9.0 to 70.3 kg ha^{-1} with mean and SD value of 29 and 12.17 kg ha^{-1}, respectively. The CV for available P_2O_5 (42.32) 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 9.74 per cent of the study area whereas, it was medium in 87.34 per cent area and high in 0.57 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. Ravikumar *et al.* (2007a) reported that the black soils of Malaprabha command area of Karnataka had low available P_2O_5due to high calcium carbonate content. The present findings are in line with the report of Patil *et al.* (2011) who reported that majority of the soils in Karnataka are medium in phosphorus content.

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

	Zn	Fe	Mn	Cu	B
			mg kg^{-1}		
Acerage	0.40	3.66	3.57	0.90	0.34
SD	0.39	1.04	0.88	0.36	0.26
Range	0.03-5.44	0.84-6.80	1.50-6.21	0.28-2.16	0.04-1.06
CV	96.07	28.52	24.65	39.69	75.03

The available K_2O content in the soils of sub-watershed ranged from 154 to 1095 kg ha^{-1} with mean and SD value of 604 and 149.72 kg ha^{-1}, respectively. The CV (24.78) 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 the entire study area had high available K (Table 3 and Fig.7). 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 the soils of Kadadi sub-watershed may be due to the predominance of potash rich micaceous and feld spar minerals in the parent material. Similar results were observed by Srikant *et al.* (2008).

The available sulphur content of soils in the sub-watershed varied from 3.1 to 37.2 mg kg^{-1} soil with mean and SD values of 13.0 and 4.56 mg kg^{-1}, soil respectively. The CV (35.06) for available Scontent indicates that, in the sub-watershed available S varied spatially. The GIS mapping of available S revealed that, the area under study was low in 13.08 per cent area and medium in 84.57 per cent in available sulphur status (Table 3 and Fig. 8). Low and medium level variation of available sulphur was due to lack of sulphur addition and continuous removal of S by crops (Srikant *et al.,* 2008).

Available micro nutrients

The available zinc in the soils of sub-watershed ranged from 0.03 to 5.44 mg kg^{-1} with mean and SD value of 0.40 and 0.39 mg kg^{-1}, respectively (Table 4). The CV (96.07) 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 89.99 per cent of the study area and sufficient in 7.66 per cent of the area (Fig. 9). The content of Zn increases with low pH and high organic carbon content but decreases with increase in pH. Since, the 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. Similar results were also reported by Ravikumar *et al.* (2007b), Patil *et al.* (2006) and Pulakeshi *et al.* (2012).

The available iron in the soils of sub-watershed ranged from 0.84 to 6.80 mg kg^{-1} with mean and SD value of 3.66 and 1.04 mg kg^{-1}, respectively (Table 4). The CV (28.52) 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 about 89.99 per cent of the study area and sufficient in 7.66 per cent of the area (Fig 10). The low Fe content

