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Status and distribution of soil fertility under different domains of central India

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Abstract
In present study GPS based 531 soils samples were collected, analysed in the lab of Department of Soil Science and Agricultural Chemistry Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during 2018-2020. Data obtained were statistically interpreted. Results suggested that the soils of the domains were found neutral to slightly alkaline in soil reaction, safe in electrical conductivity, high, low, medium and low in Bhopal, Jabalpur Vidisha and Hoshnagabd domains in organic carbon content and non-calcareous nature. Result revealed that the N, P, K and S denoted as low-L medium-M, high-H, and found to be (M-L-H-M); (L-M-H-M); (L-M-H-M); (L-M-M-M); and (L-H-M-M) in Bhopal, Jabalpur Vidisha and Hoshnagabad domains, respectively. However, in AESR10.1 as whole, revealed that organic carbon was found to be medium and macronutrients were analyzed to be L-M-M-M hence the severity of deficiency occurred in the order of N > S > P > K. The results could be used as a basis for site specific fertilization in order to supply the optimum requirements for plant growth.

Keywords: Soil fertility, nutrient index, macro-nutrient, physico chemical properties

1. Introduction
Soil is a unique natural dynamic system with variable physo-chemical and biological properties which provide life to the entire living creature on the earth termed as 'soul of infinite life'. Its proper use determines the capability of life support system and socioeconomic development of any nation. The majority of soils, however, in India are deficient in nutrients due to imbalance fertilizer application and imbalance management practices. The tremendously growing population is an acute problem that demands maximum possible production from each unit of cultivated land per unit time. Moreover, with an ever-increasing population, the cultivated land are under serious threats of depleting native soil fertility owing to intensive agriculture without optimal resource assessment-based input applications. This had resulted to persistently low crop yields. Hence, efficient management of soil fertility using modern tools is essential for ensuring food security for future generation.
Soil fertility is the inherent capacity of soil that provides essential plant elements in requisite quantities and proportions for the growth of specified plant when other factors are favourable. If continued intensive cropping is over a period of time without balanced fertilization and restoring of nutrients in soil, reduction in soil fertility and loss in crop yields is inevitable (Shah *et al*., 2013). The availability of soil nutrients for plant growth and yield production is a function of soil physical chemical and biological parameters. Hence, determination of spatial variability of soil properties is important for evaluating nutrient behaviour in the soil and for suggesting appropriate methods of enhancing nutrient availability to plant.
Study area used for various kinds of crops such as field crops, vegetables and horticulture, from longer period of time. Majority of the previous studies showed the research work conducted on this aspect is limited and stressed on undertaking fertility status. In light of above facts, a study was conducted.

2. Material and Methods
2.1 Description of study area
Madhya Pradesh lies between 21º17′ to 26º52′ N latitude and 74º08′ to 82º49′ E longitude with geographical area of 30.82 M ha (9.4% of the country).

Parent material, relief and local climate are heterogeneous in the region, thus forming many types of soils with diverse properties, depths and drainage characteristics. The soils are Inceptisols followed by Entisols, Alfisols, and Vertisols (NBSS & LUP 1996).

Four sites (clusters *viz*. I-domain at Jabalpur ACZ-III Kamure plateau and satpura hills, II-domain Hoshangabad ACZ-V Central Narmada valley, IIIrd –domain at Bhopal, Sehore and Vidsha ACZ IV-Vindhyan plateau) were taken for study during 2018-21. The latitude, longitude, and elevation at each sampling point were recorded using a handheld GPS. The coordinates of four different domains *viz.*, Hoshangabad domain is located in Central Narmada Valley Zone of Madhya Pradesh. It lies between 22º35'45" N to 23º49'30" N latitude and longitude is 77º40'10" E to 78º04'15" E longitude. The elevation is 229 m of the mean sea level. Soil of Hoshangabad district is grouped under deep black soil, clay to sandy loam in texture, pH of the soil varies in the range of 7.0 to 8.5. The domains dry in climate except during the southwest monsoon season. May is the hottest month with mean daily maximum temperature 41.10ºC. December – January forms the coldest part of the year with mean daily minimum temperature 10.93ºC. The annual normal rainfall is 995.20 mm. About 92% of the annual rainfall received from southwest monsoon.

