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Spatial Variability of Physical and Chemical Properties in Northern Himalayas of Kashmir Province

Ayman Javed[1*], Shaista Nazir Bhat[1], Rajnish Yadav[1] and Mushtaq Ahmad Wani[2]

[1]Division of Soil Science and Agricultural Chemistry, FoA Wadura, SKUAST, Kashmir, India.
[2]Directorate of Extension, SKUAST, Kashmir, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Due to geological and pedological soil-forming factors, spatial variability of soil physical and chemical properties across the agricultural fields is intrinsic by its nature, however variability may arise from tillage and other soil management practices. The main aim of this survey was to investigate the spatial variability of soil physical along with chemical properties and the preparation of thematic maps across the study area. The physico-chemical properties determined were Particle size distribution, Bulk density, Particle density, total porosity, soil resistance, soil pH, Electrical conductivity (EC), Organic carbon (OC), Nitrogen(N), Phosphorus (P), Potassium(K). Soil samples were collected from 45 sites using Geographical Positioning System (GPS) under different land-use systems. The results showed normal distribution for Sand, silt, particle density, electrical conductivity, and soil pH. Organic carbon recorded the maximum coefficient of variation (82.2%) and soil particle density (5.66%) the minimum. Soil macronutrients were medium in range excluding phosphorus which was found inadequate in the watershed. Employing such analytic work, it is feasible to devise accurate soil management practices and an unerring soil sampling system for taking efficient management judgments that result in sustainable agricultural production.

**Corresponding author: E-mail: aymanjaved12@gmail.com;*

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1. INTRODUCTION

Due geological and pedological soil forming factors spatial variability of soil physical and chemical properties across the agricultural fields is intrinsic by its nature, however variability may arise from tillage and other soil management practices. Spatial variability characterization of soil chemical properties provides significant information specifically in cultivated areas, for more sound soil use and management [1]. Different management zones or management areas can be outlined by delineating the spatial variability of soil properties which may also help in enhancing the effectiveness of sampling schemes and use of fertilizers. Variability among the physical and chemical properties of the soil are the principal reason for cause of variability in crop production [2]. Due to cultivation without restoration results in loss of organic matter that may initiate physical degradation process. Soils must be managed cautiously in order to stabilize and sustain crop production as soil management and crop production vary with the soil kind and their physical and chemical behavior [3].

Currently, information regarding the variability within soil properties is considered as a major fundamental for local management in precision farming. Therefore, studying spatial variability of both soil physical and chemical properties is very relevant in order to understand land management and the soil processes. Different land use and management practices strongly influence the soil properties [4], and understanding the variation in soil properties within farmland use is vital in determination of production barriers related to soil nutrients. It is equally essential to suggest different remedial measures for optimum production and appropriate land use management practices [5]. Sustainable land management practices are imperative to meet the changing human needs and to ensure long-term productivity of farmland [6].

Understanding of spatial variability of soil properties is vital in precision farming and also in specific nutrient management. There is a great significance in studying the spatial continuity and heterogeneity of soil properties in order to improve the efficiency of soil nutrient management also accurateness in soil surveys and mapping and offering useful information for precision fertilization and other applications to soils [7]. Spatial variability in soil characteristics are as result of amalgamation of extrinsic and intrinsic factors. Extrinsic spatial variability connotes the variation resulting from the inadequacy in management practices like tillage, irrigation and chemical application. Natural variations in soil characteristics, also referred as intrinsic spatial variability is commonly the outcome of soil forming processes, for instance due to the structure of indigenous plant communities there might be variations in the organic matter content, as a result of erosion or deposition and weathering processes there might be variations in soil texture [8]. Intricate levels of spatial and temporal variability (both scale-dependent and continuous) are displayed by soil properties. For improving the exactness of soil survey and mapping, pedodigitalization and precision farming, soil spatial analysis at farm scale [9] and on the catchment or watershed [10] basis are of utmost significance. Thus, it is a requirement to calculate the spatial variability of soil before scheming location- specific plans and policies for the future soil sampling, appropriate tillage, fertilizer, irrigation, seed rates, land use and conservation measures [11]. Geostatistical tools are used to collect the information in a significant way for the preparation of maps using spatial interpolation of point-based measurements. Use of geostatistics in studying the spatial variation of soil properties has gained more interest since 1970's as the geostatistical techniques are well structured and beneficial in characterizing the spatial variability of soil properties [12].

