

Soil fertility mapping by GIS in Mevundi sub watershed under Northern dry zone of Karnataka for site specific recommendations

P. L. PATIL, V. B. KULIGOD, S. S. GUNDLUR, JAHNAVI KATTI, I. N. NAGARAL, P. SHIKRASHETTI, H. M. GEETANJALI AND G. S. DASOG

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

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Abstract: Soil samples from Mevundia 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 very 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, Organic, Soil fertility, Watersheds

Introduction

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). 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. 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 Mevundi sub watershed in northern dry zone of Karnataka.

Material and methods

The Mevundi Sub watershed is located in Mundaragi taluka of Gadag district covering an area of 1599.05 ha (Fig 1.0), falling under northern dry zone of agro climatic zones of Karnataka.

The sub watershed is located at about 40.0 km from Gadag city. The sub-watershed 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 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 (Table 2). 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 is also received during the summer months (April-May).

Surface composite soil samples were collected during April 2016 on grid points of 250 m interval in the study area and the sample location was recorded by GPS. A total of 260 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

Table 1. Details of soil sampling in Mevundi sub watershed

Micro watershed	Code	Area(ha)	No. of Samples
Mevundi NW-2	4D4A2F1d	358.46	62
Mevundi 4	4D4A2F2b	580.11	94
Mevundi 2	4D4A2F2c	395.72	58
Mevundi 3	4D4A2F2d	270.39	46
		1604.68	260

