STATISTICAL ANALYSIS OF NUTRIENT STATUS IN SOILS OF KARNATAKA

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UNIVERSITY OF AGRICULTURAL SCIENCES, GKVK, BENGALURU-560065

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In partial fulfillment of the requirements

For the award of the degree of

Master of Science (Agriculture)

in

AGRICULTURAL STATISTICS

BENGALURU **AUGUST, 2014**

Affectionately

Dedicated to

my Beloved Parents

Sri Jayanna,

Smt. Latha and

my brother Deepak

DEPARTMENT OF AGRICULTURAL STATISTICS, APPLIED MATHEMATICS AND COMPUTER SCIENCE UNIVERSITY OF AGRICULTURAL SCIENCES GKVK, BENGALURU-560065

CERTIFICATE

This is to certify that the thesis entitled "**STATISTICAL ANALYSIS OF NUTRIENT STATUS IN SOILS OF KARNATAKA"** submitted by **Ms. DIVYASHREE, K. J., I.D No. PALB 2164,** in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRICULTURAL STATISTICS** to the University Of Agricultural Sciences, GKVK, Bengaluru, is a record of bonafide research work carried out by her under my guidance and supervision and the Thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or any other similar titles.

BENGALURU,
AUGUST, 2014

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Date:

Place: GKVK, Bengaluru ***(DIVYASHEE, K. J)***

STATISTICAL ANALYSIS OF NUTRIENT STATUS IN SOILS OF KARNATAKA

DIVYASHREE, K. J.

ABSTRACT

In the present study an attempt is made to know the effect of nutrient status on yield of ragi and paddy crops. Taluk wise secondary data on the soil parameters *viz.*, pH, EC, OC, P, K, Zn, Fe, Mn and B content for Bangalore Rural, Bangalore Urban and Ramanagaram districts were collected for the period 2007-2013. Per centdeficiency in Zn, Cu, Fe, Mn and B from 1998-2013 were collected for all districts of Karnataka. The data on productivity of paddy and ragi from 1998-2009 were collected for major growing districts of Karnataka.

The descriptive statistics showed that soils of Nelamangala taluk had highest pH and Bangalore north had highest in rest of the nutrients. P and Fe were maximum in Magadi and Bangalore East. Correlation among nutrients showed that P, K, Zn, Cu, Mn, Fe and B were positively related with pH. Further, OC and EC were positively significantly related with P, K, Zn, Cu and Mn.

With respect to deficiency in Fe, Mn and B positive significant trend were noticed in majority of the districts. While, deficiency in Zn and Cu were noticed in few of the districts. A multiple regression analysis on availability of Zn and B on the productivity of paddy and ragi showed that these nutrients were insufficient for enrichment of the soil.

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Mr. R. Munirajappa
Major Advisor

ಕರ್ನಾಟಕ ಮಣ್ಣಿನಲ್ಲಿನ ಪೋಷಕಾಂಶಗಳ ಸ್ಥಿತಿ ವಿಶ್ಲೇಷಣೆ

ದಿವ್ಯಶ್ರೀ, ಕೆ. ಜೆ.

ಪ್ರಬಂಧ ಸಾರಾಂಶ

ಪ್ರಸ್ತುತ ಅಧ್ಯಯನವು, ಕರ್ನಾಟಕ ಪ್ರದೇಶದಲ್ಲಿ ಬೆಳೆಯುವ ರಾಗಿ ಮತ್ತು ಭತ್ತದ ಇಳುವರಿಯ ಮೇಲೆ ಮಣ್ಣಿನ ಫಲವತ್ತತೆಯ ಸ್ಥಿತಿಯಿಂದ ಉಂಟಾಗುವ ಪ್ರಭಾವ ಮತ್ತು ಅದರ ಸ್ಥಿತಿಯನ್ನು ತಿಳಿಯಲು ಪ್ರಯತ್ನಿಸಲಾಯಿತು. ಈ ಅಧ್ಯಾಯನಕ್ಕಾಗಿ ೨೦೦೭ ರಿಂದ ೨೦೧೩ ರ ವರೆಗೆ ಬೆಂಗಳೂರು ಗ್ರಾಮಾಂತರ, ಬೆಂಗಳೂರು ನಗರ ಮತ್ತು ರಾಮನಗರ ಜಿಲ್ಲೆಗಳಲ್ಲಿ ಮಣ್ಣಿನ ನಿಯತಾಂಕಗಳಾದ ರಸಸಾರ, ವಿದ್ಯುತ್ ವಾಹಕ, ಸಾವಯವ ಇಂಗಾಲ, ರಂಜಕ, ಪೊಟ್ಯಾಷ್, ಸತು, ತಾಮ್ರ, ಕಬ್ಬಿಣ, ಮ್ಯಾಂಗನೀಸ್ ಮತ್ತು ಬೋರಾನ್‌ಗಳನ್ನು ಹಾಗೂ ಜಿಲ್ಲಾವಾರು ಸತು, ತಾಮ್ರ, ಕಬ್ಬಿಣ, ಮ್ಯಾಂಗನೀಸ್ ಮತ್ತು ಬೋರಾನ್‌ಗಳ ಶೇ. ಕೊರತೆಯನ್ನು ೧೯೯೮ ರಿಂದ ೨೦೧೩ ರವರೆಗೆ ಕೃಷಿ ಇಲಾಖೆಯಿಂದ ಸಂಗ್ರಹಿಸಲಾಯಿತು.

ವಿವರಣಾತ್ಮಕ ಸಂಖ್ಯಾಶಾಸ್ತ್ರದಿಂದ ತಿಳಿಯಲಾದ ಅಂಶವೇನೆಂದರೆ, ನೆಲಮಂಗಲ ಮಣ್ಣು ರಸಸಾರವನ್ನು ಹೆಚ್ಚಾಗಿ ಹೊಂದಿದೆ ಹಾಗೂ ಉಳಿದ ಪೋಷಕಾಂಶಗಳು ಬೆಂಗಳೂರು ಉತ್ತರ ಮಣ್ಣಿನಲ್ಲಿ ಕಂಡು ಬಂದಿದೆ. ಮಾಗಡಿ ಮಣ್ಣಿನಲ್ಲಿ (ರಂಜಕ) ಮತ್ತು ಬೆಂಗಳೂರು ಪೂರ್ವದ (ಕಬ್ಬಿಣದ) ಅಂಶಗಳು ಹೆಚ್ಚಾಗಿ ಕಂಡುಬಂದಿದೆ.

ರಸಸಾರದ ಜೊತೆ ದೊರೆಯುವ ರಂಜಕ, ಪೊಟ್ಯಾಷ್, ಸತು, ತಾಮ್ರ, ಕಬ್ಬಿಣ, ಮ್ಯಾಂಗನೀಸ್ ಮತ್ತು ಬೋರಾನ್ ಧನಾತ್ಮಕ ಸಂಬಂಧವನ್ನು ಹೊಂದಿರುತ್ತದೆ. ಅದೇ ರೀತಿ ವಿದ್ಯುತ್ ವಾಹಕ ಮತ್ತು ಸಾವಯವ ಇಂಗಾಲ ಅಂಶವು, ರಂಜಕ, ಪೊಟ್ಯಾಷ್, ಸತು ಮತ್ತು ಮ್ಯಾಂಗನೀಸ್ ಪೋಷಕಾಂಶಗಳ ಜೊತೆ ಗಮನಾರ್ಹ ಪ್ರವೃತಿಯನ್ನು ತೋರಿಸಿದೆ.

ಬಹುತೇಕ ಜಿಲ್ಲೆಗಳಲ್ಲಿ ಕಬ್ಬಿಣ, ಮ್ಯಾಂಗನೀಸ್ ಮತ್ತು ಬೋರಾನ್ ಕೊರತೆಯು ಧನಾತ್ಮಕ ಗಮನಾರ್ಹ ಪ್ರವೃತ್ತಿಯನ್ನು ತೋರಿಸಿದೆ. ಹಾಗೆಯೇ ಸತು ಮತ್ತು ತಾಮ್ರದ ಕೊರತೆಯು ಕೆಲವು ಜಿಲ್ಲೆಗಳಲ್ಲಿ ಕಂಡು ಬಂದಿದೆ. ಭತ್ತ ಮತ್ತು ರಾಗಿ ಬೆಳೆಯ ಉತ್ಪಾದಕತೆಗೆ ಸತು ಮತ್ತು ಬೋರಾನ್ ದೊರೆಯುವಿಕೆ ಬಗ್ಗೆ ಬಹು ನಿವರ್ತನ ವಿಶ್ಲೇಣೆ ಮಾಡಿದ್ದು, ಇದರಿಂದ ತಿಳಿಯಲಾದ ಅಂಶವೇನೆಂದರೆ ಮಣ್ಣಿನ ಫಲವತ್ತತೆಯನ್ನು ಹೆಚ್ಚಿಸಲು ಈ ಪೋಷಕಾಂಶಗಳ ಕೊರತೆಯಿದೆ.

ಕೃಷಿ ಸಂಖ್ಯಾಶಾಸ್ತ್ರ ವಿಭಾಗ,
ಕೃ. ವಿ. ವಿ., ಜಿ. ಕೆ. ವಿ. ಕೆ.,
ಬೆಂಗಳೂರು– 65

(ಶ್ರೀ ಮುನಿರಾಜಪ್ಪ. ಆರ್.)
ಪ್ರಧಾನ ಮಾರ್ಗದರ್ಶಕರು

Statistical Analysis of Nutrient Status in Soils of Bangalore District in Southeastern part of Karnataka

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INTRODUCTION

Soil fertility is greatly influenced by the presence or absence of macro and micro nutrients, which determines the over all growth and development of crop pattern.

Plant requires macronutrients with higher emphasis and relatively larger amount for its growth such as nitrogen (N), phosphorous (P), potassium (K), subsequently Calcium (Ca), magnesium (Mg) and sulfur (S). Predominantly the contribution of micronutrients also requires desirable quantity of Zinc (Zn), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Chlorine (Cl) and Boron (B).

The imbalancement in both micro and macro nutrients leading to deficiency in the fertility of the soil and further curtailment in the growth of the plant and intern the productivity of the crop.

OBJECTIVES

- ✓ To study the micronutrient status in Bangalore district of Karnataka.
- ✓ To study the impact of soil properties on the nutrient status in Bangalore district of Karnataka.
- ✓ To analyze the temporal shifts in status of micronutrients across district of Karnataka.

METHODOLOGY

Locale of the study :

- For this study Bangalore District has been selected.

Data Base :

- The secondary data on the selected soil parameters were collected from the Agriculture Department, Bangalore.
- Sample observations recorded location wise comprising of 100 samples randomly selected.

Soil Parameters:

The data were collected over 16 years from 1998-2013 for the following soil parameters.

1. Soil properties : pH, CEC, OC.
2. Nutrients
   a) Macronutrients: P&K.
   b) Micronutrients: Zn, Cu, Fe, Mn and B.

Analytical tools and techniques :

- Descriptive statistics.
- Correlation coefficient.
- Linear Trend analysis.

RESULTS

Table.1: Taluk wise mean response on selected parameters of Bangalore district

Taluks	pH	CEC(mmho)	OC(%)	P(Kg/ha)	K(Kg/ha)	Zn(ppm)	Cu(ppm)	Mn(ppm)	Fe(ppm)	B(ppm)
Devanahalli	6.72	0.19	0.39	26.01	226.12	2.18	2.19	24.17	8.56	0.40
Hoskote	6.40	0.11	0.27	35.98	69.47	1.67	1.92	31.12	15.28	0.22
D.B.pura	6.64	0.13	0.65	47.41	117.67	1.09	2.08	2.73	7.91	0.08
Nelamangala	7.28	0.14	0.69	43.56	96.43	1.43	2.11	2.94	8.25	0.09
Magadi	5.38	0.15	0.52	17.14	97.51	2.50	2.03	24.19	8.56	0.43
Ramanagaram	7.01	0.34	0.18	13.86	121.51	2.89	1.81	22.46	8.82	0.34
Channapatna	6.93	0.14	0.39	20.53	140.76	1.63	2.15	14.76	7.36	0.34
Kanakapura	7.06	0.24	0.57	32.48	134.65	1.55	2.05	18.99	9.72	0.24
B'nrth	6.83	0.12	0.71	46.02	176.33	1.61	2.55	17.04	13.90	0.17
B'east	6.60	0.13	0.69	31.77	118.16	1.44	2.27	10.96	11.76	0.14
B'south	6.54	0.12	0.39	22.40	101.63	1.49	2.44	9.10	10.40	0.11
Anekal	6.48	0.12	0.47	24.96	86.24	1.63	2.13	14.15	7.51	0.31
Bangalore	6.66	0.16	0.49	30.18	123.87	1.76	2.14	16.05	9.84	0.24

Table.2: Correlation between soil properties and nutrients

Nutrients	Soil properties		
	pH	CEC	OC
P	0.205**	0.345**	0.373**
K	0.239**	0.279**	0.029
Zn	-0.094*	0.204**	0.145**
Cu	-0.041	-0.116**	0.147**
Mn	-0.138**	0.101*	0.248**
Fe	-0.025	-0.081	0.001
B	-0.182**	0.236*	0.287*

P and K significantly positively correlated with pH.
Zn, Mn And B are significantly positively correlated with CEC.
All the nutrients are positively correlated With OC.

* Significant at 5%
** Significant at 1%

Table.3: Linear Trend analysis for percent deficiency of selected micronutrients.

	Zn		Cu		Mg		Fe		B	
Districts	Linear Growth rate(b)	R-square (%)	Linear Growth rate(b)	R-square (%)	Linear Growth rate(b)	R-square (%)	Linear Growth rate(b)	R-square (%)	Linear Growth rate(b)	R-square (%)
Bangalore(R)	0.452	6.22	0.001	0.08	0.011	3.27	0.120*	4.68	0.645*	36.74
Bangalore(U)	1.376	46.06	-0.003	0.06	-0.035*	7.96	0.082	2.22	1.162*	47.54
Kolar	-0.064	0.13	0.021	8.09	0.041*	18.94	0.261*	17.69	0.594*	21.65
Tumkur	-0.128	0.16	0.109	14.53	-0.657*	38.22	-0.196*	14.49	0.715*	82.85
Mandya	0.36	1.47	-0.036	11.12	-0.082*	20.11	0.029	2.78	-0.013	0.01
Mysore	0.833	13.1	-0.016	11.2	0.106*	43.12	0.124*	5.03	0.371*	68.86
Kodagu	0.757	22.63	-0.174	13.48	-0.03*	17.09	0.078*	18.53	0.374*	6.77
Hassan	-0.647	8.69	0.108	11.1	-0.067*	33.88	0.066*	29.05	0.676*	48.52
D. Kannada	0.579*	64.7	-0.05	1.35	0.492*	38.18	-0.049*	3.86	-0.849*	41.43
Udupi	-1.340*	50.66	-0.052	10.07	0.083	0.84	-0.017*	3.65	-0.617*	18.14
Chikmagalur	1.241	17.1	0.022	4.9	0.025*	5.94	0.043*	7.36	0.289*	5.36
Chitradurga	-1.932*	29.73	-0.087*	43.31	-0.026*	11.91	0.318*	5.36	0.477*	26.06
Davangere	-0.348	2.26	0.024	1.83	-0.039*	18.77	-0.237*	3.41	0.656*	35.71
Shimoga	1.265*	27.08	0.028	14.83	-0.004	1.95	0.052*	37.53	-0.898*	40.72
U. Kannada	1.024*	43.04	-0.007*	30.67	0.016*	4.7	-0.024*	11.2	0.698*	32.03
Dharwad	-1.182	13.94	0.058*	35.42	-0.755*	49.24	-0.067	0.03	0.007	0.09
Bellary	1.10	19.85	-0.019	12.8	0.162*	12.77	-2.339*	67.06	0.222*	5.43
Gadag	-0.096	0.20	-0.008	2.08	-0.016	0.13	-1.436*	44.33	0.043*	3.69
Raichur	0.235*	49.93	-0.003	0.64	0.139*	6.25	0.780*	4.77	-0.607*	48.08
Koppal	1.626*	35.81	-0.001	1.33	0.29	0.89	0.767*	15.45	0.557*	26.43
Bijapur	-0.550*	35.02	-0.016	5.42	-0.151*	24.81	-0.752*	10.95	0.032	2.99
Bagalkot	0.244	23.43	-0.065	2.31	0.671*	4.76	-0.222	1.24	0.157	1.22
Belgaum	-0.97	13.52	0.012*	31.24	0.016*	3.7	-0.171	1.45	0.027	2.51
Gulbarga	-0.432	10.32	0.044*	28.95	0.048*	15.8	0.067	0.11	-0.557*	42.92
Bidar	0.207	0.87	0.05	19.72	-0.697*	12.05	0.604*	41.89	-0.182*	12.94

DISCUSSION

- ➢ The over all mean pH observed as 6.66 compare to CEC (0.16), OC (0.49), P (30.18), K (123.87), Zn (1.76), Cu (2.14), Mn (16.05), Fe (9.84) and B (0.24). The extent of variation in all parameters reflecting the soil differences with in the taluks.
- ➢ The relationship observed with all the soil properties found to be significant with respect to P, Zn, Mn and B which indicate the inter relationship existing between soil properties and nutrients.
- ➢ It's interesting to note that significant shift in Mn, Fe and B with regional effect and almost uniformity noticed with other nutrients.

SUMMARY

During the research period of study the variations of soil parameters established based on geographical location, there exist significant interrelationship between soil properties with selected nutrients which leads to better productivity of crop. Short fall in deficiency of micronutrients was observed compared to other micronutrients . Balancing the desired quantity of both micro and macro nutrients which improve the soil fertility intern leads to great productivity and best output of economy of the farming committee.

Advisory Committee: Chairman: Mr. R. Munirajappa
Members : Mr. H. S. Surendra
Dr. H. Chandrashekar
Dr. C. T. Subbarayappa

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I. INTRODUCTION

Soil fertility is an important factor, which determines the growth of plant. It is determined by the presence or absence of nutrients i.e. macro and micronutrients.

Karnataka forms southwestern part of Deccan peninsular India. It lies between 11^0 $30^{|}$ and 18^0 $30^{|}$ N latitude and 74^0 $75^{|}$ and 78^0 $30^{|}$ E longitudes with a geographical area of 1.91 lake square kilometers. It experiences a wide variety of geological, climate, vegetation and physiographic conditions. As a result, the soils of Karnataka are highly diverse and variable depending upon these conditions. The northern part of the state is occupied by shallow to deep black soils. Southern part of the state is occupied by red loamy soils, whereas the heavy rainfall regions comprising Western Ghats and coastal districts are occupied by coastal alluvial and lateritic soils. With these varied agro climatic conditions and diverse soil types the state is suitable for cultivation of large variety of crops.

Bangalore Urban district is located in the southeastern part of Karnataka. It is having an extent of 2174 sq.km and is located between the north latitude 12˚39' 32'': 13˚14' 13'' and East longitude 77˚19'44'': 77˚50'13''. The district is bounded in all the directions by Bangalore rural district except in southeast, where the district is bounded by Dharmapuri district of Tamil Nadu state. The soils of the districts can be broadly grouped into red loamy soil and lateritic soil. Red loamy soils generally occur on hilly to undulating land slope on granite and gneissic terrain. It is mainly seen in the eastern and southern parts of Bangalore north and south taluks. Laterite soils occur on undulating terrain forming plain to gently sloping topography of peninsular gneissic region. It is mainly covered in Anekal taluk and western parts of Bangalore North and south taluks.

Macronutrients are essential elements used by plants in relatively large amounts for plant growth such as nitrogen (N), phosphorous (P), and potassium (K), Calcium (Ca), magnesium (Mg), and sulfur (S).

The elements are required in minute quantities for plant growth are referred as micronutrient, those are Zinc (Zn), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Chlorine (Cl) and Boron (B). Although micronutrients are required in minute quantities but have the same agronomic importance as they play a vital role in the growth of plants. They are present in small amounts ranging from few mg kg^{-1} to several thousand mg kg^{-1} in soils.

Nutrients enter into the soil system via different pathways including agricultural additives such as fertilizer, manures, lime, herbicides, fungicides and irrigation waters as well as potentially deleterious materials such as sewage sludge, municipal compost, industrial and mine wastes.

The availability of nutrients is particularly sensitive to changes in soil environment. The factors that affect the contents of such nutrients are organic matter, soil pH, lime content, sand, silt, and clay contents. There is also correlation among the nutrients contents and above-mentioned properties.

In India, there is sufficient availability of organic manures like animal dung manure (791.6 mt), crop residues (603.5 mt), green manure (4.50 m ha), rural compost (148.3 mt), city compost (12.2 mt) and bio-fertilizer (0.41 mt) (Bhattacharya and Chakraborthy, 2005) and these can become a good substitute for chemical fertilizers to maintain the soil physico-chemical and biological properties. The incorporation of organic manures improves the nutrient content and uptake. Although organic manure contain nutrients required for crop growth in small quantities as compared to the fertilizer. Besides, the presence of growth promoting principles like enzyme and hormones improve soil fertility and productivity. Integrated use of organic and inorganic through FYM, crop residues of wheat and green manuring of dhaincha also improves the organic carbon and cation exchange capacity. Available N, P_2O_5, K_2O and S status of soil increased significantly with organic sources of nutrients over their initial (Sharma *et al.*, 2001).

