*J. Farm Sci., 32(2): (167-176) 2019*

**RESEARCH PAPER**

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

P. L. PATIL, DEEPA PAWADASHETTI, K. SUNILKUMAR, RENUKA NAGARAHALLI, H. C. RAMACHANDRAIAH, DEEPA KALAPPANAVAR AND UMME SALMA SANADI

Department of Soil Science and Agricultural Chemistry, College of Agriculture, Dharwad
University of Agricultural Sciences, Dharwad - 580 005, Karnataka, India
E-mail : plpatiluasd@ gmail.com

*(Received: January, 2019 ; Accepted: May, 2019)*

**Abstract:** Soil samples from Madhalli 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 GIS environment using Arc GIS v 10.4. Soils were neutral to strongly alkaline with non saline to slight salinity. 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 micronutrients, 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 technique in the sub-watershed revealed that, available N, P, S, Zn and Fe are important soil fertility constraints.

**Key words:** Nutrients, Soil fertility, Soil fertility map, Watersheds

## Introduction

Intensively cultivated soils are being depleted with available nutrients especially micro nutrients. 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). 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 issues are addressed, the productivity of a watershed is further enhanced. The proposed study was planned with the objective of identifying available nutrients constraints in soils of Madhallisub-watershed in northern dry zone of Karnataka.

## Material and methods

The Madhalli sub-watershed is located in Gadag taluka of Gadag district covering an area of 3228 ha (Fig. 1), falling under northern dry zone of agro climatic zones of Karnataka. The sub-watershed consists of six 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 monsoonic type. The maximum temperature during summer is 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

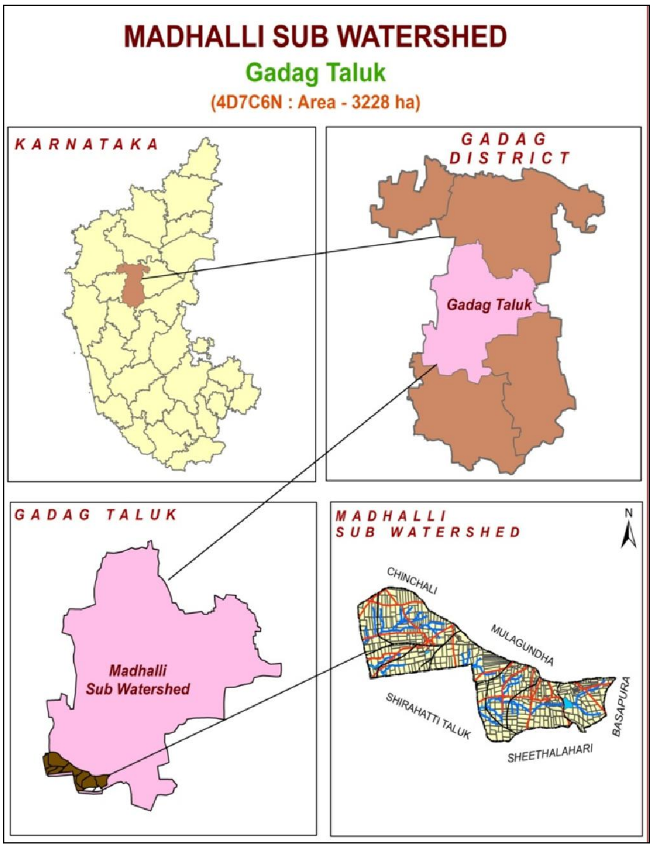


Fig.1. Location map of Madhalli sub-watershed

(June to September) bringing 315 mm and northeast monsoon about 121 mm rain during October and November months. About 88 mm of rainfall is also received during the summer months (April-May).

The soil samples in the respective micro watersheds were drawn at 250 m grid interval (Table 1) using GPS during 2017-18. The soil samples were air-dried, ground (< 2 mm) and analyzed for 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 anextractant (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 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.

## Results and discussion

### Soil reaction and electrical conductivity

Soils of the Madhalli sub-watershed were slightly alkaline to strongly alkaline in reaction (5.39-9.15) with a mean pH of 8.04, SD of 0.64 and coefficient of variation of 7.97 (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; slightly alkaline (pH 7.3-7.8), moderately alkaline (pH 7.8-8.4), strongly alkaline (pH 8.4-9.0) and very strongly alkaline (pH>9.0). Major proportion of the sub-watershed area (Fig. 2) was moderately alkaline (70.82 %) followed by slightlyalkaline (13.47 %). 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), Prabhavati *et al.* (2015) and Patil *et al.* (2016, 2017a and b, 2018a, b & c).

The EC of soils in the sub-watershed was in the range of 0.05 to 0.89 dS $m^{-1}$ with mean value of 0.18 $dSm^{-1}$and SD of 0.09 The CV (53.19%) 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 (Fig. 3) revealed that, 95.24 per cent of the area was non saline.

Table1. Details of soil sampling in Madhalli sub-watershed

| Name of sub watershed | Sl.No | Name of Micro watershed | Code | Area (ha) | No. of samples collected @ 250 m grid interval |
|---|---|---|---|---|---|
| Madhalli (4D4A6N) | 1 | Kallur-1 | 4D4A6N2d | 706 | 113 |
| | 2 | Kallur-2 | 4D4A6N2e | 219 | 35 |
| | 3 | Madhalli-1 | 4D4A6N2c | 161 | 26 |
| | 4 | Madhalli-2 | 4D4A6N2b | 214 | 34 |
| | 5 | Sheethalahari | 4D4A6N3a | 414 | 66 |
| | 6 | Sheethalahari-1 | 4D4A6N3c | 381 | 61 |
| | 7 | Sheethalahari-2 | 4D4A6N3b | 506 | 81 |
| | 8 | Yelavatthi-1 | 4D4A6N3d | 176 | 28 |
| | 9 | Yelavatthi-3 | 4D4A6N3e | 435 | 69 |
| | | | Total | 3228 | 513 |

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 Madhalli 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 Madhalli 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 Madhalli 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.

