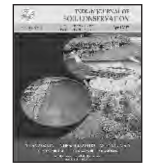
Vol. 45, No. 2, pp 141-147, 2017

Indian Journal of Soil Conservation

Online URL : http://indianjournals.com/ijor.aspx?target=ijor:ijsc&type=home



Geo-reference based soil fertility status in Hassan district of Karnataka, India for development of nutrient plan

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ARTICLE INFO

Article history :

Received : August, 2015

Revised : April, 2017

Accepted : May, 2017

Key words:

Correlation and Regression,

Geo-reference and Soil fertility,

Hassan district,

Nutrient plan

ABSTRACT

The aim of the study was to evaluate the nutrient status and their relation with other properties of soil. For this purpose, 1320 geo-referenced surface soil samples from 0-15 cm depth using GPS were collected from eight taluks of Hassan district in southern Karnataka. The results showed that pH (3.72-9.71) and EC (0.02-1.79 dS m^{-1}) of soils were acidic to alkaline with non-saline nature. About 86.59% of the soils were found to be medium in available nitrogen (315.90 kg N ha^{-1}) and 55% of samples fall under high available phosphorus (>22.50 kg P_2O_5 ha^{-1}) category. The available potassium status in surface soils of different talukas ranged from 50 to 984 kg ha^{-1}. Available sulphur content in soil varied from 0.24 to 90.81 mg kg^{-1}, with 75% soils deficient in sulphur due to continuous removal of sulphur by crops. Zinc deficient was recorded in 55.44% of soil samples analyzed and 99.54% were deficiency in boron which ranged from 0.08 to 6.70 and 0.04 to 0.82 mg kg^{-1}, respectively. The remaining micronutrients (Fe, Cu and Mn) shown to be sufficient and their values ranged between 0.77 to 802.53, 0.03 to 6.78 and 1.08 to 81.35 mg kg^{-1}, respectively. Analytical data clearly indicated that all the nutrients were significantly correlated with each other suggesting the dynamic equilibrium exists among these nutrients.

1. INTRODUCTION

Soil is the most vital and precious natural resource that sustains life on the earth. The sustainability of a productive soil mainly depends upon its ability to supply essential nutrients to the growing plants. Soil fertility is one of the important factors controlling the crop yields. Nitrogen, phosphorus, potassium and sulphur are important soil elements that control the fertility and yield of crops. Soil related limitations affecting the crop productivity including nutritional disorders can be determined by evaluating the fertility status of the soils.

Application of major nutrients (nitrogen, phosphorus, potassium) became common; therefore, the crops started responding to micronutrient fertilizers when smaller quantities were applied to soil. Intensively cultivated soils are being depleted with available nutrients especially secondary and micronutrients. Soil fertility deterioration is a major constraint for higher crop production in Karnataka. Intensive agriculture without adequate and balanced use of chemical fertilizers, non-ecofriendly tillage practices, and with little or no use of organic manure caused severe fertility deterioration of agricultural soils resulting in stagnating or even declining of crop productivity and soil health (Baruah *et al.,* 2013) only. The application of mineral fertilizers is the most advantageous and the fastest way to increase crop yields. The deficiency of these nutrients in crops leads to various types of disorders in many commercially important crops (Duarah *et al.,* 2011). Soil testing provides the information about the nutrient availability of the soil upon which the fertilizer recommendation for maximizing crop yield is made. 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 (Pulakeshi, *et al.,* 2012). Soil available nutrients status 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. Keeping in view the above importance of mineral fertilizers for crop growth and yield, the present study was carried out with an objective to assess the macro-nutrients, *i.e.,* available nitrogen (N), phosphorus (P), potassium (K), sulphur and micronutrients, *i.e.,* zinc (Zn), copper (Cu), manganese (Mn), iron (Fe) and boron (B) distribution in the surface soils and to explore the relationships among nutrients.