Harvest of soybean, the soil nutrient status was influenced by the application of organic nitrogen sources along with fulvic acid sprays. This is ascribed to presence of soybean crop which enhances the available N status of soil by nodulation. The soil available N, P_2O_5 and K_2O buildup was higher in all the treatments over initial. Whereas, the DTPA-extractable micronutrients was also enhanced due to the application of organic nitrogen source. The application of organic and chemical fertilizers is another crucial component of arable crop production systems (Kadam *et al.*, (2010)).

In Karnataka, the available nitrogen status reveals about10.3 per cent of the soils in the state fall under the low category, 35.8 per cent under medium and 53.9 per cent under high category. The areas covering Western Ghats, coastal plains and Malnad areas of the State, under forest and plantations, are high in nitrogen. Apart from these areas under irrigation and hilly regions of the plateau are high to medium in nitrogen. Rest of the area of the state is low in nitrogen.

The available phosphorus status in the soils of Karnataka reveals that about 83 per cent of the soils are low in phosphorus. About 17 per cent area is under medium category implying thereby that most of the soils need to be fertilized through phosphorus for sustainable crop production.

The potassium status is medium to high in the soil of Karnataka except in lateritic soils of Coastal Plains and Western Ghats, low in shallow red and black soils.

In recent years emphasis is given on soil micronutrient sufficiency /deficiency and are being intensively studied because of wide spread deficiencies in soils leading to reduced crop yields. The incidence of these micronutrient deficiency increasing alarming rate, on account concomitant depletion of these micronutrient elements with the addition of large amount of high analysis chemically pure fertilizer to hybrids and high yielding crop varieties and also due to decreased use of organic manures.

Micronutrient elements are integral part of the active centers of enzymes and vitamins. Zinc is of the component of series of enzymes such as dehydrogenase, protease, peptidase, phosphohydrolase, carbonic anhydrase and super oxide dismutase. It plays an important role in auxin metabolism, preferential accumulation of chlorophyll, protein synthesis and starch metabolism. Copper is a constituent of certain oxido-reductase enzymes such as tyrosine and ascorbic acid oxidase and plastocyanin an important compound involved in the photochemical reaction. Manganese appears to be concerned in the activation of several enzymes including those, which catalyze oxidation-reduction reaction and plays an important role in photosynthesis. It is essential for synthesis of protoporphyrin-9, a precursor of chlorophyll. Boron activates certain Dehydrogenase enzymes, facilitates sugar translocation and synthesis of nucleic acids plant hormones, it is essential for cell division and development.

Hence deficiency or excess supply of these micronutrient elements will be reflected upon the health of plants as evidenced by the crop plants and are very small as compared to the major nutrients; deficiency of any micronutrient element may cause an extremely disturbing effect on plant growth processes and consequent reduction in crop yield.

If the overall reserves of micronutrients in the soil are primarily determined by their content of their available forms depends on the soil type, nature of parent material, climate, vegetation and physicochemical properties of the soil.

Obvious knowledge of soil types, soil condition and various physicochemical properties influencing the distribution and availability of the micronutrients in soils may prove to be the best approach for obtaining reliable information about the micronutrients.

A statistical model is an equation or set of equations which represents the relationships among variables. Modeling may lead to less *ad hoc* experimentation, as models sometimes make it easier to design experiments to answer particular questions, or to discriminate between alternative mechanisms. Modeling provides powerful tools for investigating the dependence and nature of relationships among the variables of interest. The relationship among variables must be determined for the purpose of predicting the values of one or more variables on the basis of observation on other variables.

Model building is currently applied in many fields i.e., Agriculture, Biometrics, Economics, Education, Meteorology, Industry, Sociology, Anthropology, Archaeology etc., In agricultural studies the yield is a complex character controlled by large number of contributing characters and their interactions. It is not only influenced by a number of related characters, which are governed by a few number of soil nutrients but is also influenced to great extent by environment. In such cases meaningful interpretations can be drawn only by using proper statistical models.

With this background "Statistical analysis of nutrient status in soils of Karnataka" is planned. A study was carried out with the following objectives:

1. To estimate the extent of availability of soil chemical properties in the selected districts of Karnataka.
2. To statistically assess the extent of influence of soil properties on the nutrient status in the selected districts of Karnataka.
3. To assess the trend in deficiency of micronutrients across districts of Karnataka.
4. To study the impact of selected micronutrient status on productivity of Paddy and Ragi among districts in Karnataka.

II. REVIEW OF LITERATURE

The nutrient status of soils has an important role in influencing the yield and quality of crop in an agro ecological region. Keeping this in view, literature pertaining to nutrient status of soils, response of Paddy and Ragi to soil nutrients are reviewed here under the following headings.

2.1 To estimate the extent of availability of soil chemical properties in the selected districts of Karnataka.

2.2 To statistically assess the extent of influence of soil properties on the nutrient status in the selected districts of Karnataka.

2.3 To assess the trend in deficiency of micronutrients across districts of Karnataka.

2.4 To study the impact of selected micronutrient status on productivity of Paddy and Ragi among districts in Karnataka.

2.1 To estimate the extent of availability of soil chemical properties in the selected districts of Karnataka

Nayak *et al.* (2000) showed that, the available iron, copper, manganese content in alluvial soils of Arunchal Pradesh ranged from 7.0 to 73.6, 0.50 to 3.5, 2.7 to 53.3 mg kg^{-1} respectively in surface soils.

Gowda *et al.* (2001) showed that the Mineral (calcium, phosphorus, magnesium, copper, zinc and iron) status in soils of coastal zone of Karnataka. Extractable Ca (0.15%) and Mg (0.02%) level in soil was slightly higher than the critical level but the levels of P, Cu, Zn and Fe in soil was much higher than the critical levels.

Korikanthimath *et al.* (2002) were collected samples from coffee and cardamom growing areas in Kodagu district, Karnataka to assess the nutrient status. The results revealed that, the soils were acidic in reaction (pH 4.2 to 6.9) with high organic carbon content (0.19 to 3.3%). The available phosphorus was found to be low due to acidic pH that results in formation of aluminium and iron phosphate which are not likely to be readily available to plants. The soils were rich in potassium (84 to 966 kg/ha) and adequate in micronutrients due to the increased solubility in acidic environment and greater recycling by vegetation.

The micronutrient content, *viz.*, Calcium (Ca), Phosphorus (P), Magnesium (Mg), Copper (Cu), Zinc (Zn) and Iron (Fe) content in soil, in northern dry and northern transition zones of Karnataka were analyzed by Ramana *et al*. (2002). The phosphorus content in soil in Northern dry zone (30.30 ppm) and Northern transition zone (34.33 ppm) were found to be well below the critical level (45 to 130 ppm). The calcium (0.47%), copper (4.17 ppm) and zinc (11.27ppm) content in soil in northern transition zone were found to be higher than in the northern dry zone and were well above the critical levels in both the zones.

Nazif *et al*. (2006) studied the micronutrient status of soils of district Bhimber (Azad Jammu and Kashmir) and reported that the Iron, Copper, Zinc and Manganese ranged from 5.37-23.36, 0.59-4.38, 0.74-2.08 and 4.59-21.08 mg kg^{-1} respectively. Iron, Copper and Manganese was found high in all sites while Zinc was low in 26.66 per cent, medium in 70 per cent and high in 3.34 per cent sites. Boron ranged from 0.02-0.84 mg kg^{-1} and Boron was found low in 80 per cent and medium in 20 per cent sites.

Kelin *et al*. (2007) studied that, spatio-temporal variability of soil organic matter (SOM) in the urban–rural transition zone of Beijing. SOM content in agricultural soils were measured in 1980, 1990 and 2000 in Daxing County of Beijing in-situ and data of 1980 and 1990 were obtained from the National Soil Survey (NSS). Descriptive statistics and geostatistics were used to analyze the data. The results showed that, mean SOM was 9.95 g kg^{-1} in 1980, 12.76 g kg^{-1} in 1990 and 12.89 g kg^{-1} in 2000. SOM was spatially correlated at a larger distance of 32.0 km in the E–W direction for the three years, and at a shorter distance of 24.6, 23.3 and 19.0 km in the N–S direction in 1980, 1990 and 2000 respectively, which showed that there was more variability in SOM in the N–S areas across the period of 20 years. The SOM slightly increased from low to high levels from 1980 to 2000. The main factors affecting SOM levels were the soil texture, land use and farming practices. The increasing trend might be attributed to the widespread practices of mulching and organic manure applications.

Mustapha *et al*. (2007) studied that, soil fertility status of Bauchi State, Nigeria. The result indicated that, means of B and Zn were 0.41 and 1.46 mg kg^{-1} respectively. The B and Zn varied widely (CV >30%) between locations in the State, irrespective of the parent material.

Ravikumar *et al*. (2007) reported that the micro nutrients status of Malaprabha Right Bank Command of Karnataka for site specific recommendations. The mapping of available micro nutrient status indicated that the majority of the area was deficient in iron (0.18 to 3.51 mg/kg) and zinc (0.01 to 0.37 mg/kg), whereas manganese (0.014 to 11.38 mg/kg) and copper (0.016 to 6.78 mg/kg) status was low to sufficient.

Sarwar *et al*. (2007) reported that the micronutrients status of soils of district Palandria, Azad Kashmir and to correlate the micronutrients with Physicochemical characteristics of soil as well as to categorize the soils as high, medium and low in Cu, Zn, Fe, Mn and HWS B. The samples were collected from thirty wheat fields and thirty apple orchard soils during 2003. None of the soil sample was low in Cu, Mn and Fe contents. Zn was low in 20 per cent wheat fields and 17 per cent apple orchard soils while HWS B was low in 53 and 40 per cent in wheat and orchard soils, respectively.

Bassey *et al.* (2008) showed that, the Iron (Fe), manganese (Mn), zinc (Zn), copper (Cu) content had a mean value of 142.62, 7.43, 8.50, 4.30 mg/kg for inland depression soils and 213.16, 3.19, 2.67, 2.20 mg/kg flood plain soils, respectively. All the above values were higher than the critical values of 4.2, 0.2, 0.5 and 1.0 mg/kg for Fe, Cu, Zn and Mn respectively.

Begum *et al.* (2009) showed that the status of micronutrients and their behavior with respect to some general soil properties according to the land type in some soils of Gazipur district. Amount of total Fe, Mn, Cu and Zn varied significantly and ranged from 0.1817-0.3375 per cent, 0.0094-0.0754 per cent, 0.0028-0.0089 per cent and 0.0080-0.1216 per cent respectively in Sripurupazila. Whereas, 0.1433-0.4864 per cent, 0.0428-0.0804 per cent, 0.0020-0.0079 per cent and 0.0030-0.0399 per cent in Kaliakair upazila of different land type.

Ismail and Junusi (2009) noticed that the NPK content in a Durian Orchard at Malaysia ranged from < 0.1 to 1.0 per cent (N), < 3 to > 45 ppm (P) and 0.8 to >1.4 cmol (+)/kg (K), respectively. Nutrient map showed that the area has less sufficient of N, while P and K were sufficient.

Chunfa *et al*. (2010) studied that the soil fertility status of southeastern China and indicated that, total Cu, available Cu, and Cu availability ratio had wide ranges in values. The coefficients of variation (CVs) were 26.1 per cent, 49.6 per cent and 35.3 per cent for total Cu, available Cu, and Cu availability ratio, respectively. This indicates that available Cu concentration and Cu availability ratio had greater variation than that of total Cu concentration in the study area. The larger variation of available Cu concentration and Cu availability ratio may be the result of extrinsic factors being more of an influence on these two soil properties than on total Cu concentration. The results also indicate that SOM, TN, AP and AK also had wide ranges and high CVs (N25%) that is a consequence of the high heterogeneity of paddy soil in the study area.

Kumar and Babel (2011) studied that the soils of Jhunjhunu tehsil, the result showed that, 90 per cent of analyzed soil samples were found to be deficient in iron and 70 per cent deficient in zinc and their values ranges from 1.22 to 5.87 and 0.12 to 1.30 mg kg^{-1}, respectively. While the remaining micronutrients (Cu, Mn and B) showed to be sufficient and their values ranges between 0.17 to 3.32, 2.03 to 5.67 and 0.37 to 1.51 mg kg^{-1} respectively.

Patil *et al.* (2011) reported that the available organic carbon (OC), available N, available P_2O_5 and available K_2O in surface soils of Dharwad of Karnataka ranged from 0.35, 0.32, 0.30 and 0.16 respectively, in the study area. The organic carbon and nitrogen content in the soils was low in majority of the area, phosphorus was medium and high in available potassium status.

Vijayakumar *et al.* (2011) reported that the availability of micronutrients and their relationship with soil properties in the affected areas of Nagapattinam taluk of Tamilnadu in India. The result showed that the available micronutrients, Fe was found to be sufficient by 97 per cent and Mn deficient by 100 per cent, Zn was found to be sufficient by 53 per cent and Cu deficient by 45 per cent respectively.

Ozyazici *et al*. (2011) reported that, Fe, Cu, Zn and Mn contents of soils varied within the range of 2.1 to 168.9, 0.02 to 14.69, 0.01 to 8.45 and 0.4 to 101.4 mg kg^{-1}, respectively in the Eastern Black Sea Region of Turkey.

Lorestani *et al*. (2012) noticed that the K and P variability in soils of Hamadan Western Iran were ranged from 45.8 to 66.3 mg kg^{-1} and 2.55 to 6.05 mg kg^{-1} respectively. Thus the K and P content in soil analyzed in this study revealed that the soil is poor in P and sufficient in K.

The mean values of toposequence at Gubi, Bauchi Nigeria were 0.26, 0.36, 44.75 and 47.50 mg/kg for Zn, Cu, Fe and Mn respectively. Zn and Cu were generally "low" to "medium" in all the horizons of the pedons, and also below the critical limits for arable crop production. Fe and Mn values were "high" and above the critical limits for arable crop production in all the horizons of the pedons (Biwe and Ephraim, 2012).

The Available nitrogen was low in 93 per cent of area, phosphorus was generally low in 24 per cent and medium in 76 per cent of area and available potassium and sulphur were low to high. Regarding available micronutrients, zinc and iron were deficient in 88 per cent and 72 per cent of area respectively, whereas, copper and manganese were deficient 54 per cent and 51 per cent of area, respectively (Pulakeshi *et al*., 2012).

Tabi *et al.* (2012) revealed that the soils were relatively slightly acidic (pH 6.52), low in organic matter (1.37%) and nitrogen contents (0.57 g kg^{-1}) high in exchangeable bases, and were of moderate P supply (14.10 mg kg^{-1}). Except pH which was slightly (CV<15%) variable, most soil properties were moderately (CV=15-35%) to highly (CV>35%) variable. base status, organic matter, moisture retention, acidity and N-mineralization explained 76 per cent of the variation in soil properties.

Vidyavathi *et al.* (2012) observed that the integrated nutrient management practice in Dharwad, Karnataka recorded significantly higher available N (278.4 kg/ha), P_2O_5 (23.4 kg/ha), K_2O (355.0 kg/ha) and S (18.7 kg/ha) when compared to chemical nutrient management practice. Similarly, DTPA extractable Zn, Fe, Mn and Cu were significantly influenced by integrated nutrient management practice of 1.46, 7.96, 9.67 and 0.89 mg/kg, respectively.

Statistical analysis showed that, average contents of available Fe, Mn, Cu and Zn were 37.62, 14.80, 2.89 and 3.47 mg kg^{-1} respectively in Xichang City, China. The Coefficient variation of available Fe contents was 17.97 per cent, which was moderate variability and Mn, Cu and Zn were all greater than 35 per cent and were high variability (Zhang *et al.*, 2012).

The Available Fe, Cu and Zn in soils of northeast China varied to a high degree with coefficient of variation (CV) of 82.7 per cent, 41.7 per cent and 89.5 per cent, respectively. The CV is very sensitive to the anomalies in a dataset and high CV's for available Fe, Cu and Zn data suggested that, there must be some significant anomalous values in their distributions. Available Mn had a relatively uniform distribution with a CV of only 9.5 per cent and found that Mn deficiency was widely present throughout the field. Although Fe and Zn deficiencies were not widespread, 25.5 per cent of soil samples were deficient in available Fe and 13.3 per cent were deficient in available Zn (Mail *et al.*, 2013).

Haribhushan *et al*. (2013) recorded that, mean values for DTPA-extractable Zn, Cu, Mn, Fe and hot water extractable B were 2.36, 1.52, 113.93, 766.03 and 0.10 mg kg^{-1}, respectively in soils of Senapati district, Manipur (India). Distribution of Zn, Cu, Mn, Fe and B were influenced positively by pH, EC and organic carbon content of the soil.

2.2 To statistically assess the extent of influence of soil properties on the nutrient status in the selected districts of Karnataka

Correlation coefficient analysis helps to determine the nature and degree of relationship between any two measurable characters.

Nayak *et al.* (2000) revealed that, Fe was negatively and significantly correlated with pH and sand. Positive and significant correlation was also observed with organic carbon (r =0.48), silt (r =0.64) and CEC (r =0.54).The copper was significantly and positively correlated with pH (r =0.51) and silt (r =0.49) but it showed negative and non-significant correlation with sand and clay. Correlation studied revealed that, significant and positive correlation was found between available Mn and organic carbon, silt and CEC but showed negative correlation with pH and sand.

Patiram *et al.* (2000) reported that, Zinc was positive significant correlated with organic matter. The positive correlation may be due to the formation of organic complexes between organic matter and Zinc that protect it from leaching.

Singh *et al.* (2008) reported that, available manganese content in Entisols of Uttar Pradesh ranged from 0.4 to 0.8 mg kg^{-1} of soil. It significantly and positively correlated with organic carbon (0.15**) and negatively correlated with pH (-0.20).

The Zn, Cu, Fe, Mn and B showed positive correlations with silt plus clay and organic carbon, and negative correlations with pH and calcium carbonate content (Sharma *et al.*, 2003).

Nazif *et al*. (2006) showed that, extractable iron and manganese are negative significant correlation with soil pH and lime content, Iron was positively and significantly correlated with silt. Copper, Zinc and hot water soluble Boron were positively significantly correlated with organic matter. Both Iron and hot water soluble Boron gave negative significant correlation with sand. Other physio-chemical properties of soil showed either negative or positive non-significant correlation with micronutrient during the study.

Sarwar *et al*. (2007) showed that, the micronutrients correlation with physico-chemical characteristics of soils of Palandri, Azad Kashmir. pH was negatively and organic matter was positively correlated with all nutrients. Lime was negatively correlated with Zn, Fe, and Mn while positively correlated with Cu and B. The EC had positive correlation with B but negative with other micronutrients. Clay was positively correlated with all micronutrients except B.

The study conducted by Sharma and Sanjeev, (2007) on 32 profiles of 8 tentative soil series in Himachal Pradesh indicated that available Zn was ranged between 0.31 to 4.7mg kg^{-1} which was higher in surface horizons and decreased down the depth in most of the soil series. Available Zn showed, significant positive relation with OC (r=0.689**) and EC (r =0.792**) and negative significant correlation with silt (r =0.63**).

The results of correlation analysis revealed that in inland depression soils Fe, Mn, Zn and Cu had significant ($P \leq 0.05$) positive correlation with sand content (r = 0.55*, 0.58*, 0.58* and 0.64*, respectively) but negative and non-significant with clay fraction. In flood plain soils all the micronutrients correlated negatively with sand content but only Fe was significant with sand (r = 0.60*). Clay was correlated positively with Fe, Mn and Cu; and negatively with Zn, but only Fe was significant with clay (r = 0.65*) (Bassey *et al.,* 2008).

Behera *et al.* (2008) showed that the pH and OC content were positively correlated with the extractable and total Zn concentrations in acid soil. However the contribution of pH towards total and extractable Zn was less. The contribution of soil OC towards total and DTPA extractable Zn in acid soil was more.

Positive and significant correlation were observed between organic bound zinc and organic carbon (r = 0.75**), carbonate bound and $CaCo_3$ content (r = 0.62**) and between the residual zinc and clay content of these soils (r = 0.55**).However, the residual zinc constituted major fractions of the total zinc. This contributes 64.76 to 94.19 per cent of the total zinc of the soils (Chidanandappa *et al.,* 2008).

The coefficient of correlation for iron fractions, the organic and amorphous components had significant relation with soil properties (R^2 = 0.81 and 0.97) (Singh *et al.,* 2008).

The significant and negative correlation observed between pH and total Mn content. While, other micronutrients (Fe, Cu and Zn) showed non-significant and negative relationship. Total exchangeable bases of some soils of the Gazipur district areas have positive significant correlation with micronutrients. Interaction of micronutrients with each other showed significant relationship (Begum *et al.,* 2009).

Yadav and Meena (2009) reported that, availability of zinc increased significantly with increase in clay, organic carbon, EC and CEC. On the other hand, the availability of zinc was reduced significantly with an increase in CaCO3 and pH of soil.