Studies on non-agricultural interpretations of soils and environment have arisen new concerns for soil scientists. Moreover the idea of precision farming is growing importance. Therefore, there is a requirement for offering an approach and technique for assessment of spatial variation in soil health and also correlating different soil physical, chemical and biological properties. The information on variability in physical, chemical and biological properties of Kashmir soils is limited. It is, therefore, imperative that the gaps and inconsistencies in knowledge should be bridged if the productive capacities of soils to be improved. Therefore, the objective of this study was to estimate different physico-chemical parameters of micro-watershed and to prepare thematic maps.

2. MATERIALS AND METHODS

2.1 Study Area

The study area is the Sogam village of district Kupwara. The geographical coordinates of the area are 34º 30'51.2" N Latitude and 74º 22' 44.7" E Longitude. Sogam is at an altitude of 1788 meters above mean sea level and covers an area of 4510.90 hectares out of which 71.92 percent is cultivable area and 63.09 percent is irrigated area to total area. Climate of the area is temperate and is described by mellow summers and chilly winters with a standard minimum annual temperature of 6.3°C and maximum of 19.9°C, with a yearly precipitation of 1138.4 mm. Average chemical and physical characteristics of the study area are displayed in Table-2. The land use of the area is cereals (rice, maize, wheat, barley, oats), oilseed, fruits (Apple), vegetables, Forests, Pastures.

2.2 Soil Sample Collection

Samples were collected by Randomized Grid Sampling at different placed in sogam village of district Kupwara in autumn 2018. Sampling points were positioned using Geographical Positioning System (GPS) in order to improve precision and accuracy of sampling for field studies so that field can be re-visited any time for updating of results. Perimeter points were taken by firstly establishing the boundary of the field, perimeter readings were taken at specific distances to construct an outer layer. Data collected were transferred into Arc.GIS (10.2) software, where a map of the perimeter points was generated. A total of forty five (45) sites were taken in a systemic randomized grid design using Arc.GIS (10.2) with the depth of 0-20cm. Soil samples were gathered in polybags and air dried in the lab, whereas core samples with cylindrical cores were employed for undisturbed soil sample collection. Bulk density was determined by oven drying the undisturbed soil cores at 105° C. Disturbed soil samples, passed through a 2mm mesh were used to determine the Soil Texture, Organic Carbon, pH, Electrical Conductivity, Nitrogen, Phosphorus and Potassium.

2.3 Statistical and Geo-statistical Analysis

Minitab 13.0 was used to carry out the statistical analysis that helped in providing the principal statistical moments (mean, standard deviation, median, coefficient of variation, skewness, kurtosis, 95% C.I) (Table 2) (Table 3).

Geo-statistical method (Arc.GIS) was used to conduct spatial analysis. Spatial variability in soil properties was calculated for 0-20cm depth. Ordinary kriging i.e. grid formation was conducted in GIS then contour functions were applied to the map which will show the spatial variation. Different levels of spatial variation was distinguished by use of a color legend. The management zone for different parametres of microwatershed were delineated using conventional soil fertility evaluation method and Arc.GIS (10.2).