Table 2. Soil fertility ratings for available nutrients

| Nutrients | Fertility rating major nutrients | | |
|---|---|---|---|
| | Low | Medium | High |
| Organic carbon (g $kg^{-1}$) | <5.0 | 5.0-7.5 | >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 |

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

| Statistics | pH | EC (dS $m^{-1}$) | OC % | N (kg $ha^{-1}$) | $P_2O_5$ (kg $ha^{-1}$) | $K_2O$ (kg $ha^{-1}$) | S (kg $ha^{-1}$) |
|---|---|---|---|---|---|---|---|
| Minimum | 5.39 | 0.05 | 0.14 | 87.00 | 9.49 | 134.54 | 8.72 |
| Maximum | 9.15 | 0.89 | 0.93 | 284.20 | 47.93 | 986.28 | 22.69 |
| Mean | 8.04 | 0.18 | 0.47 | 153.30 | 25.16 | 496.94 | 14.67 |
| Standard deviation | 0.64 | 0.09 | 0.15 | 34.74 | 9.06 | 198.34 | 2.50 |
| Coefficient variance | 7.97 | 53.19 | 31.82 | 22.66 | 36.00 | 39.91 | 17.05 |

**Organic carbon**

Organic carbon content of soils of Madhalli sub-watershed ranged from 0.14 to 0.93 per cent with mean and SD values of 0.47 and 0.15 per cent, respectively. The CV (31.82) for OC content indicates that, in the sub-watershed SOC varied spatially (Table 3). GIS Mapping of OC by GIS revealed that 37.38 per cent area was mediumin soil organic carbon status and 56.74 per cent of the study area was low in organic carbon (Fig. 4). The values obtained in the present study are in agreement with those reported by Ravikumar *et al.* (2007a) and Patil *et al.*(2006) 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 and Patil *et al.* (2016, 2017a and b, 2018a, b & c).

**Available macronutrients**

The available N in soils of the sub-watershed ranged from 87.00 to 284.20 kg $ha^{-1}$ with a mean of 153.30 kg $ha^{-1}$ and SD of 34.74. The CV value of 22.66 per cent indicates that available N in soils varied spatially. The GIS mapping revealed that, 95.3 per cent of 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

