Spatial variability mapping of micronutrients to improve productivity using Geo-informatics Technology in Gujarat state, India

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Abstract— Soil surveying and mapping is an important operation, since it plays a key role in the knowledge about soil nutrients and how it can be used for agriculture. The major objective of present study was to map the spatial variability of soil micronutrients (Fe, Mn, Zn, Cu and B) in North, Center and South districts zones of Gujarat state, India. Geographic Information System (GIS) was used in this study to analyze the data of the soil micronutrients which were obtained from Anand Agriculture University (AAU), Gujarat. The micronutrients data was analyzed through spatial interpolation techniques namely Inverse Distance Weightage (IDW) method in GIS environment for suitable mapping in a selected North, Central and South districts of Gujarat state.

Various maps showing spatial distribution of micronutrients for various districts in three zones of Gujarat state were prepared. These digital maps can be used in precision farming studies with the application of fertilizers as per the requirement and the recommendations. This approach is proposed as a method for the evaluation of sustainable soil management practices such as variable rate of fertilization. This study demonstrates the usefulness of geo-informatics technology in soil survey as well as applications of various micronutrients to specific areas based on recommendations.

Index Terms— Geographic Information System (GIS), Inverse Distance Weighted (IDW), soil survey, micronutrients, spatial distribution,

1 INTRODUCTION

Micronutrient deficiency in soil has become wide spread in recent years and has resulted in low crop yields, more so after the introduction of high yielding crop varieties coupled with the use of high analysis fertilizer and increased cropping intensity.

Soil surveying and mapping provides information regarding nutrient availability in soils which forms the basis for the fertilizer recommendations for maximizing crop yields. Soil fertility maps are meant for highlighting the nutrient needs, based on fertility status of soils (and adverse soil conditions which need improvement) to realize good crop yields. Obviously, a soil fertility map for a particular area can prove highly beneficial in guiding the farmers, manufacturers and planners in ascertaining the requirement of various fertilizers in a season/year and making projections for increased requirement based on cropping pattern and intensity. GIS can be used in producing a soil fertility map of an area, which will help in formulating site specific balanced fertilizer recommendation and to understand the status of soil fertility spatially and temporally.

A systematic set of geo-referenced samples was collected from the Muktsar district covering the entire area using GPS (Global positioning system) and the maps showing the spatial variability of individual micronutrient cation (Zn, Cu, Mn and Fe) were generated using Arc Info GIS (Geographic information system). The multi-micronutrient status map was also generated by integrating the individual micronutrient cation map in GIS (Sood et al., 2009). The results of the study revealed that in Muktsar district of Punjab, 39, 7, 8 and 34 per cent of the total geographical area of the district was deficient in Zn, Cu, Mn and Fe, respectively.

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The relative importance of micronutrients is very high in crop production. The micronutrients are present in small quantities in the soil and most of the crops are sensitive to deficiencies of these micronutrients. The deficiencies of Mn, Cu, and Zn are mainly reported on sandy soils that are low in organic matter (Verma et al., 2005). Dhane and Shukla (1995) concluded that judicious use of nitrogenous and phosphatic fertilizer in the intensive cropping system may cause the quick depletion of micronutrients in soils. Recent modern technologies such as Remote Sensing (RS), DGPS, GIS and geostatistics are playing a vital role for quantifying spatial variation and interpolation of soil characteristics.

Spatial variability in soil is, important to identify the nutrient constraint zones vis-à-vis production zones to rationalize the nutrient use. The precision agriculture, therefore, largely depends upon the management of spatial variability in soil fertility which is a major production constraint (Srivastava et al., 2010).

2. STUDY AREA

For measurement of spatial variability and mapping of soil micronutrients; three districts in each North, Center and South zones of Gujarat state have been selected: i) ***North district zone:*** Patan, Mehsana, Sabarkantha, ii) ***Center district zone:*** Ahmadabad, Kheda, Panchmahals, iii) ***South district zone:*** Anand, Vadodara and Bharuch (**Figure-1**).