2. MATERIALS AND METHODS

Study Area

The comprising of 681.40 ('000 ha) lies between 13°0'0" N latitude and 76°0'0"E longitude. Climatically the area experiences warm summer and cold winter with mean annual rainfall of 1197 mm with 62 rainy days, and mean annual temperature of 17.69 to 28.17°C. The geological formation of Hassan district is made up of cretaceous red loamy soils, red sandy loam soils, lateritic soils, sandy clay loam soils. Agro-climatically, Hassan district comes under both central dry and southern dry zone and transition zones of Karnataka (Bhaskar *et al.,* 1991). The major crops cultivated in study area are ragi, groundnut, maize, redgram, paddy, sunflower, bajra and horticultural crops *viz.,* potato, tomato and other vegetables and fruits.

To study the soils of Hassan district using the district and taluk maps, villages have been identified and marked on the map. Out of 2559 villages of Hassan district, 220 were selected randomly covering 8 to 10% of total number of villages by referring to revenue number (Khata number) of each village. From each village, six soil samples were collected comprising two samples from small (<1 ha), medium (1-3 ha) and large farmers (>3 ha). Totally 1320 geo-referenced (GPS based) surface soil samples from 0-15 cm depth were collected from 8 taluks *viz.,* Alur (H_1), Arakalagudu (H_2), Arasikere (H_3), Belur (H_4), Channrayapatna (H_5), Hassan (H_6), Holenarasipura (H_7) and Sakaleshpura (H_8) of Hassan district. Soil samples collected were air dried, processed to pass through 2 mm sieve and analyzed for pH and EC (1:2.5, soil:water), organic carbon (Wet oxidation method), available N (0.32% alkaline $KMnO_4$), available P (Brays No.1 extractant; 0.03 $\underline{N}$ NH4F + 0.025 $\underline{N}$ HCl and 0.5 M $NaHCO_3$), potassium (1 neutral $\underline{N}$ NH_4OAC extractable) and sulphur (Turbidimetric method) were determined following methods described by Page *et al.* (1982). DTPA extractable Zn, Fe, Cu and Mn was determined by atomic absorption spectrophotometer (Lindsay and Norvell, 1978) and hot water soluble boron by method outlined by Wolf, 1974. Based on the soil test values for different nutrients, soil samples were generally classified into three categories *viz.,* low, medium and high. Using these fertility classes, nutrient index was calculated as per the following equation:

$$\text{Nutrient Index (NI)} = (N_L * 1 + N_M * 2 + N_H * 3)/N_T$$

Where, N_L, N_M and N_H are number of samples falling in low, medium and high classes of nutrient status, respectively and N_T is total number of samples analyzed for a given area.

Statistical Analysis

Simple correlation was computed using Pearson's equation to reveal the magnitudes and directions of relationship between selected soil parameters. Step down multiple regressions was worked out to determine the most contributing soil factor to the variability of the nutrient content in soils. The data was statistically analyzed using SPSS software (IBM SPSS Version 16).

3. RESULTS AND DISCUSSION

Soil pH and EC

Data presented in Table 1, showed that the soil pH varied from 3.72-9.71 with an average of 6.10. According to classification of soil reaction suggested by Brady (1985), 66.43% were acidic, 17.19% neutral and 16.38% were alkaline in reaction. The minimum value of pH (<4) was observed in sampling taluk H_6 and H_8, and maximum value (>8.5) was noticed in H_2, H_3, H_5 and H_7 taluks. The acidic pH in majority of the soils may be attributed to high rainfall associated with loss of bases due to leaching and presence of Al^{3+} on exchange complex. Due to high precipitation (1197 mm) and less evaporation demand, the salt accumulation is not prevalent in this region, which is suitable for crop growth. The electrical conductivity of soils varied from 0.02-1.79 dS m^{-1} with an average of 0.11 dS m^{-1}. On the basis of limits suggested by Muhr *et al.* (1965) for judging salt problems of soils, all the samples were found to be normal (EC= <1.0 dS m^{-1}). This normal EC may be ascribed to high precipitation coupled with leaching of salts to lower depths (>30 cm).

