Soil Fertility Mapping using GIS in Three Agro-climatic Zones of Belgaum District, Karnataka

Ghulappa S Dasog
University of Agricultural Sciences, Dharwad

Kanwar Lal Sahrawat
International Crops Research Institute for Se…

Suhas P. Wani
International Crops Research Institute for Se…

Journal of the Indian Society of Soil Science, Vol. 63, No. 2, pp 173-180 (2015)

Soil Fertility Mapping using GIS in Three Agro-climatic Zones of Belgaum District, Karnataka

K. Prabhavati, G.S. Dasog*, P.L. Patil, K.L. Sahrawat[1] and S.P. Wani[1]
Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, Dharwad, 580005, Karnataka

Soil fertility parameters *viz*., pH, electrical conductivity (EC), available macro- and micronutrients were determined in soil samples drawn at 300 m grid intervals from three micro-watersheds representing northern dry zone (zone-3), northern transition zone (zone-8) and hilly zone (zone-9) across a climatic gradient in Belgaum district of Karnataka. Based on the data maps were prepared in GIS environment using Arc GIS v 10.0. The soil fertility parameters clearly reflect the agro-climatic conditions under which the soils are formed. Soils of zone-3 were alkaline (pH> 8.5), soils of zone-8 slightly alkaline (7.0-8.5) and those of zone-9 slightly acidic (5.5-6.5). Whereas carbon and available nitrogen (N) in soils of both zone-3 and zone-8 were low, organic carbon (OC) was high (6.9 g kg^{-1}) but the available N was medium (412 kg ha^{-1}) in soils of zone-9. Available phosphorus (P) remained low in zones-3 and zone-8 but was marginally medium in zone-9. The available potassium (K) status of zone-3 soils was high (401 kg ha^{-1}) but was medium in zone-8 and zone-9. Available sulphur (S) was low, DTPA extractable Zn and Fe was deficient, and Mn and Cu was sufficient in soils of both zone-3 and zone-8. In zone-9, however, available S and Zn were marginally sufficient but Fe, Mn and Cu were distinctly sufficient. In conformity with mean values described above, OC, available N, P, S and Zn were low (100% area for each) and available K was high in 91.2% area in soils of zone-3. Similarly for zone-8, OC and available N was low in 2/3 of area, available P was low in 76.5% area, available K was medium in 92.0% area, and low in available S (10%), deficient in Zn (99.1% area) and Fe (100% area). In agreement with means a large area under high OC (66.2%) and medium in available N (81.2%) and low in P (71.7%) was reflected in maps of zone-9. However, available K, S and Zn were distributed equally between low and medium classes despite K being medium and S being low and Zn being sufficient suggesting maps are preferred over means. The pH was slightly lower, OC and available N distinctly higher, and available P and DTPA extractable Cu lower in forest lands compared to agricultural lands in zone-9. Land use did not influence available K and DTPA extractable Zn, Fe and Mn.

Key words: Soil fertility map, GIS, agro-climatic zones, land use, watersheds

The concept of watershed based holistic development has emerged as one of the potential approaches in rainfed areas, which can lead to higher sustainable agricultural production. It has been documented 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. Inadequate fertilizer application limits crop yield, results in nutrient mining and causes soil fertility depletion. An excessive or imbalanced application not only wastes this limited costly resource, but also pollutes the environment. In the face of economic and environmental concerns, farmers face an increasing challenge of effective soil fertility management. An approach towards justifying such concerns is site specific nutrient management which takes into account spatial variations in nutrients status, thus cutting down the possibility of over or under use of fertilizer. 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).