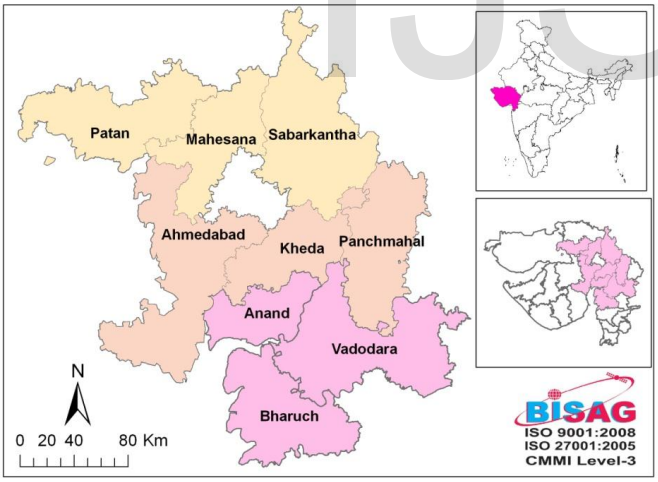


Figure-1: Location map of study area in Gujarat State

3. Objectives

The major objectives of this study are as follows:

i) To Analyze & visualize the Soil micronutrients (Fe, Mn, Zn, Cu and B) data through spatial interpolation techniques namely Inverse Distance Weightage (IDW) method in GIS environment for suitable mapping in a selected North, Central and South districts of Gujarat state.

ii) To study and map spatial variability of micronutrients GIS based interpolation technique.

iii) To assess the spatial distribution of relevant micronutrients in agricultural soils across selected three district zones of Gujarat State.

iv) To assess the spatial variability of micronutrients at the basic process level using geo-statistical analysis for nutrients and other soil management options.

v) To enhance farm profitability by optimizing nutrient recommendations on the basis of fertility maps and socio-economic specificity of the farms and farmers, respectively, in a precision agriculture mode.

4. Materials and Methods

This section describes the technical procedures followed in the GIS analyses and mapping of Soil micronutrients (Fe, Mn, Zn, Cu and B) across the North, Center and South district zones of Gujarat state. The soils micronutrients datasets were obtained from Anand Agriculture University (AAU) in spreadsheet (Excel) format. The data is of 2012 and it covers total 9 districts of North, Center and South district zones of Gujarat state. The datasets underwent several preparation, conversion, interpolation, processing and analyses steps in spreadsheet and GIS formats.

4.1 Generation of thematic maps

Thematic maps were generated for each of the soils micronutrients using Inverse Distance Weighted (IDW) interpolation provided in Arc GIS 10 software. IDW interpolation determines cell values using a linearly weighted combination of a set of sample points. The weight is a function of inverse distance. IDW lets the user control the significance of known points on the interpolated values based on their distance from the output point.

4.2 Geo-statistical analysis

After generation of thematic maps perform Geo-statistical Analysis using Geo-statistical Analyst toolbar for finding the minimum, maximum and average value of Soil micronutrients across North, Center and South districts zone of Gujarat state.

5. Results and Discussions

5.1 Micronutrients status of soils across North, Central and South district zones of Gujarat state.

The micronutrients ststus in terms of **Iron (Fe), Manganese (Mn), zinc (Zn), Copper (Cu) and Boron (B)** were analyzed for all the districts in each zone and are given in Table-1.

District Zone	Micronutrients	Minimum	Maximum	Mean
North Districts	Fe	2	16	7
	Mn	5	71	25
	Zn	0.1	8.6	1.1
	Cu	0.3	3.9	1.1
	B	0.1	1.4	0.5
Center Districts	Fe	2	38	13
	Mn	4	98	17
	Zn	0.3	3.9	1.2
	Cu	0.5	4.5	1.9
	B	0.1	2.3	0.6
South Districts	Fe	1	43	12
	Mn	3	90	19
	Zn	0.3	3.6	1.1
	Cu	1	7.8	2.7
	B	0.1	1.5	0.5

Table 1: Micronutrients status of soil across North, Central and South districts zones of Gujarat state

Based on the analysis of micronutrients of soils of districts in ach zones, they were classified in to three ratings as given in Table-2.