Organic Carbon

Soil organic matter (SOM) generally increases where biomass production is higher and where organic material additions are common. Plant residue with low C/N ratio (high nitrogen content) decomposes more quickly than those with a high C/N ratio and does not increase SOM levels quickly. Excessive tillage destroys soil aggregates increasing the rate of SOM decomposition. Stable soil aggregates increase active organic matter and protect stable organic matter from rapid microbial decomposition (Preston Sullivan, 2000). Measures that increase soil moisture, soil temperature and optimal aeration accelerate SOM decomposition. The organic carbon content in the study area ranged from 0.08-2.34% with an average of 0.65%. The organic carbon content was low (<0.50%) in 37.07% samples, 28.42% samples were medium and 34.50% were found to be high in organic carbon. Belur (H_4) taluk recorded highest mean organic carbon content (0.71%) followed by Alur (H_1). The term steady state refers to the rate of organic matter addition from crop residues, roots and manures or other organic material equals the rate of decomposition. If the rate of organic matter addition is less

Table: 1
Status of major nutrient in surface soils of Hassan district (n=1320)

S.No.	Taluks		pH (1:25)	EC (dS m^{-1})	OC (%)	Available nutrients (kg ha^{-1})			S (ppm)
						N	P_2O_5	K_2O	
1	Alur	Range	4.01 - 7.64	0.02 - 0.21	0.10 - 2.34	215.99 - 447.94	5.00 - 90.78	50.00 - 953.00	2.09 - 63.20
		Mean	5.20	0.06	0.70	307.65	30.83	204.15	14.21
2	Arakalagudu	Range	4.21 - 8.57	0.02 - 1.00	0.20 - 1.70	189.50 - 481.60	2.87 - 119.47	98.00 - 864.00	2.03 - 40.00
		Mean	5.92	0.09	0.61	301.72	36.97	207.07	14.69
3	Arasikere	Range	4.71 - 8.95	0.03 - 1.79	0.10 - 1.84	127.41 -761.39	4.19 - 158.63	94.82 - 912.97	2.35 - 74.80
		Mean	7.01	0.14	0.67	296.82	26.62	264.45	12.94
4	Belur	Range	4.05 - 8.36	0.02 - 0.96	0.10 - 1.74	201.60 - 872.32	2.44 - 40.68	77.52 - 290.99	1.38 - 77.07
		Mean	5.78	0.11	0.71	345.95	96.48	984.00	8.93
5	Channarayapatna	Range	4.78 - 9.71	0.02 - 1.00	0.20 - 1.22	210.60 - 423.22	2.78 - 75.27	70.72 - 915.52	0.24 - 67.84
		Mean	7.11	0.13	0.60	316.33	22.30	243.10	10.58
6	Hassan	Range	3.72 - 8.35	0.02 - 1.57	0.10 - 1.98	168.00 - 567.84	5.63 - 146.88	77.00 - 884.00	0.62 - 63.69
		Mean	5.99	0.11	0.66	302.07	47.56	277.03	14.63
7	Holenarasipura	Range	4.44 - 8.74	0.02 - 0.65	0.14 - 1.48	174.76 - 422.25	1.27 - 155.58	88.00 - 941.22	1.02 - 90.81
		Mean	6.40	0.14	0.66	292.08	32.95	256.00	13.06
8	Sakleshpura	Range	3.95 - 6.89	0.02 - 0.94	0.08 - 2.28	215.99 - 867.00	3.13 - 72.98	58.00 - 928.00	2.59 - 54.83
		Mean	5.40	0.09	0.63	364.56	23.39	262.44	9.68
Over all Range/Mean		Range	3.72 - 9.71	0.02 - 1.79	0.08 - 2.34	127.41 - 872.32	1.27-158.98	50.00 - 984.00	0.24-90.81
		Mean	6.10	0.11	0.65	315.90	32.66	250.65	12.34
		S.D.±	1.17	0.12	0.31	67.87	25.59	172.86	10.26

than the rate of decomposition, SOM will decline and, conversely if the rate of organic matter addition is greater than the rate of decomposition, SOM will increase (David, 2004). This might be the reason for variation in organic carbon in different taluks of Hassan district.

