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GIS based Soil Fertility Maps of Chambal Division of Madhya Pradesh, India

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ABSTRACT: Information to regarding spatial variability and distribution of soil characteristic is critical to increase use efficiency of nutrients and desire crop productivity for farming communities. Application of nutrients on the basis of soil characteristics maps connected with fertilizers recommendation may aid to curtail fertilizers input without surrendering the crop yield. For assessing the variability in soils fertility status using geo-statistical approaches, total 90 GPS based surface (0-15 cm) soil samples were collected from three districts (Morena, Bhind and Sheopur) of Chambal division after crop harvest, during *rabi* season 2019-20. The results revealed that pH, EC, OC and $CaCO_3$ of soils varied from 5.80 to 8.65, 0.12 to 0.89 dSm^{-1}, 1.50 to 10.20 g kg^{-1} and 1.0 to 65 g kg^{-1} soil, respectively. Whereas, available N, P, K and S in soils ranged from 71.25 to 348 kg ha^{-1}, 7.14 to 92.12 kg ha^{-1}, 60 to 620 kg ha^{-1} and 0 to 72 mg kg^{-1}, respectively. The deficiency of N, S, and Zn were found to be 83.41, 39.09, and 40.85 per cent in the soil samples respectively. None of the soil samples were tested deficient in P, K, Cu, Fe, Mn and B was found to be deficient. The present study clearly showed a large variability in the soil fertility status across the Chambal division was found. This information could aid in decision making for the application of plant nutrients and selection of cropping sequence for sufficient monetary returns to the farmers.

Keywords: Geo-statistical approach, NUE, Soil quality, Productivity.

INTRODUCTION

Kind the recent spatial variability supply of soil properties is important for farmers in an effort to increase nutrient use efficiency as well as crop productivity. Application of fertilizers based on soil characteristics associated with nutrient recommendation can help reduce the input of fertilizers without any yield loss. Geo-statistics is a useful tool that can be used to analyze spatial variability, interpolate point observations, and specify data using a minimum number of observations (Singh *et al.* 2014; Yadav *et al.*, 2018 and Singh *et al.*, 2017).

Soil is most important components of the sustainable agricultural production system and its quality is governed by physicochemical character & capacity of nutrient supply which ultimately reflected to crop productivity. Soil quality means the ability of the soil to perform the functions of the soil. The first mechanism is to keep the flour fertilizer within the useful limits of the land, as well as to maintain the environmental balance and maintain proper growth of plants, as well as the special importance of human health (Andrewset *et al.*, 2001). Soil is naturally heterogeneous in nature because many factors are responsible for its formation and the interaction of these factors is very complex (Maniyunda *et al.*, 2013).

It is well established that changes in land use, long-term farming and from the use of mineral fertilizers can bring about significant changes in the soil properties (Bairwa *et al.*, 2021 and Jha & Mohapatra, 2012). Dokuchaev described the soils as independent natural body with a unique morphology resulting from unique adjustment of climate, parent materials, relief and age of land. The nature & characteristics of soils are mainly depended on natural spring, topography, & climatic division in which the soil occurs.

MATERIAL AND METHODS

A. Brief description of study area

Chambal division is a part of Chambal valley of Madhya Pradesh. The three districts of Madhya Pradesh Sheopur, Morena and Bhind are under Chambal division. The Chambal division area spread over 16054 km^2 between 25°15′N to 26°48′N latitude and 76°31′E to 79°15′E longitude of 160 m above mean sea level. The topography extends from west to

east direction with medium slope gradient of 0 to 6 per cent.

B. Soil sampling and its processing

GPS based ninety soil surface samples are collected from different locations of study area. Approx 1.0 kg composite soil sample was collected and kept properly into labeled sample bags and brought to the laboratory and air dried, crushed with wooden pestle and mortar, sieved through 2 mm stainless steel sieve and used for determination of various soils fertility characteristics. The location and index map is shown in Fig. 1.

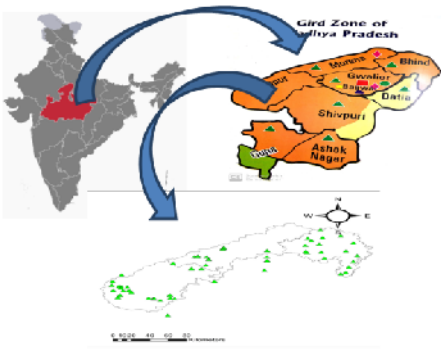

Fig. 1. Location map of study area.

