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Spatial distribution of available nutrients in Kanginhal sub-watershed in Northern dry zone of Karnataka

Ragini S Patil and PL Patil

Abstract
Soil samples from Kanginhal sub-watershed in Northern dry zone of Karnataka were drawn at 500 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 moderately alkaline to very strongly alkaline with non saline to moderate salinity. Soil organic carbon content was low to medium and available nitrogen was low. Available phosphorus and sulphur were medium to high, whereas available potassium was high in these soils. Among the micronutrients copper and manganese were sufficient while, zinc and iron were deficient.The mapping of nutrients by GIS technique in the sub-watershed revealed that OC, available N, Zn and Fe are important soil fertility constraints indicating their immediate attention for sustained crop production.

Keywords: Minerology, soil fertility map, watershed, nutrients

1. Introduction
The continuous increase in human population is leading to disturbance of the earth's ecosystem to produce food and fibre and will place greater pressure on soils to supply essential nutrients. The practice of intensive cropping with hybrid varieties for boosting food production has lead to decline in soil productivity. Therefore, it is necessary to study the spatial distribution of available nutrients to identify the extent of nutrient deficiency. 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) [1]. Furthermore, GIS generated soil fertility maps may serve as a decision support tool for nutrient management (Iftikar *et al*. 2010) [2]. Some studies on soil fertility status at representative sub-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 Kanginhal sub-watershed in Northern dry zone of Karnataka.

2. Materials and Methods
Kanginhal sub-watershed (Gadag taluk, Gadag district) was selected as study area located in Northern dry zone of Karnataka between 15°25′-15°30′ N latitudes and 75°41′-75°45′ E longitudes, covering an area of 3693.87 ha (Fig. 1). The major parent material in the sub-watershed is weathered schist. 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 temperature was 14.8 °C in winter. Mean maximum temperature was 32.85 °C and mean minimum temperature was 19.18 °C. The average annual rainfall was 539.8 mm. It was 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).
Entire sub-watershed comprises of black soils with clay texture. The depth of the soil in sub-watershed is predominately very deep and gradient of land is nearly level to very gently sloping. The sub-watershed soils are comes under moderately eroded and some portion of the soils comes under slightly eroded class.
Surface composite soil samples were collected during April 2016 on grid points of 500 m interval in the study area and the sample location was recorded by GPS. A total of 288 samples were collected from the sub-watershed. Micro-watershed wise soil sample details are furnished in Table 1.

Table 1: Details of soil sampling in Kanginhal sub-watershed (4D7C3B)

Name of Sub-watershed	Sl. No	Name of Micro-watershed	Code	Area (ha)	No. of samples collected @ 250 m grid interval
Kanginhal (4D7C3B)	1	Atalgeri-1	4D7C3B2e	558.66	37
	2	Atalgeri-2	4D7C3B2d	752.16	60
	3	Kanginhal-1	4D7C3B1d	691.64	57
	4	Kanginhal-2	4D7C3B1b	494.05	38
	5	Kanginhal-3	4D7C3B1e	302.70	23
	6	Kanginhal-4	4D7C3B1a	379.44	31
	7	Kanginhal-5	4D7C3B1c	515.23	42
			Total	3693.87	288