The Significant relationship ($p < 0.01$) were found between DTPA-extractable Cu, Zn, Fe, and Mo and total P applied in the biosolids amended plots and they were reported the long-term application of organic amendments increased micronutrient availability, but long-term application of inorganic P had no effect on micronutrient availability. Trace element concentrations varied in Oklahoma soils. The trace elements Cd, Cr, Cu, Ni, Pb, and Zn were significantly correlated with clay content while Mn was correlated with Alox as reported by Richards and Jaben (2010).

Correlation analysis revealed that, available Cu concentration was positively correlated with total Cu concentration, CEC and SOM as indicated by moderate to high correlation coefficients (r = 0.64–0.82), and Cu availability was directly correlated with SOM, pH and Cu concentration with moderate to high positive correlation (r =0.47–0.82) at 0.01 level of significance(Wua *et al*,.2010).

Kumar and Babel (2011) studied that, available micronutrient (Fe, Cu, Zn, Mn and B) status and their relationship with soil properties. The result showed that, availability of micronutrients indicating positive and significantly correlated with silt, clay, organic carbon and CEC of soils, whereas, negative and significantly correlated with sand, calcium carbonate and pH of the soils.

Vijayakumar *et al.* (2011) studied fertility status of some tsunami affected areas of Nagapattinam taluk of Tamilnadu in India. The result showed that the Fe was positive correlation with OC but negative correlation with pH. Mn also followed the same trend as that of Fe with OC, EC and pH. Cu showed positive correlation with EC and negative correlation with pH and OC. Zn showed negative correlation with OC and positive correlation with EC and pH.

The content of micronutrient was in order of Mn > Fe > Cu > Zn in arid region of Western Rajasthan and varied from 2.2 to 11.8, 2.5 to 6.5, 0.11 to 4.1 and 0.29 to 3.9 mg kg^{-1} respectively. The DTPA- Mn, Fe and Zn showed negative correlation with pH and EC of the soils, whereas Cu exhibited positive correlation with them. All the micronutrients showed positive correlation with organic carbon content of the soil (Yadav, 2011).

Kumar *et al.* (2012) showed that, pH were significantly correlated with $CaCO_3$ (r=0.72**) and organic carbon (r =-0.38**). Clay were positively and significantly correlated with CEC (r =0.64**) and EC (r =0.50**). Calcium Carbonate were significantly correlated EC(r =0.35**) and organic carbon (r =-0.44**).

Haribhushan *et al.* (2013) studied that, soil fertility status of macro and micronutrients of some soils of Senapati district, Manipur (India). The mean values for DTPA-extractable Zn, Cu, Mn, Fe and hot water extractable B were 2.36, 1.52, 113.93, 766.03 and 0.10 mg kg^{-1}, respectively. The mean values of available N, P_2O_5, K_2O and SO_4 were 382.04, 38.31, 208.86 and 22.65 kg ha^{-1}, respectively. Distribution of Zn, Cu, Mn, Fe and B were influenced positively by pH, EC and organic carbon content of the soil.

2.3 To assess the trend in deficiency of micronutrients across districts of Karnataka

Gaddi *et al*. (1999) revealed that, compound growth rates of area, production and yields of nine oilseed crops in India using data for the period 1980/81-1992/93. Crops covered were: groundnut, sunflower, safflower, castor, sesame, niger, rapeseed-mustard [Brassica juncea], linseed and soybean. The instability of area, production and yields of oilseed crops and the contribution of area and yields towards production were studied.

Positive and significant growth rates were observed for area and production of all the oilseed crops except safflower and linseed: growth rate was negative and non-significant for safflower but significant for linseed. Growth rates of yield were positive and significant for castor, sesame, linseed and rapeseed-mustard. Area and production of sunflower and soybean were highly unstable when compared to other oilseed crops. Area was found to be the major contributor to the production of sunflower and soybean, whereas yield was the major contributor to the production of castor and sesame.

Chattopadhaya *et al.* (2000) studied the different form of trend equation for growth performance of West Bengal agricultural production. Some of the trend equations were linear, parabolic and exponential. The choice of trend line adopted based on R^2 and adj R^2. Exponential function was found to be better estimator of growth in agricultural production in West Bengal.

Janaiah and Hossain (2000) employed semi-log linear regression model ($\ln G = A + Bt_u$) to examine the compound growth rates in area, yield, production, inputs and total factor productivity in rice-wheat system in India, where, G denotes area/ yield/ production/ input, A and B were, respectively, the intercept and the parameter estimated using OLS method, t was the time period and u, the random term with usual assumption. To examine empirically the hypothesis that the productivity growth in rice–wheat system is accelerating or decelerating after the mid-1980s, the time dummy was introduced into the semi-log linear function and was expressed as $\ln Y = a + b_1 T + b2\ D\ T$, where D refers to the time dummy, and 0 was assigned when time T refers to period I (1970/71 to 1984/85), and 1 when T refers to period II (1985/86 to 1995/96). The sign and significance of b 2 tells whether the growth has accelerated or decelerated or remained the same between the two sub - periods.

Pradeep and Krishna (2002) used growth models to study a critical analysis with reference to Andhra Pradesh and India .Different linear and non-linear regression growth models were studied for the purpose of estimating the growth rate and fitting the best model, which will help in better future prediction. The use of R^2, adjusted R^2 or RMS as a measure of goodness of fit and therefore, as a criterion for choosing the best model alone is not sufficient. The criteria of randomness and normality of time series data should also be satisfied. This particular aspect of fitting trend and growth rate estimation is rarely given due importance by different researchers, as a result various misleading inferences are drawn in earlier studies. Keeping this in mind they had estimated the parameters of the model and be able to infer correctly. One most important thing they had observed here is that the area under total food production is declining day by day and this is due to the replacement of area by different cash crops.

Suna *et al.* (2003) reported that, highest variation in available P and lowest for soil pH. Soil organic matter decreased significantly from 1985 to 1997 even the original land use patterns for wasteland and paddy field were not changed. The temporal changes of soil chemical properties showed a highest decreased in the area of previous paddy field, while the highest increase in an upland area changed from previous wasteland. Classic statistical method allows us to analyze the changes of soil properties between different sampling times and land use patterns. Kriging gives a spatial structure analysis and a view of soil quality changes by contour plots. This geostatistical method can be used as an analysis tool for monitoring soil quality changes.

Deka and Sarmah (2004) have made an attempt to study the growth trends in area, production and productivity of Banana in Assam. Growth trends are estimated in area, production and productivity of Banana for the period 1980-81 to 1999-2000. The fitted trend revealed that area and production of banana in the period under reference had been in upward trend in initial period, yet, decreased area and production had been prominent in the later period. On the basis of the fitted trend, future production has been predicted. Further, the decomposition of production revealed that area rather than productivity played a dominant role in increased production in the state.

Stipek *et al.* (2004) reported that, temporal changes in spatial variability of the available phosphorus, potassium and magnesium in the 10.5 ha part of the whole 54 ha field, located near Cesky Brod and soil samples were taken in 2001–2003 four times per year. For the description of field variability of selected soil parameters coefficient of variation (CV), experimental variograms with fitted models and relative nugget effect parameters have been used. Three year results showed that the lowest temporal variability, characterized by relative nugget effect had available Mg (4 –23%) and P (13 – 29%) and K (15 –49%).

Lathika *et al.* (2007) examined the growth trend in coconut areas, production and productivity in 1960-61 to 2004-05 and the performance of different district of Kerala in coconut production and assess the relative role of area and yield in explaining the trend in coconut production. The study was based on the secondary data of area in hectares under cultivation, production and productivity and the information provided in the official website of the coconut development board. The prestigious position that Kerala enjoyed in coconut area and production over the years, seems to be waning out. It should however gratifying to see the Kerala is on the path of regaining some of is lost glory in Indian coconut scenario.

Jose and Jayasekhar (2008) discussed about the spatial and temporal changes in area, production and productivity of arecanut, a commercial crop in India. Time series data has been used for the study which has been obtained from various sources such as Directorate of Economics and Statistics, CMIE. The study includes the period 1971 to 2004 which is further divided into 4 sub periods. The trend is usually obtained by assuming some parametric function and parameters are estimated by the method of least squares. The trend function is given by $Y = m(t) + e$. the compound growth rates are estimated using the exponential model $\ln(Y) = \ln(a) + \ln(b)$. in the decomposition analysis the change in production taken as follows :$\Delta P = B\Delta Y + C\Delta A + \Delta Y\Delta A$ where ΔP, ΔY and ΔA are the change in production, yield and area and B and C are base years area and yield respectively. The decomposition analysis shows that the increase in production is due to increase in yield.

Shadmehri, (2008) examine the trends in area, production and yield of Iran's agriculture production especially food grains. Compound growth rate of area, production and yield were estimated by fitting semi-log trend equation using data for 1970/71-1999/2000.Decomposition of output growth of main crops were examined by fitting component analysis model $\Delta P = A_o \Delta Y + Y_0 \Delta A + \Delta Y \Delta A$. The performance of agricultural sector was slightly better during the pre-revolutionary period than that of post-revolutionary period. The main source of growth agricultural production in pre-revolutionary period has been the growth in yield per hectare and expansion in irrigated area.

Mahir and Abdelaziz (2010) have estimated the growth rate of area, production and productivity and measure the contribution of different components to the growth rate of the main crops grown in the Gezira scheme. The study used secondary data covering the adoption of liberalization policy (1970/71 to 1991/92) and the period after the adoption of liberalization policy (1992/93 to 2007/08). Further the study conducted a decomposition analysis to determine the contribution of different components to the growth rate. The decomposition analysis revealed that the main components contributing to growth rate were area, productivity and cropping pattern.

Chikuvire and Mpepereki (2012) showed that, variability of nutrient levels was dependent on the type of niche, season and nutrient. Soil pH and nutrient levels of N, P and K, though low, remained unchanged over a two year period for all niches suggested the stable system but total C, exchangeable Ca and Mg showed highest fluctuations.

Noor *et al.* (2013) studied the spatial variability of micronutrients (Zn, Cu, Fe, Mn and B) in citrus orchards in Malakand Agency of Khyber Pakhtunkhwa Province during 2008 was assessed and mapped. The result showed that the availability of Cu, Fe and Mn were adequate in 100 per cent soil samples but Zn and B were marginal in 54.17 per cent and 83.33 per cent samples respectively. Semivariogram analysis of micronutrients status showed that the spatial structures of Cu, Fe and B were strong but that of Zn was moderate and Mn was poor indicating variation in same orchard.

2.4 To study the impact of selected micronutrient status on productivity of Paddy and Ragi among districts in Karnataka

Kandiannan *et al*. (2002) showed that Turmeric is native to India and its successful husbandry depends on the monsoon climate and the availability of irrigation. Yield forecasting in advance is required for export planning and policy decisions. A method to forecast turmeric yield from a time series of meteorological and yield data was developed and tested, using 20- year dataset of dry turmeric yield and monthly climatic variables for the crop's 9-month growing season. The variables, which had a significant correlation with yield were second month total rainfall (r =0.60), third month mean evaporation (r =-0.49), fourth month mean wind speed (r =0.61), fifth, eighth and ninth month mean minimum temperature (r =0.45, 0.51 and 0.65, respectively) and ninth month mean minimum relative humidity (r =0.66). Ten years (1979-1980 to 1988-1989) dataset were used for model building and remaining 10 years (1989-1990 to 1998-1999) data were used for testing the model. A multiple regression model was developed giving a forecast of the dry turmeric yield with a coefficient of determination of R^2= 89 per cent.

Kumar, (2003) examined that, the changing cropping in theory and practices was an economic insight in to the Agrarian West Bengal. Further the change has been associated with the increasing transformation agriculture from subsistence to commercial farming. They examined the determinants of the change in cropping system. The major influencing factors are infrastructure, transportation system, market system, cropped area, rainfall and temperature, etc. the above stated factors significantly influencing the shift in cropping pattern, for that they considered the regression model, result of analysis was R^2= 0.769.

Y_t= 37.43+19.54X_i i=1,2………………..,n district of West Bengal.

Villamide *et al.* (2003) studied the comparison among methods of nutritional evaluation of dietary ingredients for rabbits. A collaborative study has been carried out in four laboratories (UPV, UPM, CLO, INRA) with the aim of comparing different evaluation methods of feedstuffs for rabbits. Fifteen diets were designed to assay six ingredients using at least two of the following four evaluation methods: direct, substitution of a basal diet (BD), substitution of a reference feedstuff (alfalfa meal (AM)) by difference and extrapolation, and multiple regression.

Guptha and Tewari (2004) examined that, the factors affecting crop diversification an empirical analysis. The major objective was to study the extent of shift in cropping pattern, to analyze the relative contribution of area, yield, cropping pattern changes and their interaction to the growth of agricultural output due to substitution of crop areas. The major considered factors are farm size, experience, distance of farm, land rented in, share of cropping, non-crop income, price risk, yield risk, number of family members, yield risk are significantly influenced on cropping shift. Result was R^2=0.73 for index of maximum proportion.

Obrador *et al.* (2007) showed that, the available Mn and Zn in soils of Central Spain ranged from 13.0 to 51.2 and 26.4 to 56.8 per cent respectively, The R^2 values of the best-fit regression models ranging from 0.50 [Y-Zn=19.3+6.32 (WSEX+OC)-Zn] to 0.92 [Y-Zn=57.3+0.23 P−8.56 pH+20.6 DTPA-Zn].

Kumar, (2007) studied the Economics of change in cropping pattern in relation to credit and then he noticed that the change in cropping pattern and Agriculture growth in India. The existed significance difference of the change in cropping pattern between the difference groups of cultivators classified on the basis of use of credit or institutional credit, farm households without credit, with own fund only. The statistical test of the hypothesis regarding the relation between different types of cropping pattern are carried out for these regression analysis with dummy variables are used.

Y_t=37.43+19.54X_i i=1,2………………..,n households and R^2=0.71.

Different variants of agricultural diversification, concentration ratios and changes in the percent of non-food crops are explained in the present study with the structure of land holdings, irrigation intensity, institutional credit, road network and urbanization. The regression analysis showed the level of country and also for the state of Haryana. It may be noted that the individual state is an observation in the country-level regression analysis while districts are observations in the state level analysis.

Bhat *et al.* (2012) studied the optimum nutrient norms for laterite soils (Ultisols) and to assess quantitative relationship of soil fertility, leaf nutrients and nutrient uptake with yield of arecanut. At 0–30 cm soil depth, optimum nutrient concentration for P, K, Ca, Mg, Fe, Mn, Cu, Zn and B was established as 15, 192, 925, 179, 37, 88, 26, 5.5 and 1.4 mg kg^{-1}, respectively. Stepwise regression analysis identified the soil and leaf nutrient variables with a significant influence on the kernel yield of arecanut. The loadings of principal component analysis were in confirmation with the correlations among the nutrient variables and yield. The study clearly established the direct and significant relationship between soil nutrient status/nutrient uptake and yield.

Kalkhajeh *et al.* (2012) compared the multiple linear regressions (MLR), adaptive neuro-fuzzy inference system (ANFIS) and artificial neural network (ANN) models to develop PTFs for predicting CEC of Aridisols and Entisols in Khuzestan province, southwest Iran. Five soil parameters including bulk density, calcium carbonate, organic carbon, clay and silt were considered as input variables for proposed models and the results revealed that the MLP model (R^2=0.83, MSE=0.008) had the most reliable prediction when compared with the other models. The results indicated that the ANFIS model (R^2=0.50, MSE=0.009) had approximately similar accuracy with those of MLR (R^2=0.51, MSE=1.21).

A quick method was developed for diagnosis of nitrogen (N) in apple trees based on multiple linear regressions to establish the relationship between near-infrared reflectance spectra (NIRS) and the N contents of fresh and dry tissue. Spectral pretreatment methods such as derivatives, smoothing, and normalization were used. The derivatives appeared to be the most effective. The best calibration for fresh leaf gave 0.842 for the correlation coefficient of validation (Rv), 1.119 g kg^{-1} for the root mean square error of prediction (RMSEP), and 8.311 for the ratio of the range in reference data from the validation samples to the root mean square error of prediction (RER). The best calibration for dried ground samples was obtained with Rv = 0.952, RMSEP = 0.633 g kg^{-1}, the ratio performance deviation (RPD) = 3.27, and RER = 13.728. The results showed that calibrations of dry-apple leaf are robust enough for an accurate prediction of N (Zhang *et al.*, 2012).

David *et al.* (2013) revealed that, simple linear regression for Ca, laboratory data and portable X-ray fluorescence (PXRF). Ca data produced an R^2 of 0.8794. Similarly, simple linear regression for laboratory-quantified gypsum vs. PXRF S produced an R^2 of 0.9120. Multiple linear regression of laboratory quantified gypsum vs. both PXRF S and Ca produced an R^2 of 0.9127. No significant differences were observed between model generation and validation datasets. Overall, PXRF shows great promise for the direct quantification of gypsum in soils.

Nazmi, (2013) studied a structural equation model of yield components of wheat (YCW) in northwest of Iran using soil physical and chemical properties. The multiple linear regression (MLR) analysis demonstrated that the soil's chemical and physical properties measures are statistically significant in estimating YCW. Following this, and according to R square statistic, 87 per cent of the variance in YCW was explained by the soil chemical properties and 83 per cent was accounted for by soil physical properties. Considering the relative importance of the estimation of YCW variable and from the perspective of regression equations, the organic carbon and saturated point moisture made the largest contribution through the two proposed models for the soil productivity.

III. MATERIAL AND METHODS

The design of the study is an important component of research. To realize the various objectives of the study, an appropriate methodology describing sampling designs, data collection and tools of analysis for the conduct of the study are inevitable. In this chapter the methodology adopted for the present study, including the selection and description of the study area, sampling design, collection of data and analytical tools employed are presented under the following heads.

3.1 Description of the study area

3.2 Selection of the study area

3.3 Collection of data

3.4 Statistical tools employed

3.1 Description of the study area

An investigation was carried out to study nutrient status, trend and their effect on yield under ragi and paddy growing areas of Karnataka. The districts considered are Bangalore rural, Bangalore urban, Kolar, Tumkur, Mandya, Mysore, Chamrajnagar, Kodagu, Hassan, D. Kannada, Udupi, Chikamagalur, Chitradurga, Davangere, Shimoga, U. Kannada, Dharwad, Haveri, Bellary, Gadag, Raichur, Koppal, Bijapur, Bagalkot, Belgaum and Gulbarga and considered the eleven taluks *viz.*, Devanahalli, Hoskote, Doddaballapura, Nelamangala, Bangalore north, Bangalore east, Bangalore south, Anekal Magadi, Ramanagaram and Channapatna of Bangalore urban, Bangalore rural and Ramanagaram districts to assess the interrelationship between soil properties and nutrient status (**Fig. 1**).

3.1.1 Geographic location and extent:

The Karnataka state is situated between 11^{0}31' and 18^{0}15' North latitude and 74^{0}12' and 78^{0}40' east longitude lies in the west central part of peninsular India. Its maximum spread from north to south is about 700 Km and east to west is 400 Km.

The state has a geographical area of 1.91 lakh square km and is the eight largest state in the country. It has a coast line running to a length of 300 Km with port facilities at Mangalore and Karwar. For the purpose of general administration, the state is divided in to four revenue divisions viz., Bangalore, Mysore, Belgaum and Gulbarga.

Bangalore Urban district is located in the southeastern part of Karnataka. It is having an extent of 2174 sq.km and is located between the north latitude 12˚39' 32'': 13˚14' 13'' and East longitude 77˚19'44'': 77˚50'13''. The district is bounded in all the directions by Bangalore rural district except in southeast, where the district is bounded by Dharmapuri district of Tamil Nadu state (Fig-1). The district is divided into three taluks namely Bangalore north, Bangalore south and Anekal taluks. The total population of the district as per 2011 census is about 57, 59,987.

Bangalore Rural district is located at 120 15' and 130 35' North latitude 770-05' and 780 00' East Longitude spread over 2259 sqkm. The district is divided into four taluks namely Devanahalli, Hoskote, Doddaballapura and Nelamangala.

The Ramanagara district is lies between 12°24' to 13°09' north latitude and 77°06' to 77°34' East longitude. The district is bounded by Tumkur and Bangalore Rural districts in the north, by Mandya district on the west, Chamarajanagar district on the south and on east by Bangalore Urban district and Tamilnadu state. The district covers an area of 3576 sq km. The district is divided into four taluks namely Channapatna, Kanakapura, Magadi and Ramanagara. The total population of the district is about 10,82,739.

3.1.2 Physiography

Karnataka has a geographical area of 1.91 lakh sq. kms and has a variety of topographical situations ranging from the coastal plains to the gentle slopes to the Western Ghats. Greater part of Karnataka lies between 450 to 950 meters above mean sea level.

Physiographically the Bangalore district can be divided into rocky upland, plateau & flat topped hills at a general elevation of about 900amsl with its major part sloping towards south and south east forming pediplains interspersed with hills all along the western part. The pediplains form the major part of the district underlain by granites and gneisses with the highest elevation of 850 to 950 m.amsl. Major part of the pediplain constitute low relief area having matured dissected rolling topography with erosional land slope covered by a layer of red loamy soil of varied thickness. Major part of the pediplains is dissected by streamlets flowing in southern direction.

