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Mapping of spatial variability of soil texture and macronutrients in Wangath watershed, Ganderbal District of Jammu and Kashmir Using GIS

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Abstract

Knowledge of spatial variation of soil properties is important in precision farming and environmental modeling. The concept of management zones was evolved in response to large variability with the main purpose of efficient utilization of agricultural inputs with respect to spatial variation of soil properties. The objective of this study was to prepare thematic maps of variability of soil properties in Wangath watershed. Soil samples were collected from 60 sites using Geographical Positioning System (GPS) under different land use system. Samples were analyzed for physical (particle size distribution) and chemical properties (soil reaction, electrical conductivity, organic carbon, available nitrogen, phosphorus, potassium and sulphur). Soil texture varied from sandy clay loam to loam. The soils of Wangath were slightly acidic to slightly alkaline in reaction, devoid of salts. Organic carbon varied from low to high among the land uses. Available nitrogen, phosphorus, potassium and sulphur were found to be in medium range in the watershed. The values of all the parameters except electrical conductivity were significantly different between the land uses. The generated maps can serve as an effective tool for site specific nutrient management. This is prerequisite in order to optimize the cost of cultivation and address nutrient deficiency.

Keywords: GIS, USLE, soil properties, spatial variability

Introduction

Spatial variability of topsoil is an important indicator of soil quality, as well as distribution in the terrestrial ecosystem, for ecological modeling, environmental prediction, precision agriculture, and natural resources management (Wei *et al.*, 2007) [14]. Therefore, understanding of spatial variation of soil properties is very essential for refining farm management practices, modeling at landscape level and assessing the impact of agriculture on environment (Oliver, 1987) [7].

Soil variability is a direct result of soil forming factors: climate, parent material, time, geomorphology and living organisms (Jenny, 1994) [5]. Each factor may function independently or in combination with other factors over a wide range of spatial scales. Spatial scales reach from the micro-environment to the watershed and further occurring at many scales, while temporal scales extent from seconds to centuries and longer. Various processes occurring over different time steps and influenced by different patterns of soil variability. The spatial and temporal variability of soil attributes need to observe and quantify for a better understanding the influence of land management practices on soil function which ultimately can lead to efficient site specific farming practices (Sun *et al.*, 2003) [12], hence useful for making the decisions regarding planting, fertilization and harvesting of crop (Khosla *et al.*, 2010) [6]. Thus spatial variability of soil properties results from a combination of intrinsic and extrinsic factors (Jeloudar *et al.*, 2014) [4]. Intrinsic spatial variability refers to natural variations in soil characteristics due to soil formation processes, like variations in soil texture resulted from weathering, erosion, or deposition processes, and variability in organic matter content which, in undisturbed sites, can be due to the architecture of native plant communities. Extrinsic spatial variability refers to the variation caused by lack of uniformity in management practices such as chemical application, tillage, and irrigation (Ozgo, 2009) [9]. Geostatistics provides tools for analyzing spatial variability structure and distribution of soil properties and evaluating their dependence (Panagopoulos *et al.*, 2014) [12]. The objective of this study is, therefore, to assess spatial variability of soil texture and macronutrients and their thematic mapping using GIS.

Materials and Methods

The selected area, Wangath watershed belong to Kangan tehsil of district Ganderbal. It is located 16 km towards East from District head quarter. The watershed is located between 34° 16′ 41″ and 34° 19′ 26″ N latitude and 74°52′ 30″ and 74 °56′ 58″ E longitude with an average elevation of 1619 meters above Mean Sea level (MSL). The annual average rainfall of the study area is 853.20 mm. It covers a total area of 4173.91 ha, out of this 194.08 ha is under scrub land, 535.68 ha under barren land, 23.21 ha under snow and glacier, 511 ha under water bodies, 247.86 ha under open forest, 1887.63 ha under evergreen forest, 99.20 ha under built up and 36.32 ha under mixed plantation. In general the soils of Ganderbal are silt loam, belongs to order Alfisols. Mostly rainfed areas have clay loam/sandy soil and lower belt-temperate mostly irrigated consists of silt loam/clay loam soil. The natural vegetation of the area consists of trees like *Salix alba*, *Populus alba*, *Plantarinum orientalis*, *Roubinea pseudoacacia*. Among agriculture -paddy, maize, mustard, oats are main crop and other horticulture crop includes apple, pear, cherry, almond, plum, apricot and walnut.

A topographic map having a scale of 1:50,000 was used to demarcate the catchment boundary. This was followed by a systematic semi-detailed survey to describe the management practices, altitude, topography, soil depth and many other factors. After intensive traversing, profile locations were selected in the study area depending upon soil heterogeneity in physiography.

Sampling sites were selected from the study area based on the homogeneity criteria of management and cropping system, slope characteristics and conservation practices. The altitude and geographical positions in degrees were taken at the time of sampling using GPS (Global Positioning System). The exact sample locations were recorded using Global Positioning System (GPS). Sixty samples were taken from different land uses in the micro- watershed at a depth of 0-30 cm.

Standard laboratory procedures were followed in the analysis of physicochemical properties considered in the study. The air-dried samples were ground with a wooden pestle and mortar and passed through 2 mm sieve to separate the coarse fragments (> 2mm). The fine earth samples were stored in separate containers and used for various analyses. Soil samples were analyzed for texture (Hydrometer method, Bouyoucos, 1962), pH (Digital glass electrode pH meter, Jackson, 1973) [3], electrical conductivity (Solubridge conductivity meter, Jackson, 1973) [3], organic carbon (Rapid titration method, Walkley and Black, 1934) [13], Available Nitrogen (Alkaline permanganate method, Subbaih and Asijah, 1956) [11], Available Phosphorus (0.5M $NaHCO_3$, Olsen *et al.*, 1954) [8], Available Potassium (Neutral Normal Ammonium Acetate, Jackson, 1973) [3] and Available Sulphur (Turbidimetric method, Williams and Steinberg, 1959) [15].

In the present study, two software viz. Image processing ERDAS (Earth Resources Data Analysis System) (Demo version) and Arc GIS 10.2 has been used for the preparation of required database. Thematic fertility maps of the watershed were prepared so that it is used as a geo-reference by the research workers in future. ArcGIS is a tool used for spatial analysis, tabular database and conventional GIS characteristics. ERDAS Imagine is mainly used for image processing purpose.

Descriptive statistics of soil properties and nutrient content was worked out according to the method proposed by Gomez and Gomez (1984) [2].