Rating	Micronutrients (ppm)				
	Fe	Mn	Zn	Cu	B
Low	<5.0	<5.0	<0.5	<0.2	<0.1
Medium	5-10	5-10	0.5-1.0	0.2-0.4	0.1- 0.5
High	>10.0	>10.0	>1.0	>0.4	>0.5

(Source: www.gsfclimited.com)

Table 2: Rating for classification of soil micronutrients

5.1.1 Available Iron (Fe) status

The available Fe content in the soils of North district zone varied from 2 to 16 ppm with a mean value of 7 ppm considering the soil across the North districts zone of Gujarat have optimum amount of available iron while the available Fe content in the soils of center district zone is varied from 2 to 38 ppm with a mean value of 13 ppm and in south districts zone available Fe content is varied from 1 to 43 ppm with a mean value of 12 ppm considering the soil across the center and south districts zone of Gujarat have high amount of available iron. The spatial distribution maps generated using IDW, interpolation technique for districts in three zones are given in **Figures-2, 3 and 4.**

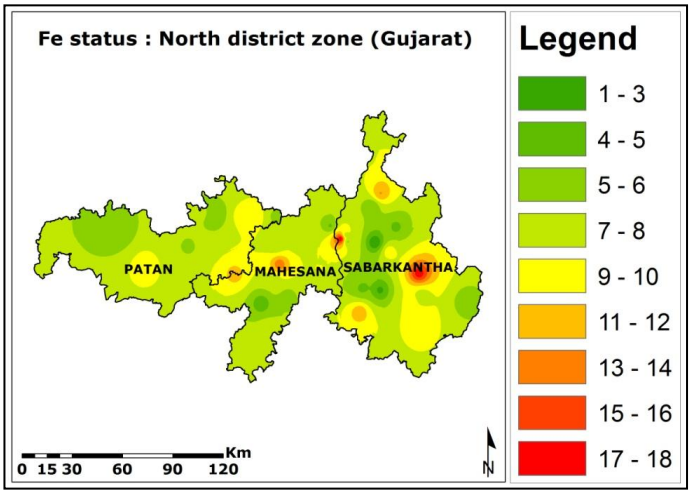


Figure-2: Iron status & spatial distribution in North district zone

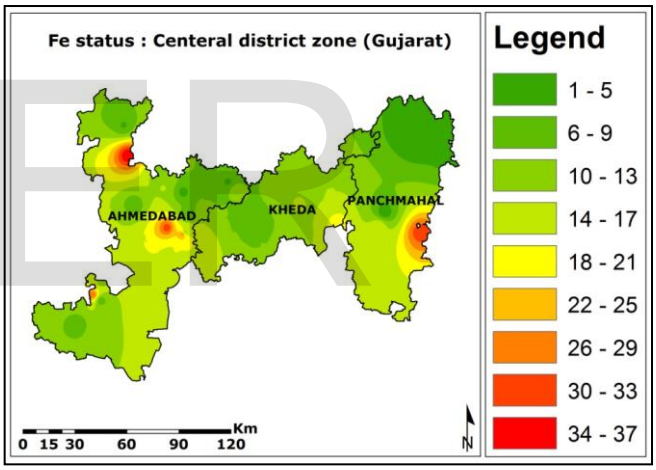


Figure-3: Iron status & spatial distribution in Center district zone

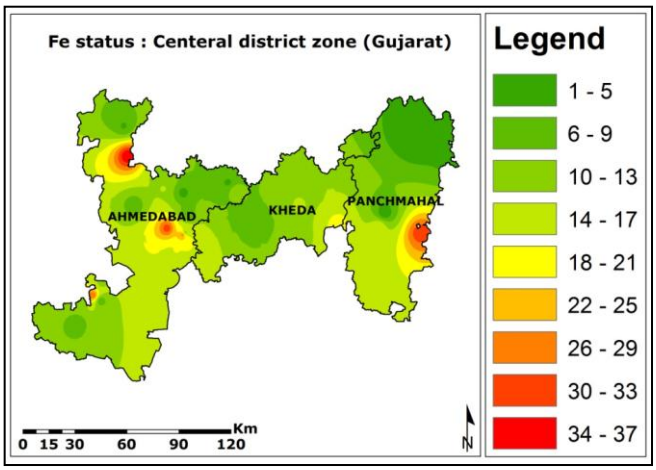


Figure-4: Iron status & spatial distribution in South district

zone

5.1.2 Available Manganese (Mn) status

The available Mn content in the soils of north district zone varied from 5 to 71 ppm with a mean value of 25 ppm while the available Mn content in the soils of center district zone is varied from 4 to 98 ppm with a mean value of 17 ppm and in