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Research Article

SPATIAL VARIABILITY IN SOIL FERTILITY OF TRIBAL DISTRICT SHAHDOL IN CENTRAL INDIA USING GEOSPATIAL TECHNIQUES

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Abstract- The present investigation is a part of trail that was continued during 2009 to 2013 and the GPS based survey work of the tribal district (Shahdol) was under taken during the year 2011-2012. From the whole district sixty eight villages have been covered and 408 soil samples were drawn at the depth of 0-20 cm. Six soil samples were taken from each village on the basis of land holding having low (<1 ha), medium (1-3 ha) and high (> 3 ha) farmer categories along with GPS data and only two soil samples were taken from each category. These soil samples were analyzed for different parameters *viz* pH, EC, O.C., available N, P, K, S and micronutrients like Zn, Cu, Fe and Mn. Spatial variability of soil chemical properties *viz.* pH, EC, organic carbon, soil available macronutrients (N, P,K) and micronutrients (Fe, Mn, Cu, Zn) were quantified through descriptive statistical analysis and the respective surface maps were prepared through ordinary kriging. The soils of the area are characterized by neutral to alkaline in pH and low to high in organic carbon content. The soil available nitrogen content were ranged from 109-476 kg ha^{-1}, available soil phosphorus were ranged from 5.9-53.2 kg ha^{-1}, available potassium were ranged from 102-827 kg ha^{-1} and available sulphur were obtained from 3.6 to 46.3 mg kg^{-1}. While values of micronutrient were reported from 0.10 to 4.73 mg kg^{-1} with Zn, 0.21 to 11.1 mg kg^{-1} with Cu, 4.5 to 84.8 mg kg^{-1} with Fe and 2.0 to 74.1 mg kg^{-1} with Mn.

Keywords- Spatial Variability, Soil Properties, Tribal, Shahdol, Central India, Geospatial

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Introduction

Shahdol district is predominantly a tribal district in the eastern part of Madhya Pradesh. The district is divided into four tehsils and five development blocks. It is very backward in the field of agriculture. The size of the fields is very small and the tribal are mainly marginal farmers. The yearly yield of the products from the fields is not enough for their home use. Paddy, Kodo, Kutki, Maize, Sesame, Mustard and Groundnut are the main crops. The farmers grown paddy in kharif and wheat in rabi season as a main crop. The Soil fertility is one of the important factors controlling yields of the crops. Soil characterization in relation to evaluation of fertility status of the soils of an area or region is an important aspect in the context of sustainable agricultural production. Macronutrients and micronutrients are more important soil elements that control its fertility. Variation in nutrient supply is a natural phenomenon and some of them may be sufficient whereas others deficient. The stagnation in crop productivity cannot be boosted without judicious use of macro and micronutrient fertilizers to overcome existing deficiencies/ imbalances.

The traditional approach to soil fertility management has been to treat fields as homogenous areas and to calculate fertilizer requirements on a whole field basis. However, it has been reported for at least 70 years that fields are not homogeneous and sampling techniques to describe field variability have been recommended [1,2]. Describing the spatial variability across a field has been difficult until new technologies such as Global Positioning Systems (GPS) and Geographic Information Systems (GIS) were introduced. GIS is a powerful set of tools for collecting, storing, retrieving, transforming and displaying spatial data [3]. GIS can be used in producing soil fertility map of an area that helps to understand the status of soil fertility spatially and temporally, which will help in formulating site-specific balanced fertilizer recommendation. These technologies allow fields to be mapped accurately and also allow complex spatial point relationships between soil fertility factors to be computed. This in turn has increased interest in the use of soil- sampling techniques that attempt to describe the variability in soil fertility factors within a field. In precision farming, the concept of 'management zone' was evolved in response to large variability with the main purpose of achieving efficient utilization of agricultural inputs with respect to spatial variation of soils and its properties. Site-specific management zones are defined as homogeneous sub-regions of a field that have similar yield limiting factors [4,5]. Conceptually, by using a management zone delineation technique, an agricultural field could be classified into management zones that reflect productivity potential. For example, a field may be classified into three zones- high, medium and low productivity potential management zones. Therefore, an appropriate understanding of spatial variability in soil properties is essential at landscape scale. The most important way to gather knowledge in this aspect is to prepare soil maps through spatial interpolation of point based measurements of soil properties [2].

Keeping in view of the physiographic characteristics in different cross sections of the area. The processed soil samples were analyzed for physico-chemical properties using standard procedures.