B. Physicochemical properties

The soil pH and electric conductivity (EC) was measured in 1:2 ratio of soil: water using the pH meter and same supernatant with the help of conductivity meter (Jackson, 1973). Organic carbon (OC) of soil was determined using the method as described by Walkley and Black (1934). The calcium carbonate content in the soil was carried out using a rapid back titration method given by Jackson (1973). Available nitrogen (N) was determined as per the method as described Subbiah & Asija (1956). Available phosphorus (P) was determined by 0.5 M sodium bicarbonate procedure as described by Olsen *et al.*, (1954) and then read on Spectrophotometer. Available potassium (K) was extracted with 1 N NH_4OAc and then calculated by Flame Photometer (Jackson, 1973). The available sulphur (S) was extracted by 0.15 % $CaCl_2$ solution and the concentration of sulphur was determined by the turbidimetric method using Spectrophotometer (Chesnin and Yien, 1951). Available micronutrients were extracted by DTPA-$CaCl_2$ solution and analyzed using atomic absorption spectrophotometer (Lindsay and Norvell, 1978). Hot water soluble boron content in the soil was analyzed by azomethine-H method as given by Berger and Truog (1939). The nutrient index (NI) values for available nutrients present in the soils were calculated utilizing the formula given by (Parker *et al.*, 1951).

RESULTS AND DISCUSSION

Nutrients content (Physcochemicals, Macro and Micro) in soils of Chambal division of Madhya Pradesh

The study pertaining to be physicochemical properties of soils of Chambal division showed that the soil pH of Chambal division as whole, varied from 5.80 to 8.65 with mean value of 7.68 and under different districts variation in soil pH ranged from 5.80 to 8.65 with mean values varied from 6.69-7.71. Variation in soil pH under different districts and division as whole might be due to variations in the parent material of soil, management practices & land uses. Similar variations in soil pH in different regions were reported by Singh *et al.* (2014); Baishya and Sharma (2017) and Yadav *et al.* (2018).

However, electrical conductivity of soils across different districts of Chambal division ranged from 0.12 to 0.89 dS m^{-1} at 25°C with average of 0.36dS m^{-1} which was in normal range (< 1 dSm^{-1} at 25°C). The deficient electrical conductivity in soil under study area might be due to sufficient rainfall received and deep water table. Similar results for different soils were also reported by Dilliwar *et al.* (2014) and Singh *et al.* (2017).

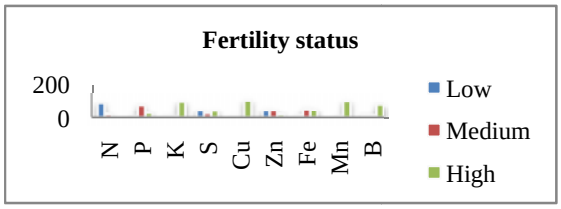

Fig. 2. Fertility status of soils of Chambal division of Madhya Pradesh.

Table 1: Descriptive statistics of physico-chemical properties and soil fertility status of soils of Chambal division of Madhya Pradesh.

Parameters	Min	Max	Mean	SD	CV	SD(%)	MS (%)	HS (%)	NI
pH	5.80	8.65	**7.68**	0.50	6.52				
EC(dSm^{-1})	0.12	0.89	**0.36**	0.15	40.39				
OC(gkg^{-1})	1.50	10.20	**4.72**	1.60	33.99				
$CaCO_3$(gkg^{-1})	1.00	65.00	**13.52**	9.46	69.97				
N ($kgha^{-1}$)	71.25	348.00	**202.26**	51.41	25.42	83.41	16.59	0.00	**1.17**
P ($kgha^{-1}$)	7.14	92.12	**20.01**	12.00	59.97	4.88	69.76	25.37	**2.20**
K ($kgha^{-1}$)	60.00	620.00	**390.13**	103.63	26.56	5.85	4.39	89.76	**2.84**
S ($mgkg^{-1}$)	0.00	72.00	**16.36**	13.42	81.99	39.09	22.73	38.18	**1.99**
Cu ($mgkg^{-1}$)	0.02	4.09	**1.53**	0.87	56.77	1.41	0.00	98.59	**2.97**
Zn ($mgkg^{-1}$)	0.07	15.00	**1.00**	1.77	175.76	40.85	40.85	18.31	**1.77**
Fe ($mgkg^{-1}$)	2.33	32.60	**10.27**	6.33	61.65	8.45	49.30	42.25	**2.34**
Mn($mgkg^{-1}$)	2.61	33.00	**11.94**	6.41	53.66	0.00	5.63	94.37	**2.94**
B ($mgkg^{-1}$)	0.06	4.56	**1.91**	1.11	58.05	15.49	8.45	76.06	**2.61**