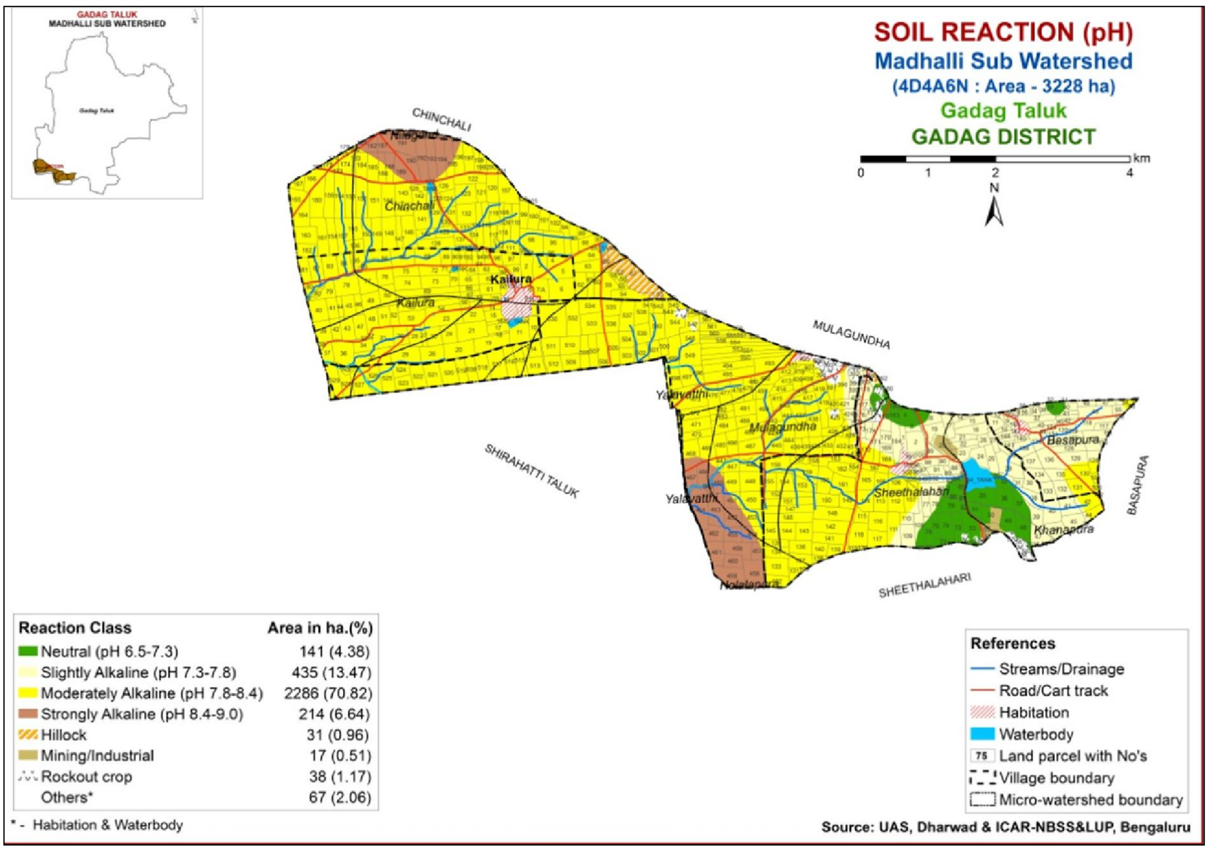


Fig. 2. Soil reaction status of Madhalli sub-watershed

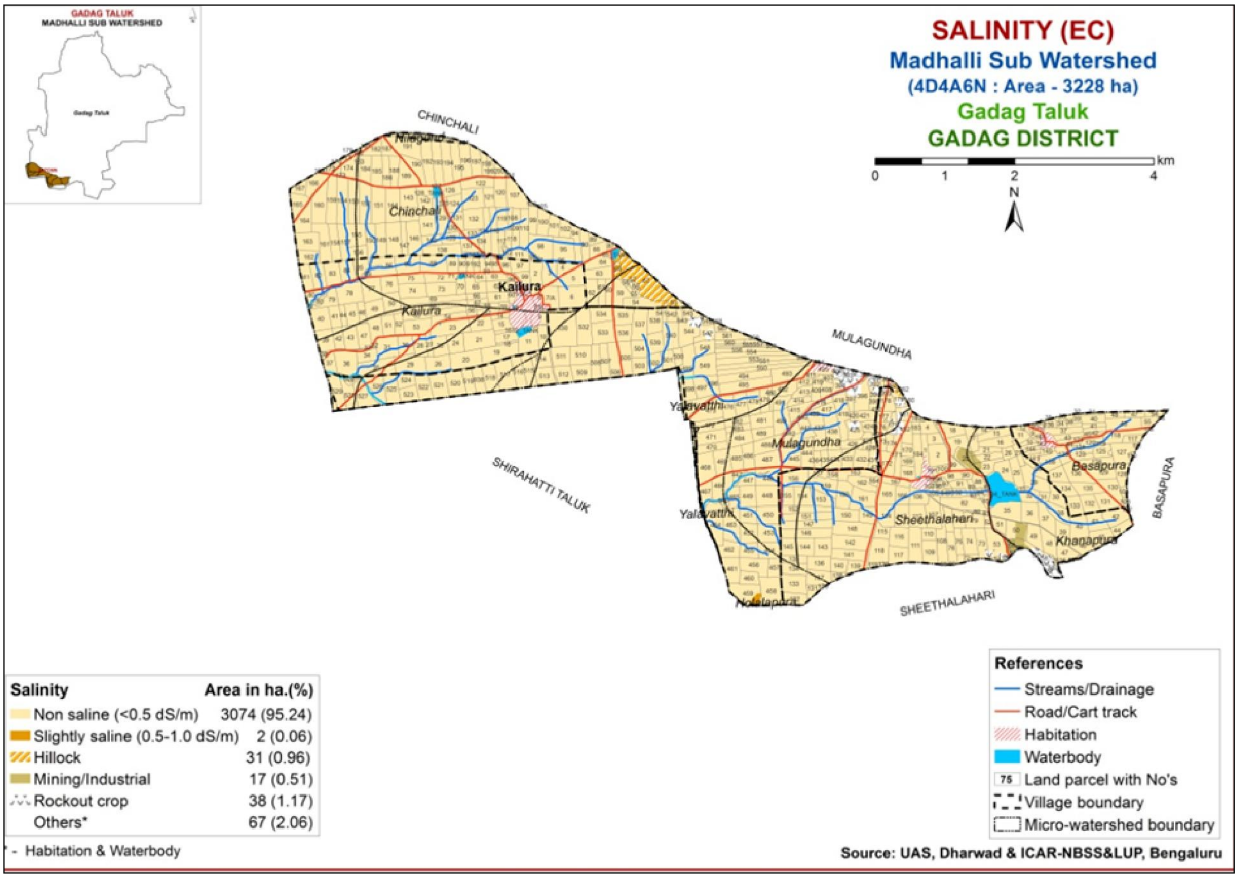


Fig. 3. Soil salinity status of Madhalli sub-watershed

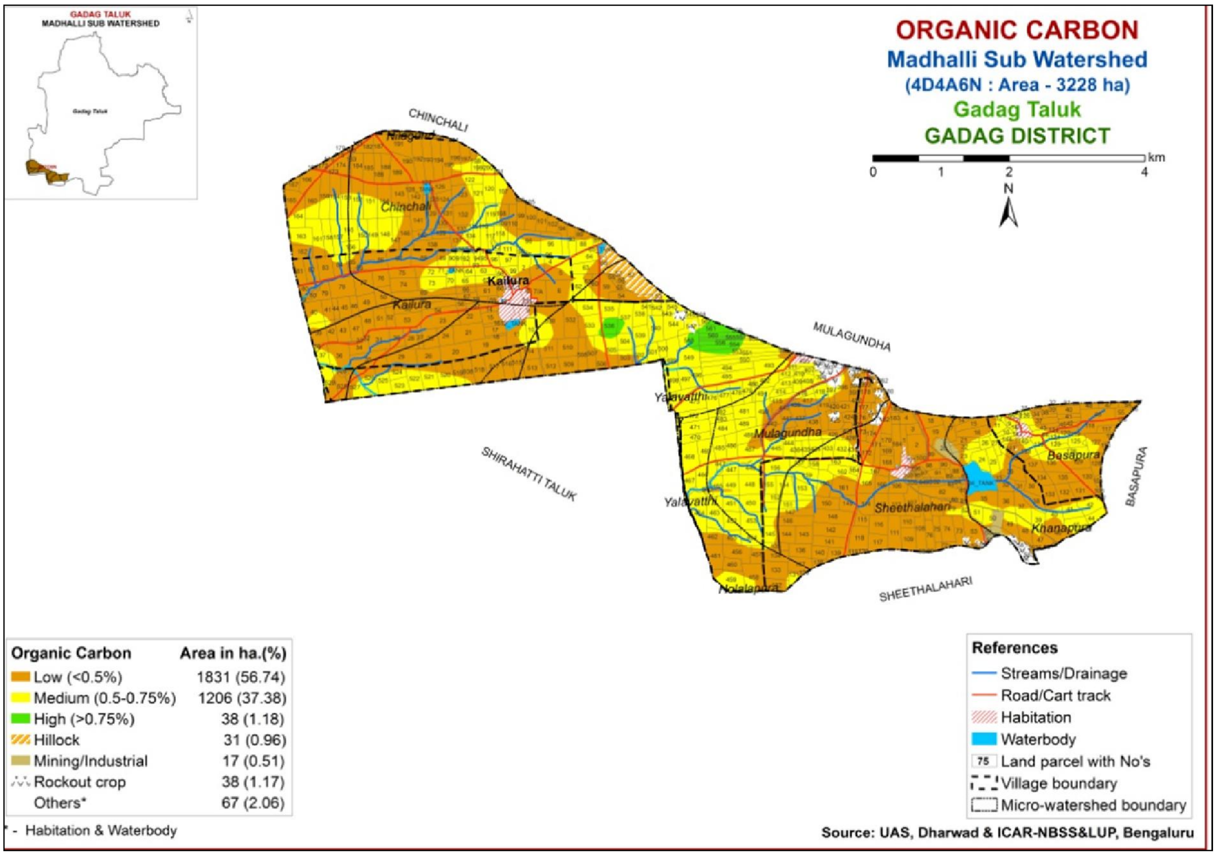


