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Spatial Pattern of Soil Physical Properties in Agricultural Soils of Different Domains of Central India

G. S. Tagore[1*], Y. M. Sharma[1], R. Sharma[2], G. D. Bairagi[2], A. K. Dwivedi[1], P. S. Kulhare[1] and Megha Vishwakarma[1]

[1]Department of Soil Science and Agricultural Chemistry, JNKVV, Jabalpur, M.P., India
[2]Department of Science and Technology, Madhya Pradesh Council of Science and Technology, Vigyan Bhavan, Nehru Nagar, Bhopal, Govt. of Madhya Pradesh, India

**Corresponding author*

ABSTRACT

Keywords

Texture, total porosity, aggregates stability, SSI, spatial variability, geo-statistical tools

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In the study soil surveys conducted and GPS based soil samples were collected from each domain *viz.*, Bhopal, Hoshangabad, Vidisha and Jabalpur of AESR 10.1 region.and for bulk density (BD), total porosity (TP), particle size distribution (Sand, Silt, Clay), analyzed then aggregate stability (AS) and structural stability index (SSI) were estimated in the Department of Soil Science and Agricultural Chemistry Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur during 2018-2020. The results noticed that the highest mean values of sand silt and clay (40.31, 28.71 and 43.22%) were recorded in cultivated land of Bhopal, Hoshangabad, and Jabalpur domains, respectively. The mean bulk density of the soils ranged from 1.47 and 1.50 Mg m^{-3} and the mean total porosity ranged from 43.30 to 44.83%, which indicated the less soil compaction. The AS ranged from 39.55 to 43.79 with whole mean value of 41.02% while the mean values of SSI (1.52%) with ranged from 1.19 to 2.39%. The average values of 32.12, 26.64 and 41.25 sand silt and clay and its ranged from 16.00 to 51.84, 13.28 to 38.90, and 23.44 to 58.00% in AESR10.1 as a whole region, respectively. The BD, TP, SSI and AS% of soil under the AESR region was found in ranged from 1.34 to 1.71 Mg m^{-3}, 35.47 to 49.43%, 0.66 to 3.70 and 35.06 to 46.86% with mean values of 1.48 Mg m^{-3}, 44.10%,1.52 and 41.02% categorized BD in the little high that might be due to clod methods adopted which gave higher BD. Geo-statistical results showed that the Gaussian model best fitted for of SSI and AS, Spherical model fitted for BD, Sand, Silt, Clay and exponential model fitted for TP in Bhopal domain. In Jabalpur domain, exponential domain best fitted for BD, TP, Clay and SSI, Spherical model for Sand and Silt, and for AS, Gaussian model is best fitted. In Vidisha domain, exponential model best fitted for BD, Silt, Clay and SSI, Gaussian model best fitted for of TP, Sand and AS while in Hoshangabad domain, exponential model is best fitted for TP, Clay, SSI, and AS, and Gaussian model best fitted for BD, Sand and Silt. The nugget/sill (N/S) ratio <25% which exhibit strong spatial dependency(SD) only for Sand, Clay and AS in Bhopal domain. The N/S ratio was found to be >25% but <75% which showed moderate SD, for BD, Silt and SSI in Bhopal domain, BD, TP, Sand and Silt in Jabalpur domain, AS and SSI in Vidisha domain, and Sand, Silt, Clay, AS and SSI in Hoshangabad domain. The N/S ratio was found to be <75% which showed weak SD for Clay, AS and SSI in Jabalpur domain and TP in Bhopal domain, BD, TP, Sand, Silt, and Clay in Vidisha domain, and BD and TP in Hoshangabad domain. Irrespective of domain cropping system and management practices were varied and have adverse effects on physical properties. Therefore, the proper soil conservation practice is important to enhance soil fertility and crop productivity.

Introduction

Smart agriculture requires the sustainable use of soil resource, because soil can easily lose its quality and quantity within a short period of time for different reasons such as intensive cultivation, leaching and soil erosion (Kiflu and Beyene, 2013). Agricultural practice, therefore, requires basic knowledge of sustainable use of the land (Takele *et al.*, 2014). A success in soil management to maintain the soil quality depends on the understanding of how the soil responds to agricultural practices over time (Duguma *et al.,* 2010). However, the basis of this sustainable agricultural development is good quality of the soil, since maintenance of soil quality is an integral part of sustainable agriculture and the convenient witness to enhance the crop productivities (Liu *et al.*, 2010).

On the other hand, the ever-increasing human population is most challenging in India. This is the atrocious threat in, which soil properties are adversely damaged thereby leads to land degradation and hampered the sustainability of soil resources. The major causes of land degradation, natural resources depletion and environmental deterioration. Cultivation on soil with inadequate management in soil conservation or vegetation cover (Aytenew and Kibret, 2016). In addition, the topography of the land has also a great impact on the soil quality and soil depth due to the interaction impact of cultivation practices and slope (Pavlu *et al.,* 2007). Therefore, reducing resource degradation, increasing agricultural productivity, reducing poverty, and achieving food security are major challenges (Qadir *et al.,* 2014). Thus, possible effort should be focused on the maintenance of the physical, environment for production of crops, through sustainable use of natural resources (Adeyemo and Agele, 2010). With the increment of human population, intensively expansion of farmland has begun to influence the soil properties (Mustapha, 2007). However, when the intensification limit is reached, human population is rapidly growing, intensification i.e. the frequent and continuous utilization of the available land has continued. Various studies have been conducted to assess the effect of land use types on soil physical (Lemenih *et al.*, 2005; Lemma *et al.,* 2006; Yimer *et al.*, 2008).

Aggregate stability is related to soil erosion resistance and organic matter content. Deterioration of aggregate stability will lead to a decrease in MWD, an increase in bulk density and a decrease in macroporosity. Apart from these physical soil properties, aggregate stability also has mutual links with chemical and biological soil parameters. Tillage breaks down aggregates through mechanical stress. This exposes SOC to microbes, with the SOC subsequently mineralized and lost. In particular, disaggregation of macroaggregates reduces macroporosity, which in turn causes an associated decrease in microbial biomass and activity (Sparling *et al.,* 2000; Neves *et al.*, 2003). However, any form of soil perturbation that results in a short-term increase in soil aeration actually increases oxidative microbial activity and leads to a reduction in SOC (Chantigny, 2003). The decline of SOC through the oxidation process is further enhanced when disaggregation allows microbes to access SOC previously bound within inaccessible micropores (Sollins *et al.*, 1996; Martens *et al.*, 2003).

It is fact that soil vary from place to place even within the same field. As a result, the spatial structure can vary at scales that differ by several orders of magnitude from a few meters to hundred kilometers. Such variation with distance can be described well with the help of geo-statistics (Carr and Meyers 1984, woodcock et. al., 1981, Collin sand woodcock

1999). For quantifying the distribution of spatial patterns geo-statistics has been applied to performed spatial interpolation (Zhang and Srinivasan, 2009). At small scales, the use of measurements from individual points might be appropriate. However at larger scales, it is required to draw special attention to the appropriate representation of the spatial patterns, which are usually interpolated from point measurements Many studies use geo-statistics for determination of spatial variability and map creation of soil characteristics (Jian-Bing *et al.,* 2008, Zhang and Grath 2004). Thus our hypothesis is that diverse cropping systems different rooting behavior when cultivated using different management practices may have an impact on soil properties and thus the quality of soil and productivity. Currently, the soil was drastically degraded because of continuous cultivated and mining the nutrients, which may results in the decline of soil fertility and limit crop productivity, which in turns affect the farming communities. Additionally, the good land has been converted into urban lands in the study area. In order to put the proper recommendations for sustainable utilizations of soil resources and improve crop productivity, the information about soil physical properties are essential. Therefore, the study was conducted to assess physical parameter of soil under different domains in central India.

Materials and Methods

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 and LUP). The selection was done on the basis of cropping system their prevalence in the region and significance in terms of likely variability in soil fertility status. The study was conducted in four domains namely Bhopal, Hoshangabad Jabalpur and Vidisha where major cropping systems are soybean-wheat, soybean-chickpea, rice-wheat-summer moong, rice-wheat and soybean-wheat predominantly were selected. Medium black soil is found in the site which is good for crops like wheat, gram and soya bean. The climate and soil patterns have strong impacts on the spatial distribution of soil organic carbon density.

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 22^{o}35'45" N to 23^{o}49'30" N latitude and longitude is 77^{o}40'10" E to 78^{o}04'15" 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.

Among the four domains, second Bhopal domain was situated (23^{o}15'45" N to 23^{o}26'45" N and longitude is 76^{o}01'15" E to 76^{o}24'30" 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 (23^{o}08'15" N to 23^{o}20'45" N and longitude is 79^{o}37'45" E to 80^{o}01'30" 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.

Soil sample collection and their processing for analysis

On a 5*5 km grid across the study area in 2018-2020 and randomly selected and GPS based (0-15 cm depth) soil samples 105, 142, 153 and 131 were collected from each domain *viz.*, Bhopal, Jabalpur, Vidisha and Hoshangabad, respectively during post harvest period (September-October or March-June). Collected samples were air dried under shade, crushed in a wooden log to break the clods and aggregates and visible root fragments were removed; afterwards each sample was sieved through a 2 mm sieve and then split into two sub-samples.

Bulk density

The bulk density (BD) of the soil was measured from undisturbed soil samples collected using a core sampler after drying the core samples in an oven at 105 °C (Black, 1965). The bulk density was calculated by using the following relation:-

$$BD\ (Mg\ m^{-3}) = \frac{\text{Weight of oven dry soil (Mg)}}{\text{Volume of soil } (m^{-3})}$$

Where BD = Bulk density, Mg m^{-3} = Mega gram per cubic meter

Clod method (Black 1965)

Bulk density is a measure of the weight of the soil per unit volume expressed as grams per centimeter cube (Mg m^{-3}) (usually given on an oven-dry (105 °C) basis. Bulk density = mass of clod (gm) / volume of clod (ml). In case the clods, collected from the fields, contain coarse fragments the clod was grinded and sieved through 2 mm sieve. The CF was washed with water, oven dried and weighed. The volume of CF was obtained by dividing mass of CF by 2.65 (density of CF). Bulk density of clods containing CF was calculated by the following formula:

Bulk density = (mass of clod - mass of CF) / (volume of clod (ml) - volume of CF)

Core method (Blake and Harte, 1986)

Samples were oven-dried (105 °C for 48 h) and bulk density was estimated as the mass of oven-dry soil divided by the core volume (100 cm^3).The core sampler was driven into the soil with the aid of a mallet. Soil at both ends of tube was trimmed and the end flushed with a straight – edged knife. The core sampler with its content was dried in the oven at 105 ^{0}C to a constant weight. The core sampler was removed from the oven after 48 hours. The sampler with its content was allowed to cool. The weight of core sampler with content is recorded. The volume was determined by measuring the height and radius of the core sampler. The bulk density (BD) was calculated using the formula (equation 2) by (Anderson & Ingram, 1993):

BD = (W1 – W2) x V-1 (2)

Where W2 = Weight of core cylinder + oven – dried soil/grams W1 = Weight of empty core cylinder/grams V = Volume of core cylinder ($\pi r^2 h$), cubic centimeters where: Π = 3.142, r = radius of the core cylinder and h = height of the core cylinder.