*Corresponding author (Email: gdasog@gmail.com)
Present address
[1]International Crops Research Institute for Semi-Arid Tropics, Patancheru, Hyderabad

Table 1. Particulars of watersheds studied

Sl. No.	Microwatershed and Code	Area (ha)	Agroclimatic zone	MAR (mm)	Geology	Land use
1.	Yadawad 4D7D3I1a*	572.9	Northern dry zone (zone-3)	507.6	Basalt	Entirely agriculture
2.	Hukkeri 4D7D7D2a*	498.3	Northern transition zone (zone-8)	658.4	Basalt	40% agriculture 60% open scrub
3.	Khanapur 4D7C9L1c*	586.2	Hilly zone (zone-9)	1859.1	Peninsular gneiss	69% agriculture 26% forest

MAR=Mean Annual Rainfall
*As per Microwatershed Atlas supplied by Karnataka Remote Sensing Application Centre, Bangalore (unpublished document)

Furthermore, GIS generated soil fertility maps may serve as a decision support tool for nutrient management (Iftikar *et al*. 2010). A number of studies on soil fertility mapping have been documented (Ravikumar *et al.* 2004) but no study was made including more than one watershed across a climatic gradient. In this background, a study was initiated with the objective to map the spatial distribution of soil fertility parameters in selected microwatersheds representing different agro-climatic zones in Belgaum district, Karnataka.

Materials and Methods

Study Sites

The Belgaum district is situated to the east of the Western Ghats in the northwestern part of Karnataka state. The district presents wide variation in agro-climatic conditions so that it is divided into three agro-climatic zones (Fig. 1) *viz*., northern dry zone (zone-3), northern transition zone (zone-8) and hilly zone (zone-9), the particulars of which are furnished in table 1.

Soil Analysis

Surface samples were collected using a hand held GPS on grid points of 300 m interval in the study area. A total of 186 samples (69, 57 and 60 samples from Yadawad, Hukkeri and Khanapur micro-watersheds, respectively) were thus collected. The soil samples were air-dried, ground (< 2 mm) and analyzed for chemical and fertility parameters. The pH (1:2) and electrical conductivity (EC) (1:2) 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 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). Available phosphorus (Olsen P) was measured using sodium bicarbonate ($NaHCO_3$) as an extractant (Olsen and Sommers 1982). Available nitrogen (N) was estimated from soil organic C values as organic C has been used as an index of available N (Sahrawat *et al.* 2010). 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 and standard deviation for each set of data.

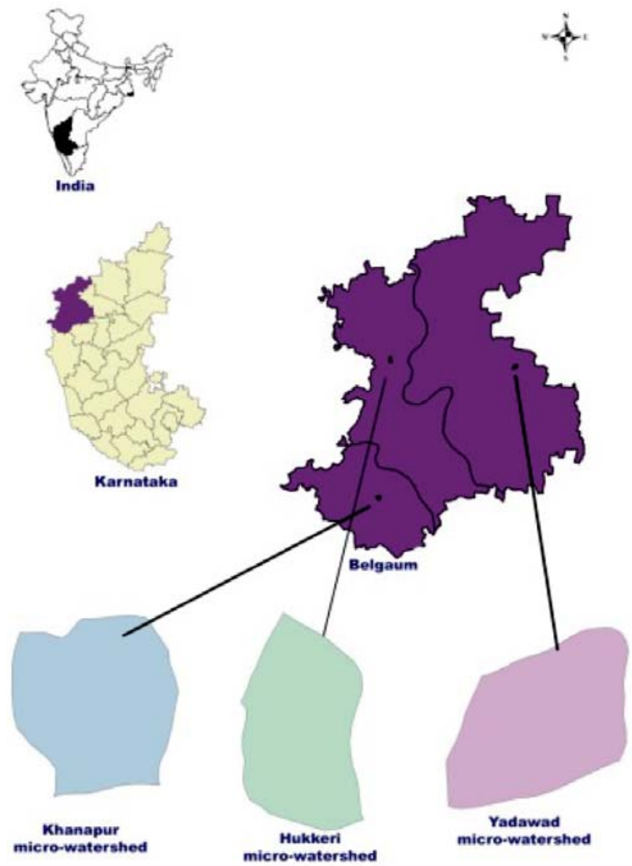

Fig. 1. Map showing Belgaum district and the locations of watersheds from the three agro- climatic zone

Soil fertility maps were prepared using Arc Info v 10.0 employing kriging as the interpolation method. Five classes of pH were employed *viz*., acidic (pH <5.5), slightly acidic (5.5-6.5), neutral (6.5-7.5), slightly alkaline (7.5-8.5) and alkaline (>8.5). The ratings employed for different fertility parameters are presented in table 2.