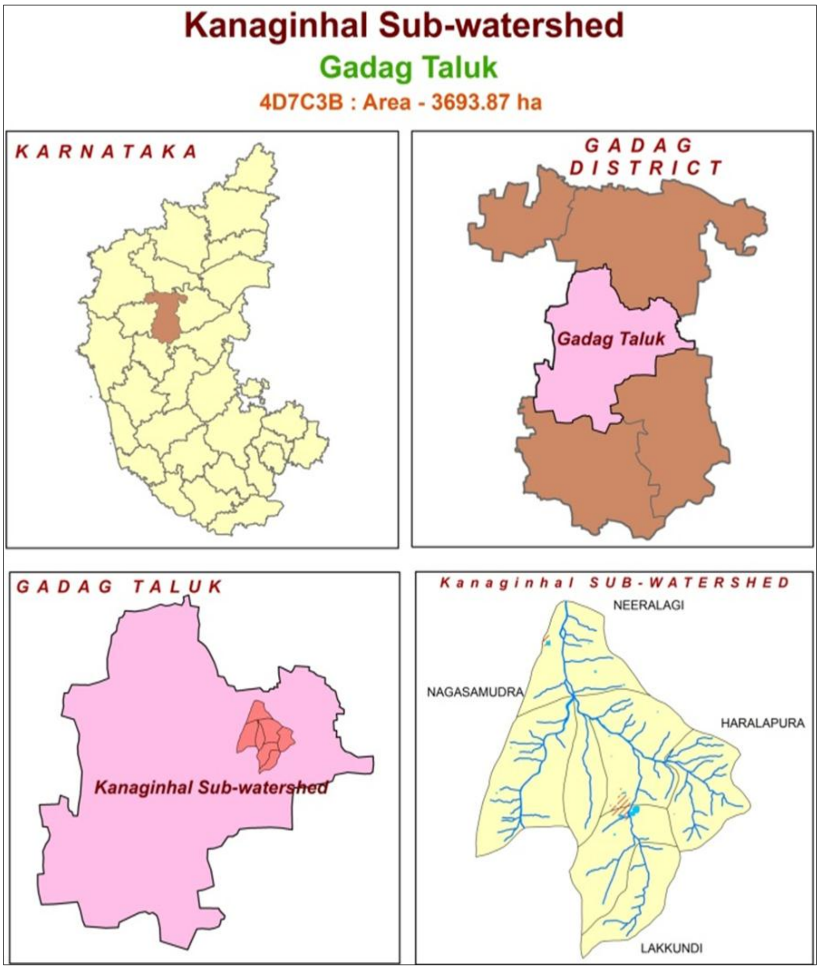

Fig 1: Location map of Kanginhal sub-watershed

The soil samples were air-dried, ground (< 2 mm) and analyzed for chemical and available parameters. The pH (1:2.5) and electrical conductivity (EC) (1:2.5) of soils were measured using standard procedures as described by Sparks (1996) [14]. Organic carbon (OC) was determined using the Walkley and Black's wet oxidation method (Sparks 1996) [14]. Available nitrogen (N) was estimated by modified alkaline permanganate method (Sahrawat and Burford1982). Available phosphorus (Olsen P) was measured using sodium bicarbonate ($NaHCO_3$) as an extractant (Sparks 1996) [14]. Available potassium (K) was determined using the ammonium acetate method (Sparks 1996) [14]. Available sulphur (S) was measured using 0.15% calcium chloride ($CaCl_2$) as an extractant (Sparks 1996) [14]. Micronutrients (Fe, Zn, Cu and Mn) were extracted by DTPA reagent using the procedure outlined by Lindsay and Norvell (1978) [3]. 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 interpreted as low, medium and high and that of available zinc, iron, copper and manganese are interpreted as deficient and sufficient by following the criteria given in Table 2.

A database file (*dbf*) 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 Kanginhal sub-watershed was created. The *dbf* file opened in the project window and in X- field, X-coordinates were selected and Y-field, Y- coordinates were selected. The Z- field was used for different nutrients. The Kanginhal sub-watershed shape file was also opened and from the surface menu of Arc GIS spatial analyst "*Interpolate grid option*" was selected. On the output '*grid specification dialogue*'', output, grid extend chosen was same as Kanginhal sub-watershed shape and interpolation method employed was spline. The generated map was reclassified based on ratings of 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	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
Zinc (Zn)	<0.6		>0.6
Iron (Fe) Calcareous soils	<4.5		>4.5
Copper (Cu)	<0.2		>0.2
Manganese (Mn)	<1.0		>1.0

3. Results and Discussion

3.1. Soil reaction and electrical conductivity

Soils of the Kanginhal sub-watershed were moderately alkaline to very strongly alkaline (7.28 - 9.88) in reaction with a mean pH of 8.49, standard deviation of 0.40 and coefficient of variation of 4.66 per cent (Table 3). Higher soil reaction in the sub-watershed is mainly because of calcareousness nature of the soils. The coefficient of variation of soil pH indicates that, it did not vary spatially. Major proportion of the sub-watershed area (Fig. 2.) was strongly alkaline (55.87 %) and remaining area was very strongly alkaline (3.59 %) and moderately alkaline (37.53 %). The higher pH of soils in the Kanginhal sub-watershed could be attributed to low intensity of leaching and accumulation of bases. Similar results and inferences were also drawn in soils of Northern dry zone of Karnataka (Nadaf *et al.* 2015; Patil *et al.* 2017a and b and Patil *et al.* 2018a and b) [5, 7, 9, 6, 10]. Strongly alkaline area is to be reclaimed by application of gypsum and leaching with good quality of water. Rain water may be harvested by compartment bunding and used for leaching. Alkalinity tolerant crops may be grown.

