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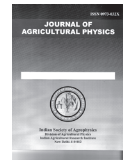

Research Article

Spatial Variability of Saline Soil Properties in Karnal District of Haryana

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ABSTRACT

Different soil parameters were studied, total 121 soil samples were collected from 0-15 and 15-30 cm depths from saline soil of Karnal district, Haryana. The study aimed to determine the spatial variability of these soil parameters in district level. With the help of geostatistical analyst of ArcGIS software krigged map of different soil parameters were prepared. The map was made for both 0-15 cm and 15-30 cm soils. Different model parameters (nugget, partial sill, range and RMSE) were studied to determine spatial dependence of the soil properties. The best semivariogram model was selected based on lowest root mean square error (RMSE). Soil parameters *i.e.*, fractal dimension (D), bulk density (BD), glomalin content and pH showed low variability, clay, sand % and total organic carbon (TOC) showed medium variability and silt , organic carbon (OC), mean weight diameter (MWD), hydraulic conductivity (HC), EC and microbial biomass carbon (MBC) showed high variability. Different soil parameters showed different semivariogram models, based on the model parameters we need to design the management practices as per the requirement of the soil. With the help of these maps we can delineate the low performing parameters in a particular region and improve management according to the need due to shortage of land resources and food supply on global scale.

Key words: Kriging, Saline soil, Semivariogram, Soil properties

Introduction

It is intimidating work to carry on sustainable crop production in salt-affected arid and semi-arid region due to extreme climatic variability, varied soil fertility and land as well as water degradation (Moharana *et al*., 2019). Long-term use of alkaline residual groundwater for irrigation results in clay dispersion, structural instability, hinders plant growth and makes the soil unsuitable for crop production (Minhas *et al*., 2019). Prolonged use of low quality irrigation water in salt-affected soil declines the chemical and physical health of soils. It is important to prepare soil spatial variability maps of soil salinity/sodicity to understand soil physical health status and required management strategies to achieve optimum crop yield. Different spatial tools like semivariogram, kriging, co-kriging, regression kriging etc. can be used to prepare spatial variability maps which are efficient in predicting parameters value at unsampled location (Bhunia *et al*., 2018). Kriging model is reported to have higher accuracy over other models for estimating spatial variability of soil aggregate stability as a geostatistical technique (Vogel *et al*., 2010). Conventional method of assessing soil

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salinity, it required huge cost, time and other investments (Bhattacharya *et al*., 2021), whereas with the help of krigged maps, crucial parameters can be identified and location-specific management can be done accordingly (Bhattacharya *et al*., 2018), thus, it will reduce error and cost (Nawar *et al*., 2017). With this background, a study was undertaken to prepare the spatial variability maps of Karnal district of Haryana and to identify the areas with high salinity and sodicity.

Materials and Methods

Study area

The area falls under subtropical continental type of climate. Normal rainfall of the area is 590 mm with 31 to 35 rainy days in a year. The southwest monsoon largely contributes to the overall rainfall of about 82.39% which ranges from July to September. The study area is under Indo-Gangetic Alluvium. The texture is mainly sandy clay loam and clay loam. The soil belongs to the order Entisol, suborder fluvents, and great group ustifluvents.

Soil sampling and analysis

Total 121 samples were collected from 17 villages from 3 blocks (Nilokheri, Assandh and Nissang) in Karnal district of Haryana during October and November 2020 from 0-15 and 15-30 cm of soil depths Bulk density of the soils was measured by the procedure outlined by Blake and Hartge (1986). Bulk density was obtained by dividing weight of the oven-dried soil by the volume of core. Fractal dimension was measured using Zeta size analyser which works on the principle of Mie scattering. The volume fraction of soil and the mass of each soil class was generated by multiplying the density of each size class (Bai *et al*., 2020). Soil texture was determined by International pipette method. Yoder sieve apparatus was used to determine aggregate size distribution. Organic carbon (OC) was determined by Walkley and Black method. Glomalin content was measured colorimetrically by Bradford protein assay method (Wright and Upadhyaya, 1998). Constant head permeameter method was used for measurement of saturated hydraulic conductivity (Klute and Dirksen, 1986). TOC analyser (Elementor, Germany) was used to measure total organic carbon. Fumigation-extraction method was used to determine microbial biomass carbon (MBC). Microbial biomass carbon was measured by fumigation-extraction method (Jenkinson and Powlson, 1976). Suspension of 1:5 (soil: water) was required to estimate electrical conductivity (EC). The pH was estimated by soil water suspension method (soil: water 1:2.5) using a pH meter.