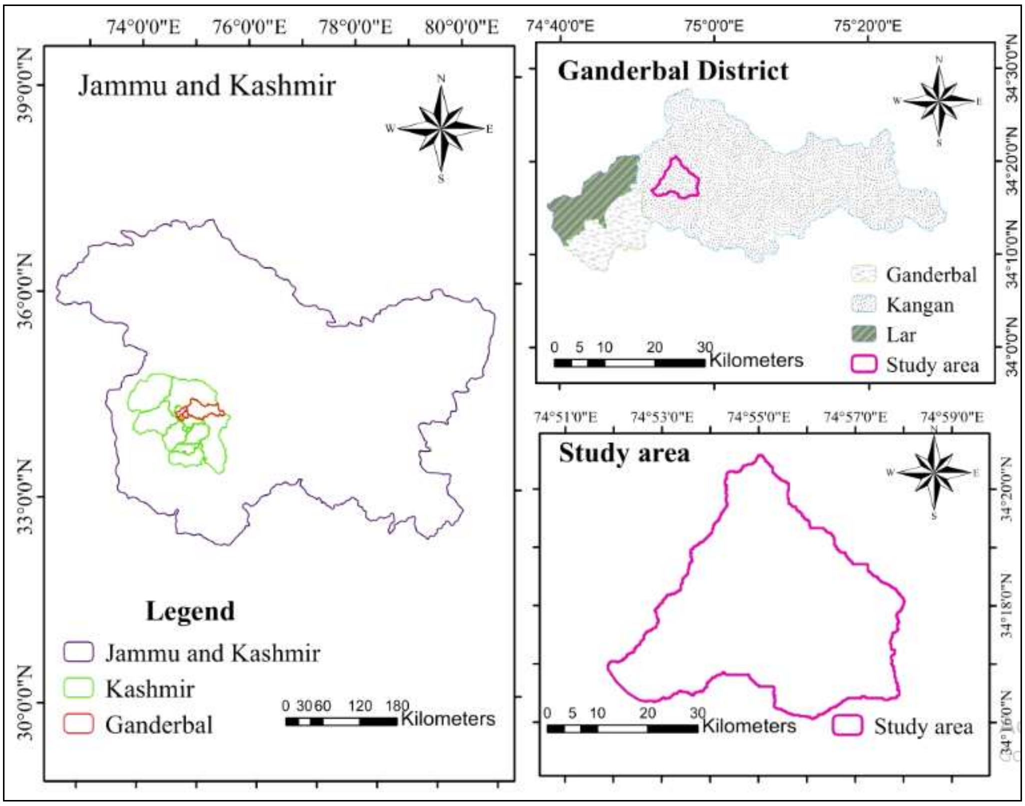

Fig 1: Location map of Wangath watershed

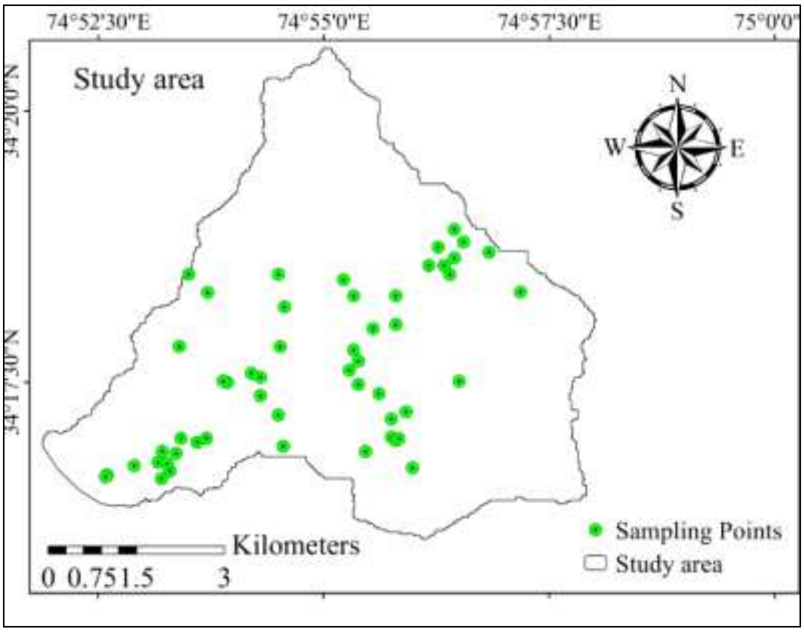

Fig 2: Location and extent of Wangath watershed

Result and Discussion

The data regarding particle size distribution is presented in Table 1 indicate that soils of the watershed vary from sandy clay loam to loam. The clay sand and silt statistically ranged from 18.56 to 22.32, 39.66 to 43.60 and 34.41 to 41.50 percent with mean values of 20.40, 41.63 and 37.95 per cent respectively. Paddy soils mostly fall in sandy clay loam range and soils under maize cultivation observed loamy in texture which may be attributed due to higher altitudes with steep slopes have less penetration of water, more erosion, low temperature thus less development of soil like in forests having very low amount of clay and high amount of sand. Forest soils varied in texture from silt loam to silt while wasteland and horticulture soils observed silt loam and loam texture respectively.

In general, the soils were slightly acidic to alkaline in reaction as pH varied statistically from 7.18 to 7.30 with a mean of 7.24 in the watershed (Table 2). Highest pH was observed in wasteland (7.69) while lowest in forests (6.56). This may be attributed due to uptake of bases by tree biomass, acidic nature of litter after its decomposition, leaching of salts from upper layers which lead to low pH as in case of forestry and accumulation of salts in case of wastelands.

The soils of the studied watershed were below the critical limits (<1 dSm^{-1}) in electrical conductivity for growing crops. It statistically ranged from 0.18 to 0.21dSm^{-1} with mean value of 0.20 dSm^{-1}(Table 2). Highest mean value was observed in wasteland (0.29 dSm^{-1}) while lowest in forest land use (0.09dSm^{-1}). It can be due to accumulation of calcium carbonate in case of wastelands and low salt content of forest litter.

All the soil samples taken from Wangath watershed have medium to high amount of organic carbon except wasteland soils (Table 2). It statistically varies from 6.70 to 9.32 g kg^{-1} with a mean of 8.02 g kg^{-1}. Forest soils recorded highest organic carbon content (22.71 g kg^{-1}) found in wasteland (3.24g kg^{-1}). It may be attributed to high biomass production and lower decomposition at higher reaches as compared to wastelands having lower biomass because of less vegetation.

The available nitrogen status of the watershed statistically ranged from 341.88 to 361.75 kg ha^{-1}with mean of 351.62 kg ha^{-1} (Table 3). All the soils of watershed fall under medium category. Soils of forest observed highest nitrogen content (444.22 kg ha^{-1}) while lowest content in wastelands (265.40 kg ha^{-1}). It is attributed due to high OM and overall high turnout of nitrogen during decomposition in forests as compared to other land use systems.

The available phosphorus found medium in the studied watershed and statistically ranged from 15.06 to 17.04 kg ha^{-1} with mean of 16.05 kg ha^{-1} (Table 3). The maximum value was found in forest (22.66 kg ha^{-1}) and minimum in wastelands (10.5 kg ha^{-1}). The available phosphorus content in soils could be attributed because of favorable soil reaction and high organic matter leading to the formation of organophosphate complexes and coating of iron and aluminum particles by humus (Ashraf, 2014) [1].

