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GIS based Fertility Maps of Soils of Alirajpur District of Madhya Pradesh, India

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ABSTRACT

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Geo-statistics is an important tools extensively used for analyzing the spatial variability, interpolating between point observations and ascertaining the interpolated values with specified error using a minimum number of observations. GPS based two hundred seventy two surface soil samples were collected randomly from agricultural area of Alirajpur district of Madhya Pradesh under AICRP on MSN project. Results recorded that the 73.90, 26.10, 77.57, 64.71, 93.01 and 25.37 per cent soil samples were found to be deficient in N, P, K, S, Zn, and Fe respectively. Considering nutrient index values of <1.67 for low, 1.67-2.33 for medium and >2.33 for high fertility status, the soils of the study area were found to be in the category of low for OC, N, K, S and Zn; medium for P; and high with Mn, Cu, Fe and B. From the study, it is concluded that the soils of tribal dominated Alirajpur district is deficient in many numbers of nutrients. Therefore balanced and soil test based nutrient management practices should be followed to alleviate nutrient deficiencies of soils for sustainable crop production. None of the soil samples were tested low in Cu and Mn were found to be deficient. GIS based fertility maps showed that the fertility status of N, P, K, S, Zn, and Fe were deficient in major areas of research. Thus, these maps are useful for recommendation of fertilizers to increase the productivity.

Introduction

Soil characterization is an important aspect in view of sustainability (Singh *et al.*, 2017). Both macro- as well as micro- nutrients, play a vital role to govern the fertility of soil and control the productivity of crops (Bharti *et al.*,

2017). Currently, crop productivity is declining or stagnating because of imbalanced and inadequate fertilizers application coupled with low efficiency of other inputs mostly in the tribal belt of the country. Also, response efficiency of chemical fertilizer nutrients has declined tremendously under an intensive

agriculture system in recent years (Meena *et al.*, 2017). Intensive cultivation and indiscriminate use of high analysis chemical fertilizers results in deficiency of micronutrients (Singh *et al.*, 2007). Application of nutrients based on requirements for optimum production at each location because there is high spatial variability of macro-nutrients within individual fields (Ruffo *et al.*, 2005). Thus, information on spatial variability of soil nutrients is important for sustainable management of soil fertility (Fraisie *et al.*, 1999). In this context, it is necessary to evaluate the fertility status of the soil and to promote the recommendations of soil test for balanced nutrition to maintain soil health due to the randomness of variations from one place to another. Geo-statistics has been used extensively to characterize the spatial variability of soil attributes (Cambule *et al.*, 2014). Farmers of Alirajpur district have very little knowledge of fertility status of area is limited; therefore, the desired level of productivity is not being achieved even after utilizing all inputs. Hence, the present study was carried out in the limited area. Understanding of spatial variability and distribution of soil properties is critical for the farmer attempting to increase nutrients use efficiency and crop productivity. Application of fertilizers on the basis of soil characteristics associated with fertilizers recommendation may aid in minimizing the fertilizers input without any yield loss. Geo-statistics is an applied tools extensively used for analyzing the spatial variability, interpolating between point observations and ascertaining the interpolated values with specified error using a minimum number of observations (Long *et al.*, 2014 and Cambule *et al.*, 2014). The information about spatial variability in physical, chemical and biochemical properties as well as microbiological processes of soil had great importance in the selection of crops and cropping system and also broad extent the

ideas about prevailing management practices (Weindorf and Zhu, 2010; Cao *et al.*, 2011 and Liu *et al.*, 2013). Spatial variability in pH, soil organic matter, total and available NPK as well as micro-nutrients have been studied by many researchers under contrasting soil and management systems to refine and implement the site-specific nutrient management (Franzen *et al.*, 2002 and Li *et al.*, 2011).

Soil is one of the key components of the sustainable agricultural production system and its quality is governed by physico-chemical characteristics and nutrient supplying capacity which ultimately reflected through crop productivity. Soil quality was defined as the capacity of specific kind of soil to function, within the ecosystem and land use boundaries, to sustain productivity, maintain environmental quality and promote plant growth as well as human health (Andrews *et al.*, 2001). The concept of soil quality was introduced for proper stratification and allotment of agricultural inputs (Warkentin and Fletcher, 1977). Soils are inherently heterogeneous in nature because many factors contribute its formation and the complex interactions of these factors (Maniyunda *et al.*, 2013). Characterizing spatial variability of soil nutrients in relation to site properties, including climate, land use, landscape position, and other variables, is important for understanding how ecosystems work and assessing the effects of future land use change on soil nutrients (Wang *et al.*, 2001). It is well established that a change in land use, long-term intensive cultivation and chemical mineral fertilization can cause significant variations in soil properties (Jha and Mohapatra, 2010). The nature and characteristics of the soils are mainly dependent on geological formations, topography, and climate of the region in which the soil occurs. Dokuchaev who considered the soils to be as independent natural body each with a unique morphology resulting from

the unique combination of climate, living matter, parent materials, relief and age of landform.