Whereas, organic carbon content in soils of different districts of Chambal division was varied from 1.50 to 10.20 g kg^{-1} with mean values ranged from 4.04 to 6.07 g kg^{-1}, while for Chambal division as whole OC varied from 1.50 to 10.20 g kg^{-1} with average value of 4.72 g kg^{-1}. Variation in organic carbon content in soil samples was may be due to variation in land use pattern, adding of OM in the 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 Yadav *et al.*, (2018) also support the conclusion of present study.

Calcium carbonate content in soils of different districts ranged from 1.0 to 65 g kg^{-1} with average values varied from 9.77 to 29.17 g kg^{-1}. Results also indicated that the deficient & the sufficient values of $CaCO_3$in the soil were obtained in Morena and Bhind districts, respectively might be due to calcareous parent materials and deficienter leaching process. Similar results were reported by Dilliwar *et al.* (2014) Singh *et al.* (2014) and Yadav *et al.*, (2018).

Available N, P, K and S content in soils of Chambal division ranged from 71.25 to 348.00 kg ha^{-1}, 7.14 to 92.12 kg ha^{-1}, 60.00 to 620.00 kg ha^{-1} and 0.00 to 72.00 mg kg^{-1} with mean value of 202.26 kg ha^{-1}, 20.01 kg ha^{-1}, 390.13 kg ha^{-1} and 16.36 mg kg^{-1}, respectively. This might be due to increased rate of de-nitrification at deficient values. Removal of the surface soil containing sufficient OC due to erosion was responsible for the deficient nitrogen. This is because at sufficient pH, calcium precipitates with P as Ca-phosphate and reduce P availability. This might be due to creation of favorable soil environment with presence of sufficient organic matter. This may be due to organic S constitutes the major share of total S present in soil. Zn, Cu, Fe, Mn and B contents in soil varied from 0.07 to 15.0, 0.02 to 4.09, 2.33 to 32.60, 2.61 to 33.00 and 0.06 to 4.56 mg kg^{-1} with mean values of 1.00, 1.53, 10.27, 11.94 and 1.91 mg kg^{-1}, respectively.

Fertility status in soils of Chambal division: In Chambal division about 55.61 and 39.51 per cent soil samples were found deficient and medium in organic carbon, respectively. However, 83.41, 4.88, 5.85, and 39.09 per cent soil samples were deficient and 16.59, 69.76, 4.39 and 22.73 per cent soil samples were medium in N, P, K and S, respectively. While, soil samples sufficient in available P, K, and S were 25.37, 89.76 and 38.18 per cent, respectively. Nutrient index (NI) was found to be 1.17, 2.20, 2.84 and 1.99 for N, P, K, and S, respectively. In soils of Chambal division 98.59, 42.25, 94.37 and 76.06 per cent soils samples were rated to be sufficient for Cu, Fe, Mn and B, respectively.

Spatial variability distribution of macronutrients in the soils of different districts of Chambal division: Data pertaining to variation in soil physicochemical properties in Bhind, Morena and Sheopur district of Chambal division are observed that in Bhind district, pH, EC, OC and $CaCO_3$ of soil samples varied from 6.98 to 8.14, 0.14 to 0.82 dS m^{-1}, 2.40 to 10.20 g kg^{-1} and 15 to 65 g kg^{-1} with mean value of 7.69, 0.48 dS m^{-1}, 4.64 g kg^{-1}, and 29.17 g kg^{-1} respectively (Table 2). Those values of pH, EC, OC and $CaCO_3$ of the soil samples varied from 6.90 to 8.20, 0.12 to 0.76 dS m^{-1}, 1.50 to 8.60 g kg^{-1} and 1.00 to 23.50 g kg^{-1} with mean value of 7.71, 0.34 dS m^{-1}, 4.04 g kg^{-1}, and 9.77 g kg^{-1} respectively in Morena district. Further, it was found that in Sheopur district of Chambal division the values of pH, EC, OC and $CaCO_3$ of the soil samples varied from 5.80 to 8.00, 0.12 to 0.49 dS m^{-1}, 2.20 to 10.00 g kg^{-1} and 12 to 24 g kg^{-1} with mean value of 6.69, 0.28 dS m^{-1}, 6.07 g kg^{-1}, and 18.30 g kg^{-1} respectively. Results also revealed that the macronutrients (N, P, K, and S) status in Bhind, Morena and Sheopur districts of Chambal division are presented (Table 3 and 4).