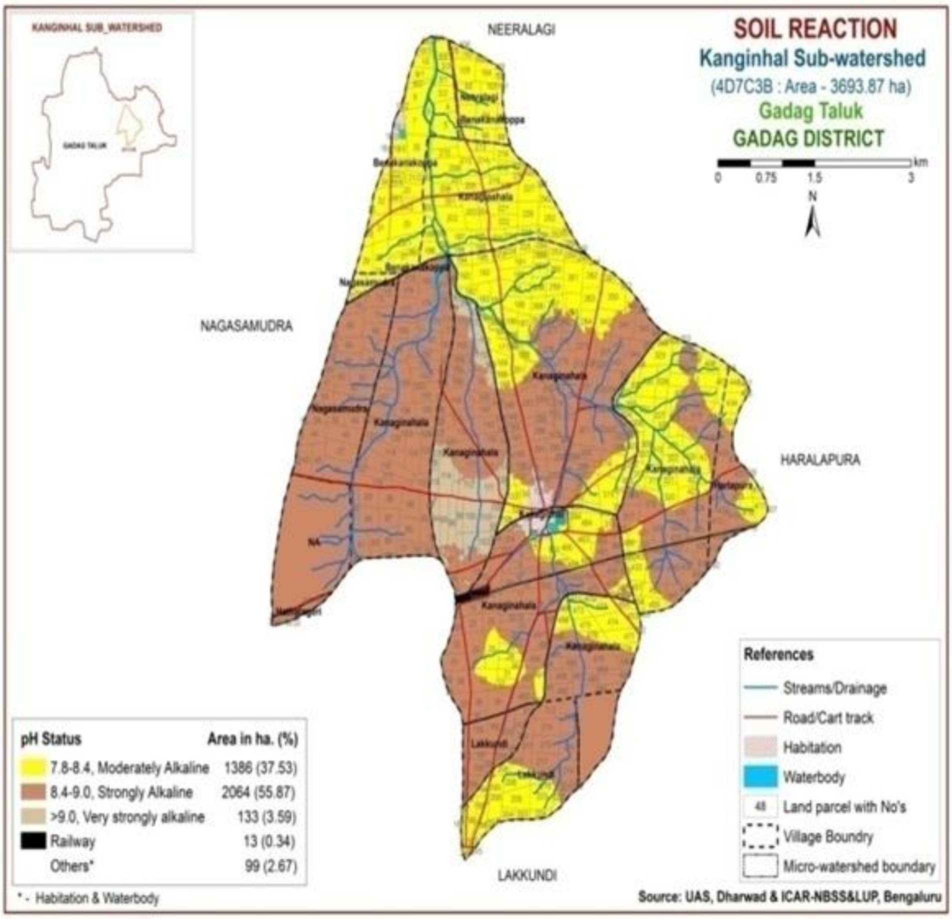

Fig 2: Soil Reaction status of Kanginhal Sub-watershed

The EC of soils in the sub-watershed was in the range of 0.13-1.52 dS m^{-1} with mean value of 0.53 dS $m^{-1}$and standard deviation of 0.31dS m^{-1}. The CV (58.19 %) of EC values indicate that salt content in the sub-watershed varied spatially (Table 3 and Fig. 3). Salinity might be due to lesser percolation of water and higher salt content in the parent material of black soils. Black soils with fine texture are known to have lower water permeability characteristics leading to lesser percolation of water and more accumulation of salts (Sumithra *et al.*, 2013) [15]. GIS Mapping of soluble salt content in the sub-watershed revealed that, the area under non saline, slightly saline and moderately saline were 1192 (53.92 %), 1496 (40.50 %) and 95 ha (2.56 %), respectively. These results are in confirmation with the findings in the soils of Bedwatti and Mevundi watershed of Karnataka (Patil *et al.* 2017a and b) [7, 9]. This is attributable to the accumulation of salts due to poor drainage condition of the soils.

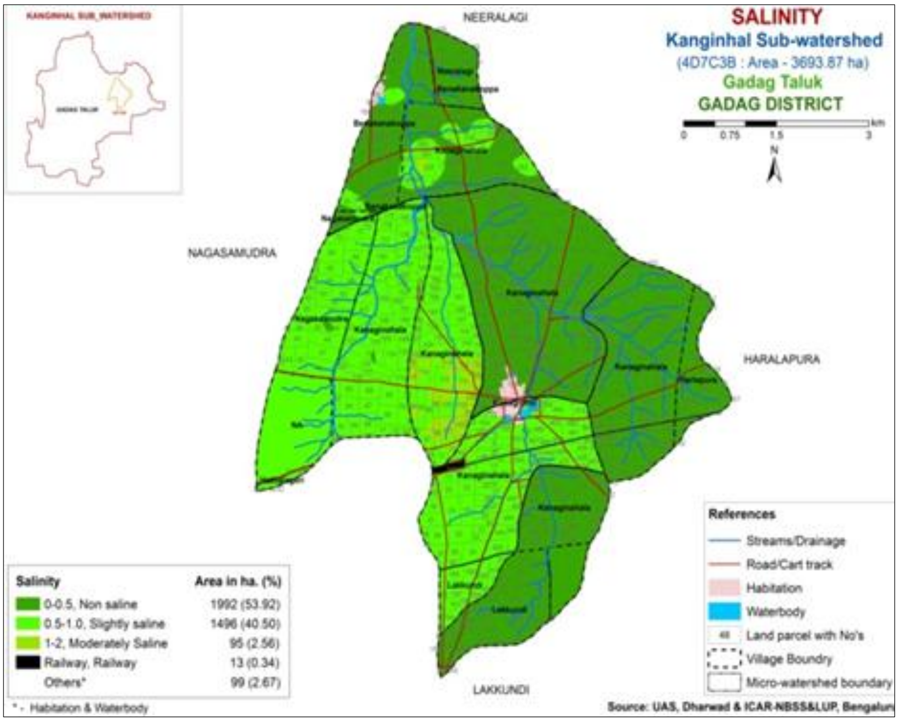

Fig 3: Salinity status of Kanginhal sub-watershed

Table 3: Chemical properties and available major nutrients status in Kanginhal sub-watershed

Statistics	pH	EC	OC	N	P_2O_5	K_2O	S
		dS m^{-1}	g kg^{-1}	kg ha^{-1}			mg kg^{-1}
Minimum	7.28	0.13	2.1	67	20.96	254	6.94
Maximum	9.88	1.52	9.5	269	76.28	725	38.58
Mean	8.49	0.53	4.9	151.30	45.25	488.16	19.32
SD	0.40	0.31	1.3	36.99	10.84	103.35	6.60
CV	4.66	58.19	25.57	24.45	23.96	21.17	34.16

3.2 Organic carbon

Organic carbon content of soils of Kanginhal sub-watershed was ranged from 2.1-9.5 g kg^{-1} with mean and standard deviation value of 4.9 and 1.3 g kg^{-1}, respectively. The CV (25.57 %) for OC content indicates that SOC varied spatially in the sub-watershed (Table 3). Mapping of OC by GIS revealed that soil organic carbon is low in 59.31 per cent of the area and medium in 37.68 per cent of the area (Fig 4). The reason for low organic carbon content in these soils may be attributed to the prevalence of arid condition (Patil *et al.* 2018a and b) [6, 10], 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 in soils. Organic carbon status of soils is to be enhanced by crop residue management for improving physical, chemical and biological properties and fertility status.