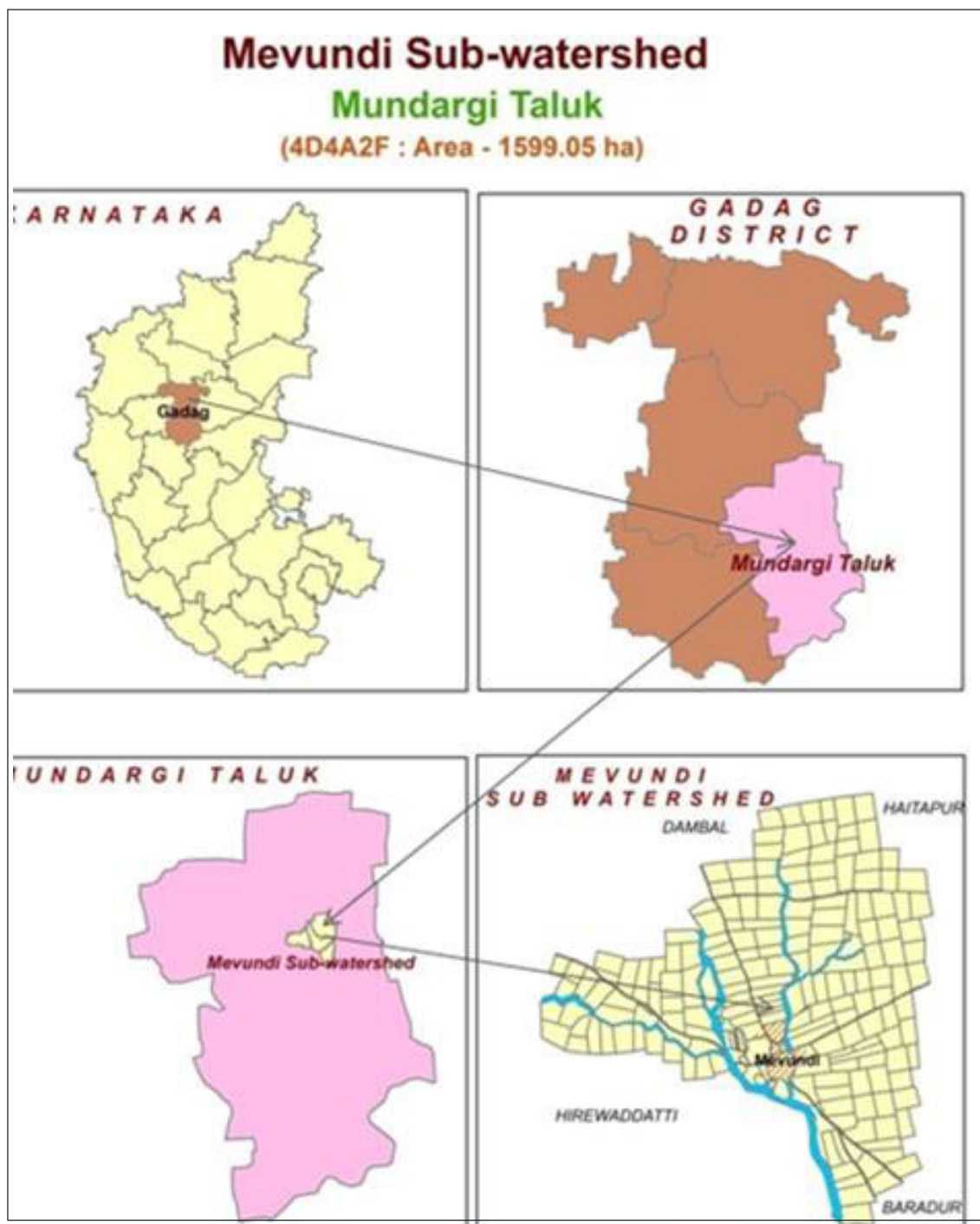


Fig.1. Location map of Mevundi sub watershed

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.

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 Mevundi sub watershed area was created in *Arc GIS* 10.4.

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

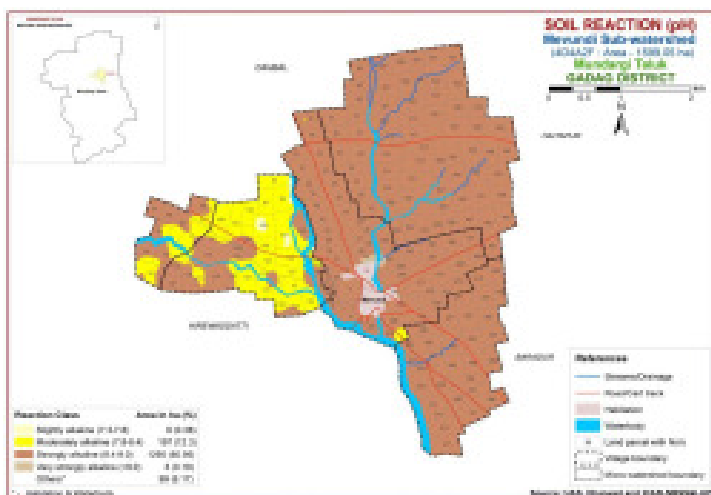


Fig. 2. Soil reaction status of Mevundi sub watershed

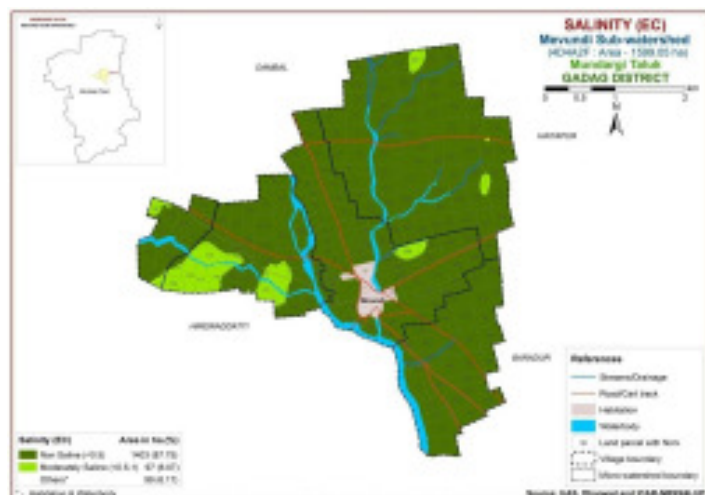


Fig. 3. Soil salinity status of Mevundi sub watershed

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 Mevundi 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 Mevundi 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 Mevundi sub-watershed were slightly alkaline to strongly alkaline in reaction (7.36-9.33) with a mean pH of 8.55, standard deviation of 0.38 and coefficient of variation of 4.42 (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 strongly alkaline (81%) followed by moderately alkaline (12.3%). 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) and Prabhavati *et al.* (2015). The EC of soils in the sub-watershed was in the range of 0.02 to 1.2 dSm^{-1} with mean value of 0.29 dSm^{-1} and standard deviation of 0.18. The CV (62.42%) 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, 88 per cent of the area was non saline and 6 percent of the area was moderately saline.