south districts zone available Mn content is varied from 3 to 90 ppm with a mean value of 19 ppm considering the soils across the North, Center and South districts zone of Gujarat have high amount of available manganese. The spatial distribution maps generated using IDW, interpolation technique for districts in three zones are given in **Figures-5, 6 and 7**.

Recommendation: If the amount of manganese is low or optimum then it is recommended to give 10 kg ha^{-1} manganese sulphate in the soil. If the level of manganese is high then there is no need to use manganese contain fertilizer.

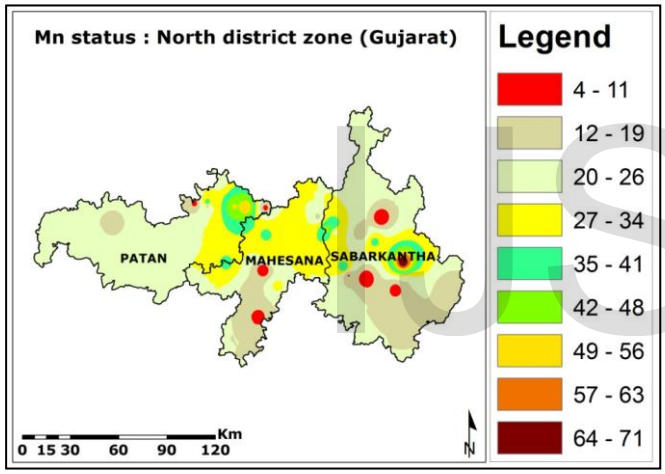


Figure-5: Manganese status & spatial distribution in North district zone

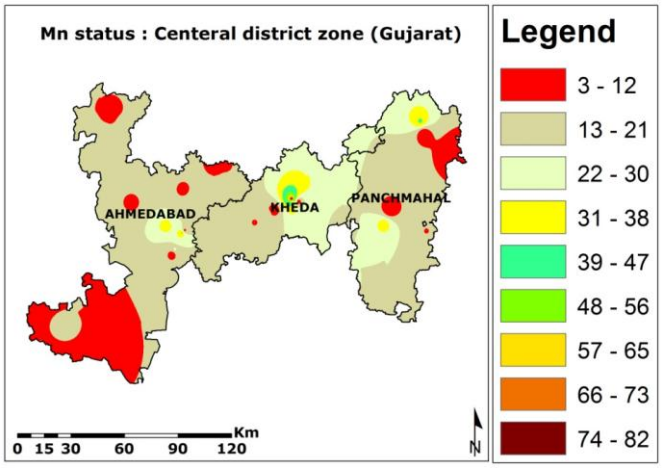


Figure-6: Manganese status & spatial distribution in Center district zone

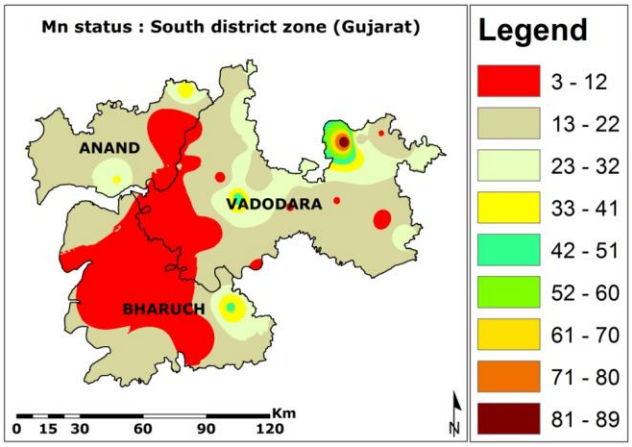


Figure-7: Manganese status & spatial distribution in South district zone

5.1.3 Available Zinc (Zn) status

The available Zn content in the soils of North district zone varied from 0.1 to 8.6 ppm with a mean value of 1.1 ppm while the available Zn content in the soils of center district zone is varied from 0.3 to 3.9 ppm with a mean value of 1.2 ppm and in south districts zone available Zn content is varied from 0.3 to 3.6 ppm with a mean value of 1.1 ppm considering the soils across the North, Center and South districts zone of Gujarat have high amount of available zinc. The spatial distribution maps generated using IDW, interpolation technique for districts in three zones are given in **Figures-8, 9 and 10**.