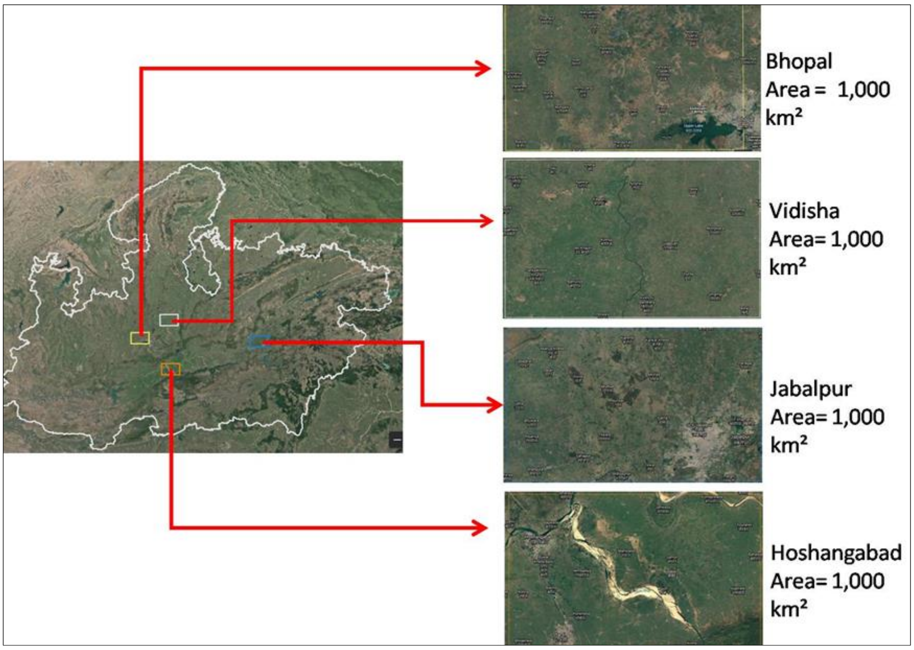

Fig 1: Location of study sites

Among the four domains, second Bhopal domain was situated (23º15'45" N to 23º26'45" N and longitude is 76º01'15" E to 76º24'30" E) Bhopal and Sehore districts.

The third site Vidisha domain, (23º35'15" N to 23º48'30" N and longitude is 77º39'15" E to 78º02'15" E.) located and had been under continuous soybean-wheat soybean-chickpea sequence. Vidisha district is lying in the central part of Madhya Pradesh. It has an area of 7371 km2 lying between the North Latitudes 220 20' and 240 22' and East Longitudes 770 16' and 780 18'" and falls under the Survey of India toposheet No. 54H, 54L, 55E and 55 I. Physiographically the district has been divided into three major units i.e. Malwa Plateau, Vindhyan Hill range and Alluvium plain. Vindhyan formations comprising of sandstone shales and breccias are exposed in the western and southeastern part of the district. The small patches of Vindhayans are exposed in the form of hills. A major part of Nateran, Gyarspur and Basoda blocks is occupied by Vindhyan formation and comprises of sandstone and shales. The sandstones are normally hard, Quartzitic, massive and compact. However, they are jointed at the surface level.

The fourth site Jabalpur domain is situated (23º08'15" N to 23º20'45" N and longitude is 79º37'45" E to 80º01'30" E) and altitude of 383.3 m above mean sea level in the vicinity supported a rice-wheat. Geologically, all kinds of rock formations are found in Jabalpur district as a whole but with regard to soil, Deccan trap is important which has the colour and properties of soil. Soil order was Vertisol, Typic Haplusterts, very fine montmorrilonite, hyperthermic, *Kheri* Series and clayey in texture.

2.2.1 Selection of sites

We performed multi-layer thematic overlay analysis in GIS environment (Arc-GIS v10.3.1) in order to identify representative soil sampling locations from agricultural land uses by employing Survey of India (SOI) topo-sheets (RF 1:50000) as base map. Thematic layers of the valley i.e. geology, physiography, elevation, slope, LULC etc. were sourced from the Bhuvan web mapping service of National Remote Sensing Centre (NRSC: http://bhuvan.nrsc.gov.in/gis /thematic) which were originally derived from LISS III image of Indian Remote Sensing satellite (IRS-P6) by NRSC (2018–2019). Apart from this, the slope aspects were derived from Digital Elevation Model (ASTER-GDEM). Thereafter, we selected 531 geo-referenced points following random sampling technique across major cropping systems. Relatively, large sample size was selected from Vidisha domain as they considered for wheat acreage and yield mapping.