Organic carbon

Organic carbon content of soils of Mevundi sub watershed was ranged from 1.2-9.4 g kg^{-1} with mean and standard deviation value of 4.3 and 1.6 g kg^{-1} respectively. The CV (62.42) for OC content indicates that, in the sub watershed SOC varied spatially (Table 3). GIS Mapping of OC by GIS revealed that 63 per cent of the study area

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

	pH	EC (dS m^{-1})	OC (g kg^{-1})	N	P_2O_5 (kg ha^{-1})	K_2O	S (mg kg^{-1})
Range	7.36-9.33	0.02-1.20	1.2-9.4	49-273	3.44-87.59	107-693	0.77-25.46
Average	8.55	0.29	4.3	132.8	26.13	392	10.9
SD	0.38	0.18	1.6	43.0	12.04	106	5.47
CV	4.42	62.42	37.86	32.4	46.1	27	50.2

was low in organic carbon and 31 per cent area was medium in soil organic carbon status (Fig. 4). The values obtained in the present study are in agreement with those reported by for, 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.

Available macro nutrients

The available N in soils of the sub watershed ranged from 49 to 273 kg ha⁻¹ with a mean of 132.8 kg ha⁻¹ and SD of 43. The CV value of 32.4 percent 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.

The available P₂O₅ content of the sub watershed was ranged from 3.44-87.59 kg ha⁻¹ with average and SD value of 26.13 and 12.04 kg ha⁻¹ respectively. The CV of 46.1 per cent for available P₂O₅ distribution in the sub watershed indicates that, it was varied spatially. Mapping of available P₂O₅ by GIS revealed that, available P₂O₅ was low in 29.24 per cent of the study area whereas, it was medium in 64.6 per cent of the study area (Table 3 and Fig 6). Low P₂O₅ 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 for black soils of Malaprabha command area of Karnataka that available P₂O₅ status in the soils was low due to high calcium carbonate content.

The available K₂O content in the Mevundi sub watershed was ranged from 107-693 kg ha⁻¹ with mean