Materials and Methods

Description of study area

Geographically, the Alirajpur district is situated 22°18'19" latitude and 74°21'09" longitude and at an altitude of 315 m above mean sea level. Administratively, district covers an area of 2165 km² and divided into six blocks name as Bhabara, Jobat, Sondwa, Kathiwarra, Alirajpur and Udaigarh. Location and sampling site maps of study area is given in Figure 1.

Soil sampling and their processing

GPS based two hundred seventy two surface soil samples were collected across all the blocks of Alirajpur district of Madhya Pradesh (India). Composite soil sample was collected and kept into properly labeled sample cloth bags. Soil samples were brought to the laboratory and air dried, crushed with wooden pestle and mortar, sieved through 2 mm stainless steel sieve.

Laboratory analysis

Soil pH, electrical conductivity (EC), soil organic carbon, and calcium carbonate was determined using standard procedure described by Jackson (1973). Available N was determined as per the method is given by Subbiah and Asija (1956). Available P was determined by 0.5 M sodium bicarbonate procedure as described by Olsen *et al.*, (1954) using Spectrophotometer. Available K was extracted with 1 N NH₄OAc and then measured by Flame Photometer (Jackson, 1973). The available sulphur was extracted by 0.15% CaCl₂ solution and the concentration of sulphur was determined by the turbidimetric

method using spectrophotometer (Chesnin and Yien, 1951). Available micro-nutrients were extracted by DTPA-CaCl₂ solution and analyzed using atomic absorption spectrophotometer (Lindsay and Norvell, 1978). Hot water soluble boron in soil was analyzed by azomethine-H method as outlined by Berger and Truog (1939). The nutrient index (NI) values for available nutrients present in the soils was calculated utilizing the formula suggested by Parker *et al.*, (1951) and classified this index as low (<1.67), medium (1.67 to 2.33) and high (>2.33).

Fertility maps prepared

Spatial correlation structure of available nutrients in the soil and spatially estimates their values at unsampled locations using geo-statistical tool in GIS 9.3.1 software.

Descriptive statistics of soil properties

Data presented in table 1 the mean values for pH, EC, SOC and CaCO₃ content 6.53, 0.09 dS m⁻¹, 5.20 g kg⁻¹ and 34.82 g kg⁻¹ with a range of 4.70 to 8.40, 0.03 to 0.90 dS m⁻¹, 0.47 to 12.92 g kg⁻¹ and 5.0 to 115 g kg⁻¹, respectively. The available N, P, K, and S content in soils of Alirajpur district ranged from 76.0 to 382.0 kg ha⁻¹, 1.34 to 62.13 kg ha⁻¹, 53.52 to 529.85 kg ha⁻¹ and 0.55 to 33.90 mg kg⁻¹ with mean value of 186.36 kg ha⁻¹, 21.01 kg ha⁻¹, 201.39 kg ha⁻¹ and 8.99 mg kg⁻¹, respectively. Fraction of Zn, Cu, Fe, Mn, and B contents in the soil varied from 0.03 to 1.98, 0.06 to 3.74, 1.07 to 36.0, 1.34 to 43.0 and 0.03 to 4.76 mg kg⁻¹ with mean values of 0.30, 0.96, 9.92, 14.54 and 1.67 mg kg⁻¹, respectively.