2.2.2 Soil sampling

GPS based a total (531) five hundred thirty one surface soil samples (0-15 cm) were collected from farmer's field *viz.*, Bhopal (n=105), Jabalpur (n=142), Vidisha (n=153) and Hoshangabad (n=131) during 2018-2020 during the off season from the agricultural land to avoid the effect of fertilization during crop cultivation. For each sampling point, 1.0 kg of representative composite soil sample was collected and logged into properly labelled sample bag. Soil samples were not taken from unusual areas like animal dung accumulation places, poorly drained and any other places that cannot give representative soil samples. During soil sampling, spatial information (latitude and longitude), topography, slope, elevation, land use type, crop type, local soil name, soil colour, crop residue management, rate of last year fertilizer application and type were collected from each site. The soil samples were dried at room temperature (25±3 ◦C) stone and debris from samples were removed and then ground to pass a 2 mm sieve.

2.2.3. Laboratory methods for estimation of soil properties

Physico-chemical properties

The soil pH was measured in a soil: water ratio of 1: 2.5 using the pH meter and supernatant of same was used for electrical conductivity determination with the help of conductivity-meter Jackson (1973) [11]. Organic carbon in soil was determined using method as described by (Walkley and Black 1934) [31]. The calcium carbonate in soil was carried out using rapid back titration method as described by Jackson (1973) [11].

2.2.4 Macronutrients

Available N was determined as per standard method. Available P was determined by 0.5 M sodium bicarbonate by Olsen *et al*., (1954) [19] and then measured by Spectrophotometer. Available K was extracted with 1 N NH4OAc and then measured by Flame Photometer Jackson (1973) [11]. The available S was extracted by 0.15 percent $CaCl_2$ solution and the concentration of sulphur was determined by the turbidimetric method using Spectrophotometer Chesnin and Yien (1951) [7].

Table 1: Critical limits for soils categorization (Singh *et al*., 2007 [9, 12, 14, 27, 28]; Sethy, 2016)

Parameters	Low	Medium	High
OC (gkg^{-1})	<2.5	2.5-7.5	> 7.5
N ($kgha^{-1}$)	<250	250-400	> 400
P ($kgha^{-1}$)	<10	10-20	> 20
K ($kgha^{-1}$)	<250	250-400	> 400
S ($mgkg^{-1}$)	<10	10-20	> 20

2.2.5 Nutrient index calculation

The nutrient index (NI) values for available nutrients present in the soils were calculated utilizing the formula and classified this index as low (<1.67), medium (1.67 to 2.33) and high (> 2.33).

$$NI = [(NL \times 1) + (NM \times 2) + (NH \times 3)]/NT$$

Where, NL, NM and NH are the number of soil samples falling in low, medium and high categories for nutrient status and are given weight age of 1, 2 and 3, respectively. NT is the total number of soil samples.

2.3 Statistical analysis

The obtained soil data were analyzed by plotting various charts and diagrams/graph tables, mean, Pearson correlation and one-way analysis of variance using SPSS version 21.0. PCA, While Pearson correlation was employed to determine the nature of association between the soil variable in order to understand the possible factors that affected their build up in soil.

3. Results and Discussion

3.1.1 Status of physico-chemical properties of the soils of various domains

3.1.1.1 Soil reaction (pH)

A comparison of soil pH values under different domains is represented in Table 2. Various domains exhibited the following order in their pH values: Vidisha > Hoshangabad > Bhopal > Jabalpur. The highest pH value was shown by Vidisha domain. It had the mean pH value of 7.90 with a range of 7.50 to 8.24 and the value of coefficient of determination of 2.21%. In Hoshangabad, the pH values varied from 7.17 to 8.45 with a mean value of 7.82 and 3.94% CV. In Bhopal, it vacillated around a mean value of 7.59 that ranged from 6.70 to 8.18and 3.87% value of coefficient of determination. Soil pH values (1:2 soil water ratio) ranged from 6.50 to 8.30 and CV of 4.93% in Jabalpur domain with a mean value of 7.53. The lower pH values in Jabalpur domain where major cropping system is followed is rice-wheat cropping systems probably due to long term effect of increased accumulation of organic carbon under anaerobic environment and hence the production of organic acids and associated dissolution and leaching bases (Benbi and Brar 2009). Tomar *et al*. (1968) [29] reported pH varying from 7.0 to 7.5 for deep black, 6.1 to 8.3 for medium black soils and 4.8 to 7.8 for shallow black soils of Madhya Pradesh. Raghuwanshi *et al*. (1992) [23] analysed brown soils and reported slightly acidic (pH 5.6 to 6.6) while the black soil of Jabalpur was neutral to alkaline (pH 7.2). Soil reaction is prime importance in controlling the availability of nutrients, since it affects directly their solubility as well as activity in the soil environment. The similar results were obtained at another palace by Chandra *et al*. (2012) [5], Mukherjee and Lal (2014) [17] and Cherubin *et al*. (2016) [6].