Table 1. Methodology used in this study

	Methodology	
Soil physical properties:		
Bulk Density	Core sampler method	Blake, [13]
Particle density	Pycnometer method	Gupta and Dakshinamoorthy, [14]
Soil Resistance	Soil Penetrometer	Herrick and Jones, [15]
Texture	Hydrometer Method	Bouycous [16]
Soil Chemical properties		
Ph	1:2.5 soil: water suspension with a digital glass electrode pH meter	Jackson, M.L. [17]
Electrical Conductivity	Solubridge conductivity meter	Jackson,M.L. [17]
Organic Carbon	Walkley and Black's rapid titration	Walkley and Black. [18]
Available Nutrients		
Available Nitrogen	Alkaline potassium permanganate method	Subbiah and Asijah. [19]
Available Phosphorus	0.5M $NaHCO_3$	Olsen et al. [20]
Available Potassium	Neutral Normal Ammonium Acetate	Jackson, M. L. [17]

Table 2. Mean bulk density, particle density, soil resistance, pH, electrical conductivity), organic carbon, sand, silt and clay contents of the study area

Bulk density (gcm^{-3})	Particle density (gcm^{-3})	Porosity (%)	Soil resistance ($Kgfcm^{-2}$)	pH (%)	EC (dSm^{-1})	OC (%)	Sand (%)	Silt (%)	Clay (%)
1.380	2.48	40.40	13.47	6.69	0.18	9.09	38.54	33.34	28.35

Table 3. Descriptive statistics of bulk density, particle density, soil resistance, pH, electrical conductivity, organic carbon, sand, silt and clay contents of the study area

Physico-chemical parameters	Unit	Skewness	Kurtosis	CV (%)	95% C.I	p-value
Bulk Density	gcm^{-3}	0.313	-0.383	8.89	1.343- 1.416	0.405
Particle Density	gcm^{-3}	-0.615	1.324	5.661	2.441- 2.525	0.208
Porosity	%	-1.78	7.25	17.029	38.35- 42.49	0.02
Soil resistance	$kgfcm^{-2}$	1.71	8.70	14.09	12.90- 14.05	0.001
pH	1:2.5	0.34	-0.55	10.76	6.47 - 6.90	0.175
EC	dSm^{-1}	0.728	-0.106	73.12	0.143 - 0.224	0.010
OC	gkg^{-1}	1.55	0.438	82.2	6.84- 11.34	0.00
Sand	%	0.31	0.7	29.9	35.08 - 42.01	0.25
Silt	%	0.23	0.38	37.3	28.72 - 35.97	0.085
Clay	%	-0.65	0.03	29.2	25.86 - 30.84	0.037

CV coefficient of variation; C.I confidence interval

Table 4. Staistical parameters of macronutrients in the soil

Macronutrient	Unit	Mean	Skewness	Kurtosis	CV(%)	95% C.I	p-value
Nitrogen(N)	$Kgha^{-1}$	334.0	1.08	0.13	18.65	315.94 –353.46	0.00
Phosphorus(P)		16.72	-0.62	-0.96	22.54	15.59-17.85	0.00
Potassium(K)		167.37	0.91	-0.20	29.5	152.51-182.22	0.00

