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Mapping of soil physico-chemical properties and soil separates in the transition zone of foothills of Shivaliks of Kathua region using GIS approach

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Abstract

Study area lies in between 32°17' N to 32°55' N of latitude and 75°70' E to 76°46' of longitude and exhibits different range of climate ranging from sub-tropical to temperate areas and to some extent alpine in upper regions of Bani and Lohai Malhar blocks. Composite surface soil samples from one hundred and twenty (206) locations distributed randomly across the whole of the district were collected at the depth of 0-15cms using global positioning system (GPS). Inverse distance weighting (IDW) technique was adopted to generate prediction maps of the soil properties. The choice of either technique to prepare filled contour maps of soil properties was based upon error analysis. The process of digitization and generation of maps was carried out with ArcGIS 10.3. The major portion of soils of the district was having a pH between 6 to 7. More than 50 percent of soils of Kathua District were having neutral pH but some areas depicted values ranging between 7 to 8 on pH scale. Very few areas were having pH less than 5. The areas near international border and areas that were on northern side of NH-1A depicted pH status ranging between 6 to 8. The hilly terrains lying on southern side of NH-1A in majority depicted pH status ranging between 6 to 7. The Electrical Conductivity map represented a higher EC in hilly terrains as compared to low land plain areas and low hill terrains. The hilly terrains noticed EC reading more than 0.3 dS/m whereas central portion of district observed EC in between 0.1 to 0.2 dS/m. As far as organic carbon is concerned, more than 50 percent of area had the higher range, whereas, rest of the area had OC in the medium to low range. The northern area of district which usually constituted the hilly portion and forest portion was having high OC than southern portion which is highly cultivated and mostly inhabited. The Organic Carbon in hilly terrains or on the left hand side of NH 1A usually lies between 1.50 to 3.00 percent and the portion on the right hand side lies between 0.75 to 1.50 percent. Clay Loam texture was usually dominant throughout the district. High clay content was observed in the southern hilly terrains whereas the same texture was dominant in some lower areas too. Silt content was high in extreme hilly terrains whereas silt distribution was 15 to 20 percent in lower plain areas. In some areas of central parts of district the silt content was less than 15 percent. The sand percentage in northern Kathua district was very high, mostly in the areas adjoining to river Ravi and high in areas adjoining International Border (Pakistan).

Keywords: pH, EC, organic carbon, sand, silt, clay, GPS

Introduction

In the early 1960's, India was totally dependent on import of food materials but as soon the advancements were introduced into the Indian Agriculture a lot of things changed. Green Revolution and the introduction of HYV's, chemical fertilizers, new chemicals to retard the disease and pest growth lead to the beginning of a new era of food security in India. But after 4 decades of beginning of green revolution, the second generation soil problems is now a new challenge to Soil Researchers. The maximized use of major chemical fertilizers like Urea, DAP, MOP etc. has not only created a huge disturbance in soil physical conditions but has also forced crops to be more sensitized towards other second generation problems.

Soil physic-chemical characteristics such as pH, CEC, CaCO₃ and O.M showed spatial variation across landscapes; therefore, soil properties are widely analyzed by researchers across the world so as to apply the data to manage and plan the agricultural and industrial areas (Wang *et al.*, 2000) [15]. In general, the soil properties are mostly different at the distant sampling sites than to adjacent sampling sites (Wang *et al.*, 2000) [15]. To quantify spatial Characteristics in soil properties many statistical studies have been applied to come up with

