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GIS and GPS based soil fertility mapping of village Dhodha, district Balodabazar, Chhattisgarh

Sonia Mistry, KK Sahu, Amit Singh Sengar and Ravishankar Dadsena

Abstract
Comprehensive investigation on 180 georeferenced surface soil samples were collected randomly and systematically analyzed for fourteen physico-chemical parameters. The laboratory analysis revealed that the soils were in neutral to slightly alkaline pH range, non- saline and low to medium in organic matter levels. The macronutrient status showed low (100%) available N, low to medium (67.22% & 32.77%) available P, medium to high (33.88% & 66.11%) available K, low to high (31.11% & 68.88%) available Ca, low to high (23.88% & 76.11%) available Mg and low (100%) available S. DTPA- extractable micronutrients *viz*. Fe, Mn, Cu and Zn status revealed availability in "sufficient" ranges, while hot water extractable B status were in "deficient" range. An effort to corroborate these findings were supported by soil fertility index maps prepared using advanced GIS based Arc GIS10.3 software.

Keywords: Soil fertility map, physico-chemical parameters, Geographic Information System (GIS), Global Positioning System (GPS)

Introduction
Soil fertility is the ability of the soil to provide all the essential plant nutrients in available forms and in a suitable balance, to sustain plant growth and optimize crop yield. Earlier the land could support plant growth efficiently without addition of synthetic fertilizers, pesticides etc. which in long run prove to be detrimental to soil quality and soil health.

Unscientific land use and cropping techniques have led to soil erosion and degradation of soil quality. Moreover, soil properties have spatial variability owing to innate (parent materials, and climate) and external factors such as crop rotation, indigenous fertility status and soil management practices. This summons for the site- specific appraisal for soil fertility evaluation.

Gathering soil samples by means of GPS is of great consequence for preparing thematic soil fertility maps. The use of GPS tells the latitude and longitude of the area concerned with accuracy anywhere round the globe. It is of great significance in agriculture for as it provides soil nutrient status of different locations for forthcoming supervision (Mishra *et al*., 2014) [4].

Materials and Methods Description of the study area
The study area village Dhodha is situated in Simga Block of Balodabazar district, Chhattisgarh between the latitudes of 21.6394o N and longitude of 81.8607 °E. The climate is usually hot, sub-humid and semi-arid with average rainfall of 1020 mm annually.

The soils in general, are predominantly black in colour and locally called Kanhar soils which fall under the category of Vertisols. These soils were found to be calcareous, neutral to slightly alkaline in soil reaction. Cracks on the surface are common feature. The soils have crumb or granular structure in the surface soil.

Soil sampling and analysis
Total 180 geo coordinated surface soil samples (0-15 cm) were collected randomly and were air dried thereafter sieved through a 2 mm sieve. The physico-chemical properties were analyzed following established standard procedures. Piper's method (1967) 1:2.5 soil water suspension for pH using a glass electrode pH meter, soluble salt- bridge process as suggested by Black, 1965 was used to determine EC, organic carbon (OC) was determined using Walkley and Black's rapid titration process (1934) [12].

Procedure determined by Subbiah and Asija (1959) [11] was used to evaluate available nitrogen, method suggested by Olsen *et al*. 1954 [54], 0.5M $NaHCO_3$ (pH-8.5) as extracting agent was used to measure available P in the soil, and P in the extract was measured in a spectrophotometer using the ascorbic acid process defined by Olsen and Watanabe (1965) [14]. The method suggested by Jackson, for available K, extracted with neutral normal ammonium acetate (Hanway and Heidal, 1952) [2].

Following Versenate (EDTA) method, Ca in the solution is titrated with 0.01 N EDTA using ammonium purpurate (murexide) which at pH 12.0 change colour from red to purple at the end point of titration. Then Ca + Mg in solution is titrated with

0.01 N EDTA using Eriochrome Black T indicator at pH 10.0 in the presence of ammonium chloride- ammonium hydroxide buffer. The colour changes from wine red to blue or green at the end point of the titration. The Mg content is determined by the difference (Page, 1982) [7]. Williams and Steinberg (1969) [13] identified a turbidimetric process for determining available S in soil.

Lindsay and Norvell (1978) [3] defined a system for determining the micro-nutrients Zn, Cu, Fe, and Mn. Berger and Troug (1939) [1] identified a method for determining available B in soil. Using this method, hot water was used as the extracting agent.