Fig. 4. Soil organic carbon status of Madhalli sub-watershed

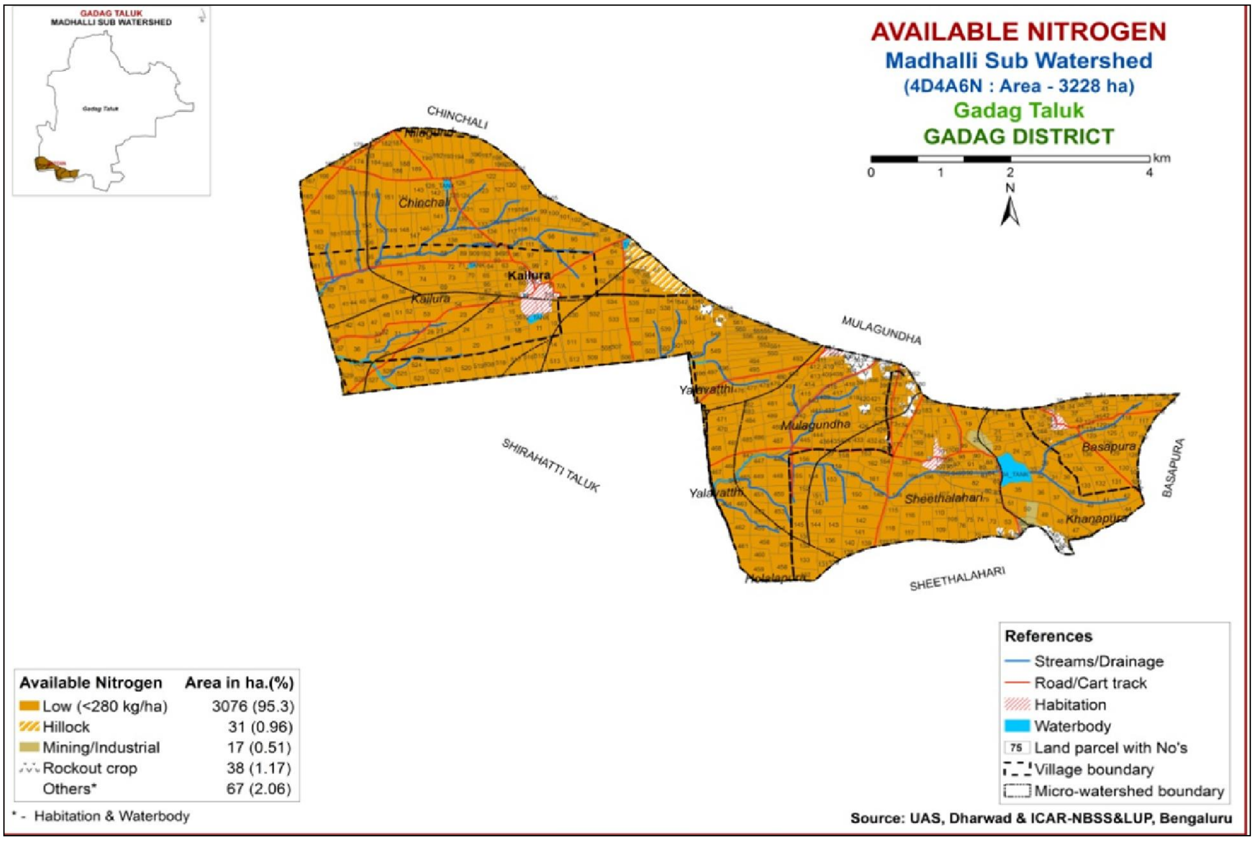


Fig. 5. Available nitrogen status of Madhalli sub-watershed

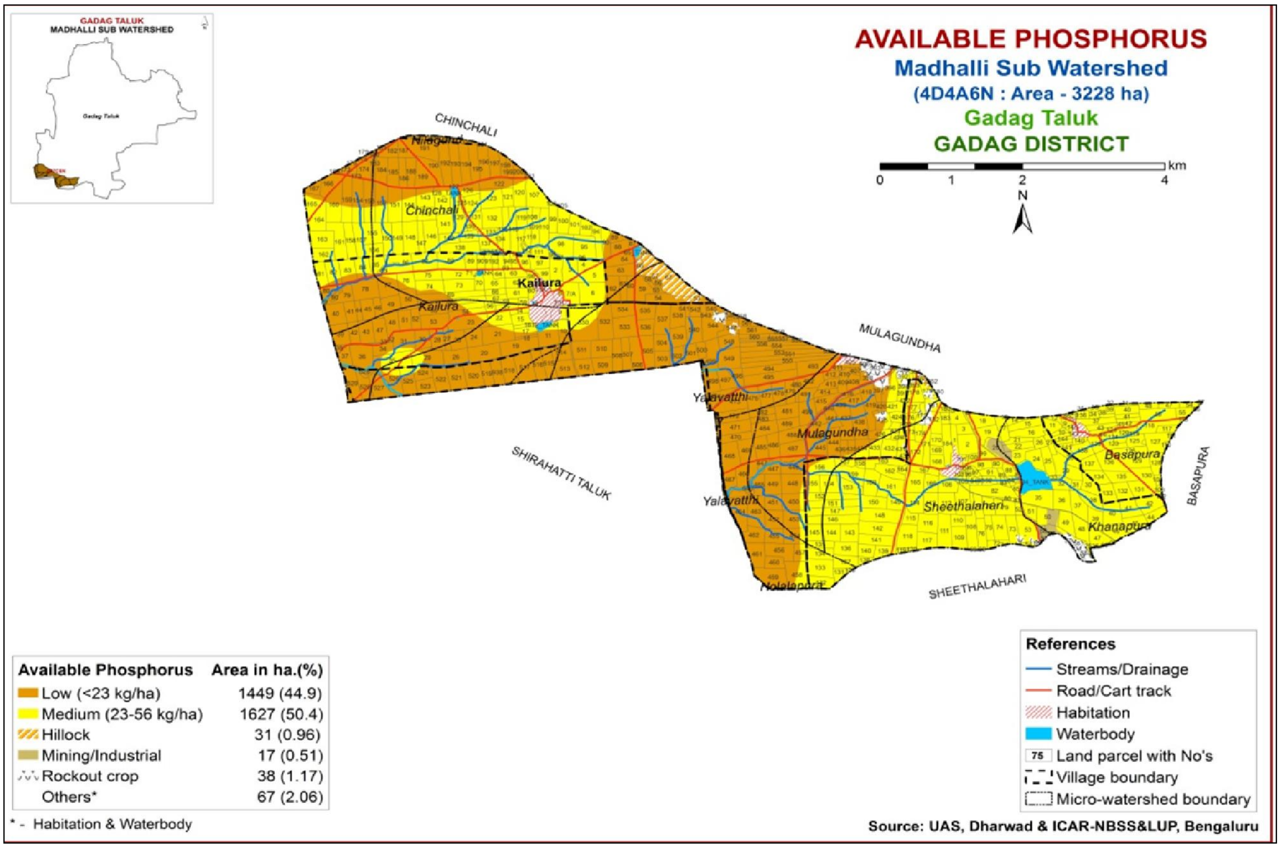


Fig. 6. Available Phosphorus status of Madhalli sub-watershed