new data favoring spatial variability (Salehi *et al.* 2005) [10]. The unique property of soil physico-chemical characteristics to exhibit spatial dependency and which cannot be captured by classical statistical methods, modern statistics application is therefore widely accepted. (Burrough, 1991; Lin *et al.*, 2005) [1, 7]. To overcome this issue, geostatistical interpolation methods have been applied by various researchers in estimating the spatial variability in soil properties (Cambardella *et al.*, 1994; Webster & Oliver, 2007) [3, 17]. In large geographic areas, geostatistical interpolation models are very efficient and effective tool in analyzing spatial variations of soil properties (Sokouti & Mahdian, 2011) [13]. In theory, the geostatistical models incorporate limited number of field measurement data to a large geographical area and estimate concentration surface of the variables over the whole study area (Sokouti & Mahdian, 2011) [13]. The geostatistical interpolation models application to soil properties' spatial data generated is important for accurate soil management and application (Goovaerts, 1999) [4]; (Sokouti & Mahdian, 2011) [13]. According to Burrough (1991) [1] soil survey applications were the first uses of GIS. Also, GIS is now fully established in soil survey practice and analysis and is now also used for map production, thereby facilitating users to request for specialized information, preparing model related to environment and finally deriving suitability maps. Information pertaining to such use of GIS-based fertility maps has been meager in India (Sen and Majumdar, 2006; Sen *et al.*, 2008) [12, 13]. The current study was aimed to evaluate and map the spatial distribution of soil physico-chemical properties in plains and hilly areas of the Transition Zone of foothills of Shivaliks of Kathua region using GIS approach under one macro and three micro agro climatic zones.

Material and Methods

Study Area

Study area lies in between 32°17' N to 32°55' N of latitude and 75°70' E to 76°46' of longitude and exhibits different range of climate ranging from sub-tropical to temperate areas and to some extent alpine in upper regions of Bani and Lohai-Malhar blocks. Kathua district has five tehsils viz. Basohli,

Bani, Billawar, Hiranagar and Kathua. Basohli is located at 32.50°N, 75.82°E. The area is located at an elevation of 460 meters above mean sea level and is situated in the uneven hills of shivaliks. It is situated in the right bank of Ravi River. Bani is a small tehsil and a glaciated valley which is at a height of 1280 meters from mean sea level in the lap of lofty mountains. There is temperate and polar type of climate leading to mercury drop even below freezing point of water. Severe winters and moist summer are main climatic characteristics of this valley. Billawar is located at 32.62°N 75.62°E with an average elevation of 844 m ASL and is situated in the lap of Shivaliks between the banks of Naj and Bhini Rivers. Kathua is located at Jammu to the Northwest, the Doda and Udhampur districts to the north and Pakistan working boundary to the west. Hiranagar is located at 32.45° N, 75.27°E and the average elevation ASL is 308 meters. Main crops of the area are Paddy and Wheat. The annual rainfall in the area is about 1300 mm approximately. The area is mostly irrigated and productive.

Experimental Methods

Composite surface soil samples from two hundred and six (206) locations distributed randomly across the whole of the area were collected at the depth of 0-15cms using global positioning system (GPS). The exact sample location will be recorded using a handheld GPS receiver and then were analyzed as per the standard procedure for laboratory analysis. ArcGIS 10.3 was used to digitize the nutrient map of the area. Soil samples were processed and analyzed for physico-chemical parameters as per standard guidelines. Soil pH of the samples were determined in 1:2.5:: soils: water ratio (w/v) using glass electrode pH meter. Electrical Conductivity was analyzed in 1:2.5:: soil: water suspension with Electrical conductivity meter. Also mechanical findings i.e. Clay, Silt and Sand content analysis of soil samples was done by International Pipette Method as outlined by USDA and texture values were then incorporated in "Texture Analysis" software. Finally, organic carbon was estimated using Chromic Acid Digestion method (Walkley & Black, 1934).