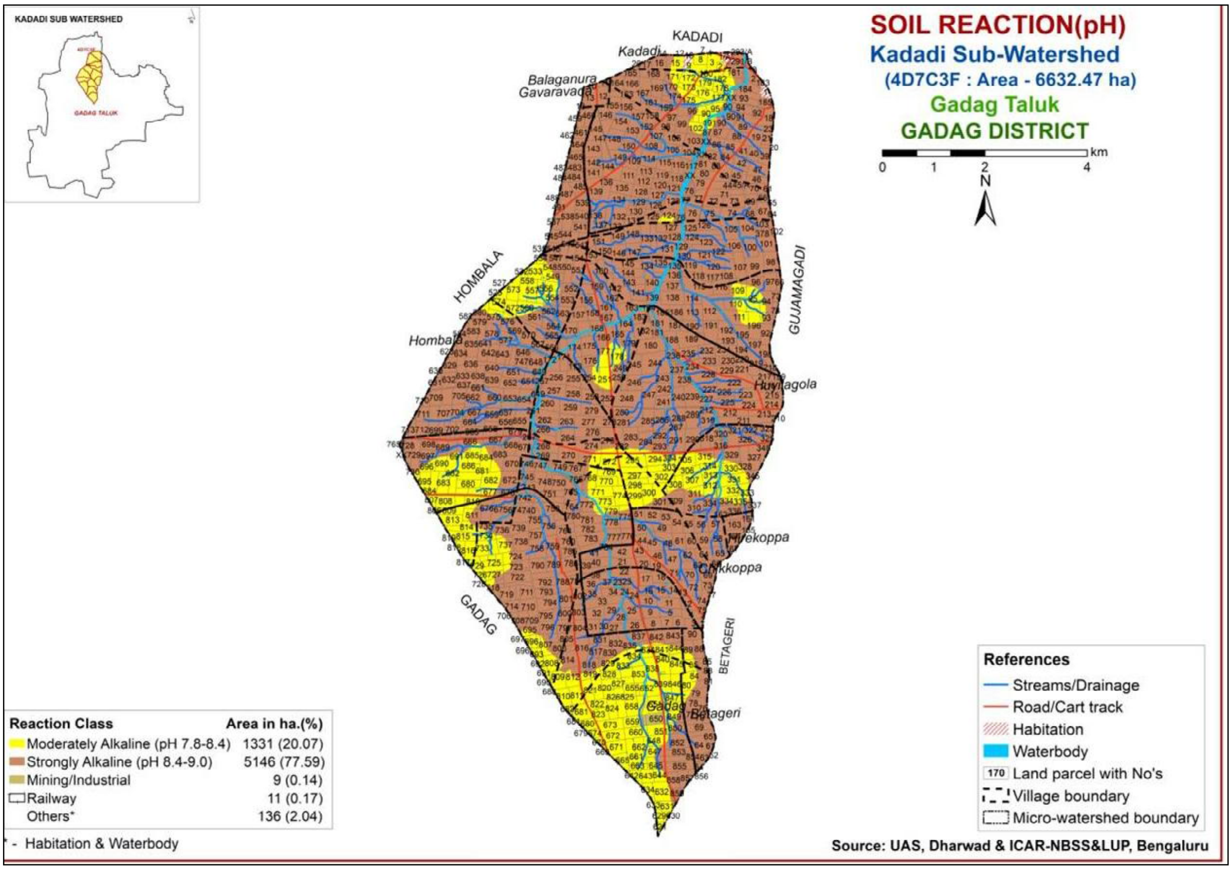

Fig. 2. Soil Reaction status of Kadadi sub-watershed

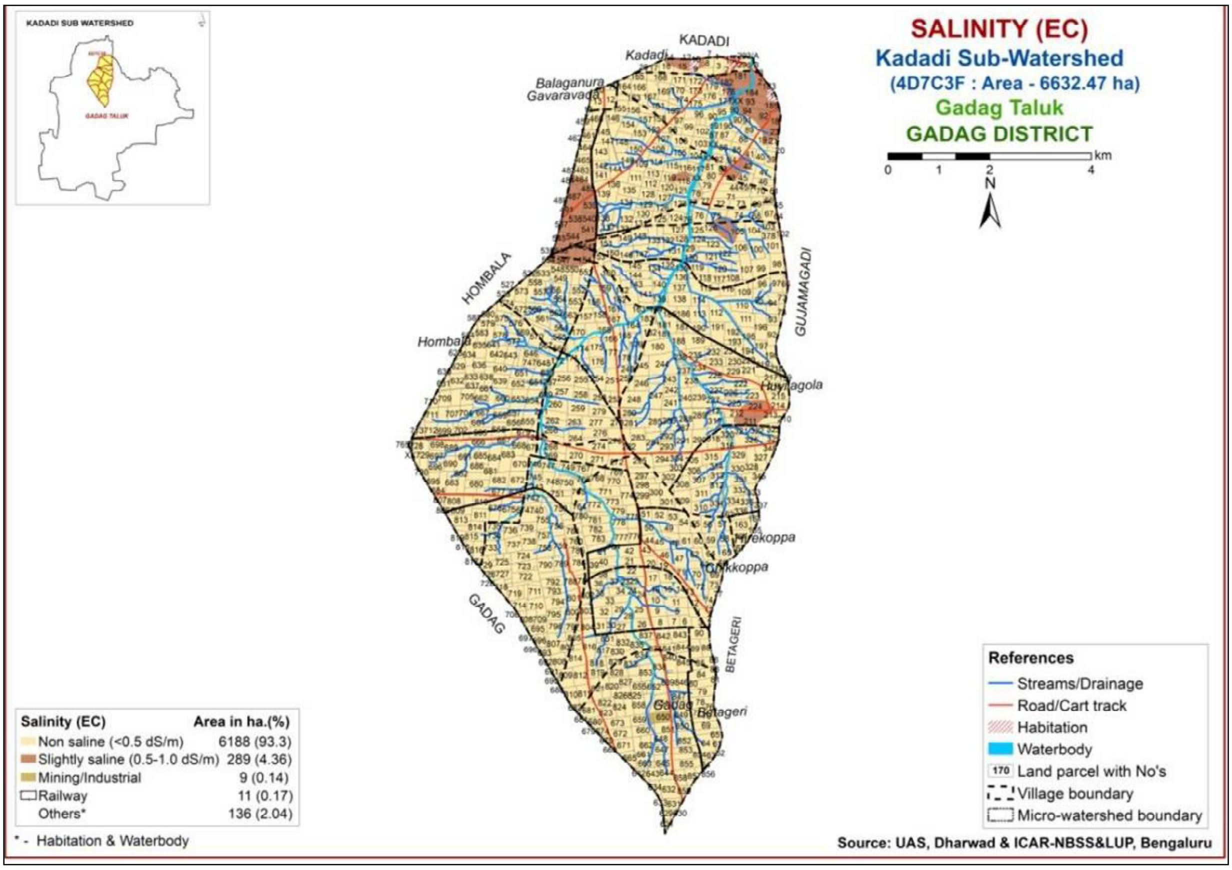

Fig.3.Salinity status of Kadadi sub-watershed

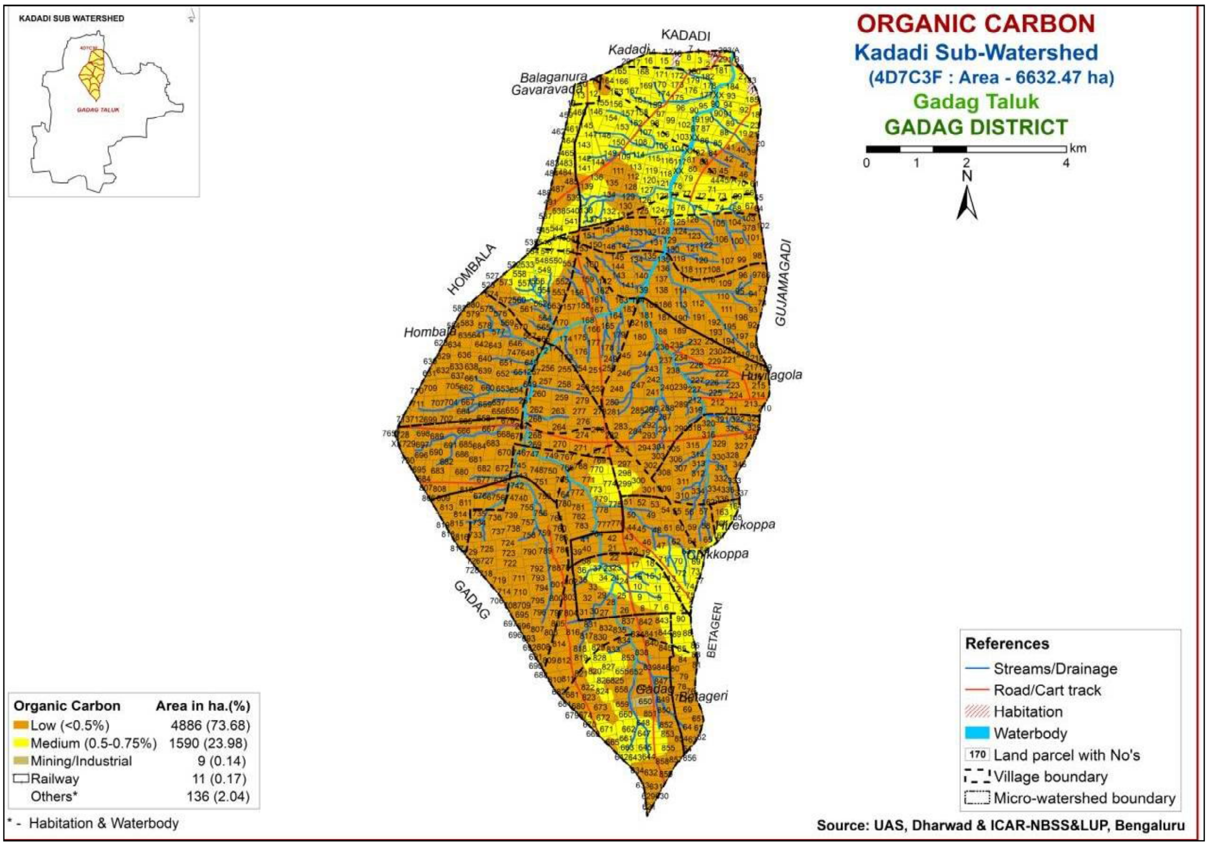

Fig. 4. Soil Organic Carbon status of Kadadi sub-watershed

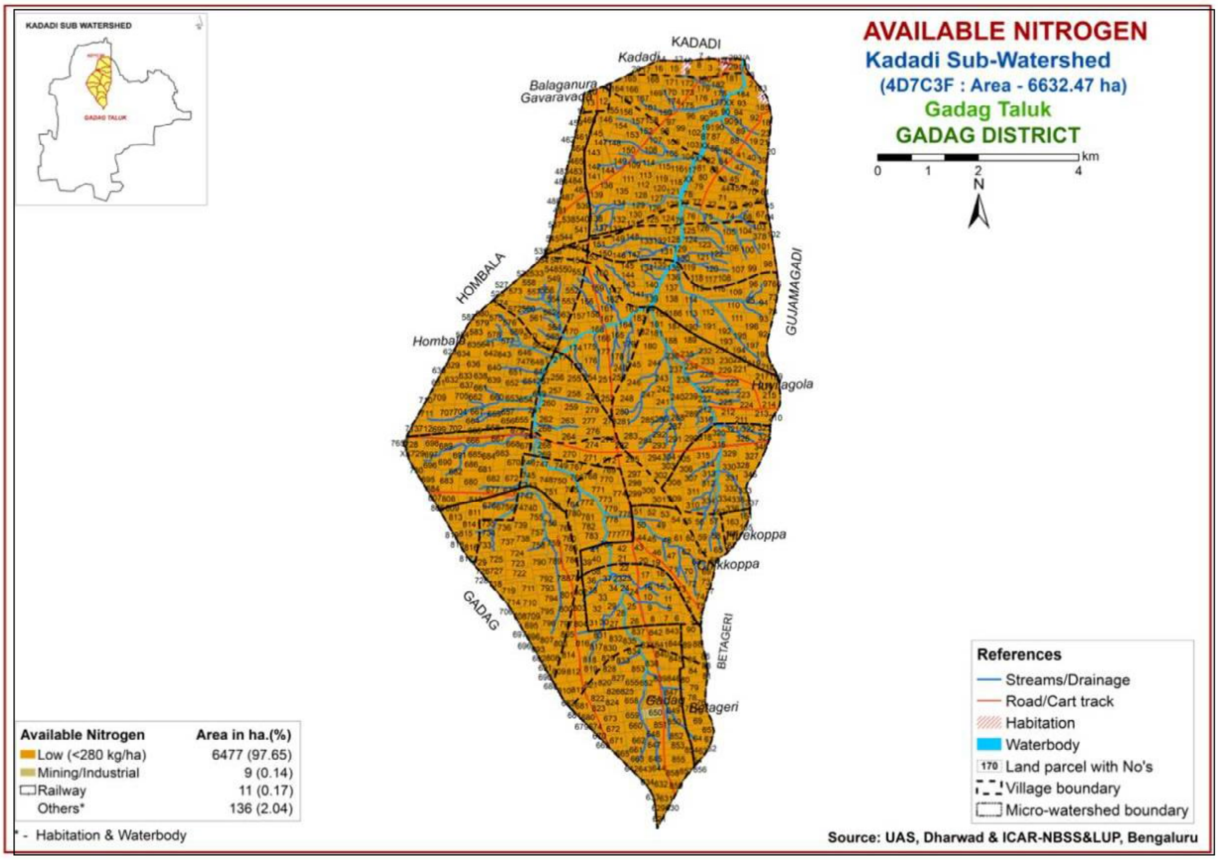

Fig. 5. Available Nitrogen status of Kadadi sub-watershed

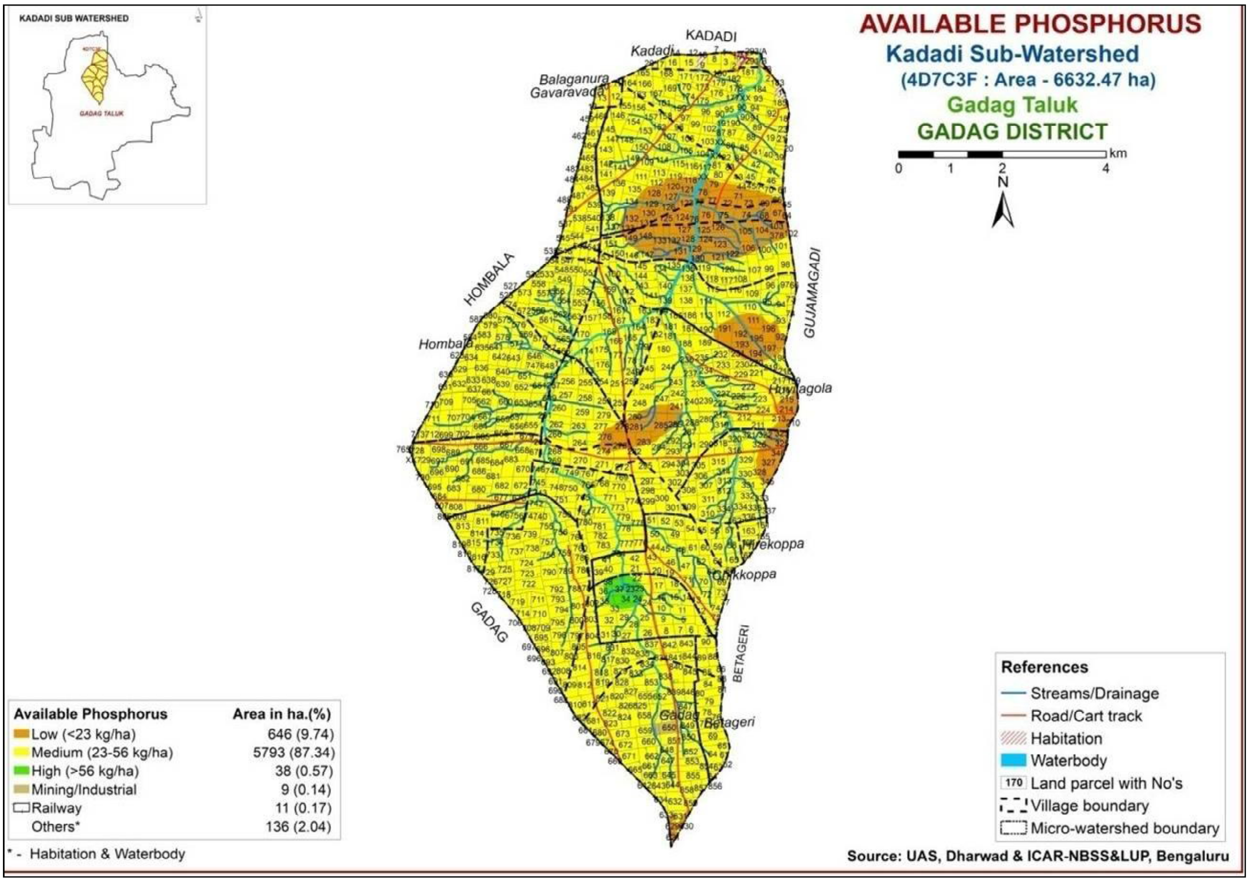

Fig.6. Available Phosphorus status of Kadadi sub-watershed

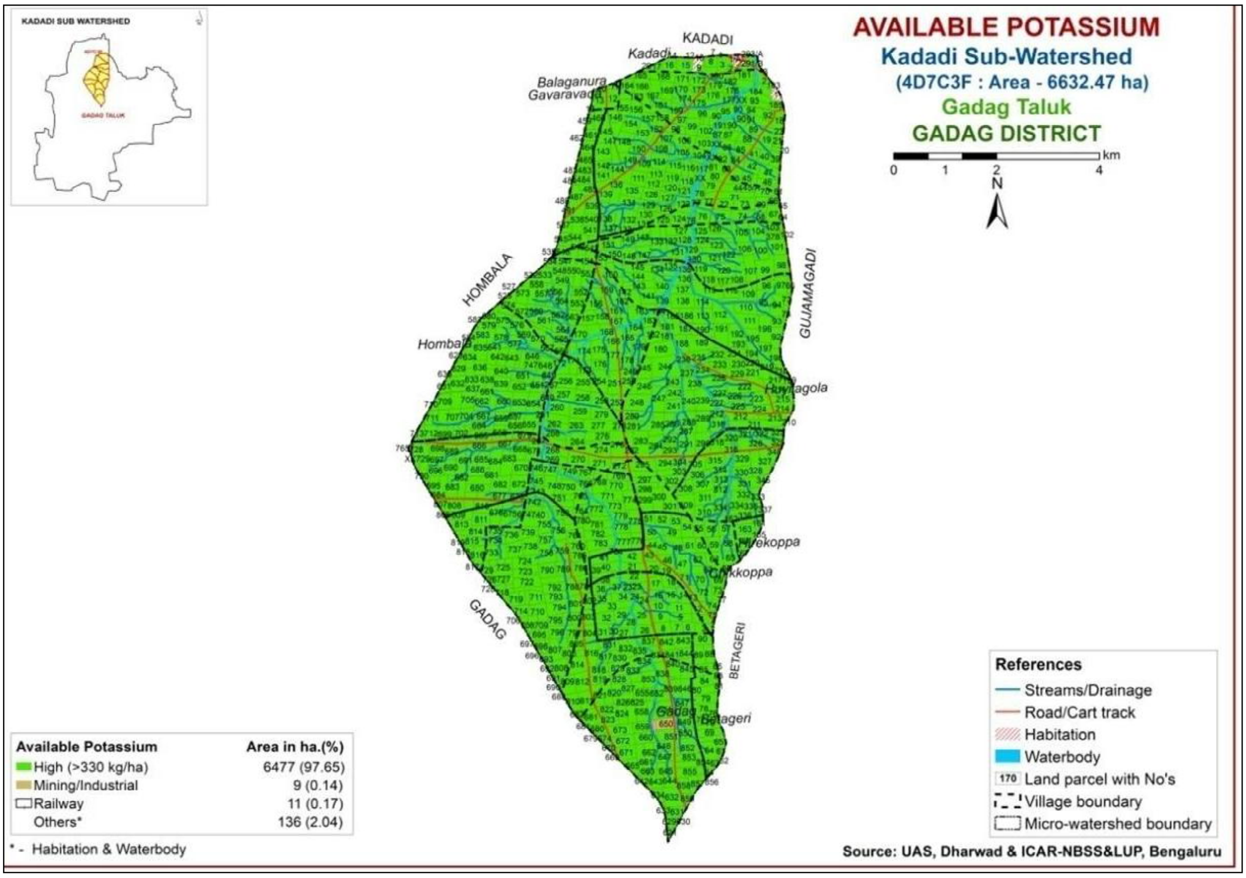

Fig.7. Available Potassium status of Kadadi sub-watershed