The available potassium statistically ranged from 165.66 to 182.62 kg ha^{-1} with mean value of 174.14 kg ha^{-1}(Table 3). The highest and lowest values were estimated in forest (266.10 kg ha^{-1}) and horticulture soils (151.20 kg ha-1) respectively. Potassium is found in medium range in all sites.

The area under study found low to medium in available sulphur status with a mean value of 12.48 mg kg^{-1}. The available sulphur content of watershed statistically ranged from 12.12 to 12.84 mg kg^{-1}. The maximum available sulphur was analyzed in forests (14.6 mg kg^{-1}) whereas minimum value was found in wasteland soils (9.68 mg kg^{-1}). It may be due to high amount of OM in forests as compared to agri-horticulture and intense cultivation in agri-horticultures by pulses and vegetables which leads to removal of more S for protein synthesis.

Conclusion

Texture of different land use system in the watershed change from sandy clay loam to loam. The available macronutrients were in medium range in the watershed. Spatial distribution of soil properties can be used confidently for improving soil sampling strategies and site-specific management practices within the study area according to their management and reclamation requirements. Soil fertility maps were prepared which can be used by the researcher as geo-reference in future.

Table 1: Descriptive statistics of soil particle size distribution under different land uses of Wangath watershed

LUS	**Crop**	**Sand (%)**	**Silt (%)**	**Clay (%)**	**Textural class**
Agriculture	Paddy	48.05	23.41	28.58	Sandy clay loam
	Maize	40.71	41.92	17.35	Loam
	Mean ± SE	44.13 ± 0.70	33.28 ± 1.52	22.59 ± 0.86	-
	95% C.I	42.70 - 45.56	30.21 - 36.35	20.85 - 24.33	-
Horticulture	Apple	39.32	41.57	19.08	Loam
	Mean ± SE	39.32 ± 1.55	41.57 ± 1.61	19.08 ± 0.13	-
	95% C.I	35.65 - 43.01	37.76 - 45.38	18.76 - 19.40	-
Forest	Mean ± SE	32.23 ± 4.44	62.68 ± 5.07	4.89 ± 0.62	Silt loam, silt
	95% C.I	19.88 - 44.58	48.60 - 76.75	3.17 - 6.60	-
Wasteland	Mean ± SE	18.12 ± 4.87	66.75 ± 5.25	15.1 ± 0.4	Silt loam
	Overall mean	41.63	37.95	20.40	
	95%C.I	39.66 - 43.61	34.41 - 41.50	18.56 - 22.23	
Skewness		-1.72	0.76	-0.42	
Kurtosis		4.07	0.74	-0.14	
p-value		0.00	0.009	0.00	

LUS = Land use system; SE = Standard error; C.I = Confidence interval

Table 2: Descriptive statistics of soil Physico-chemical properties under different land uses of Wangath watershed

LUS	**Crop**	**pH (1:2.5)**	**EC (dS m^{-1})**	**OC (g kg^{-1})**
Agriculture	Paddy	7.24	0.21	4.28
	Maize	7.29	0.20	8.13
	Mean ± SE	7.26 ± 0.02	0.20 ± 0.01	6.33 ± 0.3
	95% C.I	7.23 - 7.30	0.18 - 0.21	5.69 - 6.97
Horticulture	Apple	7.41	0.20	9.50
	Mean ± SE	7.41 ± 0.02	0.20 ± 0.01	9.50 ± 0.54
	95% C.I	7.354 - 7.470	0.18 - 0.22	8.22 - 10.79
Forest	Mean ± SE	6.56 ± 0.037	0.09 ± 0.01	22.71 ± 1.20
	95% C.I	6.46 - 6.66	0.05 - 0.12	19.27 - 26.15
Wasteland	Mean ± SE	7.69 ± 0.04	0.29 ± 0.01	3.23 ± 0.11
Overall mean		7.24	0.19	8.02
95%C.I		7.18 - 7.30	0.18 - 0.20	6.70 - 9.32
Skewness		-1.52	-0.48	2.14
Kurtosis		3.04	0.26	4.78
p-value		0.00	0.51	0.00

LUS = Land use system; SE = Standard error; C.I = Confidence interval

Table 3: Descriptive statistics of soil chemical properties under different land uses of Wangath watershed

LUS	**Crop**	**Av. N (kg ha^{-1})**	**Av. P (kg ha^{-1})**	**Av. K_2O (kg ha^{-1})**	**Av. S (mg kg^{-1})**
Agriculture	Paddy	359.82	19.33	163.98	12.00
	Maize	336.10	12.36	170.98	13.18
	Mean ± SE	347.17 ± 3.35	15.62 ± 0.58	167.72 ± 2.61	12.63 ± 0.15
	95% C.I	340.41 – 353.92	14.53 – 16.07	162.45 – 172.98	12.32 – 12.94
Horticulture	Apple	340.32	15.76	151.20	11.01
	Mean ± SE	340.32 ± 10.10	15.76 ± 0.32	151.20 ± 2.86	11.01 ± 0.24
	95% C.I	316.44 – 364.21	15.01 – 16.52	144.43 – 157.96	10.43 – 11.59
Forest	Mean ± SE	444.22 ± 12.42	22.66 ± 0.23	266.10 ± 7.139	14.60 ± 0.71
	95% C.I	409.74 – 478.69	22.00 – 23.31	246.28 -285.92	12.63 – 16.57
Wasteland	Mean ± SE	265.40 ± 7.40	10.50±0.20	180.45 ± 8.15	9.68 ± 0.12
Overall mean		351.62	16.05	174.14	12.48
95%C.I		341.48 – 361.75	15.06 – 17.04	165.66 – 182.62	12.12 – 12.84
Skewness		0.94	0.22	1.89	-0.06
Kurtosis		2.31	-1.34	3.90	0.37
p- value		0.00	0.00	0.00	0.00