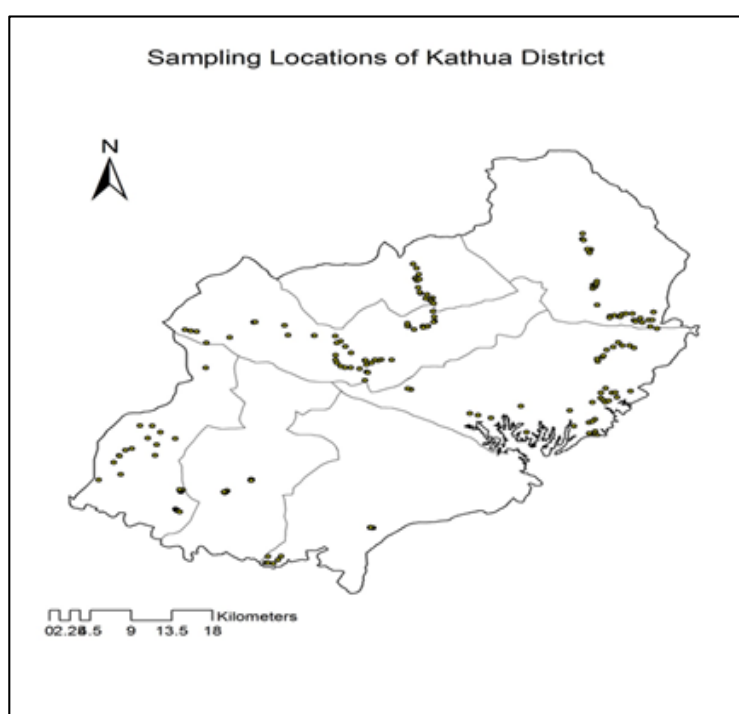


Fig 1: Map of Kathua district of Jammu with sampling locations

Statistical Analysis and Mapping

Descriptive Statistical analysis of the data which included mean values, Coefficient of variation, Minimum and Maximum Values, standard deviation, standard error of mean, Skewness and Kurtosis was carried out using SPSS.

Inverse distance weighting (IDW) technique was adopted to generate prediction maps of the soil properties. The choice of either technique to prepare filled contour maps of soil properties was based upon error analysis (Robinson & Metternicht, 2006) [9]. The process of digitization and generation of maps was carried out with ArcGIS 10.3.

Result & Discussion

The pH of the soils of Kathua District varied from varied from 2.98 to 8.55 with a mean value of 6.76 (Table 1). The coefficient of variation (CV) was only 13.13 per cent. The data was slightly negatively skewed (-0.14) having a Kurtosis value of 0.68. More than 50 per cent of soils of district were having neutral pH (6.5-7.5) but some areas depicted values ranging between 7 to 8 on pH scale. Very few areas were having pH less than 5. The areas near international border and areas that were on northern side of NH-1A depicted pH status ranging between 6 to 8. The hilly terrains lying on southern side of NH-1A in majority depicted pH status ranging between 6 to 7. (Figure 2A). Very wide variation was observed in the pH content of the soils. The high variation in soil reaction was due to the variation in slope, topography and use of organic manures at different rates (Jatav *et al.*, 2007) [6]. The electrical conductivity (EC) of the soils of Kathua District ranged from 0.004 to 1.027 dS/m with a mean value of 0.19 dS/m. The CV was 83.05 per cent with Skewness and kurtosis being 2.23 and 7.48, respectively. (Table 1) The Electrical Conductivity map represented a higher EC in hilly terrains as compared to low land plain areas and low hill terrains. The hilly terrains noticed EC reading more than 0.3 dS/m whereas central portion of district observed EC in between 0.1 to 0.2 dS/m. (Figure 2B) Soils did not show any salinization as the maximum value of EC was 1.027 dS m⁻¹. The decreasing pattern of EC down to altitude may be due to the leaching of salts in deeper layers of soil of various ions (chlorine, Cl⁻; sulphate, SO₄²⁻; bicarbonate, HCO₃⁻; carbonate, CO₃²⁻; Na⁺; Ca²⁺; Mg²⁺; and K⁺). The very low EC of soils can be linked to surface runoff of soluble salts during heavy monsoon rains because of uneven topography of the region (Jatav *et al.*, 2007) [6].