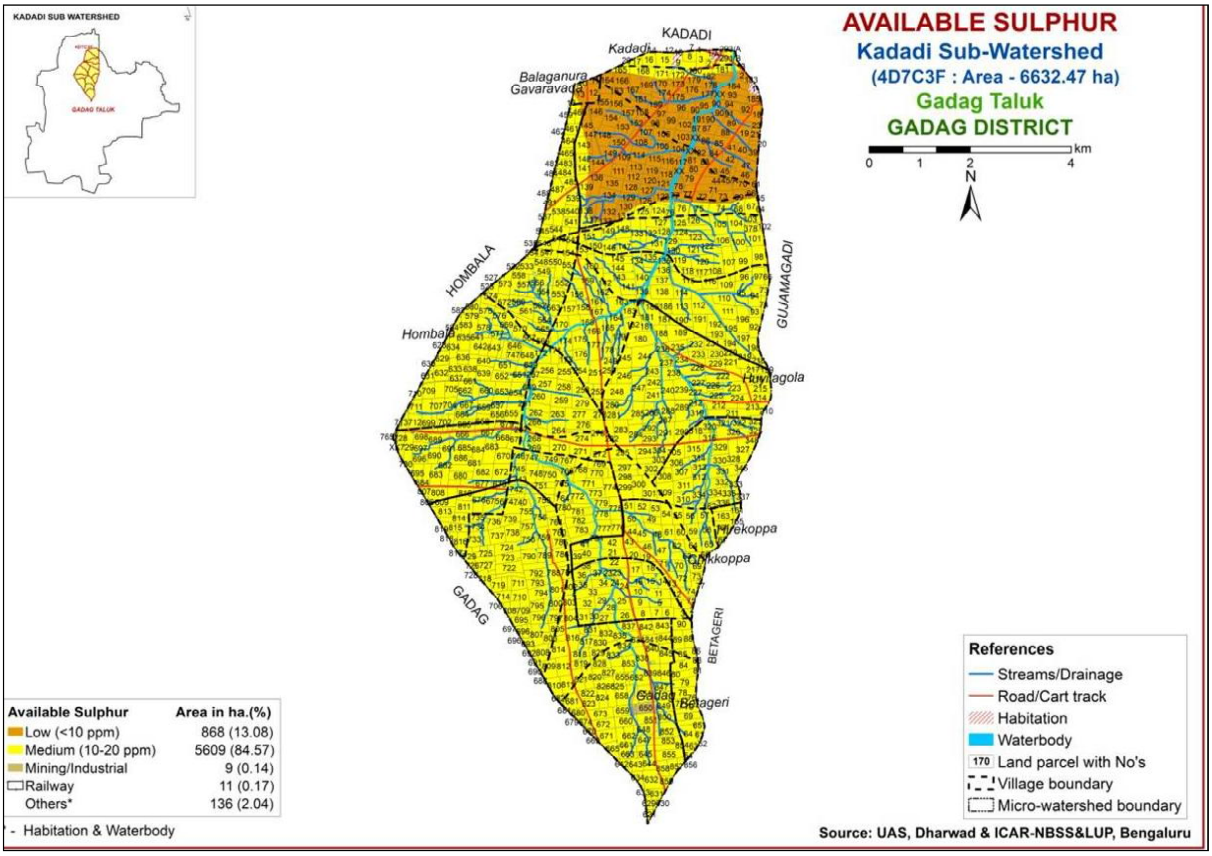

Fig.8. Available Sulphur status of Kadadi sub-watershed

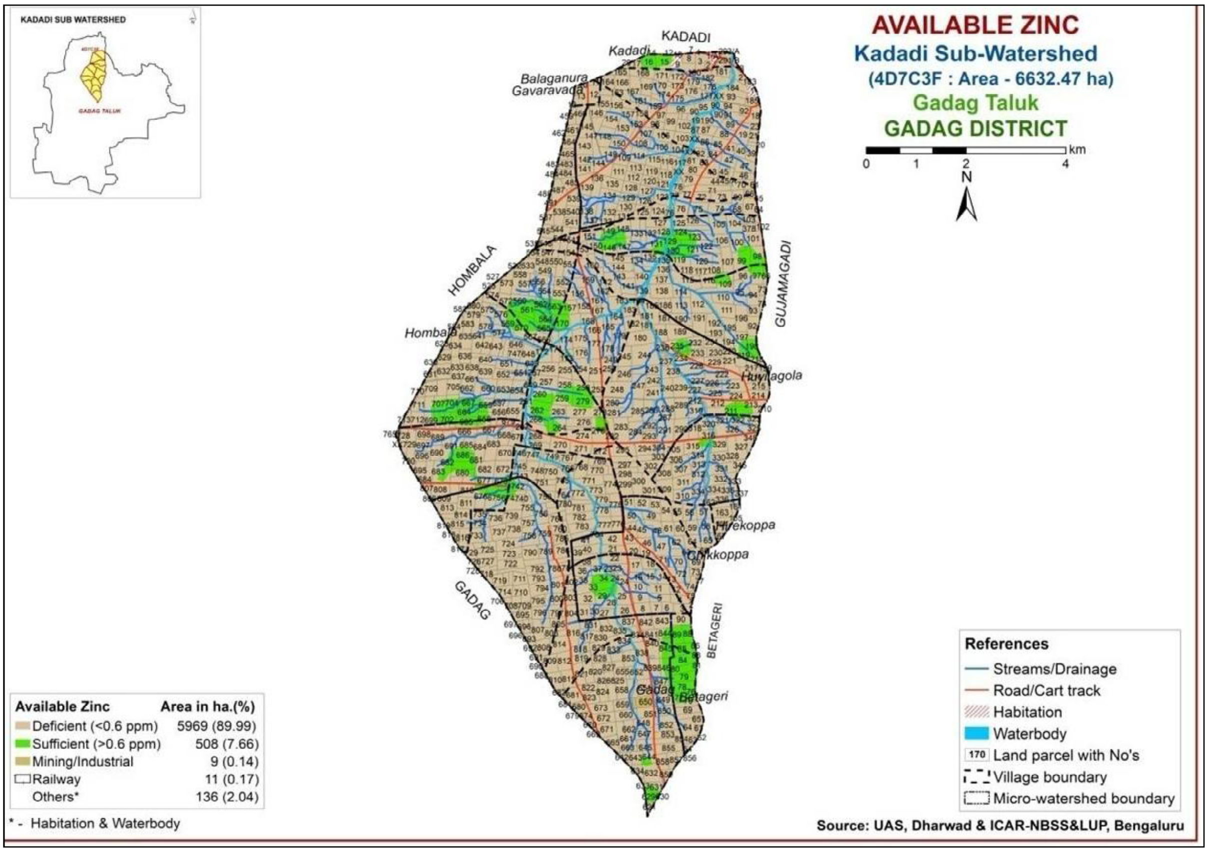

Fig. 9. Available Zinc status of Kadadi sub-watershed

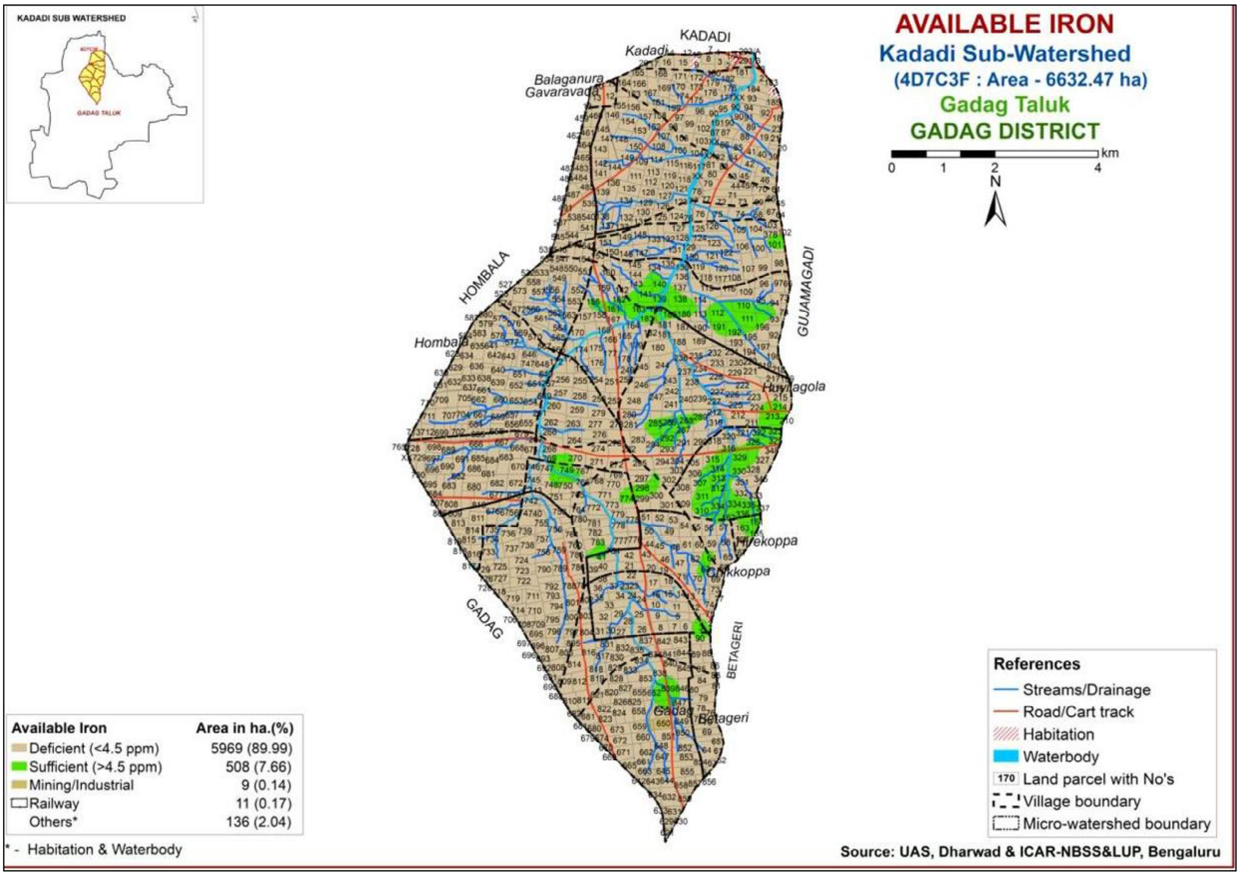

Fig.10. Available Iron status of Kadadi sub-watershed

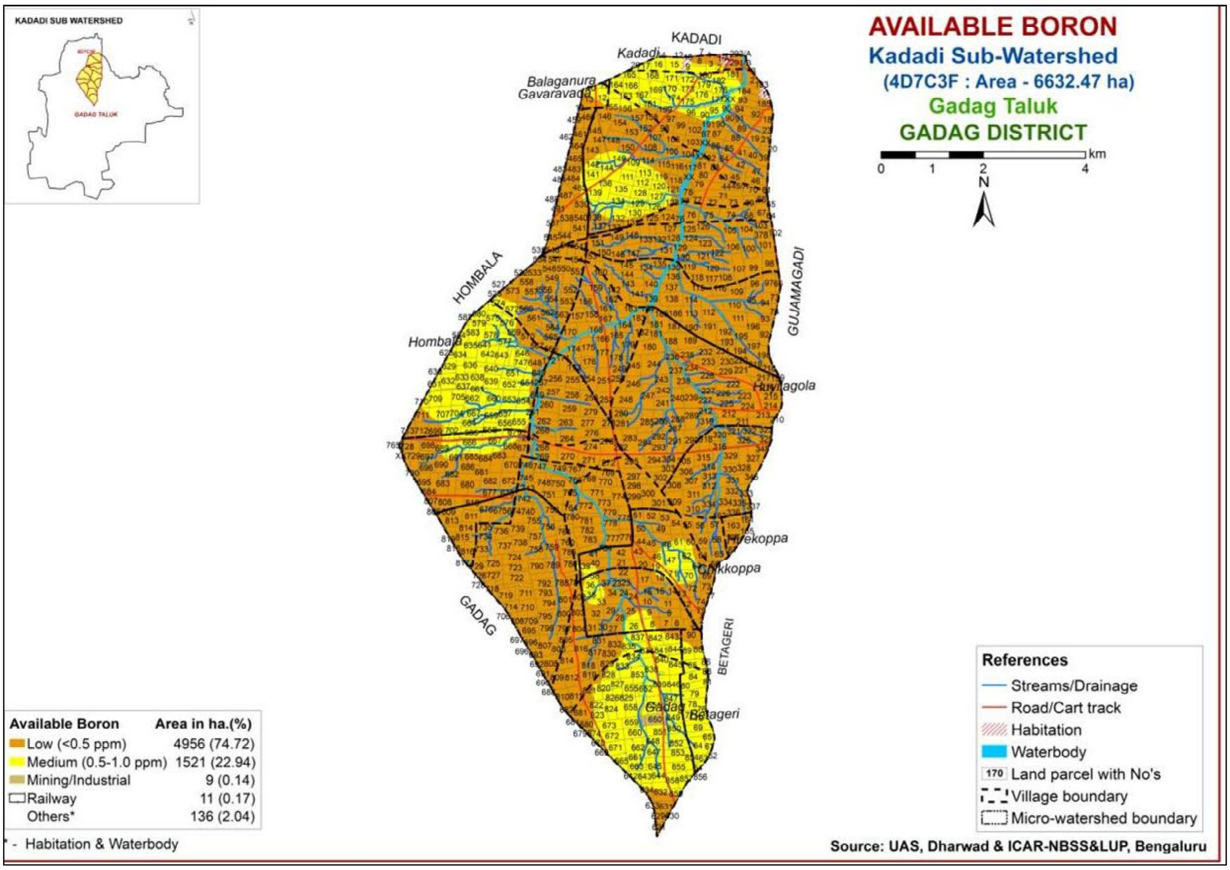

Fig.11. Available Boron status of Kadadi sub-watershed

may be due to precipitation of Fe by $CaCO_3$ and decreased its availability. Similar results were also observed by Ravikumar *et al.* (2007b) and Patil *et al*. (2006). This type of variation may be due to the soil management practices and cropping pattern adopted by different farmers in this region.