According Hillel (1980) and Yang and Yang (2005), there are three classes about coefficient of variation (C.V.) of soil nutrients, weak variation (C.V. = <0.1), medium variation (C.V. = 0.1–1.0), strong variation

(C.V. = > 1.0). The EC had the largest variation (CV = 88.91%) followed by Cu (CV = 83.26%) while, pH was found least variable (CV = 13.49%). Coefficient of variation less than 10%, 10 to 100%, and more than 100% was considered as low, moderate, and high variability, respectively. The pH had least variability (CV = 13.49 %), while CaCO₃ and SOC had moderate variability (CV = 54.24 and 60.32 %, respectively. Macronutrients were found moderately variable which ranged from 39.85 to 77.79 per cent. Micronutrients were also found moderately variable which ranged from 68.80 to 83.26 per cent in Alirajpur district as a whole. The available K in soil had lowest variability (CV=39.85 %) followed by available N (43.68 %), available P (69.80 %), and S had the highest variability (77.79 %). Among the micronutrients, Cu was found highly variable (CV = 83.26 %) followed by Zn (79.09%), Fe (73.85%) and Mn (70.45 %) and lowest in B (68.80%). Overall pH had low variability where as other soil properties showed moderate variability.

Fertility status

As per Subbiah and Asija (1956), the available N was found to be low (73.90%) and medium (26.10%) in soil samples. It may be due low organic matter content of soil as well as rapid loss of applied N in soil. On the basis of the limits suggested by Muhr *et al.*, (1963), the available phosphorus content was found to be low (26.10%), medium (34.56%) and high (39.34%) in the soil samples. The low amount of available P may be due to application of lower doses of P fertilizers, fixation of P on clay minerals or CaCO₃ surfaces with the time elapsed between fertilizer application and crop nutrients uptake. It may also be due low organic matter content of soil (Sanyal *et al.*, 2015) (Table 2).

According to Muhr *et al.*, (1963), the available potassium content was found to be low

(77.57%) in the soil samples, high in 1.84% soil samples and 20.59% of soil samples were found in medium. For these, soils available micro-nutrients status using critical limit as given in table 4 for DTPA-extractable Zn content was found to be deficient in 93.01%, medium in 5.88% and high in 1.10% soil samples. The data showed the DTPA extractable Fe content was found medium in 31.99% soil samples and none of the soil samples were tested low in Cu, Fe, Mn, and B content, respectively. All soil samples were found sufficient in case of Cu content. The present study result was supported by Athokpam *et al.*, (2013).

Physico-chemical properties of soils in different blocks of Alirajpur district

Data pertaining to variation in physico-chemical properties of soil of Alirajpur, Bhabra, Jobat, Kathiwar, Sondwa and Udaigarh blocks of Alirajpur district are presented in table 3. The values in the soil pH of Alirajpur, Bhabra, Jobat, Kathiwar, Sondwa, and Udaigarh blocks of soil samples varied from 4.90 to 8.20, 5.20 to 7.20, 4.78 to 8.00, 5.00 to 8.40, 5.60 to 8.10 and 4.70 to 7.90 with mean value of 6.53, 6.22, 6.75, 5.82, 7.08 and 6.33; EC varied from 0.03 to 0.43 dS m⁻¹, 0.04 to 0.13 dS m⁻¹, 0.03 to 0.65 dS m⁻¹, 0.03 to 0.35 dS m⁻¹, 0.04 to 0.90 dS m⁻¹ and 0.04 to 0.32 dS m⁻¹ with mean value of 0.09, 0.08, 0.09, 0.06, 0.13 and 0.09 dS m⁻¹; further SOC varied from 0.55 to 12.92 g kg⁻¹, 1.53 to 12.07 g kg⁻¹, 0.51 to 11.89 g kg⁻¹, 0.47 to 8.45 g kg⁻¹, 0.51 to 12.91 g kg⁻¹ and 1.20 to 12.12 g kg⁻¹ with mean value of 4.58, 5.60, 4.89, 3.24, 7.27 and 6.37 g kg⁻¹ and CaCO₃ varied from 10.00 to 115.00 g kg⁻¹, 20.00 to 100.00 g kg⁻¹, 5.00 to 90.00 g kg⁻¹, 10.00 to 50.00 g kg⁻¹, 5.00 to 100.00 g kg⁻¹ and 15.00 to 115.00 g kg⁻¹ and 40.66 g kg⁻¹ with mean value of 30.66, 37.00, 32.44, 26.83, 47.16 and 40.66 g kg⁻¹, respectively.

Macro-nutrient status

Available nitrogen content in the soils of Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks ranged from 78 to 382, 93 to 355, 78 to 342, 76 to 27, 87 to 356 and 90 to 350 kg ha⁻¹ with the mean values of 170.9, 201.8, 177.71, 138.63, 237.84 and 212.53 kg ha⁻¹, respectively. It was also found that variability in available N content in the soil of Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks was 48.23, 31.34, 38.66, 39.74, 36.77 and 40.54 per cent respectively.