Table 2. Soil fertility ratings for available nutrients

Nutrients	Fertility ratings		
	Low	Medium	High
Organic carbon (g kg^{-1})	<5	5-7.5	>7.5
Nitrogen (kg ha^{-1})	<280	280-560	>560
Phosphorus (kg P_2O_5 ha^{-1})	<23	23-56	>56
Potassium (kg K_2O ha^{-1})	<140	140-330	>330
Sulphur (kg ha^{-1})	<10	10-20	>20

Micronutrients	Deficient	Sufficient
Zinc (mg kg^{-1})	<0.6	>0.6
Iron (mg kg^{-1})	<4.5	>4.5
Copper (mg kg^{-1})	<0.2	>0.2
Manganese (mg kg^{-1})	<1.0	>1.0

The soils of Yadawad micro-watershed are deep black soils with high clay and $CaCO_3$ content, those in Hukkeri are medium deep to deep with modearte texture and those calcareous, and highly clayey and soils are (Prabhavati 2013).

Results and Discussion

Soil reaction and electrical conductivity

Soils of Yadawad micro-watershed were alkaline with a mean pH of 8.92 (Table 3), mainly because of calcareousness nature of these soils. Soils of Hukkeri micro-watershed were slightly alkaline with a mean pH of 7.7. The soils of Khanapur micro-watershed were slightly acidic with a mean pH of 5.85, due to leaching of bases induced by high annual rainfall at Khanapur (Patil and Dasog 1999). Slightly lower pH value in forest area compared to agricultural lands (Table 3) might be due to the organic acids released during decomposition of organic matter added from leaf litter under forest land use. In conformity with the mean values, the entire Yadawad micro-watershed was alkaline, 89.9% of Hukkeri micro-watershed has slightly alkaline and 92.9% of Khanapur micro-watershed soils were slightly acidic (Table 4). The EC in all the three micro-watersheds was in normal range with no salinity hazard.

Organic carbon

The mean OC increased from 4.0 g kg^{-1} in soils of zone-3, through 4.7 g kg^{-1} in zone-8 to 6.9 g kg^{-1} in zone-9. However, within zone-9 (Khanapur micro-watershed), the OC content in forest area was higher with a mean value of 8.0 g kg^{-1} compared to 6.6 g kg^{-1} (Table 3). The higher value of OC in forest land use was probably because of addition of litter and slower oxidation of the fresh organic material.

The entire Yadawad micro-watershed in zone-3 and 63.2% of area in Hukkeri was low in OC with medium status in remaining 36.8% area. Low OC in these soils is attributed to rapid rate of decomposition due to high temperature and lack of addition of FYM and crop residues. The area under high category for OC dominated in Khanapur micro-watershed (66.2%), followed by medium status (25%). Higher OC content is due to high rainfall and forest vegetation prevailing there. Cultivation accelerated oxidation of organic

Table 3. Fertility parameters of soils from the three ago-climatic zones in Belgaum

Soil fertility parameter	Zone-3 (Yadawad)		Zone-8 (Hukkeri)		Zone-9 (Khanapur)					
					Entire watershed		Agricultural land		Forest land	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
pH (1:2)	8.92	0.27	7.70	0.53	5.85	0.44	6.11	0.37	5.76	0.44
EC (1:2) (dS m^{-1})	0.25	0.10	0.17	0.10	0.09	0.04	0.10	0.04	0.08	0.03
Organic C (g kg^{-1})	4.0	1.3	4.37	2.2	6.9	2.7	6.6	2.6	8.0	2.9
Av. N (kg ha^{-1})	240	79	279	133	412	161	390	153	475	175
Av. P_2O_5 (kg ha^{-1})	10	4	19	13	25	31	34	26	8	6
Av. K_2O (kg ha^{-1})	401	97	223	98	178	75	173	73	202	76
Av. S (mg kg^{-1})	4.32	1.54	5.83	2.89	9.87	4.24	8.74	3.36	10.53	4.57
DTPA Zn (mg kg^{-1})	0.18	0.04	0.32	0.14	0.73	0.33	0.76	0.34	0.68	0.32
DTPA Fe (mg kg^{-1})	1.27	0.79	1.98	1.16	15.24	3.89	15.59	4.15	13.71	20.70
DTPA Mn (mg kg^{-1})	3.81	1.70	6.01	4.00	11.37	4.91	10.59	4.92	13.84	4.22
DTPA Cu (mg kg^{-1})	0.32	0.19	0.35	0.14	0.49	0.44	0.60	0.48	0.22	0.16