**CV coefficient of variation; C.I confidence interval*

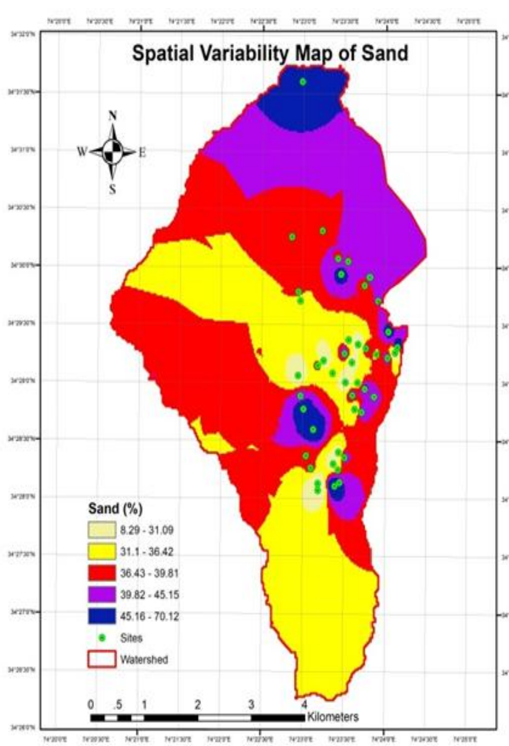
2.4 Ordinary Kriging of Soil Attributes

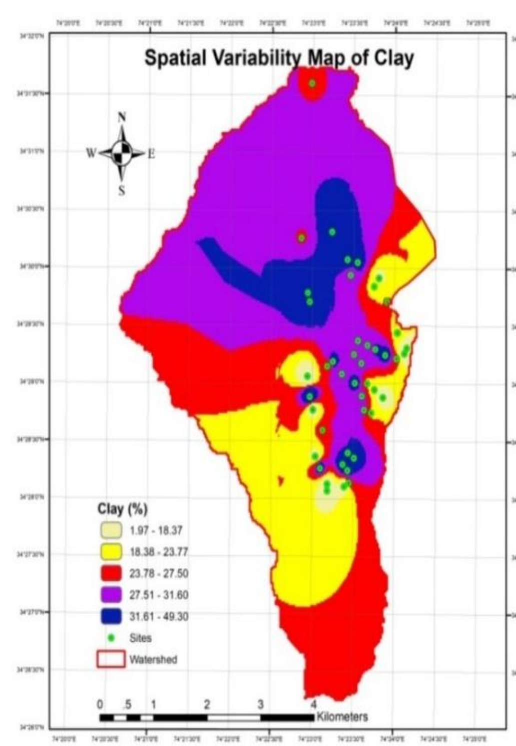
Semi-variogram parameters were utilized for the preparation of surface maps of fundamental soil characteristics using ordinary kriging. The estimation of soil properties at non-sampled areas are assessed by ordinary kriging, z(u) using weighted linear combination of known soil properties z(uα) situated inside an area W(u) focused on u.

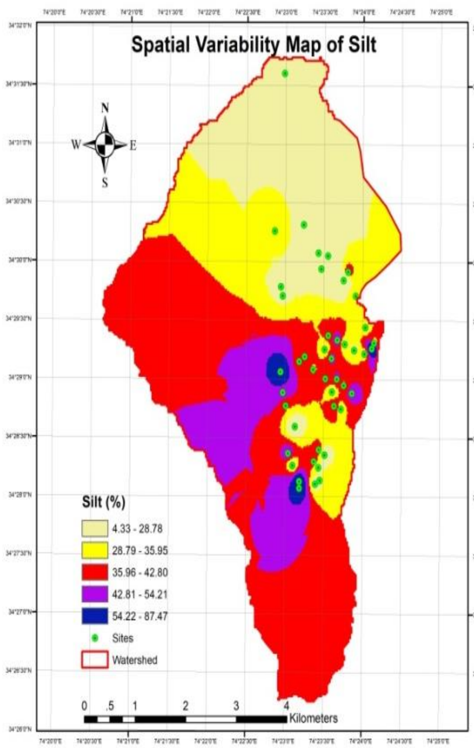
3. RESULTS AND DISCUSSION

Table 3 and Table 4 shows the statistical values for soil properties. The coefficient of variation values (CV) signifies very high variability for aggregate size distribution, electrical conductivity (73.12%), organic carbon (82.2%), phosphorus (22.54%), and potassium (29.5%), medium variability for nitrogen (18.65%), soil porosity (17.02%), soil resistance (14.09%), pH (10.76%) and low variability for bulk density (8.89%) and particle density (5.66%). On the basis of coefficient of variation (CV), Gomez and Gracia [21], suggested the classification as low, medium, high and very high 10%, 10-20%, 20-30% and >30% variability respectively. Within the watershed, due to the non-homogeneity in the fertilizer distribution the soil management practices could be contributing to the greater variabilities among data.