About 81.93 and 18.07, 75 and 25, 80.95 and 19.05, 93.33 and 6.67, 47.37 and 52.63 and 55.26 and 44.74 soil samples were rated to be low and medium, respectively indicating nutrient index value of 1.18, 1.25, 1.19, 1.07, 1.53 and 1.45 in the soils of Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks. Available P content in the soils of Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks was ranged from 1.67 to 59.11, 6.91 to 59.61, 1.45 to 49.92, 1.34 to 59.11, 1.60 to 62.13 and 1.34 to 59.61 kg ha⁻¹ with a mean of 21.21, 31.77, 16.77, 15.65, 27.43 and 19.73 kg ha⁻¹, respectively. It was also found that variability in available P in the soil of Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks was 67.32, 53.86, 67.24, 82.25, 63.87 and 64.53 per cent respectively. About 24.10, 36.14 and 39.76; 10, 15 and 75; 33.33, 41.27 and 25.40; 43.33; 30 and 26.67, 15.79; 31.58 and 52.63, 23.68; 36.84 and 39.47 per cent samples drawn from Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks were observed low, medium and high, respectively. Soil samples were observed to be medium and high indicating nutrient index value of 2.16, 2.65, 1.92, 1.83, 2.37 and 2.16 of Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks. Available K content in the soils of Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa

and Udaigarh blocks was ranged from 56.91 to 398, 76.06 to 336.83, 63.67 to 383.04, 53.52 to 505.88, 56.91 to 337.96 and 62.54 to 529.85 kg ha⁻¹ with a mean of 189.73, 203.03, 216.03, 236.78, 171.93 and 203.28 kg ha⁻¹, respectively. It was also found that variability in available P in the soil of Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks was 35.40, 36.06, 33.38, 53.84, 31.40 and 42.54 per cent. About 70, 16.67 and 13.33; and 78.95, 18.95 and 2.63 per cent soil samples were found low, medium and high, respectively, indicating nutrient index of 1.43 and 1.24 in the soil of Kathiwara and Udaigarh blocks. However, in Alirajpur, Bhabra, Jobat and Sondwa blocks the nutrient index of 1.20, 1.25, 1.33 and 1.03 *i.e.* medium, showing, respectively. About 79.52 and 20.48, 75 and 25, 66.67 and 33.33 and 97.37 and 2.63 per cent samples were low and medium, respectively. Available sulphur (S) content in soils of Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks was ranged from 0.55 to 31.09, 1.10 to 31.09, 0.82 to 32.14, 0.82 to 33.90, 0.82 to 28.00 and 0.82 to 18.20 mg kg⁻¹ with a mean of 7.21, 10.08, 10.12, 9.79, 10.62 and 8.16 mg kg⁻¹, respectively. It was also found that variability in available P in soil of Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks was 89.65, 76.61, 59.29, 97.25, 77.58 and 57.15 per cent. About 75.90, 20.48 and 3.61; 55, 35 and 10; 55.56, 41.27 and 3.17; 66.67, 20 and 13.33 and 55.26, 28.95 and 15.79 per cent samples drawn from Alirajpur, Bhabra, Jobat, Kathiwara and Sondwa blocks were observed low, medium and high, respectively. Soil samples were observed to be medium and high indicating nutrient index value of 1.28, 1.55, 1.48, 1.47 and 1.61 of Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks. About 68.42 and 31.58 soil samples were rated to be low and medium, respectively indicating nutrient index value of 1.32 in only soils of Udaigarh block.