Table 2: Status of soil physico-chemical properties of different district of Chambal division.

District		pH	EC(dS m^{-1})	OC(g kg^{-1})	$CaCO_3$(g kg^{-1})
Morena	**Min**	6.90	0.12	1.50	1.00
	Max	8.20	0.76	8.60	23.50
	Mean	**7.71**	**0.34**	**4.04**	**9.77**
	SD	0.28	0.14	1.32	4.89
	CV	3.64	41.25	32.61	50.02
Bhind	**Min**	6.98	0.14	2.40	15.00
	Max	8.14	0.82	10.20	65.00
	Mean	**7.69**	**0.48**	**4.64**	**29.17**
	SD	0.35	0.23	2.16	13.78
	CV	4.60	48.78	46.58	47.24
Sheopur	**Min**	5.80	0.12	2.20	12.00
	Max	8.00	0.49	10.00	24.00
	Mean	**6.69**	**0.28**	**6.07**	**18.30**
	SD	0.70	0.13	2.47	3.00
	CV	10.52	44.99	40.72	16.42

Table 3: Status of macro-nutrients in soils of different district of Chambal division.

Districts		kg ha^{-1}			
		N	P	K	S
Morena	Min	71.25	7.14	303.60	1.00
	Max	228.40	28.70	620.00	52.00
	Mean	**172.32**	**15.72**	**444.05**	**13.60**
	SD	38.67	4.09	74.21	11.70
	CV	22.44	25.99	16.71	85.99
Bhind	Min	146.00	10.50	300.00	16.23
	Max	348.00	31.65	579.10	56.20
	Mean	**257.73**	**23.26**	**393.87**	**25.85**
	SD	51.20	6.02	75.58	10.54
	CV	19.87	25.90	19.19	40.79
Sheopur	Min	97.00	8.00	60.00	0.00
	Max	325.00	58.00	457.00	72.00
	Mean	**237.07**	**21.67**	**269.53**	**21.60**
	SD	62.75	15.21	116.65	18.68
	CV	26.47	70.21	43.28	86.47

Table 4: Fertility status and nutrient index of macronutrients in soils of different districts in Chambal division.

Districts	Status	N	P	K	S
Morena	DS (%)	100.00	8.75	0.00	48.75
	MS (%)	0.00	77.50	0.00	21.25
	HS (%)	0.00	13.75	100.00	30.00
	NI	**1.00**	**2.05**	**3.00**	**1.81**
Bhind	DS (%)	40.00	0.00	0.00	0.00
	MS (%)	60.00	33.33	0.00	33.33
	HS (%)	0.00	66.67	100.00	66.67
	NI	**1.60**	**2.67**	**3.00**	**2.67**
Sheopur	DS (%)	40.00	13.33	20.00	26.67
	MS (%)	60.00	60.00	33.33	20.00
	HS (%)	0.00	26.67	46.67	53.33
	NI	**1.60**	**2.13**	**2.27**	**2.27**

Available nitrogen content in the soils of Bhind, Morena and Sheopur districts were ranged from146 to 348, 71.25 to 228.40 and 97 to 325 kg ha^{-1} with averaged values of 257.73, 172.32 and 237.07 kg ha^{-1}. It was also found that the variability in available N content in the soil of Bhind, Morena and Sheopur districts was 19.87, 22.44 and 26.67 per. About 40 and 60, 100 and 0 and 40 and 60 soil samples were rated to be deficient and medium, respectively indicating nutrient index values of 1.60, 1.0 and 1.60 in the soils of Bhind, Morena and Sheopur districts.