Findings from current study show (Table 2 and Table 3) that the physical characteristics confirmed the clay loam texture under all land uses. Similar findings were observed by Handoo [22] and Ramzan [23]. The content of sand silt and clay varied from 35.88-43.81% with an overall mean of 38.54%, 30.14-33.76% with an overall mean of 33.34% and 21.84-30.94% averaging 28.35% respectively. The soil bulk density is considered as a red flag indicator of soil health. The bulk density of micro-watershed ranged from 1.28-1.42 gcm^{-3} averaging 1.38 gcm^{-3}. Reynolds et al. [24] suggested that 0.9 to 1.2 Mg/m^3 is the ideal range of bulk density for crop production. The findings were in unanimity with Abad et al. [25]. Soil particle density in micro-watershed ranged from 2.42 to 2.55 gcm^{-3} with an overall mean of 2.48 gcm^{-3}, the results were in accordance with Gupta et al. [26] who found 2.44 to 2.62 Mgm^{-3} particle density for cultivated lands and 2.38 to 2.62 Mgm^{-3} for forest lands. Soil porosity varied from 37.64 to 47.34% with the mean value of 40.40%. These values were in consonance with the literature reported by Hussain et al. [27] and Haque et al. [28]. The present study suggested that the soil resistance of micro-watershed varied from 11.28 to 14.12 $kgfcm^{-2}$ with the mean value of 13.47 $kgfcm^{-2}$. Investigation of Cotching et al. [29] on vertisols found 3.2MPa penetration resistance a depth of 60 cm. Soil pH stands as a major significant chemical characteristic feature of soil solution as the response of higher plants and microorganisms is distinct to their environment. The pH of soils of micro-watershed was found ranging from 6.53 to 6.99 with the mean value of 6.69. These results were in unanimity with Jalali et al. [30], Ganai et al., [31] and Ramzan [23]. The soils of micro-watershed were devoid of salts, majority of samples were having EC<0.8dsm^{-1} with the average value of 0.183dsm^{-1}. Organic carbon content was medium to high in range according to Walkley and Black's rapid titration method [18]. The results were corroborating with the findings of Gebreselassie [32] and Nisar and Lone [33]. Nitrogen plays a major role in the plant nutrition because it is related with crucial living processes. Also nitrogen as a part of protein is a key component of protoplasm and enzyme activity of the cells. The soils of watershed were medium in available nitrogen ranging from 297.06 to 386.8 $kgha^{-1}$ averaging to 334.0 $kgha^{-1}$ according to alkaline potassium permanganate method, Subbiah and Asija [19]. The results were in agreement with the findings of Dar et al. [34]. There was low to medium amount of available phosphorus in surface soils according to 0.5M$NaHCO_3$, Olsen et al., [20] ranging from 13.07 to 19.41 $kgha^{-1}$ with the overall mean of 16.72 $kgha^{-1}$. The available phosphorus content in soil can be ascribed to favorable soil reaction and high organic matter resulting in the development of organophosphate complexes and coating of iron and aluminum particles by humus, Ashraf. S. [35]. Results were found to be similar to the observations by Dar et al. [34], Najar [36], Pandey et al. [37]. The available potassium in soil was found low to medium according to Neutral Normal Ammonium Acetate, Jackson, [17] ranging from 147.77 to 212.1 $kgha^{-1}$ with the average value of 167.37 $kgha^{-1}$. Similar findings were observed by Ashraf [35].