Total Porosity (TP)

The total porosity of soil samples was estimated from the values of bulk density (BD) and particle density (PD) (assuming an average particle density of mineral soil is 2.65 Mg m^{-3}). Then the total porosity (TP) was calculated as,

TP (%) = (1-Bulk density/Particle density) * (100)

Particle size distribution (Soil textural analysis)

Particle size distribution was determined by the International Pipette method (Day 1965). A 20g soil sample was treated with 20 ml Hydrogen peroxide (30%) for digestion of organic matter on a hot plate. Thereafter, 1g sodium Hexa-metaphosphate was added as dispersing agent along with 100ml water. The suspension was stirred for 15 minutes using electric stirrer. The sand was separated by wet sieving through 72-mesh sieve. Silt and clay were collected in one liter cylinder. Volume of silt plus clay suspension in the cylinder was made to one liter and the composition was thoroughly mixed using a plunger. A 25ml portion 12 of the suspension was pipette out at a depth of 10cm in the cylinder after allowing the requisite settling time in accordance with Stokes' law. The clay content was computed based upon the clay content in the suspension obtained after it was allowed to settle. Then silt fraction was calculated by subtracting the sand and clay contents.

Bouyoucous hydrometer method (Bouyoucous, 1962), after OM was destroyed or burned by using hydrogen peroxide (H_2O_2), soil particles dispersed and disintegrated by sodium carbonate (Na_2CO_3) and sodium hexametaphosphate ($NaPO_3$) in distilled water and finally using amyl alcohol to destroy the soil solution foam. After the particle size distributions were determined in percent, the textural class of the soil could obtained by using USDA soil textural triangle classification system (USDA, 2008).

Aggregate Stability (AS)

Aggregate stability and have chosen to estimate it from soil organic matter using the relation derived by Kemper and Koch

Aggregate stability (%) = 40.8+17.6*log (SOM) +0.73*log(%clay)

Structural stability index (SSI)

A structural stability index (SSI) was calculated as suggested by Reynolds *et al.*, (2009).

SSI (%) = ((SOC x 1.724) / (silt + clay))*100

Geo-statistical analysis in Arc GIS Environment

It was necessary to normalize the data prior to the geo-statistical analysis because of high skewness and the presence of outliers. Logarithmic transformations were selected to normalize the dataset. When skewness coefficient is < 0.5 there is no need to convert data, but if this coefficient is between 0.5 and 1, and more than 1 for normalizing data square root and logarithm must be used, respectively. If the data distributions are largely deviate from a normal distribution, data transformations are often performed in order to reduce the influence of extreme values on spatial analysis.

$f(x) = \ln(x)\ \lambda=0,$

Where, f(x) is the transformed value and x is the value to be transformed. For a given data set (x1, x2…xn), the parameter is estimated based on the assumption that the transformed values (y1, y2…yn) are normally distributed. When λ = 0, the transformed becomes the logarithmic transformation.

Geo-statistical methods were used to analyse the spatial correlation structures of soil properties and spatially estimate their values at unsampled locations using geo-statistical tool in GIS 9.3.1 software.

The above phenomenon is the best accomplished studying the semi variogram (Warrick *et al.,* 1986) which is a plot of semi-variance that characterizes the rate of change of a mapped variable with respect to distance. Semi-variogram (*h*) is computed as half the average squared difference between the soil properties of data pairs. Semiariogram ŷ(h) is computed as half the average squared difference between the soil properties of data pairs. The structure of spatial variability was analyzed through semivariograms. A semivariogram from the set of sample data is calculated using the following equation (Chile` s and Delfiner 1999):

$$\hat{Y}(h)=\frac{1}{2N(h)}\sum_{\alpha=1}^{N(h)}[(z(\mu_{\alpha})-z(\mu_{\alpha}+h)]^2$$

Where, N (h) is the number of data pairs separated by lag distance h; z (uα) is measured value at point a; and z (uα+h) is measured sample value at point uα+h.

A semi- variogram was calculated using the measured data. Next, this was generally fitted with a theoretical model, such as Exponential, Spherical J-Bessel K- Bessel, Stable and Gaussian models Goovarts, (1999). Choice of the best- fitted model was based on the lowest residual sum of square (RSS) and the largest coefficient of determination (R^2). The model provided information about the spatial structure as well as the input parameters (i.e. nugget, sill and range) for the Kriging interpolation. Nugget is the variance at distance zero, sill is the semi- variance value at which the semi-variogram reaches the upper bound after its initial increase, and range is a value (x axis) at which one variable becomes spatially independent.

The semivariograms were generated through Arc Map 10 of Arc-GIS software. For the analysis of the spatial variability of different soil fertility parameters, the experimental semivariograms and semivariance were calculated using the following formula: Semivariance estimations may depend on the parameters such as being intervals, number of lags and anisotrophy. Experimental semivariograms were fitted by theoretical models with parameters viz. nugget (Co), sill (Co+Cj) and the range of spatial dependence (a). Cambardella *et al.,*(1994) proposed the calculation of a dependence degree (DD) expressed as a ratio between the nugget effect value (C0) and the sill (C0+C1) and classified as Weak if DD > 75%, Moderate for 26% < DD <75%, and Strong for DD < 25% (equation)

DD = 100*(C1/C0 +C1)

Results and Discussion

Soil physical characteristics

Bulk density

Data presented in table.1 showed that the bulk density represents the overall density of a soil mass (the weight of the dry mineral divided by the overall volume occupied by the soil particles and pore spaces). In particular, it greatly affects the infiltration capacity of the soil, nutrient availability and other physical and chemical processes that take place in the soil system. The bulk density of soil varied from 1.34 to1.71 Mg m^{-3} with mean value of 1.48 Mg m^{-3} in AESR 10.1. BD had variability in AESR 10.1 (CV = 5.12 percent). Bulk density was in order of Vidisha >Bhopal > Hoshanagabad >Jabalpur. In Vidisha domain, it varied from 1.36 to 1.69 with a mean value of 1.50 Mg m^{-3}. In Bhopal, it hovered around a mean value of 1.49 and ranged from 1.35 to 1.59 with a value of CV of 4.25%. The Hoshanagbad domain exhibited a mean BD of 1.47 with a range from 1.36 to 1.71 Mg m^{-3}. The Jabalpur domain exhibited a mean BD of 1.46 with a range from 1.34 to 1.67 Mg m^{-3}. Though, the mean BD is comparatively low in Jabalpur domain. The Vidisha domain showed comparatively higher BD and the lowest variability than other was observed in Bhopal domain. BD in the little high that might be due to clod methods adopted which gave higher BD. Bulk density values are highly indicative of the nature and status of the soil quality. Higher bulk density values indicate higher degree of soil compaction, which further affects the infiltration capacity of the soil. The infiltration capacity of the soil greatly affects the hydrological and ecological regimes of the area.

The higher bulk density of soil in cultivated land might be due to the practice of ploughing in cultivated soil, which tends to lower the quantity of OM of that soil through animal trafficking and expose the soil surface to direct strike by rain drops. This finding is in agreement with Yitbarek *et al.,* (2013) who found the highest bulk density under cultivated land at a soil depth of 0-20 cm. Additionally, Takele *et al.,* (2014) and Abad *et al.,* (2014) suggested that the bulk density of cultivated land was higher at soil depth of 0-30 cm. Paradoxically, Lelisa and Abebaw (2016) found that the higher bulk density. Generally, the ranges of bulk density values observed in this study are within the ranges expected value (1.1 to 1.4 Mg m^{-3}) in most mineral soils. Since the bulk density was within the expected values the aeration and water movement within the soil structure is in conducive situation that attain plant growth and determine the numbers and diversity of soil microbes thereby they furnish the versatile function in agrarian activities.

The bulk density of Vertisols varies greatly because of their swelling and shrinking nature, which changes with moisture content. The soils have high BD when they are dry, and have low BD when they are in a swollen state. Bulk density has been reported to vary from 1.0 to 2.0 Mg m^{3}, depending on the moisture content. Bulk density usually tends to increase with depth, due to compression caused by overburden weight.

Total porosity (%)

Data regarding to the mean values of total porosity under different domains, the mean total porosity of Vidisha, Bhopal, Hoshangabad and Jabalpur were 43.30, 43.94, 44.35 and 44.83%, respectively (Table.3). In the case of Jabalpur domain it ranged from 36.98 to 49.43% and with CV= 6.20%, the higher value of total porosity was recorded at this particular domain. In the case of Hoshangabad domain it ranged from 35.47 to 48.68% and with CV= 6.68%. In the case of Bhopal domain it ranged from 40.00 to 49.06% and with CV= 5.68%. However, In Vidisha domain it ranged from 36.23 to 48.68% and with CV= 6.83%, the lower value of total porosity was recorded at this particular domain. The soil total porosity was insignificantly and positively correlated with soil OM and clay. This is because of the soil contained OM and clay particles have meso or microspores, which has low soil aeration and water percolation. But it was significantly and positively correlated with $CaCO_3$ and CEC. According to Landon (1991) the favorable total porosity of sand particles was about 40% whereas that of clay content soil is about 50% and above to sustain and regulate the activities of soil biota. Therefore, having this as departure the findings of this study is in agreement with these ideas and confirms no problems of soil properties via water infiltration and soil aeration under different domains. Moreover, the high total porosity of the soil implies that the less problem of water logging and surface runoff.

Structural stability index (SSI%)

Data presented in table.3 showed the overall trend in SSI was Bhopal > Vidisha > Jabalpur > Hoshanagabad. In Bhopal domain, it varied with a CV of 24.62% from 1.29 % to 3.70 % with a mean value of 2.39%. In Vidisha, it hovered around a mean value of 1.48% and ranged from 0.77% to 2.87% with a value of CV of 32.91%. The Jabalpur domain exhibited a mean SSI of 1.24% with a range from 0.66% to 2.07%. The Hoshanagbd domain exhibited a mean SSI of 1.19% with a range from 0.66 % to 1.90%. Though, the mean SSI and the variability are comparatively low in Hoshangabad domain. The Bhopal domain showed comparatively higher SSI than otherwas observed in this particular domain. The highest SSI% was under Bhopal domain. Adverse impacts of management practices on soil physical and structural properties have also markedly increased soil loss and degradation by erosion when compared. Most structural damage and compaction from poaching occurs at 10 cm below the soil surface and poaching may even reduce bulk density in the top 10 cm (Scholefield *et al.*, 1985).

Aggregate stability (AS %)

Table 3 showed that the AS was found in trend in Bhopal > Vidisha > Jabalpur > Hoshanagabad. In Bhopal domain, it varied with a CV of 4.34% from 39.36% to 46.86% with a mean value of 43.79%.

In Vidisha, it hovered around a mean value of 41.32% and ranged from 36.29% to 46.73% with a value of CV of 6.00%. The Jabalpur domain exhibited a mean AS of 40.03% with a range from 35.41% to 44.27%. The Hoshanagbd domain exhibited a mean AS of 39.55% with a range from 35.06% to 43.12%.

Though, the mean AS and the variability is comparatively low in Hoshangabad domain. The Bhopal domain showed comparatively higher AS than other was observed in this particular domain.

The highest AS% was under Bhopal domain. Microbial activity is only checked when aggregate stability and macroporosity have deteriorated to the extent that remaining pore spaces are too small to be accessible to bacteria (Sollins *et al.*, 1996). Indicator for soil physical quality and for soil aggregate stability in particular. It could possibly be a more sensitive indicator of long-term change than either macroporosity or bulk density, depending on its relative ability to resist rapid temporal changes. Increased SOC levels, particularly light fraction SOC from manure amendments or crop residues, are known to improve aggregate stability, MWD and overall soil structure (Tripathy and Singh, 2004).