The available Manganese in the soils of sub-watershed ranged from 1.50 to 6.21 mg kg^{-1} with mean and SD value of 3.57 and 0.88 mg kg^{-1}, respectively (Table 4). The CV (24.65) 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 Manojkumar (2011) in the soils of northern transition zone of Karnataka derived from basalt.

The available copperin the soils of entire sub-watershed was sufficient and ranged from 0.28to 2.16 mg kg^{-1} with mean and SD value of 0.90 and 0.36 mg kg^{-1}, respectively (Table 4). The CV (39.69) 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. Ravikumar *et al*. (2007b), Pulakeshi *et al.* (2012) and Manojkumar (2011) also observed sufficient status of available copper in soils of north Karnataka.

The available boron in the soils of sub-watershed ranged from low to medium, and values are ranged from 0.04 to 1.06 mg kg^{-1} with mean and SD value of 0.34 and 0.26 mg kg^{-1}, respectively (Table 4, Fig.11). The CV (75.03) for available boron content indicates that, it varied spatially in the sub-watershed. Mapping of available boron by GIS revealed that, it was low in the 74.72 per cent of study area and medium in 22.94 per cent of study area. Ravikumar *et al*. (2007b), Pulakeshi *et al.* (2012) and Manojkumar (2011) also observed sufficient status of available boron in soils of north Karnataka.

Conclusion

The soils of Kadadi sub-watershed in northern dry zone of Karnataka are moderately alkaline to strongly alkaline with non saline to slight salinity. Alkaline soils in the study area need immediate attention for their management to arrest further degradation. Majority of area in micro-watershed is low in available nitrogen, low to medium in available phosphorous, soil organic carbon was low to high, available potassium was high, available boron and sulphur was low to medium. Regarding available micronutrients, zinc and iron were deficient in more than 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 major portion of the study area was deficient in available N, P, S, Zn and Feare important soil fertility constraints indicating their immediate attention for sustainable crop production. The deficient micronutrient may be replenished to avoid the crops suffering from their deficiency and for optimum utilization of other nutrients.