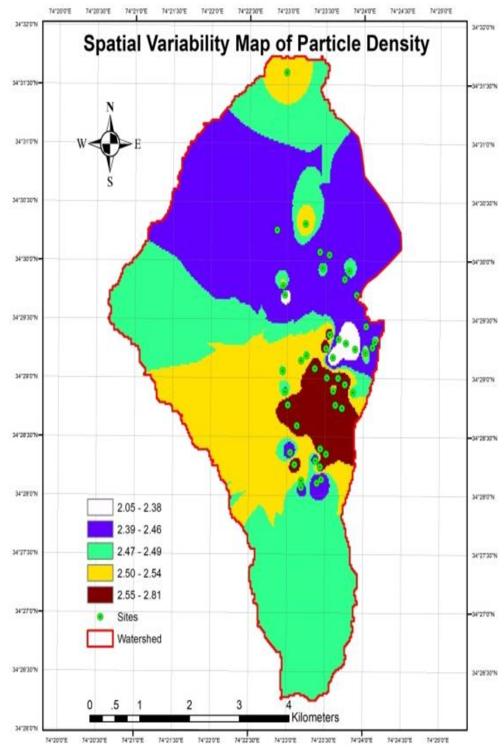
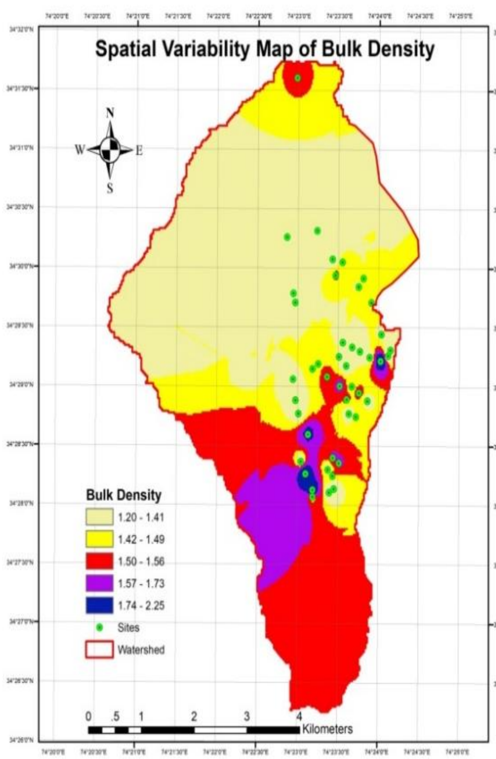
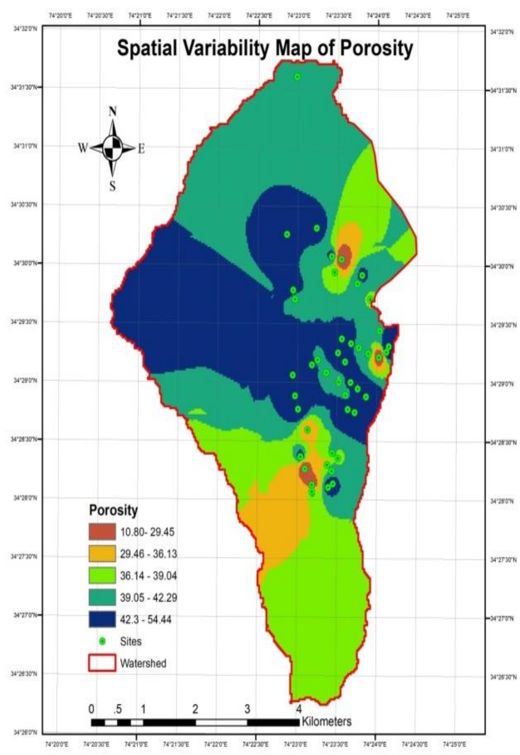