However, Amezketa (1999) noted that aggregate stabilisation from SOC is concerned with macro aggregates (>250 μm), with SOC acting as a deflocculent on micro aggregates. Clay mineralogy is another important aggregating factor.

The physiochemical effect of different clays affects aggregation because of the variation in specific surface area, Cation Exchange Capacity (CEC) and consequently, high physiochemical interaction capacity. Some clay mineralogies are more sensitive to chemical dispersion because surface irregularity and smaller edge to face attraction forces, such as illite.

Soil pH also acts as a primary factor controlling clay dispersion/flocculation (Amezketa, 1999). Biological indicators, such as nutrient mineralization, are also influenced by a decline in aggregate stability (Webb *et al.*, 2003).

Texture of soils under different domains

Soil texture has a significant bearing on different soil fertility properties. The distribution of sand, silt and clay content in different domains is presented in Table.2.

Sand content

The sand content in various domains followed the order: Bhopal domain> Hoshangabad > Jabalpur > Vidisha domain (Table.2).

Among all the domains the highest sand content was demonstrated by Bhopal domain which followed different cropping systems including soybean-wheat; soybean-chickpea and so many other systems. It had a mean sand content of 40.31 % that varied from 33.21 to 51.84 % with a coefficient of variation (CV) of 10.56 %.

In Hoshangabd domain, the sand content varied from 20 to 39% with average value of 31.37% and a coefficient of variation of 13.46 %. In Jabalpur domain, the sand content vacillated around a mean value of 29.71 % in the range of 20 to 38 % with 12.58 % coefficient of variation.

Vidisha domain exhibited a mean value of 29.33 % and ranged from 16 to 40 % with a CV of 17.31%. Among different domains, Vidisha domain demonstrated highest variability in sand content (17.31%) followed by Hoshangabd (13.46), Jabalpur (12.58) and Bhopal (10.56 %) domains.

Fig.1 Location of study area

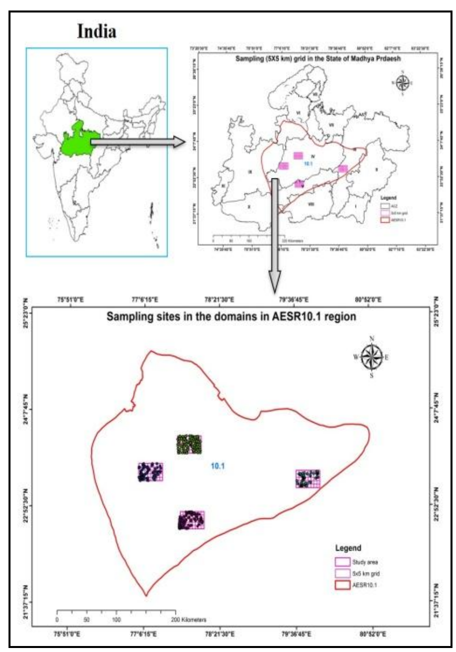


Table.1 Descriptive statistics of physical characteristic under different domains

Domain	Mean	Min	Max	Range	Median	SD	SE	CV%	Variance	Kurtosis	Skewness
	Bulk density (Mg m3)										
Bhopal	1.49	1.35	1.59	0.24	1.50	0.06	0.01	4.25	0.00	-0.71	-0.49
Jabalpur	1.46	1.34	1.67	0.33	1.45	0.07	0.01	5.04	0.01	-0.16	0.65
Vidisha	1.50	1.36	1.69	0.33	1.50	0.08	0.01	5.21	0.01	-0.57	0.15
Hoshangabad	1.47	1.36	1.71	0.35	1.46	0.08	0.01	5.33	0.01	-0.23	0.64
AESR 10.1	1.48	1.34	1.71	0.37	1.48	0.08	0.00	5.12	0.01	-0.49	0.34
	TP%										
Bhopal	43.94	40.00	49.06	9.06	43.40	2.38	0.23	5.43	5.68	-0.71	0.49
Jabalpur	44.83	36.98	49.43	12.45	45.28	2.78	0.23	6.20	7.73	-0.16	-0.65
Vidisha	43.30	36.23	48.68	12.45	43.40	2.96	0.24	6.83	8.73	-0.57	-0.15
Hoshangabad	44.35	35.47	48.68	13.21	44.91	2.96	0.26	6.68	8.79	-0.23	-0.64
AESR 10.1	44.10	35.47	49.43	13.96	44.15	2.86	0.12	6.49	8.20	-0.49	-0.34
	SSI %										
Bhopal	2.39	1.29	3.70	2.41	2.43	0.59	0.06	24.62	0.35	-0.88	0.11
Jabalpur	1.24	0.66	2.07	1.40	1.22	0.33	0.03	26.58	0.11	-0.71	0.27
Vidisha	1.48	0.77	2.87	2.10	1.34	0.49	0.04	32.91	0.24	-0.02	0.93
Hoshangabad	1.19	0.66	1.90	1.24	1.12	0.29	0.03	24.21	0.08	-0.74	0.28
AESR 10.1	1.52	0.66	3.70	3.04	1.36	0.62	0.03	40.71	0.38	0.84	1.16
	Aggregate stability (%)										
Bhopal	43.79	39.36	46.86	7.50	44.09	1.90	0.19	4.34	3.61	-0.84	-0.37
Jabalpur	40.03	35.41	44.27	8.86	40.13	2.19	0.18	5.46	4.78	-0.65	-0.14
Vidisha	41.32	36.29	46.73	10.44	41.17	2.48	0.20	6.00	6.14	-0.68	0.44
Hoshangabad	39.55	35.06	43.12	8.07	39.34	1.99	0.17	5.04	3.98	-0.72	-0.11
AESR 10.1	41.02	35.06	46.86	11.80	40.89	2.66	0.12	6.48	7.06	-0.59	0.18

Table.2 Descriptive statistics of particle size distribution (%) under different domains

	Sand%										
Domain	**Mean**	**Min**	**Max**	**Range**	**Median**	**SD**	**SE**	**CV%**	**Variance**	**Kurtosis**	**Skewness**
Bhopal	40.31	33.21	51.84	18.63	39.92	4.26	0.42	10.56	18.12	-0.35	0.45
Jabalpur	29.71	20.00	38.00	18.00	30.00	3.74	0.31	12.58	13.96	0.14	-0.37
Vidisha	29.33	16.00	40.00	24.00	30.00	5.08	0.41	17.31	25.80	-0.10	-0.36
Hoshangabad	31.37	20.00	39.00	19.00	32.00	4.22	0.37	13.46	17.82	-0.34	-0.49
AESR 10.1	32.12	16.00	51.84	35.84	31.70	6.02	0.26	18.75	36.27	0.33	0.31
	Silt%										
Bhopal	21.27	13.28	32.72	19.44	21.28	3.15	0.31	14.79	9.90	1.05	0.30
Jabalpur	27.07	16.00	38.90	22.90	27.15	4.02	0.34	14.84	16.15	-0.03	-0.14
Vidisha	28.15	15.90	37.00	21.10	28.90	4.41	0.36	15.66	19.42	-0.06	-0.37
Hoshangabad	28.71	20.00	36.00	16.00	29.60	3.91	0.34	13.62	15.30	-0.39	-0.30
AESR 10.1	26.64	13.28	38.90	25.62	27.00	4.80	0.21	18.03	23.06	-0.57	-0.17
	Clay%										
Bhopal	38.42	23.44	46.50	23.06	39.08	4.11	0.40	10.71	16.92	1.09	-0.76
Jabalpur	43.22	30.00	58.00	28.00	43.00	5.70	0.48	13.19	32.50	-0.28	0.08
Vidisha	42.52	34.60	53.00	18.40	42.00	4.50	0.36	10.58	20.25	-0.50	0.36
Hoshangabad	39.92	30.00	50.00	20.00	40.00	4.36	0.38	10.92	18.99	-0.26	0.13
AESR 10.1	41.25	23.44	58.00	34.56	41.00	5.10	0.22	12.36	26.00	0.22	0.22

Table.3 Characteristics of semi variogram of physical properties of soils under different domain

Domain(n)	Parameter	Model	Range(m)	Nugget	Partial Sill	Sill	NS ratio	lag size(m)	RMSS	ASE
Bhopal	BD	Spherical	360.522	0.0020069563	0.0010709454	0.0030779017	0.65	700.739	0.943	0.059
Jabalpur	BD	EXP.	9006.513	0.0043659746	0.0021350240	0.0065009986	0.67	750.543	0.979	0.074
Hoshanagabd	BD	Gaussian	10312.619	0.0062649625	0.0003351683	0.0066001308	0.95	859.385	0.948	0.082
Vidisha	BD	Exp.	10530.726	0.0058667950	0.0000000000	0.0058667950	1.00	877.560	1.000	0.079
Bhopal	TP	Exp.	360.522	4.1271275306	0.0071964567	4.1343239873	1.00	531.029	0.972	2.175
Jabalpur	TP	Exp.	5586.513	5.8763338337	3.0446123881	8.9209462218	0.66	665.543	0.989	2.779
Hoshanagabd	TP	Exp.	669.860	8.8795679953	0.3393123965	9.2188803918	0.96	909.385	0.962	3.242
Vidisha	TP	Gaussian	11670.726	8.2385346095	0.2882088361	8.5267434456	0.97	972.560	1.004	2.968
Bhopal	SAND	Spherical	360.522	0.0000000000	16.5947173755	16.5947173755	0.00	639.597	0.916	4.156
Jabalpur	SAND	Spherical	2144.265	7.7728577596	7.1340588940	14.9069166536	0.52	855.322	1.022	3.501
Hoshanagabd	SAND	Gaussian	15133.082	10.0439938252	10.8441178069	20.8881116321	0.48	1984.396	1.008	3.445
Vidisha	SAND	Gaussian	5242.651	23.3933410480	7.0396367886	30.4329778367	0.77	436.888	1.000	5.429
Bhopal	SILT	Spherical	343.744	4.0096770394	4.1096515521	8.1193285915	0.49	631.029	1.148	2.998
Jabalpur	SILT	Spherical	1225.591	5.8830708063	11.2342687204	17.1173395266	0.34	650.326	1.041	3.655
Hoshanagabd	SILT	Gaussian	36651.506	12.1690560134	5.9961272977	18.1651833111	0.67	3054.292	1.012	3.614
Vidisha	SILT	Exp.	3514.772	18.8740510647	0.6834375122	19.5574885769	0.97	721.671	1.000	4.683
Bhopal	CLAY	Spherical	360.522	3.5507019872	11.2886851649	14.8393871522	0.24	639.228	1.008	3.995
Jabalpur	CLAY	Exp.	10205.574	360.8131379751	52.6507638419	413.4639018170	0.87	850.465	0.991	20.153
Hoshanagabd	CLAY	Exp.	12030.534	7.1890114701	13.6401320547	20.8291435247	0.35	2485.126	1.085	3.630
Vidisha	CLAY	Exp.	6268.554	17.8630902858	4.9614822244	22.8245725102	0.78	622.379	0.985	4.803
Bhopal	AS	Gaussian	5461.203	0.5417196021	3.0306726899	3.5723922920	0.15	613.891	1.033	1.188
Jabalpur	AS	Gaussian	5786.073	3.8173306018	0.9756554005	4.7929860022	0.80	656.087	1.036	2.090
Hoshanagabd	AS	Exp.	8199.395	0.0731935049	0.1049612525	0.1781547574	0.41	683.283	0.915	0.366
Vidisha	AS	Gaussian	5258.599	4.6025331828	1.8686552438	6.4711884266	0.71	600.864	1.014	2.452
Bhopal	SSI	Gaussian	5415.315	0.0954977804	0.2627952989	0.3582930793	0.27	660.004	0.880	0.437
Jabalpur	SSI	Exp.	10115.947	0.0907194260	0.0193544195	0.1100738456	0.82	970.353	1.006	0.323
Hoshanagabd	SSI	Exp.	3711.847	0.0374259266	0.0350615539	0.0724874804	0.52	918.715	0.933	0.264
Vidisha	SSI	Exp.	7836.806	0.1506760833	0.1053581881	0.2560342714	0.59	953.067	1.016	0.479