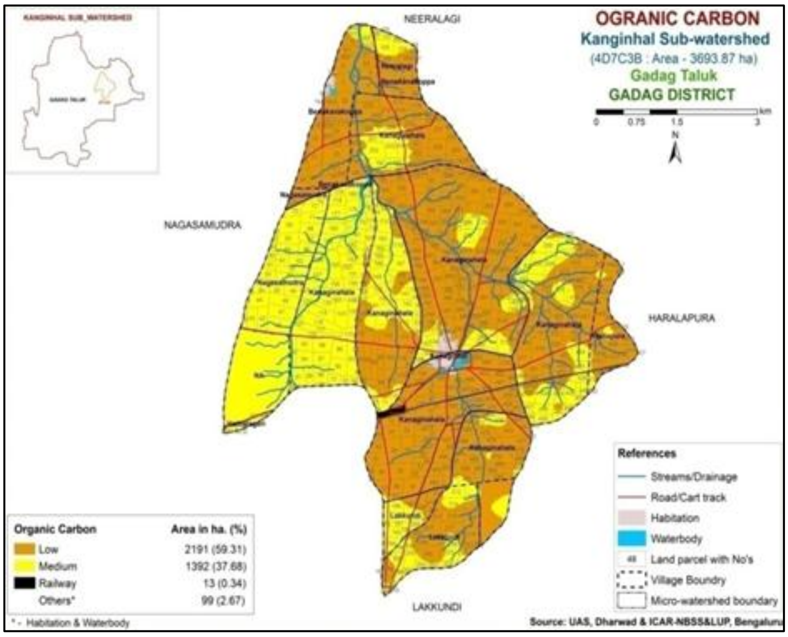

Fig 4: Soil organic carbon status of Kanginhal Sub-watershed

3.3 Available macronutrients

The available N in soils of the sub-watershed ranged from 67-269 kg ha^{-1} with a mean of 151.30 kg ha^{-1} and SD of 36.99 kg ha^{-1}. The CV of 24.45 indicates that available N in soils varied spatially. GIS mapping revealed that, the entire cultivated area (3583 ha) in the 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 (Pulakeshi *et al.* 2012; Patil *et al.* 2018a and b) [11, 6, 10]. 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. Since the soils of the entire sub-watershed area was low in available nitrogen status, crops are to be supplied with 25 per cent more than the recommended dose of N. Use of bio fertilizers for seed treatment may be popularised for increasing N supply to the crops. In wider row spacing crops sunhemp may be grown and incorporated at flowering stage.

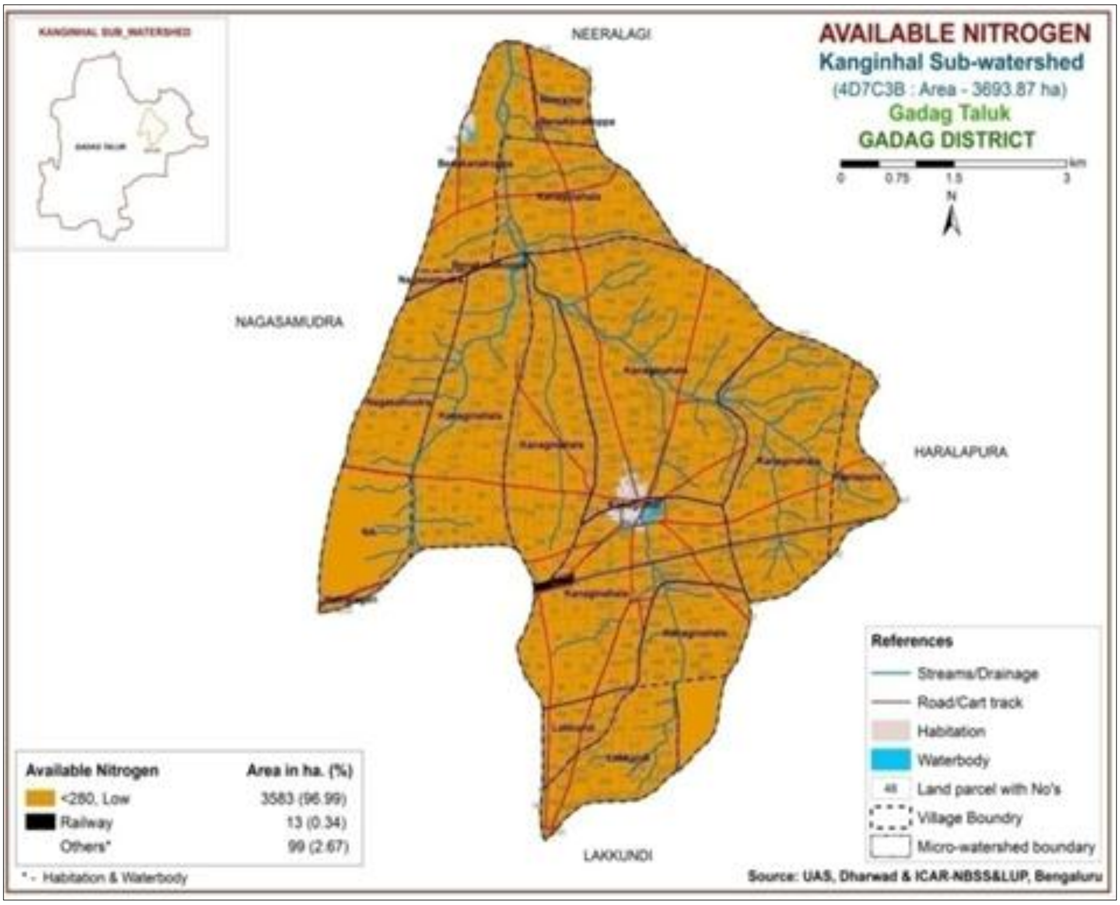

Fig 5: Available nitrogen status of Kanginhal Sub-watershed

The available P_2O_5 content of the sub-watershed was ranged from 20.96 to 76.28 kg ha^{-1} with average and SD value of 45.25 and 10.84 kg ha^{-1}, respectively. The CV (23.96 %) 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 medium in 3319 ha (Table 3 and Fig 6). Medium P_2O_5 availability in these soils is related to their high pH, calcareousness and low organic matter content. The present findings are in line with those of Patil *et al.* (2016; 2017a and b) [7, 9] who reported that majority of the soils in Karnataka were low to medium in phosphorus content. Available P_2O_5 was high in 264 ha and the higher phosphorus content in these soil is due to continuous application of DAP to the pulse crop, as pulse is the main *kharif* crop in this area.