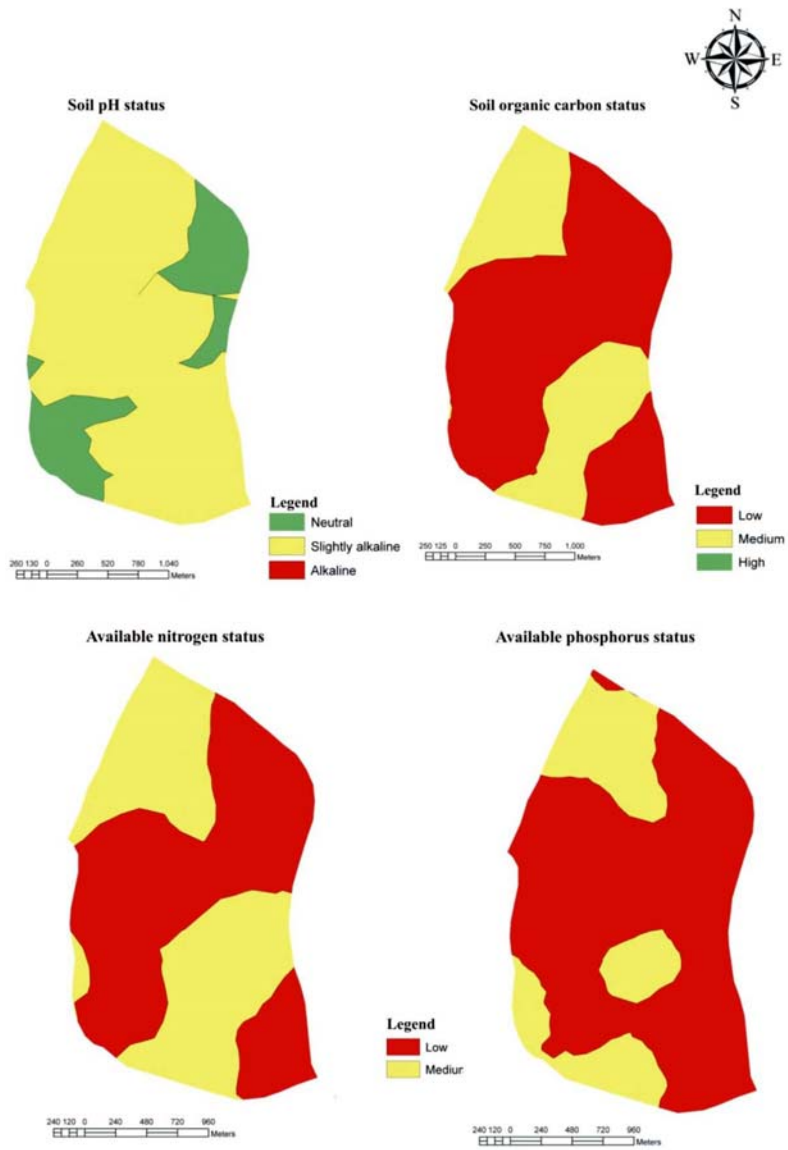

Fig. 2. Soil pH, organic carbon and nutrient mapping of Hukkeri micro-watershed

matter resulting in rapid decomposition of crop residues and organic sources (Doran and Smith 1987).

Available macronutrients

The available N in zone-3 soils was low with a mean of 240 kg ha^{-1} increasing slightly to 279 kg ha^{-1} in zone-8 with a pronounced increase to 412 kg ha^{-1} in zone-9 keeping with the trend in OC (Table 3). All of Yadawad micro-watershed (zone-3) area and a major part (62.%) of Hukkeri micro-watershed (zone-8) exhibited low available N, which could be attributed to low amount of OC as major portion of the N pool is contributed by organic matter (Prasuna Rani *et al.* 1992). The reason might be low rainfall and low vegetation cover, facilitating faster degradation and removal of organic matter leading to N deficiency reflecting the trend in OC observed in these soils under prevailing climatic conditions. Further, soils under forest land had higher available N with a mean value of 475 kg ha^{-1} than those under agricultural land use (390 kg ha^{-1}) because of high OC status of forest soils.