Statistical analysis

The analytical data was statistically analyzed by using standard methods for standard deviation, range and average by the procedure described by Panse and Sukhatme (1978) [8]:

Standard deviation

The standard deviation of each parameters were computed using the formula as computed by Panse and Sukhatme (1978) [8].

$$SD = \sqrt{\sum_{i=1}^{n} \frac{(Xi-\bar{X})^2}{n-1}}$$

Where,
n = Number of data points or observations
X = Mean of Xi
Xi = each of the values of the data

Range

Range of each observations were computed by deducting the minimum values from the maximum values.

Average

The average of each parameters were computed using the following formula:

$$X = \frac{X_1 + X_2 + X_3 + \dots\dots\dots + X_n}{X_n}$$

Where,
X: Average of parameter
X1 to Xn: Number of observations

Soil Fertility Map

Soil fertility maps were prepared by using GPS reading for the physicochemical parameters: pH, EC and OC and available soil macronutrients: N, P, K, Ca, Mg and S and available micronutrients: Fe, Mn, Cu, Zn and B for depicting the spatial variability using sophisticated geospatial tools *viz*. ArcGIS- 10.3 software.

Results and Discussion

The soils under study were evaluated for nutrient availability with respect to the major nutrients and nutrient index figures for categorization of soils into different fertility classes.

Soil reaction (pH)

The soil pH values of the samples ranged from 6.50 to 7.90 with a mean value 7.11±0.43 indicated that the soil was neutral to slightly alkaline in reaction. Percentage distribution of soil samples are depicted in (Table 1). The spatial distribution and status of pH at the research site (*Dhodha* village) is depicted in Fig.1.

Table 1: Distribution of soil samples under different pH ratings

Soil pH			
Classes	**Range**	**No of Samples**	**% of samples tested**
Neutral	6.5- 7.5	144	80
Slightly alkaline	7.5- 8.5	36	20

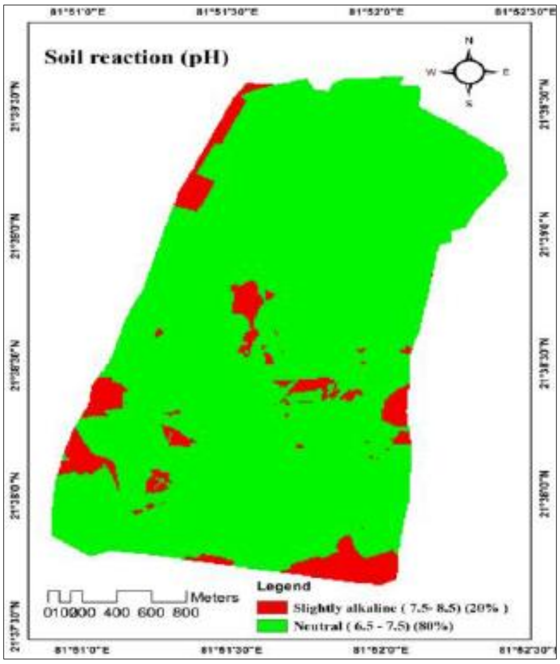

Fig 1: Soil reaction (pH) map

Soil soluble salt content as electronic conductivity (EC)

Soil EC ranged from 0.10 to 0.53 dS m-1, with a mean value of 0.34 ± 0.14 dS m-1. The results indicated very low value of EC throughout a wide range. Spatial distribution of total soluble salt content of soils of *Dhodha* village in the form of EC is depicted in Fig.2. All the samples (100%) were having low value range, classed as "Good" indicating that no corrective measures are required in these soils, as the soils were in good condition and did not produce any problem of soil salinity (Table2.).

Table 2: Distribution of soil samples under different EC ratings

Soil EC (dS m-1)			
Classes	**Range**	**No of Sample s**	**% of samples tested**
Good (No harmful effect on crop)	< 1	180	100.00

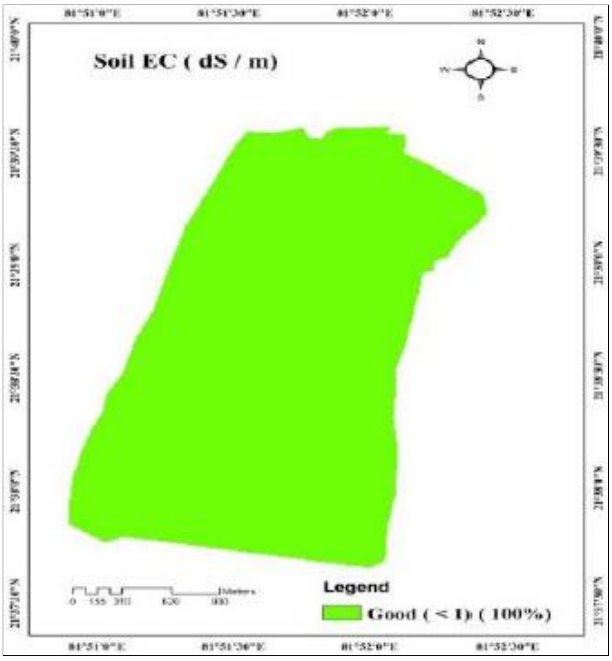

Fig 2: Soil Electrical conductivity map

Soil organic carbon content (OC)