Micro-nutrient status

The DTPA extractable Zn content in soils of Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks varied from 0.03 to 0.97, 0.17 to 1.97, 0.04 to 1.50, 0.05 to 1.13, 0.08 to 1.98 and 0.04 to 1.03 mg kg⁻¹ with a mean value of 0.27, 0.50, 0.27, 0.25, 0.29 and 0.34 mg kg⁻¹, respectively. It was moderately variable by showing 51.81, 76.74, 78.88, 90.24, 108.72 and 61.99 per cent variability in respective blocks. In soils of Bhabra, Jobat and Sondwa block about 75.00, 20 and 5; 95.24, 3.17 and 1.57; and 94.74, 2.63 and 2.63 per cent soils samples were rated to be low, medium and high, respectively. Nutrient index of Zn was also calculated to be 1.30, 1.06 and 1.08 *i.e.* medium, high and high respectively. However, 96.39 and 3.61; 93.33 and 6.67; 89.47 and 10.53 per cent samples were found medium and high in the soils of Alirajpur, Kathiwara and Udaigarh blocks respectively indicating high nutrient index (1.04, 1.07 and 1.11). The DTPA extractable Cu content varied from 0.09 to 3.74, 0.59 to 3.15, 0.16 to 3.16, 0.06 to 2.55, 0.18 to 3.42 and 0.06 to 3.36 mg kg⁻¹ with a mean value of 0.96, 1.27, 0.85, 0.48, 0.95 and 1.40 mg kg⁻¹ in the soils of Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks, respectively. Variability in available Cu in soils of above respective blocks was 95.56, 47.58, 81.93, 102.74, 76.67, and 58.99 per cent. None of soil samples were found to be deficient in the soils of all Blocks. The Fe content ranged from 1.55 to 25.54, 3.65 to 30.00, 1.43 to 36.00, 1.07 to 21.90, 1.33 to 16.15 and 1.48 to 34.55 mg kg⁻¹ with a mean value of 7.55, 19.53, 9.20, 11.56, 6.04 and 13.79 mg kg⁻¹ in the soils of Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks, respectively. Available Cu had 65.20, 43.31, 75.83, 45.98, 65.11 and 67.55 per cent variability in above respective blocks. In Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks about 32.53, 39.76 and 27.71; 1.20, 1.20 and 90.00; 25.40,

36.51 and 38.10; 10.00, 20.00 and 70.00; 47.37, 28.95 and 23.68 and 10.53, 34.21 and 55.26 per cent soil samples were rated as low, medium and high, respectively. Nutrient index of Fe was found to be 1.95, 2.58, 2.13, 2.60, 1.76 and 2.45 *i.e.* low, medium, and high, respectively.

The DTPA extractable Mn content in the soil samples varied from 1.34 to 42.00, 4.58 to 43.00, 2.49 to 38.94, 2.43 to 38.79, 1.97 to 35.85, and 1.73 to 43.00 mg kg⁻¹ with average values of 12.34, 26.64, 12.17, 18.32, 10.02 and 18.43 mg kg⁻¹ in Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks, respectively. Variability in available Mn in the soil was 71.05, 45.35, 67.56, 52.21, 85.19 and 58.80 per cent in above respective blocks. In Alirajpur, Jobat, Kathiwara, Sondwa and Udaigarh blocks, about 8.43 and 91.57; 6.35 and 93.65; 3.33 and 96.67; 23.68 and 76.32 and 5.26 and 94.74 per cent soils samples were found medium and high, respectively. NI indicated that the Mn status was found to be high in the soil of the all blocks.

Hot water soluble boron in soil

The hot water soluble B content in the soil varied from 0.03 to 4.43, 0.45 to 2.88, 0.05 to 4.76, 0.69 to 4.43, 0.64 to 3.64 and 0.05 to 3.85 mg kg⁻¹ with mean values of 1.91, 1.42, 1.02, 2.41, 2.07 and 1.36 mg kg⁻¹ in Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks, respectively. It was moderately variable to the extent of 60.85, 60.25, 106.17, 44.29, 37.60 and 81.79 per cent in the soil samples of above respective blocks. In Alirajpur, Bhabra, Jobat, and Udaigarh blocks 18.07, 8.43 and 73.49; 1.20, 10.84 and 50.00; 47.62, 20.63 and 31.75 and 23.68, 23.68 and 52.63 per cent soils samples were found low, medium and high, respectively. The NI of soils in above respective blocks was found to the tune of 2.55, 2.45, 1.84 and 2.29 which was high. However, 3.33 and 96.67 and

7.89 and 92.11 per cent samples were noted medium and high, respectively indicating nutrient index of 2.97 and 2.92 (high) in the soil of Kathiwar and Sondwa blocks.

Physico-chemical properties of soils

Results pertaining to physico-chemical properties of soils of Alirajpur district showed that the soil pH of Alirajpur district as whole, varied from 4.7 to 8.4 with mean value of 6.5 in different blocks. Variation in soil pH under different blocks and district as whole might be due to variations in parent material of soil, management practices and land uses. Similar variations in soil pH under different regions were also reported by Raghuvanshi *et al.*, (1992); Dubliya (2011); Singh *et al.*, (2014) and Baishya and Sharma (2017).