LUS = Land use system; SE = Standard error; C.I = Confidence interval

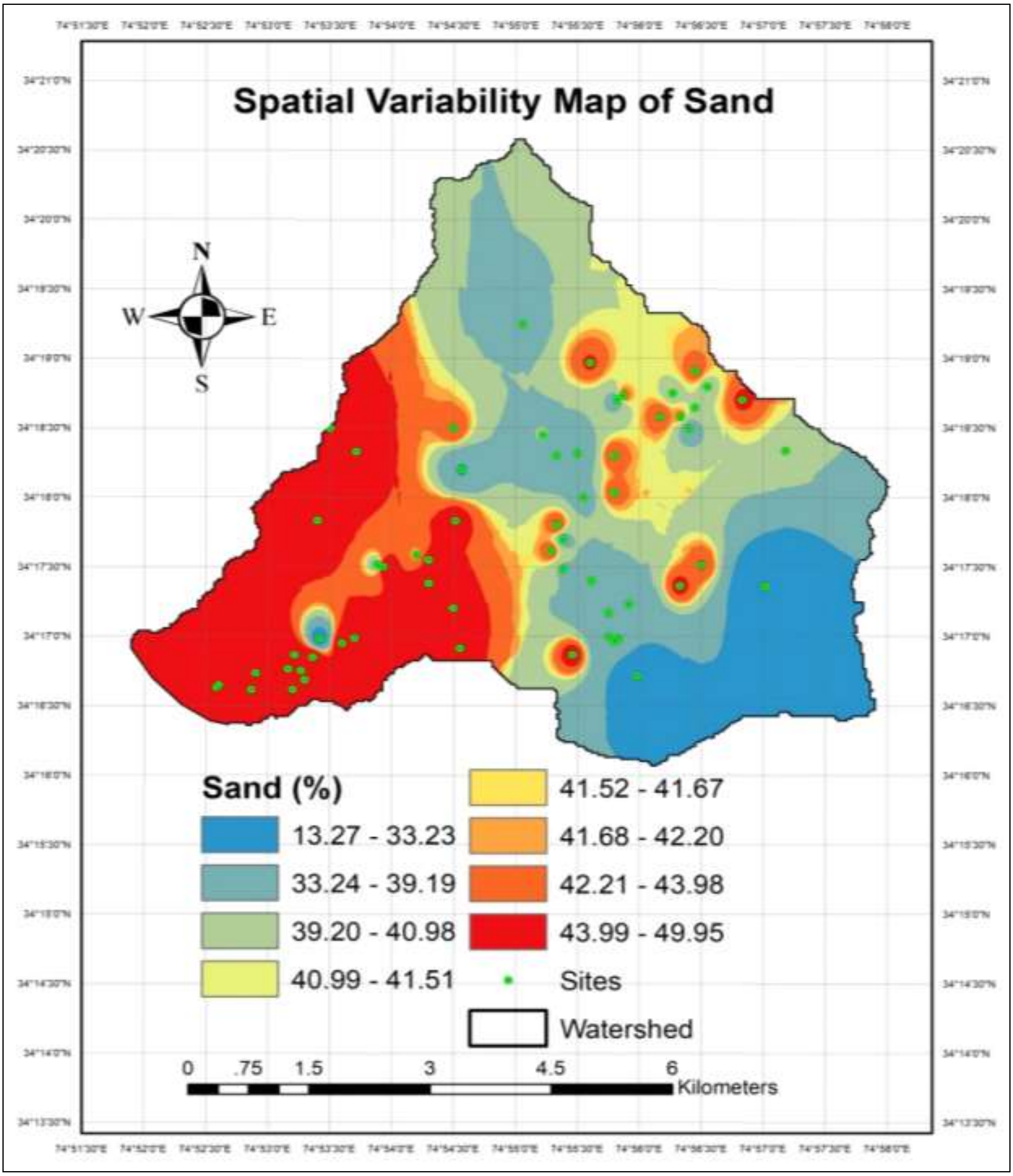

Fig 3: Sand content in the soils of Wangath watershed

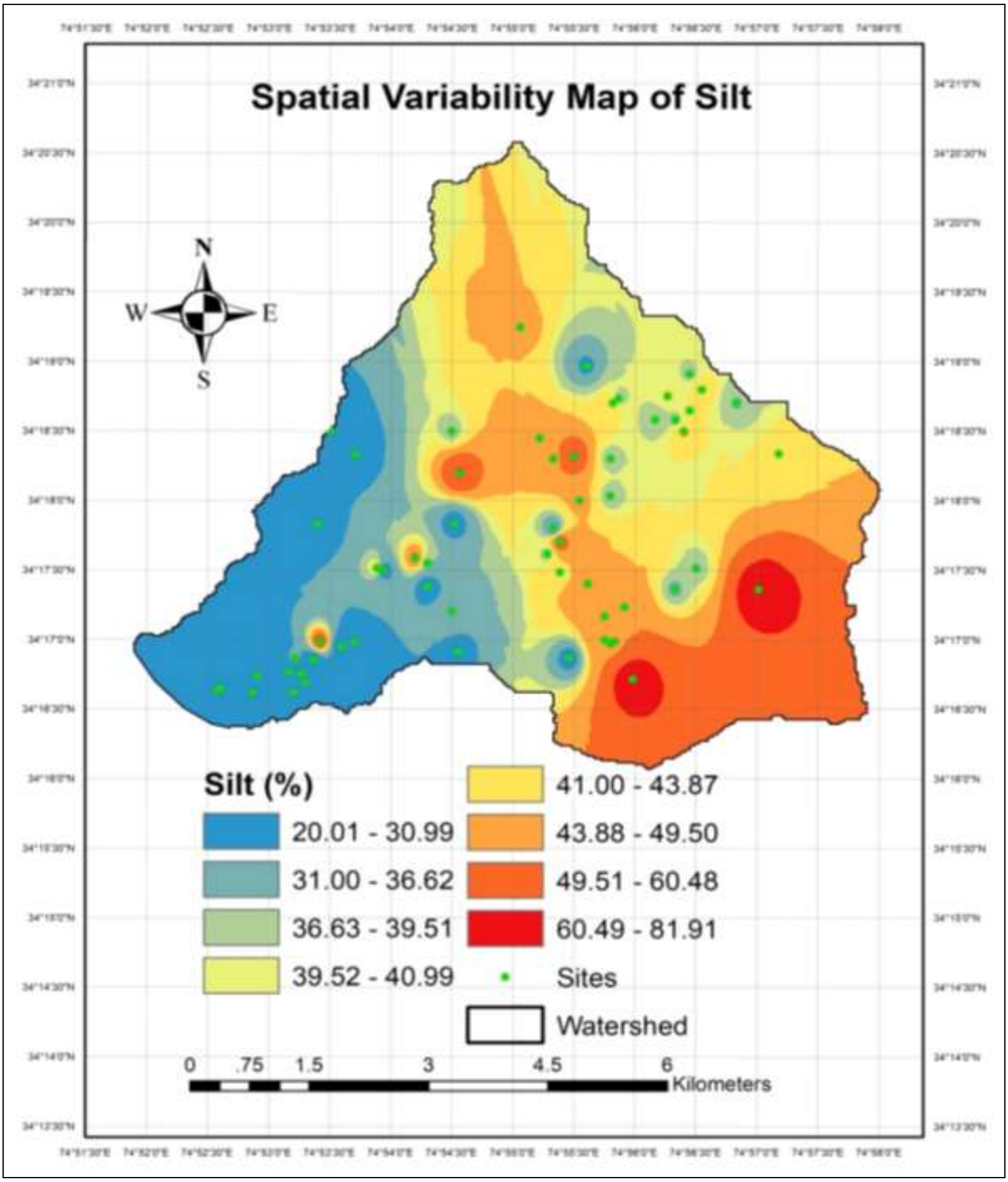