The available K_2O content in the sub-watershed was ranged from 254 to 725 kg ha^{-1} with mean and SD value of 488.16 and 103.35 kg ha^{-1}, respectively. The CV (21.27 %) 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, entire study area was in high category (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*., 2017a and b) [7, 9]. 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 soils of Kanginhal sub-watershed may be due to the predominance of potash rich micaceous and feldspar minerals in parent material.

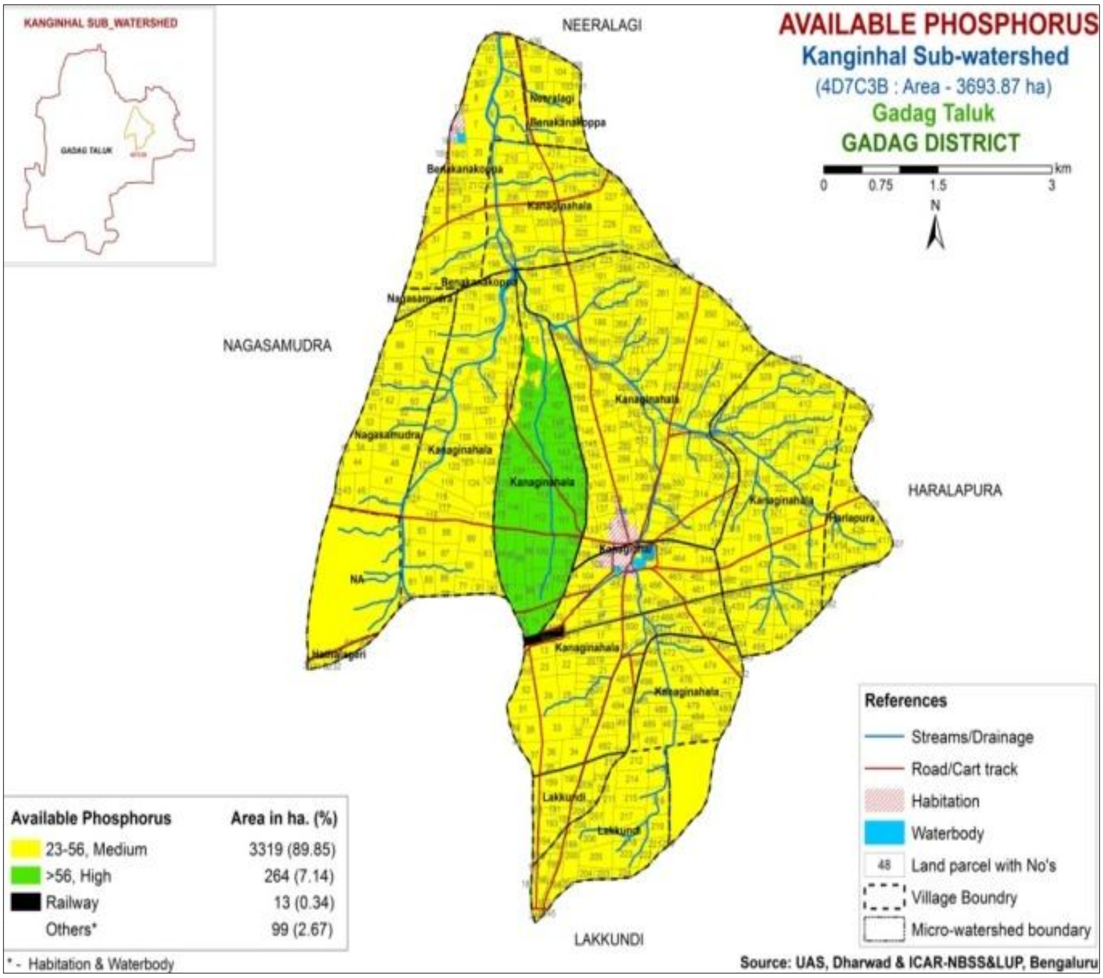

Fig 6: Available phosphorus (P_2O_5) status of Kanginhal Sub-watershed

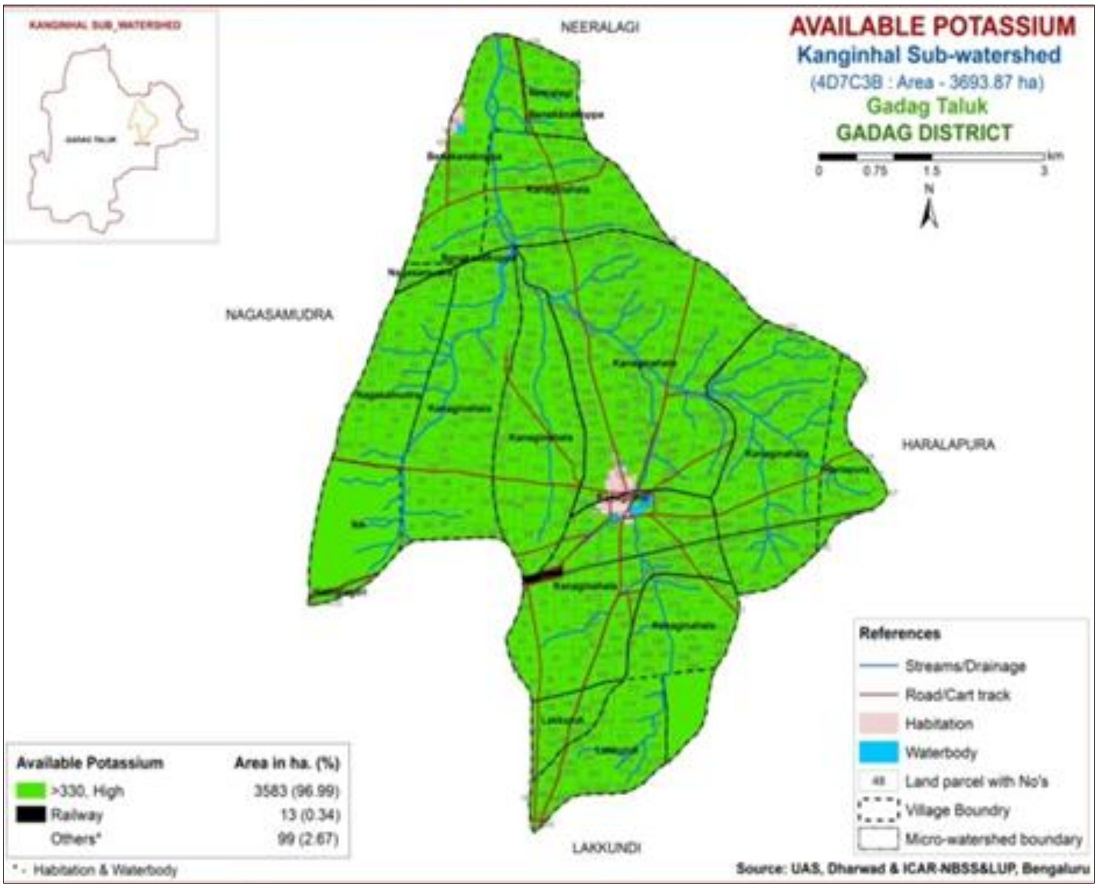

Fig 7: Available potassium (K_2O) status of Kanginhal Sub-watershed

The available sulphur content of soils of the sub-watershed varied from 6.94 to 38.58 mg kg^{-1} soil with mean and SD values of 19.32 and 6.60 mg kg^{-1}, respectively. The CV (34.16 %) for available S content indicates that, in the sub-watershed available S varied spatially (Table 3). GIS mapping