Statistical and geospatial technique

The data analysis module of Microsoft Excel (2013) was used to perform descriptive statistics. The variability of soil properties was calculated with the help of coefficient of variability (CV). Skewness value was also estimated which helped to find the normal distribution wherever found necessary. Geostatistical Analyst of ArcGIS 9.3.1 software was used to generate krigged map (ArcGIS, 2009). Semi-variograms were calculated to assess the structure of spatial variability. The spatial dependence among the selected soil parameters was indicated by parameters like nugget and sill of the geostatistical model.

Results and Discussion

Descriptive statistics of total dataset

Descriptive statistics of total, training and testing dataset of all parameters studied are given in Table 1. The large SD and CV values indicated a large variability in the soil parameters of the study area. When CV was between 0-15%, then the parameter is said to have low variability. CV value of 16-35 indicate medium variability and CV > 35% denote high variability in the parameters. The box and whisker plots of the studied parameter is given in Fig. 2.

Spatial distribution of Soil pH and EC

To see the spatial distribution of soil pH and EC in the study area, kriged maps were generated for 0-15 and 15-30 cm of soil depths (Fig. 1 and 2). Semivariogram models were selected from the lowest RMSE value. The best selected model, along with the model parameters for pH and EC in 0-15 and 15-30 cm soil depths are given in Table 2. In 0-15 cm soil depths, soil pH varied from 8.24 to 10.08 whereas, in 15-30 cm soil depth, it ranged from 8.36

Table 1. Descriptive statistics of the parameters studied in study area

Parameters	Minimum	Maximum	Mean	SD	Skewness	Kurtosis	SE	CV	Variability
Clay (%)	10	40	20.8	6.59	0.46	0.068	0.59	31.68	Medium
Silt (%)	4	44	22.09	8.60	0.26	-0.35	0.78	38.93	High
Sand (%)	30	82	57.34	11.50	-0.21	-0.38	1.04	20.05	Medium
TOC (%)	0.26	1.17	0.65	0.21	0.35	-0.52	0.019	32.30	Medium
OC (%)	0.08	0.88	0.41	0.17	0.35	0.15	0.015	41.46	High
MWD (mm)	0.18	1.21	0.61	0.24	0.49	-0.38	0.021	39.34	High
D	2.59	2.97	2.73	0.07	0.44	0.32	0.006	2.56	Low
BD (Mg/m^3)	1.20	1.86	1.55	0.12	0.081	0.472	0.01	7.74	Low
HC (cm/hr)	1.59	19.16	8.65	3.73	0.32	-0.095	0.338	43.12	High
Glomalin (μg/kg)	14.79	32.43	23.62	3.165	0.338	-0.007	0.287	13.39	Low
pH	8.24	10.76	9.15	0.52	0.58	0.395	0.047	5.70	Low
EC (dS/m)	2.24	12.16	5.05	2.11	1.44	1.73	0.19	41.82	High
MBC (μg/g soil)	9.60	613.45	162.8	116.70	1.35	2.66	10.60	71.68	High