Materials and Methods

Shahdol district is predominantly a tribal district, situated in the eastern part of Madhya Pradesh. This district is situated between 23°00' N and 24°18'N latitude and 81°00' E to 82°00' E longitude [6]. Shahdol district experiences a temperate climate characterized by a hot summer, well-distributed rainfall during the south-west monsoon season and mild winter. The month of May is the hottest month with mean daily maximum temperature at 41.4^{0}C and mean daily minimum temperature at 26.5^{0}C. With the onset of south-west monsoon during June, there is an appreciable drop in day temperature, while at the end of the September or in early October, there is slight increase in day temperature but nights become progressively cooler. January is generally the coolest month with the mean daily maximum temperature at 25.6^{0}C and the mean daily minimum temperature at 8.4^{0}C. The average daily maximum temperature is about 41.4^{0}C and minimum temperature is about 26.5^{0}C. The normal average rainfall of Shahdol district is 1211.6 mm of which about 86.6% of the total precipitation falls in the south-west Monsoon period [6].

The soils in the area are generally of clayey loam types with sandy loam soil in some areas. In the northern and central parts of the District, the undulating plateau with mounds are covered with slightly deep soil, well drained, fine to fine loamy soils on gentle slopes marked by moderate erosion. The southern hilly region is covered by very shallow loamy soils, somewhat excessively drained. The soils developed on moderately steep slopes are marked by severe erosion. The soils have been classified as Ustocherpts/ Ustorthents/ Rhodustalfs/ Haplustalfs/ Haplusterts, as per pedological taxonomy [6].

Shahdol district was selected for fertility mapping as a tribal district and low fertilizer consumption among the district of Madhya Pradesh. This study was the part of continued experiment during 2009-2013 which was funded by the Government of India. The list of the villages and other information were obtained from IISS, Bhopal. This district comprised of four tehsils *(viz.* Sohagpur, Beohari, Jaisinghnagar, Jaitpur). These tehsils were considered as strata. Eight percent (aprox.) villages (68 nos.) were selected from each tehsil using Simple random sampling without replacement (SRWOR). From each selected village, six farmers [two of each category viz. large (>3 ha), medium (1-3 ha) and small (<1 ha)] were selected for collecting further information. One field was selected from each selected farmers keeping in view that the selected fields falls in the same village. From each selected field six soil samples were thoughrology mixed and a portion of this was retained for nutrient estimation. The location of the mid field was recorded using GPS. All the soil samples so collected were than analyzed for pH, EC, O.C., N, P, K, S, Zn, Cu, Fe and Mn.

Soil pH was determined in a 1:2.5 soil water suspension by glass electrode using pH meter [7]. The soil suspensions used for pH determinations were allowed to settle down and conductivity of supernatant liquid was determined by using conductivity meter [7]. Organic carbon was determined by [8] rapid titration method. In this method, the organic matter was oxidized by chromic acid utilizing the heat generated during the dilution of sulphuric acid (H_2SO_4). The excess of dichromate was back titrated with ferrous ammonium sulphate solution. Soil available nitrogen was estimated using alkaline permanganate method [9]. The soil available phosphorus was estimated by ascorbic acid method [10]. The available potassium was extracted by neutral 1 N ammonium acetate and it was estimated using flame photometer [11]. The processed soil samples were extracted with DTPA-$CaCl_2$ – TEA solution [12] for micronutrient analysis. The available Zn, Cu, Fe and Mn content in the extract was determined with the help of atomic absorption spectrophotometer. Simple averaging of soil test values for each macro and micronutrient was done to get the average status in the revenue villages. Descriptive statistical analysis of soil properties were done by using SPSS v 20- 32bit software. Base map of the Shahdol district was digitized and georeferenced. Polygons were superimposed on the geo-referred map. Latitude, longitude and analysis data were entered into attributed table and linked to Arc GIS software for making thematic soil fertility maps by Indian Institute of Soil Science, Bhopal (M.P.) – India (http://www.iiss.nic.in/mapd_3.htm)

Results and Discussions

Descriptive Statistics of Soil Properties

The descriptive statistics of soil properties are presented in [Table-1]. Organic carbon varied from 0.20 to 0.99 per cent with a mean value of 0.57. (CV = 31.4 per cent) while, pH was found least variable (CV = 12.8%). The soil chemical properties namely pH and organic carbon displayed strong spatial dependence whereas, cation exchange capacity showed moderate spatial dependence [13]. The results also corroborated with [14,15]. The obtained results also were in line with those of [16] in saline-sodic soil of California's San Joaquin Valley. They observed that EC consistently had highest coefficient of variation while pH in the saturation extract consistently had lowest CV at all the studied soil depth.