Available nitrogen

Available nitrogen status in surface soils varied from 127.41 to 872.32 kg ha^{-1} with an average value of 315.90 kg ha^{-1}. On the basis of ratings suggested by Subbaih and Asija (1956), 86.59% of the soils were found to be medium (280-560 kg ha^{-1}) and 11.51% were low and only 1.89% soils were high in nitrogen status. Among the taluks, H_8 (88.33%) and H_5 (82.22%) were predominantly medium in N status. The variation in N content may be related to management practices, application of FYM and fertilizer to previous crops (Ashok Kumar, 2000). The low organic matter content, low rainfall and vegetation in these soils facilitates faster degradation and removal of organic matter leading to N-deficiency. In addition, nitrogen applied to crops is taken up or lost through leaching and volatilization also leads to nitrogen deficiency. The medium N status in soils may be due to continuous application of N fertilizer recommended dose for the crop which maintains the nitrogen status in these soils. The nitrogen status of Hassan district was slightly better than the reported for the other parts of the state of Karnataka (Anon., 1998). They reported that 35.8% of the soils in Karnataka state were medium in available nitrogen particularly in the areas under irrigation and hilly region of the plateau, while rest of the area was low in available nitrogen content.

Available Phosphorus

Phosphorus is the second most important macronutrient available in the biological system. This constitutes less than 1% to the dry organic weight. It is also a second most limiting nutrient often affecting plant growth, which exists in soil in both organic and inorganic forms. The data on available phosphorus indicates, very low (1.27 kg ha^{-1}) to very high (158.98 kg ha^{-1}) status of phosphorus in Hassan district. Highest average values of P was obtained in Hassan (H_6) (96.48 kg ha^{-1}) and Belur (H_4) (40.68 kg ha^{-1}) taluks. In Hassan district, 55% of samples fall under high (>22.50 kg P ha^{-1}) category. Though the phosphorus is the second most limiting element in soil, higher P content in soils of the study area might have increased due to addition of phosphatic fertilizers specially the DAP for the crops (specially for the potato crop) grown in that area.

Available Potassium

Potassium is an important essential element for plant growth, with its importance in agriculture well recognized. Total soil K reserves are generally large, although the distribution of K differs from soil to soil as a function of the dominant soil minerals present. The available potassium status in surface soils of different talukas of Hassan district ranged from 50 to 984 kg ha^{-1}. Considering the mean values, the highest K content of 984 kg K ha^{-1} was recorded in Belur taluk (H_4) and the lowest value of 204.15 kg ha^{-1} in Alur (H_1) with overall mean value of 250.65 kg K ha^{-1}. About 6.82, 55.60 and 44.39% samples were fall under low, medium and high category, respectively. The soils containing <104 kg K ha^{-1}, 104-250 kg K ha^{-1} and above 250 kg K ha^{-1}, were categorized as low, medium and high categorized, respectively. All the soils of Hassan district were medium in K status, which indicates that K fertilizers were scantily applied in the last 2 decades as the low category has virtually remained the same and the high area has fallen (Datta, 2011).

Response of crops to applied potassium depends on the threshold levels of potassium. Datta (2011) has developed a model based on available K, buffering capacity, rate constant of release and fixation and threshold levels which predicts potential K supply of a soil. It showed that response of crops to applied fertilizer depends on the position of threshold levels of K release in relation to its present level of available K. It's now firmly established that because of heavy withdrawals of nutrients from soil under multiple cropping systems like potato-maize, potato-ragi, maize-green gram, tomato-cucurbits with high yielding and fertilizer responsive varieties, the potassium status of soil is changing rapidly.

Available sulphur

Available sulphur content in soil varied from 0.24 to 90.81 mg kg^{-1} with mean value of 12.34 mg kg^{-1}. The mean available sulphur status was found to be low in Belur taluk (8.93 mg kg^{-1}) and high in Arakalagudu taluk (H_2) (14.69 mg kg^{-1}) considering 10 mg S kg^{-1} as threshold value (Balanagoudar and Satyanarayan, 1990). About 75% soil samples were found to be deficient. Sakaleshpura (H_8) soils were low in available sulphur followed by Belur (H_4) (70.48%) taluk. Low level of sulphur is due to lack of sulphur in soils of the study area and continuous removal of sulphur by crops (Balanagoudar, 1989). According to Scherer *et al.* (2012), organic sulphur was more in surface horizons which could be attributed to the higher organic carbon content in surface layers. Deveraj (1994) also observed that fine texture soils are generally well supplied with sulphur. There was a very poor correlation among organic carbon, nitrogen and sulphur content of the soils.