The soils of the districts can be broadly grouped into red loamy soil and lateritic soil. Red loamy soils generally occur on hilly to undulating land slope on granite and gneissic terrain. It is mainly seen in the eastern and southern parts of Bangalore north and south taluks. Laterite soils occur on undulating terrain forming plain to gently sloping topography of peninsular gneissic region. It is mainly covered in Anekal taluk and western parts of Bangalore North and south taluks.

The soils of Bangalore Rural districts are broadly classified in to four categories viz (i). Loamy soil (ii) Lateritic soil (iii) Lateritic gravelly soil and (iv) Red sandy soil. Red loamy soils generally occur on hilly to undulating land slope on granite and granite gneisses. Lateritic soil occurs in undulating terrain forming plain to gently sloping topography of peninsular gneiss region. Lateritic gravelly soils occur in upland regions of lateritic soils, Red sandy soil occurs in undulating land slopes. These soils are derived from acidic rocks granites and granitic gneiss.

A major part of the Ramanagaram district is occupied by red sandy and red loamy soil. Red sandy soil mainly occurs in Channapatna, Kanakapura and Ramanagara taluks in undulating land slopes. These soils are derived from acidic rocks, granites and granitic gneiss. These soils occur on gently sloping pediplain. They are dark brown colour with loam to sandy loam composition on the surface and sandy clay loam to clayey soils in the sub surface horizons. They are neutral to alkaline in nature. Red loamy soils generally

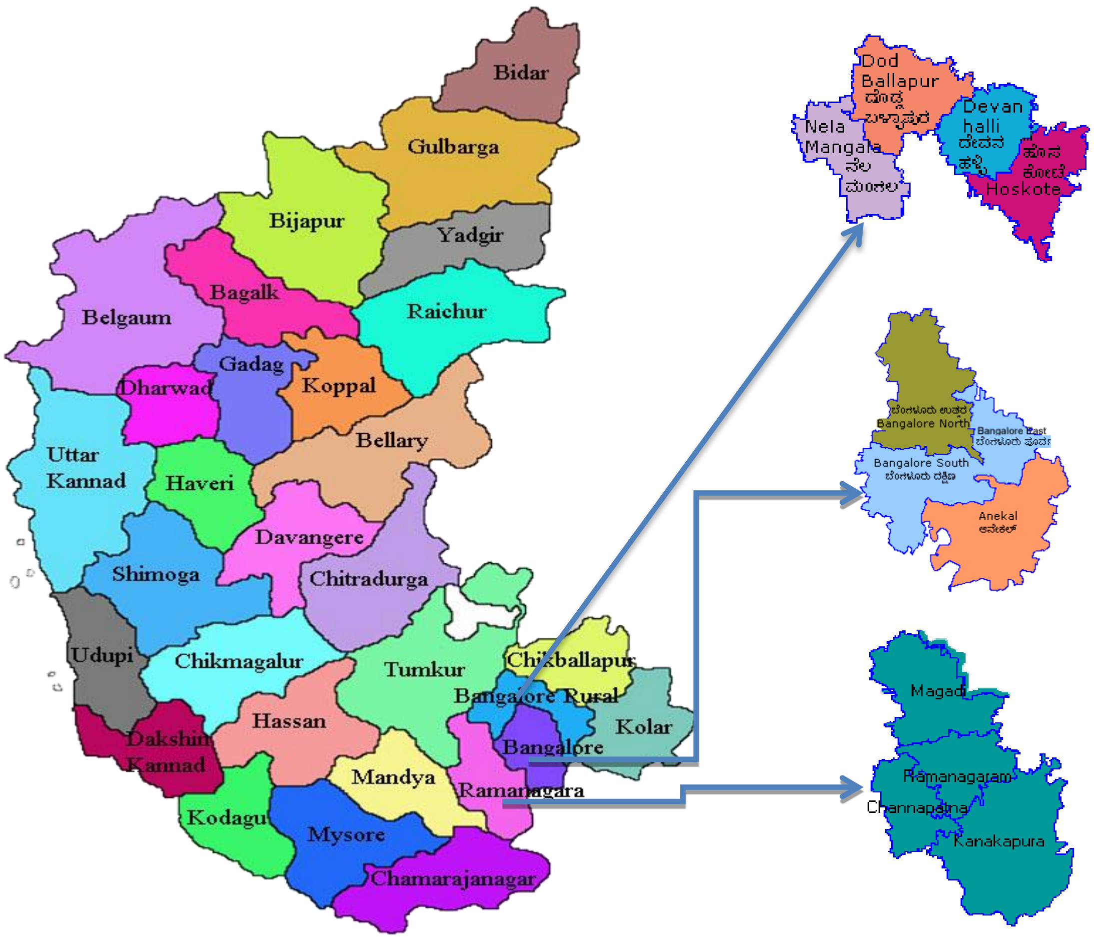

Fig. 1. Location of study district in Karnataka state.

occur on hilly to undulating land slope on granite and granite gneisses. It is mainly covered in Magadi taluk and parts of Channapatna and Kanakapura taluks.

3.2 Selection of the study area

The focus of the study was confined to the statistical evaluation of the soil chemical properties namely, pH, EC, OC, P, K, Zn, Fe, Mn and B content in selected districts of sample size hundred from each taluk (randomly selected) and yields of different crops like ragi and paddy. The study was carried out in districts of Karnataka based on common crops grown and also based on criteria of different soil types.

3.3 Collection of data

The required data for the present study included only secondary data (**Fig.2**).

3.3.1 Nature and source of secondary data

The taluk wise secondary data on the soil parameters *viz.,* pH, EC, OC, P, K, Zn, Fe, Mn and B content of Bangalore Rural, Bangalore Urban and Ramanagaram districts for a period of six years from 2007-2013 totally hundred samples from each taluk per year (Random selection) and District wise, per cent deficiency (Zn, Cu, Fe, Mn and B) for a period sixteen years from 1998-2013 were collected from Agricultural Department. Similarly, productivity data of paddy and Ragi of twelve years from 1998-99 to 2009-2010 were collected from Directorate of Economics and Statistics, Bangalore and India stat website.

3.4 Statistical tools employed

The methods of analysis employed in the study are presented under the following headings:

3.4.1 Descriptive statistics

The descriptive statistics such as the Mean, Standard Deviation (SD) and Skewness were used to study the status of the soil chemical properties in Bangalore Rural, Bangalore Urban and Ramanagaram districts of Karnataka. The standard formulae were used to compute the above said measures.

3.4.2 Karl Pearson's Correlation analysis

The correlation analysis was carried out to determine the degree of association between two variables. In the present study, the degree of relationships between soil properties (pH, CEC, OC) and nutrients *viz.,* P, K, Zn, Cu, Mn, Fe and B were determined by using Karl Pearson's correlation coefficient which was calculated as,

$$r_{(x,y)} = \frac{\mathrm{Cov}\ (X,Y)}{\sigma_x \sigma_y}$$

In case of bivariate distribution

$$\text{Cov}(X, Y) = \frac{\sum(X_i - \overline{X})(Yi - \overline{Y})}{n-1}$$

$$\sigma_x^2 = \frac{\sum(X_i - \overline{X})^2}{n-1} \quad \text{and}$$

$$\sigma_y^2 = \frac{\sum(Yi - \overline{Y})^2}{n-1}$$

Where,

r (x,y) is the correlation coefficient between X and Y .

X_i is the first variable and Y_i second variable.

$\overline{X}$ is the mean of the variable X_i and $\overline{Y}$ is the mean of the variable Y_i.

Test procedure:

H_0: There is no correlation between soil properties and nutrients (ρ=0).

H_1: There is significant correlation between soil properties and nutrients ($\rho \neq 0$).

Under H_0, the sampling distribution of test statistic is

$$t = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \quad \textit{which follows } t_\alpha \textit{ distribution with (n-2) df}$$

Where,

n is the number of pairs of observation.

r is the correlation coefficient.

3.4.3 Trend analysis

Trend analysis is done by fitting the trend lines separately for each per cent deficiency of micronutrients viz., Zinc, Copper, Manganese, Iron and Boron over a period of 1998-2013. Further, the trend line presented using graphs of Free hand curve fitting to know the trend of soil parameters over time and the result is presented in graph to know the trend of the soil micronutrients over period of time.

3.4.3.1. Linear regression model

Linear model is fitted for all mentioned micronutrients considering the period 1998-2013. The linear model is as follows;

$$Y = b_0 + b_1X_i + e_i$$

Where,

b_0	: Intercept
b_1	: Slope
X_i	: Time period
Y	: Zinc, Copper, Manganese, Iron and Boron deficiency (one parameter at a time has been taken).
e_i	: Error component

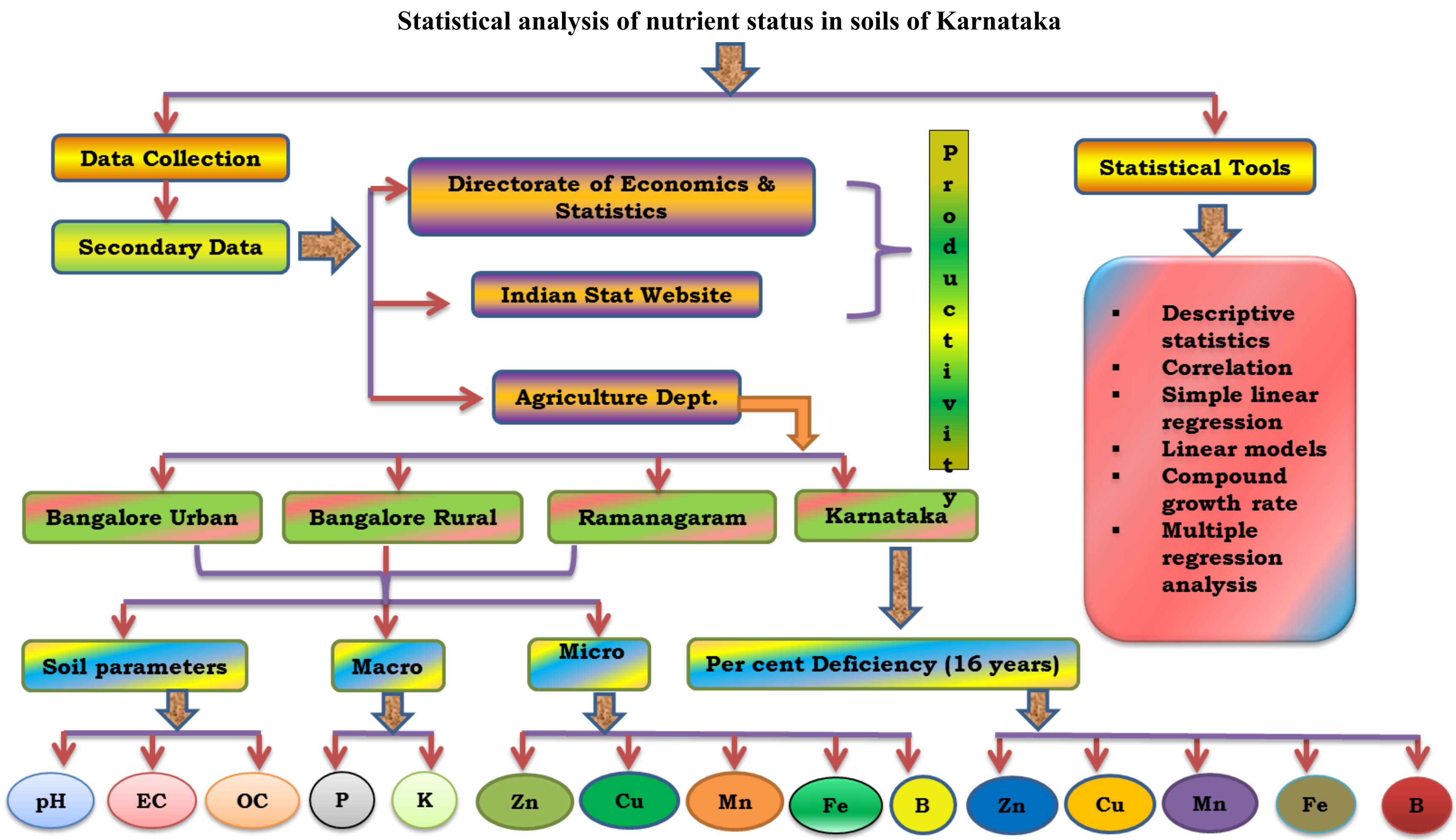

Fig. 2. Study design of the investigation

3.4.3.2 Compound growth rate analysis

Growth of any variables indicates its past performance. The analysis of growth is usually used in economic studies to find out the trend of a particular variable over a period of time. It clearly indicates the performance of the variable under consideration and hence it can be very well used for making policy decisions.

The growth in the soil parameters of different location was estimated using the exponential growth function of the form:

$$Y_t = ab^t u_t \qquad \text{(a)}$$

Where,

Y_t – Dependent variable for which growth rate was estimated (soil parameters)
a – Intercept
b – Regression coefficient
t – Years which takes values, 1,2,3,……………,n
u_t – Disturbance term for year 't'

Equation 'a' can be transformed into log linear form as follows.

$$\ln y = \ln a + t \ln b + \ln u_t \qquad \text{(b)}$$

This equation was estimated using ordinary least square (OLS) technique. The compound growth rate (g) in percentage was then computed from the relationship,

$$g = (\text{Antilog of } \ln b - 1) * 100$$

The significance of the regression coefficient was tested using the student 't' test.

3.4.4 Linear regression models

3.4.4.1 Simple linear regression analysis

The available nutrient value was predicted using linear regression analysis by considering soil property as independent variable:

$Y = \alpha + \beta x + \varepsilon$ was the model under consideration (Nageshwara T Rao, 2nd Editn, 2007).

Where,

α is the intercept
β is the regression co-efficient.
ε is the random error.

Here the task was to find out the estimates of $\hat{\alpha}$ (α = a) and $\hat{\beta}$ (β = b). They were calculated as

$$\hat{\beta} = b = \frac{n(\sum XY) - \sum X \sum Y}{n \sum X^2 - (\sum X)^2} \qquad \text{and} \qquad \hat{\alpha} = a = \bar{Y} - b\bar{X}$$

The significance of the regression model was tested using F statistic. Here the null hypotheses was set as,

HB_0: $\beta = 0$

To test this F – test was used.

$$F = \frac{\text{Regression sum of squares} / (n-2)}{(\text{Error sum of squares})/(n-k)}$$

Where,

Regression sum of squares $(x_{i)} = \sum (bi) \sum (x_i\, y)$
Error sum of squares $(y_{i)} = \sum y^2 -$ SSR

This calculated F value was compared with table F for 1 and (n-2) degrees of freedom.

R^2 measures the contribution of the linear function of independent variables to the variation in dependent variable. Based on the R^2 and MSE, model of best fit to the data was selected.

3.4.4.2 Multiple linear regression analysis

When the numbers of variables which explain the dependent variable are more than one, multiple linear regression analysis can be used. Here, the model is,

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots\ldots\ldots + \beta_p X_p + \varepsilon$$

Where, Y is the dependent variable and X_i's are the independent variables with β_i's as the partial regression coefficients of Y on X_i's where i= 1, 2,…..P. In the present study, Y was taken as crop yield and X_i's were soil parameters viz., Zn, Cu, Mn, Fe, B.

In the multiple linear regression analysis, the estimates of coefficients (β_i's and α) are to be computed using the method of least squares. The final relation can be represented in matrix form as follows.

$$\hat{\beta} = (X'X)^{-1} X'Y$$

Where,

$$\begin{bmatrix} b_0 \\ b_1 \\ \vdots \\ b_p \end{bmatrix} = \begin{bmatrix} \sum X_0^2 & \sum X_0 X_1 \ldots\ldots\ldots & \sum X_0 X_p \\ \sum X_1 X_0 & \sum X_1{}^2 \ldots\ldots\ldots & \sum X_1 X_p \\ \vdots & & \\ \sum X_p X_0 & \ldots\ldots\ldots\ldots\ldots\ldots & \sum X_p{}^2 \end{bmatrix}^{-1} \begin{bmatrix} \sum X_0 Y \\ \sum X_1 Y \\ \vdots \\ \sum X_p Y \end{bmatrix}$$

and

$$\alpha = a = \bar{Y} - \left(b_1\bar{X}_1 + \cdots\cdots\cdots + b_p\bar{X}_p\right)$$

The significance of the model was tested by using the Regression ANOVA.

Table 3.1. Regression ANOVA

Source of variation	Degrees of freedom (df)	Sum of Squares (SS)	Mean sum of squares (MSS)	F calculated
Regression	P	$\widehat{\beta}'X'y - n\bar{y}^2$	Reg.SS/P	(RegMSS)/MSSE
Residual	n-p-1	$y'y - \widehat{\beta}'X'y$	Res.SS/n-p-1	
Total	n-1	$y'y - n\bar{y}^2$	Total SS/n-1	

Estimate of V (β) = MSSE $X(X'X)^{-\prime}$

By using the regression ANOVA an attempt is made in testing the null hypothesis that β=0 against alternative hypothesis β≠0. Reject null hypothesis if calculated F-value was more than the table F-value. If the model was significant, applying individual t-test to find the significance of individual β_i. By the t-test the null hypothesis was that β≠0 against the alternative hypothesis, i=1,2,3,……..,p.

The formula for individual t-test was given by

$$t_{cal} = \frac{|\widehat{\beta_1}|}{SE(\widehat{\beta_1})} \sim t_{(\alpha,n-p-1)df}$$

Where, SE (β) was the square root of i^{th} diagonal element of the matrix v (β). Reject the null hypothesis if calculated t-value is greater than the table t-value or accept the null hypothesis if calculated t-value is less than table t-value with (n-p-1) degrees of freedom.

Model adequacy is tested by using Mean sum of squares of error, coefficient of determination (R^2) and adjusted R^2. Coefficient of determination (R^2) was computed as

$$R^2 = \frac{\text{SS due to regression}}{\text{Total sum of squares}} = \frac{b\sum(X_i - \bar{X})(Y_i - \bar{Y})}{\sum(Y_i - \bar{Y})^2}$$

Coefficient of determination (R^2) explains the variation in prediction variable (Y) by regression through the fitted regression equation.

IV. RESULTS

In this chapter, the secondary information collected from various sources was analyzed by using appropriate statistical tools. Results of statistical analysis are presented in respect of objectives of the study under the following headings:

4.1 To estimate the extent of availability of soil chemical properties in the selected districts of Karnataka.

4.2 To statistically assess the extent of influence of soil properties on the nutrient status in the selected districts of Karnataka.

4.3 To assess the trend in deficiency of micronutrients across districts of Karnataka.

4.4 To study the impact of selected micronutrient status on productivity of Paddy and Ragi among districts in Karnataka.

4.1 To estimate the extent of availability of soil chemical properties in the selected districts of Karnataka

The descriptive statistics such as Mean, Standard Deviation and Skewness were used to study the fertility status of eleven taluks *viz.,* Devanahalli, Hoskote, Doddaballapura, Nelamangala, Bangalore North, Bangalore East, Bangalore South, Anekal, Magadi, Ramanagaram and Channapatna of Bangalore Rural, Bangalore Urban and Ramanagaram districts are presented in Table 4.1.1 to 4.1.3b.

Soil electrochemical properties

The data presented in Table 4.1.1 indicates that the taluk wise descriptive statistics of soil electrochemical properties (pH, EC and OC) of Bangalore Rural, Bangalore Urban and Ramanagaram districts. It is evident from the findings that the highest pH observed in Nelamangala 7.28 as compare to lowest in Ramanagaram 5.73. The highest electrical conductivity was observed in Bangalore North 0.44 d Sm^{-1} as compare to lowest in Channapatna 0.02 d Sm^{-1}. Similarly, Bangalore North obtained the highest organic carbon 8.50 g kg^{-1} as compare to lowest in Ramanagaram 4.40 g kg^{-1}.

The deviation in the soil electrochemical properties viz., pH, EC and OC as measured by the SD was revealed to be highest in Magadi 0.74, Ramanagaram 0.09 and Bangalore North 0.34 as compare to lowest in Bangalore South 0.17, Hoskote 0.01 and Devanahalli 0.08 respectively.

Also, the distribution of pH and EC has observed to be positively skewed in 7 taluks *viz.,* Devanahalli, Doddaballapura, Magadi, Channapatna, Bangalore North, Bangalore East, and Anekal and 9 taluks viz., Hoskote, Doddaballapura, Nelamangala, Magadi, Channapatna, Bangalore North, Bangalore East, Bangalore South and Anekal, respectively. The distribution of organic carbon has found to be positively skewed in 9 taluks *viz.,* Doddaballapura, Nelamangala, Magadi, Ramanagaram, Channapatna, Bangalore North, Bangalore East, and Bangalore South.