Fig.2a Semi-variogram of BD Mg m-3 in soils of Bhopal domains

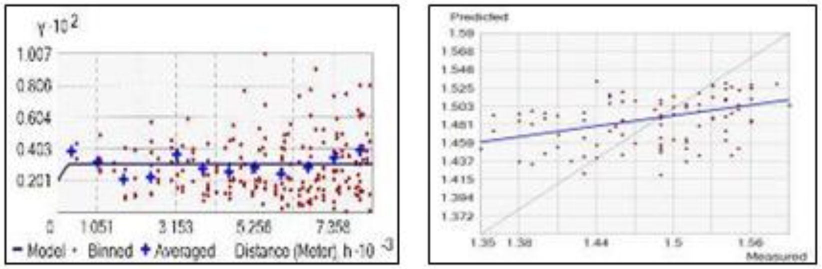


Fig.2b Semi-variogram of PD % in soils of Bhopal domains

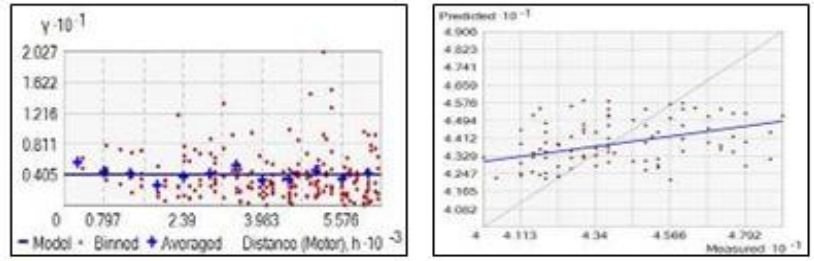


Fig.2c Semi-variogram of sand % in soils of Bhopal domains

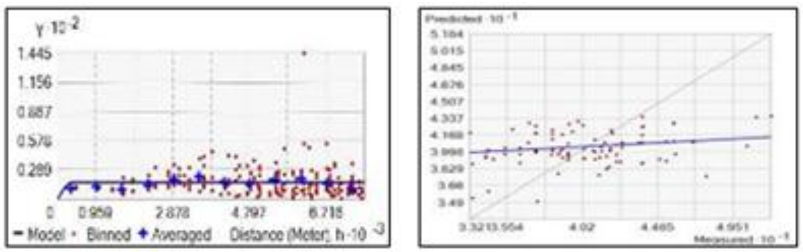


Fig.2d Semi-variogram of silt % in soils of Bhopal domains

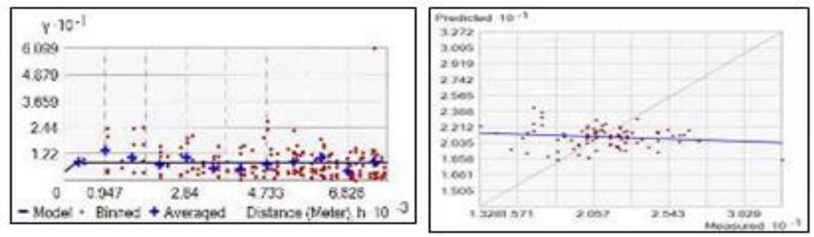


Fig.2e Semi-variogram of clay% in soils of Bhopal domains

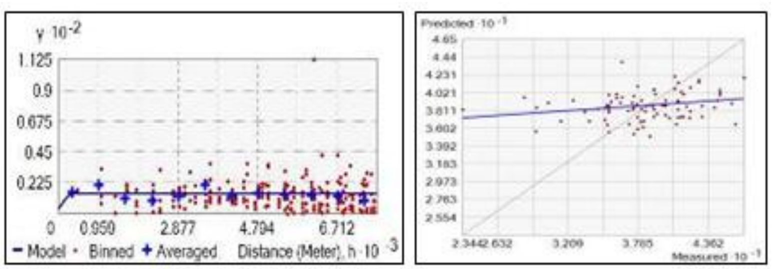


Fig.2f Semi-variogram of AS% in soils of Bhopal domains

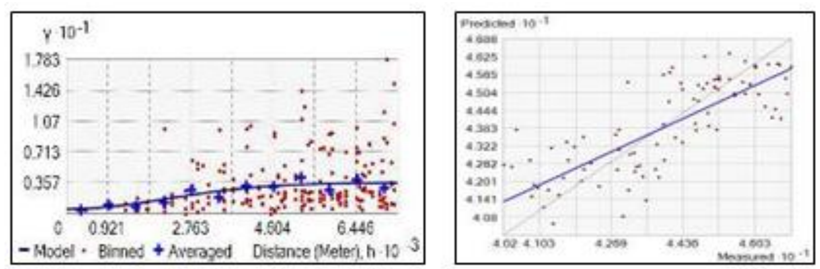


Fig.3a Semi-variogram of SSI% in soils of Bhopal domains

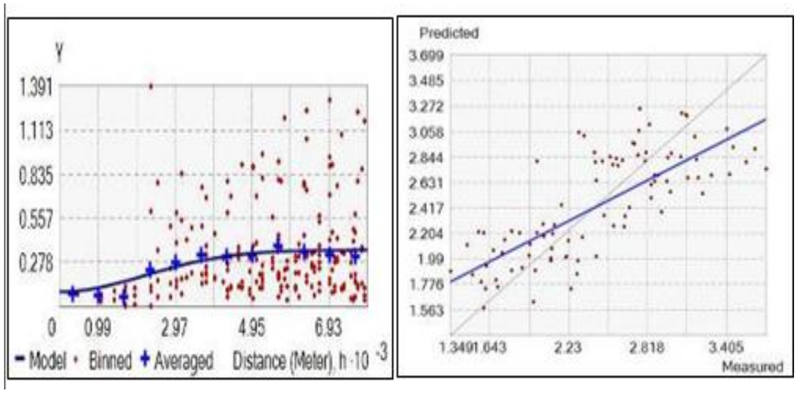


Fig.3b Semi-variogram of SSI (% in soils of Hoshangabad doml domains

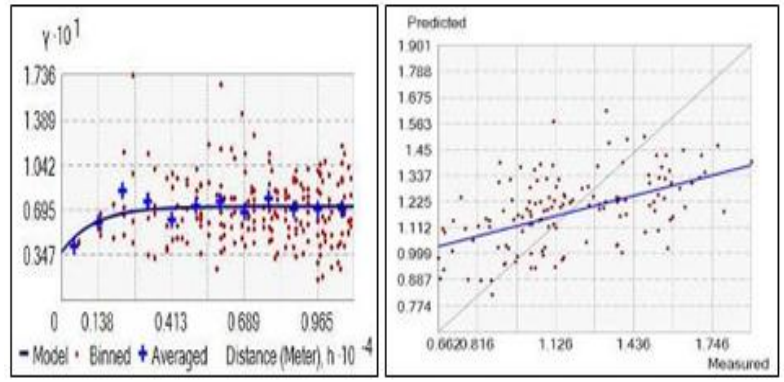


Fig.3c Semi-variogram of SSI (% in soils of Jabalpur domains

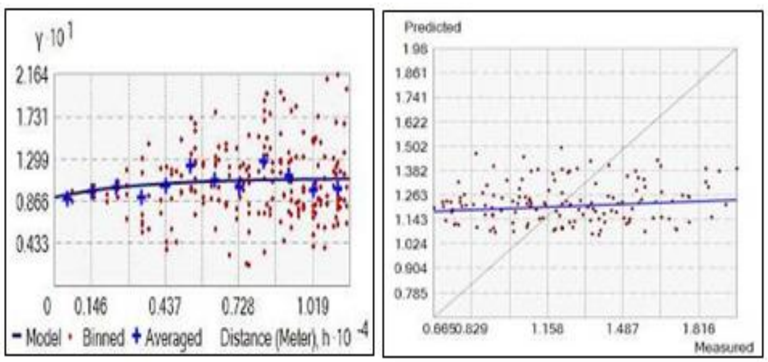


Fig.3d Semi-variogram of SSI (% in soils of Vidisha domains

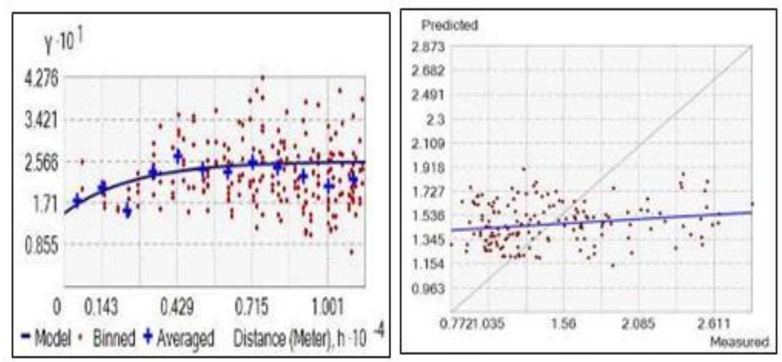


Fig.4a Semi-variogram of BD (Mg m^{-3} in soils of Hoshangabad-doml domains

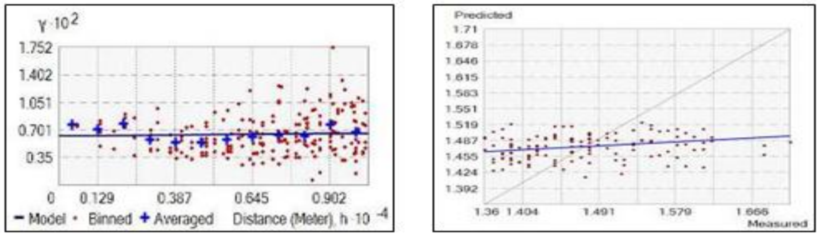


Fig.4b Semi-variogram of PD (% in soils of Hoshangabad domains

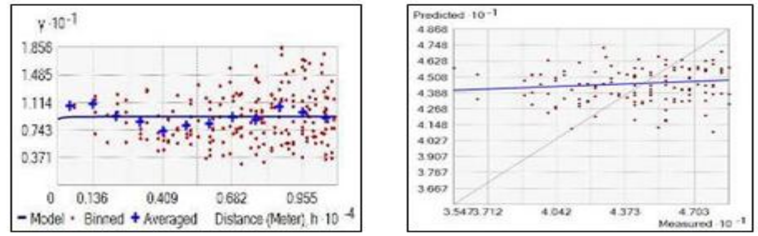


Fig.4c Semi-variogram of Sand (% in soils of Hoshangabad-doml domains

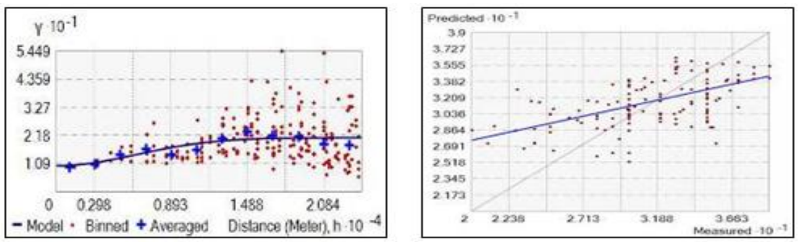


Fig.4d Semi-variogram of Silt (% in soils of Hoshangabad domains

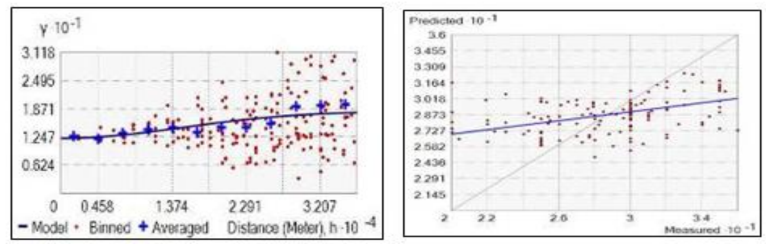


Fig.4e Semi-variogram of Clay (% in soils of Hoshangabad-doml domains

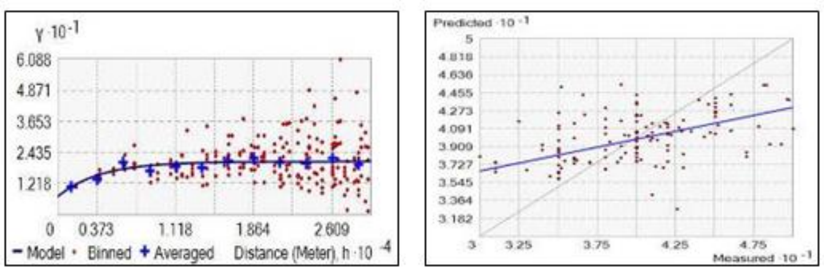


Fig.4f Semi-variogram of AS (% in soils of Hoshangabad domains

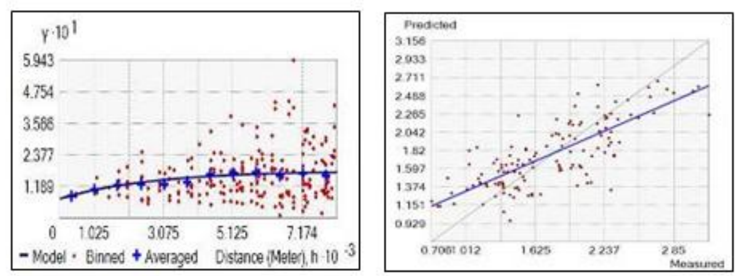


Fig.5a Semi-variogram of BD (Mg m^{-3} in soils of Jabalpur

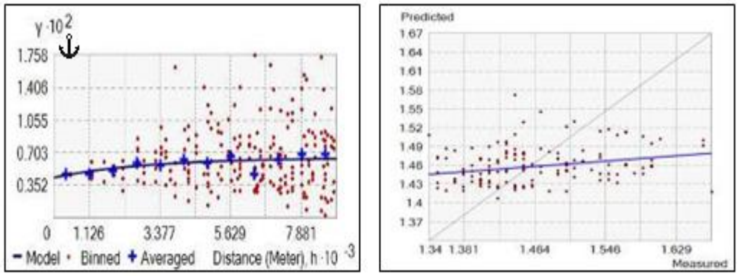


Fig.5b Semi-variogram of PD (% in soils of Jabalpur domains

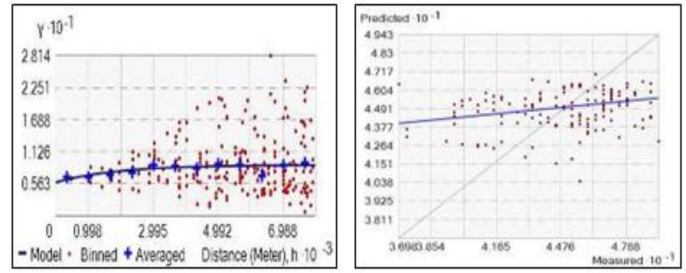


Fig.5c Semi-variogram of Sand (% in soils of Jabalpur domldomains