Fig 4: Silt content in the soils of Wangath watershed

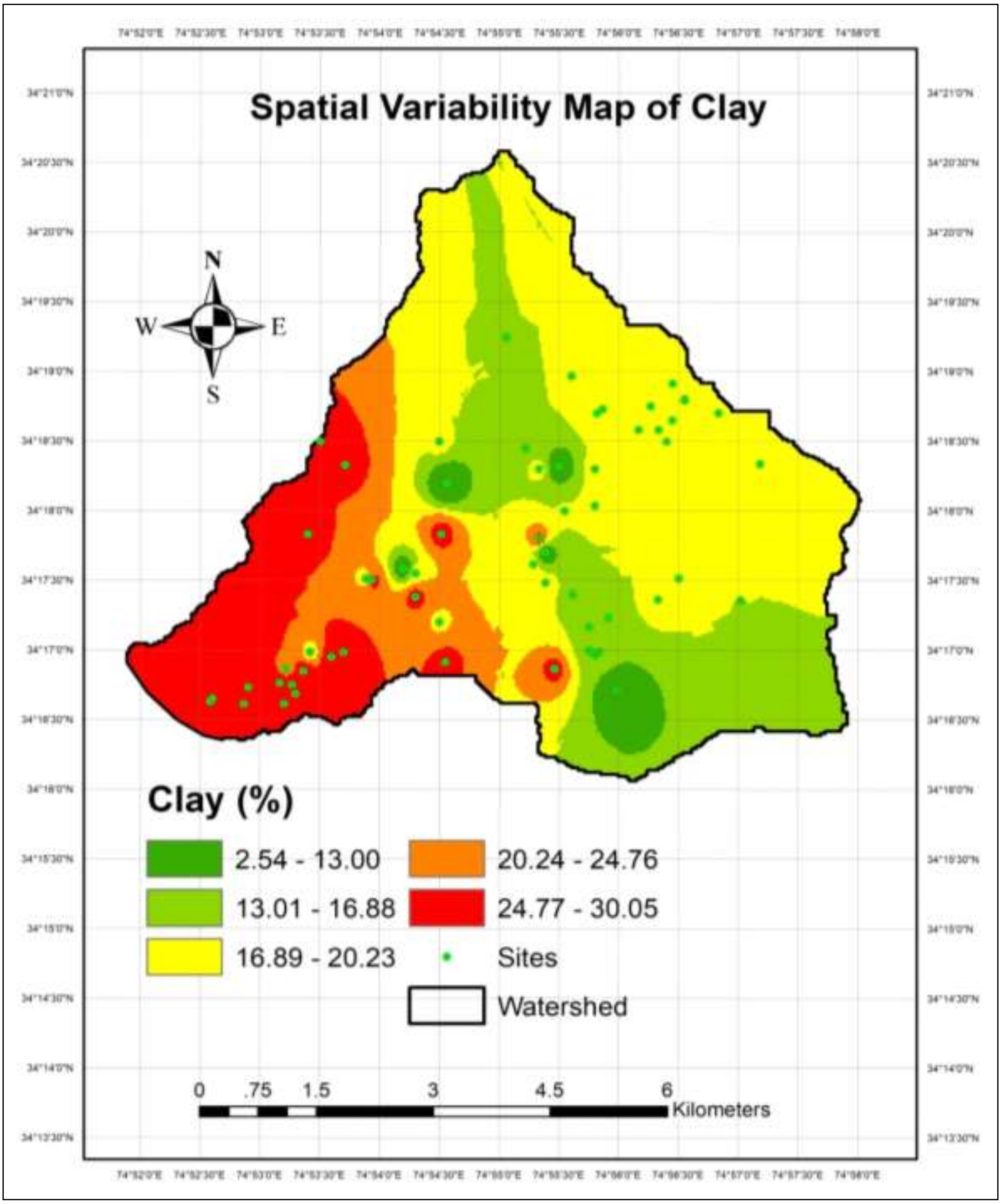

Fig 5: Clay content in the soils of Wangath watershed

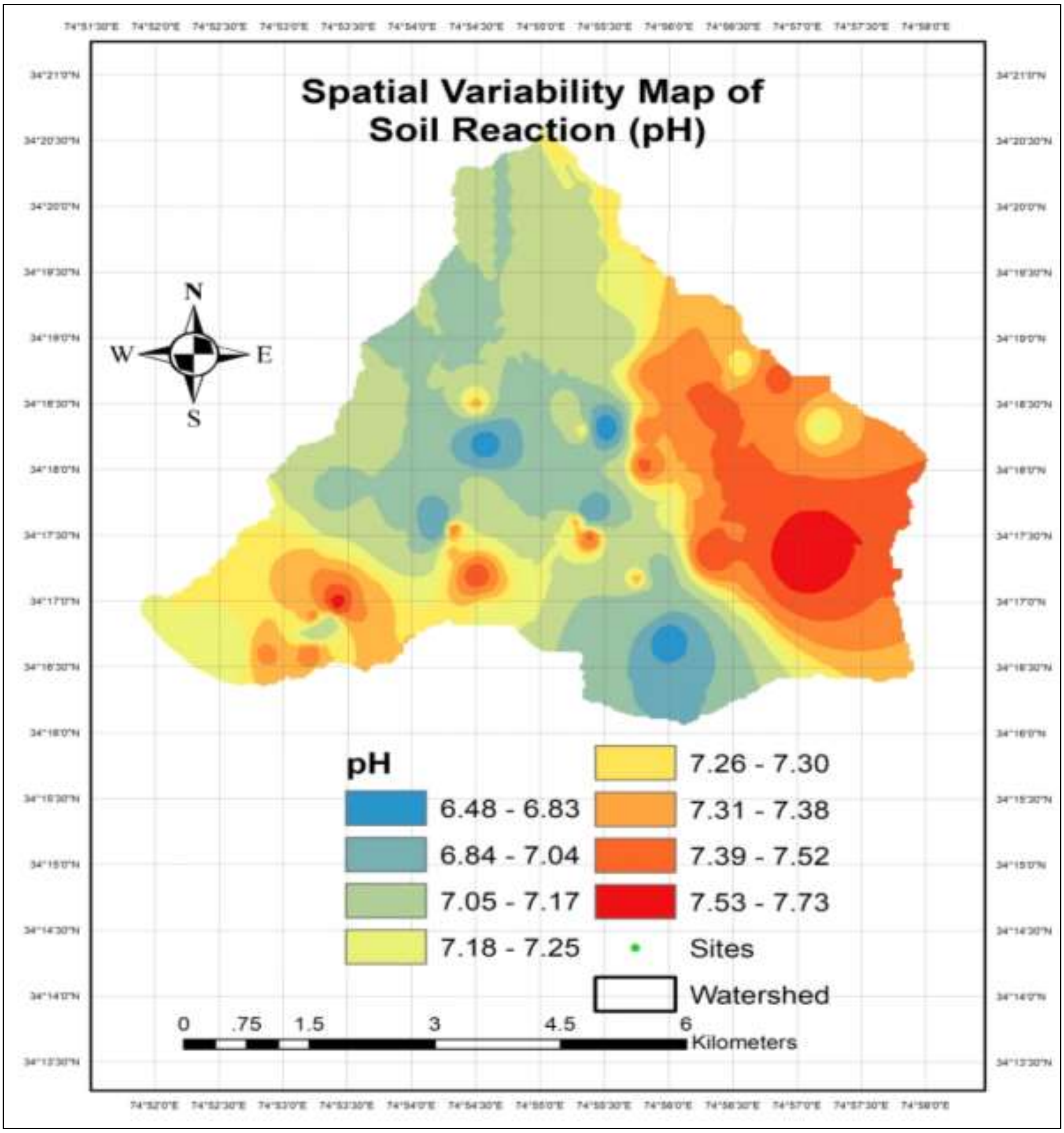