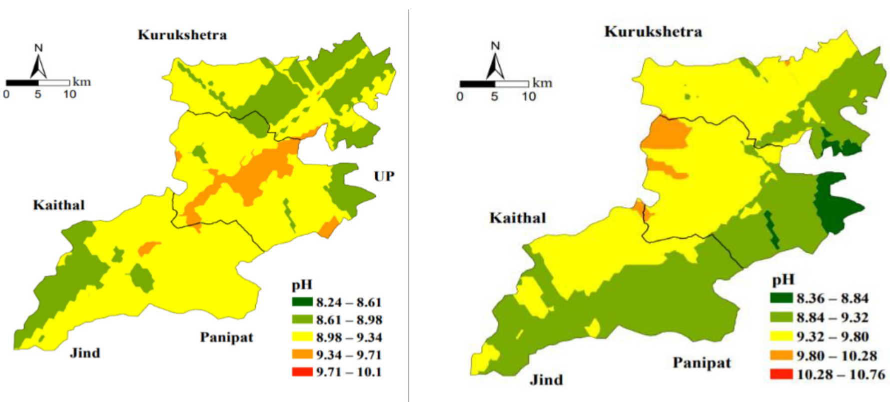

Fig. 1. Spatial variability maps of soil pH in 0-15 and 15-30 cm soil depths

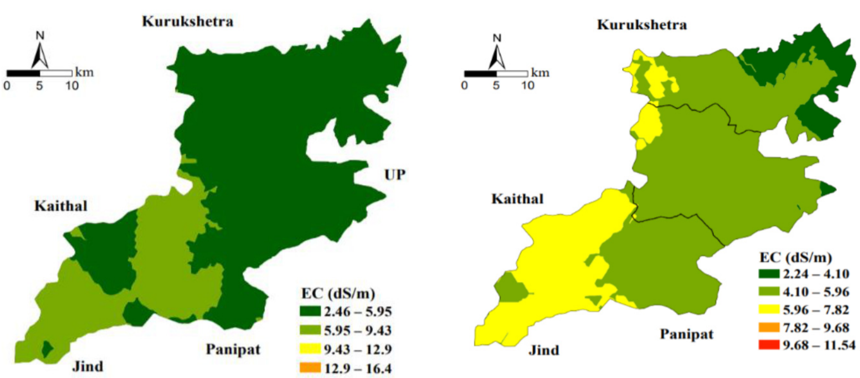

Fig. 2. Spatial variability maps of soil EC in 0-15 and 15-30 cm soil depths

Table 2. Model parameters of semivariogram model selected for kriging of pH, EC, MBC, glomalin, texture, TOC, OC, HC, MWD and BD of 0-15 and 15-30 cm soil layers

Parameters	Model	Nugget	Range	Partial Sill	RMSE
			0-15 cm		
pH	Spherical	0.04	0.00	0.17	0.45
EC	Exponential	3.79	0.15	1.84	2.62
			15-30 cm		
pH	Exponential	0.00	0.00	0.37	0.55
EC	Gaussian	4.72	0.17	0.00	2.23
			0-15 cm		
MBC	Gaussian	9436.81	0.34	0.00	100.31
Glomalin	Gaussian	9.30	0.36	2.14	3.23
			15-30 cm		
MBC	Gaussian	14819.84	0.05	8826.25	131.91
Glomalin	Exponential	6.21	0.03	4.45	3.12
			0-15 cm		
Sand	Circular	62.67	0.00	76.59	12.45
Silt	Circular	7.09	0.00	92.01	9.31
Caly	Circular	5.47	0.00	42.00	6.66
			15-30 cm		
Sand	Exponential	77.96	0.10	46.81	10.20
Silt	Exponential	25.45	0.09	51.98	6.97
Clay	Gaussian	40.03	0.13	0.00	6.44
			0-15 cm		
TOC (%)	Circular	0.62	0.09	51.98	0.17
OC (%)	Circular	0.51	0.10	47.43	0.13
			15-30 cm		
TOC (%)	Circular	0.53	0.0	49.67	0.19
OC (%)	Circular	0.64	0.0	54.21	0.15
			0-15 cm		
HC	Circular	7.25	0.00	4.52	3.27
MWD	Exponential	0.04	0.19	0.02	0.23
BD	Circular	0.01	0.03	0.01	0.09
			15-30 cm		
HC	Gaussian	10.12	0.04	2.14	3.16
MWD	Gaussian	0.05	0.01	0.02	0.24
BD	Gaussian	0.01	0.09	0.00	0.11