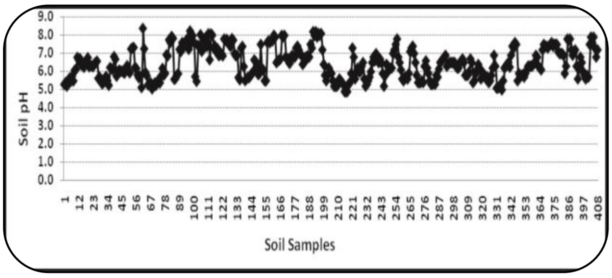
Among the chemical properties, available N, P, K and S varied from 109.0 to 476.0 kg ha^{-1}, 5.9 to 53.2 kg ha^{-1}, 102 to 827 kg ha^{-1}, and 3.6 to 46.3 mg kg^{-1} with mean value of 273 kg ha^{-1}, 15.9 kg ha^{-1}, 325 kg ha^{-1}, and 21.0 mg kg^{-1} respectively. The available micronutrients Zn, Cu, Fe and Mn varied from 0.10 to 4.73, 0.21 to 11.1, 4.5 to 84.8 and 2.0 to 74.1 mg kg^{-1} with mean values of 0.68, 2.03, 44.5, and 34.4 mg kg^{-1}. Among the macronutrients and sulphur (NPK and S), the coefficient of variation ranging from 28.4 to 54.5%. While in case of micronutrient available Zn was found to be highly variable (CV = 110.6%) followed by available Cu (CV = 84.9%), Mn (CV= 54.9%) and lowest CV (54.7%) was calculated with Fe. Available N was found to be moderately variable (CV = 27 per cent). All the micronutrients were highly variable with CV ranging from 60–71 per cent. Among the soil fertility parameters, EC, organic carbon, available P, Zn and Cu were found non-normal due to higher value of skewness and kurtosis. Findings of [17] is strongly supported the results. Available macronutrients (N, P, K) and micronutrients (Fe, Mn, Cu, Zn) showed moderate spatial dependence. Reported ranges of spatial dependence were 53.1 m sampled at 25 by 25 m [18] to 8.9 km sampled at 2 by 2 km [19] for available N; 25.8 m sampled at 50 m interval [15] to 47.7 m sampled at 25 by 25 m [18] for available P and 60 m sampled at average interval of 20 m [20] to 6.9 km sampled at 2 by 2 km [19] for available K. Among the micronutrients, available Zn was spatially correlated for a shorter distance and at a distance less than the range, measured soil property of two samples become more alike with decreasing distance between them [21]. Spatial dependence of DTPA extractable Zn, Fe, Cu and Mn were also reported [22].

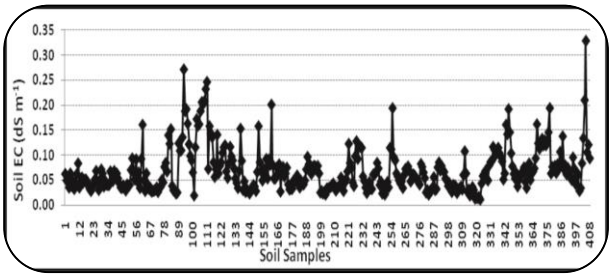
Table-1 *Descriptive Statistics of Soil Properties*

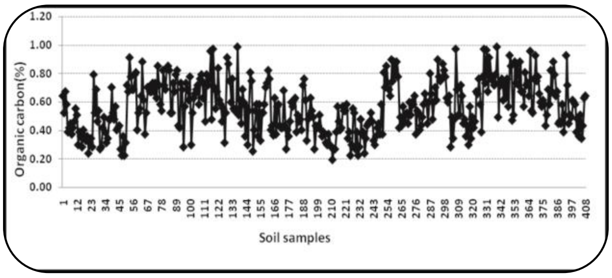
Parameters	Minimum	Maximum	Mean	SE of Deviation	CV (%)	Skewness	Kurtosis
pH	4.9	8.4	6.5	0.83	12.8	0.28	-0.93
EC (dsm^{-1})	0.01	0.33	0.07	0.04	62.7	1.89	5.0
Organic Carbon (%)	0.20	0.99	0.57	0.18	31.5	0.19	-0.71
Available N (kg ha^{-1})	109	476	273	85.8	28.4	0.21	-0.67
Available P (kg ha^{-1})	5.9	53.2	15.9	8.5	53.4	1.64	3.0
Available K (kg ha^{-1})	102	827	325	177.1	54.5	0.97	0.21
Available S (mg kg^{-1})	3.4	46.3	20.9	9.79	46.8	-0.87	0.14
Available Zn (mg kg^{-1})	0.10	4.73	0.68	0.76	110.6	3.14	11.0
Available Cu (mg kg^{-1})	0.21	11.1	2.03	1.7	84.9	1.97	5.3
Available Fe (mg kg^{-1})	4.5	84.8	44.5	24.3	54.7	0.05	-1.4
Available Mn (mg kg^{-1})	2.0	74.1	34.4	18.9	54.9	0.21	-0.92