Fig 6: Soil reaction (pH) of the soils of Wangath Watershed

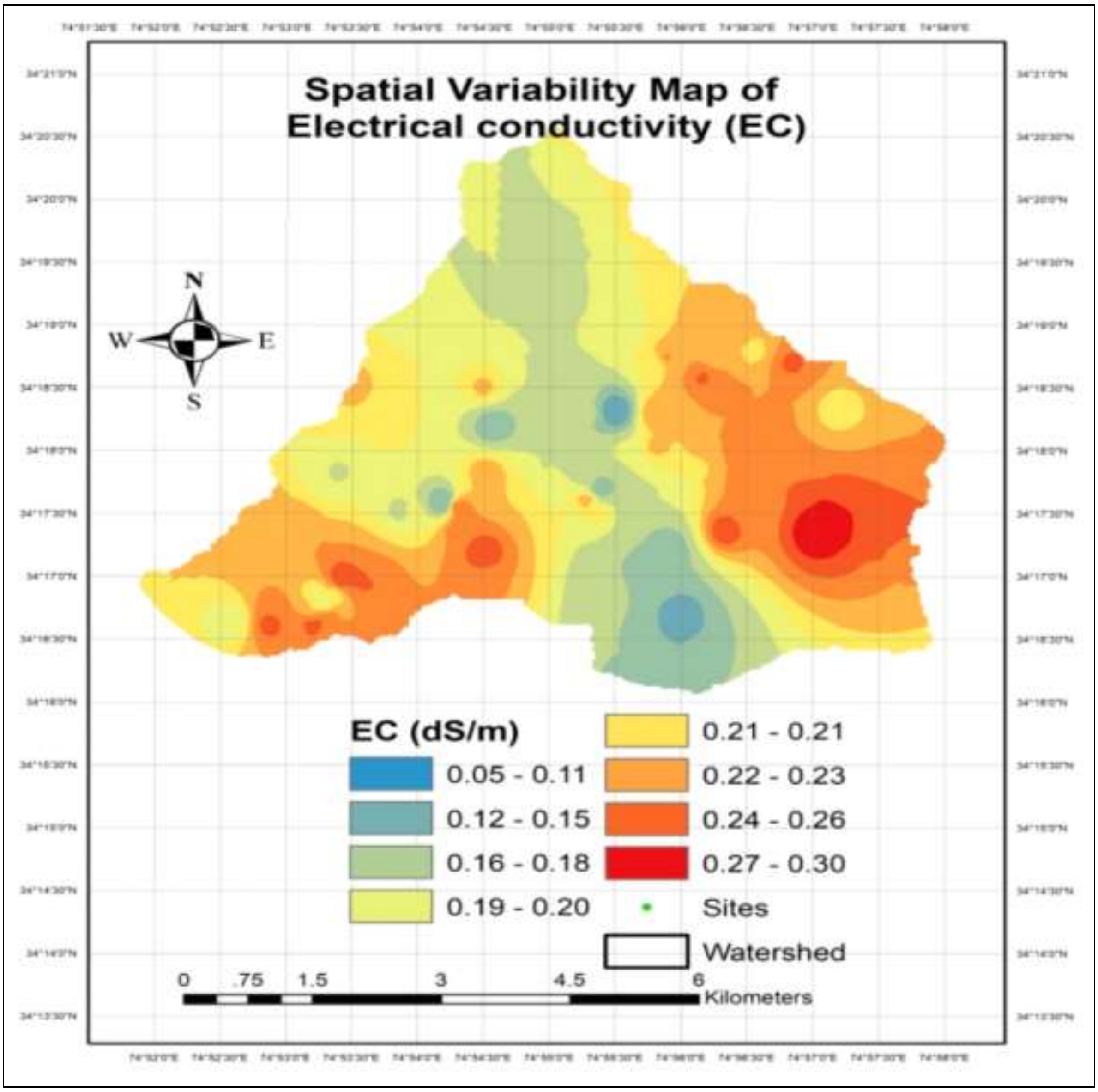

Fig 7: Electrical conductivity (EC) of the soils of Wangath Watershed

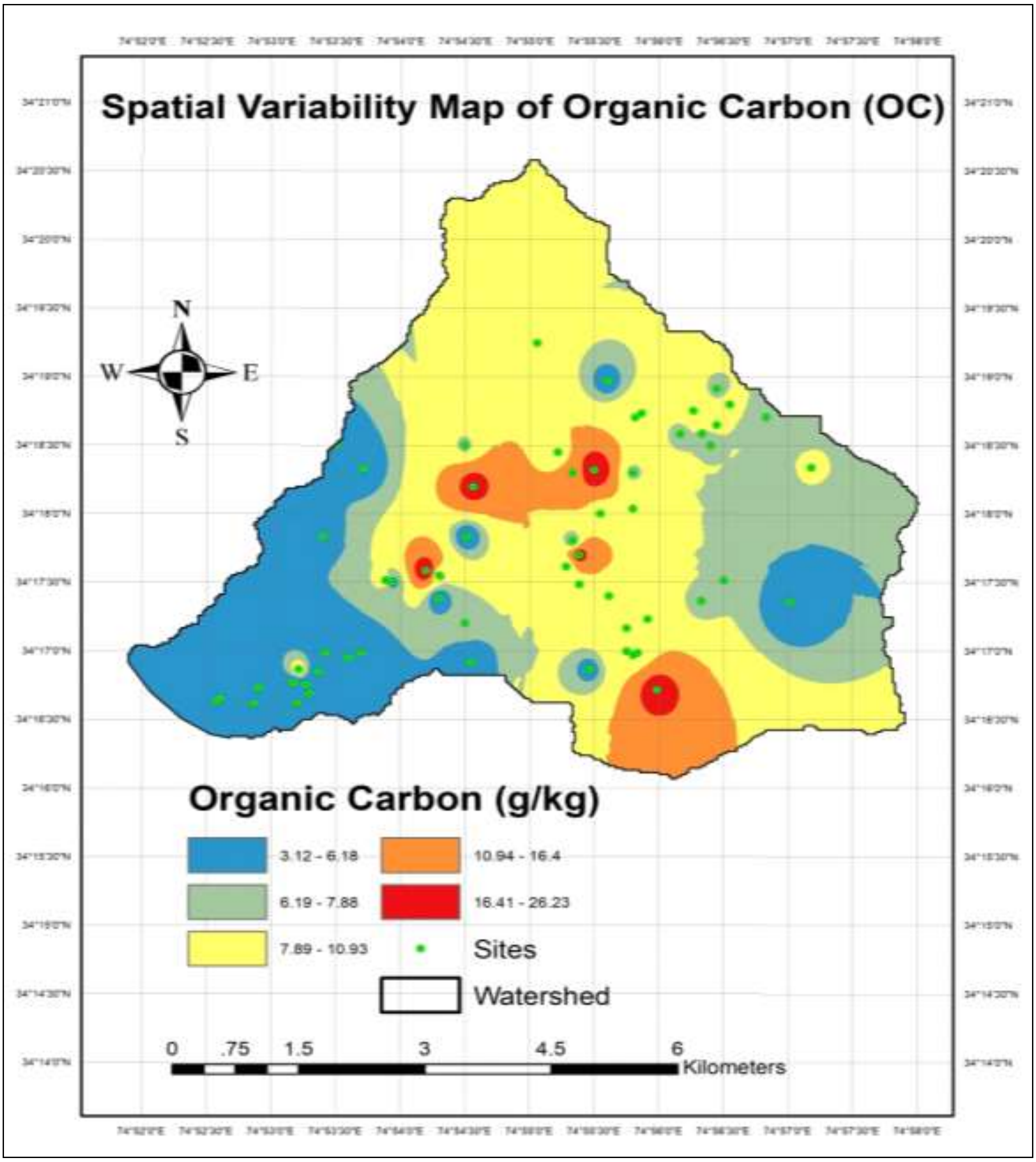