Soil Organic carbon (OC) varied from 0.15 to 3.90 per cent. The mean value was 1.70. The CV for Organic Carbon was 54.04 per cent. The Skewness and Kurtosis value was 0.28 and -1.28, respectively. (Table 1) As far as organic carbon is concerned, more than 50 per cent of area had the higher range, whereas, rest of the area had OC in the medium to low range. The northern area of district which usually constituted the hilly portion and forest portion was having high OC than southern portion which is highly cultivated and mostly inhabited. The Organic Carbon in hilly terrains or on the left hand side of NH 1A usually lies between 1.50 to 3.00 per cent and the portion on the right hand side lies between 0.75 to 1.50 per cent. (Figure 2C) Soil Carbon in the soils of District Kathua was usually high because most of the areas of hilly terrains are least cultivated and covered with forest type of vegetation that facilitates the addition of organic material to the soil through leaf and plant litter. Wang *et al.* (2010) [16] found that SOC concentration decreased with increasing soil depth under all land used and was significantly different across the vertical soil profile. High organic carbon in upper

layers is because of addition of organic manures in the form of leaf litter in forest or manures in case of agriculture soils. Jatav *et al.*, (2007) [6] reported that the high range of organic carbon content in potato growing soils of Shimla and the presence of greater variability can be linked to the application of FYM and other organic manures at different rates by the farmers, depending upon the individual land holding pattern. Higher organic carbon content can also be due to the addition of dead wooden parts, leaves and crop residues through natural vegetation of forests may be a second reason ultimately leading to accumulation of organic matter in such soils.

Clay content of the soils varied from 10.00 to 50.00 per cent with a mean value of 28.04 per cent respectively. The CV for clay was 32.27 per cent. The Skewness and kurtosis value was -0.14 and -0.53, respectively. Silt content of the soils varied widely with values ranging from as low as 9.00 and to as high as 57.00 per cent. The mean value was 20.88 per cent. The CV for the soil silt content was 34.11 per cent respectively. Positive Skewness was observed in the data with a value of 1.35 and value for Kurtosis was 3.85. Sand content varied from 18.00 to 77.00 per cent. The CV was 21.68 per cent and the data was slightly negatively skewed (-0.07). Clay Loam texture was usually dominant throughout the district. High clay content was observed in the southern hilly terrains whereas the same texture was dominant in some lower areas too. Silt content was high in extreme hilly terrains whereas silt distribution was 15 to 20 per cent in lower plain areas. In some areas of central parts of district the silt content was less than 15 per cent. The sand percentage in northern Kathua district was very high, mostly in the areas adjoining to river Ravi and high in areas adjoining International Border (Pakistan). (Figure 2) Wide variation was observed in clay, silt and sand content of farm soil. Based on the soil separates the dominant textural class was the clay loam, with over 70 per cent samples falling in this category. Rest of the 30 per cent was shared among the textural classes viz. sandy loam, sandy clay and sandy clay loam. Based on coefficient of variation (CV) low variability was observed for pH (<15 per cent) whereas moderate variation was observed for Clay, Sand and Silt. High variation (> 35 per cent) was observed for EC and OC. Similar results with respect to variability in some physical and chemical properties of soil have been observed by other workers (Osuku *et al.* 2014).

Spatial Variability

Geo-statistical techniques were used to find the spatial correlations of the Sand, Silt, Clay, pH, Electrical Conductivity and Organic Carbon in soil and spatially estimate the values of the soil properties at unsampled locations jointly in both hilly and plain areas. It is necessary to analyze whether the contents of Sand, Silt, Clay, pH, Electrical Conductivity and Organic Carbon in soil samples are normally distributed and to analyze this property the Kriging method was used. In which the first point is to analyze the presence of spatial structure in the data by variogram analysis. In parameter estimation, the data distribution was found to be normal and the KS test was used to analyze the distribution of the data. It was noticed that the skewness and kurtosis indices of all the parameters are near to the standard value of zero and thereby depicting that distribution is normal. To calculate sample weighing factors for spatial interpolation by ordinary Kriging procedures the information that was generated with variogram was used. Ordinary Kriging was used to create the spatial distribution