Table 4.1.1: Descriptive statistics of soil electrochemical properties (pH, EC and OC) in selected areas (2007-2012)

N= 100

Districts	Taluks	pH			EC (dSm^{-1})			OC($g\ kg^{-1}$)		
		Mean	**SD**	**Skewness**	**Mean**	**SD**	**Skewness**	**Mean**	**SD**	**Skewness**
Bangalore Rural	Devanahalli	6.72	0.60	0.00	0.03	0.04	-0.45	4.80	0.08	-0.39
	Hoskote	6.40	0.25	-0.64	0.03	0.01	0.31	4.80	0.13	-0.11
	Doddaballapura	6.98	0.24	0.30	0.11	0.03	0.50	6.20	0.14	0.93
	Nelamangala	7.28	0.29	-0.59	0.12	0.03	0.58	5.10	0.33	0.47
Bangalore Urban	Bangalore North	7.09	0.42	0.14	0.44	0.02	1.66	8.50	0.34	0.45
	Bangalore East	6.35	0.34	0.52	0.06	0.06	6.35	6.70	0.29	0.33
	Bangalore South	6.65	0.17	-0.43	0.11	0.02	1.75	4.80	0.12	0.44
	Anekal	6.35	0.20	1.42	0.15	0.02	0.59	4.80	0.16	2.71
Ramanagaram	Magadi	7.12	0.74	0.80	0.32	0.09	3.30	7.60	0.27	0.57
	Ramanagaram	5.73	0.47	-0.65	0.07	0.08	-0.65	4.40	0.09	1.28
	Channapatna	6.90	0.51	0.06	0.02	0.07	1.97	4.80	0.16	1.40

Macronutrients

Similarly, Descriptive statistics of Phosphorous and Potassium was calculated for all the taluks of Bangalore Rural, Bangalore Urban, and Ramanagaram districts separately for a period 2007-2012 presented in Table 4.1.2. The highest Phosphorous concentration 81.23 kg ha^{-1} found in Magadi and lowest in Bangalore South 13.86 kg ha^{-1}. The highest Potassium content was found in Magadi 254.67 kg ha^{-1} as compare to lowest in Hoskote 69.47 kg ha^{-1}, respectively.

The deviation of Phosphorous and potassium were found to be highest in Bangalore East 16.51 and Channapatna 72.15 as compare to lowest in Doddaballapura 1.66 and 9.45, respectively. Also, the distribution Phosphorous and Potassium has found to be positively skewed in 6 taluks *viz.,* Devanahalli, Magadi, Ramanagaram, Channapatna, Bangalore south and Anekal and 4 taluks viz., Hoskote, Nelamangala, Magadi and Channapatna, respectively.

Micronutrients

Result pertaining to Zinc, Copper, Manganese, Iron and Boron content of surface soils of all the taluks of Bangalore Rural, Bangalore Urban, and Ramanagaram districts were presented in Table 4.1.3a and Table 4.1.3b.

It is evident from finding that the highest Zinc was found in Bangalore North 3.78 ppm as compare to lowest in Channapatna 0.24 ppm. Similarly, the highest Copper and Manganese found in Bangalore north 3.89 ppm and 31.12 ppm, respectively as compare to lowest in Ramanagaram 0.40 ppm and Channapatna 2.94 ppm, respectively.

The deviation in the Zinc and Copper as measured by the SD was found to be highest in Ramanagaram 1.75 and Bangalore north 0.75 as compare to lowest in Channapatna 0.55 and Hoskote 0.40, respectively. Whereas, highest deviation of Manganese was observed in Bangalore North11.68 as compare to lowest in Doddaballapura 1.03.

The distribution Zinc has found to be positively skewed in all the 11 taluks of Bangalore Rural, Bangalore Urban and Ramanagaram districts, respectively. Also, the distribution of Copper and Manganese has found to be positively skewed in 4 taluks *viz.*, Doddaballapura, Bangalore South and Anekal and 8 taluks *viz.,* Devanahalli, Hoskote, Doddaballapura, Nelamangala, Magadi, Bangalore North, Bangalore East and Bangalore South, respectively (Table 4.1.3a).

The result presented in Table 4.1.3b indicate that the highest content of Iron and Boron was found in Bangalore East 15.31 ppm and Bangalore North 1.46 ppm, as compare to lowest in Bangalore South 3.66 and Anekal 0.21 ppm, respectively. The deviation of Iron and Boron was found to be highest in Bangalore East 8.27 and Channapatna 0.16 as compare to lowest in Magadi 1.89 and Doddaballapura 0.05, respectively. The distribution of Iron was found to be positively skewed in all the taluks of Bangalore Rural, Ramanagaram and Bangalore Urban and Boron was positively

Table 4.1.2: Descriptive statistics of macronutrients (P_2O_5 and K_2O) in selected areas (2007-2012)

N= 100.

Districts	Taluks	P_2O_5 (kg ha^{-1})			K_2O (kg ha^{-1})		
		Mean	**SD**	**Skewness**	**Mean**	**SD**	**Skewness**
Bangalore Rural	Devanahalli	26.01	9.39	1.42	96.43	42.16	-1.20
	Hoskote	22.40	10.68	-0.81	69.47	15.63	1.63
	Doddaballapura	46.63	1.66	-3.09	112.90	9.45	-4.13
	Nelamangala	31.77	7.74	-1.59	181.44	33.71	0.70
Bangalore Urban	Bangalore North	81.23	8.52	1.13	228.00	32.39	0.77
	Bangalore East	17.76	6.65	3.26	99.46	26.82	-0.48
	Bangalore South	16.59	5.69	1.89	86.24	72.15	1.42
	Anekal	47.41	6.62	-4.10	254.67	46.14	-0.12
Ramanagaram	Magadi	35.98	16.51	-0.31	154.56	20.05	-0.95
	Ramanagaram	13.86	9.42	0.99	97.51	37.48	-0.41
	Channapatna	18.20	13.73	0.39	87.36	35.28	-0.40

Table 4.1.3a: Descriptive statistics of micronutrients (Zn, Cu and Mn) in selected areas (2007-2012)

N= 100

Districts	Taluks	Zn(ppm)			Cu (ppm)			Mn (ppm)		
		Mean	**SD**	**Skewness**	**Mean**	**SD**	**Skewness**	**Mean**	**SD**	**Skewness**
Bangalore Rural	Devanahalli	0.64	0.60	0.30	1.11	0.46	-0.10	7.98	4.69	0.33
	Hoskote	1.83	0.66	0.98	1.29	0.40	-0.38	5.34	7.96	0.14
	Doddaballapura	2.18	0.89	1.68	2.14	0.57	0.65	24.17	1.03	0.57
	Nelamangala	1.45	0.82	0.38	1.08	0.64	-0.04	7.32	1.48	0.77
Bangalore Urban	Bangalore North	2.89	0.97	0.98	3.89	0.75	-0.60	31.12	11.68	0.76
	Bangalore East	0.50	1.75	1.85	2.58	0.68	-0.17	13.58	10.19	0.71
	Bangalore South	0.24	0.55	0.03	2.67	0.71	0.35	13.64	11.56	2.26
	Anekal	3.78	0.83	1.51	1.15	0.65	0.05	11.50	8.33	-0.20
Ramanagaram	Magadi	2.89	0.68	0.46	2.44	0.49	-0.18	24.45	4.69	0.33
	Ramanagaram	0.26	0.86	1.34	0.41	0.67	-0.38	5.56	8.69	-1.26
	Channapatna	1.11	0.74	0.11	1.91	0.66	0.54	2.94	7.98	-0.31

Table 4.1.3b: Descriptive statistics of micronutrients (Fe and B) in selected areas (2007-2012).

N= 100

Districts	Taluks	Fe (ppm)			B (ppm)		
		Mean	SD	Skewness	Mean	SD	Skewness
Bangalore Rural	Devanahalli	9.97	1.99	0.60	0.38	0.10	0.30
	Hoskote	7.15	7.22	1.90	0.40	0.10	3.72
	Doddaballapura	11.76	5.43	0.51	0.38	0.05	1.33
	Nelamangala	7.91	3.66	0.81	0.86	0.06	0.09
Bangalore Urban	Bangalore North	8.85	1.89	0.60	0.40	0.10	0.30
	Bangalore East	8.04	2.33	2.04	0.34	0.13	-0.90
	Bangalore South	4.48	4.37	0.86	0.50	0.16	0.47
	Anekal	12.68	8.01	1.86	1.46	0.08	0.01
Ramanagaram	Magadi	15.31	8.27	2.13	0.94	0.08	0.71
	Ramanagaram	3.66	5.15	1.03	0.32	0.07	0.33
	Channapatna	5.48	4.11	1.03	0.21	0.14	-0.35

skewed in 9 taluks *viz.*, Devanahalli, Hoskote, Doddaballapura, Nelamangala, Magadi, Channapatna, Bangalore North, Bangalore East and Bangalore South, respectively.

4.1.4 Classification of taluks based on availability of soil chemical properties to the plant growth and development

Based on the mean pH values obtained, three categories were made *viz.*, Acidic, Neutral and Alkaline conditions. It is evident from the findings that 7 taluks viz., Devanahalli, Doddaballapura, Nelamangala, Bangalore North, Bangalore South, Magadi and Channapatna fall in neutral category (63.6 %) and rest of the four taluks fall into Acidic category (36.4 %). Further, EC was classified into three categories *viz.*, Normal, Critical and Very critical as indicated in Table 4.1.4.1 All the taluks of Bangalore Rural, Bangalore Urban and Ramanagaram districts fall in Normal category (100 %).

Table 4.1.4.2 shows that the available Phosphorous (P_2O_5) and Potassium (K_2O) were classified into three categories *viz.*, Low, Medium and High. It is evident from the findings that 5 taluks *viz.*, Hoskote, Bangalore South, Anekal Ramanagaram and Channapatna fall in low Phosphorous category (45.5 %) and rest of the five taluks fall into Medium category (45.5 %) except Magadi (9.0%). Whereas, seven taluk *viz.*, Devanahalli, Hoskote, Doddaballapura, Bangalore South, Anekal, Ramanagaram and Channapatna fall in low Potassium category (63.6 %) and rest of the four taluks fall in Medium category (36.4%).

The classification of micronutrients viz., Zinc, Copper, Manganese, Iron and Boron were presented in Table 4.1.4.3a and 4.1.4.3b. Zinc was found (27.3%) deficient in 3 taluks viz., Ramanagaram, Channapatna and Bangalore east, Rest of the eight taluks are fall in critical category (27.3 %). All the 11 taluks (100%) of Bangalore Rural, Ramanagaram and Bangalore Urban districts were fall in above critical category of Copper, Manganese and Iron content. Boron was classified into two categories *viz.*, Deficient and Critical. Devanahalli, Hoskote, Doddaballapura, Magadi, Ramanagaram, Bangalore South and Anekal fall in deficient condition (63.6%) as compare to remaining four taluks fall into critical condition (36.4%).

4.2 To statistically assess the extent of influence of soil properties on the nutrient status in the selected districts of Karnataka

4.2.1 Correlation analysis

Correlation coefficient analysis establishes to determine the nature and degree of relationship between soil properties and nutrients.

The result presented in Table 4.2.1 indicates that the pH was non-significant positively correlated with all the nutrients viz., Phosphorous (0.536), Potassium (0.570), Zinc (0.340), Copper (0.488), Manganese (0.463), Iron (0.084) and Boron (0.381). The EC was significant (at 5%) positively correlated with Phosphorous (0.675), Zinc (0.710) and Copper (0.669). However, highly significant with Potassium (0.863**) and Manganese (0.847**). Iron and Boron were non-significantly with EC. The Organic Carbon was highly significant and positively correlated with all the nutrients *viz.*,

Soil chemical properties are classified based on requirement of the plant growth

Table 4.1.4.1: Classification of pH and EC as per specification limits

N=11

Soil properties	Classification	Standard limits	Districts			Response	
			Bangalore Rural	Bangalore Urban	Ramanagaram	Taluk	%
pH	Acidic	< 6.5	Hoskote	Bangalore East and Anekal	Ramanagaram	4	36.4
	Neutral	6.5-7.5	Devanahalli, Doddaballapura and Nelamangala	Bangalore North and Bangalore South	Magadi and Channapatna	7	63.6
	Alkaline	> 7.5	-	-	-	0	0.0
EC (dSm^{-1})	Normal	0-0.8	Devanahalli, Hoskote, Doddaballapura and Nelamangala	Bangalore North, Bangalore East, Bangalore South and Anekal.	Magadi, Ramanagaram and Channapatna	11	100.0
	Critical	0.8-1.6	-	-	-	0	0.0
	V.Critical	1.6-3.2	-	-	-	0	0.0

Note: 100 Sample were taken for the study, classification made based on the mean values.

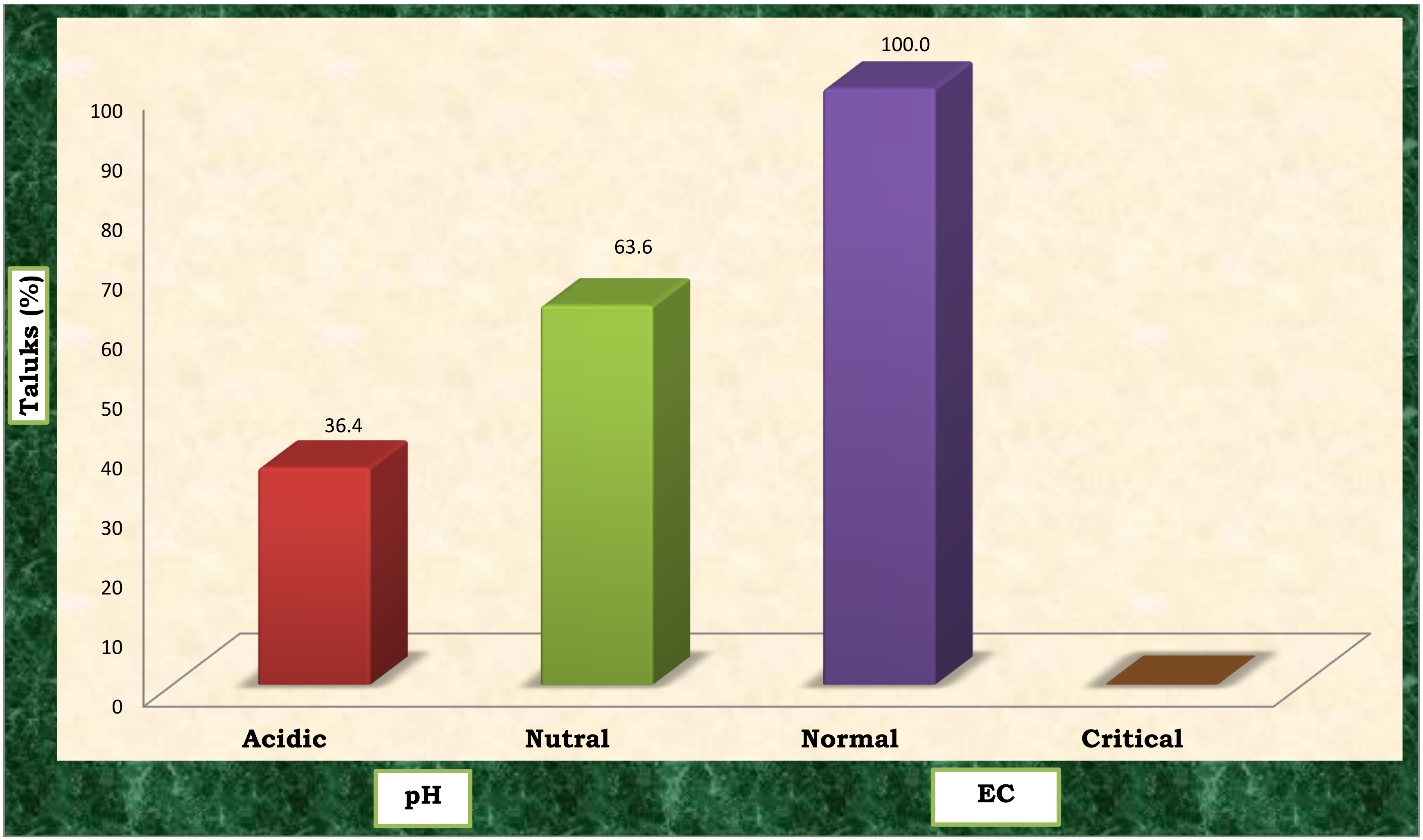

Fig. 3: Classification of soil electrochemical properties as per the specification limits

Table 4.1.4.2 Classification of macronutrients of P_20_5 and K_20 as per the specification limits

N=11

Soil properties	Classification	Standard limits	Districts			Response	
			Bangalore Rural	Bangalore Urban	Ramanagaram	Taluk	%
P_2O_5 (kg ha^{-1})	Low	< 22.9	Hoskote	Bangalore South and Anekal	Ramanagaram and Channapatna	5	45.5
	Medium	22.9-56.33	Devanahalli, Doddaballapura and Nelamangala	Bangalore North and Bangalore East	-	5	45.5
	High	> 56.33	-	-	Magadi.	1	9.0
K_20 (kg ha^{-1})	Low	< 141	Devanahalli, Hoskote and Doddaballapura	Bangalore South and Anekal	Ramanagaram and Channapatna	7	63.6
	Medium	141-336	Nelamangala	Bangalore North and Bangalore East	Magadi	4	36.4
	High	> 336	-	-	-	0	0.0

Note: 100 Sample were taken for the study, classification made based on the mean values.

Table 4.1.4.3a: Classification of micronutrients of Zn, Cu and Mn as per the specification limits

Soil properties	Classification	Standard limits	Districts			Response	
			Bangalore Rural	Bangalore Urban	Ramanagaram	Taluk	%
Zn (ppm)	Deficient	< 0.6	-	Bangalore East	Ramanagaram and Channapatna.	3	27.3
	Critical	≥ 0.6	Devanahalli, Hoskote, Doddaballapura and Nelamangala	Bangalore North, Bangalore South and Anekal	Magadi	8	72.7
Cu (ppm)	Deficient	< 0.2	-	-	-	0	0.0
	Critical	≥ 0.2	Devanahalli, Hoskote, Doddaballapura and Nelamangala	Bangalore North, Bangalore East, Bangalore South and Anekal	Magadi, Ramanagaram and Channapatna	11	100.0
Mn (ppm)	Deficient	< 2	-	-	-	0	0.0
	Critical	≥ 2	Devanahalli, Hoskote, Doddaballapura and Nelamangala	Bangalore North, Bangalore East, Bangalore South and Anekal	Magadi, Ramanagaram and Channapatna	11	100.0

Note: 100 Sample were taken for the study, classification made based on the mean values.