Fig 8: Organic carbon content of the soils of Wangath watershed

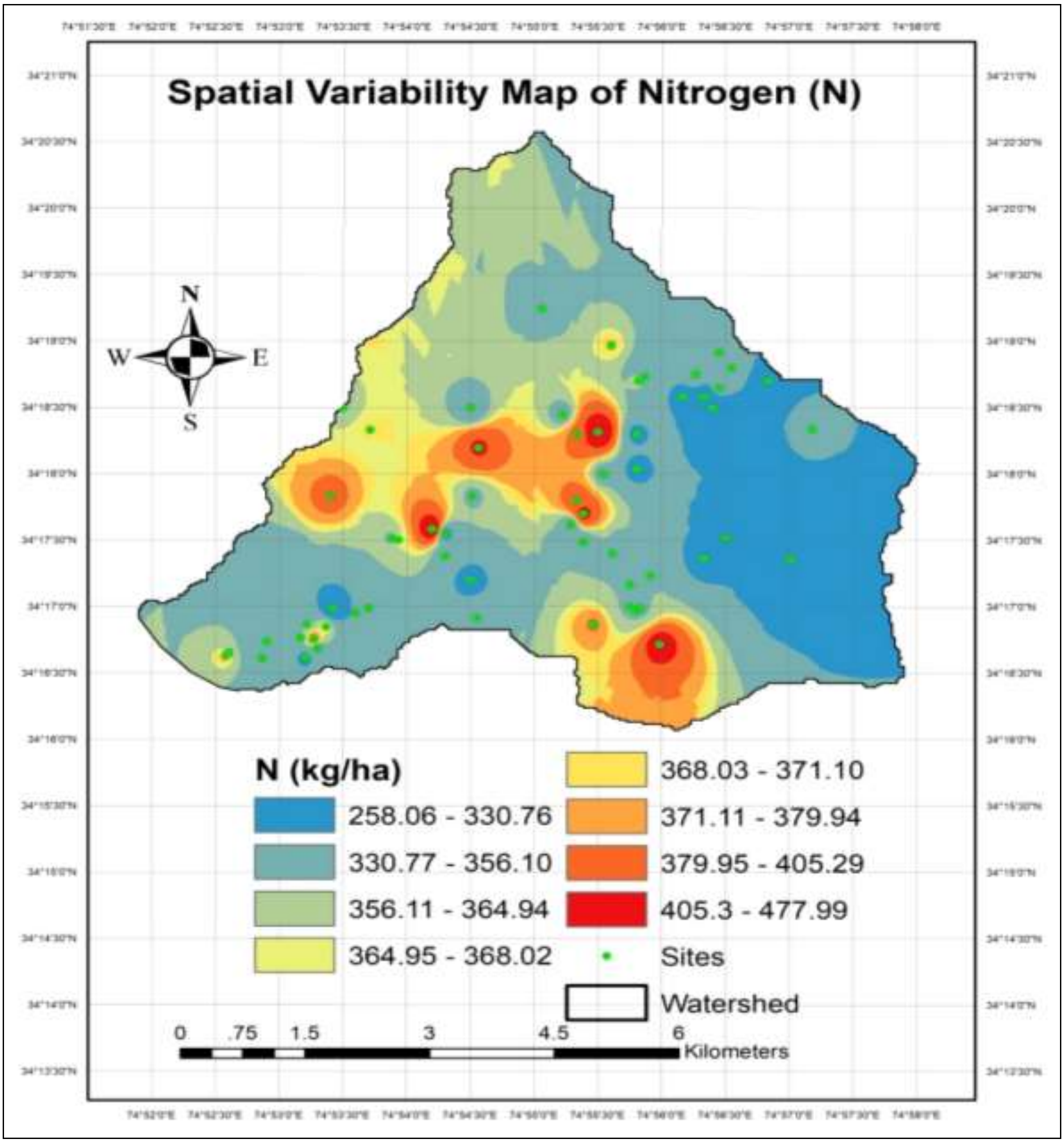

Fig 9: Available nitrogen content of soils of Wangath watershed