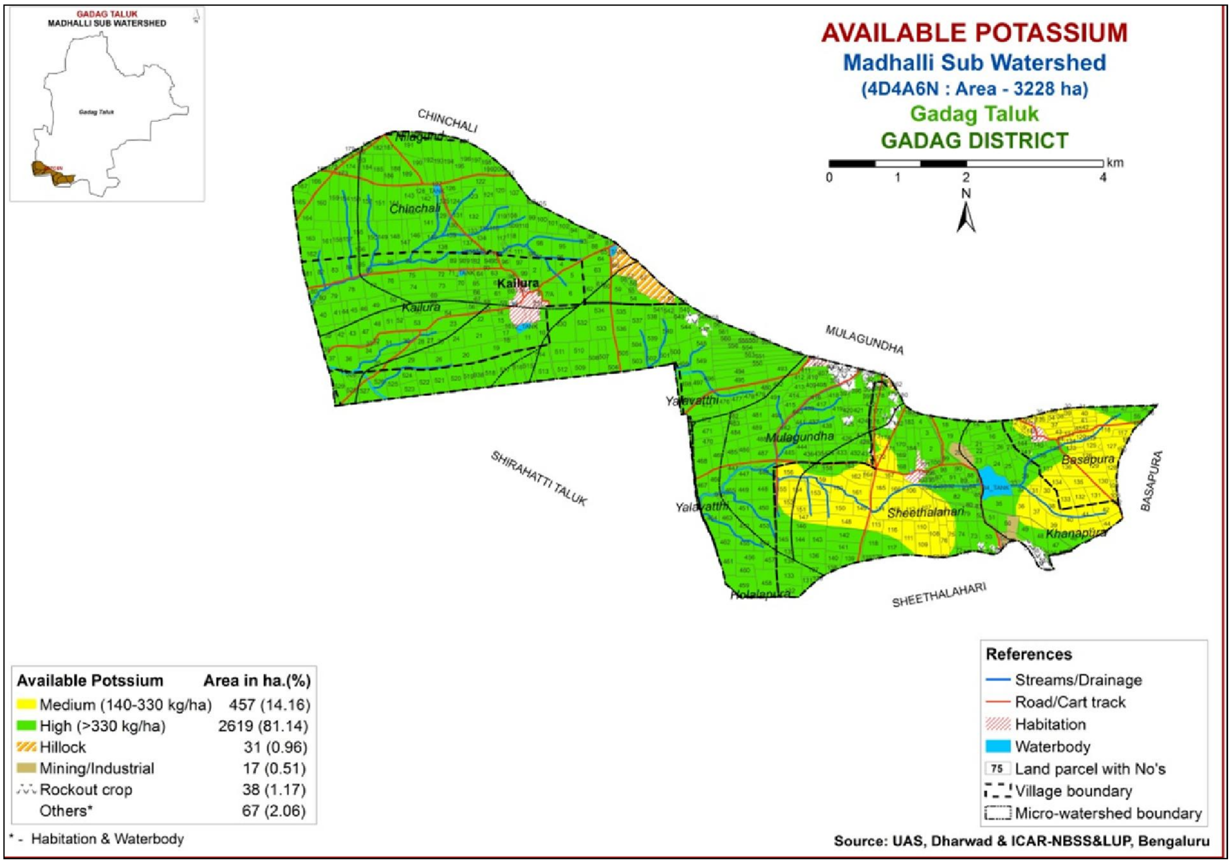


Fig. 7. Available potassium status of Madhalli sub-watershed

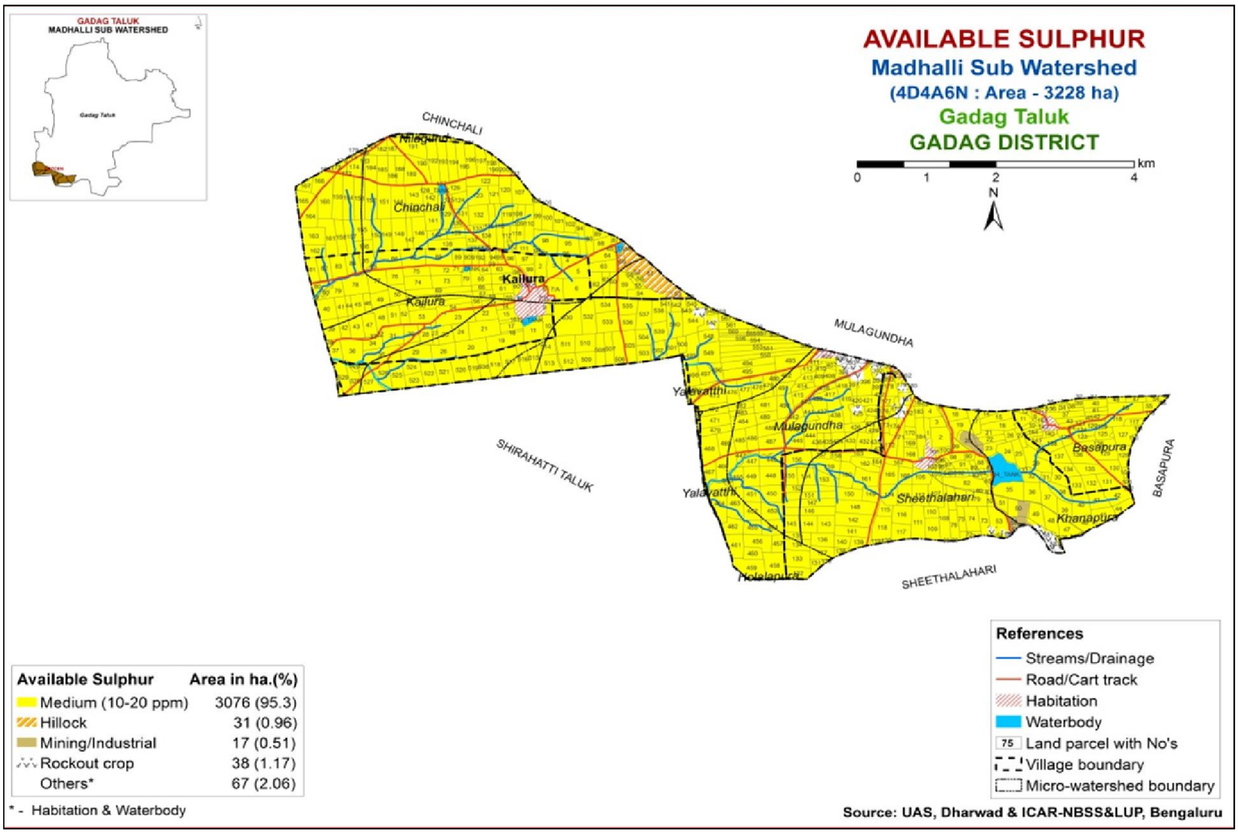


Fig. 8. Available sulphur status of Madhalli sub-watershed

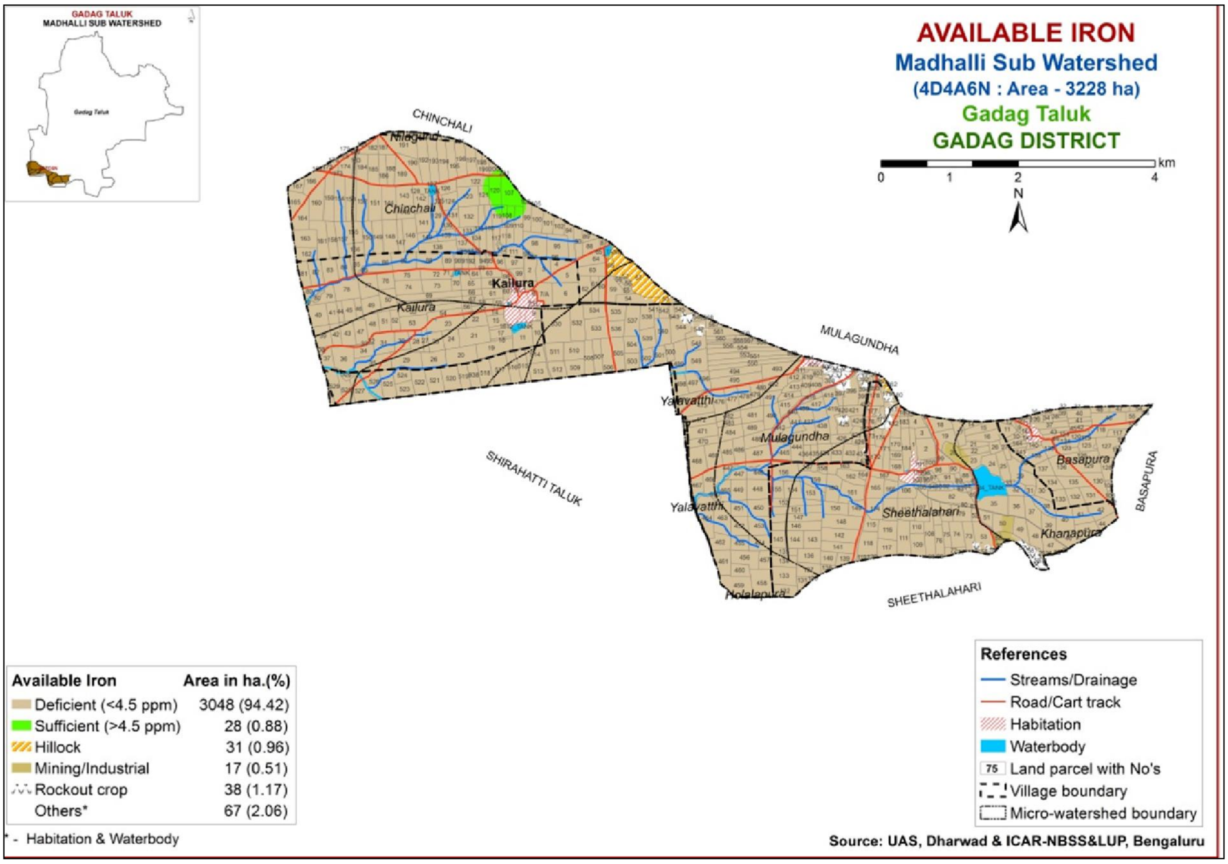