The OC content ranged from 0.26% to 0.58% with a mean value of 0.50±0.14%. Distribution of soil samples based on the OC content is depicted in Table.3. Spatial distribution of soil OC content of *Dhodha* village is illustrated in Fig. 3.

Table 3: Distribution of soil samples under different Soil Organic Carbon ratings

Soil Organic Carbon (%)			
Classes	**Range**	**No of Samples**	**% of samples tested**
Low	<0.5	70	38.88
Mediu m	0.5- 0.75	110	61.11

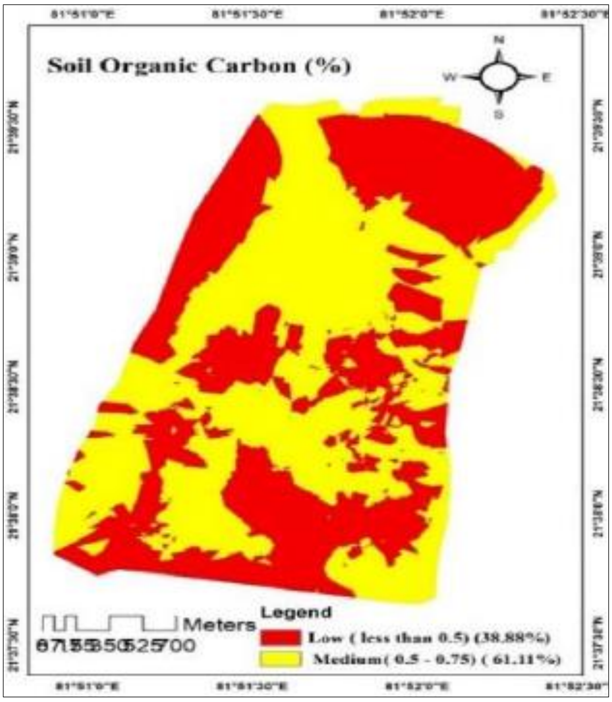

Fig 3: Soil organic carbon (OC) map

Macro-nutrient status

Available nitrogen (N)

Results indicated that the available N content of the soils ranged from 110-263 kg ha-1 with a mean value of 172.79±44.97 kg ha-1. The per cent distribution of the samples under low range (< 280 kg ha-1) is shown in the Table 4. Spatial distribution of available N content of the soils is depicted in Fig.4. Nutrient Index value (NIV) of the area for N fertility was found to be 1.00 and hence fall in low fertility range. It may be due to low OC content which is the main source of nitrogen (98%). Nitrogen is the most limiting nutrient in the black soils, which is mainly subjected to leaching and volatilization losses (Stewart, 1988) [10].

Table 4: Distribution of soil samples under different Soil Available Nitrogen ratings

Soil Available N (Kg ha-1)			
Classes	**Range**	**No of Samples**	**% of samples tested**
Low	< 280	180	100