maps of soil Sand, Silt, Clay, pH, Electrical Conductivity and Organic Carbon with the maximum search radius set to the autocorrelation range of the corresponding variable. The exponential model was suitable for estimation of soil properties. The ratio of nugget variance to sill expressed in percentages (C_0/C_0+C_0) can be regarded as a criterion for classifying the spatial dependence of the soil parameters. If this ratio is less than 25%, then the variable has strong spatial dependence (Shi *et al.*, 2005). The Sand, Silt, Clay, pH, Electrical Conductivity and Organic Carbon showed weak spatial dependence as the ratio of nugget variance exceeded 75% and have a spatial structure in moderate form. A weak spatial dependence can be drifted towards extrinsic factors of the sampling area (Cambardella *et al.*, 1994) [3]. So, all semi-variograms were in anisotropic form and were depicted using Exponential math models. The filled prediction maps were generated for soil properties using the ArcGIS Geo-statistics tool. The correlation range measures the spatial separate distances within which data are auto correlated (Cahn *et al.*, 1994) [2]. This may imply that Sand, Silt, Clay, pH, Electrical Conductivity and Organic Carbon in soil contents were more sensitive to extrinsic factors such as fertilization.

Conclusion

Soil maps obtained through these techniques showed a wide variation in Physico-chemical properties as well as in the available nutrient status of soils of Kathua District. If we

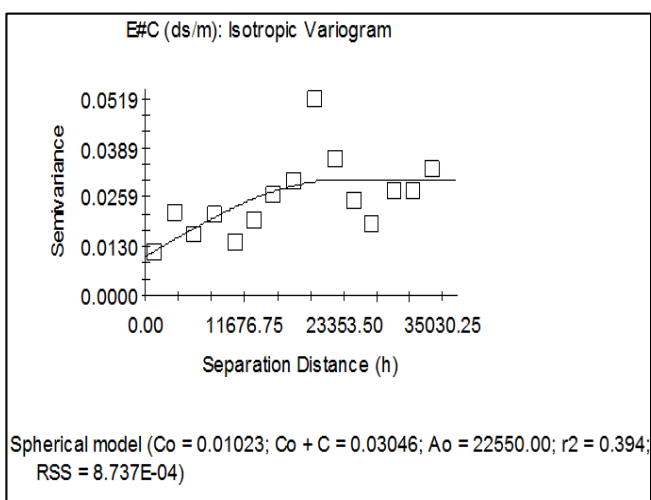
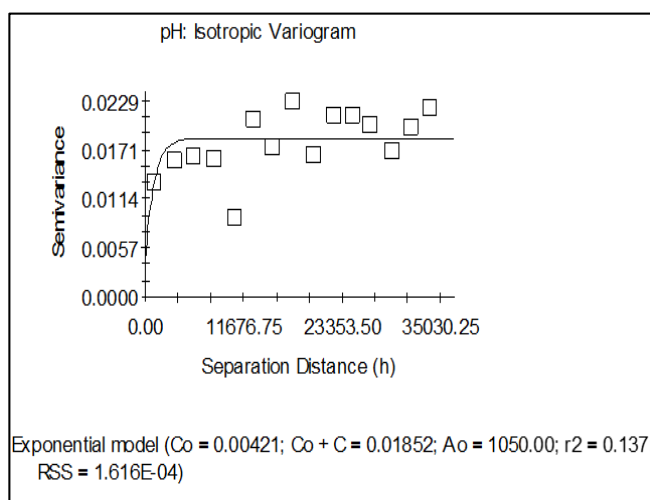
visually analyze the pH map, it depicts that the soils of hilly terrain are having very low pH because of maximum forest dominated area but some parts of the northern Kathua bordering Himachal Pradesh are also having normal pH in the range of 6-7. Areas bordering Pakistan and NH 1A and some portion of Tehsil Hiranagar depicted very high pH (maximum up to 8.0). In case of E.C, saline soils were not observed throughout the district as maximum EC recorded was 1.027 dsm^{-1} . In overall aspect, EC readings were maximum in samples of hilly terrains especially in the areas bordering Himachal Pradesh. Due to maximum accumulation of leaf litter and decomposition of plant biomass in forest areas lead to production of high O.M content in soils. The very high O.M content was observed in soils of hilly terrains mainly of Tehsil Bani and upper areas of Tehsil Billawar including Lohai Malhar and Macheedi. The areas of Southern Kathua along River Ravi and International Border where Wheat-Rice cropping pattern is dominant also showed medium to high level of organic carbon. Clay Loam texture was usually dominant throughout the district. High clay content was observed in the southern hilly terrains whereas the same texture was dominant in some lower areas too. Silt distribution was high in extreme hilly terrains. The sand percentage in northern Kathua district was very high, mostly in the areas adjoining to river Ravi and high in areas adjoining International Border (Pakistan).