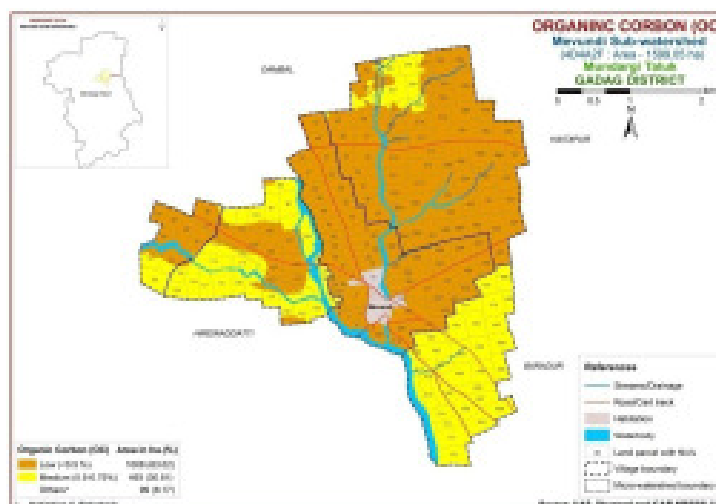


Fig. 4. Organic carbon status of Mevundi sub watershed

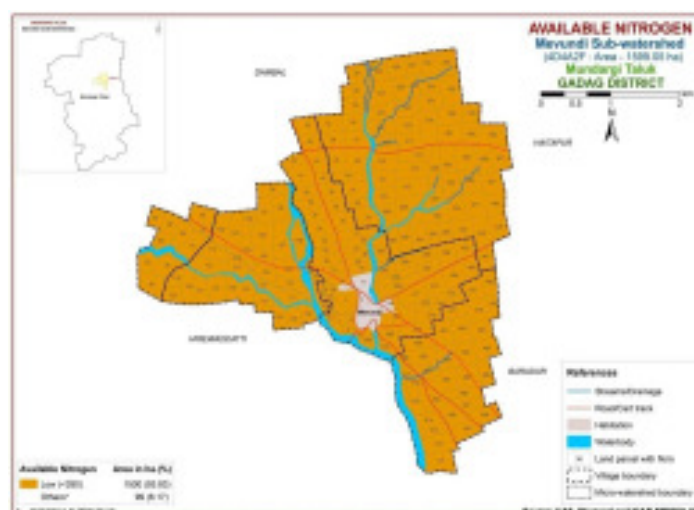


Fig. 5. Available nitrogen status of Mevundi sub watershed

and SD value of 392 and 106 kg ha⁻¹ respectively. The CV (27%) for available K₂O content indicates that, it varied spatially in the sub watershed. Mapping of available K₂O content in the sub watershed by GIS revealed that, 67 per cent of the study area was in high category (Table 3 and Fig. 7) and 27 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 Mevundi 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) and Pulakeshi *et al.* (2012).

The available sulphur content of soils of the sub watershed varied from 0.77-25.46 mg kg⁻¹ soil with mean and SD values of 10.9 and 5.47 mg kg⁻¹ soil respectively. The CV (50.2%) 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 low to medium in available sulphur status with 31 and 62 per cent of the study area respectively

Table 4. Available micro nutrients status in Mevundi sub watershed

	Fe	Mn	Cu	Zn
	mg kg ⁻¹			
Range	0.16-6.40	1.37-12.30	0.16-4.07	0.20-16.34
Average	1.40	5.67	0.86	2.04
SD	1.25	2.75	0.42	2.76
CV	88.8	48.57	48.86	135.22