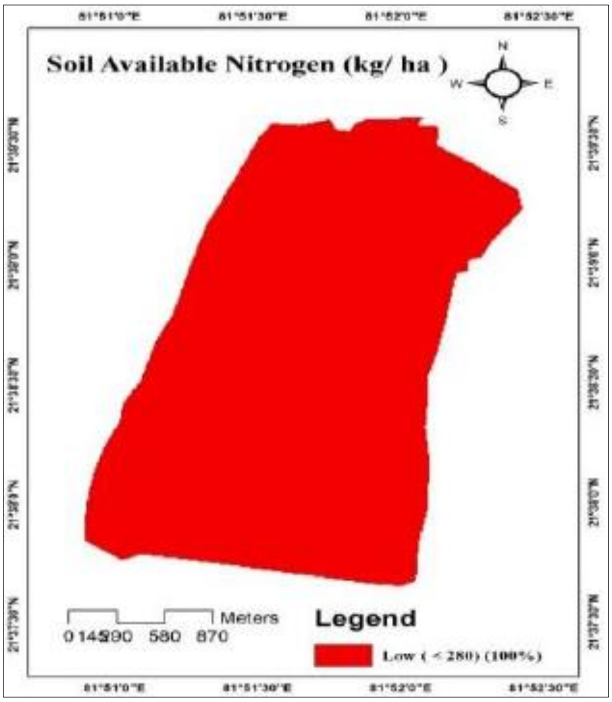

Fig 4: Soil available N map

Available phosphorus (P) status in soil

The available P content was found in the range of 10.02-17.54 kg ha-1 with a mean 11.95±1.36 kg ha-1. Spatial distribution of available P of *Dhodha* village is also shown in Fig.5. As most of the soil samples (67.22%) depicted in Table 5. had a low rating for available P, the NIV of the study area for P fertility was worked out to be 1.32 and it was found under low NIV range.

Table 5: Distribution of soil samples under different Soil Available Phosphorus ratings

Soil Available P (Kg ha-1)			
Classes	**Range**	**No of Samples**	**% of samples tested**
Low	<12.5	121	67.22
Mediu m	12.5-25	59	32.77

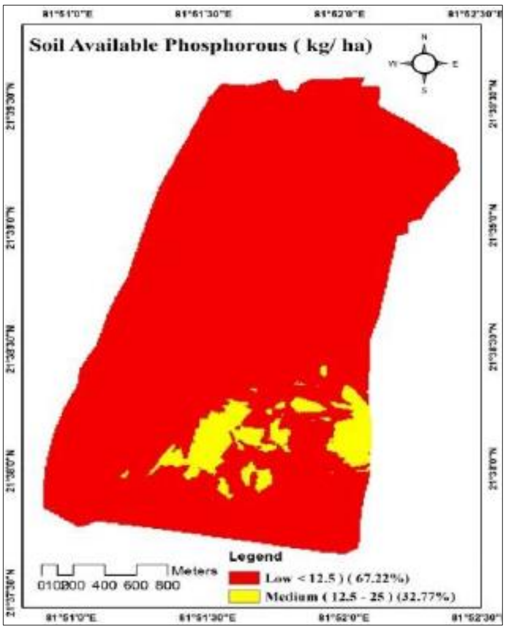

Fig 5: Soil available P map

Available potassium (K) status in Soil

The available K content was found under the category of *medium to high* and ranged 300 to 478 kg ha-1 with an average value of 368.18±49.09 kgha-1. It was found that 33.88% and 66.11% samples were under *medium* and *high* category respectively (Table 6). Fig.6 presents spatial distribution of available K in *Dhodha* village. The NIV was found to be 2.66 which fall into the *high* category. The higher available potassium status in *Vertisols* may be attributed to the predominance of potash rich mica containing minerals. Soils of the study area were slightly alkaline in reaction which causes dissolution of large amounts of potash bearing minerals.

Table 6: Distribution of soil samples under different Soil Available Potassium ratings

Soil Available K (Kg ha-1)			
Classes	**Range**	**No. of Samples**	**% of samples tested**
Medium	135-335	61	33.88
High	>335	119	66.11

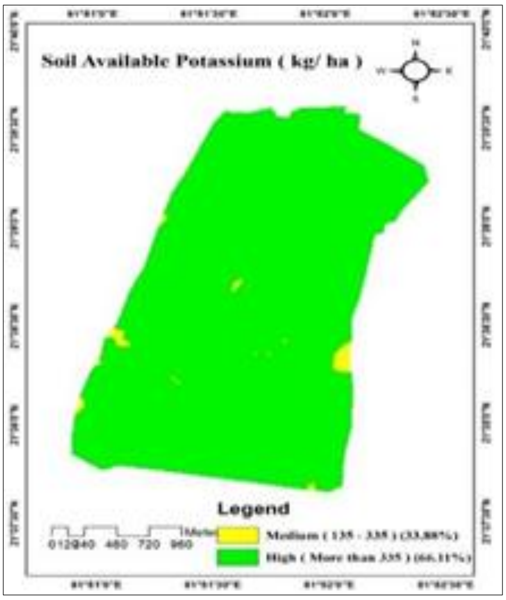

Fig 6: Soil available K map

Available calcium (Ca)

The available Ca content was found under the category of *low to high* and ranged 521 to 700 kg ha-1 with an average value of 666.12±34.53 kg ha-1. It was found that 31.11% and 68.88% samples were under *low* and *high* category respectively (Table 7). Fig.7 presents spatial distribution of available Ca in *Dhodha* village. The NIV values was found to be 2.37 which falls under *high* category.