DTPA Extractable Micronutrients

The DTPA-Zn in soils of Hassan district ranged from 0.08 to 6.70 mg kg^{-1} (Table 2). Out of 1320 samples, 55.44% were deficient, while 44.56% samples were sufficient indicating wide spread of Zn deficiency in Hassan district. The highest Zn deficiency (79.33%) was observed in Arakalagudu. The mean DTPA-Zn content of the district was found to be below the critical limit (0.97 mg kg^{-1}). In general, the deficiency of Zn was pronounced in most of the villages of the eight taluks of Hassan district.

The DTPA-Fe content varied from 0.77 to 802.53 mg kg^{-1} with mean value of 35.88 mg kg^{-1}. The deficiency of Fe was only 8.39% in Hassan district while 91.61% of soils were sufficient in Fe availability (Nagaraju *et al.,* 2015). Among the 220 villages of the taluks, only 8.39% samples were deficient in Cu. The variation in the DTPA-Cu availability in district may be attributed to the difference in the topography, texture and organic matter status of soils. Mn is essential to all the organisms and is responsible for the production of molecular oxygen in plants during photosynthesis. Manganese deficiency in the study area was only 0.16%, when compared to other micronutrients. Mn is considerably sufficient in all the samples studied and these results corroborate with the findings of Sharma *et al.* (2006) in soils of Leh district of cold arid region of Ladakh. Hot water soluble boron content in

Table: 2
Status of DTPA extractable micronutrients in different taluks of Hassan district

S.No.	Taluks	Total No. of samples		DTPA Micronutriment status (mg kg^{-1})				Hot water soluble B
				Zn	Fe	Cu	Mn	
1	Alur	150	Range	0.08 - 5.98	9.60 - 802.53	0.10 - 5.35	2.25 - 57.40	0.04 - 0.68
			Mean	0.70	63.55	1.55	22.87	0.12
2	Arakalagudu	150	Range	0.13 - 4.65	3.48 - 86.85	0.13 - 4.68	2.08 - 55.23	0.04-0.14
			Mean	0.51	39.66	1.51	23.12	0.05
3	Arasikere	180	Range	0.18 - 4.48	2.00 - 70.53	0.13 - 6.75	3.20 - 54.05	0.04 - 0.48
			Mean	0.56	12.19	1.39	23.74	0.06
4	Belur	210	Range	0.18 - 6.70	3.40 - 97.67	0.03 - 6.78	1.08 - 78.80	0.04 - 0.68
			Mean	1.11	42.67	1.57	20.69	0.10
5	Channarayapatna	180	Range	0.18 - 4.20	0.77 - 84.30	0.25 - 5.25	2.20 - 60.58	0.04 -0.34
			Mean	0.59	12.87	2.16	22.40	0.07
6	Hassan	210	Range	0.18 - 5.58	3.70 - 96.80	0.25 - 5.78	2.38 - 70.10	0.04 - 0.82
			Mean	1.07	39.57	1.77	19.38	0.11
7	Holenarasipura	120	Range	0.15 - 4.10	2.20 - 84.38	0.08 - 6.17	2.95 - 81.35	0.04 - 0.50
			Mean	0.68	23.51	1.40	19.63	0.06
8	Sakleshpura	120	Range	0.13 - 6.08	8.58 - 98.45	0.28 - 6.60	1.95 - 71.83	0.04 - 0.22
			Mean	1.53	53.01	2.25	24.02	0.06
	Over all Mean	1320	Range	0.08 - 6.70	0.77 - 802.53	0.03 - 6.78	1.08 - 81.35	0.04 -0.82
			Mean	0.85	35.88	1.70	21.98	0.08
			S.D.±	0.88	32.57	1.16	13.83	0.07

surface soils ranged from 0.04-0.82 with mean of 0.08 mg kg^{-1}. About 99.54% soil samples were deficient on hot water soluble boron in Hassan district. Soil derived from igneous rocks and those in tropical and temperate region of the world have much lower B concentration than the soils derived from sedimentary rocks and those in arid and semi arid regions (Ho, 2000). Decrease in hot water soluble boron might also be associated with the surface adsorption of borate by freshly precipitated $Al(OH)_3$.