However, electrical conductivity of soils across different blocks of Alirajpur district ranged from 0.03 to 0.90 dS m⁻¹ at 25°C with average of 0.09 dS m⁻¹ which was in normal range (< 1 dS m⁻¹ at 25°C). The low electrical conductivity in soil under study area might be due to high rainfall received and deep water table. Similar results for different soils were also reported by Tomar (1968); Singh (2012); Dilliwar *et al.*, (2014) and Singh *et al.*, (2014).

Whereas, organic carbon in the soil of different blocks of Alirajpur district was varied from 0.47 to 12.92 g kg⁻¹ with mean values ranged from 3.24 to 7.27 g kg⁻¹, while for Alirajpur district as whole SOC varied from 0.47 to 12.92 g kg⁻¹ with average value of 5.2 g kg⁻¹. Variation in organic carbon content in the soil samples may be due to variation in land use pattern, addition of organic matter in soil. Mandal *et al.*, (2011) also found that crop species and cropping systems may play an important role for variations in soil organic carbon. Findings of Singh *et al.*, (2014) and Yang *et al.*, (2014) also support the results of the present study.

Calcium carbonate content in the soil of different blocks of Alirajpur district ranged from 5 to 115 g kg⁻¹ with average values varied from 26.83 to 47.16 g kg⁻¹. Results also indicated that lowest and the highest values of CaCO₃ in the soil were obtained in Sondwa and Udaigarh blocks, respectively might be due to calcareous parent materials and lower leaching process. Similar results were reported by Dilliwar *et al.*, (2014) and Singh *et al.*, (2014).

Status and spatial distribution of macro-nutrients in the soil of different block of Alirajpur district

Results pertaining to status of macro-nutrients in the soil of different blocks of Alirajpur district showed that the contents of available N, P, K and S in soils of different blocks varied from 76 to 382, 1.34 to 62.13, 53.52 to 529.85 kg ha⁻¹ and 0.55 to 33.90 mg kg⁻¹ with mean values of 186.36, 21.01, 201.39 kg ha⁻¹ and 8.99 mg kg⁻¹, respectively. Results also showed that available P, K and S in the soil were moderately variable and available N in soil was less variable in terms of coefficient of variation across different blocks of Alirajpur district. Maniyunda *et al.*, (2013); Ravikumar and Somashekar (2014) and Olorunlana (2015) also reported similar findings. However, Denton *et al.*, (2017) reported high variability in available phosphorus and potassium (C.V = >35%) but moderate variability in available N, CEC and SOC and less variability in pH (C.V = <15%).

Results also revealed that deficiency of N, P, K, and S in the soil of Alirajpur district as whole was found to the extent of 73.9, 26.1, 77.6 and 64.7 per cent in the soil samples, and 26.1, 34.6, 20.6 and 29.0 per cent soil samples were found medium, respectively. Whereas, 39.34, 1.84 and 6.25 per cent soil samples were analyzed high in P, K and S status,

respectively. Nutrient index (NI) was found to be 1.26, 2.13, 1.24 and 1.42 for N, P, K and S, respectively. The categories of the soil fertility status were made with respect to N, P,

K and S as medium high medium and low. Kumar *et al.*, (2014) and Ravikumar and Somashekar (2014) also closely reported similar findings.

Table.1 Descriptive statistics of formulations (n=272)

Parameters	Min	Max	Mean	SD	CV (%)
pH	4.70	8.40	6.53	0.88	13.49
EC	0.03	0.90	0.09	0.08	88.91
OC	0.47	12.92	5.20	3.14	60.32
CaCO₃	5.00	115.00	34.82	18.89	54.24
N	76.00	382.00	186.36	81.40	43.68
P	1.34	62.13	21.01	14.66	69.80
K	53.52	529.85	201.39	80.26	39.85
S	0.55	33.90	8.99	6.99	77.79
Zn	0.03	1.98	0.30	0.23	79.09
Cu	0.06	3.74	0.96	0.80	83.26
Fe	1.07	36.00	9.92	7.32	73.85
Mn	1.34	43.00	14.54	10.24	70.45
B	0.03	4.76	1.67	1.15	68.80

Table.2 Fertility status and NI of soils of Alirajpur district (n=272)

Parameters	Low	Medium	High	NI
N	73.90	26.10	0.00	1.26
P	26.10	34.56	39.34	2.13
K	77.57	20.59	1.84	1.24
S	64.71	29.04	6.25	1.42
Zn	93.01	5.88	1.10	1.08
Cu	7.35	23.90	68.75	2.61
Fe	25.37	31.99	42.65	2.17
Mn	0.00	8.46	91.54	2.92
B	20.22	15.44	64.34	2.44