Fig. 1. Spatial variability map of sand, silt clay and particle density





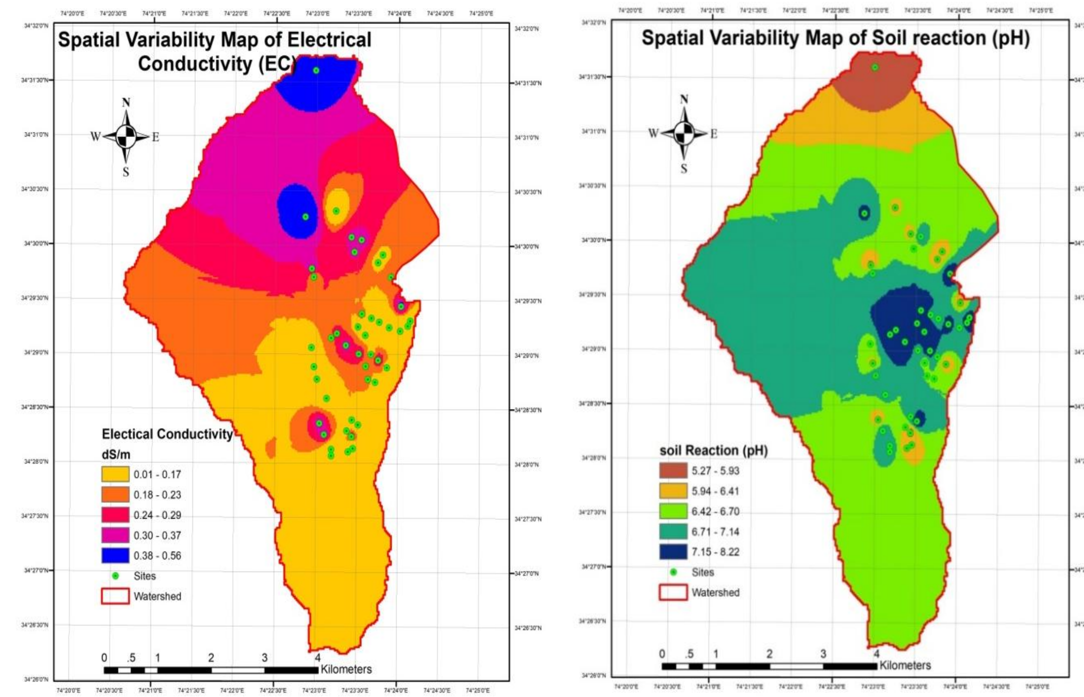
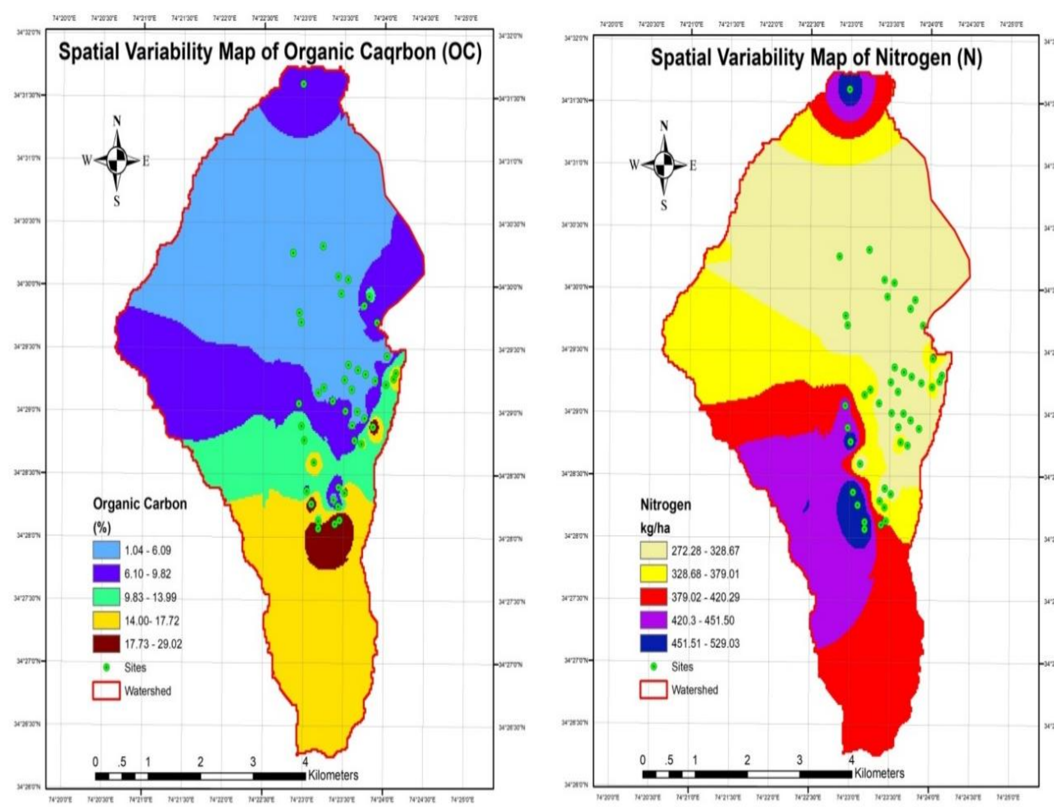