3.1.1.2 Electrical conductivity (EC)

A comparative evaluation of electrical conductivity of soil is presented in Table 2. The electrical conductivity followed the following order: Vidisha > Bhopal > Hoshanagabad > Jabalpur. Electrical conductivity values varying from 0.10 to 0.58 dS m^{-1} with a mean value of 0.30 d m and 25.94% coefficient of variation were witnessed in Vidhisha domain. The EC values in Bhopal ranged from 0.10 to 0.67 dS m^{-1} with a mean value of 0.28 dS m^{-1} and 38.74% coefficient of variation. The Hoshanagabd system exhibited an average EC value of 0.17 dS m^{-1} and it varied from 0.09 to 0.36 dS m^{-1}. The Jabalpur domain however showed a mean EC value of 0.17 dS m^{-1}; ranged from 0.10 to 0.33 dS m^{-1} and 38.02% CV. The higher EC status in Vidhisha domain can be assigned to the increased tumover of above ground biomass. A comparative positive skewness was observed in all domains. This trend signifies the presence of certain salinity hotspots that may have arisen from depressions in the domains. Greater variability of EC values were observed for Bhopal followed by Jabalpur, Hoshanagbad and Vidisha. On the basis of limits the electrical conductivity, the EC was existed as normal in all the farms < 1 dSm^{-1} at 25°C. The low conductivity in the soil under study might be due to high rainfall received and deep-water table. Similar results were reported by Prasad *et al*. (2017) [22]. Elsewhere. Similar ranges in pH values were also reported by Pathak *et al*. (1983) [20]; Tripathi *et al*. (1994) [30]; Tripathi (1998) [30]; Baishya and Sharma (2017) [2] and Patil *et al*. (2017) [1, 21, 26] elsewhere.

3.1.1.3 Soil organic carbon (SOC)

Dichromate oxidizable organic carbon content of soil determined by Walkley and Black (1934) [31] method of different domains is depicted in Table 2. The overall trend in dichromate oxidizable organic carbon was Bhopal > Vidisha > Jabalpur > Hoshanagabad. In Bhopal domain, it varied with a CV of 23.68% from 450 to 11.85 g kg-1 with a mean value of 8.24 g kg^{-1}. In Vidisha, it hovered around a mean value of 6.09% and ranged from 3.0 to 11.60 g kg-1 with a value of CV of 34.44%. The Jabalpur domain exhibited a mean SOC content of 5.06 g kg-1 with a range from 2.70 to 8.40 g kg^{-1}. The Hoshanagbd domain exhibited a mean SOC content of 4.74 g kg-1 with a range from 2.56 to 7.27 g kg^{-1}. Though, the mean organic carbon content is comparatively low in Hoshangabad domain. The Bhopal domain showed comparatively higher organic carbon content than other and the lowest variability (CV% = 23.68%) in soil organic carbon content was observed in this particular domain. The highest organic carbon content under Bhopal domain may be ascribed to the heavy and large amount surface covering above ground biomass, good rooting systems and large root biomass of the leguminous crop. It is also noticeable that Jabalpur domain also exhibited higher soil organic carbon content with higher amount of silt and clay content in the soil but lower than Bhopal domain and moreover a higher amount of external addition of organic matter to the rice-wheat field significantly increased the SOC content of the soil. But where, it was less observed that sand content is higher and there was no external addition of organic matter to field.