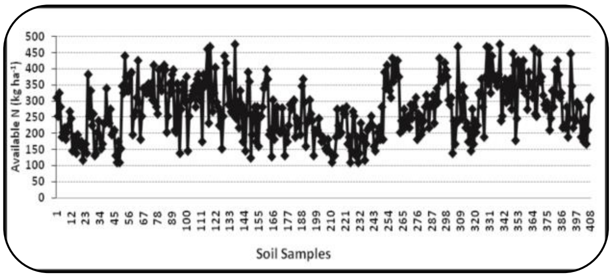
Soil status based on observed samples

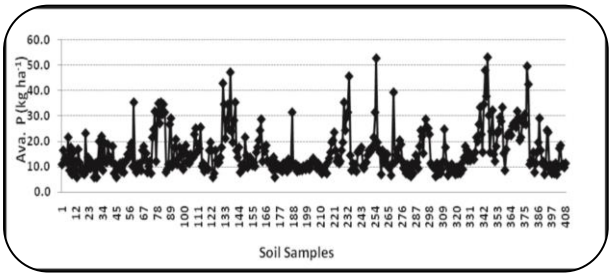
The soil reaction was acidic in 58% area, 29% in neutral and 13% area of the district were found slightly alkaline [Fig-1 & map-A] similar finding was also recorded by [23]. All soil samples were found in safe range with regard to EC in the studied district [Fig-2 & map-B]. The organic carbon status of the soil was medium (0.50 to 0.75%) in 45% area of the district, high (0.75%) in 17% and low (0.50%) in 38% area of the district [Fig-3 & map-C]. Overall status of the organic carbon entire area was medium with the average value of 0.57%. The high and medium organic carbon content in district is due to the dense forest area with undulating topography present in this district. Similar finding was also reported [24,25]. The organic carbon in Indian soils ranges from 0.5 to 1.5 per cent [26].