Correlation

To assess the relationship between different soil parameters *viz.,* pH, EC, OC and available N, P, K and S, DTPA extractable Zn, Fe, Cu, Mn and hot water soluble B, a simple correlation coefficient among these parameters has been worked out (Table 3). The correlation studies revealed that the pH has highly significant positive correlation with EC (r = 0.292**), K (r = 0.279**) and S (r = 0.100**), whereas highly significant negative correlation was observed with Fe and Mn (r =-0.547** and -0.233**, respectively). This might be due to leaching losses of water soluble micronutrients with high rainfall leading to low content of micronutrients in the soils even though these micro-nutrients are most soluble and readily available under acidic condition. Electrical conductivity was significantly positively correlated with OC, N, P, K, S, Zn, Cu and B.

Organic carbon was highly significantly positively correlated with K (r = 0.075**) and B (r = 0.058*). Soils which are high in organic carbon content, exhibit higher adsorptive and bonding energy. As the organic matter is the prime absorbent of boron, therefore, the total B content and organic matter are main sources of available boron in soil. Whereas, no proper correlation was observed between soil organic carbon content and available nitrogen status in soil (r = 0.03). This clearly indicates that organic carbon status of the soil is not giving any information on the status of available nitrogen. Similarly, nitrogen has significant negative correlation with pH (r=0.101**) and highly significant positive correlation with K, Zn, Fe, Cu, Mn, and B. Whereas phosphorus had highly significant negative correlation with pH (r = -0.186**) and had positive correlation with EC, K, S, Zn, Fe and B. Available P content was medium at some sites in the study area where pH was neutral. The near neutral pH has a significant role in enhancing the P availability. Available P increases with increasing pH up to neutral pH. However, as the pH increases above neutral level, available P status of the soil decreases. Similarly, available P is negatively correlated with organic carbon; however, it was non significant indicating organic carbon is not influencing by available P. The increase in available phosphorus due to increase in pH may be due to lowering of activities of Fe^{2+} and Al^{3+} which increases the solubility of strengite and variscite and increases electro-negativity of colloidal complex with a consequent decrease in sorption of P. At some locations of the study area P was exceptionally high, might be due to different nutrient management practices among the farmers. Available potassium has highly significant positively correlation with all the parameters studied except Fe, where it had highly significant negatively correlation.

Nutrient Index

The fertility ratings of the surface soils were assessed for the macro and micro nutrients by working out the nutrient index values (NIV) and are depicted in the Table 4. In Hassan district, the available nitrogen NIV for N ranged from 1.59 to 1.97. Whereas, index values of different taluks ranged from low to medium and overall ratings for the whole district was medium. All the taluks in the district were medium in available phosphorus index value (2.29). Nutrient index value for available potassium and sulphur ranged from 2.07 to 2.41 and 1.34 to 1.91 with a mean of 2.28 and 1.60, respectively. As per the NIV, available potassium was medium whereas, sulphur was low. The NIV for micronutrients ranged from 1.19 to 1.79, 1.76 to 2.00, 1.93 to 2.00 and 1.99 to 2.00 for Zn, Fe, Cu and Mn, respectively. Notably low fertility rating was recorded for Zn for most of the taluks and medium for Cu,