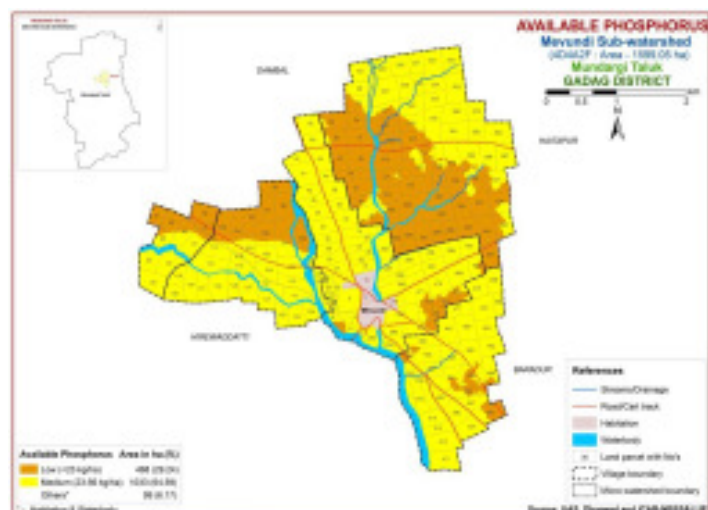


Fig. 6. Available phosphorus status of Mevundi sub watershed

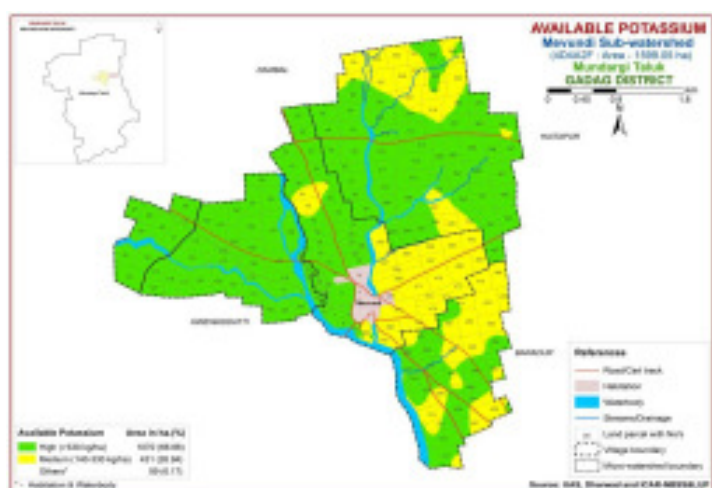


Fig. 7. Available potassium status of Mevundi sub watershed

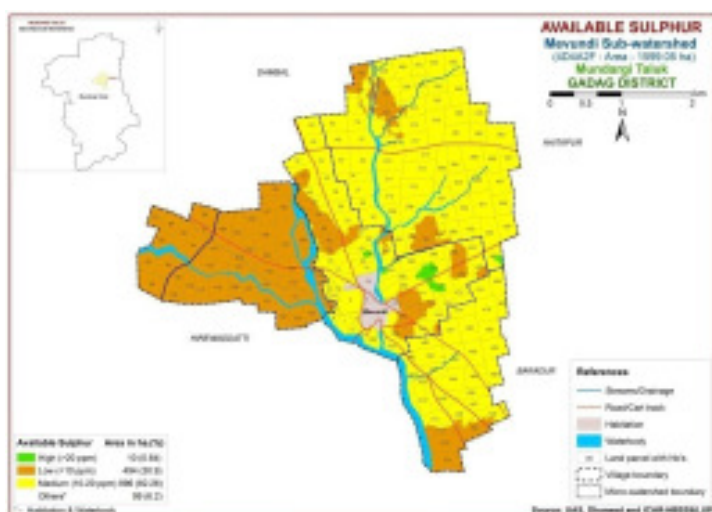


Fig. 8. Available sulphur status of Mevundi sub watershed

(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 gypsiferous 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 and Pulakeshi *et al.*, 2012).

Available micro nutrients

The available iron in the sub watershed was ranged from 0.16-6.40 mg kg⁻¹ with mean and SD value of 1.4 and 1.25 mg kg⁻¹ respectively (Table 4). The CV (88.8%) 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 entire study area (Fig. 9). The low Fe content may be due to precipitation of Fe by CaCO₃ and decreased its availability. Similar results were also observed by Ravikumar *et al.* (2007b), Patil *et al.* (2006) and Pulakeshi *et al.* (2012) The available iron in surface soils had no regular pattern of distribution. This type of variation may be due to the soil management practices and cropping pattern adopted by different farmers (Srikant *et al.*, 2008).

The available Manganese in the sub watershed was ranged from 1.37-12.30 mg kg⁻¹ with mean and SD value of 5.67 and 2.75 mg kg⁻¹ respectively (Table 4). The CV (48.57%) 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.

The available copper in the entire sub watershed was sufficient and ranged from 0.16-4.07 mg kg⁻¹ with mean and SD value of 0.86 and 0.42 mg kg⁻¹ respectively (Table 4). The CV (48.86%) 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) observed sufficient status of available copper in soils of North Karnataka.

The available zinc in the sub watershed was ranged from 0.20-16.34 mg kg⁻¹ with mean and SD value of 2.04 and 2.76 mg kg⁻¹ respectively (Table 4). The CV (135.22%) 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 32 per cent of the study area and sufficient in 62 per cent of the area (Fig. 10). 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 CaCO₃, 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 and Pulakeshi *et al.*, 2012).



Fig. 9. Available iron status of Mevundi sub watershed

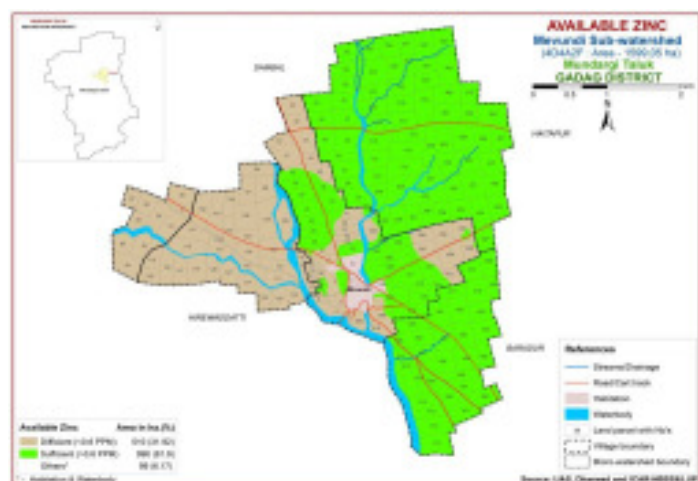


Fig. 10. Available zinc status of Mevundi sub watershed

Conclusion

From the study, it can be concluded that, soils of Mevundi sub-watershed in northern dry zone of Karnataka are neutral to very strongly alkaline with non saline to slight salinity. Alkaline soils in the study area need immediate attention for their management to arrest further degradation. Soil organic carbon content was low to medium. Available nitrogen was low, available phosphorus was low to medium, available potassium was medium to high and sulphur was low to medium. Regarding available 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 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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