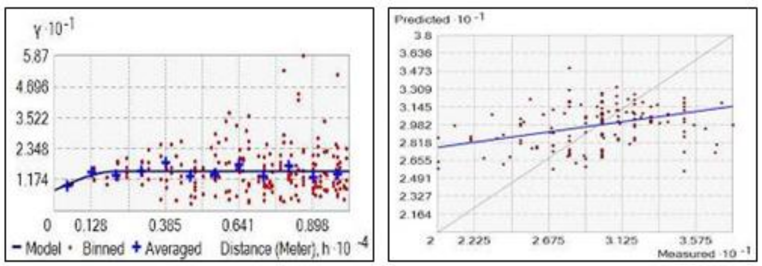


Fig.5d Semi-variogram of Silt (% in soils of Jabalpur domains

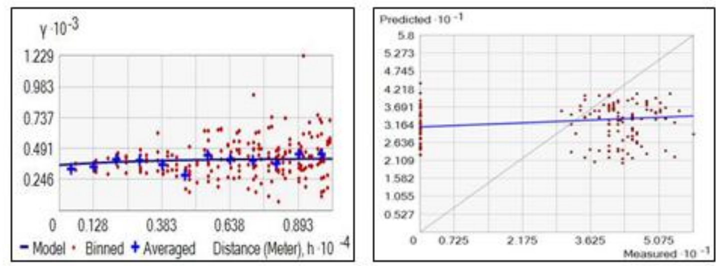


Fig.5e Semi-variogram of Clay (% in soils of Jabalpur domains

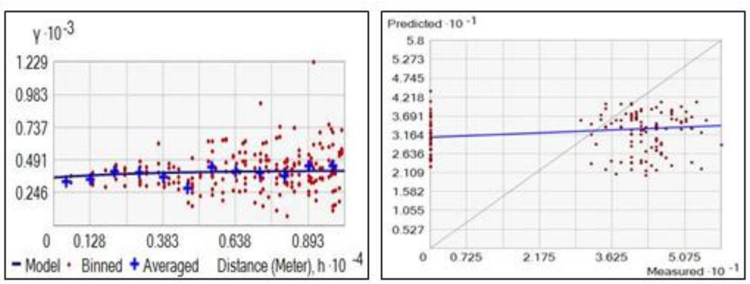


Fig.5f Semi-variogram of AS (% in soils of Jabalpur domains

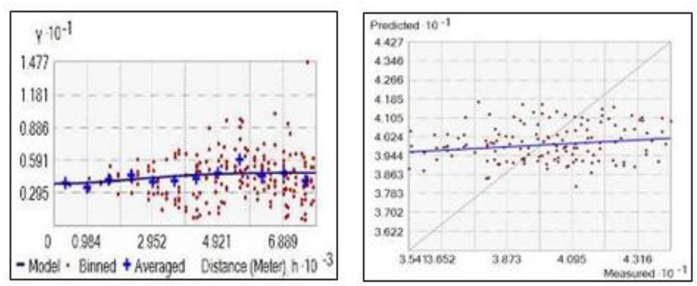


Fig.6a Semi-variogram of BD (Mg m^{-3} in soils of Vidisha

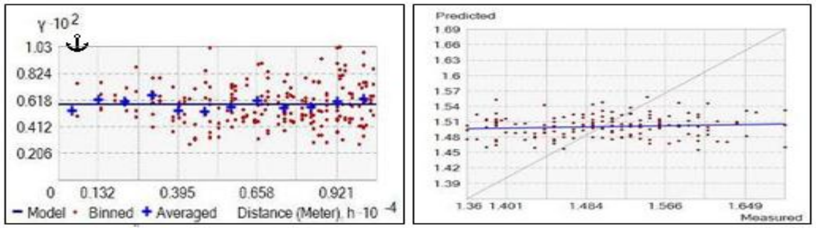


Fig.6b Semi-variogram of PD (% in soils of Vidisha domains

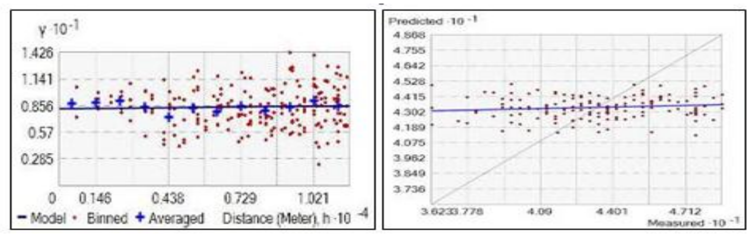


Fig.6c Semi-variogram of Sand (% in soils of Vidisha domains

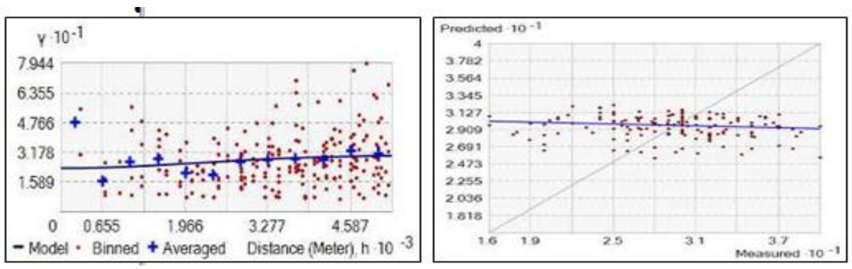


Fig.6d Semi-variogram of Silt (% in soils of Vidisha domains

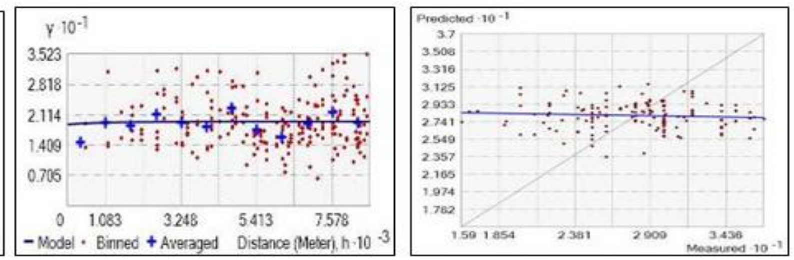


Fig.6e Semi-variogram of Clay (% in soils of Vidisha domains

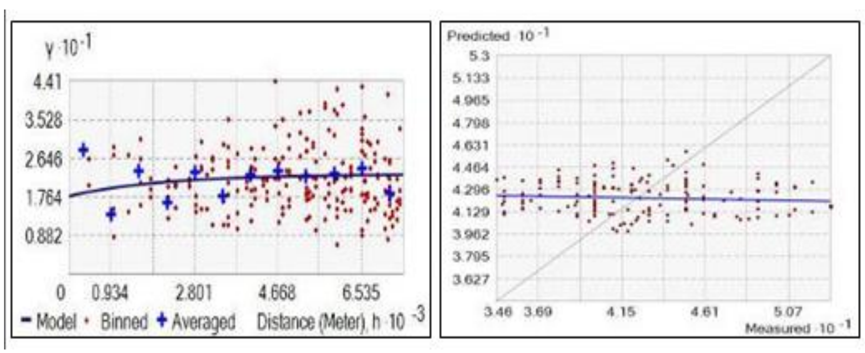


Fig.6f Semi-variogram of AS (% in soils of Vidisha r domains

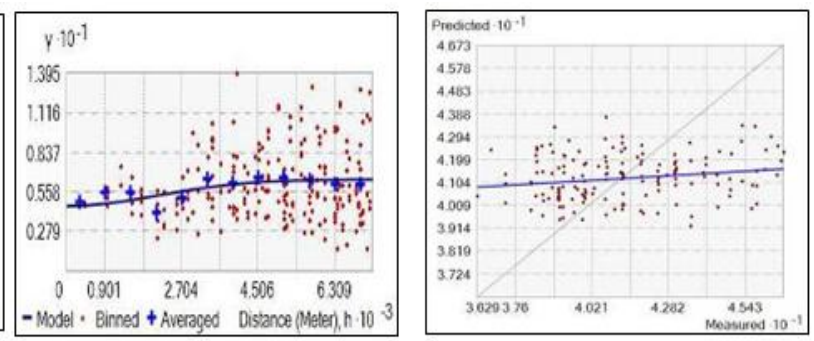


Fig.7 BD Mg m^{-3} of soil under different domain

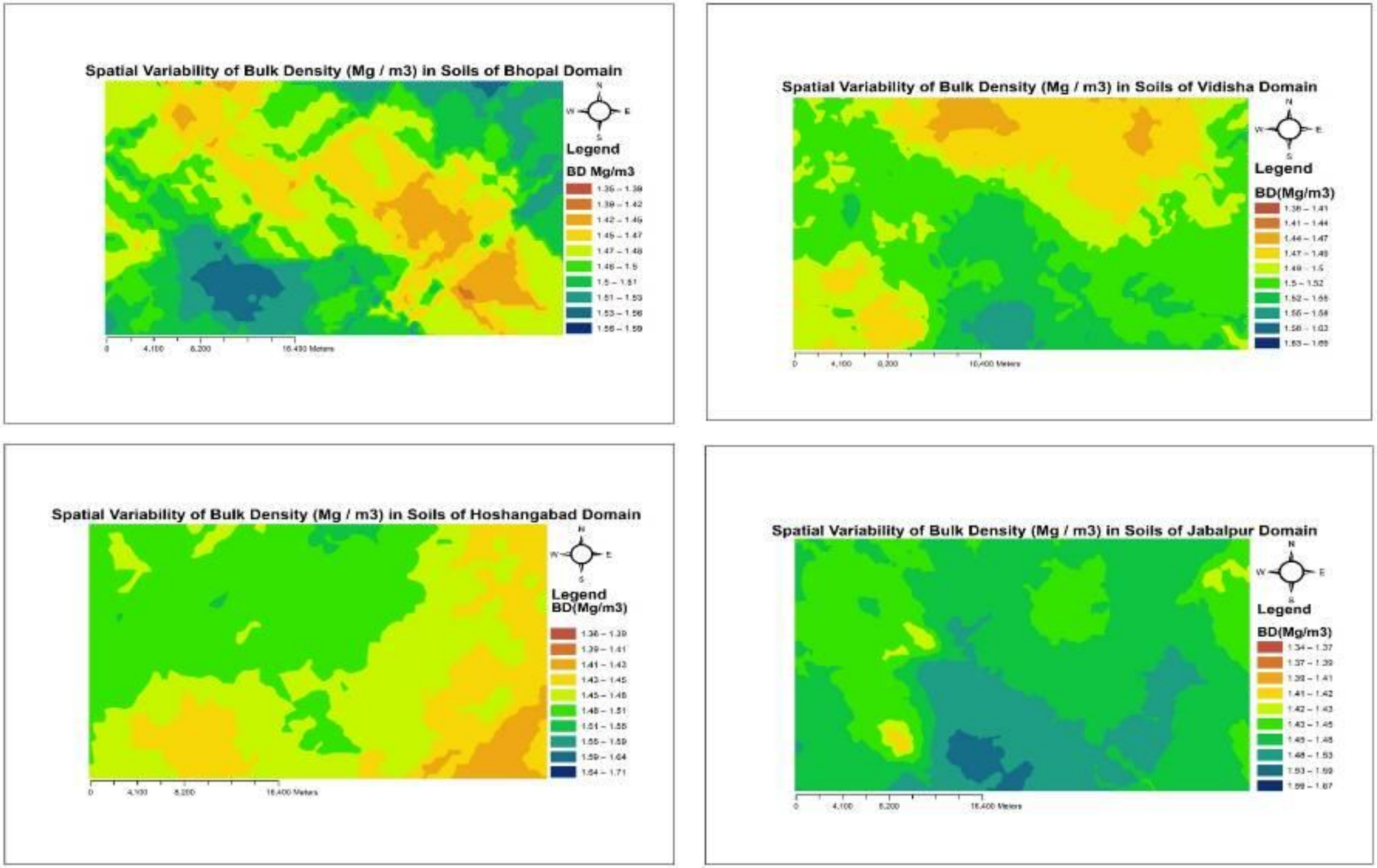


Fig.8 TP (%) of soil under different domain

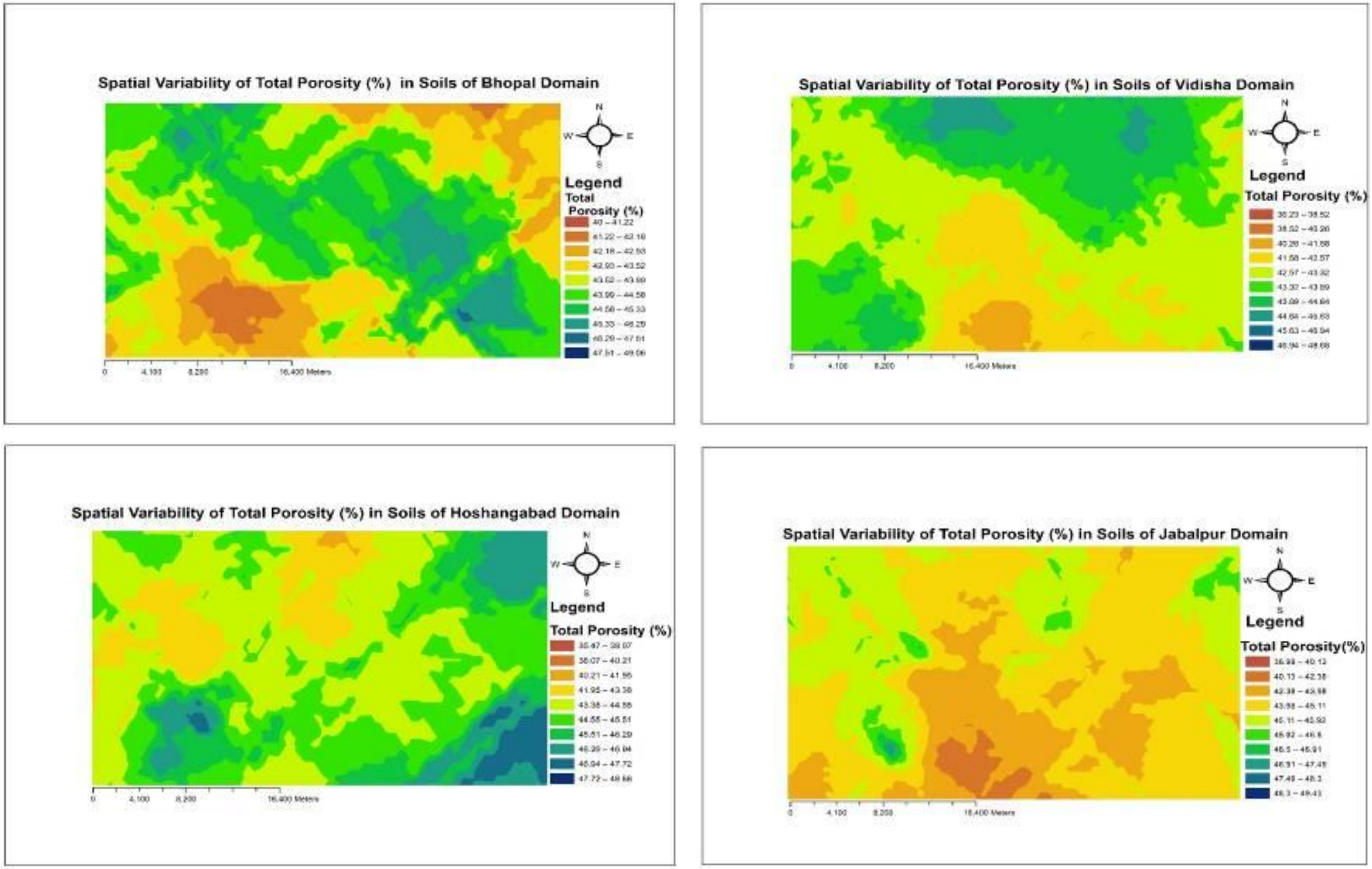


Fig.9 Sand % in soils under different domains

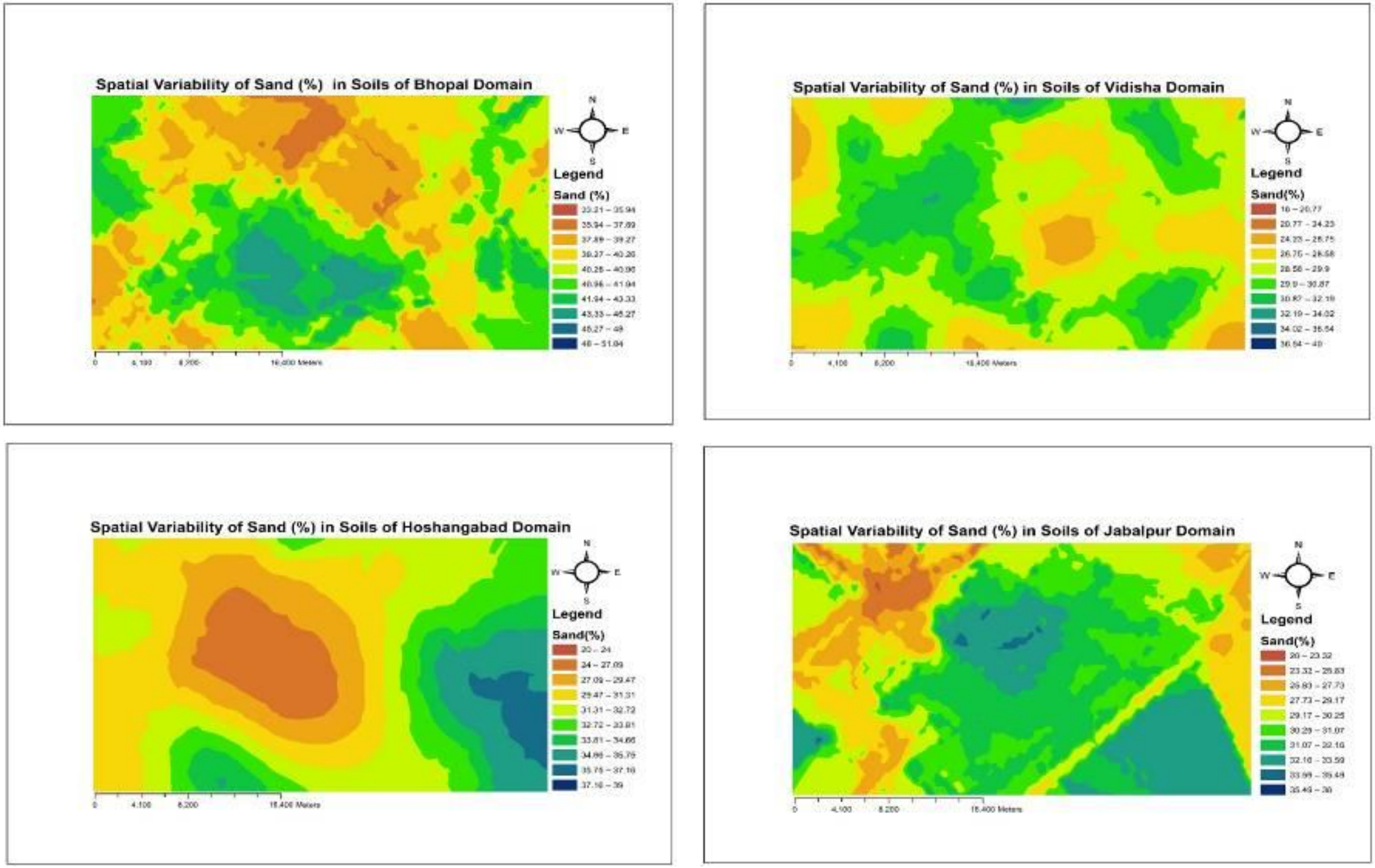


Fig.10 Silt% in soils under different domains

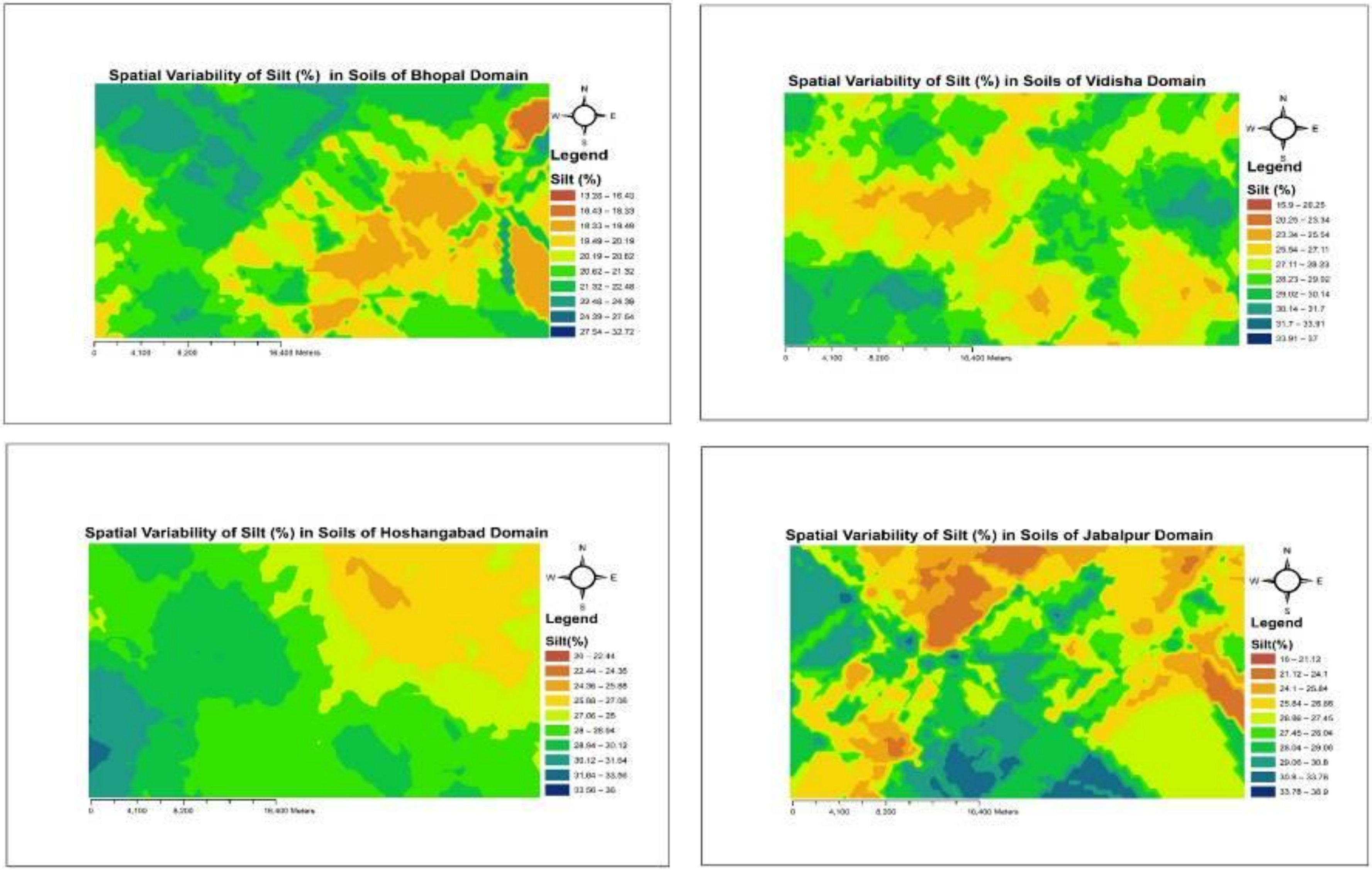


Fig.11 Clay % in soils of different domains

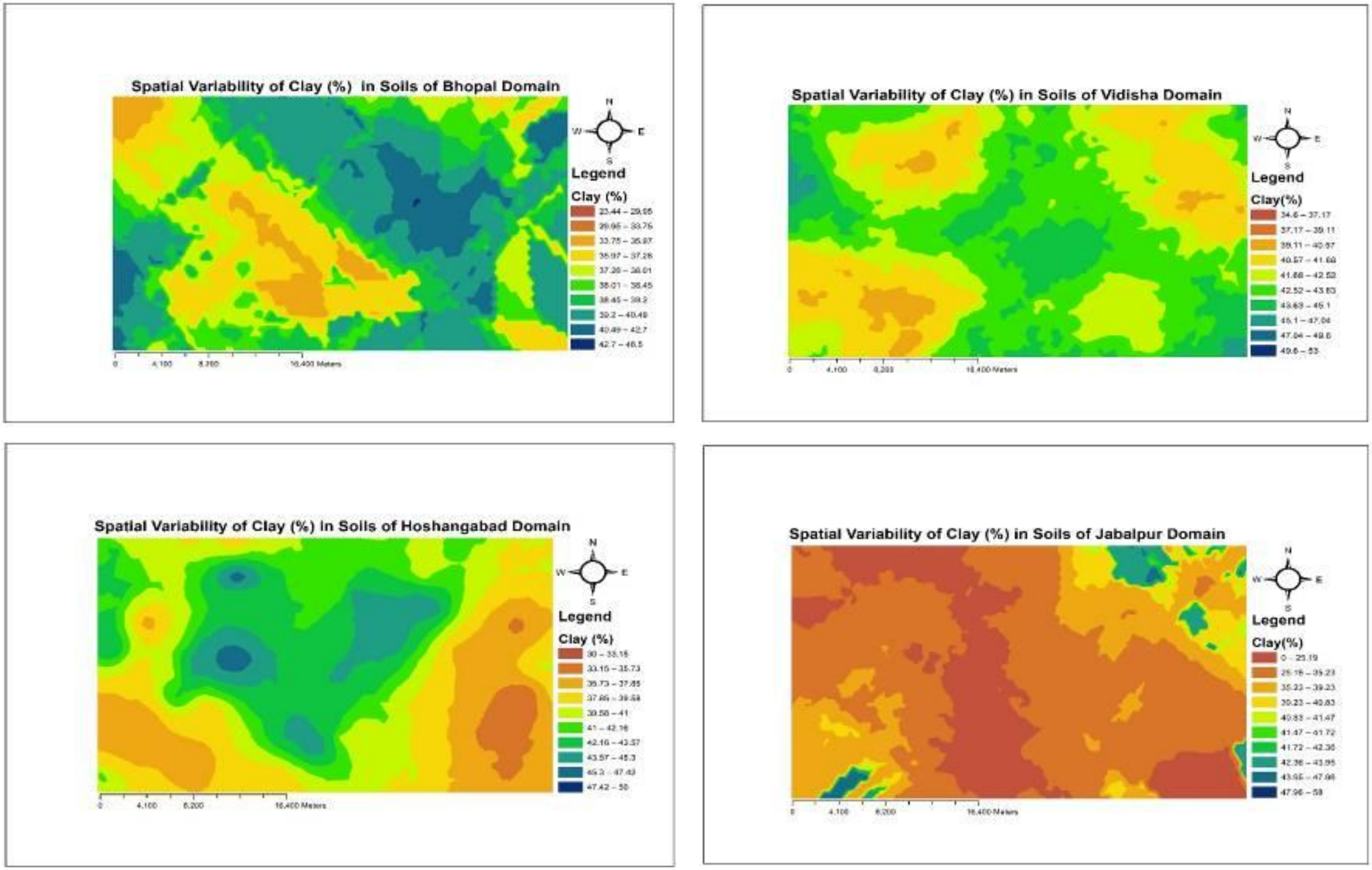


Fig.12 AS% in soils under different domains

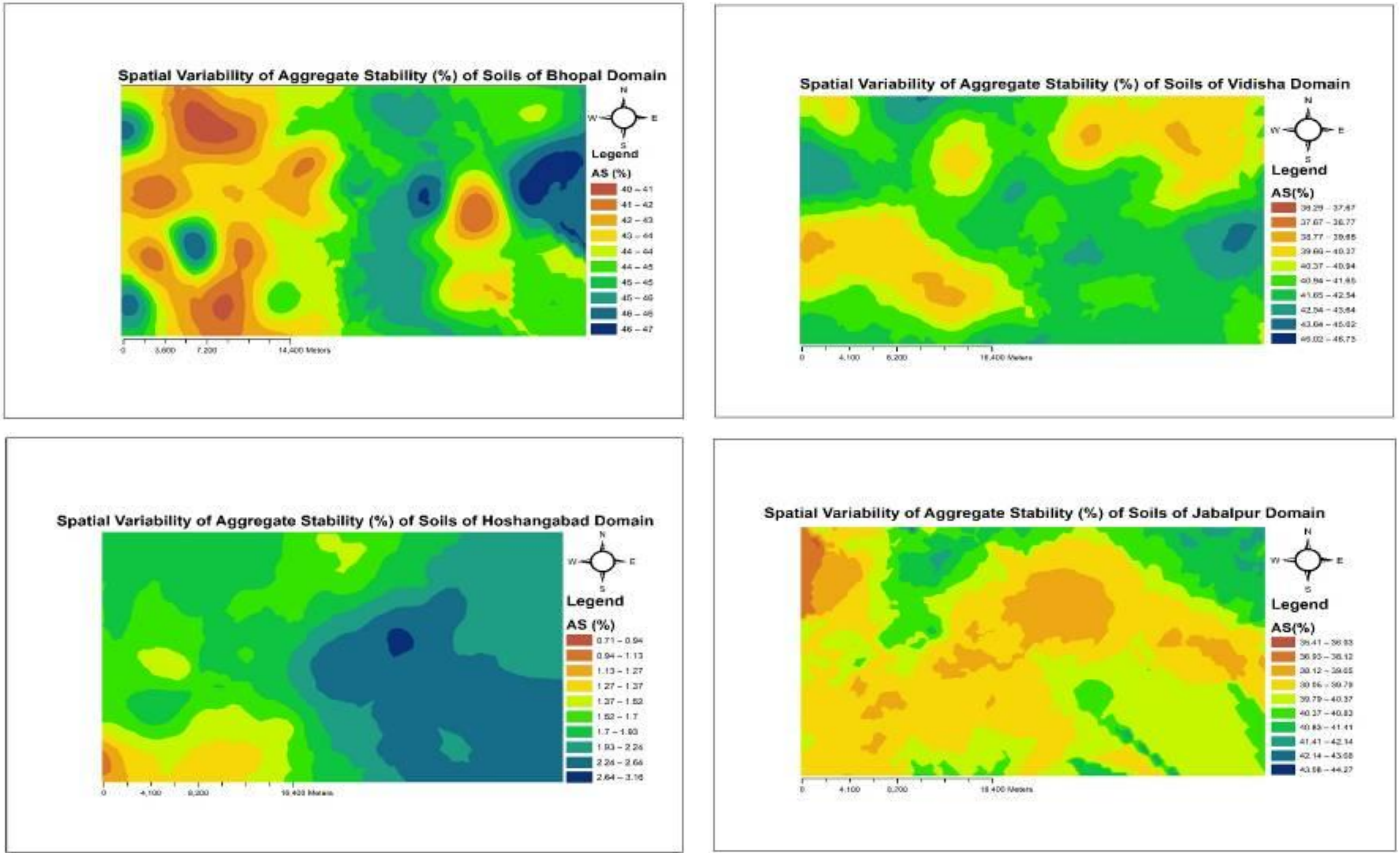
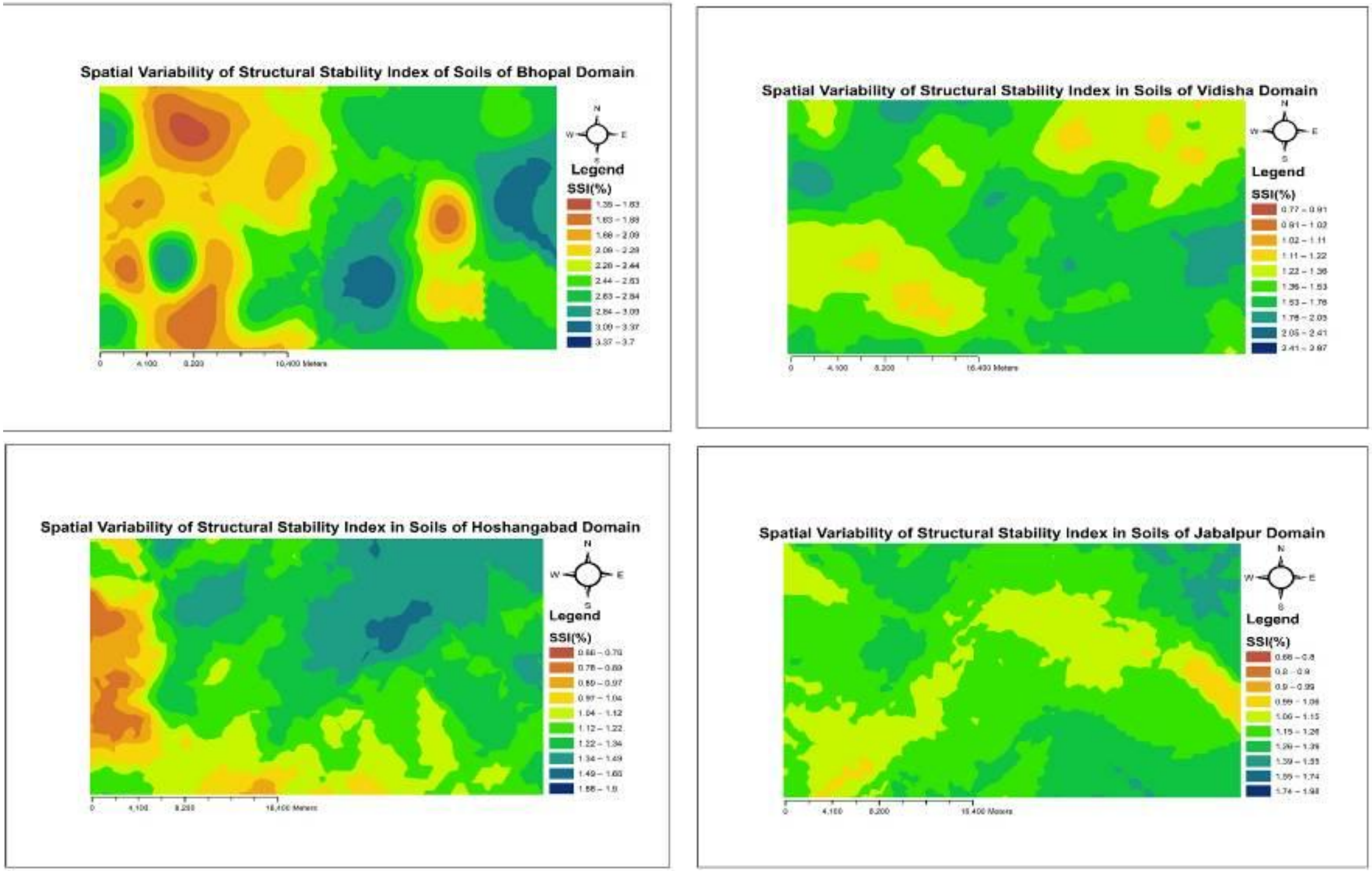


Fig.13 SSI% in soils under domains



The reason might be due to the preferential removal of clay particles and its downward movement into the subsurface soil layer through the process of clay migration.

Similarly, Chemada *et al.*, (2017) stated that the clay content of cultivated land was increased from the surface to subsurface soil layer due to the long period of cultivation.