of available S revealed that (Fig.8.), available sulphur in soils was medium in 61.17 percent of TGA and high in 35.82 percent of TGA of the sub-watershed. Medium to high available sulphur status was also observed in the soils of Hirehalla sub-watershed in Northern dry zone of Karnataka (Patil *et al.* 2018a) [6].

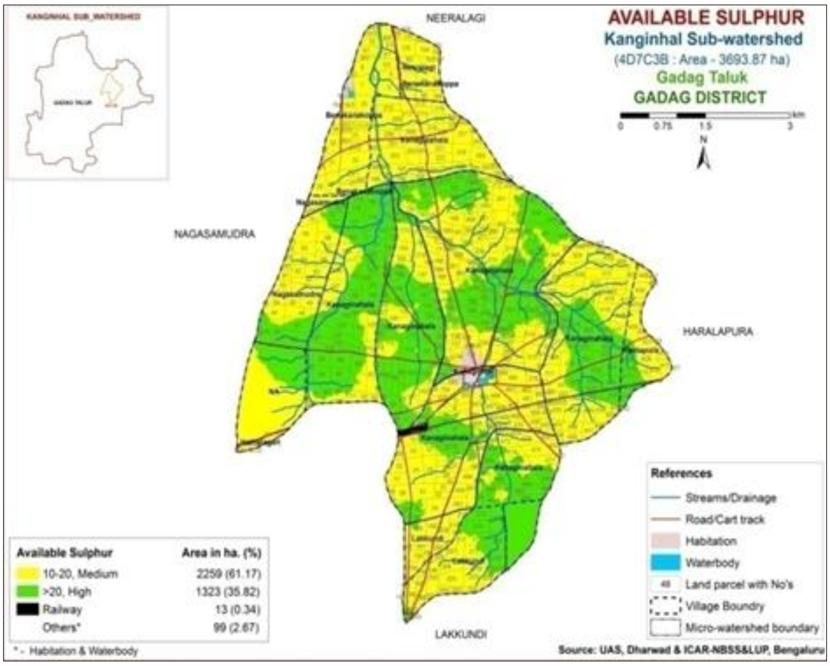

Fig 8: Available sulphur status of Kanginhal Sub-watershed

3.4 Available micronutrients

The available zinc in the sub-watershed was ranged from 0.11 to 5.12 mg kg^{-1} with mean and SD value of 0.40 and 0.36 mg kg^{-1}, respectively (Table 4 and Fig. 9.). The CV (89.78 %) 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 93.69 per cent of the study area and sufficient in 3.30 per cent of the area (Fig 8). 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. Zinc deficiency in major part of the study area in soils of North Karnataka was also reported by Ravikumar *et al.* (2007) [12], Pulakeshi *et al.* (2012) [11] and Patil *et al.* (2017a and b; 2018a and b) [7, 9, 6, 10].