Recommendation: If the amount of zinc is low or optimum then it is recommended to give 10 kg ha^{-1} zinc sulphate in the soil. If the level of zinc is higher then there is no need to use zinc contain fertilizer.

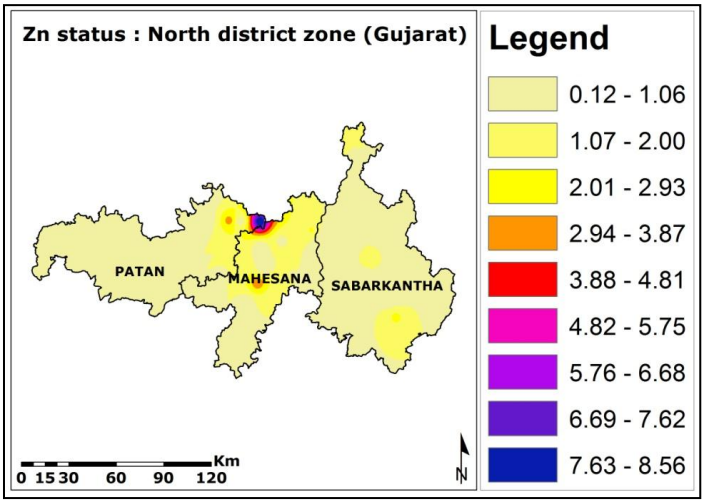


Figure-8: Zinc status & spatial distribution in North district zone

the level of Cu is higher then there is no need to use Cu contain fertilizer.