Available phosphorus content in the soils of Bhind, Morena and Sheopur districts were ranged from 10.50 to 31.65, 7.14 to 28.70 and 8.0 to 58.0 kg ha^{-1} with the averaged values of 23.26, 15.72 and 21.67 kg ha^{-1}, respectively. It was also found that the variability in available P in soil of Bhind, Morena and Sheopur districts were 25.90, 25.99 and 70.21 per cent.About 0, 33.33 and 66.67; 8.75, 77.50 and 2.05;13.33, 60 and 26.67 per cent samples drawn from Bhind, Morena and Sheopur districts were observed deficient, medium and sufficient, respectively. Soil samples were observed to be medium and sufficient representing the NI values of 2.67, 2.05 and 2.13 of Bhind, Morena and Sheopur districts.

Available potassium content in the soils of Bhind, Morena and Sheopur districts was ranged from 300 to 579.10, 303.60 to 620 and 60 to 457 kg ha^{-1} with the mean of 393.87, 444.05 and 269.53 kg ha^{-1}, respectively. It was also found that variability of available P in the soil of Bhind, Morena and Sheopur districts was 19.19, 16.71 and 43.28 per cent. About 100 per cent soil samples were found sufficient in both, respectively, indicating nutrient index of 3 in the soil of Bhind & Morena district. However in Sheopur the nutrient index of 2.27; and 20, 33.33 and 46.67 per cent samples deficient, medium and sufficient, respectively.

Available sulphur content in soils of Bhind, Morena and Sheopur districts were ranged from 16.23 to 56.20, 1.0 to 52 and 0 to 72 mg kg^{-1} with a mean of 25.85, 13.60 and 21.60 mg kg^{-1}, respectively. It was also found that variability in available P in soil of Bhind, Morena and Sheopur districts were 40.79, 85.99 and 86.47 per cent. About 0, 33.33 and 66.67; 48.75, 21.25 and 30; and 26.67, 20 and 53.33 per cent samples drawn from Bhind, Morena and Sheopur districts were observed deficient, medium and sufficient, respectively. Soil samples were observed to be deficient, medium and sufficient indicating the nutrient index values of 2.67, 1.81 and 2.27 of Bhind, Morena and Sheopur districts. Kumar *et al.* (2014), Ravikumar and Somashekar (2014), Singh *et al.* (2017), Yadav *et al.* (2018) also reported similar findings.

Micronutrient status

The micronutrients (Zn, Cu, Fe, Mn and B) status in Morena, Bhind and Sheopur districts of Chambal division are presented (Table 4 and 6). The DTPA extractable Zn content in the soils of Morena, Bhind and Sheopur varied from0.24 to 15.00, 0.07 to 1.85 and 0.15 to 2.25 mg kg^{-1} with a mean value of 1.39, 0.60 and 1.03 mg kg^{-1}, respectively. In soils of in Morena and Bhinddistricts about 35.71, 39.29 and 25.00 and 57.14, 35.71 and 7.14 per cent soils samples were rated to be deficient, medium and sufficient, respectively, and 100 per cent samples of Sheopur district rated sufficient. Nutrient index of Zn was also calculated to be 1.89, 1.50 and 2.07, respectively.

Table 5: Status of micro-nutrients of soils of different districts of Chambal division.

Districts		mg kg^{-1}				
		Cu	**Zn**	**Fe**	**Mn**	**B**
Morena	**Min**	0.48	0.24	2.76	4.90	0.13
	Max	4.09	15.00	17.45	17.25	4.56
	Mean	**1.65**	**1.39**	**7.98**	**10.12**	**1.89**
	SD	1.04	2.72	3.95	3.91	1.27
	CV	62.81	195.44	49.56	38.68	67.39
Bhind	**Min**	0.02	0.07	2.33	2.61	0.06
	Max	3.35	1.85	18.78	20.40	3.40
	Mean	**1.37**	**0.60**	**8.83**	**9.60**	**1.71**
	SD	0.80	0.41	4.25	4.67	1.03
	CV	58.09	68.36	48.10	48.60	60.27
Sheopur	**Min**	0.58	0.15	8.24	8.98	0.76
	Max	2.90	2.25	32.60	33.00	3.62
	Mean	**1.62**	**1.03**	**17.23**	**19.73**	**2.31**
	SD	0.64	0.62	8.29	7.16	0.84
	CV	39.43	60.21	48.12	36.32	36.25

Table 6: Fertility status and nutrient index of Micronutrients in soils of different districts in Chambal division.