The presence of higher concentration of organic carbon of surface samples was due to incorporation of organic matter on the upper layer of the soil, through roots and other plant residues and manures. Mandal *et al*. (2011) and Yang *et al*. (2014) [14, 15] observed that crop species and cropping systems that may also play an important role in maintaining SOC stock because both quantity and quality of their residues that are returned to the soils vary greatly affecting their turnover or residence time in soil and thus its quality. Intensive cultivation and removal of plant biomass from the fields, may affect soil organic matter concentration, deteriorating implicit soil physical properties (Li *et al*., 2007) [13] and also a rapid oxidation of soil organic matter. Similar finding was reported by Nath (2014) [18], Dhakar (2017) [8], Amara *et al*. (2017) [1], Santhi *et al*. (2018) [25] and Katkar *et al*. (2019). However, low OC content in soils may be attributed to the poor vegetation and high rate of organic matter decomposition under hyper thermic temperature regime which leads to extremely high oxidizing conditions. The results of the present investigation are in close proximity with the findings of Singh *et al*. (2014) [9, 12, 14, 27, 28] also reported that Haplusterts of Vertisols should have higher organic carbon density than Haplustalfs of Alfisols because of higher rainfall and larger quantity of 2: 1 type of clay minerals. Similar results also reported in fine, montmorillonitic, isohyper thermic Chromic Haplusterts by Dubliya (2011) [10]; Dilliwar *et al*. (2014) [9, 28]; Dhakar (2017) [8]; Patil *et al*. (2017) [1, 21, 26] and Kundu *et al*. (2001) also reported increases SOC after soybean-wheat sequence.

3.1.1.4. Calcium carbonate ($CaCO_3$)

The overall trend in $CaCO_3$ was Vidisha > Hoshanagabad > Jabalpur > Bhopal. In Vidisha, it hovered around a mean value of 37.88 g kg-1 and ranged from 5.0 to 75.0 g kg-1 with a value of CV of 39.10%. The Hoshanagbd domain exhibited a mean CaCO3 content of 34.77 g kg-1 with a range from 5.0 to 70.0 g kg^{-1} and CV 51.61% The Bhopal domain exhibited a mean CaCO3 content of 23.62 g kg-1 with a range from 5.0 to 45.0 g kg^{-1} and CV 44.76%. In Jabalpur domain, it varied with a CV of 23.91% from 5.0 to 50.0 g kg-1 with a mean value of 23.92 g kg^{-1}. Though, the mean CaCO3 content is comparatively low in Bhopal and Jabalpur domain. The Vidisha domain showed comparatively higher CaCO3 content followed by Hoshanagabad than other and the lowest variability (CV% = 39.10%) was observed in this particular domain.

Results of study, concluded that the soils are non-calcareous in nature (<15% CaCO3). Concentration of CaCO3 is high might be due to least leaching process. Similar results were reported by Shinde *et al*. (2016) [26]. Bulk density and pH had least variability of CV = 3.29% and 2.92%. The EC, CaCO3, OC had CV value of 11.25, 14.87 and 17.28, respectively.

Table 2: Descriptive statistics of physico-chemical properties of soils under different domains

	pH										
Domain	**Mean**	**Min**	**Max**	**Range**	**Median**	**SD**	**SE**	**CV%**	**Variance**	**Kurtosis**	**Skewness**
Bhopal	7.59	6.70	8.18	1.48	7.60	0.29	0.03	3.87	0.09	0.53	-0.44
Jabalpur	7.53	6.50	8.20	1.70	7.50	0.37	0.03	4.93	0.14	0.28	-0.62
Vidisha	7.90	7.50	8.24	0.74	7.90	0.17	0.01	2.21	0.03	-0.46	-0.02
Hoshangabad	7.82	7.17	8.45	1.28	7.80	0.31	0.03	3.94	0.09	-0.78	0.15
AESR 10.1	7.72	6.50	8.45	1.95	7.78	0.33	0.01	4.28	0.11	0.98	-0.70
Domain	**EC dSm^{-1}**										
Bhopal	0.28	0.10	0.67	0.57	0.28	0.11	0.01	38.74	0.01	0.32	0.60
Jabalpur	0.17	0.10	0.33	0.23	0.16	0.06	0.01	38.02	0.00	-0.74	0.54
Vidisha	0.30	0.10	0.58	0.48	0.30	0.08	0.01	25.94	0.01	2.76	0.71
Hoshangabad	0.17	0.09	0.36	0.27	0.15	0.06	0.01	37.29	0.00	0.63	1.02
AESR 10.1	0.23	0.09	0.67	0.58	0.22	0.10	0.00	43.77	0.01	0.59	0.73
Domain	**OC g kg^{-1}**										
Bhopal	8.24	4.50	11.85	7.35	8.30	1.95	0.19	23.68	3.81	-1.00	0.00
Jabalpur	5.06	2.70	8.40	5.70	4.95	1.42	0.12	27.99	2.01	-0.51	0.41
Vidisha	6.09	3.00	11.60	8.60	5.70	2.10	0.17	34.44	4.39	0.07	0.97
Hoshangabad	4.74	2.56	7.27	4.71	4.46	1.21	0.11	25.53	1.46	-0.78	0.34
AESR 10.1	5.90	2.56	11.85	9.29	5.49	2.13	0.09	36.02	4.52	0.09	0.87
Domain	**$CaCO_3$ g kg^{-1}**										
Bhopal	23.62	5.00	45.00	40.00	25.00	10.57	1.03	44.76	111.78	-0.59	-0.19
Jabalpur	23.91	5.00	50.00	45.00	25.00	9.30	0.78	38.92	86.57	0.24	0.28
Vidisha	37.88	5.00	75.00	70.00	35.00	14.81	1.20	39.10	219.31	-0.17	0.30
Hoshangabad	34.77	5.00	70.00	65.00	35.00	17.95	1.56	51.61	322.09	-0.87	0.05
AESR 10.1	30.57	5.00	75.00	70.00	30.00	15.12	0.66	49.46	228.68	0.00	0.53