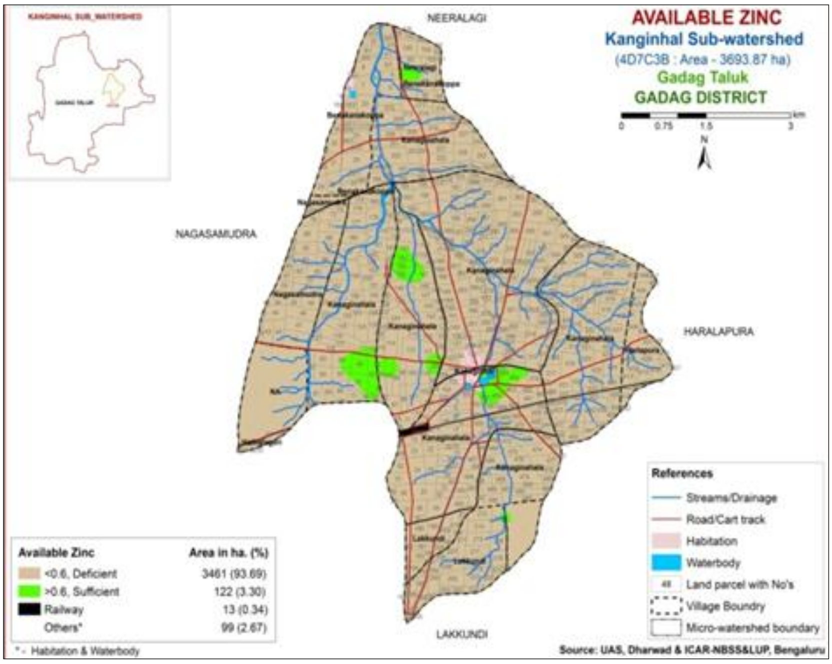

Fig 9: Available zinc status of Kanginhal Sub-watershed

The available iron in the sub-watershed was ranged from 0.9 to 9.11 mg kg^{-1} with mean and SD value of 3.93 and 1.41 mg kg^{-1}, respectively (Table 4 and Fig. 10.). The CV (35.79 %) for available Fe content indicates that, it varied spatially in the sub-watershed. Mapping of available Fe by GIS revealed that, available iron is deficient in 76.06 percent of TGA (Fig 9). The low Fe content may be due to precipitation of Fe by $CaCO_3$ and decreased its availability (Patil *et al.* 2017a and b) [7, 9] also observed deficiency of iron in calcareous soils of North Karnataka. The available iron in surface soils did not follow regular pattern of distribution. This type of variation may be due to the soil management practices and cropping pattern adopted by different farmers.

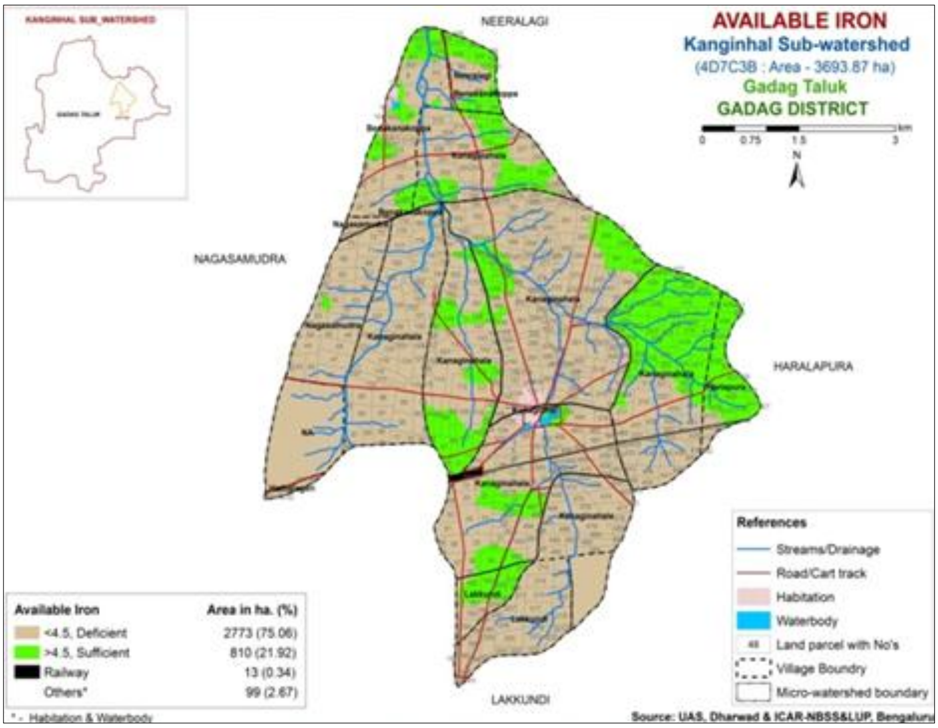

Fig 10: Available iron status of Kanginhal Sub-watershed

The available manganese in the sub-watershed was ranged from 0.52 to 12.37 mg kg^{-1} with mean and SD value of 4.46 and 1.69 mg kg^{-1}, respectively (Table 4 and Fig. 11). The CV (37.82 %) 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 96.91 per cent of area of the sub-watershed. Sufficient content of manganese was also observed in Vertisols of Malaprabha command area (Ravikumar *et al*. 2007) [12] and in the soils of Northern Karnataka. (Patil *et al.* 2018a and b) [6, 10]