Table 7: Distribution of soil samples under different Soil Available Calcium ratings

Soil Available Ca (kg ha-1)			
Classes	**Range**	**No. of Samples**	**% of samples tested**
Low	< 672	56	31.11
High	>672	124	68.88

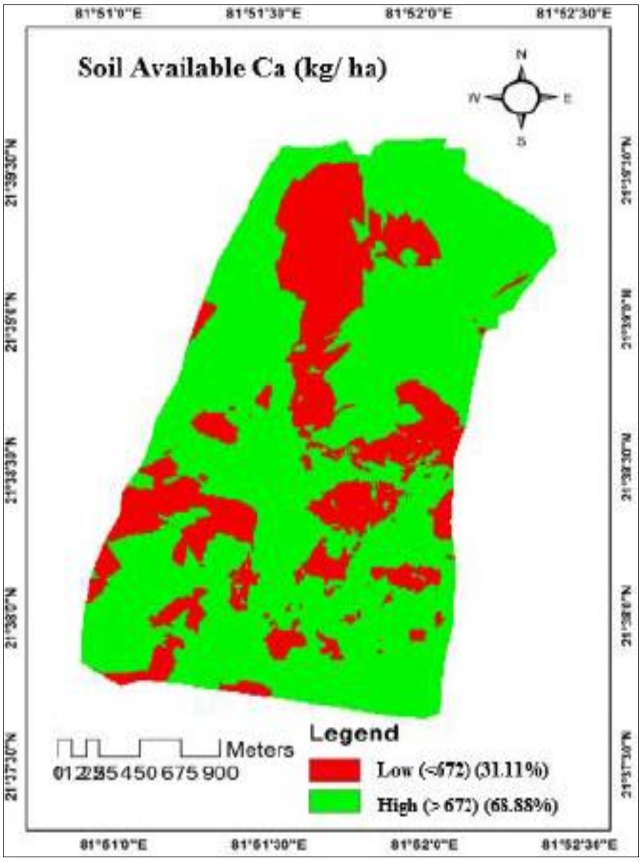

Fig 7: Soil available Ca map

Available Magnesium (Mg)

The available Mg was found under the category of *low to high* and ranged 205 to 397 kg ha-1 with an average value of 324.95±47.88 kg ha-1. It was found that 23.88% and 76.11% samples were under *low* and *high* category respectively (Table.8). Spatial distribution of available Mg is depicted in Fig.8. The NIV was found to be 2.52 which fall into the *high* category.

Table 8: Distribution of soil samples under different Soil Available Magnesium ratings

Soil Available Mg (Kg ha-1)			
Classes	**Range**	**No. of Samples**	**% of samples tested**
Low	< 270	43	23.88
High	>270	137	76.11

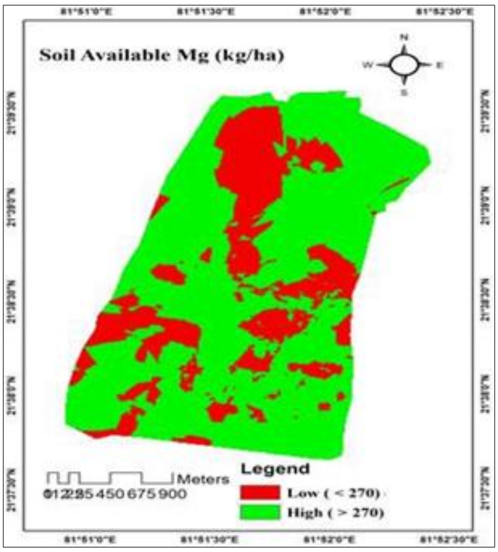

Fig 8: Soil available Mg map

Available sulphur (S)

The S concentration of the studied area ranged 10.04-19.67 kg ha-1 with an average value 13.76±2.21 kg ha-1. It was further found that entire sample (100%) was found to be in *low* category (Table 9).The spatial distribution of available S in *Dhodha* village is shown in Fig. 9. NIV of available Sulphur was worked out to be 1.00 that comes under *low* category. Low available sulphur status of the study area may be attributed to the low organic carbon status of the area and inadequate use of organic manures i.e. FYM, compost, vermicompost, green manure in the cultivation area.