Table 1: Statistical Parameters of Soil Physico-chemical properties of Soils of Hilly Areas of North Western Shivaliks of Jammu region

	pH	E.C (dS/m)	O.C (%)	Clay (%)	Silt (%)	Sand (%)
Minimum	2.98	0.004	0.15	10.00	9.00	18.00
Maximum	8.55	1.02	3.90	50.00	57.00	77.00
Mean	6.76	0.19	1.70	28.04	20.88	51.08
Std. Deviation	0.88	0.16	0.92	9.04	7.12	11.07
Std. Error	0.06	0.01	0.06	0.63	0.49	0.77
Coefficient of Variation (%)	13.13	83.05	54.04	32.27	34.11	21.68
Skewness	-0.14	2.23	0.28	-0.14	1.35	-0.07
Kurtosis	0.68	7.48	-1.28	-0.53	3.85	-0.53

Table 2: Characteristics of calculated semi-variograms for pH, EC, OC, Sand, Silt & Clay in study area.

Soil Properties	Residual SS	R ²	Proportion (C/ [Co + C])	Model	Nugget Variance	Sill (Co+C)	Nugget/ Sill	Per cent	Range (A)
pH	1.616E-04	0.137	0.773	Exponential	0.543	1.087	0.49	49	948000
EC	8.737E-04	0.394	0.664	Spherical	0.010230	0.030460	0.33	33	22550
OC	0.0510	0.488	0.718	Spherical	0.242	0.723000	0.33	33	29550
Clay	3.712E-03	0.150	0.987	Gaussian	9.50	76.630	0.12	12	1299.03
Silt	6.107E-03	0.066	0.834	Exponential	5.800	47.43	0.12	12	2130.00
Sand	5.506E-04	0.085	0.987	Spherical	0.100	108.50	0.0009	0.09	1440.00



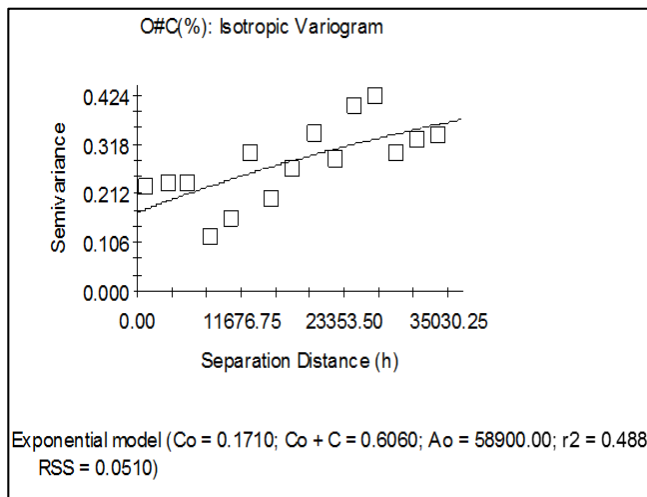


Fig 2: Experimental and fitted Semivariogram model for soil physico-chemical properties (pH, EC & OC)