The available P also exhibited a progressive increase from zone-3 (10 kg ha^{-1}) through zone-8 (19 kg ha^{-1}) to zone-9 (29 kg ha^{-1}). However, agricultural lands exhibited higher available P (34 kg ha^{-1}) than forest lands (24 kg ha^{-1}) due possibly to application of phosphatic fertilizers to crops by farmers. There is high variablity associated with this parameter as seen by high standard deviation values. The entire

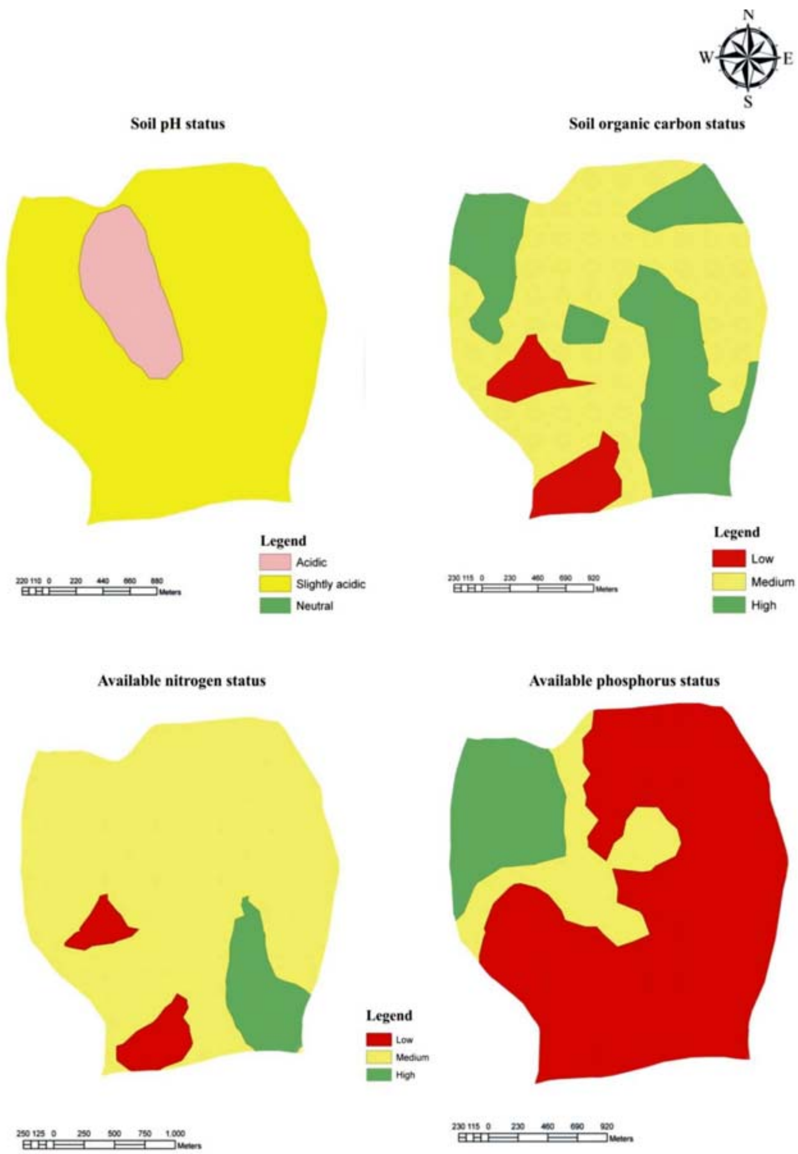

Fig. 3. Soil pH, Organic carbon and nutrient mapping of Khanapur micro-watershed

Yadawad micro-watershed, 76.5% of Hukkeri and 71.7% of Khanapur micro-watershed was low in available P (Table 4 and Fig. 3). Whereas low availability of P in Yadawad is due to its fixation due by $CaCO_3$, it is due to the presence of sesquioxides and low activity clays (Patil and Dasog 1999) in Khanapur micro-watershed.