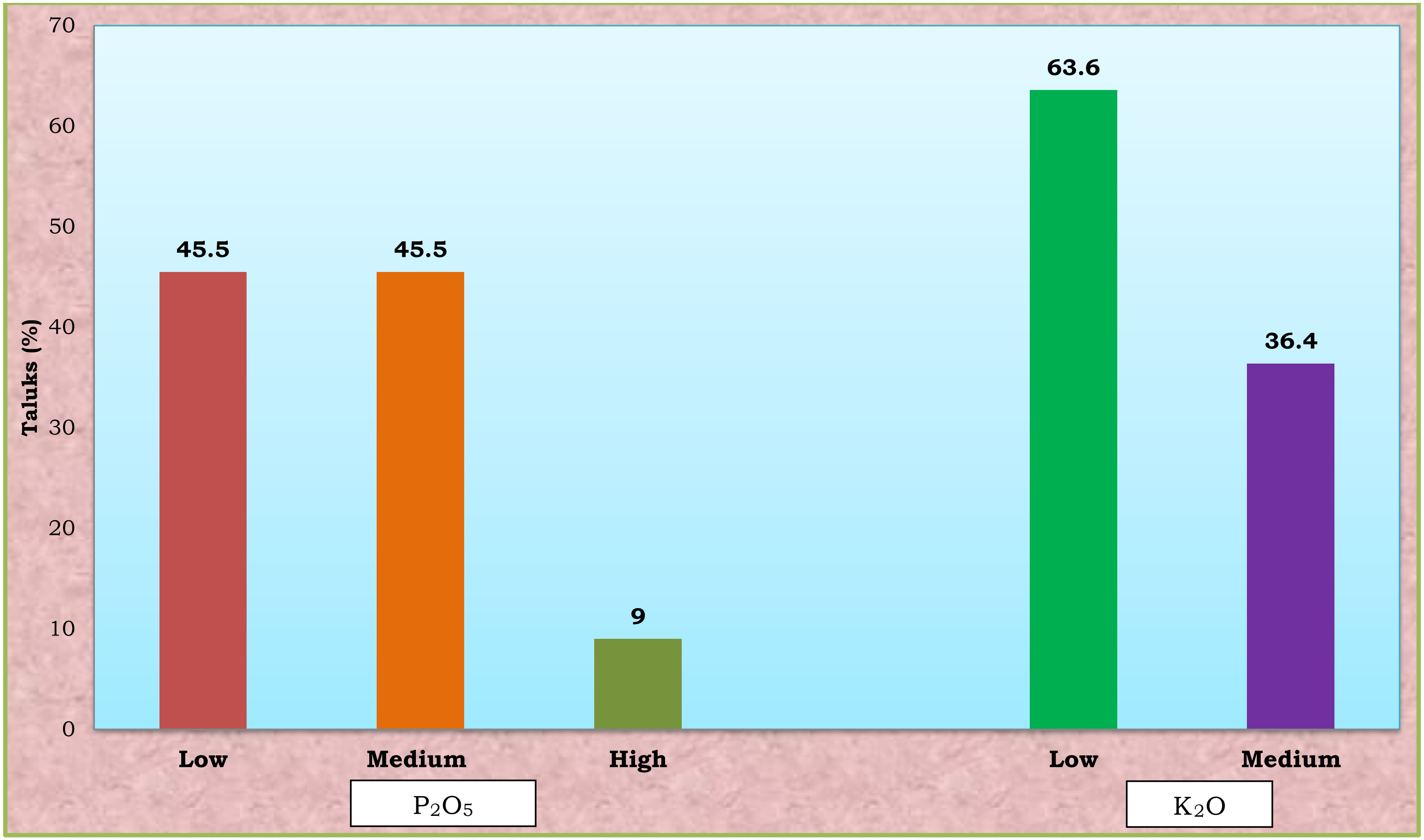

Fig. 4: Classification of macronutrients as per the specification limits

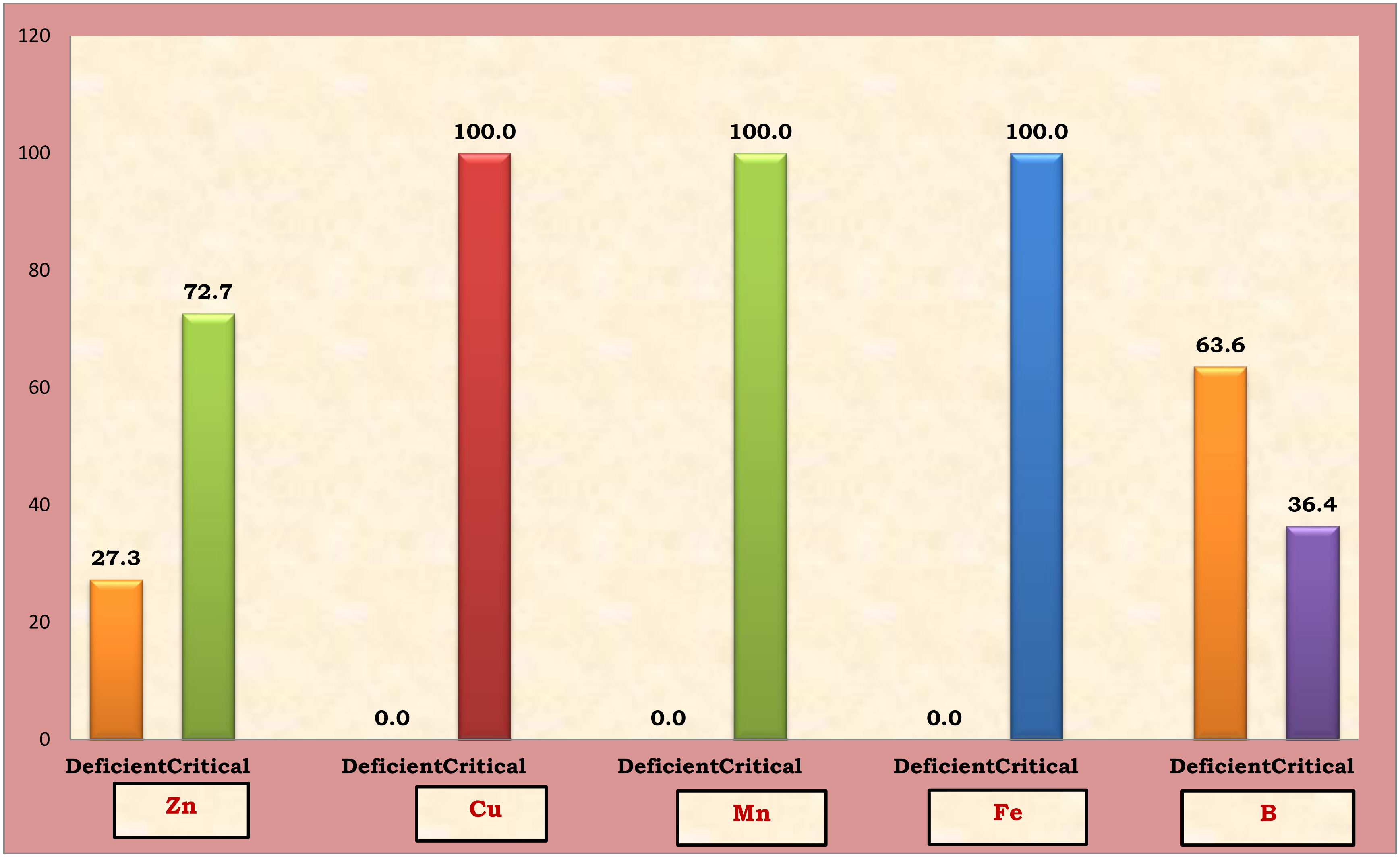

Fig. 5: Classification of micronutrients as per the specification limits

Table 4.1.4.3b: Classification of micronutrients of Fe and B as per the specification limits

N=11

Soil properties	Classification	Standard limits	Districts			Response	
			Bangalore Rural	Bangalore Urban	Ramanagaram	Taluk	%
Fe (ppm)	Deficient	< 2.5	-	-	-	0	0.0
	Critical	≥ 2.5	Devanahalli, Hoskote, Doddaballapura and Nelamangala	Bangalore North, Bangalore East, Bangalore South and Anekal	Magadi, Ramanagaram and Channapatna	11	100.0
B (ppm)	Deficient	< 0.5	Devanahalli, Hoskote and Doddaballapura	Bangalore South and Anekal	Magadi and Ramanagaram	7	63.6
	Critical	≥ 0.5	Nelamangala	Bangalore North and Bangalore East	Channapatna	4	36.4

Note: 100 Sample were taken for the study, classification made based on the mean values.

Table 4.2.1: Inter-relationship between soil properties and nutrients of selected areas

Nutrients	Soil properties		
	pH	**EC**	**OC**
P	0.536	0.675*	0.817**
K	0.570	0.863**	0.878**
Zn	0.340	0.710*	0.918**
Cu	0.488	0.669*	0.814**
Mn	0.463	0.847**	0.890**
Fe	0.084	0.279^{NS}	0.661*
B	0.381	0.565^{NS}	0.690*

****** Significant at 1 % level, ***** Significant at 5 % level

NS: Non -Significant

Phosphorous (0.817), Potassium (0.878), Zinc (0.918), Copper (0.814), Manganese (0.890), Iron (0.661) and Boron (0.690) showed significant.

4.2.2 Linear regression analysis

The result presented in Table 4.2.2.1 to 4.2.2.3 indicates the linear regression coefficient of all the nutrients separately. The regression coefficient for availability of Phosphorous, Potassium, Zinc, Copper, Manganese, Iron and Boron was found to be non-significant with pH. The regression coefficient for availability of Phosphorous as compare to significant with Zinc, Potassium and Manganese was found to be highly significant with EC. Further, the regression coefficient for availability of Phosphorous, Potassium, Zinc, Copper and Manganese was highly significant (at 1%) Iron and Boron was found to be significant with OC.

4.3 To assess the trend in deficiency of micronutrients across the districts of Karnataka

The data presented in Table 4.3.1 indicates that the mean percentage deficiency of selected micronutrients across the district of Karnataka. The deficiency of Zinc and Boron were found to be highest in majority of the districts as compare to other micronutrients *viz.*, Copper, Manganese and Iron.

Trend analysis was carried out to observe the temporal shift in the deficiency of micronutrients across the district of Karnataka for the period 1998-2013. The trend for deficiency of five nutrients *viz.*, Zinc, Copper, Manganese, Iron and Boron have been analyzed and fitted linear trend equations to the data and results were presented in the Table 4.3.2 to 4.3.6 for each district.

The data presented in Table 4.3.2 indicates that the linear trend and compound growth rate of percent deficiency of Zinc, across the different district of Karnataka. The linear trend for 5 districts *viz.*, D.Kannada, Shimoga, U.Kannada, Raichur, Koppal showed the significant increasing trend i.e., shift in deficiency of Zinc and as well as change in the growth rate. Chamrajnagar, Udupi, Chitradurga and Bijapur districts have obtained the significant decreasing. However, remaining 18 districts i.e., Bangalore rural, Bangalore urban, Kolar, Tumkur, Mandya, Mysore, Kodagu, Hassan, Chikamagalur, Davangere, Dharwad, Haveri, Bellary, Gadag, Bagalkot, Belgaum, Gulbarga and Bidar showed there is no shift in deficiency of Zinc over a period of time.

Table 4.3.3 shows that the linear trend and compound growth rate of percent deficiency of Copper, across the different district of Karnataka. The linear trend for Dharwad, Belgaum and Gulbarga showed the significant increasing trend i.e. shifts in deficiency of Copper and as well as change in the growth rate. Further, Chitradurga and U.Kannada districts have obtained the significant decreasing trend. However, 22 districts i.e., Bangalore rural, Bangalore urban, Kolar, Tumkur, Mandya, Mysore, Kodagu, Hassan, Chikamagalur, D.Kannada, Shimoga, Raichur, Koppal, Chamrajnagar, Udupi, Bijapur, Davangere, Haveri, Bellary, Gadag, Bagalkot, Belgaum, Gulbarga and Bidar showed there is no shift in deficiency of Copper over a period of time under study.

Table 4.2.2.1: Regression equation representing the relationship between nutrients and pH

Dependent Variables	pH					
	Constant (a)	Regression coefficient (b)	SE of Regression Coefficient (SE_b)	't' Value	R^2	RMSE
P	6.290	0.012^{NS}	0.006	1.909	0.288	0.403
K	6.136	0.004^{NS}	0.002	2.070	0.324	0.393
Zn	6.477	0.129^{NS}	0.119	1.080	0.116	0.449
Cu	6.267	0.224^{NS}	0.133	1.680	0.239	0.417
Mn	6.383	0.022^{NS}	0.014	1.560	0.215	0.425
Fe	6.595	0.011^{NS}	0.042	0.250	0.117	0.476
B	6.429	0.462^{NS}	0.373	1.230	0.145	0.442

NS: Non-Significant

Table 4.2.2.2: Regression equation representing the relationship between nutrients and electrical conductivity

Dependent Variables	EC					
	Constant (a)	Regression coefficient (b)	SE of Regression Coefficient (SE_b)	't' Value	R^2	RMSE
P	-0.012	0.004*	0.002	2.700	0.455	0.103
K	-0.110	0.002**	0.001	5.112	0.744	0.070
Zn	0.005	0.078*	0.026	3.025	0.504	0.097
Cu	-0.035	0.089*	0.033	2.690	0.447	0.103
Mn	-0.029	0.012**	0.003	4.780	0.718	0.073
Fe	0.043	0.010^{NS}	0.012	0.875	0.077	0.133
B	0.021	0.199^{NS}	0.097	2.050	0.318	0.114

****** Significant at 1 % level, ***** Significant at 5 % level
NS: Non -Significant

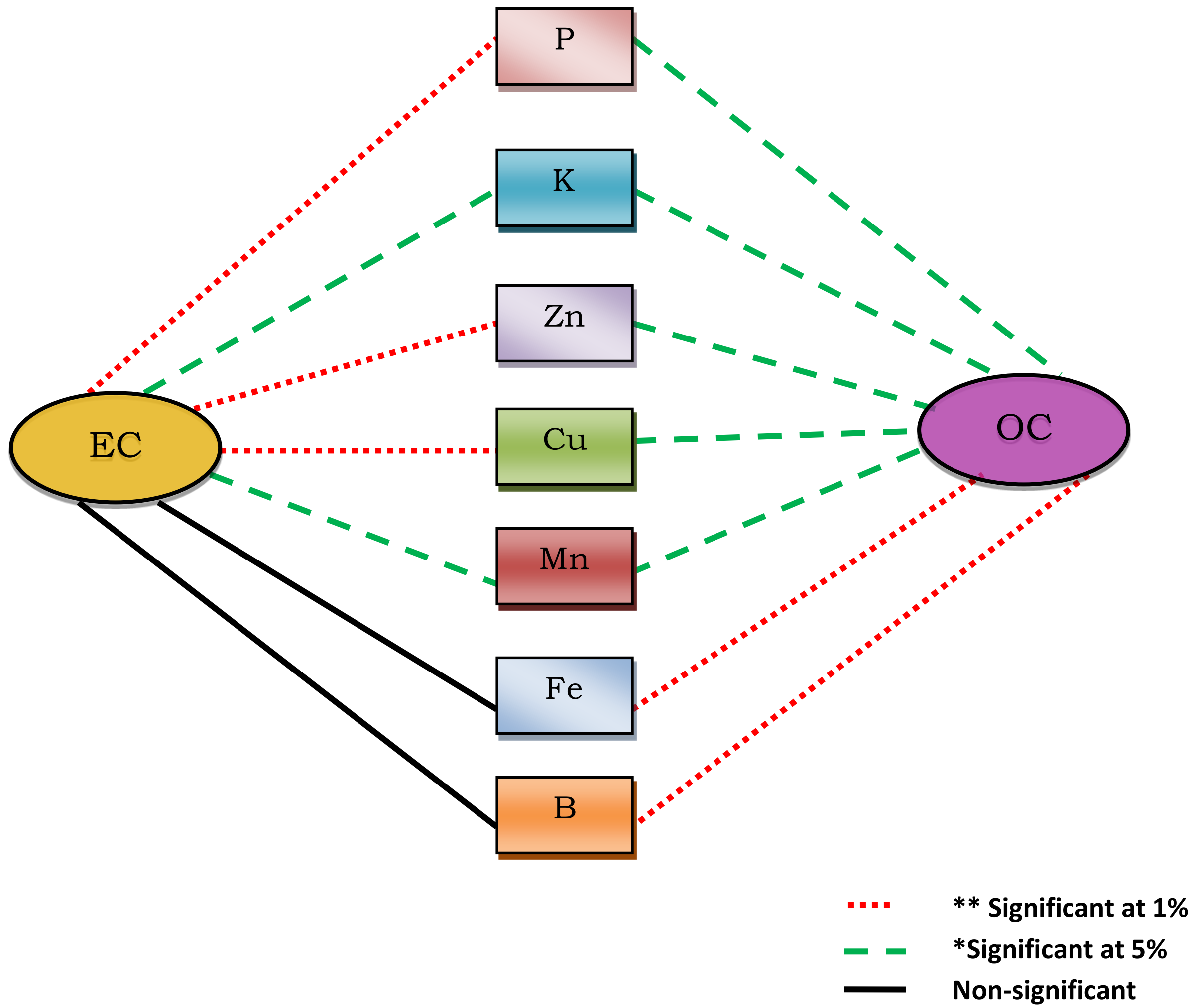

Fig. 6: Inter-relationship between soil properties and nutrients of selected areas

Table 4.2.2.3: Regression equation representing the relationship between nutrients and organic carbon

Dependent Variables	OC					
	Constant (a)	**Regression coefficient (b)**	**SE of Regression Coefficient (SE_b)**	**' t' Value**	**R^2**	**RMSE**
P	3.853	0.056**	0.013	4.250	0.6677	0.833
K	3.111	0.019**	0.004	5.500	0.7711	0.692
Zn	3.964	1.055**	0.152	6.951	0.8432	0.572
Cu	3.564	1.126**	0.268	4.201	0.6628	0.839
Mn	3.913	0.131**	0.023	5.860	0.7926	0.658
Fe	3.482	0.253*	0.096	2.640	0.4372	1.084
B	4.268	2.529*	0.885	2.861	0.4762	1.045

** Significant at 1% level, * Significant at 5% level

Table 4.3.1: District wise deficiency percentage of selected micronutrients (1998-2013)

Districts	Deficiency (%)				
	Zn	Cu	Mn	Fe	B
Bangalore rural	47.35	0.95	1.43	13.78	31.77
Bangalore urban	48.09	3.15	2.89	12.75	40.19
Kolar	48.73	1.96	2.35	15.26	31.70
Tumkur	73.27	6.57	24.55	13.61	30.88
Mandya	76.39	2.93	3.85	4.48	36.48
Mysore	62.63	1.15	3.74	13.64	35.68
Kodagu	45.79	12.30	1.91	4.20	37.07
Hassan	66.31	7.45	2.74	3.26	28.49
D. Kannada	62.74	11.05	16.60	5.86	45.66
Udupi	75.28	3.90	21.80	2.51	62.98
Chikmagalur	70.47	2.42	2.41	3.88	29.46
Chitradurga	71.37	3.19	2.32	34.54	26.59
Davangere	70.78	4.46	2.10	30.68	28.15
Shimoga	60.32	1.73	0.77	2.22	34.43
U. Kannada	49.98	0.27	1.88	2.03	34.07
Dharwad	77.09	2.46	23.05	58.51	5.20
Bellary	82.22	1.23	11.18	63.95	23.08
Gadag	86.50	1.29	11.12	54.44	5.86
Raichur	87.42	1.70	14.08	61.05	30.72
Koppal	74.26	0.15	74.81	59.32	25.83
Bijapur	86.79	1.71	10.40	58.57	4.47
Bagalkot	14.10	10.15	74.57	49.31	33.81
Belgaum	80.55	0.54	1.97	47.85	4.03
Gulbarga	87.83	1.90	2.87	53.85	18.10
Bidar	59.53	2.74	76.75	22.54	11.63

Table 4.3.2: Estimates of trend on percent deficiency of Zinc across the districts of Karnataka (1998-2013)

Districts	Intercept	Trend	R^2 Value	Compound Growth rate (%)
Bangalore rural	43.51	0.452	0.062	0.68
Bangalore urban	36.39	1.376	0.461	3.19
Kolar	49.28	-0.064	0.001	-0.26
Tumkur	74.35	-0.128	0.002	-0.15
Mandya	73.33	0.360	0.015	0.39
Mysore	55.55	0.833	0.131	1.60
Chamrajnagar	88.90	-2.112*	0.493	-2.82
Kodagu	39.35	0.757	0.226	1.71
Hassan	71.81	-0.647	0.087	-1.03
D. Kannada	57.82	0.579*	0.647	0.90
Udupi	86.67	-1.340*	0.507	-1.70
Chikamagalur	59.92	1.241	0.171	2.15
Chitradurga	87.78	-1.932*	0.297	-3.56
Davangere	73.73	-0.348	0.023	-0.34
Shimoga	49.57	1.265*	0.271	2.15
U. Kannada	41.28	1.024*	0.430	2.06
Dharwad	87.14	-1.182	0.139	-1.67
Haveri	74.75	0.285	0.016	0.28
Bellary	72.87	1.100	0.198	1.73
Gadag	87.31	-0.096	0.002	-0.14
Raichur	85.42	0.235*	0.499	0.27
Koppal	60.43	1.626*	0.358	2.40
Bijapur	91.46	-0.550*	0.350	-0.65
Bagalkot	12.03	0.244	0.234	1.67
Belgaum	88.80	-0.970	0.135	-1.46
Gulbarga	91.50	-0.432	0.103	-0.53
Bidar	57.77	0.207	0.009	0.41

* Significant at 5% level.

All other values are non-significant

Table 4.3.3: Estimates of trend on percent deficiency of Copper across the districts of Karnataka (1998-2013)

Districts	Intercept	Trend	R^2 Value	Compound Growth rate (%)
Bangalore rural	0.936	0.001	0.001	-0.08
Bangalore urban	3.171	-0.003	0.001	-0.07
Kolar	1.778	0.021	0.081	1.03
Tumkur	5.647	0.109	0.145	1.57
Mandya	3.231	-0.036	0.111	-1.46
Mysore	1.278	-0.016	0.112	-1.23
Kodagu	13.78	-0.174	0.135	-1.38
Hassan	6.538	0.108	0.111	1.45
D. Kannada	11.480	-0.050	0.014	-0.46
Udupi	4.338	-0.052	0.101	-1.40
Chikamagalur	2.230	0.022	0.049	0.84
Chitradurga	3.937	-0.087*	0.433	-2.65
Davangere	4.257	0.024	0.018	0.51
Shimoga	1.493	0.028	0.148	1.60
U. Kannada	0.327	-0.007*	0.307	-2.44
Dharwad	1.963	0.058*	0.354	2.47
Bellary	1.384	-0.019	0.128	-1.39
Gadag	1.355	-0.008	0.021	-0.77
Raichur	1.718	-0.003	0.006	-0.25
Koppal	0.152	-0.001	0.013	-0.48
Bijapur	1.849	-0.016	0.054	-1.01
Bagalkot	10.700	-0.065	0.023	-0.50
Belgaum	0.441	0.012*	0.312	2.42
Gulbarga	1.526	0.044*	0.289	2.37
Bidar	2.314	0.050	0.197	1.94

* Significant at 5% level.