Districts	Status	Cu	Zn	Fe	Mn	B
Morena	DS (%)	0.00	35.71	10.71	0.00	21.43
	MS (%)	0.00	39.29	67.86	0.00	10.71
	HS (%)	100.00	25.00	21.43	100.00	67.86
	NI	**3.00**	**1.89**	**2.11**	**3.00**	**2.46**
Bhind	DS (%)	3.57	57.14	10.71	0.00	17.86
	MS (%)	0.00	35.71	50.00	14.29	7.14
	HS (%)	96.43	7.14	39.29	85.71	75.00
	NI	**2.93**	**1.50**	**2.29**	**2.86**	**2.57**
Sheopur	DS (%)	0.00	20.00	0.00	0.00	0.00
	MS (%)	0.00	53.33	13.33	0.00	6.67
	HS (%)	100.00	26.67	86.67	100.00	93.33
	NI	**3.00**	**2.07**	**2.87**	**3.00**	**2.93**

The DTPA extractable Cu content in soils of Morena, Bhind and Sheopur districts varied from0.48 to 4.09, 0.02 to 3.35 and 0.58 to 2.90 mg kg^{-1} with a mean value of 1.65, 1.37 and 1.62 mg kg^{-1}, respectively. In soils of Morena, Bhind and Sheopur districts about 100, 96.43 and 100 per cent soils samples were rated to sufficient, respectively. However, soils of Morena, Bhind and Sheopur districts, respectively indicating sufficient nutrient index 3.0, 2.93 and 3.0.

The DTPA extractable Fe content in the soils of Morena, Bhind and Sheopur districts varied from 2.76 to 17.45, 2.33 to 18.78 and 8.24 to 32.60 mg kg^{-1} with a mean value of 7.98, 8.83 and 17.23 mg kg^{-1}, respectively. In soils of Morena, Bhind and Sheopur districts about 10.71, 67.86 and 21.43; 10.71, 50.0 and 39.29 and 0,13.33 and 86.67 per cent soils samples were rated to be deficient, medium and sufficient, respectively. Nutrient index for Fe was also calculated to be 2.11, 2.29 and 2.87 respectively.

The DTPA extractable Mn content in the soils of Morena, Bhind and Sheopur districts varied from 4.90 to 17.25, 2.61 to 20.40 and 8.98 to 33.0 mg kg^{-1} with a mean value of 10.12, 9.60 and 19.73 mg kg^{-1}, respectively. In soils of Morena, Bhind and Sheopur districts have 100, 85.71 and 100 per cent soils samples were rated to be sufficient, respectively. Nutrient index for Mn was also calculated to be 3.0, 2.86 and 3.0, respectively, all district are indicating good nutrient index.

The hot water soluble B content in the soils of Morena, Bhind and Sheopur districts varied from 0.13 to 4.56, 0.06 to 3.40 and 0.76 to 3.62 mg kg^{-1} with a mean value of 1.86, 1.71 and 2.31 mg kg^{-1}, respectively. In the soils of Morena, Bhind and Sheopur districts about 21.43, 10.71 and 67.86; 17.86, 7.14 and 75.00 and 0, 6.67 and 93.33 per cent soils samples were rated to be deficient, medium and sufficient, respectively (Fig. 3). Nutrient index for B was also calculated to be 2.46, 2.57 and 2.93, respectively. The results are in good agreement with those reported by Singh *et al.* (2014); Singh *et al.* (2017), and Yadav *et al.* (2018).

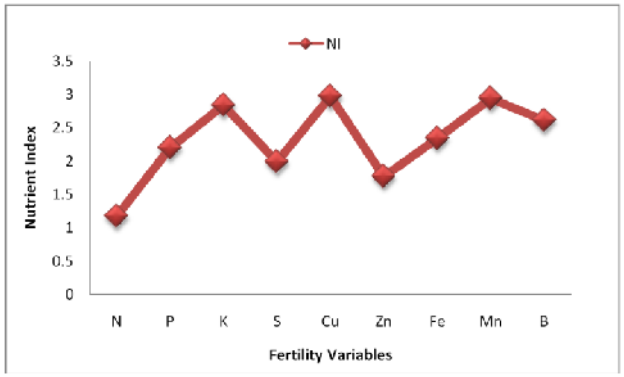

Fig. 3. Index of nutrient availability in soils of Chambal division.