The available K was high (401 kg ha^{-1}) in soils of zone-3 and dropped sharply in zone-8 (223 kg ha^{-1}) and zone-9 (178 kg ha^{-1}) due to progressive increase in leaching intensity in these soils imposed by the rainfall gradient. It has been brought out more clearly in maps as 91.2% area of Yadawad micro-watershed (zone-3) is high, 92.0% of Hukkeri (zone-8) is medium and an equal area distributed between low and medium status in Khanapur watershed (zone-9). Low available K in zone-9 soils signifies higher leaching regime as evidenced by low base saturation in these soils (Patil and Dasog 1999).

The mean available S in soils of all the three zones was low with zone-9 tending on borderline of low and medium (Table 4). While the entire micro-watershed area of Yadawad and Hukkeri are mapped as low in S, the area is divided equally between the low and medium status in Khanapur micro-watershed (zone-9) 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 which abound in zone-3 and to a greater extent in zone-8 (Balanagoudar

Table 4. Area under different soil fertility categories in the three agro-climatic zones

Soil fertility parameter	Category	Zone-3 (Yadawad)		Zone-8 (Hukkeri)		Zone-9 (Khanapur)	
		Area (ha)	% of TWA	Area (ha)	% of TWA*	Area (ha)	% of TWA
pH (1:2)	Acidic					41.4	7.07
	Slightly acidic					544.8	92.9
	Neutral			55.2	11.1		
	Slightly alkaline			443.2	88.9		
	Alkaline	572.9	100.0				
Organic C (g kg^{-1})	Low	572.9	100.0	314.8	63.2	46.1	7.9
	Medium			183.6	36.8	152.1	26.0
	High					388.0	66.2
Av. N (kg ha^{-1})	Low	572.9	100.0	338.1	67.8	48.4	8.3
	Medium			160.3	32.2	475.9	81.2
	High					62.0	10.6
Av. P_2O_5 (kg ha^{-1})	Low	572.9	100.0	381.2	76.5	420.2	71.7
	Medium			117.2	23.5	83.9	14.3
	High					82.2	14.0
Av. K_2O (kg ha^{-1})	Low			39.8	8.0	291.8	49.8
	Medium	50.7	8.9	458.6	92.0	294.5	50.2
	High	522.2	91.2				
Av. S (mg kg^{-1})	Low	572.9	100.0	498.3	100.0	289.8	49.4
	Medium					296.4	50.6
DTPA-Zn (mg kg^{-1})	Deficient	572.9	100.0	494.0	99.1	311.9	53.2
	Sufficient			4.4	0.9	274.3	46.8
DTPA-Fe (mg kg^{-1})	Deficient	572.9	100.0	498.3	100.0		
	Sufficient					586.2	100.0
DTPA-Mn (mg kg^{-1})	Sufficient	572.9	100.0	498.3	100.0	586.2	100.0
DTPA-Cu (mg kg^{-1})	Deficient					132.6	22.6
	Sufficient	572.9	100.0	498.3	100.0	453.6	77.4

*TWA – Total watershed area

and Satyanarayana 1990). In Khanapur micro-watershed, the soils under forest was marginally medium in available S content (10.52 mg kg^{-1}) compared to low available S (8.74 kg ha^{-1}) in agricultural lands (Table 4).

DTPA extractable micronutrients

There was a graded increase in DTPA extractable Zn in soils going from zone-3 (0.18 g kg^{-1}) through zone-8 (0.32 g kg^{-1}) to zone-9 (0.73 g kg^{-1}). The former two are deficient in Zn and the last one is sufficient guided by the critical value of 0.6 mg kg^{-1} as these soils are alkaline in nature resulting in decreased solubility and mobility (Vijayashekhar *et al.* 2000). The entire micro-watershed area of Yadwad and 99.1% of Hukkeri is shown as deficient (Table 4). In Khanapur, however, the area with deficient and sufficient Zn were nearly equally divided (Fig. 4). The DTPA extractable Fe content of soils of zone-9 was distinctly higher than zones-3 and 8 (Table 4). While the entire micro-watershed representing zones- 3 and 8 is mapped as low, the converse was true of zone-9.