Table.3 Status of physico-chemical properties of soils of different blocks of Alirajpur district

		Min	Max	Mean	SD	CV	PSD	PSM	PSH	NI
Alirajpur (n=83)	N	78.00	382.00	170.90	82.42	48.23	81.93	18.07	0.00	1.18
	P	1.67	59.11	21.21	14.28	67.32	24.10	36.14	39.76	2.16
	K	56.91	398.00	189.73	67.17	35.40	79.52	20.48	0.00	1.20
	S	0.55	31.09	7.21	6.46	89.65	75.90	20.48	3.61	1.28
Bhabra (n=20)	N	93.00	355.00	201.80	63.25	31.34	75.00	25.00	0.00	1.25
	P	6.91	59.61	31.77	17.11	53.86	10.00	15.00	75.00	2.65
	K	76.06	336.83	203.03	73.21	36.06	75.00	25.00	0.00	1.25
	S	1.10	31.09	10.08	7.73	76.61	55.00	35.00	10.00	1.55
Jobat (n=63)	N	78.00	342.00	177.71	68.70	38.66	80.95	19.05	0.00	1.19
	P	1.45	49.92	16.77	11.28	67.24	33.33	41.27	25.40	1.92
	K	63.67	383.04	216.03	72.12	33.38	66.67	33.33	0.00	1.33
	S	0.82	32.14	10.12	6.00	59.29	55.56	41.27	3.17	1.48
Kathiwara (n=30)	N	76.00	278.00	138.63	55.10	39.74	93.33	6.67	0.00	1.07
	P	1.34	59.11	15.65	12.87	82.25	43.33	30.00	26.67	1.83
	K	53.52	505.88	236.78	127.49	53.84	70.00	16.67	13.33	1.43
	S	0.82	33.90	9.79	9.53	97.25	66.67	20.00	13.33	1.47
Sondwa (n=38)	N	87.00	356.00	237.84	87.45	36.77	47.37	52.63	0.00	1.53
	P	1.60	62.13	27.43	17.52	63.87	15.79	31.58	52.63	2.37
	K	56.91	337.96	171.93	53.99	31.40	97.37	2.63	0.00	1.03
	S	0.82	28.00	10.62	8.24	77.58	55.26	28.95	15.79	1.61
Udaigarh (n=38)	N	90.00	350.00	212.53	86.17	40.54	55.26	44.74	0.00	1.45
	P	1.34	59.61	19.73	12.73	64.53	23.68	36.84	39.47	2.16
	K	62.54	529.85	203.28	86.47	42.54	78.95	18.42	2.63	1.24
	S	0.82	18.20	8.16	4.67	57.15	68.42	31.58	0.00	1.32

Table.4 Micro-nutrients status in the soil of different blocks of Alirajpur district