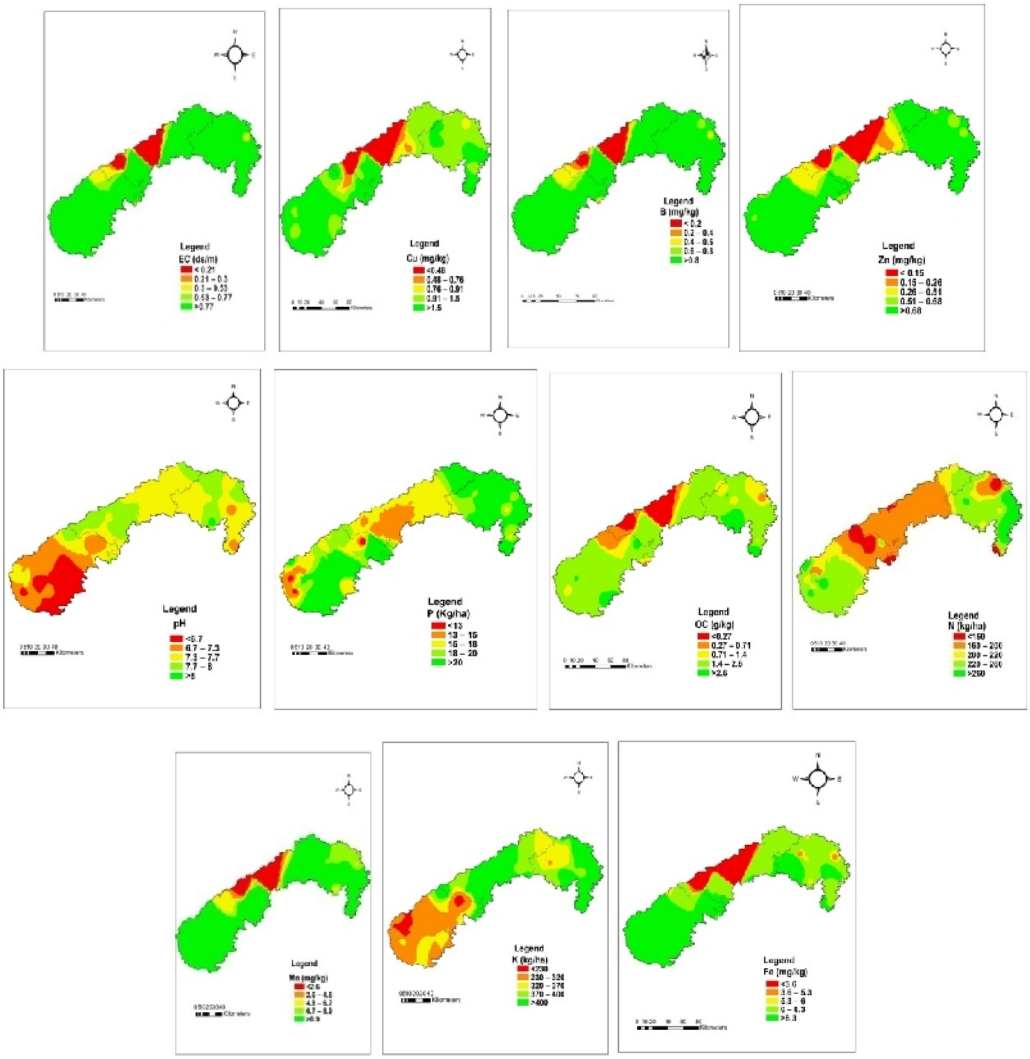

Fig. 4. -16- Spatial variability maps of soil fertility of Chambal division of Madhya Pradesh.

CONCLUSION

Soils of Chambal division were found neutral to slightly acidic to alkaline in reaction, safe in electrical conductivity, deficient to medium in organic carbon, non-calcareous in nature, extent of N deficiency in soils samples were to the extent of 83.41 % and extent of K excess in soils samples were to the extent of 89.76 % and extent of Cu, Mn and B excess in soils samples were to the extent of 98.59, 94.37 and 76.06 per cent, respectively. Application of fertilizers on the basis of soil characteristics maps associated with fertilizers recommendation may aid to curtail fertilizers input without surrendering the crop yield.

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Conflict of Interest. Nil

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