Fig. 2. Spatial variability map of porosity, bulk density, electrical conductivity and soil reaction (pH)



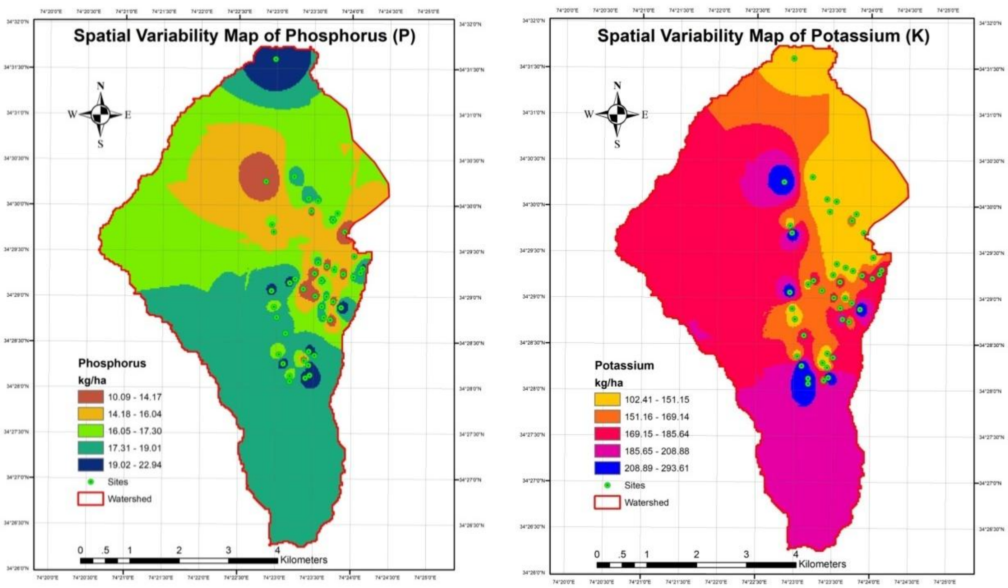


Fig. 3. Spatial variability map of organic carbon, nitrogen, phosphorus and potassium

4. CONCLUSION

Land use system causes a significant impact on distribution of soil resistances, potassium. Excluding phosphorus which was found deficient, all the soil properties in the watershed existed in optimum range. For improving the soil sampling strategies and site-specific management practices across area of study in accordance with their management and reclamation requirements, spatial distribution of soil properties can be used positively. The variability of the measured soil physico-chemical parameters will help to explain eventual anomalies of the results of future planned experiments.it is also recommended that adequate fertilization and good crop and/or soil management are practiced based on the soil variability in the concerned watershed. This will help to progress the productivity and fertility of the soils within the watershed for sustainable production, Soil pH should be adjusted to the recommended level to achieve utmost balanced nutrient availability, Soils with high clay content should be irrigated less frequently than those with high sand content, but with greater quantity of water and over longer periods.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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