The DTPA extractable Mn content in soils of all the three zones was sufficient against the critical level 1.0 mg kg^{-1} (Lindsay and Norvell 1978) but was distinctly higher in zone-9 soils similar to Fe. Low soil pH coupled with the ferromanganese nature of the parent material, on which these soils developed might have contributed for sufficiency of extractable Mn as observed also by Prasad and Sahi (1989).

The soils of all the three watersheds contained DTPA extractable Cu of > 0.2 g kg^{-1} considered critical. However, the variability was quite pronounced in Khanapur micro-watershed compared to others with agricultural lands having more Cu than forest lands (Table 4). This situation is best reflected in maps as 100% of Yadwad and Hukkeri watersheds are shown as sufficient in Cu but in Khanapur, 22.6% area is shown as deficient which is akin to the 26% area under forest (Table 1). Raghupathi (1989) also reported that DTPA extractable Cu content in north Karnataka soils was sufficient and ranged from 0.2 to 1.2 mg kg^{-1} and that Cu was associated with OC and organic-Cu was the dominant fraction.

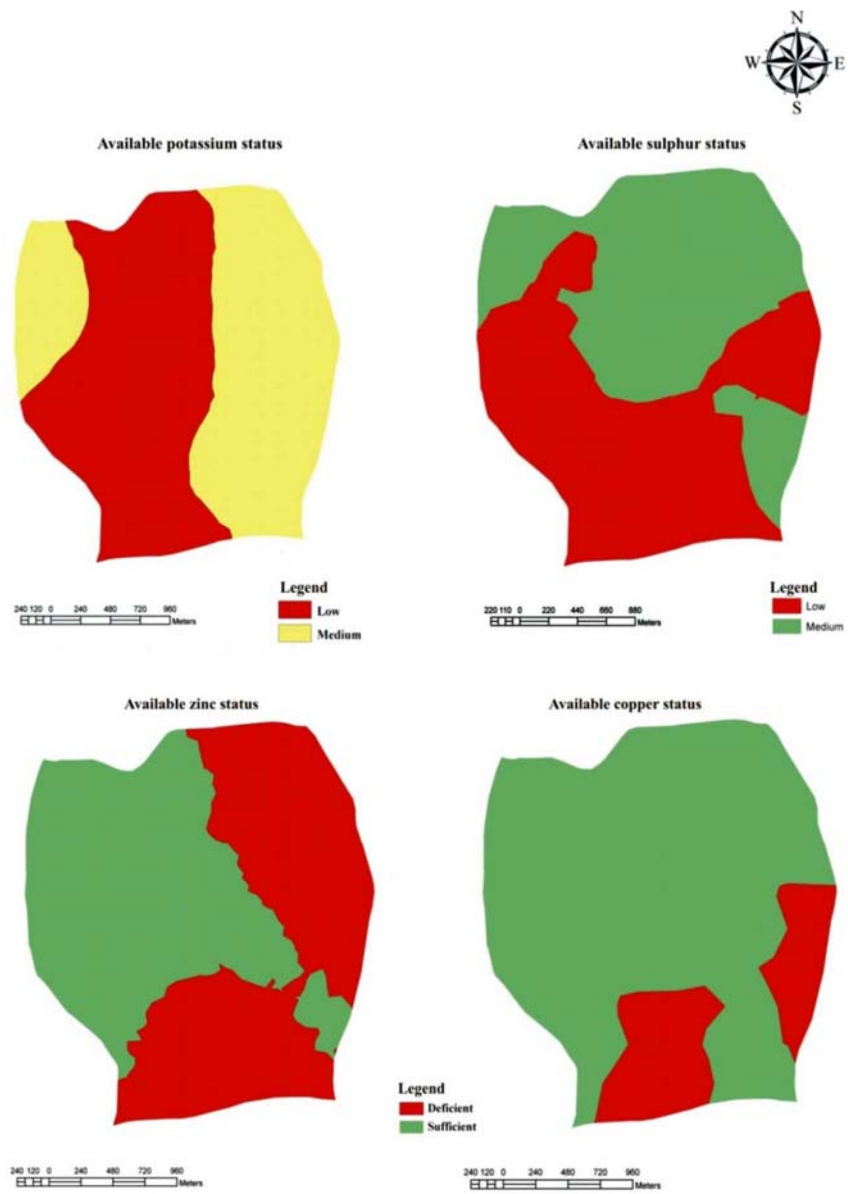

Fig. 4. Available nutrients mapping of Khanapur micro-watershed area

Conclusions

The study brings out the differences in soil fertility parameters across a climatic gradient within a district. The influence was best seen for parameters like pH, OC, available N, K, S and Zn with zones-3 and 8 being similar and zone-9 distinctly different. It also highlights the importance of mapping the various parameters which gives the spatial extent rather than the means which have limited applicability for soil management. For soil fertility monitoring, it may be ideal to identify some benchmark sites, preferably a watershed and monitor the changes periodically to see the trends of soil fertility changes.

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.

Balanagoudar, S.R. and Satyanarayana, T. (1990) Depth distribution of different forms of sulphur in Vertisols and Alfiols. *Journal of the Indian Society of Soil Science* **38**, 634-640.

Doran, J.W. and Smith, M.S. (1987) Organic matter management and utilization of soil and fertilizer nutrients. In *Soil Fertilizer and Organic Matter in Different Components of Production System* (Mortvedt *et* *al.*, Eds). *SSSA Special Publication*. **19**, Madison, USA, pp. 396.