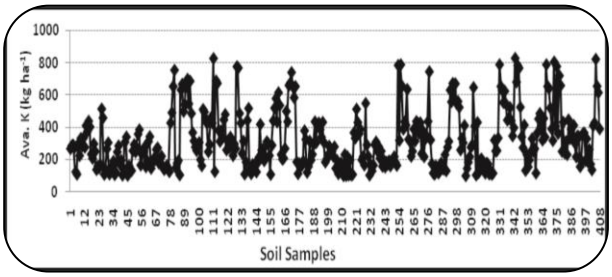


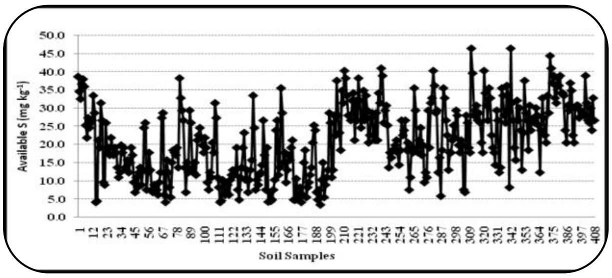


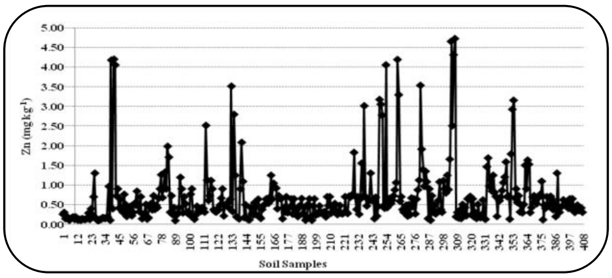


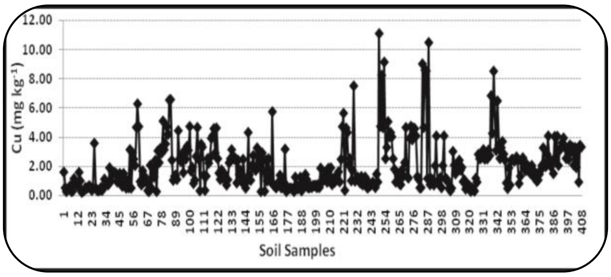


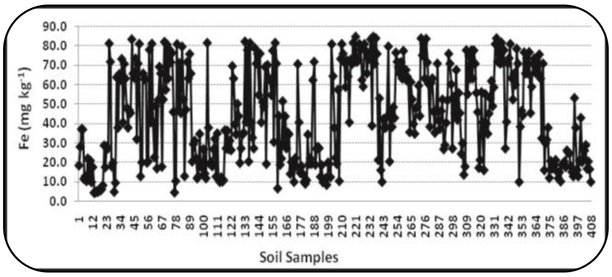


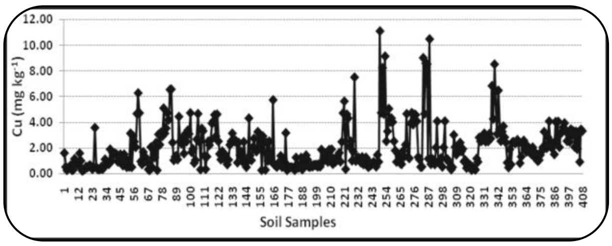




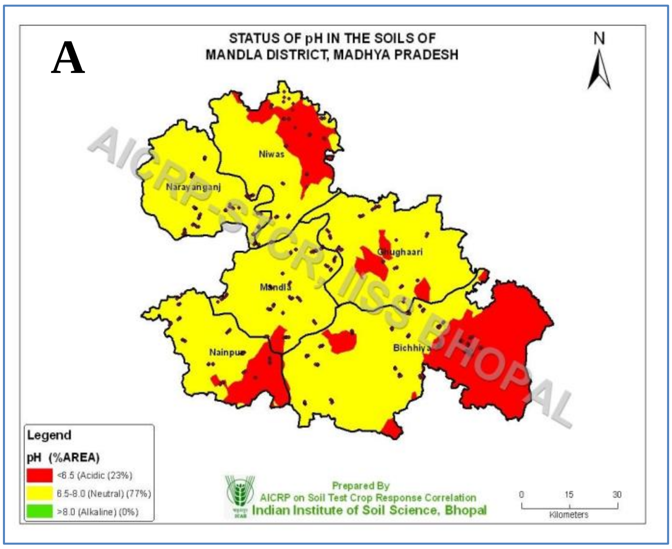


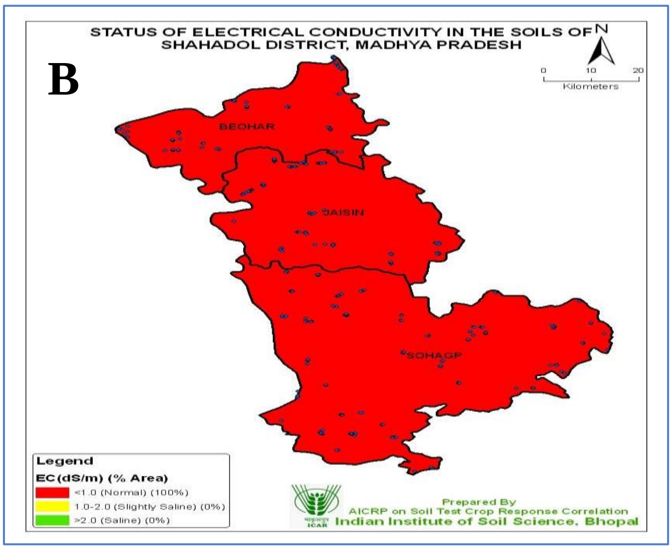




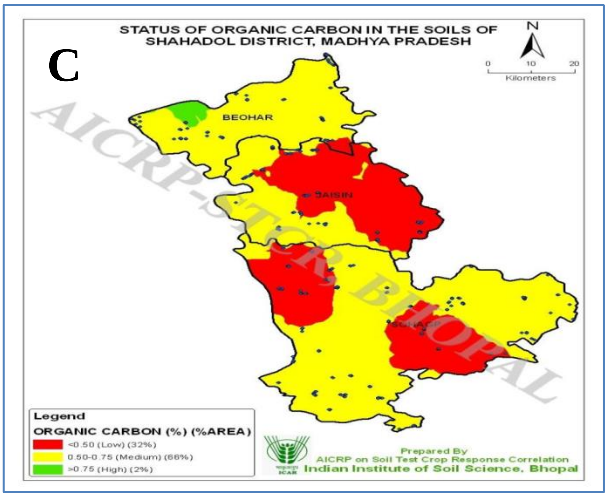


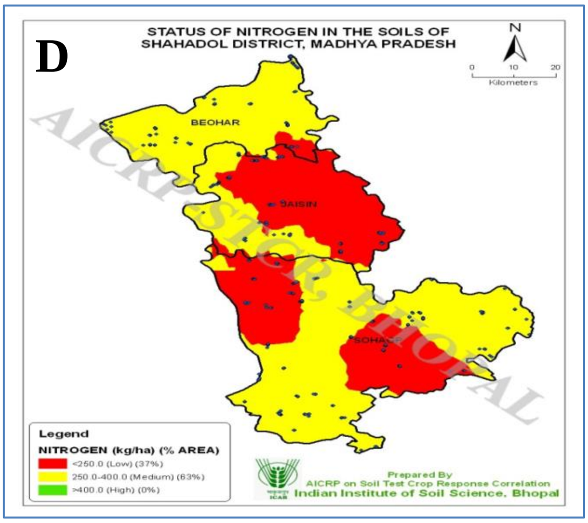
The lower organic carbon content in these soils may be attributed to the poor management practices such as lack of addition of crop residues and organic manures. Intensive cropping is also one of the reasons for low soil organic carbon content. Soils of semi-arid region have low organic carbon than sub-humid soils [27]. The organic matter build up in soils is related to natural vegetation, cropping history and temperature [26]. The status of the available N was also medium (251 to 400 kg ha^{-1}) in 50% area of the district and 42% area was low in N content while only 8% area was high(>400 kg ha^{-1}) in available N [Fig-4 & map-D]. Nitrogen is the most limiting nutrient in black soils [28], which is subjected to losses through leaching and volatilization. The total nitrogen content in the soils is dependent on temperature, rainfall and altitude [29]. Similar result was also found by [24, 25].