3.1.2 Macronutrient status in soils
3.1.2.1 Available N
The available N content in soils under various domains is represented in Table 3. The available N in various domains followed the order: Bhopal > Hoshangabd > Vidisha > Jabalpur. In Bhopal, it varied from 131.17 me kym 411.21 kg ha-1 with a mean value of 289.71 kg ha-1 and CV 23.57%. In Hoshanagbd, it ranged from 109.63 to 362 kg ha^{-1} with a mean value of 223.50 kg ha-1 with a higher CV 25.61%. The Vidisha domain showed nitrogen content range of 165.00 to 300.00 kg ha-1 and an average value of 221.64 kg ha-1 with 16.67% coefficient of variation. In case of Jabalpur domain, it stayed around mean value of 219.19 mg kg with a range of 138.06 to 296.06 kg ha-1 and a CV of 18%. Among different domains, Hoshangabad domain showed maximum variability followed by Bhopal, Jabalpur and Vidisha. Denton *et al*. (2017) showed that the soil properties with high variability in terms of coefficient of variation are available phosphorus and potassium (C.V = > 35%), N, CEC and OC were all moderately variable (C.V = 34–15%) while pH had low variability (C.V =<15%). These variations in chemical properties are mostly related to the different soil management practices and the parent material on which the soil is formed. Olorunlana (2015) revealed that the variability of the soil properties is mainly due to textural characteristics, chemical properties and organic matter. Ravikumar and Somashekar (2014) [24] reported that there is not much variation in soil fertility status of soils developed on various landforms in soils of Markandeya river basin. Maniyunda *et al*. (2013) [16] reported that available P (CV=149%) had highest variability, while K, OC, TN, AP and AS were consistently highly variable with CV > 35%.

3.1.2.2 Available phosphorus (P)
Soil available phosphorus content, determined by Olsen method under different domain is represented in Table 3. Soil available phosphorus content followed the order of Hoshangabd > Vidisha > Jabalpur > Bhopal. Hoshanagbd exhibited higher amount of phosphorus content that ranged from 2.07 to 56.56 kg ha-1 with a man value of 25.95 kg ha-1 and a coefficient of variation of 55.76%. In Vidisha, the available P content varied from 6.45 to 26.73 kg ha^{-1} with a mean value of 15.26 kg ha-1 and with greater variability of 31.41%. In Jabalpur domain, the available P content varied from 1.98 to 30.90 kg ha^{-1} with a mean value of 15.02 kg ha-1 and with greater variability of 54.29%. However, Bhopal domain exhibited comparatively lower *P* content than other domain. It may be due to binding of phosphates with the root exudates of soybean plant and also the uptake by wheat plant. But the Bhopal, had the greater variability same as Jabalpur and Hoshangabd. The Hoshanagbad had a very high amount of phosphorus content.

3.1.2.3 Available potassium (K)
Soil available K content, determined under different domain is represented in Table 3. Soil available K content followed the order of Bhopal > Jabalpur > Hoshangabd > Vidisha. Bhopal exhibited higher amount of K content that ranged from 173.60 to 752.00 kg ha-1 with a man value of 488.04 kg ha-1 and a coefficient of variation of 31.29%. In Jabalpur domain, the content stayed around a mean value of 473.92 kg ha^{-1} and revolved within the range of 145.60 to 772.91 and 30.45% CV. In Hoshanagabd domain, it ranged from 209.44 to 884.48 with a mean value of 423.71 Kg ha-1 and 30.58% coefficient of variation. Vidiaha domain exhibited the lowest amount of mean available potassium content (357.20 kg ha-1) and it varied from 227.36 to 561.12 Kg ha^{-1} with the lowest coefficient of variation of 21.53%.