Fig. 9. Available Iron status of Madhalli sub-watershed

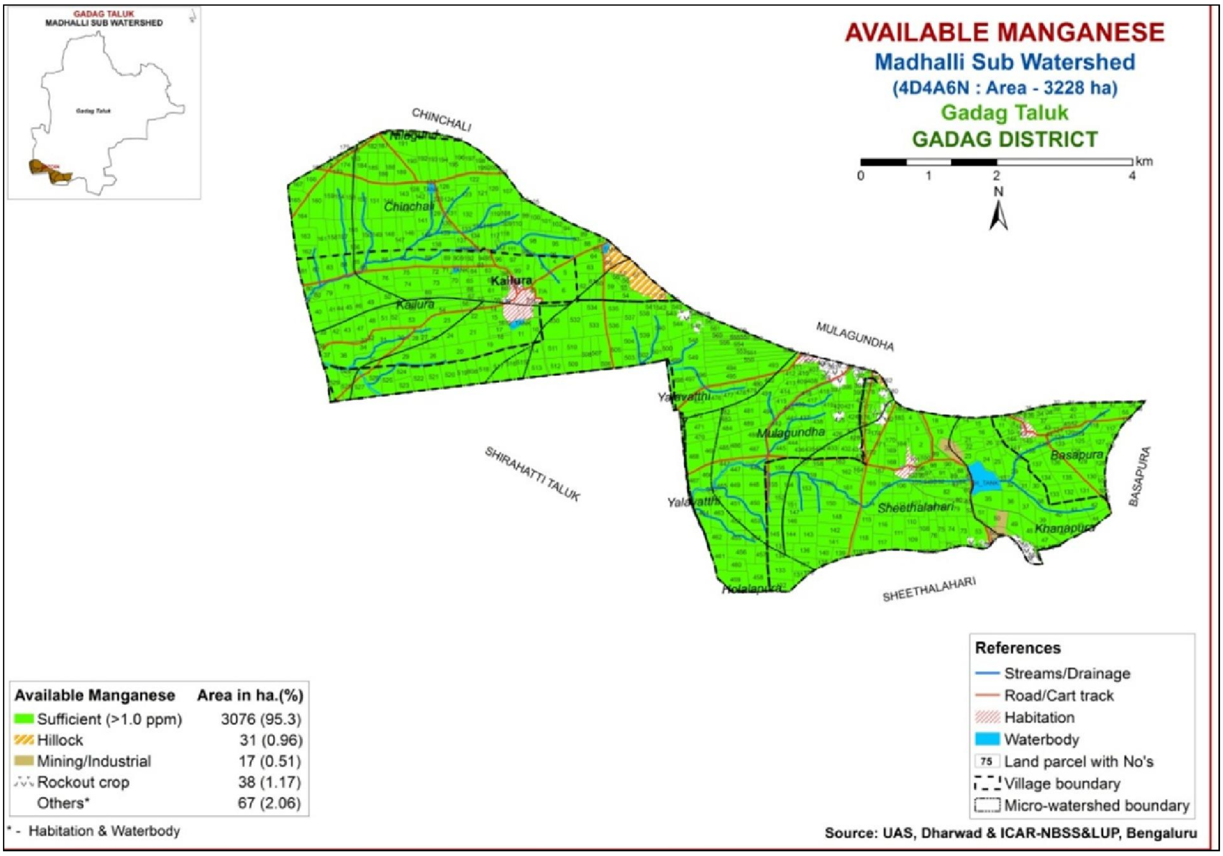


Fig. 10. Available manganese status of Madhalli sub-watershed

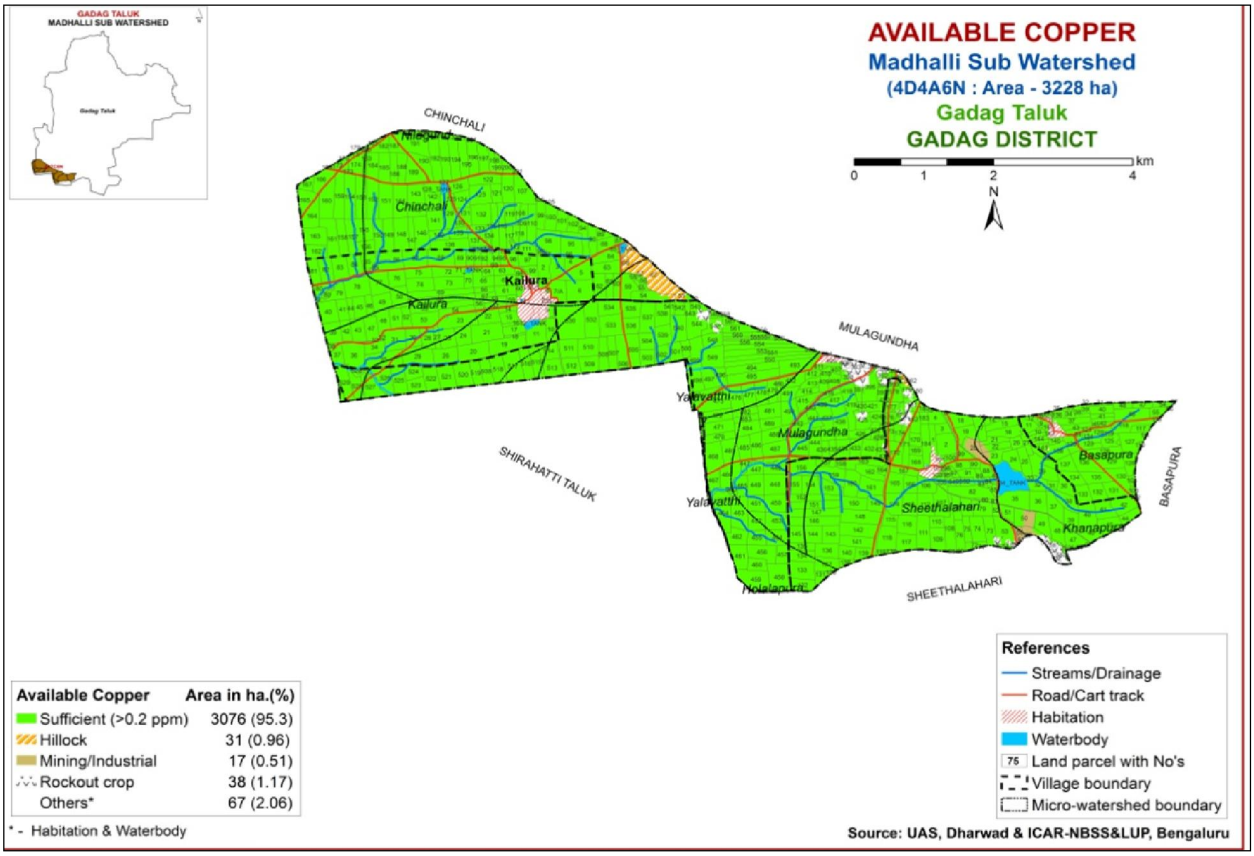


Fig. 11. Available copper status of Madhalli sub-watershed