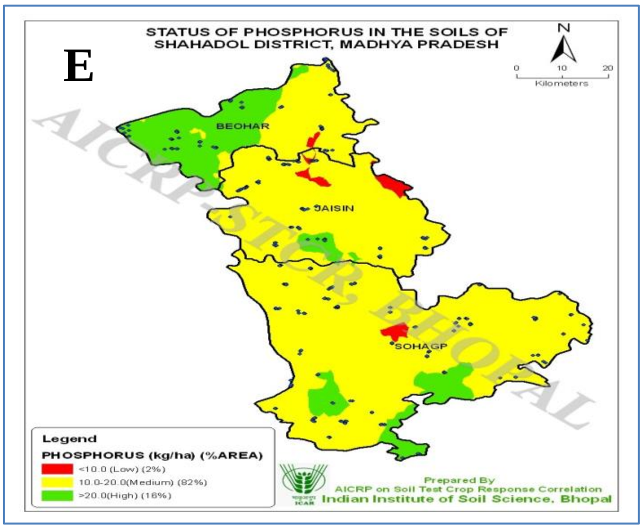


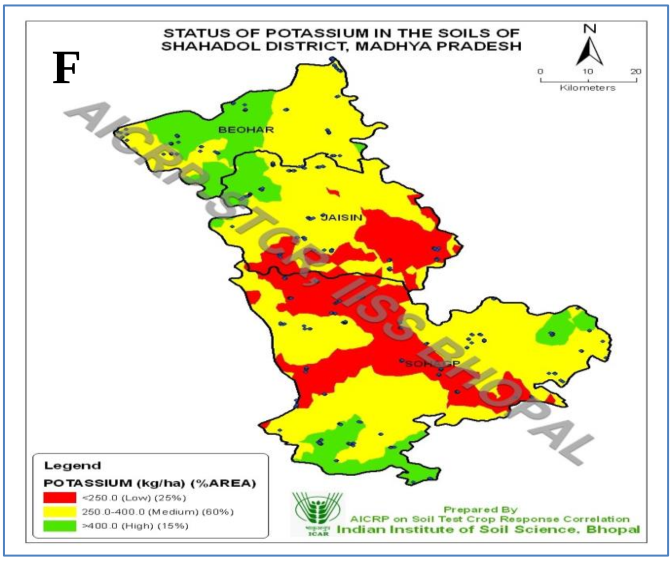


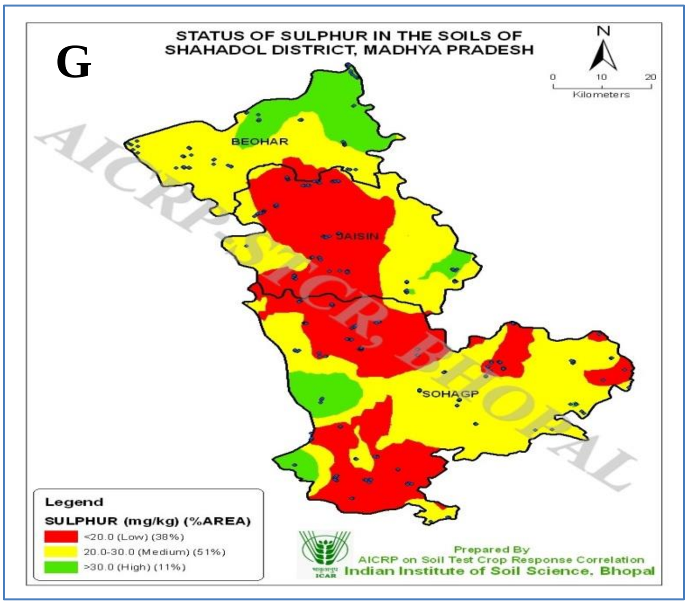
The available P status [Fig-5& map-E] of the soil was medium (11 to 20 kg ha^{-1}) in 54% area of the district, 21% area was high (>20 kg ha^{-1}) in available P content and low (<10 kg ha^{-1}) content was found in 25% area of the district. Overall available P status of the entire area was medium with mean value of 15.9 kg ha^{-1} [Table-1]. The present findings are in line with those of [30,31]who reported that majority of soils in Karnataka and more so in Malaprabha command were medium in phosphorus content. Similar result was also found by [24, 25]. The available K status of the soil was low (< 250 kg ha^{-1}) in 41% area of the district. Medium and high available K content in the soil almost equal (30 % and 29 % respectively) to the area of the district [Fig-6 & map-F]. Overall the status of the area was low. Mean values of the available K was 325 kg ha^{-1}[Table-1]. Similar finding was also reported [32, 25]. The available S status was high (> 20 mg ha^{-1}) in 49% area of the district and sulphur content was medium in 30% area while low sulphur was found in only 16% area of the district. Overall sulphur content was high in the district with mean. Similar finding was also observed [33, 25]. The status of available micronutrient were high (Zn, Cu, Fe and Mn limits were >1.2, >4.0, >9.0 and > 0.40 respectively) with Cu, Fe, and Mn in 90 to 95% area of the district while only low content of Zn was observed in 60 % area of the district [Figs-8, 9, 10 & 11 and maps G,H,I & J respectively]. Similar findings were also evaluated [34]. The range of spatial dependence was found to vary among soil parameters and within the same field. Soil nutrients were found to be affected by farmer management [35].