Table: 3
Correlation matrix between soil characteristics

Soil characteristics	pH	EC	OC	N	P	K	S	Zn	Fe	Cu	Mn	B
pH	1.00	0.292**	0.040	-0.101**	-0.186**	0.279**	0.100**	-0.010	-0.547**	0.050	-0.233**	-0.040
EC		1.00	0.057*	0.246**	0.119**	0.341**	0.325**	0.072**	-0.158**	0.056*	0.050	0.055*
OC			1.00	0.030	-0.020	0.075**	0.000	0.020	0.010	0.030	0.000	0.058*
N				1.00	0.010	0.222**	0.020	0.206**	0.145**	0.270**	0.319**	0.165**
P					1.00	0.198**	0.091**	0.221**	0.110**	-0.072**	0.010	0.142**
K						1.00	0.118**	0.209**	-0.135**	0.168**	0.121**	0.145**
S							1.00	-0.030	-0.030	0.010	-0.054*	0.040
Zn								1.00	0.105**	0.224**	0.114**	0.174**
Fe									1.00	0.127**	0.086**	0.084**
Cu										1.00	0.235**	0.059*
Mn											1.00	0.079**
B												1.00

**Correlation is significant at the 0.01 level (2-tailed) ; *Correlation is significant at the 0.05 level (2-tailed)

Table: 4
Status of available nutrients and nutrient indices in Hassan district (n= 1320)

S.No	Taluk	N NIV		P NIV		K NIV		S NIV		Zn NIV		Fe NIV		Cu NIV		Mn NIV	
1	Alur	1.74	M	2.26	M	2.07	M	1.81	M	1.35	L	2.00	M	1.95	M	2.00	M
2	Arakalagudu	1.66	L	2.50	H	2.13	M	1.91	M	1.21	VL	1.98	M	1.97	M	2.00	M
3	Arasikere	1.59	L	2.09	M	2.39	H	1.56	L	1.19	VL	1.76	M	1.96	M	2.00	M
4	Belur	1.84	M	2.51	H	2.39	H	1.36	L	1.60	L	1.99	M	1.93	M	2.00	M
5	Channarayapatna	1.82	M	2.07	M	2.36	H	1.47	L	1.32	V	1.79	M	2.00	M	2.00	M
6	Hassan	1.64	L	2.70	H	2.41	H	1.81	M	1.77	M	1.99	M	2.00	M	2.00	M
7	Holenarasipura	1.67	M	2.28	M	2.25	M	1.53	L	1.33	VL	1.82	M	1.96	M	2.00	M
8	Sakleshpura	1.97	M	1.89	M	2.25	M	1.34	L	1.79	M	2.00	M	2.00	M	1.99	M
	Overall range/Mean	1.74	M	2.29	M	2.28	M	1.60	L	1.45	L	1.92	M	1.97	M	2.00	M

Mn and Fe. This low value of Zn was very common in the entire district which covers to an extent of 65% Zn deficiency in Karnataka.

Multiple Regression Analysis

The result of step-wise multiple regression analysis of the joint contribution (R^2) of predictor variables on the availability of nutrients in soil was shown in Table 5. The results showed that out of 9 predictor variables (Available N, P, K , S and DTPA extractable Zn, Fe, Cu, Mn and hot water soluble B), all variables were significant in influencing the availability of the N, P, K and S status in soils with increase in soil pH ($R^2 = 0.774$), where 77. 40% of nutrient availability will be varied due to soil reaction. Soil reaction was significantly ($p<0.01$) contributing (99.90%) towards the status of micronutrient in soil, where pH helps to increase the solubility of micronutrient at neutral pH, whereas at higher pH, the availability of micronutrient will be affected. In general, deficiencies of most of the micronutrients are accentuated by one of five situations like strongly weathered soils, coarse-textured soils, high-pH soils, organic soils, and soils low in organic matter, either inherently or by erosion or through land-shaping processes which remove the topsoil. The variation in major and micronutrients availability in soils was directly affected by the electrical conductivity which explains 64.2 and 66.7% variability, respectively. A lower level of OC variance ($R^2 = 0.317$) was obtained with inclusion of available N, P, K and S. The joint use of predictor variables of micronutrients further decreased the regression values. However, only 27.30% contribution was recorded from organic matter towards the availability of micronutrients in soil. Organic matter and manure applications affect the immediate and potential availability of micronutrient cations (Haribhushan *et al.,* 2013). SOM was negatively correlated with all the micronutrients, except boron, though none of these relationships were significant. Although most studies have recorded positive relations between SOM and micronutrients (Li *et al.,* 2007; Wang *et al.,* 2009), the inverse relationship observed in this experiment is similar to that reported by Haldar and Mandal (1979) who attributed this