Helmke, P.A. and Sparks, D.L. (1996) Lithium, sodium, potassium, rubidium and cesium. In *Methods of Soil Analysis*, Part 3, *Chemical Methods* (D.L. Sparks, Eds.). pp. 551-574. Madison, Wisc.:SSSA and ASA.

Jackson, M.L. (1973) *Soil Chemical Analysis*. Prentice Hall of India Pvt Ltd., 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.

Iftikar, W., Chattopadhyaya, G.N., Majumdar, K. and Sulewski, G.D. (2010) Use of village-level soil fertility maps as a fertilizer decision support tool in the red and lateritic soil zone of India. *Better Crops* **94**, 10-12.

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

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

Patil, P.L. and Dasog, G.S. (1999) Genesis and classification of ferruginous soils in western ghat and coastal region of north Karnataka. *Agropedology* **9**, 1-15.

Prabhavati, K. (2013) Studies on land degradation in the three agro-climatic zones of Belgaum district, Karnataka. *Ph.D. Thesis.* University of Agricultural Sciences, Dharwad.

Prasad, S.N. and Sahi, B.P. (1989) Distribution of manganese in relation to soil properties in some typical soil profiles. *Journal of the Indian Society of Soil Science* **37**, 567-570.

Prasuna Rani, P.P., Pillai, R.N., Bhanuprasad, V. and Subbaiah, G.V. (1992) Nutrient status of some red and associated soils of Nellore district under Somasila project in Andhra Pradesh. *The Andhra Agricutural Journal* **39**, 1-5.

Raghupathi, H.B. (1989) Investigation on soil copper and crop response in selected soils of Karnataka. *Ph.D. Thesis.* University of Agricultural Sciences, Dharwad.

Ravikumar, M.A., Patil, P.L. and Dasog, G.S. (2004) Characterization and mapping of soil resources of 48A distributary of Malaprabha right bank command, Karnataka for land use planning. *Karnataka Journal of Agricultural Sciences* **22**, 81-88.

Sahrawat, K.L. Wani, S.P., Pardhasaradhi, G. and Murthy, K.V.S. (2010) Diagnosis of secondary and micronutrient deficiencies and their management in rainfed agro ecosystems: Case study from Indian semi-arid tropics. *Communications in Soil Science and Plant Analysis* **41**, 346-360.

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

Vijayasekhar, R., Kuligod, V.B., Basavaraj, P.K., Dasog, G.S. and Salimath, S.B. (2000) Studies on micronutrient status in important black soil series of UKP command Karnataka. *Andhra Agricultural Journal* **47**, 141-143.

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.

Received 1 December 2014; Accepted 28 May 2015