Table 9: Distribution of soil samples under different Available Sulphur ratings

Soil Available S (Kg ha-1)			
Classes	**Range**	**No. of Samples**	**% of samples tested**
Low	<22.5	180	100

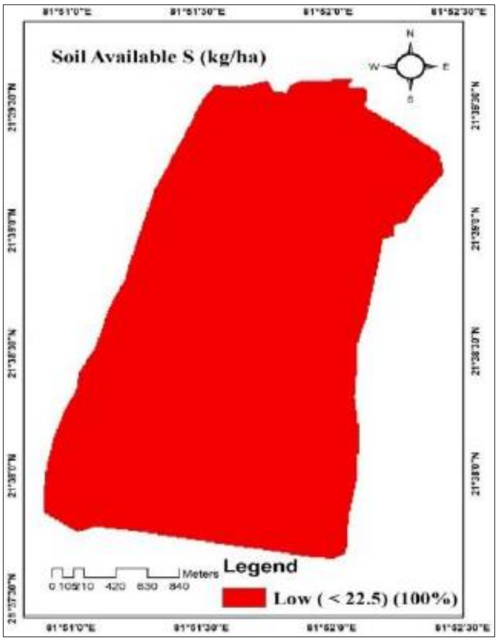

Fig 9: Soil available S map

Micro-nutrient status available iron (Fe) status in soil

Fe status varied from 11.24 – 52.76 mg kg-1 with a mean value of 30.43±10.89 mg kg-1. All of the 180 soil samples were found under the category of *sufficient range* of Fe and it can be inferred that these soils had no major limitation of Fe in crop production and soil sustainability (Table.10). Fig.10 showed spatial distribution of available Fe of *Dhodha* village. The NIV was 3 that fell into the *sufficient range*.

Table 10: Distribution of soil samples under different Iron ratings

Soil Fe (mg kg-1)			
Classes	**Range**	**No. of Samples**	**% of tested Samples**
Sufficient	>9.0	180	100

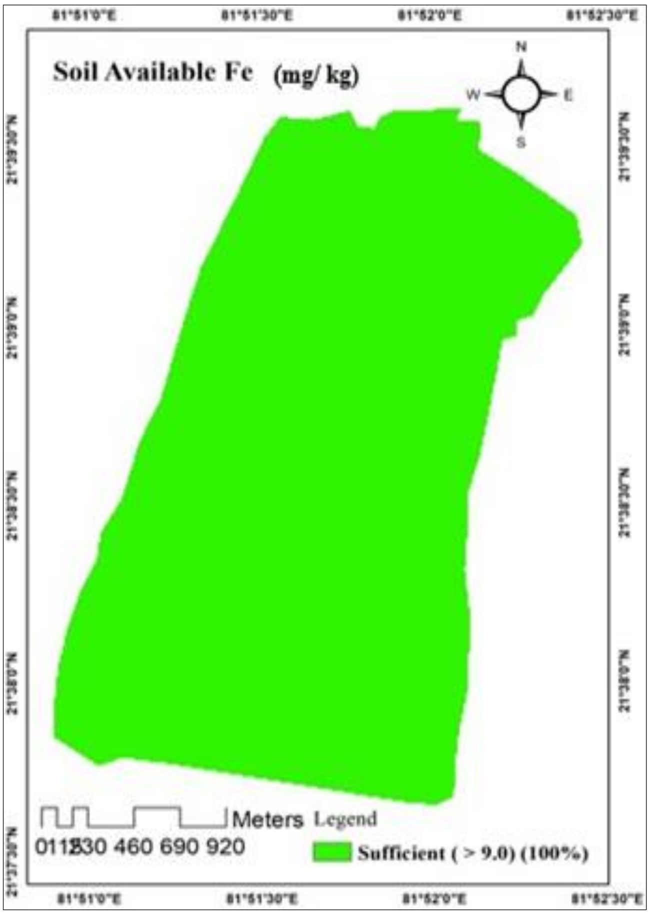

Fig 10: Soil available Fe map

Available Manganese (Mn) status in soil

The available Mn ranged from 13.24 to 31.25 mg kg-1with an average value of 19.85±4.14 mg kg-1. It was also found that all examined soil samples fit into the *sufficient* Mn fertility group (Table 11), showing that soil Mn concentration did not pose a substantial crop production limitation. The NIV of Soil for Mn fertility was worked out to be 3 that fall into the *high range.* Spatial distribution of Mn is illustrated in Fig.11.