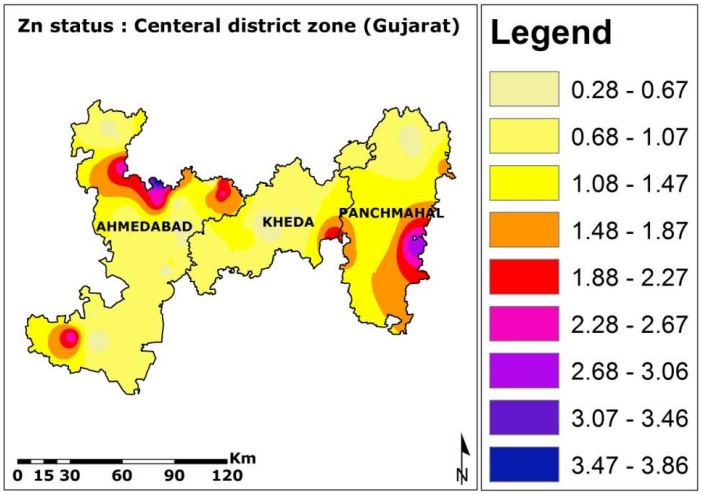


Figure-9: Zinc status & spatial distribution in Center district zone

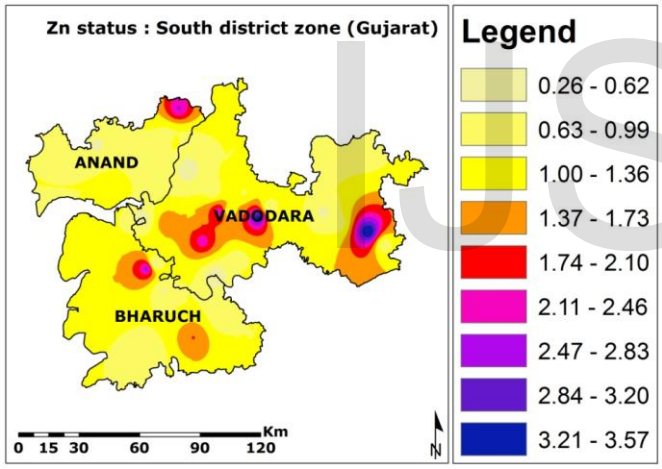


Figure-10: Zinc status & spatial distribution in South district zone

5.1.4 Available Copper (Cu) status

The available Cu content in the soils of North district zone varied from 0.3 to 3.9 ppm with a mean value of 1.1 ppm while the available Cu content in the soils of center district zone is varied from 0.5 to 4.5 ppm with a mean value of 1.9 ppm and in south districts zone available Cu content is varied from 1 to 7.8 ppm with a mean value of 2.7 ppm considering the soils across the North, Center and South districts zone of Gujarat have high amount of available copper. The spatial distribution maps generated using IDW, interpolation technique for districts in three zones are given in **Figures-11, 12 and 13.**

Recommendation: If the amount of copper is low then it is recommended to give 2 to 4% copper sulphate in the soil. If