3.1.2.4 Available sulphur (S)
Soil available S content, determined under different domain is represented in Table 3. Soil available S content followed the order of Bhopal > Hoshangabd > Vidisha > Jabalpur. Bhopal exhibited higher amount of S content that ranged from 4.77 to 28.60 mg kg^{-1} with a mean value of 14.11 mg kg^{-1} and a coefficient of variation of 50.08%. In Hoshangabad domain, the content stayed around a mean value of 12.78 mg kg^{-1} and revolved within the range of 2.94 to 26.70 mg kg^{-1} and 52.10% CV. In Vidisha domain, it ranged from 1.40 to 30.70 mg kg^{-1} with a mean value of 12.57 mg kg^{-1} and 51.95% coefficient of variation. Jabalpur domain exhibited the lowest amount of mean available S content (11.58 mg kg^{-1}) and it varied from 3.10 to 23.46 mg kg^{-1} with the lowest coefficient of variation of 45.39%.

According to Ravikumar and Somashekar (2014) [24] the NPK status of Karnataka was L-L-H. However, in Uttar Pradesh, NPK status was L-M-M (Kumar *et al*. 2013) [12]. The status of N might be related to soil management, application of FYM and fertilizer to previous crop. The low available phosphorous could also be ascribed to the high amount of free oxides of Ca_2+, Mg_2+ and Na+ which induce the fixation and subsequent precipitation of phosphorus as well as to the low amount of organic matter. The potassium status was high that might be due to predominance of K rich micaceous in parent material.

Table 3: Descriptive statistics of available macro nutrients (N, P, K and S) under different domains

	Available N (kg ha^{-1})										
Domain	**Mean**	**Min**	**Max**	**Range**	**Median**	**SD**	**SE**	**CV%**	**Variance**	**Kurtosis**	**Skewness**
Bhopal	289.71	131.17	411.21	280.04	297.00	68.27	6.66	23.57	4661.34	-0.45	-0.43
Jabalpur	219.19	138.09	296.06	157.97	221.81	39.46	3.31	18.00	1556.83	-0.80	-0.19
Vidisha	221.64	165.00	300.00	135.00	210.00	36.96	2.99	16.67	1365.80	-1.01	0.29
Hoshangabad	223.50	109.63	362.00	252.37	221.71	57.23	4.98	25.61	3275.55	-0.18	0.21
AESR 10.1	234.97	109.63	411.21	301.58	231.44	57.19	2.48	24.34	3270.88	0.21	0.55
Domain	**Available P (kg ha^{-1})**										
Bhopal	8.97	1.18	24.43	23.25	7.88	6.27	0.61	69.89	39.28	-0.06	0.89
Jabalpur	15.02	1.98	30.90	28.92	14.43	8.16	0.68	54.29	66.53	-1.21	0.20
Vidisha	15.26	6.45	26.73	20.29	14.45	4.79	0.39	31.41	22.98	-0.58	0.45
Hoshangabad	25.95	2.07	56.56	54.49	24.70	14.47	1.26	55.76	209.29	-0.78	0.36
AESR 10.1	16.62	1.18	56.56	55.37	14.45	10.87	0.47	65.43	118.17	1.90	1.27
Domain	**Available K (kg ha^{-1})**										
Bhopal	488.04	173.60	752.00	578.40	492.80	152.70	14.90	31.29	23317.10	-0.90	-0.13
Jabalpur	473.92	145.60	772.91	627.31	497.28	144.30	12.11	30.45	20822.15	-0.43	-0.46

Vidisha	357.20	227.36	561.12	333.76	347.87	76.92	6.22	21.53	5916.54	0.60	0.92
Hoshangabad	423.71	209.44	884.48	675.04	404.32	129.58	11.28	30.58	16791.76	3.06	1.57
AESR 10.1	430.76	145.60	884.48	738.88	408.80	136.68	5.93	31.73	18682.58	-0.02	0.58
Domain	**Available S (mg kg^{-1})**										
Bhopal	14.11	4.77	28.60	23.83	14.02	7.07	0.69	50.08	49.93	-1.11	0.40
Jabalpur	11.58	3.10	23.46	20.36	11.20	5.25	0.44	45.39	27.61	-0.59	0.29
Vidisha	12.57	1.40	30.70	29.30	11.10	6.53	0.53	51.95	42.61	0.62	0.93
Hoshangabad	12.78	2.94	26.70	23.76	10.31	6.66	0.58	52.10	44.31	-0.79	0.59
AESR 10.1	12.66	1.40	30.70	29.30	11.20	6.41	0.28	50.60	41.05	-0.27	0.66