to 10.76. In 0-15 cm soil layer, 75 % of the area was under 8.98 to 9.34 but in 15-30 cm soil depths, 55% of the area was under 9.32 to 9.80 class. In both the soil layers, the most of the area is under moderately saline category as per classification proposed by Chesworth (2008). The EC map of 0-15 cm soil layer showed that in 80% of the area, EC varied from 2.46 to 5.95 dSm^{-1}. In 15-30 cm soil layer, around 28% of the study area had EC value of 5.96 to 7.82 dSm^{-1} and 62% of the study area had EC value of 4.10 to 5.96 dSm^{-1}. The current study reported a lower pH value in 0-15 cm soil layer as compared to 15-30 cm soil layer. The EC value was more in 0-15 cm soil layer as compared to 15-30 cm soil layer. The rainfall had helped to remove the accumulated salts from the surface by leaching to the deeper layers. Spatial variability analysis of 121 georeferenced soil samples from 0-15 and 15-30 cm of depths showed extensive heterogeneity in soil EC and pH which is in agreement with study conducted by Barman *et al.*

(2021) in Kaithal district of Haryana. The variability of soil salinity is seasonal (Mandal *et al*., 2018). The EC of the study area was highly variable in nature due to its high CV value. Results revealed that semivariograms had the same nugget, sill, and range parameters, indicating the isotropic nature of EC and pH in the horizontal dimension for all data sets. Koganti *et al*. (2018) reported an increase in EC with depth, which is in agreement with our study.

Spatial distribution of sand, silt and clay percentage

Spatial variability of sand, silt and clay % in 0-15 and 15-30 cm soil layers are given in Fig. 3 and 4. The best situated semivariogram model along with the model parameters are shown in Table 2. The semivariogram models were selected as per their lowest RMSE values. In 0-15 cm soil depth the range of sand has 30 to 82% whereas, in 15-30 cm soil depth the range of sand has 30 to 75% . The ranges of silt content in 0-15 cm and 15-30 cm soil depth more from 4 to 44% and 6 to 40% respectively. Fractal dimension (D) quantified soil structure which is used to be a qualitative property. The D value of our study varied from 2.59 to 2.97. In the study area 15.7% of the samples had D value in between 2.75 and 2.80, 73.5% of samples had D value in between 2.81 and 2.96 and 10.7% of samples in between 2.59 and 2.74. In our study area, among sand, silt and clay particle, both the soil depths, average sand content was more than silt and clay particles. As most of the study was having average EC of more than 4dSm^{-1}, the clay in the soils remain in aggregated conditions, so the saline soils have good physical condition. More sand content in the area would help to leach out the excess salts from the root zone, which is very beneficial for plant growth. So, sandy loam can withstand more salinity than clayey type soil. The results indicated that as the particle size increased, the D value decreased and *vice-versa*.

Variation of Walkley-Black carbon and Total organic carbon in soil

The kriged map of TOC showed that TOC ranged from 0.32 to 1.16% in 0-15 cm soil, whereas, in 15-30 cm soil depth, it varied from 0.25 to 1.15% (Fig.