Locations	Parameter	Min	Max	Mean	SD	CV	PSD	PSM	PSH	NI
Alirajpur(n=83)	Zn	0.03	0.97	0.27	0.14	51.81	96.39	3.61	0.00	1.04
	Cu	0.09	3.74	0.96	0.92	95.56	8.43	28.92	62.65	2.54
	Fe	1.55	25.54	7.55	4.92	65.20	32.53	39.76	27.71	1.95
	Mn	1.34	42.00	12.34	8.77	71.05	0.00	8.43	91.57	2.92
	B	0.03	4.43	1.91	1.16	60.85	18.07	8.43	73.49	2.55
Bhabra(n=20)	Zn	0.17	1.97	0.50	0.38	76.74	75.00	20.00	5.00	1.30
	Cu	0.59	3.15	1.27	0.61	47.58	0.00	0.00	100.00	3.00
	Fe	3.65	35.00	19.53	8.46	43.31	1.20	1.20	90.00	2.85
	Mn	4.58	43.00	26.64	12.08	45.35	0.00	0.00	100.00	3.00
	B	0.45	2.88	1.42	0.86	60.25	1.20	10.84	50.00	2.45
Jobat(n=63)	Zn	0.04	1.50	0.27	0.21	78.88	95.24	3.17	1.59	1.06
	Cu	0.16	3.16	0.85	0.70	81.93	7.94	30.16	61.90	2.54
	Fe	1.43	36.00	9.20	6.98	75.83	25.40	36.51	38.10	2.13
	Mn	2.49	38.94	12.17	8.22	67.56	0.00	6.35	93.65	2.94
	B	0.05	4.76	1.02	1.08	106.17	47.62	20.63	31.75	1.84
Kathiwara (n=30)	Zn	0.05	1.13	0.25	0.22	90.24	93.33	6.67	0.00	1.07
	Cu	0.06	2.55	0.48	0.50	102.74	20.00	43.33	36.67	2.17
	Fe	1.07	21.90	11.56	5.32	45.98	10.00	20.00	70.00	2.60
	Mn	2.43	38.69	18.32	9.57	52.21	0.00	3.33	96.67	2.97
	B	0.69	4.43	2.41	1.07	44.29	0.00	3.33	96.67	2.97
Sondwa(n=38)	Zn	0.08	1.98	0.29	0.31	108.72	94.74	2.63	2.63	1.08
	Cu	0.18	3.42	0.95	0.73	76.67	2.63	23.68	73.68	2.71
	Fe	1.33	16.15	6.04	3.94	65.11	47.37	28.95	23.68	1.76
	Mn	1.97	35.85	10.02	8.53	85.19	0.00	23.68	76.32	2.76
	B	0.64	3.64	2.07	0.78	37.60	0.00	7.89	92.11	2.92
Udaigarh(n=38)	Zn	0.04	1.03	0.34	0.21	61.99	89.47	10.53	0.00	1.11
	Cu	0.06	3.36	1.40	0.82	58.99	2.63	0.00	97.37	2.95
	Fe	1.48	34.55	13.79	9.32	67.55	10.53	34.21	55.26	2.45
	Mn	1.73	43.00	18.43	10.83	58.80	0.00	5.26	94.74	2.95
	B	0.05	3.85	1.36	1.11	81.79	23.68	23.68	52.63	2.29

Figure.1 Location map of study area

Spatial variability of OC in soils of Alirajpur district of MP

Status of available micro-nutrients and nutrient index in different block of Alirajpur district

Results relevant the status of available micro-nutrients (Zn, Cu, Fe, Mn, and B) in the soil across different blocks of Alirajpur district showed variability in available Zn, Cu, Fe, Mn, and B to the extent of 0.03 to 1.98, 0.06 to 3.74, 1.07 to 36, 1.34 to 43 and 0.03 to 4.76 mg kg⁻¹ with mean values of 0.30, 0.96, 9.92, 14.54 and 1.67 mg kg⁻¹, respectively. Results also showed that in Alirajpur district as whole 7.35 and 20.22% soil samples were tested low in Cu and B, respectively but none of the soil sample was found deficient in Mn. It was also across Alirajpur, Bhabra, Jobat, Kathiwara, Sondwa and Udaigarh blocks of Alirajpur district variability in Zn, Cu, Fe, Mn and B contents in the soil samples was 51.81, 76.74, 78.88, 90.24, 108.72 and 61.99; 95.56, 47.58, 81.93, 102.74, 76.67 and 58.99; 65.20, 43.31, 75.83, 45.98, 65.11 and 67.55; 71.05, 45.35, 67.56, 52.21, 85.19 and 58.80 and 60.85, 60.25, 106.17, 44.29, 37.60 and 81.79 per cent, respectively. Micro-nutrients in the soil were moderately variable and none of the soil samples tested low in Mn and Cu hence these are not a major problem in Alirajpur district as a whole. The results are in good agreement with those reported by Thakre *et al.*, (2013); Noor *et al.*, (2013) and Zhang *et al.*, (2014).

Fertility maps of Alirajpur district

Spatial variability maps of pH, EC, SOC, CaCO₃ and available N, P, K, S, Zn, Cu, Fe, Mn and B was prepared employing geo-statistical for which natural logarithmic transformation was used to reduce the skewness of the data distributions. Ordinary Kriging was chosen to create the spatial distribution maps of soil characteristics with the maximum search radius being set to the autocorrelation range of the corresponding variable. Semi-Variograms used for analysis

of spatial distribution of above properties of soil. Results showed that no apparent anisotropy was found for any studied variable through variograms. Similar findings were also reported by Srinivasan and Poongothai (2013).

Conclusion in the present study is soils of Alirajpur district were found neutral to slightly acidic in reaction, safe in electrical conductivity, low to medium in organic carbon, non-calcareous in nature and extent of N, P, K, S, Zn, Cu, Fe and B deficiencies in soils samples were to the extent of 73.9, 26.1, 77.6, 93.0, 7.4, 25.4 and 20.2 %, respectively.

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