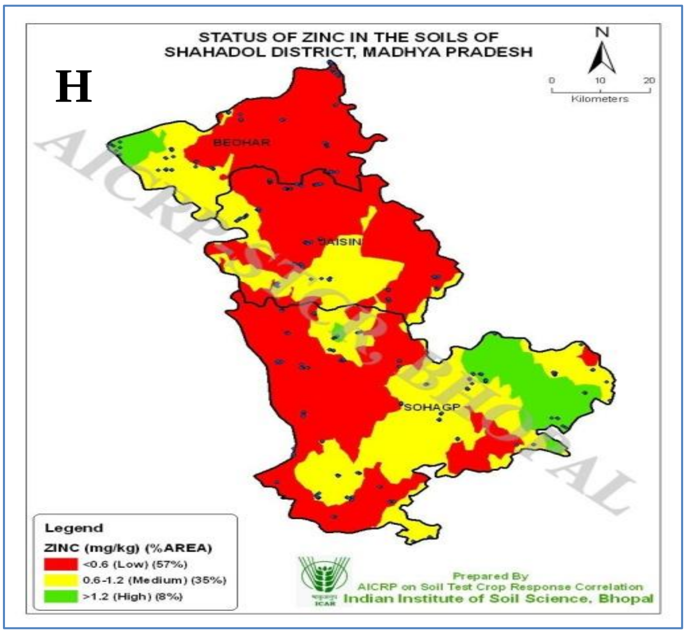


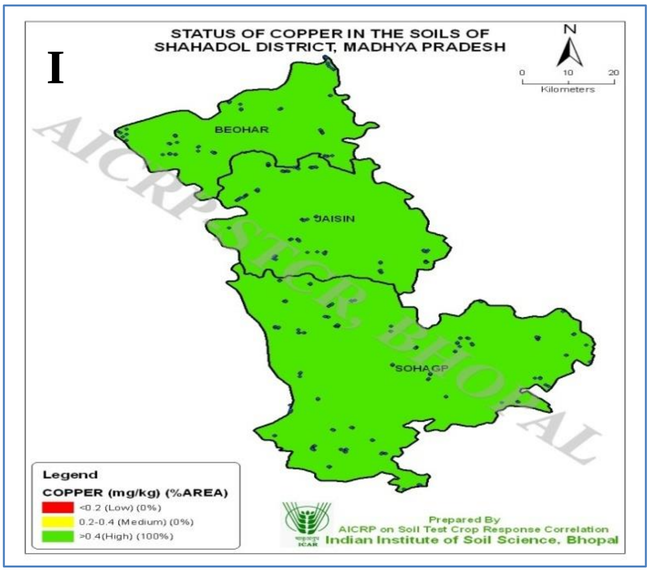


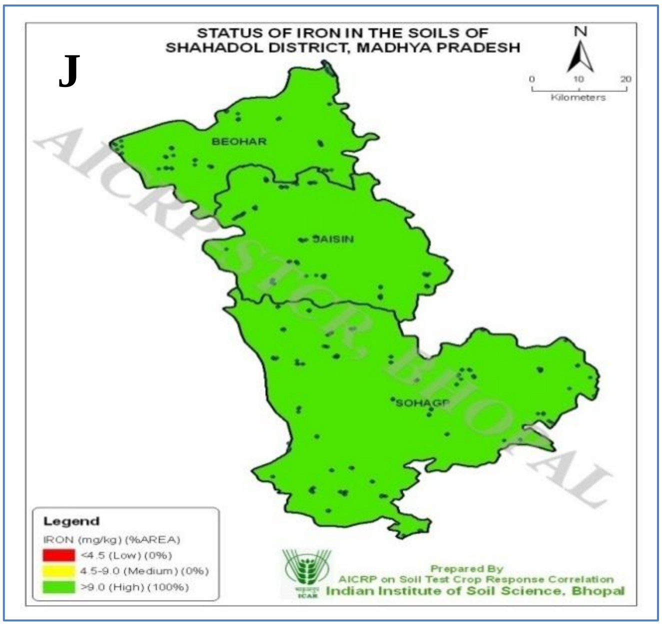


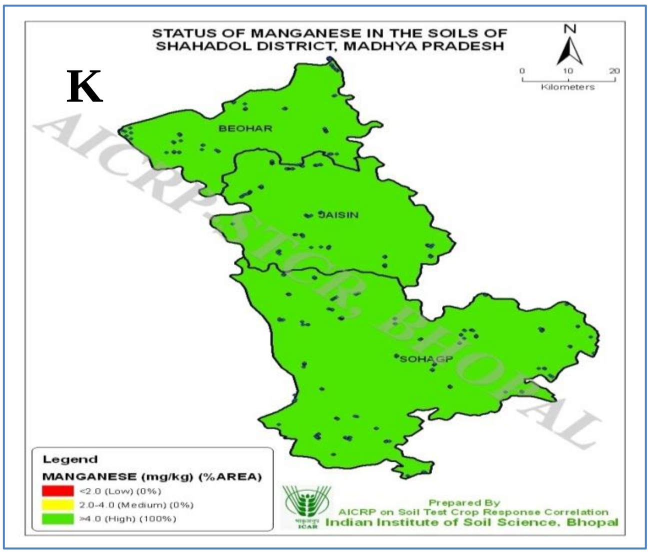












Source: Indian Institute of Soil Science, Bhopal (http://www.iiss.nic.in/mapd_3.htm)

Author Contributions: All the mentioned work had done by all authors and only map had prepared at Indian Institute of Soil Science, Bhopal, Madhya Pradesh 462001 because the present work is a part of Government of India Project and the research work conducted at Department of Soil Science, Jawaharlal Nehru Agricultural University, Jabalpur, 482004, Madhya Pradesh, India

Map Source: Indian Institute of Soil Science, Bhopal, Madhya Pradesh 462001

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Conflict of Interest: None declared

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