All other values are non-significant

The result for different growth models estimated for percent deficiency of Manganese in 25 districts of Karnataka for 16 years are presented in Table 4.3.4. The linear trend for 10 districts *viz.*, Kolar, Mysore, D.Kannada, Chikamagalur, U.Kannada, Raichur, Bellary, Bagalkot, Belgaum and Gulbarga showed the significant increasing trend i.e. shifts in deficiency of Manganese and as well as change in the growth rate. Further, Bangalore Urban, Tumkur, Mandya, Kodagu, Hassan, Chitradurga, Davangere, Dharwad, Bijapur, Bidar districts have obtained the significant decreasing trend and remaining 5 districts i.e., Bangalore rural, Udupi, Shimoga, Gadag and Koppal showed there is no shift in deficiency of Manganese over a period of time.

The data presented in Table 4.3.5 reveals the linear trend and compound growth rate of percent deficiency of Iron, across the different district of Karnataka. The linear trend for 11 districts *viz.*, Bangalore rural, Kolar, Mysore, Kodagu, Hassan, Chikamagalur, Chitradurga, Shimoga, Raichur, Koppal and Bidar showed the significant increasing trend whereas 9 districts *viz.*, Tumkur, D. Kannada, Udupi, Davangere, U. Kannada, Haveri, Bellary, Gadag and Bijapur have obtained the significant decreasing trend i.e., shift in deficiency of Iron and as well as change in the growth rate over a period of time.

The result for different growth models estimated for percent deficiency of Boron in 27 districts of Karnataka for 16 years are presented in Table 4.3.6. The linear trend for 14 districts *viz.*, Bangalore rural, Bangalore urban, Kolar, Tumkur, Mysore, Kodagu, Hassan, Chikamagalur, Chitradurga, Davangere, U.Kannada, Bellary, Gadag and Koppal showed the significant increasing trend i.e., deficiency of Manganese increases and as well as change in the growth rate. However, six districts D.Kannada, Udupi, Shimoga, Raichur, Gulbarga and Bidar have obtained the significant decreasing trend. Further, 7 districts i.e., Mandya, Chamrajnagar, Dharwad, Haveri, Bijapur, Bagalkot and Belgaum showed there is no shift in deficiency of Boron over a period of time.

4.4 To study the impact of selected micronutrient status on productivity of Paddy and Ragi among districts in Karnataka

The fourth objective of the study was to examine the impact of micronutrients on productivity in agriculture across different district of Karnataka during the period of 1998-2009. To measure the impact of micronutrients on productivity, Multiple Linear Regression analysis was performed. The productivity of paddy and Ragi was considered as dependent variable and availability of Zinc and Boron accounted as independent variables. The results of correlation and regression multiple analysis are presented in Table 4.4.1 to Table 4.4.4.

Correlation coefficient between selected nutrients and productivity of Paddy.

The result presented in Table 4.4.1 indicates that the Zn was significant negatively correlated (4 districts) with productivity of paddy in Bangalore Urban, D. Kannada, Shimoga, and Bagalkot districts of Karnataka. However, the reaming districts (21 districts) were found to be non-significant.

Table 4.3.4: Estimates of trend on percent deficiency of Manganese across the districts of Karnataka (1998-2013)

Districts	Intercept	Trend	R^2 Value	Compound Growth rate (%)
Bangalore rural	1.337	0.011	0.033	0.77
Bangalore urban	3.186	-0.035*	0.080	-1.34
Kolar	1.993	0.041*	0.189	1.64
Tumkur	30.130	-0.657*	0.382	-2.40
Mandya	4.548	-0.082*	0.201	-3.22
Mysore	2.839	0.106*	0.431	2.71
Kodagu	2.157	-0.03*	0.171	-1.37
Hassan	3.309	-0.067*	0.339	-2.42
D. Kannada	12.420	0.492*	0.382	2.52
Udupi	21.100	0.083	0.008	0.24
Chikamagalur	2.205	0.025*	0.059	1.21
Chitradurga	2.537	-0.026*	0.119	-1.07
Davangere	2.429	-0.039*	0.188	-1.80
Shimoga	0.807	-0.004	0.019	-1.15
U. Kannada	1.743	0.016*	0.047	0.84
Dharwad	29.460	-0.755*	0.492	-4.38
Bellary	9.800	0.162*	0.128	1.38
Gadag	11.260	-0.016	0.001	-0.37
Raichur	12.900	0.139*	0.062	0.65
Koppal	72.350	0.290	0.009	0.33
Bijapur	11.684	-0.151*	0.248	-1.43
Bagalkot	68.880	0.671*	0.048	1.08
Belgaum	1.835	0.016*	0.037	0.64
Gulbarga	2.465	0.048*	0.158	1.68
Bidar	82.670	-0.697*	0.120	-0.96

* Significant at 5% level.

All other values are non-significant

Table 4.3.5: Estimates of trend on percent deficiency of Iron across the districts of Karnataka (1998-2013)

Districts	Intercept	Trend	R^2 value	Compound Growth rate (%)
Bangalore rural	12.76	0.120*	0.047	0.93
Bangalore urban	12.06	0.082	0.022	0.50
Kolar	13.04	0.261*	0.177	1.71
Tumkur	15.28	-0.196*	0.145	-1.21
Mandya	4.228	0.029	0.028	0.36
Mysore	12.59	0.124*	0.050	0.75
Chamrajnagar	62.64	-0.024	0.001	-0.09
Kodagu	3.534	0.078*	0.185	1.96
Hassan	2.694	0.066*	0.291	2.00
D. Kannada	6.271	-0.049*	0.039	-1.18
Udupi	2.660	-0.010*	0.037	-0.71
Chikamagalur	3.510	0.043*	0.074	1.15
Chitradurga	31.84	0.318*	0.054	1.31
Davangere	32.70	-0.237*	0.034	-0.71
Shimoga	1.778	0.052*	0.375	2.21
U. Kannada	2.225	-0.024*	0.112	-1.22
Dharwad	59.1	-0.067	0.001	4.63
Haveri	30.15	-0.344*	0.110	-1.03
Bellary	83.83	-2.339*	0.671	-3.56
Gadag	66.65	-1.436*	0.443	-2.88
Raichur	54.42	0.780*	0.048	7.25
Koppal	52.80	0.767*	0.155	1.89
Bijapur	64.96	-0.752*	0.109	-0.94
Bagalkot	51.20	-0.222	0.012	-0.33
Belgaum	49.30	-0.171	0.014	-0.52
Gulbarga	53.28	0.067	0.001	0.17
Bidar	17.40	0.604*	0.419	2.91

* Significant at 5% level.

All other values are non-significant

Table 4.3.6: Estimates of trend on percent deficiency of Boron across the district of Karnataka (1998-2013)

Districts	Intercept	Trend	R^2 value	Compound Growth rate (%)
Bangalore rural	26.29	0.645*	0.367	1.94
Bangalore urban	30.31	1.162*	0.475	3.07
Kolar	26.65	0.594*	0.217	2.60
Tumkur	24.79	0.715*	0.828	2.43
Mandya	36.59	-0.013	0.001	0.06
Mysore	32.52	0.371*	0.689	1.02
Chamrajnagar	30.63	0.187	0.021	0.49
Kodagu	33.88	0.374*	0.068	1.29
Hassan	22.75	0.676*	0.485	2.25
D. Kannada	52.88	-0.849*	0.414	-2.18
Udupi	68.22	-0.617*	0.181	-1.04
Chikamagalur	27.00	0.289*	0.054	1.26
Chitradurga	22.54	0.477*	0.261	1.95
Davangere	22.57	0.656*	0.357	2.28
Shimoga	42.07	-0.898*	0.407	-3.14
U. Kannada	28.14	0.698*	0.320	2.06
Dharwad	5.143	0.007	0.001	-0.14
Haveri	21.80	0.082	0.008	0.69
Bellary	21.19	0.222*	0.054	1.32
Gadag	5.499	0.043*	0.037	0.65
Raichur	35.88	-0.607*	0.481	-2.26
Koppal	21.10	0.557*	0.264	2.48
Bijapur	4.193	0.032	0.030	0.51
Bagalkot	32.48	0.157	0.012	0.41
Belgaum	3.802	0.027	0.025	1.13
Gulbarga	22.84	-0.557*	0.429	-3.46
Bidar	13.18	-0.182*	0.129	-1.58

* Significant at 5% level.

All other values are non-significant

Table 4.4.1: Correlation coefficients between selected nutrients and productivity of Paddy (1998-2009)

Districts	Correlation coefficient (r)	
	Zinc (Zn)	**Boron (B)**
Bangalore rural	0.444	-0.814**
Bangalore urban	-0.709**	-0.678*
Kolar	-0.034	-0.415
Tumkur	0.458	-0.366
Mandya	-0.282	-0.257
Mysore	-0.466	-0.104
Kodagu	-0.185	-0.466
Hassan	-0.440	-0.667*
D. Kannada	-0.658*	-0.207
Udupi	0.438	-0.173
Chikamagalur	-0.052	0.096
Chitradurga	-0.152	-0.699*
Davangere	-0.081	-0.117
Shimoga	-0.759**	0.202
U. Kannada	0.168	0.051
Dharwad	-0.196	-0.454
Bellary	-0.293	-0.367
Gadag	-0.019	-0.23
Raichur	-0.339	0.181
Koppal	-0.500	-0.174
Bijapur	0.285	-0.777**
Bagalkot	-0.579*	-0.307
Belgaum	-0.512	-0.274
Gulbarga	0.292	-0.629*
Bidar	0.215	0.384

****** Significant at 1% level, * Significant at 5% level.

All other values are non-significant.

The boron was negatively significantly correlated with productivity of paddy (6 districts) in Gulbarga, Bangalore Rural, Bangalore Urban, Chitradurga, Hassan and Bijapur. However, the reaming districts (19 districts) were found to be non-significant.

Estimates of Regression coefficients for Paddy

Table 4.4.2 shows that Boron was found to be significant for the productivity of paddy in Bangalore rural, Bangalore urban, Chitradurga and Gulbarga districts, whereas Zinc was found to be significant (3 districts) for Bangalore Urban, D. Kannada and Gulbarga districts, rest of the districts (19 districts) *viz.*, Kolar, Tumkur, Mandya, Mysore, Kodagu, Hassan, Udupi, Chikamagalur, Davangere, U. Kannada, Dharwad, Bellary, Gadag, Raichur, Koppal, Bijapur, Bagalkot, Belgaum and Bidar, were found to establish non significance for both Zinc and Boron on productivity of paddy.

The zinc had shown positive influence on productivity of paddy in 15 districts of Karnataka *viz.*, Bangalore rural, Bangalore urban, Kolar, Tumkur, Hassan, Udupi, Chitradurga, Davangere, U. Kannada, Dharwad, Koppal, Bijapur, Gulbarga, Bidar and negatively influence the productivity of paddy in Mandya, Mysore, Kodagu, D. Kannada, Chikamagalur, Shimoga, Bellary, Gadag, Raichur, Bagalkot and Belgaum.

The Boron influences negatively on the productivity of paddy in 15 districts of Karnataka *viz.*, Bangalore rural, Bangalore urban, Kolar, Tumkur, Kodagu, Hassan, D. Kannada, Chitradurga, Davangere, Dharwad, Gadag, Raichur, Koppal, Bijapur, Bagalkot, Belgaum, Gulbarga, Bidar and positively influence the remaining districts of Karnataka.

It is evident from findings that 6 districts *viz.*, Bangalore rural (0.695), Bangalore urban (0.699), Hassan (0.433), D. Kannada (0.360), Chitradurga (0.325), Shimoga (0.329), Bijapura (0.369) and Gulbarga (0.452) obtained the highest R^2 values from the analysis. Productivity of paddy is explained by selected independent variables (Zinc and Boron).

Correlation coefficient between selected nutrients and productivity of ragi relationship

The result presented in Table 4.4.3 indicates that the Zn was significantly positively correlated with productivity of Ragi in Bangalore Rural and Hassan districts of Karnataka and significantly negatively correlated (2 districts) with productivity of Ragi in Chikamagalur and Gadag. However, the reaming districts (13 districts) were found to be non-significant. Boron was non-significantly correlated with productivity of Ragi in all the districts of Karnataka.

Estimates of regression coefficient for Ragi (1998-2009)

Table 4.4.4 shows that Zinc was found to be significant for the productivity of ragi in Bangalore rural, Chikamagalur and Gadag districts, rest of the districts *viz.*, Bangalore urban, Kolar, Tumkur, Mandya, Mysore, Kodagu, Hassan, Chitradurga, Davangere, Shimoga, U. Kannada, Dharwad, Bellary and Belgaum, were found to establish non significance for both Zinc and Boron on productivity of ragi.

Table 4.4.2: Estimates of regression coefficients for Paddy (1998-2009)

Districts	Intercept	Regression coefficient(b)		R^2 Value
		Zinc (Zn)	Boran (B)	
Bangalore rural	6.048	0.027	-0.065*	0.695
Bangalore urban	5.094	-0.039*	-0.068*	0.699
Kolar	18.094	0.004	-0.236	0.176
Tumkur	16.957	0.016	-0.215	0.300
Mandya	2.151	-0.002	0.014	0.189
Mysore	0.789	-0.035	0.061	0.220
Kodagu	6.521	-0.020	-0.044	0.265
Hassan	7.388	0.001	-0.064	0.433
D. Kannada	30.403	-0.394*	-0.241	0.360
Udupi	1.308	0.042	0.008	0.194
Chikamagalur	-10.453	-0.011	0.196	0.132
Chitradurga	5.713	0.016	-0.044*	0.325
Davangere	3.047	0.008	-0.001	0.075
Shimoga	-31.105	-0.039*	0.567	0.329
U. Kannada	0.989	0.013	0.004	0.030
Dharwad	14.450	0.021	-0.141	0.230
Bellary	1.201	-0.002	0.026	0.129
Gadag	25.042	-0.014	-0.234	0.077
Raichur	104.064	-2.838	-0.938	0.156
Koppal	4.921	0.011	-0.028	0.110
Bijapur	18.882	0.088	-0.188	0.369
Bagalkot	2.670	-0.011	-0.017	0.084
Belgaum	-10.740	-0.013	0.135	0.105
Gulbarga	-8.894	0.002	-0.139*	0.452
Bidar	-3.040	0.006	0.040	0.223

* Significant at 5% level.

All other values are non-significant.

Table 4.4.3: Correlation coefficients between selected nutrients and productivity of Ragi (1998-2009)

Districts	Correlation coefficient (r)	
	Zinc (Zn)	Boran (B)
Bangalore rural	0.781**	-0.199
Bangalore urban	-0.215	-0.282
Kolar	0.153	0.603*
Tumkur	0.195	0.029
Mandya	0.297	0.089
Mysore	-0.039	0.172
Kodagu	0.242	-0.300
Hassan	0.638*	0.262
Chikamagalur	-0.752**	-0.113
Chitradurga	0.088	-0.060
Davangere	0.329	0.070
Shimoga	0.077	0.120
U. Kannada	-0.026	-0.031
Dharwad	0.005	-0.290
Bellary	0.318	-0.004
Gadag	-0.644*	0.007
Belgaum	-0.166	-0.188

****** significant at 1% level   * Significant at 5% level.

All other values are non-significant.

Table 4.4.4: Estimates of regression coefficients for Ragi (1998-2009)

Districts	Intercept	Regression coefficient (b)		R^2 Value
		Zinc (Zn)	Boran (B)	
Bangalore rural	0.236	0.027*	0.002	0.614
Bangalore urban	3.595	-0.006	-0.020	0.085
Kolar	-9.657	0.002	0.168	0.254
Tumkur	0.287	0.003	0.014	0.042
Mandya	1.911	0.009	-0.007	0.103
Mysore	-3.427	-0.003	0.077	0.041
Kodagu	1.492	0.008	-0.010	0.139
Hassan	-0.369	0.014	0.018	0.222
Chikamagalur	-0.044	-0.024*	0.032	0.569
Chitradurga	1.536	0.006	-0.005	0.016
Davangere	1.029	0.010	0.001	0.108
Shimoga	-10.76	0.002	0.192	0.023
U. Kannada	0.257	-0.014	0.025	0.224
Dharwad	8.151	0.002	-0.077	0.089
Bellary	1.772	0.009	-0.013	0.155
Gadag	15.32	-0.027*	-0.144	0.585
Belgaum	6.446	-0.008	-0.056	0.055

* Significant at 5% level

All other values are non-significant

The zinc had shown positive influence on productivity of ragi in 11 districts of Karnataka *viz.*, Bangalore rural, Kolar, Tumkur, Mandya, Kodagu, Hassan, Chitradurga, Davangere, Shimoga, Dharwad and Bellary and negatively influences the productivity of ragi in Bangalore urban, Mysore, Chikamagalur, U. Kannada, Gadag, and Belgaum.

The Boron influences positively on the productivity of ragi in 9 districts of Karnataka *viz.*, Bangalore rural, Kolar, Tumkur, Mysore, Hassan, Chikamagalur, Davangere, Shimoga, and U.Kannada and negatively influences the remaining eight districts of Karnataka.

It is evident from findings that Bangalore rural (0.614), Gadag (0.585) and Chikamagalur (0.569) obtained the highest R^2 values from the analysis. This indicates that around 61.4, 58.5 and 56.9 per cent of the variations in dependent variable i.e., productivity of ragi is explained by selected independent variables (Zinc and Boron).

V. DISCUSSION

The results presented in the previous chapter have been discussed in this chapter under the following objectives.

5.1 To estimate the extent of availability of soil chemical properties in the selected districts of Karnataka.

5.2 To statistically assess the extent of influence of soil properties on the nutrient status in the selected districts of Karnataka.

5.3 To assess the trend in deficiency of micronutrients across districts of Karnataka.

5.4 To study the impact of selected micronutrient status on productivity of Paddy and Ragi among districts in Karnataka.

As the study was empirical in nature based on the secondary data, in order to obtain the structural knowledge, basic statistics were obtained.

5.1 Descriptive Statistics for Soil Chemical Properties:

The Descriptive statistics was calculated for all the taluks of Bangalore district to know the variability of soil chemical properties.

5.1.1 Soil electrochemical properties (pH, EC and OC)

Soil pH is an important chemical property which helps in understanding process of chemical element in soil and the result presented in Table 4.1.1 shows that the highest pH found in Nelamangala as compare to lowest in Ramanagaram. The taluks are classified into three different categories *viz.*, Acidic, Neutral and Alkaline based on availability of pH for plant growth and development. Also, the distribution of pH observed to be positively skewed in 7 taluks and rest of the taluks are negatively skewed (Table 4.1.4.1). When compare the values of descriptive statistics in the above mentioned taluks showed that soil was slightly acidic (36.4%) to neutral (63.6%) in range of sample size hundred (Random selection). The variation in pH among soils under different taluks may be attributed to variation in rainfall, topographic position and management practices. Similar finding of slightly acidic pH was reported by Korikanthimath *et al.* (2002) and Tabi *et al.* (2012). Haribhushan Athokpam *et al.* (2013) also reported that soils were strongly acidic to neutral in reaction. Acidic in reaction of the district might be due to the high rainfall leading to the leaching losses of bases from the surface soils. Application of ammonical nitrogenous fertilizers and decomposition of organic residues hastened the soil acidity.

Electrical conductivity is a measure of total soluble salts, ranged from 0.03 to 0.44 d Sm^{-1} in the soils under study and was found to be normal in all the taluks (100 %) with respect to plant growth. Also, the distribution of EC has observed to be positively skewed in 9 taluks (Table 4.1.1 and Table 4.1.4.1). As observed, the soils from these twelve taluks recorded relatively low soluble salt concentration probably due to leaching of salts in these areas and poor drainage. This is conformity with the results of Dubey *et al.* (1983) who opined that the higher electrical conductivity of soils would result due to accumulation of salts. The wide variation of EC of the soils might be due to the different concentration of basic cations in the soils (Haribhushan Athokpam *et al.*, 2013).

It is universally accepted that SOM has beneficial effect on soil biological, chemical and physical properties as well as it is a contributor of plant nutrients, which in turn increases the productive capacity of soil. Table 4.1.1 showed that the organic carbon was highest in Bangalore north as compare to lowest in Ramanagaram. When compare the values of descriptive statistics in the above mentioned taluks indicate that soils belong to low to high organic carbon status and organic carbon has found to be positively skewed in 9 taluks viz., Doddaballapura, Nelamangala, Magadi, Ramanagaram, Channapatna, Bangalore North, Bangalore East, and Bangalore South. Low content might be due to coarse soil texture, cultivation practices and reduced application of organic matter to soil (Dudal, 1965). High status could be ascribed to regular addition of organics in the form of FYM and compost. Similar observation were noticed by Chidanandappa (2003) and Krishnamurthy (2001) indicating that application of organic manures enhances the organic carbon content in soils. This is conformity with the results of Haribhushan Athokpam *et al.* (2013) who opined that the variation in organic carbon content in the soil is due the luxuriant grasses growth along with the seasonal decomposition of vegetative parts and roots.

5.1.2 Macronutrients (Phosphorous and Potassium)

Table 4.1.2 showed that the phosphorous was highest in Magadi taluk as compare to lowest in Bangalore south. When compare the values of descriptive statistics in the above mentioned taluks indicate that 45.5 per cent soils belong to low,45.5 % in medium and 9.09 per cent high in phosphorous status and Low content might be due to coarse soil texture, cultivation practices and reduced application of organic matter to soil (Dudal, 1965).