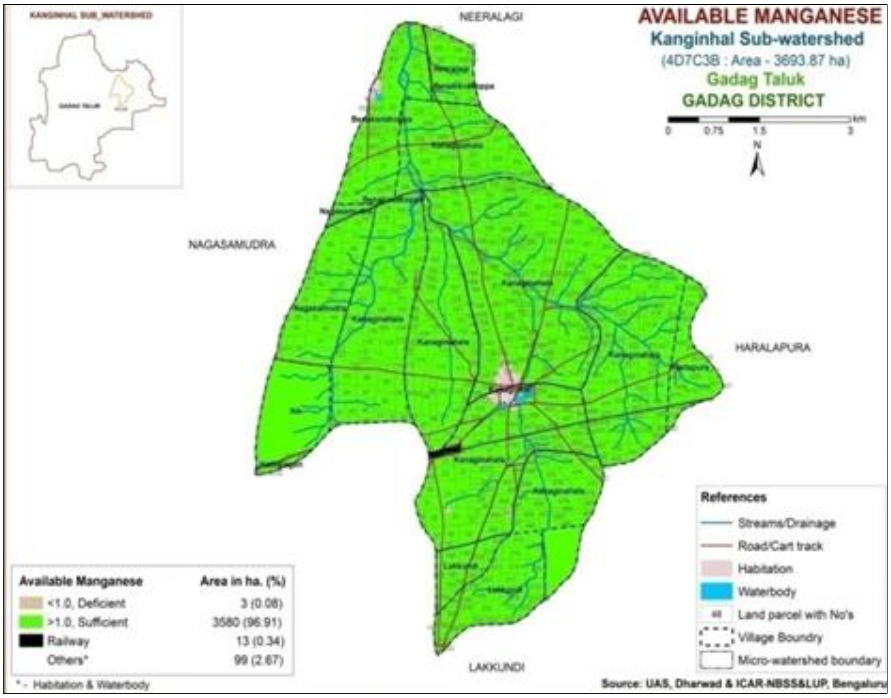

Fig 11: Available manganese status of Kanginhal Sub-watershed

The available copper in the entire sub-watershed was sufficient and ranged from 0.11-1.93 mg kg^{-1} with mean and SD value of 1.71 and 1.03 mg kg^{-1} respectively (Table 4 and Fig. 12). The CV (24.45 %) 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 cultivated area of the sub-watershed. Similar results were also observed in soils of Malaprabha command area (Ravikumar *et al*. 2007) [12].

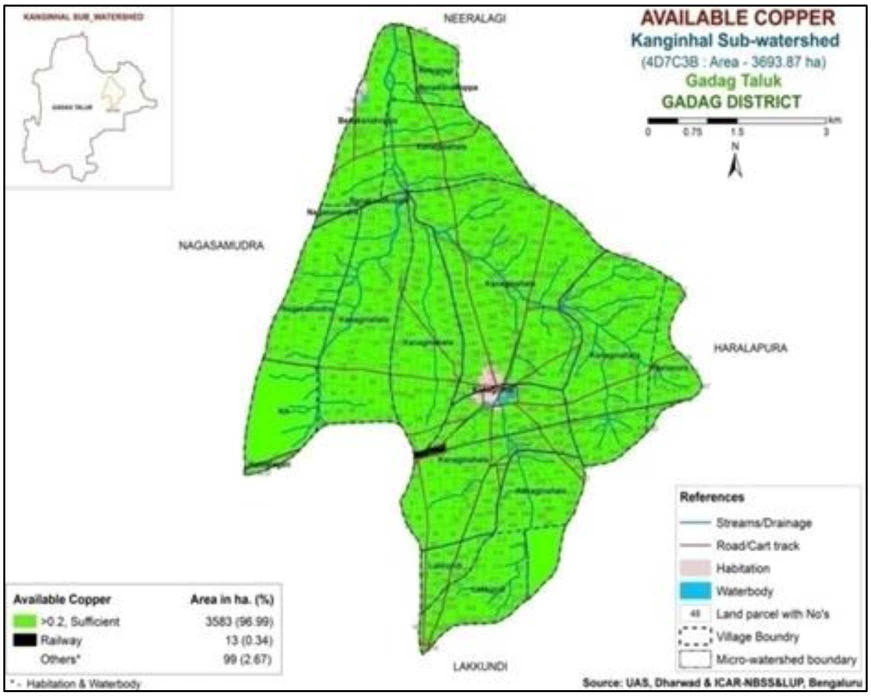

Fig 12: Available copper status of Kanginhal Sub-watershed

Table 4: Available micronutrients status in Kanginhal sub-watershed

Nutrients Statistics	Fe	Mn	Cu	Zn
	mg kg^{-1}			
Minimum	0.9	0.52	0.11	0.11
Maximum	9.11	12.37	1.93	5.12
Mean	3.93	4.46	0.70	0.40
SD	1.41	1.69	0.30	0.36
CV	35.79	37.82	42.55	89.18

4. Conclusion

From the study, it can be concluded that, soils of Kanginhal sub-watershed in Northern dry zone of Karnataka are slightly alkaline to very strongly alkaline with non saline to moderate 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 medium to high, available potassium was high and sulphur was medium to high. Regarding available micronutrients, zinc and iron were deficient in the entire 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 OC, available N, Zn and Fe are important soil fertility constraints indicating their immediate attention for sustained crop production. The deficient micronutrient need to be replenished to avoid the crops suffering from their deficiency and for optimum utilization of other nutrients.

5. Acknowledgement

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