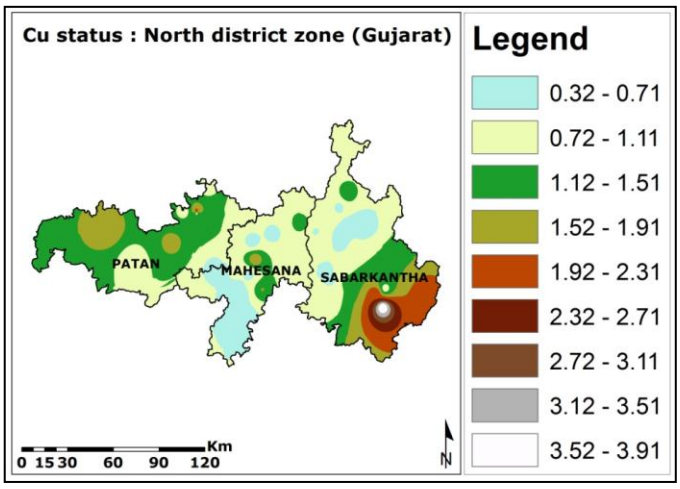


Figure-11: Copper status & spatial distribution in North district zone

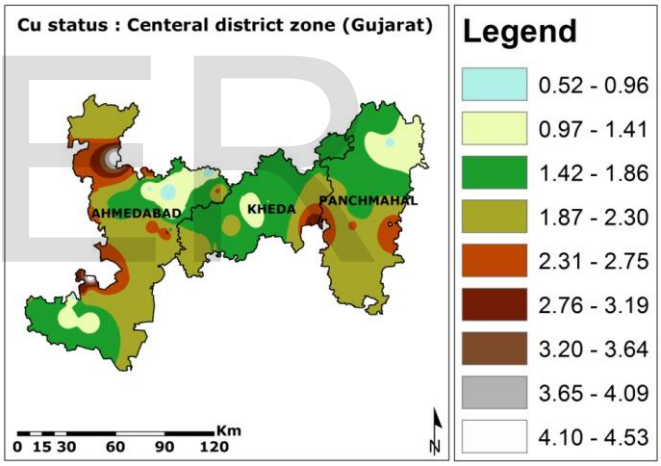


Figure-12: Copper status & spatial distribution in Center district zone

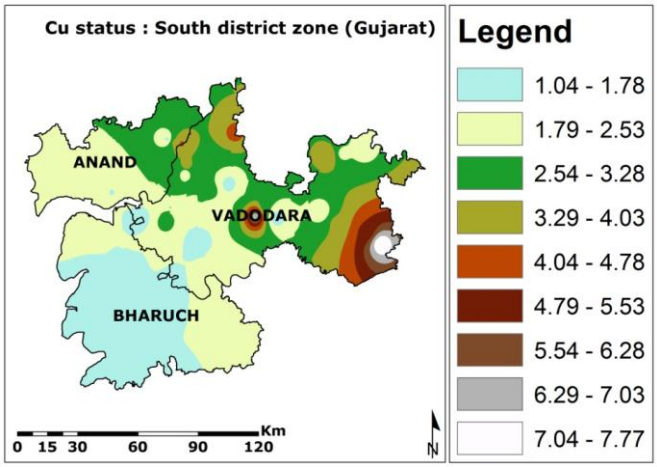


Figure-13: Copper status & spatial distribution in South dis-

trict zone

5.1.5 Available Boron (B) status

The available B content in the soils of north district zone varied from 0.1 to 1.4 ppm with a mean value of 0.5 ppm considering the soils across the north districts zone of Gujarat have optimum amount of available boron while the available B content in the soils of center district zone is varied from 0.1 to 2.3 ppm with a mean value of 0.6 ppm considering the soils across the center districts zone of Gujarat have high amount of available boron and in south districts zone available B content is varied from 0.1 to 1.5 ppm with a mean value of 0.5 ppm considering the soils across the south districts zone of Gujarat have optimum amount of available boron. The spatial distribution maps generated using IDW, interpolation technique for districts in three zones are given in **Figures-14, 15 and 16**.

Recommendation: If the amount of boron is low then it is recommended to give 4 to 5% boric acid in the soil. If the level of boron is higher then there is no need to use boron contain fertilizer.

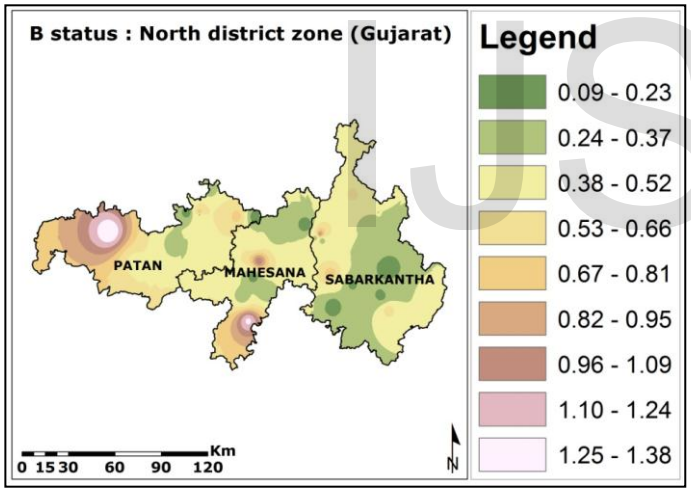


Figure-14: Boron status & spatial distribution in North district zone

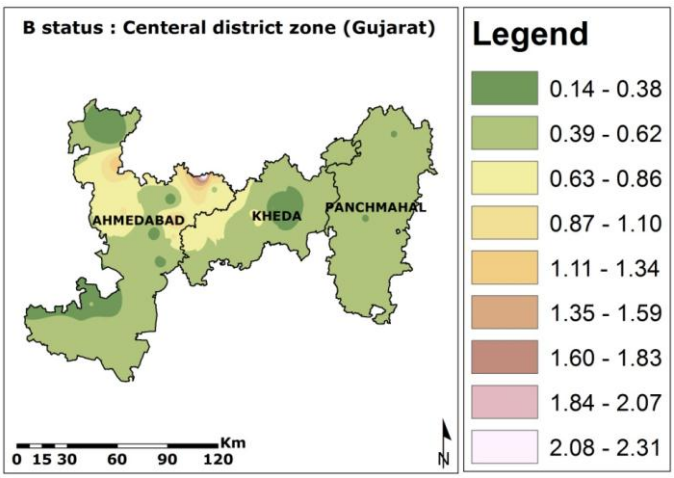
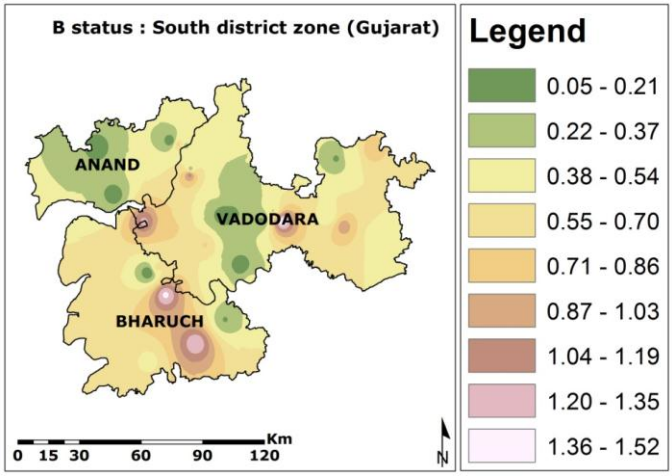