Additionally, Gebrelibanos and Assen (2013) reported that lower clay and higher sand content was found in the surface layer and higher clay contents was found in the subsurface layer of cultivated land.

Silt content

The sand content in different domains followed the order: Hoshangabad >Vidisha>Jabalpur >Bhopal domain.

Table.2 showed the silt content among all the domains showed that the highest amount of silt content with a mean value of 28.71 % that ranged from 20 to 26 % with 13.62 % coefficient of variation. In the domain, predominant cropping systems followed including paddy-wheat; soybean-wheat, soybean-chickpea and so many other systems. In Vidisha domain, It had a mean silt content of 28.15 % that varied from 15.90 to 37 % with a coefficient of variation (CV) of 15.66 %. The Jabalpur domain showed average silt content of 27.07 % which was varied from 16 to 38.90 % with a coefficient of variation of 14.84 %. In Bhopal domain, the silt content varied from 13.28 to 32.72 % with a mean value of 21.26% and a coefficient of variation of 14.79 %. Among different domains, Vidisha domain demonstrated highest variability in sand content followed by Jabalpur, Bhopal and Hoshangabad domains.

Clay content

The clay content in different domains followed the order: Jabalpur >Vidisha> Hoshangabad >Bhopal domain. Table.2 describes the clay content among all the domains, Jabalpur domain showed that the maximum clay content with a mean value of 43.22 % that ranged from 30 to 58% with 13.19 % coefficient of variation. In the domain, predominant cropping systems followed including paddy-wheat; soybean-wheat, soybean-chickpea and so many other systems. In Vidisha domain, the clay content varied from 34.60 to 53 % with a mean value of 42.52 % and 10.58 % coefficient of variation. The Hoshangabad domain showed average clay content of 39.92 % which was varied from 30 to 50 % with a coefficient of variation of 10.92%. In Bhopal domain, the silt content varied from 