Table 11: Distribution of soil samples under different Manganese ratings

Soil Mn mg kg-1			
Classes	**Range**	**No of Samples**	**% Samples**
High	>7.0	180	100

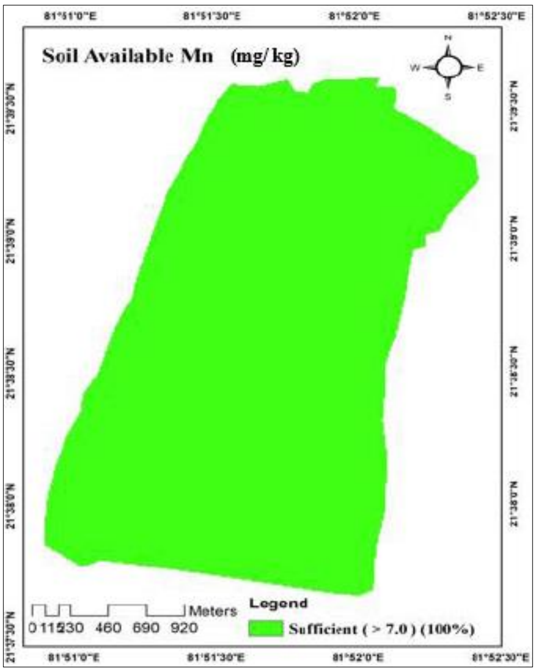

Fig 11: Soil available Mn map

Available Copper (Cu) Status in Soil

The results of DTPA extractable Cu concentration ranged from 0.10 to 2.07 mg kg-1, with an average of 1.02±0.45 mg kg-1. Samples were categorized into distinct categories based on the available nutrient content. 6.11% and 93.88% samples were found under *deficient and sufficient rating* groups (Table.12). These results are also shown in Fig.12 that represents spatial distribution of available Cu in soils of *Dhodha* village. The NIV of Soil for Cu fertility was worked out to be 2.87 and all of the samples fall under high category.

Table 12: Distribution of soil samples under different Copper ratings

Soil Cu (mg kg-1)			
Classes	**Range**	**No of Samples**	**% Samples**
Deficient	<0.2	11	6.11
Sufficient	>0.4	169	93.88

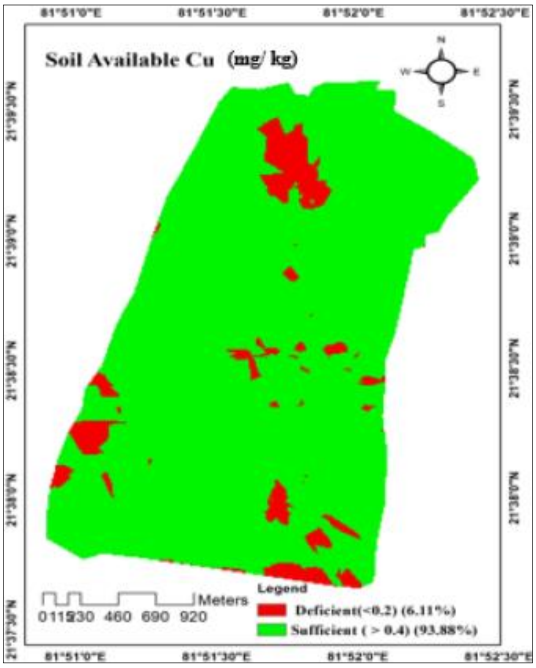

Fig 12: Soil available Cu map

Available zinc (Zn) status in soil

Soil available Zn status in the study area was found to be in the range between 0.31 to 1.92 mg kg-1 with a mean value of 0.98± 0.32 mg kg-1. These findings were classified into two different rating categories. Accordingly it was found that about (82.77%) samples and (17.22%) samples were under *sufficient* and *deficient* range respectively (Table.13). The same results are shown in Fig.13 with the spatial distribution of available Zn in *Dhodha* village. The Nutrient Index of Soil for Zn fertility was found to be 2.65. It fell into the *high* range.

Table 13: Distribution of soil samples under different Zinc ratings

Soil Zn (mg kg-1)			
Classes	**Range**	**No of Samples**	**% Samples**
Deficient	<0.6	31	17.22
Sufficient	> 1.2	147	82.77