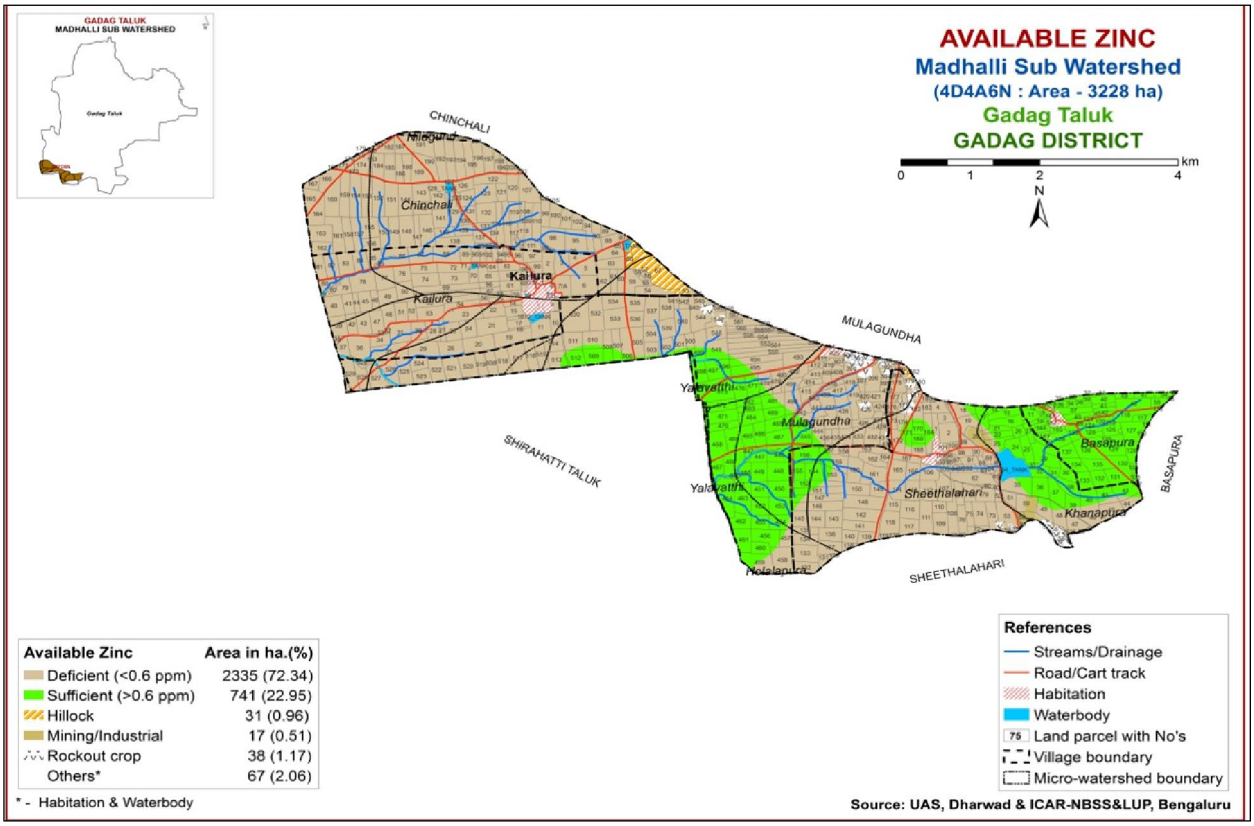


Fig. 12. Available zinc status of Madhalli sub-watershed

status was reported by Pulakeshi *et al.* (2012) in non-saline clay to sandy loams and calcareous soils and Patil *et al.* (2016, 2017a and b, 2018a, b & c).