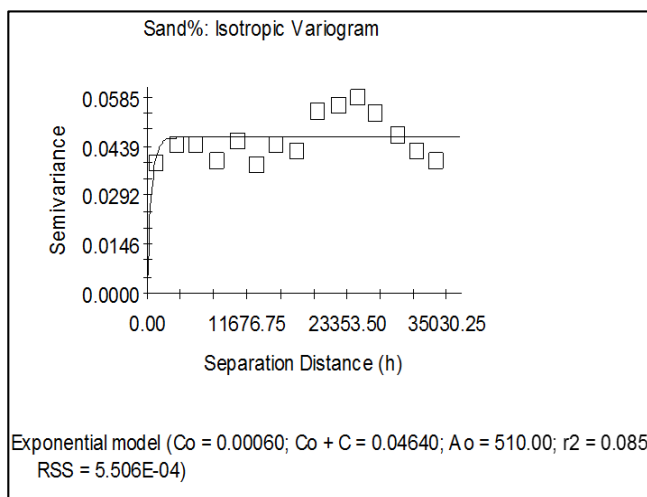
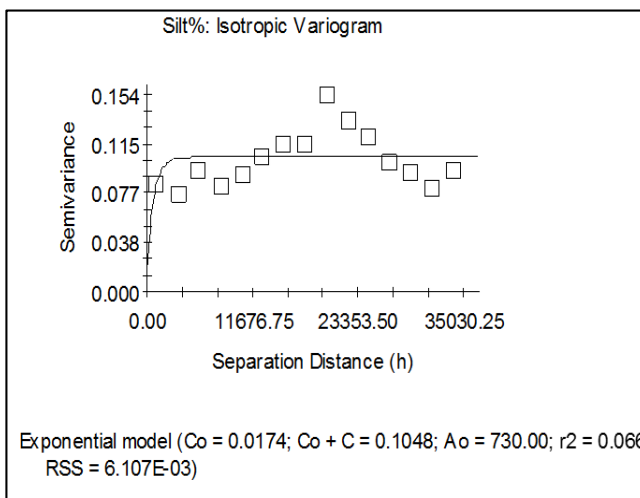
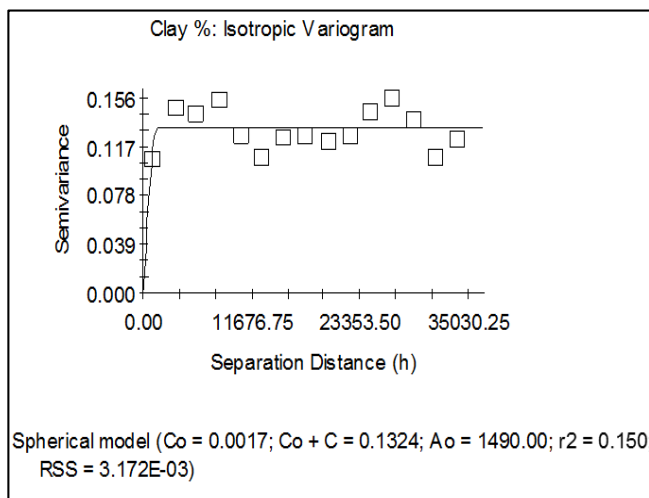


Fig 3: Experimental and fitted Semivariogram model for soil physico-chemical properties (Clay, Silt & Sand)