Figure-15: Boron status & spatial distribution in Center district zone

Figure-16: Boron status & spatial distribution in South district zone



From the spatial distribution maps the micronutrients status in different districts in three zones is summarized in three categories like minimum, maximum and mean values (**Figure-17).**

6. CONCLUSION

The results of this study refer to the effective role that can be played by GIS, especially in the spatial distribution mapping using IDW interpolation technique for producing thematic maps of micronutrients in the soils of North, Center and South district zone of Gujarat state. Spatial distribution maps generated under the study will be useful for guiding the farmers to decide the amount and kind of nutrients to be applied for economic returns based on site specific nutrient management.

It also prioritizes the talukas of district which needs immediate attention for achieving the optimum crop yields. Geostatistical analysis estimates an average status of micronutrients in the soil of study area. Both the spatial distribution maps and geo-statistical analysis reflect on spatial variability of micronutrients in the soils of North, Center and South district zones of Gujarat state. This study also brings out the recommendations of micronutrients based on the status of deficiency or based on the requirements of the crops based on the soil characteristics.

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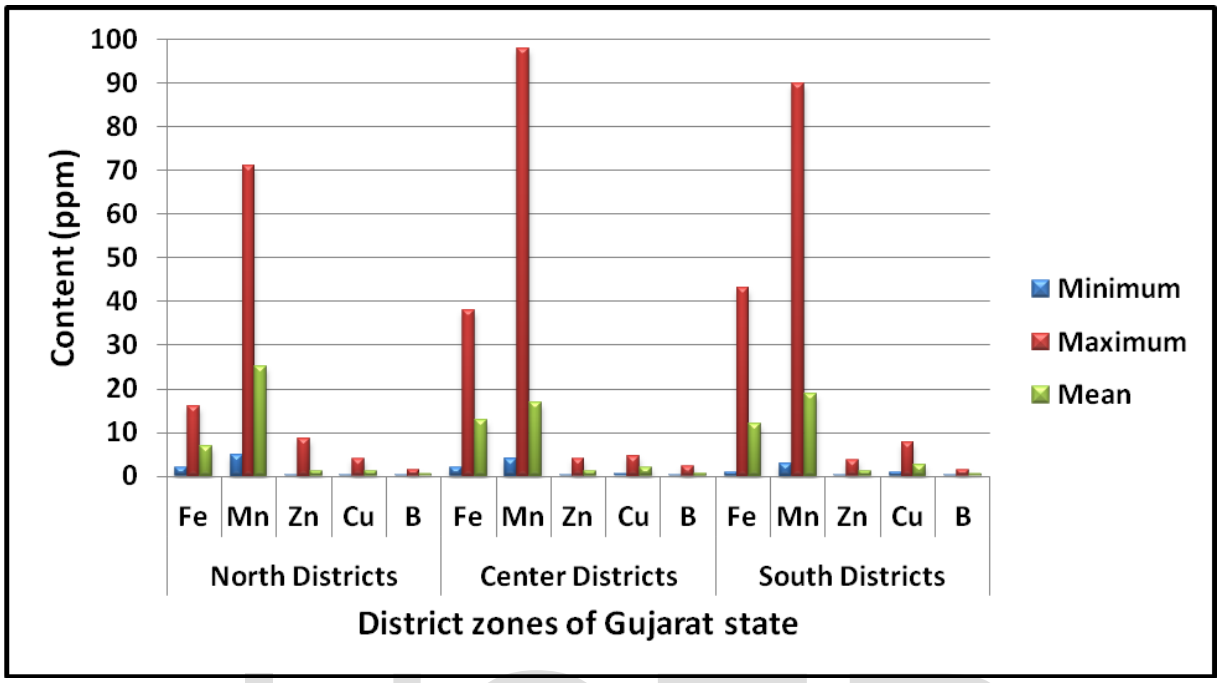

Figure-17: Variability status of micronutrients across North, Central and South district zones of Gujarat State

Gujarat University, Patan for his kind encouragement to undertake Project at BISAG, Gandhinagar.

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