3.1.3. Macronutrients status

Data presented in table 4 showed that In Bhopal, Jabalpur, Vidisha and Hoshnagabd domain, about 24.76,73.33 and 1.90; 74.65,25.35 and 0.0, 68.63,31.37 and 0.00, 63.36,36.64 and 0.00, 60.26,39.36 and 0.38% soil samples were rated to be low and medium and high, in N, respectively indicating nutrient index value of 1.77, 1.25, 1.31 1.37 and 1.40. However, negligible were observed to be high in N. About, 67.62,22.86 and 9.52;37.32,27.46 and 35.21;8.50,71.24 and 20.26,15.27,22.90 and 61.83 and 29.57,38.04 and 32.39% soil samples were observed to be low, medium and high in P indicating nutrient index value of 1.42,1.98,2.12,2.47 and 2.03 in soil of Bhopal, Jabalpur, Vidisha and Hoshnagabd domain, respectively. The K status in soil of Bhopal, Jabalpur, Vidisha and Hoshnagabd domain, about 8.57, 22.86 and 68.57; 9.86, 17.61 and 72.54;2.61,76.47 and 20.92;2.29,46.56 and 51.15 and 5.65, 42.75 and 51.60 percent soil samples were observed to be low, medium and high, respectively, indicating nutrient index of 2.60, 2.63,2.18,2.49 and 2.46. However, In soils of

Table 4: Soil fertility status under different domains

Domain		OC	N	P	K	S
Bhopal (n = 105)	PSD	2.86	24.76	67.62	8.57	41.90
	PSM	35.24	73.33	22.86	22.86	33.33
	PSH	61.90	1.90	9.52	68.57	24.76
	NI	2.59	1.77	1.42	2.60	1.83
Jabalpur (n = 142)	PSD	51.41	74.65	37.32	9.86	36.62
	PSM	42.25	25.35	27.46	17.61	53.52
	PSH	6.34	0.00	35.21	72.54	9.86
	NI	1.55	1.25	1.98	2.63	1.73
Vidisha (n = 153)	PSD	39.87	68.63	8.50	2.61	37.91
	PSM	38.56	31.37	71.24	76.47	50.33
	PSH	21.57	0.00	20.26	20.92	11.76
	NI	1.82	1.31	2.12	2.18	1.74
Hoshangabad (n = 131)	PSD	63.36	63.36	15.27	2.29	48.85
	PSM	36.64	36.64	22.90	46.56	29.77
	PSH	0.00	0.00	61.83	51.15	21.37
	NI	1.37	1.37	2.47	2.49	1.73
AESR10.1 (n = 531)	PSD	41.43	60.26	29.57	5.65	41.05
	PSM	38.42	39.36	38.04	42.75	42.75
	PSH	20.15	0.38	32.39	51.60	16.20
	NI	1.79	1.40	2.03	2.46	1.75

Bhopal, Jabalpur, Vidisha and Hoshnagabd domain, about 41.90, 33.33 and 24.76;36.62,53.52 and 9.86;37.91,50.33 and 11.76;48.85,29.77 and 21.37 and 41.05,42.75 and 16.20 percent soil samples were observed to be rated low, medium and high in S, respectively. Accordingly nutrient index was also observed to be 1.83, 1.73, 1.74, 1.73 and 1.75 in soils, respectively. However, samples were found to be deficient and fell in medium in respect of N, P, K and S. These variations in soil chemical properties were mostly related to the different cropping systems and soil management practices, including nutrient management carried out in the study area. Similar result was also reported by Ghimire *et al*. (2018); Mondal and Sekhon (2019); Sharma and Sood (2020) [2, 14], and Zhang *et al*. (2020) at other locations.

4. Conclusion

From the study it could be concluded that in AESR10.1 as whole, organic carbon was found to be medium and macronutrients were analyzed to be L-M-M-M and the severity of deficiency occurred in the order of N > S > P > K. Therefore, the supply of organics/FYM/amendment are important, which can increase crop productivity and minimize environmental risk and the results could be used as a basis for site specific fertilization in order to supply the optimum requirements for plant growth.

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