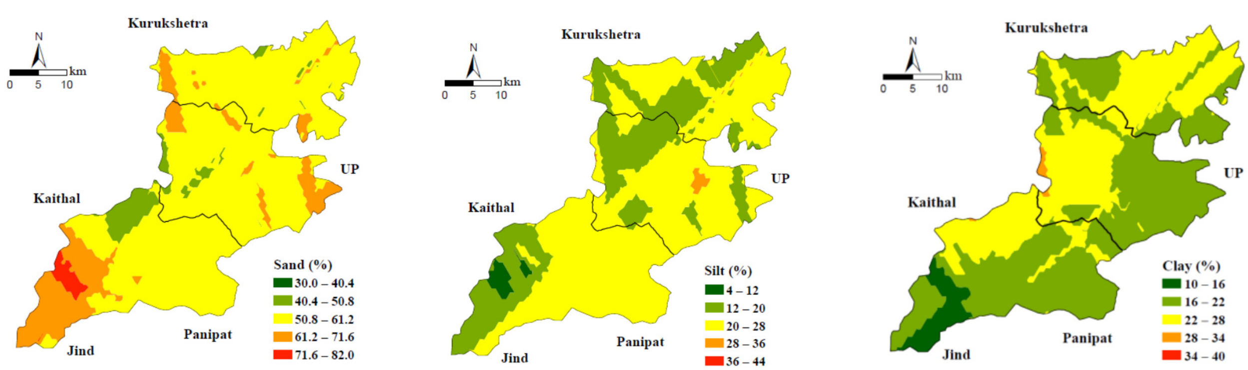

Fig. 3. Spatial distribution of sand, silt and clay percentage of the study area for 0-15 cm soil layer

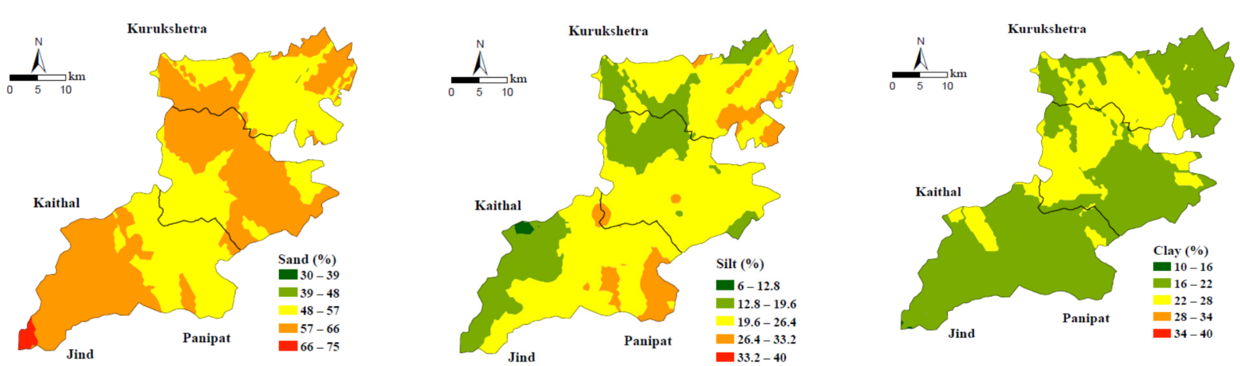

Fig. 4. Spatial distribution of sand, silt and clay percentage of the study area for 15-30 cm soil layer

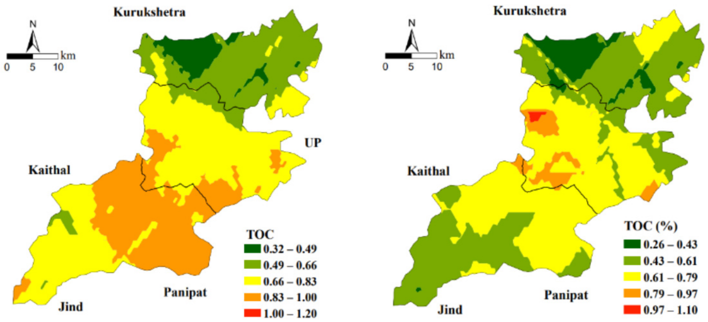

Fig. 5. Spatial distribution of total organic carbon (%) in 0-15 and 15-30 cm of soil

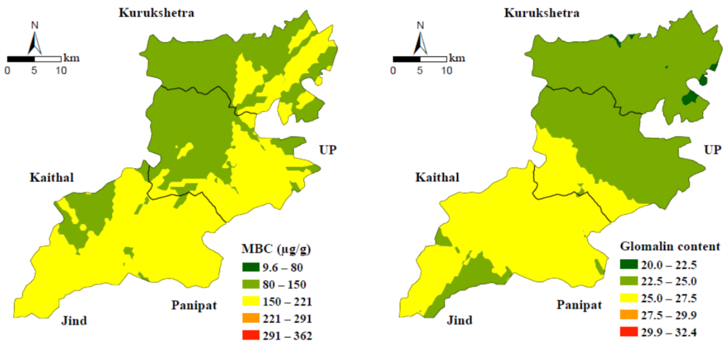

Fig. 6. Spatial distribution of MBC (µg/g) and glomalin content (µg/kg) in 0-15 cm soil depth