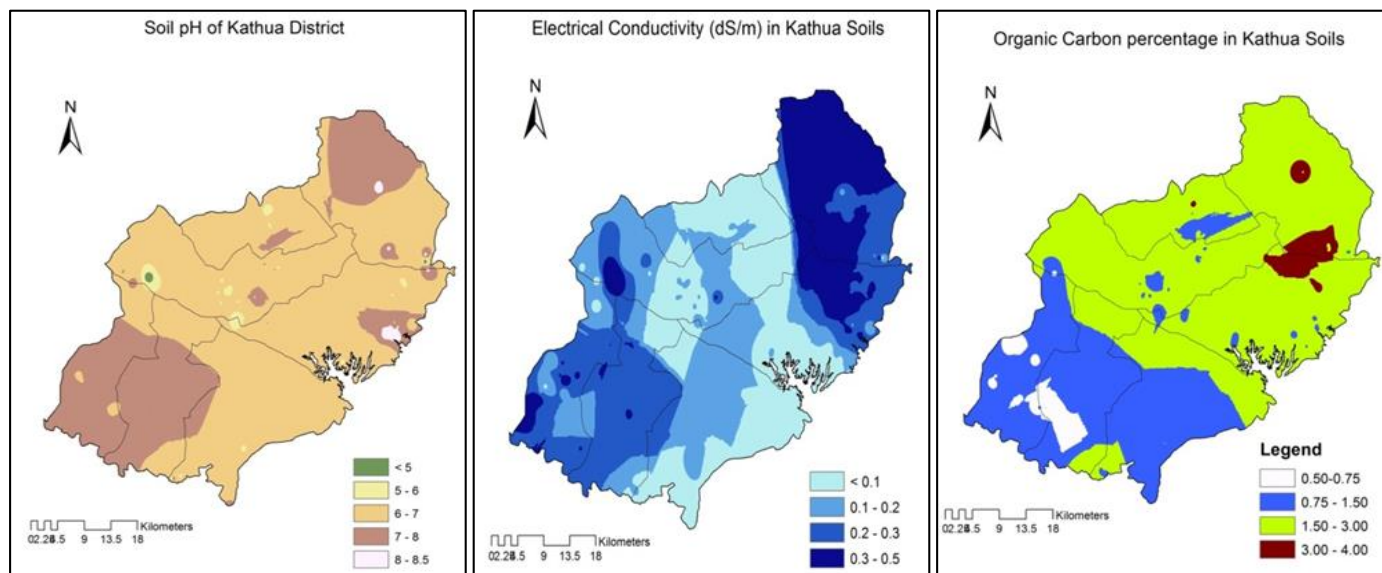


Fig 4: Spatial distribution maps of soil physico-chemical properties (pH, EC & OC) Interpolated by ordinary Kriging.

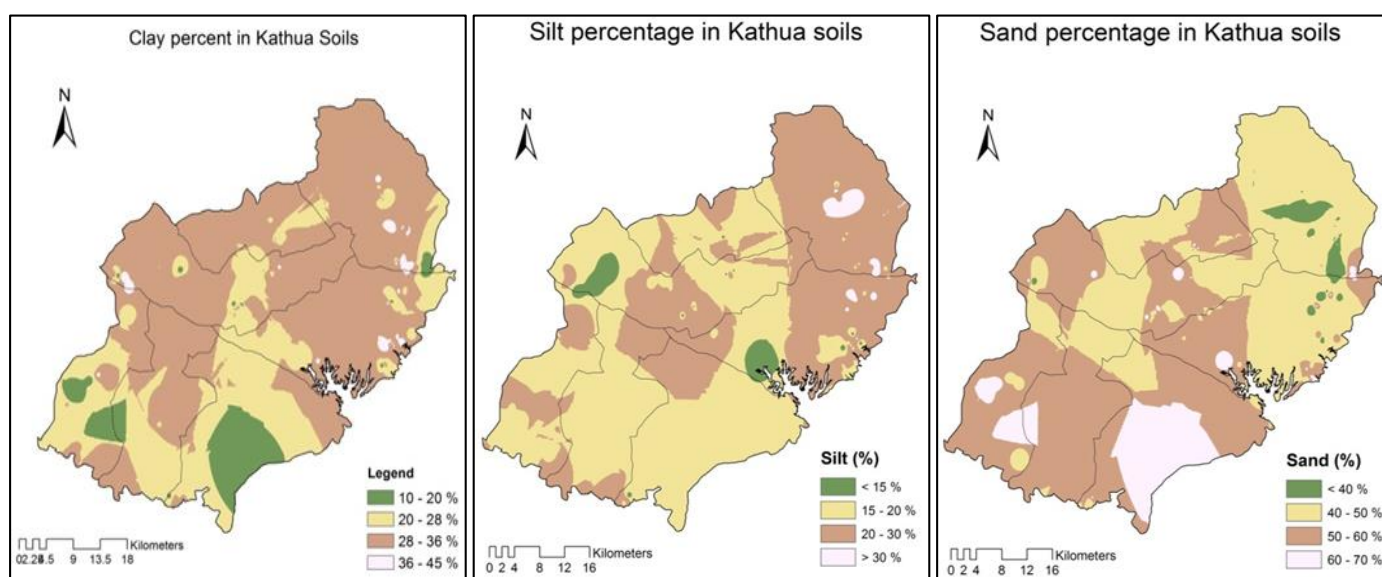


Fig 5: Spatial distribution maps of soil physico-chemical properties (Clay, Silt & Sand) Interpolated by ordinary Kriging.

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