Table 4.1.3 showed that the highest potassium found in Magadi as compare to lowest in Hoskote. When compare the classification of values of descriptive statistics in the above mentioned taluks indicate that, soils belong to low (72.7%) to medium (45.5%) status in red soil and results are presented in Table 4.1.4.2 Black soils were higher in available potassium status than red soils which may be due to predominance of K rich micaceous and feldspars minerals in parent material.

Also, the distribution Phosphorous and Potassium has found to be positively skewed in 6 taluks *viz.*, Devanahalli, Magadi, Ramanagaram, Channapatna, Bangalore south and Anekal and 4 taluks *viz.*, Hoskote, Nelamangala, Magadi and Channapatna, respectively.

5.1 3 Micronutrients

The result presented in Table 4.1.3a to 4.1.3b and 4.1.4.3a to 4.1.4.3b were revealed that the DTPA- extractable micronutrients viz., Zinc, Copper, Manganese and Iron were above the critical limits in soils of almost all the taluks of Bangalore Rural, Ramanagaram and Bangalore Urban district. The content of DTPA Zn, Cu, Mn and Fe which is far higher than critical level might be attributed primarily to lower soil pH, as pH decreases the solubility of these micronutrients increases (Brady and Weill, 1996). Secondly, the higher soil organic carbon content might have enhanced the microbial activity in the soil, and consequent release of complex organic substances (chelating agents) which form stable chelates with these elements thus decreases the susceptibility to precipitation, fixation, oxidation and leaching of micronutrients (Tisdale *et al.*, 1995). These results are in conformity with findings of Deepak Kher (1993) and Rajeev Kumar *et al.* (1993).

In general boron content was lower (63.3%) in soils under different locations of Bangalore Rural district. The lower available boron content in acid soils might be attributed to boron sorption to iron and aluminum oxides on surfaces of soil (Goldberg and Glaubio, 1985).

5.2 Inter-relationship between Soil Properties and Nutrients of selected districts of Karnataka

The regression analysis and correlation between dependent variables (nutrients) and explanatory variables (soil properties) were calculated. The results obtained from the Table 4.2.1 and Table 4.2.2.1 to 4.2.2.4 discussed in the following headings.

5.2.1 Influence of pH on availability of nutrients

Soil pH was positively correlated with Phosphorous, Potassium, Zinc, Copper, Manganese, Iron and Boron. In acidic soil all the nutrients are positively correlated with pH. Whereas, in alkaline soils the soil nutrients are negatively correlated with pH. Acidic reaction may be due to the high rainfall leading to the leaching losses of bases from the surface soils. It, leads to positive effect on nutrient status. These results are in conformity with findings of Behera et al. (2008) and Haribhushan Athokpam *et al.* (2013) who opined that the DTPA-extractable micro- nutrient cations are positively correlated with soil pH.

5.2.2 Influence of EC on Availability of nutrients

All the nutrients *viz.,* Phosphorous, Potassium, Zinc, Copper, and Manganese were positively and significantly correlated with EC and non-significantly negatively correlated with rest of the nutrients *viz.,* Iron and Boron and regression coefficient also observed, significant for Phosphorous, Potassium, Zinc, Copper, and Manganese. The correlation gives a degree of association whereas, regression give the actual contribution of independent variable on dependent variable i.e. availability of nutrients. This is conformity with the results of Sharma *et al.* (2007) who opined that available Zinc significantly positively correlated with EC.

5.2.2 Influence of OC on Availability of nutrients

Similarly, OC was significantly positively correlated with all the nutrients. Due to decomposition of organic matter, pH decreases in soil locally, which helps in increasing solubility of Zn from soil materials. Addition of organic matter improves the soil structure and aeration, which increase the availability of Fe (Singh and Banerjee 1984).

The availability of the metal cations (Zn, Cu, Fe, and Mn) increases with increase in organic matter content because organic matter may chelate with metal cations. Similar, finding was reported by Sharma *et al.* (2003). The positive correlation may be due to the formation of organic complexes between organic matter and Zinc that protects it from leaching as it was reported by Patiram *et al.* (2000).Organic matter and manure applications affect the immediate and potential availability of micro- nutrient cations (Rengel, 2007). The micro- nutrient cations react with certain organic molecules to form organometallic complexes as chelates and soluble chelates can increase the availability of the micro- nutrient and protect it from precipitation reactions.

5.3 Trend analysis

Trend analysis was carried out to know the changes in the deficiency of micronutrients over the period of 1998-2013.

The data presented in Table 4.3.1 indicates that the mean percentage deficiency of selected micronutrients across the district of Karnataka. The deficiency of Zinc and Boron were found to be highest in the majority of districts as compare to other micronutrients. Deficiency might be due to cultivation of high yielding varieties, application of NPK fertilizers and other environmental factors.

Table 4.3.2 shows the linear trend and compound growth rate of percent deficiency of Zinc across the different district of Karnataka. D.Kannada, Shimoga, U.Kannada, Raichur, Koppal showed the significant increasing trend i.e. shift in deficiency of Zinc and as well as change in the growth rate. Chamrajnagar, Udupi, Chitradurga and Bijapur districts have obtained the significant decreasing trend, Rest of the districts i.e., Bangalore rural, Bangalore urban, Kolar, Tumkur, Mandya, Mysore, Kodagu, Hassan, Chikamagalur, Davangere, Dharwad, Haveri, Bellary, Gadag, Bagalkot, Belgaum, Gulbarga and Bidar showed that there was no shift in deficiency of Zinc over a period of time.

Table 4.3.3 shows the linear trend and compound growth rate of per cent deficiency of Copper across the districts of Karnataka. Dharwad, Belgaum and Gulbarga showed significant increasing trend i.e. shift in deficiency of Copper as well as change in growth rate. Whereas, Chitradurga and U. Kannada districts have obtained significant decreasing trend. Rest of the districts i.e. Bangalore rural, Bangalore urban, Kolar, Tumkur, Mandya, Mysore, Kodagu, Hassan, Chikamagalur, Davangere, Haveri, Bellary, Gadag, Bagalkot, Chamrajnagar, Udupi, Bijapur, Shimoga and Bidar districts have showed that there was no shift in the deficiency of Copper over a period of time.

Table 4.3.4 shows the trend and compound growth rate of percent deficiency of Manganese across the districts of Karnataka. Kolar, Mysore, D. Kannada, Chikamagalur, U. Kannada and Bellary showed significant increasing trend i.e. shift in deficiency of Manganese as well as change in growth rate was observed. Whereas, Bangalore Urban, Tumkur, Mandya, Kodagu, Hassan, Chitradurga, Davangere, Dharwad, Bijapur and Bidar districts have showed significant decreasing trend. It was observed that rest of the district does not have shift in Manganese deficiency. Manganese deficiency was observed to be less compared to other micronutrients in the above mentioned districts.

Table 4.3.5 shows trend and compound growth rate of per cent deficiency of Iron across the districts of Karnataka, 10 districts viz., Bangalore rural, Kolar, Mysore, Kodagu, Hassan, Chikamagalur, Chitradurga, Shimoga, Raichur and Koppal showed significant increased trend. It implies that, shift in deficiency of Iron as well as change in growth rate was observed. Whereas, Tumkur, Chamrajnagar, D. Kannada, Udupi, Davangere, U. Kannada, Haveri and Bellary showed significant decreasing trend. It was observed that, rest of the districts does not have shift in Iron deficiency.

Table 4.3.6 shows linear trend and compound growth rate of per cent deficiency of Boron across the districts of Karnataka. It was observed that, the linear trend for 14 districts viz., Bangalore rural, Bangalore urban, Kolar, Tumkur, Mysore, Hassan, Kodagu, Chikamagalur, Chitradurga, Davangere, U.Kannada, Bellary, Gadag and Koppal have showed significant increasing trend. It implies that, shift in deficiency of Boron and deficiency was observed in these districts. Whereas, D. Kannada, Udupi, Shimoga, Raichur and Bidar districts showed significant decreasing trend. The rest of the districts were observed to have no shift in deficiency of Boron.

The shift in deficiency of micronutrients might be due to cultivation of high yielding varieties, application of NPK fertilizers and also depend on nature of parent material, climate, vegetation, soil type and physicochemical properties of the soil.

5.4 Multiple regression analysis

The multiple regression analysis was done by considering availability of selected micronutrients like Zinc and Boron on productivity of paddy results found to be significant with high R^2 value. Out of 7 micronutrients, Zinc and Boron showing the highest impact on productivity of Paddy and Ragi that, reason Zinc and Boron are considered as independent variables.

The result presented in Table 4.4.1 indicates that the Zn was significantly negatively correlated (4 districts) with productivity of paddy in Bangalore Urban, Shimoga, D. Kannada and Bagalkot districts of Karnataka showing decrease in productivity. However, the reaming districts (19 districts) were found to be non-significant.

The boron was negatively significantly correlated with productivity of paddy (6 districts) in Gulbarga, Bangalore Rural, Bangalore Urban, Chitradurga, Hassan and Bijapur (productivity decreases). However, the reaming districts (19 districts) were found to be non-significant.

Table 4.4.2 showed that Boron was found to be significant for the productivity of paddy in Bangalore rural, Bangalore urban, Chitradurga and Gulbarga districts, whereas Zinc was found to be significant (3 districts) for Bangalore Urban, D. Kannada and Gulbarga districts, rest of the 19 districts *viz.*, Kolar, Tumkur, Mandya, Mysore, Kodagu, Hassan, Udupi, Chikamagalur, Davangere, U. Kannada, Dharwad, Bellary, Gadag, Raichur, Koppal, Bijapur, Bagalkot, Belgaum and Bidar, were found to establish non significance for both Zinc and Boron on productivity of paddy.

Zinc was positively influences on productivity of paddy in 15 districts of Karnataka *viz.*, Bangalore rural, Bangalore urban, Kolar, Tumkur, Hassan, Udupi, Chitradurga, Davangere, U. Kannada, Dharwad, Koppal, Bijapur, Bagalkot, Gulbarga, Bidar and negatively influence the productivity of paddy in Mandya, Mysore, Kodagu, D. Kannada, Chikamagalur, Shimoga, Bellary, Gadag, Raichur, Bagalkot and Belgaum.

The Boron influences negatively on the productivity of paddy in 15 districts of Karnataka viz., Bangalore rural, Bangalore urban, Kolar, Tumkur, Kodagu, Hassan, D. Kannada, Chitradurga, Davangere, Dharwad, Gadag, Raichur, Koppal, Bijapur, Bagalkot, Belgaum, Gulbarga, Bidar and positively influences the remaining districts of Karnataka.

It is evident from findings that highest R^2 was found in Bangalore rural, the highest R^2 value has indicated that around 69.5 of the variations in dependent variable i.e., productivity of paddy is explained by selected independent variables (Zinc and Boron).

The result presented in Table 4.4.3 indicates that the Zn was significantly positively correlated with productivity of Ragi in Bangalore Rural and Hassan districts of Karnataka and significantly negatively correlated (2 districts) with productivity of Ragi in Chikamagalur and Gadag. However, the reaming districts (13 districts) were found to be non-significant. Boron was non-significantly correlated with productivity of Ragi in all the districts of Karnataka.

Table 4.4.4 showed that Zinc was found to be significant for the productivity of ragi in Bangalore rural, Chikamagalur and Gadag districts, rest of the districts viz., Bangalore urban, Kolar, Tumkur, Mandya, Mysore, Kodagu, Hassan, Chitradurga, Davangere, Shimoga, U. Kannada, Dharwad, Bellary and Belgaum, were found to establish non significance for both Zinc and Boron on productivity of ragi.

The zinc had shown positive influence on productivity of ragi in 11 districts of Karnataka viz., Bangalore rural, Kolar, Tumkur, Mandya, Kodagu, Hassan, Chitradurga, Davangere, Shimoga, Dharwad and Bellary and negatively influences the productivity of ragi in Bangalore urban, Mysore, Chikamagalur, U. Kannada, Gadag and Belgaum.

The Boron influences positively on the productivity of ragi in 9 districts of Karnataka *viz.*, Bangalore rural, Kolar, Tumkur, Mysore, Hassan, Chikamagalur, Davangere, Shimoga and U. Kannada and positively influences the reaming districts of Karnataka.

The highest R^2 in Bangalore rural district showed that, 61.4% of the variations in dependent variable i.e., productivity of ragi is explained by selected independent variables (Zinc and Boron).

VI SUMMARY

6.1 Concepts of soil nutrients

Soil fertility is determined by the presence or absence of soil nutrients i.e. macro and micronutrients. The elements are required in minute quantities for plant growth and are referred as micronutrients *viz*., Zinc (Zn), Copper (Cu), Iron (Fe), Manganese (Mn), Molybdenum (Mo), Chlorine (Cl) and Boron (B). Macronutrients are essential elements used by plants in relatively large amount for plant growth such as nitrogen (N), phosphorous (P), potassium (K), Calcium (Ca), magnesium (Mg), and sulfur (S). The availability of these soil nutrients is particularly sensitive to changes in soil environment. The factors that affect the contents of such nutrients are organic matter, soil pH, lime, sand, silt, and clay contents. There is also a correlation among the nutrient contents and above-mentioned properties. Deficiency or excess supply of these micronutrient elements will be reflected upon the health of plants as evidenced by the crop plants and are very small as compared to the major nutrients, deficiency of any micronutrient element may cause an extremely disturbing effect on plant growth processes and consequent reduction in crop yield. Hence studying a model to know the effects of these soil nutrients on the crop plants is an important aspect of statistical investigation.

6.2 Study regions

The study area consists of nutrient status and their effect on yield under ragi and paddy growing areas of Karnataka state. The districts considered are Bangalore rural, Bangalore urban, Kolar, Tumkur, Mandya, Mysore, Chamrajnagar, Kodagu, Hassan, D. Kannada, Udupi, Chikamagalur, Chitradurga, Davangere, Shimoga, U. Kannada, Dharwad, Haveri, Bellary, Gadag, Raichur, Koppal, Bijapur, Bagalkot, Belgaum and Gulbarga and eleven taluks of Bangalore district namely Devanahalli, Hoskote, Doddaballapura, Nelamangala, Magadi, Ramanagaram, Channapatna, Bangalore North, Bangalore South, Bangalore East and Anekal.

6.3 Data Base, Period of Study and Selected crops

The taluk wise secondary data on the soil parameters *viz.,* pH, EC, OC, P, K, Zn, Fe, Mn and B content of Bangalore Rural, Bangalore Urban and Ramanagaram districts of six years data from 2007-2013 of sample size hundred (Random selection) and District wise, per cent deficiency (Zn, Cu, Fe, Mn and B) of sixteen years data from 1998-2013 were collected from Agricultural Department. Similarly, productivity data of paddy and Ragi of twelve years from 1998-99 to 2009-2010 were collected from Directorate of Economics and Statistics, Bangalore and India stat website.

6.4 Objectives of investigation

6.1 To estimate the extent of availability of soil chemical properties in the selected districts of Karnataka.

6.2 To statistically assess the extent of influence of soil properties on the nutrient status in the selected districts of Karnataka.

6.3 To assess the trend in deficiency of micronutrients across districts of Karnataka.

6.4 To study the impact of selected micronutrient status on productivity of Paddy and Ragi among districts in Karnataka.

6.5 Nutrient status

In the present study descriptive statistics was used to know the fertility status of eleven taluks *viz.*, Devanahalli, Hoskote, Doddaballapura, Nelamangala, Magadi, Ramanagaram, Channapatna, Bangalore north, Bangalore east, Bangalore south and Anekal of Bangalore Rural, Ramanagaram and Bangalore Urban district of sample size hundred (Random selection).

The result shows that highest pH was found in Nelamangala as compared to lowest in Ramanagaram. Similarly, Bangalore north was found to be highest in EC, OC, K, Zn, Cu, Mn and B. The highest P and Fe were found in Magadi and Bangalore East respectively.

6.6 Correlation and Regression analysis

The correlation and regression analysis were calculated for selected districts of Karnataka.

6.6.1 Influence of pH, CEC and OC on Availability of nutrients

In acid condition all the nutrients viz., Phosphorous, Potassium, Zinc, Copper, Manganese, Iron and Boron were positively correlated with pH. Acidic in reaction of the district might be due to the high rainfall leading to the leaching losses of bases from the surface soils. Application of nitrogenous fertilizers and decomposition of organic residues hastened the soil acidity.

EC was significantly positively correlated with Phosphorous, Potassium, Zinc, Copper and Manganese thereby indicating that all the mentioned nutrients increases with an increase in EC in acid soil, rest of the nutrients was found to be non-significant.

OC was significantly positively correlated with all the selected nutrients viz., Phosphorous, Potassium, Zinc, Copper, Manganese, Iron and Boron. The availability of the metal ions (Zn, Cu, Fe, Mn) increases with increase in organic matter content because organic matter may supply chelating agents.

6.7 Trend analysis

The per cent deficiency of Zinc and Boron were found to be high in all the districts of Karnataka as compare to other micronutrients and trend analysis was carried out to find out the changes in the deficiency of micronutrients *viz.*, Zinc, Copper, Manganese, Iron and Boron over the period of time.

D.Kannada, Shimoga, U.Kannada, Raichur and Koppal showed the significant increasing trends in deficiency of Zinc i.e. shift in deficiency of Zinc as well as change in the growth rate was observed. Chamrajnagar, Udupi, Chitradurga and Bijapur districts have obtained the significant decreasing trend.

Dharwad, Belgaum and Gulbarga showed significant increasing trend in deficiency of Copper i.e. shift in deficiency of Copper as well as change in growth rate was observed. Whereas, Chitradurga and U. Kannada districts have obtained significant decreasing trend. Rest of the districts i.e. Bangalore rural, Bangalore urban, Kolar, Tumkur, Mandya, Mysore, Kodagu, Hassan, Chikamagalur, Davangere, Haveri, Bellary, Gadag, Bagalkot, Chamrajnagar, Udupi, Bijapur, Shimoga and Bidar districts have showed that there was no shift in the deficiency of Copper over a period of time.

The linear trend and compound growth rate of per cent deficiency of Manganese in Kolar, Mysore, D. Kannada, Chikamagalur, U. Kannada and Bellary showed shift in deficiency of Manganese as well as change in growth rate was observed. Whereas, Bangalore Urban, Tumkur, Mandya, Kodagu, Hassan, Chitradurga, Davangere, Dharwad, Bijapur and Bidar districts have showed significant decreasing trend. It was observed that rest of the district does not have shift in Manganese deficiency. Since, Manganese deficiency was observed to be less compared to other micronutrients in the above mentioned districts.

The linear trend calculated for Bangalore rural, Kolar, Mysore, Kodagu, Hassan, Chikamagalur, Chitradurga, Shimoga, Raichur and Koppal have showed significant increasing trend in deficiency of Iron. Whereas, Tumkur, Chamrajnagar, D. Kannada, Udupi, Davangere, U. Kannada, Haveri and Bellary showed significant decreasing trend. It was observed that, rest of the districts does not have shift in Iron deficiency.

It was observed that, the linear trend for 14 districts viz., Bangalore rural, Bangalore urban, Kolar, Tumkur, Mysore, Hassan, Kodagu, Chikamagalur, Chitradurga, Davangere, U.Kannada, Bellary, Gadag and Koppal have showed significant increasing trend in deficiency of Boron. Whereas, D. Kannada, Udupi, Shimoga, Raichur and Bidar districts showed significant decreasing trend. The rest of the districts were observed to have no shift in deficiency of Boron.

6.8 Correlation analysis

Correlation coefficient between selected nutrients and productivity of Paddy

Zn was significant negatively correlated (4 districts) with productivity of paddy in Bangalore Urban, D. Kannada, Shimoga, and Bagalkot districts of Karnataka.

The boron was significantly negatively correlated with productivity of paddy (5 districts) in Gulbarga, Bangalore Rural, Bangalore Urban, Chitradurga, Hassan and Bijapur.

Correlation coefficient between selected nutrients and productivity of ragi relationship

Zn was significantly positively correlated with productivity (increases) of Ragi in Bangalore Rural and Hassan districts of Karnataka and significantly negatively correlated (5 districts) with productivity (decreases) of Ragi in Chikamagalur and Gadag.

6.9 Multiple regression analysis

The multiple regression analysis was done by considering availability of selected micronutrients like Zinc and Boron on productivity of paddy results found to be significant with high R^2 value.

The highest R^2 in Bangalore rural district showed that, 61.4% of the variations in dependent variable i.e., productivity of ragi is explained by selected independent variables (Zinc and Boron).

6.10 Policy implication

1. The deficiency of micronutrients increased over a period of time .So, that it is better to apply organic manures to the soil.
2. In most of the districts deficiency of Zinc and Boron was high; it shows negative impact on productivity of Paddy and Ragi. Application of recommended dose of Zinc and Boron fertilizer increases the productivity of selected crops.

6.11 Future line of work

1. The research study can be extended to other Agriculture and Horticultural crops like Cereal, Pulses, fruits, plantation crops, Spices, Ornamental crops and vegetables with respect to district wise analysis.
2. Similar analysis could be carried out by considering other nutrients.

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