5). TOC was around 17.9% more in 0-15cm soil depth as compared to 15-30 cm soil depth. Out of 121 soil samples, 65.3% (79) were under low carbon category, whereas, 14.87 % (18) were under medium and high carbon content classes (Table 2). The kriged map of TOC showed that in 0-15 cm soil depth. The map of aggregate stability preparaed from krigging showed higher MWD in surface soil (0-15 cm). With increasing the pH, the value of MWD increased by 18.33% in 0-15 cm soil depth, whereas in 15-30 cm soil depth the increment was 10.71%.

Spatial distribution of MBC and glomalin content

When salinity was increased from surface (0-15 cm) to sub-surface(15-30 cm), the MBC depleted by 18.9% in case of 8-9.5 pH level and in case of more than 9.5 pH level the depletion was 23.09% from 0-15 cm to 15-30 cm soil depth (Fig. 6 and 7). In surface soil also the MBC showed huge reduction with higher pH by 7.43% from lower pH (8-9.5) to higher pH (>9.5). Similar result was observed in sub-surface layer with 12.14% reduction from lower pH (8-9.5) to higher pH (>9.5). Easily extractable glomalin related soil protein (EE-GRSP) is a complex carbohydrate chain (Wright and Upadhaya, 1998). In a shallow (40 cm) soil profile glomalin showed decreasing trend with increasing depth (Bai *et al*., 2009). The same pattern has been found in our study. Wright *et al*. (1998) have showed that, there is strong positive correlation between water stable aggregate and glomalin content. Results showed that, with decreasing value of MWD in sub-surface the glomalin has also reduced. With increase in BD with lower depth the glomalin content also reduced. The value of MWD was higher with increasing glomalin content with decreasing soil depth, so glomalin content showed positive relationship with MWD and negative relationship with soil BD, pH and EC (Luna *et al*., 2016).

Spatial distribution of HC, MWD and BD

The spatial distribution of HC, MWD and BD of soil was created with the help of kriged map at 0-15 cm and 15-30 cm soil depth (Figure 8, 9 and 10). In 0-15 cm soil depth the range of HC was 2.50 to

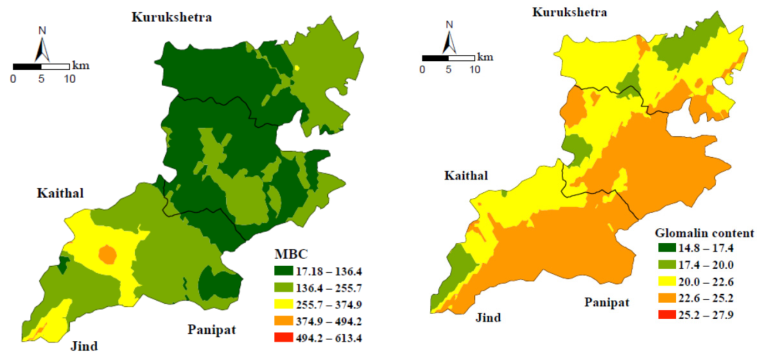

Fig. 7. Spatial distribution of MBC (µg/g) and glomalin content (µg/kg) in 15-30 cm soil depth

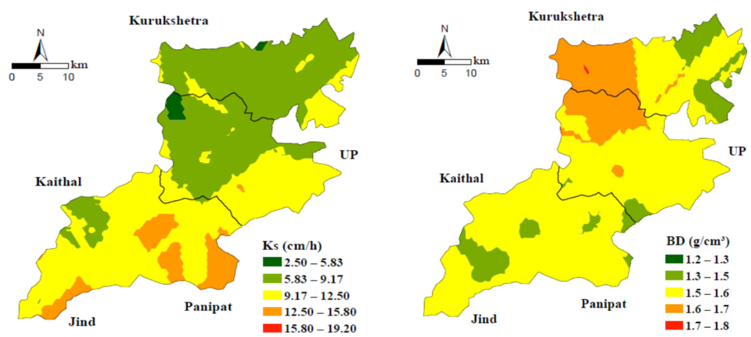

Fig. 8. Spatial distribution of Hydraulic Conductivity (HC) (cm/hr) and Bulk Density (BD) (Mg/m^3) in 0-15 cm soil depth