Acknowledgement: The study is part of the Sujala-III project funded by World Bank through Government of Karnataka. The authors duly acknowledge the support.

References

Adornado H A and Yoshida M, 2008, Crop suitability and soil fertility mapping using geographic information system (GIS). *Agricultural Information Research*, 17: 60-68.

Helmke P A and Sparks D L, 1996, Lithium, sodium, potassium, rubidium and cesium. In: *Methods of Soil Analysis*, *Part 3, Chemical Methods* (DL Sparks, Ed.), Madison, Wisconsin. American Society of Agronomy and Soil Science Society of America, pp. 551-574.

Jackson M L, 1973, Soil Chemical Analysis, Prentice Hall New Delhi.

Lindsay W L and Norvell W A, 1978, Development of DTPA soil test for zinc, iron, manganese and copper. *Soil Science Society of America Journal*, 42: 421-428.

Manojkumar Babi, 2011, Characterization and classification of soils of Bastawad micro water shed in northern transition zone of Karnataka. *M. Sc. (Agri.) Theses*, University of Agricultural Sciences, Dharwad, Karnataka, India.

Nelson D W and Sommers L E, 1996, Total carbon, organic carbon, and organic matter. In: *Methods of Soil Analysis, Part 3. Chemical Methods* (DL Sparks,1996Ed.), Madison, Wisconsin. American Society of Agronomy and Soil Science Society of America, pp. 961-1010.

Olsen S R and Sommers L E, 1982, Phosphorus. In: *Methods of Soil Analysis, Part 2*,2nd edition (AL Page *et al*., Eds.), Madison, Wisconsin. American Society of Agronomy and Soil Science Society of America, pp. 403-430.

Patil P L, Bidari B I, Manjunatha Hebbara, Jahnavi Katti, Samirkhan Dilvaranaik, Vishwanatha S, Geetanjali H M and Dasog G S, 2017a, Identification of soil fertility constraints by GIS in Bedwatti sub-watershed under northern dry zone of Karnataka for site specific recommendations. *Journal of Farm Sciences*, 30(2): 206-211.

Patil P L, Kuligod V B, Gundlur S S, Katti Jahnavi, Nagaral I N, Shikrashetti P, Geetanjali H M and Dasog G S, 2016, Soil fertility mapping in Dindur sub-watershed of Karnataka for site specific recommendations. *Journal ofIndian Society of Soil Science*, 64: 381-390.

Patil P L, Kuligod V B, Gundlur S S, Katti Jahnavi Nagaral I N, Shikrashetti P, Geetanjali H M and Dasog G S, 2017b, Soil fertility mapping by GIS in Mevundi sub-watershed under northern dry zone of Karnataka for site specific recommendations. *Journal of Farm Sciences,* 30(2): 200-205.

Patil P L, Radder B M, Patil S G, Aladakatti Y R, Meti C B and Khot A B, 2006, Response of maize to micronutrients and moisture regimes in vertisols of Malaprabha Command, *Karnataka. Journal of Indian Social Soil Science,* 54: 261-264.

Patil P L, Radder B M and Aladakatti Y R, 2011, Effect of moisture regimes, zinc and iron levels on yield, WUE and nutrients uptake in chilli + cotton cropping system. *Journal of Indian Society of Soil Science*, 59: 401-406.

Patil P L, Chetana Bansode, Deepa Pawadashetti, Ramachandraiah, H C, Devaranavadagi V S, Appalal Naik, Hundekar S T and Dasog G S, 2018a, Identification of soil fertility constraints by GIS in northern dry zone of Karnataka for site specific recommendations. *Journal of Farm Sciences,* 31(1): 54-63

Patil P L, Ramachandraiah H C, Devaranavadagi V S, Appalal Naik, Veeresh S, Jyothi V, Kavita Patil, Chetana Bansode, Deepa Pawadashetti, Pooja Naik, Hundekar S T, Gaddanakeri S A and Dasog G S, 2018b, Identification of soil fertility constraints by GIS in Dudihal sub-watershed under northern dry zone of Karnataka for site specific recommendations. *Journal of Farm Sciences,* 31(1): 64-73.

Prabhavati K, Dasog G S, Patil P L, Sahrawat K L and Wani S P, 2015, Soil fertility mapping using gis in three agroclimatic zones of Belgaum district, Karnataka. *Journal of Indian Society of Soil Science*, 63:173-180.

Pulakeshi P H B, Patil P L, Dasog G S, Radder B M, Bidari B I and Mansur C P, 2012, Mapping of nuntrients status by geographic information system (GIS) in Mantagani village under northern transition zone of Karnataka. *Karnataka Journal of Agricultural Sciences*, 25: 332-335.

Ravikumar M A, Patil P L and Dasog G S, 2007a, Mapping of nutrients status of 48A fistributary of Malaprabha Right Bank Command of Karnataka by GIS technique. I-Major nutrients. *Karnataka Journal of Agricultural Sciences*, 20: 735-737.

Ravikumar M A, Patil P L and Dasog G S, 2007b, Mapping of nutrients status of 48A distributary of Malaprabha Right Bank Command of Karnataka by GIS technique. II-Micro nutrients. *Karnataka Journal of Agricultural Sciences,* 20: 738-740.

Sahrawat K L and Burford J R, 1982, Modification of alkaline permanganate method for assessing the availability of soil nitrogen in upland soils. *Soil Science*, 133: 53-57.

Srikant K S, Patil P L and Dasog G S and Gali S K, 2008, Mapping of available major nutrients of a micro-watershed in northern dry zone of Karnataka. *Karnataka Journal of Agricultural Sciences,* 21: 391-395.

Tabatabai M A, 1996, Sulfur. In: *Methods of Soil Analysis, Part 3. Chemical Methods* (D.L. Sparks, Ed.). Madison, Wisconsin. American Society of Agronomy and Soil Science Society of America, pp. 921-960.