23.44 to 46.50 % with a mean value of 38.42% and a coefficient of variation of 10.71%. Among different domains, Vidisha domain demonstrated highest variability in sand content followed by Jabalpur, Bhopal and Hoshangabad domains. Among all domains, the lowest clay content exhibited by Bhopal domain. The data hint at considerable within domains variability in distribution of soil separates and the need to examine spatial variability through geo-statistics.

Spatial variability maps generated using geo-statistical tool

Ordinary Kriging was chosen to create the spatial distribution maps of soil characteristics with maximum search radius being set to autocorrelation range of the corresponding variable. Data presented in Table 3 and Figs. depicted in 3.1 (a-f),3.2(a-d),3.3(a-f),3.4(a-f) and Figs.(3.2.1 to 3.2.7).

Characteristic of Semi-variogram

Semi-variogram used for analysis distribution of some physical properties of soils are presented in Table.1. In this study, all variogram were in isotropic form and were fitted using basic math models, such as Spherical, Exponential, Gaussian, and J-Bessel based on the values of weighted residual sums of squares and relative spatial structure indicator (Nugget/Sill) that indicated spatial dependency. Filled contour maps (Prediction map) were created and geo-statistical result are interpreted are as follows:

For of BD, TP, Sand, Silt, Clay, AS and SSI, in Bhopal domain, Gaussian model best fitted for of SSI and AS, Spherical model fitted for BD, Sand, Silt, Clay and Exponential model fitted for TP. In Jabalpur domain, Exponential domain best fitted for BD, TP, Clay and SSI, Spherical model for Sand and Silt, and for AS, Gaussian model is best fitted. In Vidisha domain, Exponential model best fitted for BD, Silt, Clay and SSI, Gaussian model best fitted for of TP, Sand and AS. And in Hoshangabad domain, Exponential model is best fitted for TP, Clay, SSI, and AS, and Gaussian model best fitted for BD, Sand and Silt.