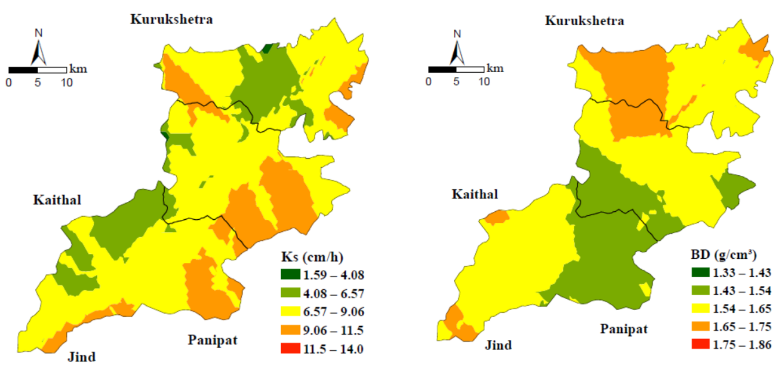

Fig. 9. Spatial distribution of Hydraulic Conductivity (HC) (cm/hr) and Bulk Density (BD) (Mg/m^3) in 15-30 cm soil depth

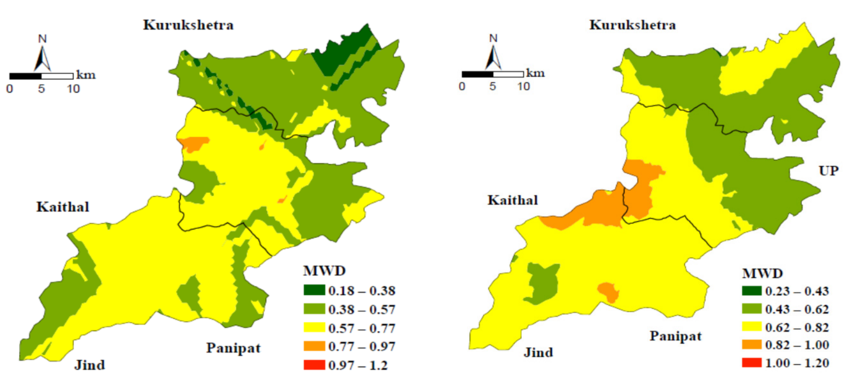

Fig. 10. Spatial variation of mean weight diameter (mm) of 0-15 and 15-30 cm of soil layer

19.2 cm/hr whereas, in 15-30 cm soil depth the range was 1.59 to 14 cm/hr. In 0-15 cm soil depth the range of MWD was 0.23 to 1.2 mm and in 15-30 cm soil depth the range was0.18 to 1.2 mm. In 0-15 cm soil depth the range of BD was 1.2 Mg/m^3 to 1.8 Mg/m^3 but, in 15-30 cm soil depth it ranged from1.33 Mg/m^3 to 1.86 Mg/m^3. In 0-15 cm soil depth, when the pH of soil is >9.5 the hydraulic conductivity also reduced by 8.77% when the EC increased from 4.59ds/m to 6.21 dS/m from lower pH class to the higher pH class.

It may be concluded that the concentration of the salt in soil increases with the decrease of soil particle size. TOC content in class 2 (pH>9.5) soils were 0.02% more than class 1 (pH= 8-9.5) soil though the difference was not statistically significant. Average MWD was 0.11 mm more in class 2 soils as compared to class 1 soils. Glomalin content had positive correlation with HC and sand content and negative are with BD, clay and silt, but the correlations were not significant. No significant correlation was obtained with MBC and other soil parameters. The soil pH had significant negative correlation with sand content whereas, it showed significant positive correlation with clay content. Soil EC showed a strong positive correlation with soil pH.

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