The available $P_2O_5$ content of the sub-watershed was ranged from 9.49 to 47.93 kg ha$^{-1}$ with average and SD values of 25.16 and 9.06 kg ha$^{-1}$, respectively. The CV of 36.00 per cent for available $P_2O_5$ distribution in the sub-watershed indicates that, it varied spatially. Mapping of available $P_2O_5$by GIS revealed that, available $P_2O_5$ was low in 44.9 per cent of the study area whereas, it was medium in 50.4 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) and Patil *et al.* (2011) reported that, available $P_2O_5$ status in black soils of Malaprabha command area of Karnataka was low due to high calcium carbonate content. Similar results were also reported by Patil *et al.* (2018b) for the soils of Belageri sub-watershed of Karnataka.

The available $K_2O$ content in the Madhalli sub-watershed ranged from 134.54 to 986.28 kg ha$^{-1}$ with mean and SD values of 496.94 and 198.34 kg ha$^{-1}$, respectively. The CV (39.91 %) 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, 81.14 per cent of the study area was in high category (Table 3 and Fig.7) and 14.16 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 (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 Madhalli 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), Pulakeshi *et al.* (2012) and Patil *et al.* (2018a).

The available sulphur content of soils of the sub-watershed varied from 8.72 to 22.69 kg ha$^{-1}$ soil with mean and SD values of 14.67 and 2.50 kg ha$^{-1}$ soil, respectively. The CV (17.05 %) 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 sulphur status with 95.3 per cent of the study area, respectively (Table 3 and Fig. 8). The area is divided equally between the high and medium status 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 (Srikant *et al*., 2008, Pulakeshi *et al.* 2012 and Patil *et al.,* 2016 and 2017a & b.

**Available micro nutrients**

The available iron in the sub-watershed ranged from 0.27 to 6.07 mg kg$^{-1}$ with mean and SD values of 2.59 and 1.36 mg kg$^{-1}$, respectively (Table 4). The CV (52.59 %) 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 94.42 per cent followed by sufficient in 41.07 per cent of the entire study 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 Ravikumar *et al.* (2007b), Patil *et al.* (2006), Pulakeshi *et al.* (2012) and Patil *et al.* (2017a and 2018b). The available iron in surface soils has no regular pattern of distribution. This type of variation may be due to the soil management practices and cropping pattern adopted by different farmers.

Table 4. Available micro nutrients status in Madhalli sub watershed

| Statistics | Micro nutrients (mg kg$^{-1}$) | | | |
|---|---|---|---|---|
| | Fe | Mn | Cu | Zn |
| Minimum | 0.27 | 1.08 | 0.06 | 0.21 |
| Maximum | 6.07 | 5.89 | 2.64 | 7.58 |
| Mean | 2.59 | 3.53 | 0.82 | 2.02 |
| Standard deviation | 1.36 | 1.01 | 0.45 | 1.83 |
| Coefficient of variance | 52.59 | 28.58 | 54.14 | 90.25 |

The available manganese in the sub-watershed ranged from 1.08 to 5.89 mg kg$^{-1}$ with mean and SD values of 3.53 and 1.01 mg kg$^{-1}$, respectively (Table 4). The CV (28.58 %) 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 Ravikumar *et al.* (2007b) in Vertisols of Malaprabha command area, Patil *et.al.* (2017a) in Bedwatti sub watershed under northern dry zone of Karnataka, Pulakeshi *et al*. (2012) in the soils of northern transition zone of Karnataka derived from chlorite schist and Patil *et al*. (2018c) in Dudihal sub-watershed under northern dry zone of Karnataka.

The available copper in the entire sub-watershed was sufficient and ranged from 0.06 to 2.64 mg kg$^{-1}$ with mean and SD values of 0.82 and 0.45 mg kg$^{-1}$, respectively (Table 4). The CV (54.14 %) 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). Ravikumar *et al.* (2007b) and Pulakeshi *et al.* (2012) observed sufficient status of available copper in soils of north Karnataka.

The available zinc in the sub-watershed ranged from 0.21 to 7.58 mg kg$^{-1}$ with mean and SD values of 2.02 and 1.83 mg kg$^{-1}$, respectively (Table 4). The CV (90.25%) 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 72.34 per cent of the study area and sufficient in 22.95 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. 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 (Patil *et al*., 2006, Pulakeshi *et al.,* 2012 and Patil *et al.,* 2018a).

**Conclusion**

From the study, it could be concluded that, soils of Madhalli sub-watershed in northern dry zone of Karnataka are neutral to strongly alkaline with non saline. 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 technique in the sub-watershed revealed that major portion of the study area was deficient in available N, P, S, Zn and Fe are important soil fertility constraints indicating their immediate attention for sustained crop production. The deficient micro nutrients 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* (Ed. D L Sparks). adison, Wisc.: SSSA and ASA, pp. 551-574.

Jackson M L, 1973, Soil Chemical Analysis. 1st Edn., Prentice Hall Ltd., New Delhi, India.

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

Nelson D W and Sommers L E, 1996, Total carbon, organic carbon, and organic matter. In: *Methods of Soil Analysis, Part 3. Chemical Methods* (Ed. D L Sparks). Madison, Wisc. SSSA and ASA, pp. 961-1010.

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

Patil P L, Bansode Chetana, Pawadashetti Deepa, Ramachandraiah H C, Devaranavadagi V S, Naik Appalal, 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, Bidari B I Hebbara Manjunatha, Katti Jahnavi, Dilvaranaik Samirkhan, 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, Dilawaranaik Samirkhan, Pawadashetti Deepa, Sanadi Ummesalma, Katti Jahnavi, Ramachandraiah, H C, Hebbara Manjunatha and Dasog G S, 2018b, Identification of soil nutrient constraints by GIS technique in Belageri sub-watershed of Karnataka for site specific recommendations. *Journal of Farm Sciences,* 31(4): 419-428.

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 of the Indian 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 the Indian Society of 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 the Indian Society of Soil Science,* 59: 401-406.

Patil P L, Ramachandraiah H C, Devaranavadagi V S, Naik Appalal Veeresh S, Jyothi V, Patil Kavita, Bansode Chetana, Pawadashetti Deepa, Naik Pooja, Hundekar S T, Gaddanakeri S A and Dasog G S, 2018c, 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 agro-climatic zones of Belgaum district, Karnataka. *Journal of the 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 distributary 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 microwatershed 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* (Ed. D.L. Sparks ). Madison, Wisconsin. American Society of Agronomy and Soil Science Society of America, pp. 921-960.

Wani S P, 2008, Taking soil science to farmers' doorsteps through community watershed management. *Journal of the Indian Society of Soil Science,* 56: 367-377.