The nugget/sill (N/S) ratio <25% which exhibit strong spatial dependency only for Sand, Clay and AS in Bhopal domain. The N/S ratio was found to be >25% but <75% which showed moderate spatial dependency, for BD, Silt and SSI in Bhopal domain, BD, TP, Sand and Silt in Jabalpur domain, AS and SSI in Vidisha domain, and Sand, Silt, Clay, AS and SSI in Hoshangabad domain. The N/S ratio was found to be <75% which showed weak spatial dependency for Clay, AS and SSI in Jabalpur domain and TP in Bhopal domain, BD, TP, Sand, Silt, and Clay in Vidisha domain, and BD and TP in Hoshangabad domain.

In Bhopal domain, correlation range (m) for BD, TP, Sand, Silt, Clay, AS and SSI are 360.522, 360.522, 360.522, 343.744, 360.522, 5461.203 and 5415.315, respectively. In Jabalpur domain, correlation range (m) for BD, TP, Sand, Silt, Clay, AS and SSI are 9006.513, 5586.513, 2144.265, 1225.591, 10205.574, 5786.073 and 10115.947, respectively. In Vidisha domain, correlation range (m) for BD, TP, Sand, Silt, Clay, AS and SSI are 10530.726, 11670.726, 5242.651, 3514.772, 6268.554, 5258.599, and 7836.806, respectively. In Hoshangabad domain, correlation range (m) for BD, TP, Sand, Silt, Clay, AS and SSI are 10312.619, 669.860, 15133.082, 36651.506, 12030.534, 8199.395 and 3711.847, respectively.

The objective of the study was to assess soil physical condition as affected by different domains and land use types. The study area has low bulk density, which is indicating the higher soil clay soil particles in Jabalpur domain. The higher sand recorded in the Bhopal land while the lower was found in Vidisha domain. Generally, Jabalpur domain the has low BD high clay particles and high porosity while in Vidisha it showed high BD, low sand particles, low total porosity. Therefore, the supply of organics/FYM/amendment are important, which can increase crop productivity and minimize environmental risk.

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