Table: 5
Multiple regressions for available nutrients in Hassan district soils

Equation	Statistics (R^2)
pH = 17.968 - 0.032 N - 0.031 P - 0.007 K - 0.212 S	0.774
pH = 6.340 - 0.202 Zn - 0.39 Fe + 0.202 Cu + 0.030 S + 3.888 B	0.999
EC = 0.717 - 0.002 N + 0.000 P + 0.000 K - 0.013 S	0.642
EC = 0.183 + 0.013 Zn - 0.002 Fe - 0.004 Cu - 0.001 Mn - 0.029 B	0.667
OC = 0.639 + 0.000 N + 0.002 P+ 0.000 K	0.317
OC = 0.478 + 0.052 Zn - 0.001 Fe - 0.075 Cu - 0.010 Mn + 1.152 B	0.273

relationship to the soil moisture condition. Other unexplained variables may have also contributed to this inverse relationship. The direct relationship between micronutrients and SOM recorded in this study corresponds to that of most studies (Li *et al.*, 2007; Wang *et al.,* 2009); although Shuman (1988) noted that high SOM at the topsoil reduces micronutrient availability.

Nutrient Plan for Hassan District Based on Fertility Status

Soil fertility management for Hassan district was made based on the GPS-GIS based fertility status. Hassan district is having 66.43% of acidic soils which should be amended with agricultural lime, based on severity of acidity and lime requirement. In Hassan and Sakaleshpura taluks severe of acidic soils can be reclaimed to greater extent if agricultural lime is provided through subsidy. The organic matter content was low (< 0.50%) in 37.07% of the total area. These soils should be supplied with well decomposed farm yard manure/organic manure/crop residues/growing green manuring crops/ incorporation of vermicompost and adding microbial culture like trichoderma for faster decomposition is needed to maintain better organic carbon level in these soils.

Among the taluks in H_3 11.51% area has low N and in H_8 (88.33%) and H_5 (82.22%) soils were medium in N status where, 'N' can be supplied with sufficient quantity of 'N' fertilizers particularly slow 'N' releasing fertilizers like neem coated urea or super granular urea and also addition of organics (FYM/green manure/vermicompost) in sufficient quantities. About 55% of the Hassan district area was high in available 'P'. Further build up of 'P' in soil can be avoided by application of only 50% of recommended dose of fertilizer as maintenance dose. Only few patches were low in available 'K'. About 44.39% soils were high in available K content. These high K areas can be applied only with 50% recommended dose of potassium.

In Hassan district about 75% soils are deficient with respect to sulphur, which should be supplied with elemental S or SSP depending upon the crop requirements. In Channarayapatana and Arakalgud taluks, Zn SO_4 @ 25 kg ha^{-1} should be applied to correct Zn deficiency which covers an area of 55.44%. About 99.54% soil samples of Hassan district were deficient in hot water soluble boron, where application of borax or granubor @ 2 kg ha^{-1} can overcome the deficiency. In addition, sufficient quantity of organic residues should be incorporated in these areas to add more micronutrients to soils.

4. CONCLUSIONS

The study clearly indicated that soils of Hassan district were acidic to alkaline in reaction with non-saline in nature. About 86.59% soils were medium in available nitrogen and 55% of samples were high in available phosphorus status. The available potassium status was very low to high. 55.44% soils were deficient in sulphur content. Zinc deficiency was recorded in soil samples and 99.54% were deficient in boron. Fe, Cu and Mn were sufficient. The nutrients were significantly correlated with each other suggesting the dynamic equilibrium among these nutrients. Wherever nutrient deficiencies are noticed, those soils should be supplied through fertilizers in addition to applying significant quantities of organic matter. Similarly, wherever high available P and K were recorded, 50% of the recommended dose (as per package of practice) of these nutrients should be applied as maintenance dose.

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