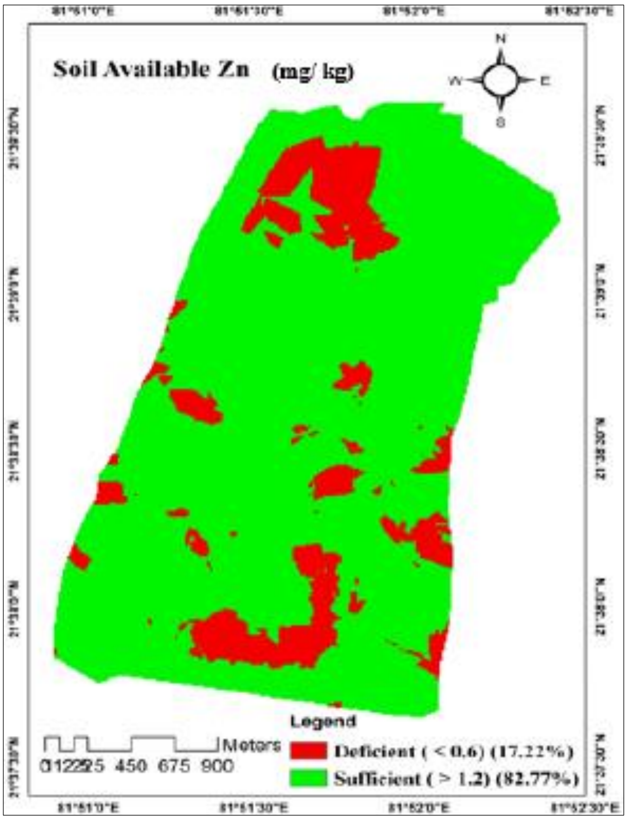

Fig 13: Soil available Zn map

Available boron (B) status in soil

The available B concentration of soil ranged from 0.10 to 1.20 mg kg-1 with an average value of 0.33 mg kg-1. According to the standard rating values of B status in the soil, 91.66% and 8.33% samples were found under the *deficient and sufficient* category respectively (Table.14). The spatial distribution of B content in soils of *Dhodha* village is also shown in Fig.14.

The low B status of the soil can be attributed to alkaline pH of the study area and various other factors such as insufficient levels of organic carbon which may be washed out of the upper soil surface layer due to rainfall or other erosive agents.

Table 14: Distribution of soil samples under different Boron ratings

Soil Zn (mg kg-1)			
Classes	**Range**	**No of Samples**	**% Samples**
Deficient	<0.5	165	91.66
Sufficient	>1.0	15	8.33

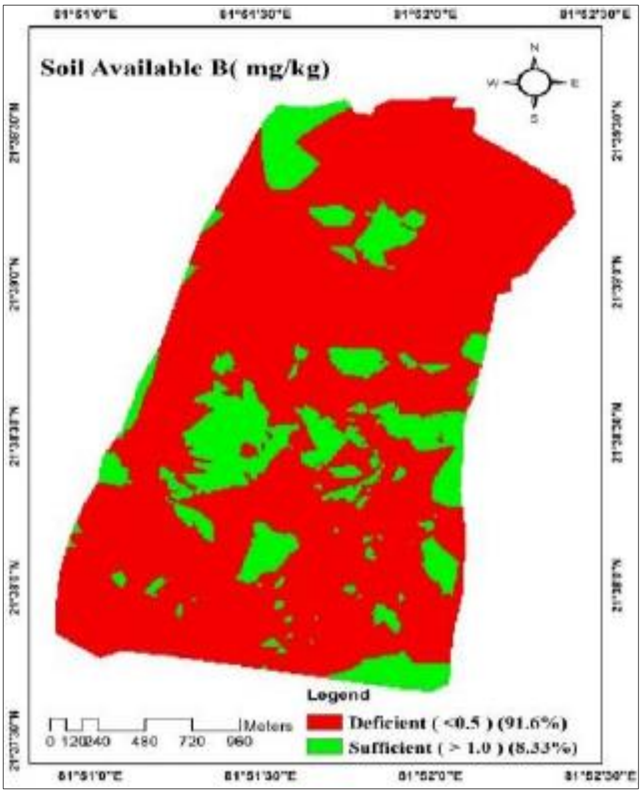

Fig 14: Soil available B map

Conclusion

The soils of the village Dhodha, district Balodabazar, Chhattisgarh were found to be predominantly *neutral to slightly alkaline* in reaction, electric conductivity was also found quite low (<0.21 dS m^{-1}) and under the category *"good"*. These characteristics enable the soils suitable for cultivation of almost all the crops without any major problems and without applying any corrective measures.

The soils of the village were found to be low in Nitrogen, Phosphorous and Sulphur. High in K, Ca and Mg status. Among micro-nutrients Zn, Fe, Cu and Mn were in sufficient level, while hot water extractable B was found to be in deficient levels. Soil fertility maps of the concerned study area revealed no spatial variability for N, S, Fe and Mn.

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