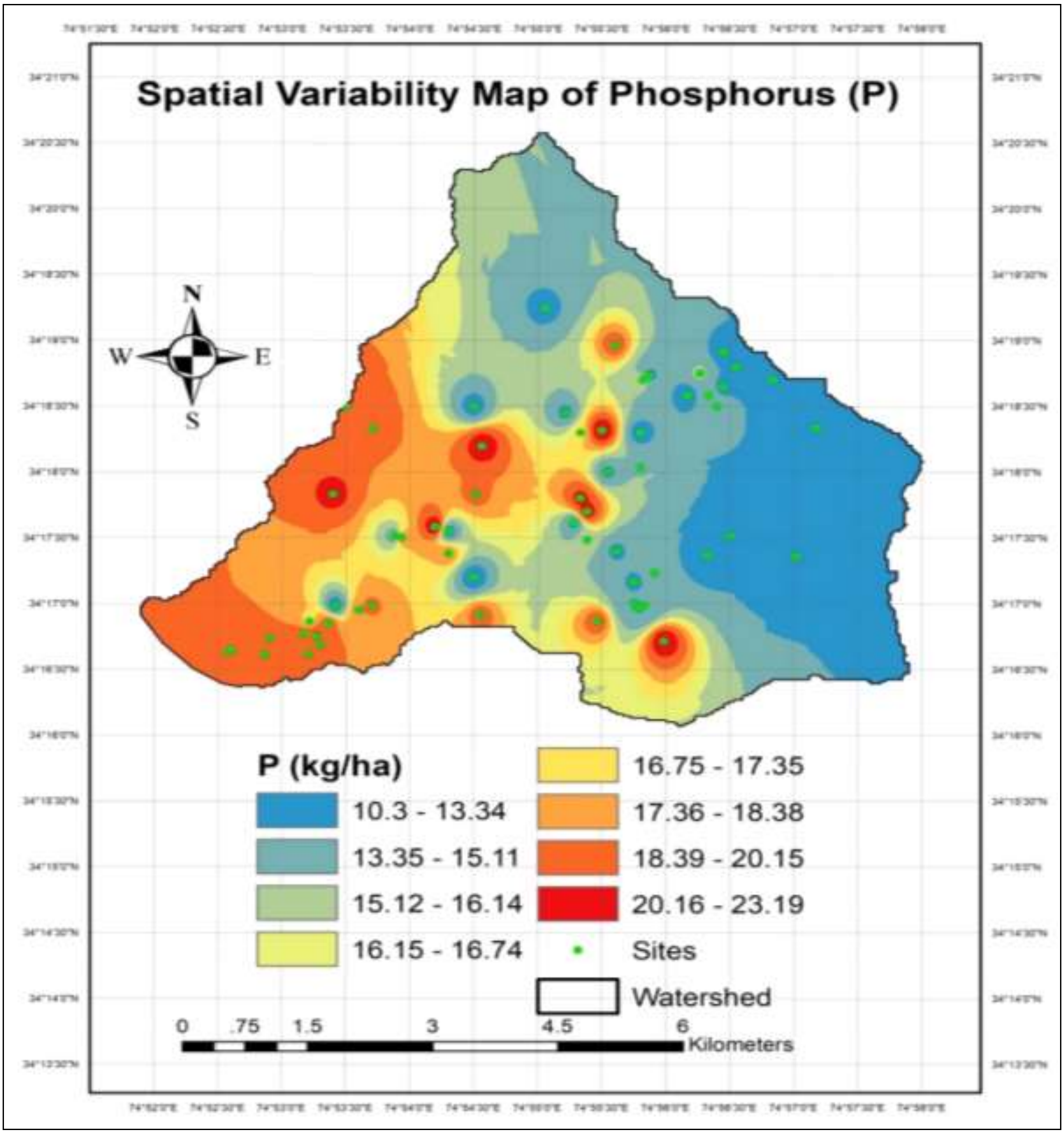

Fig 10: Available phosphorus content of soils of Wangath watershed

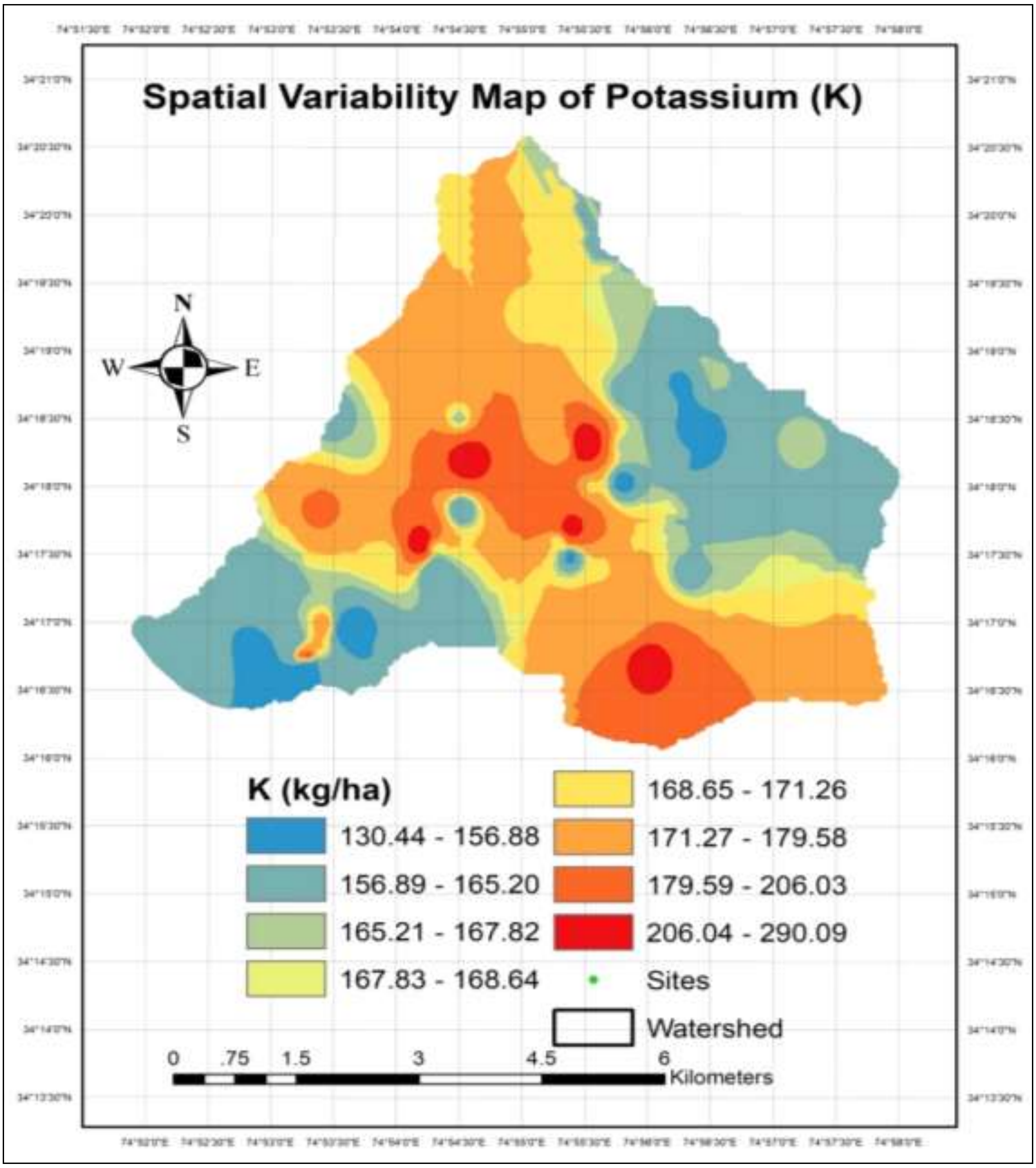

Fig 11: Available potassium content of soils of Wangath watershed

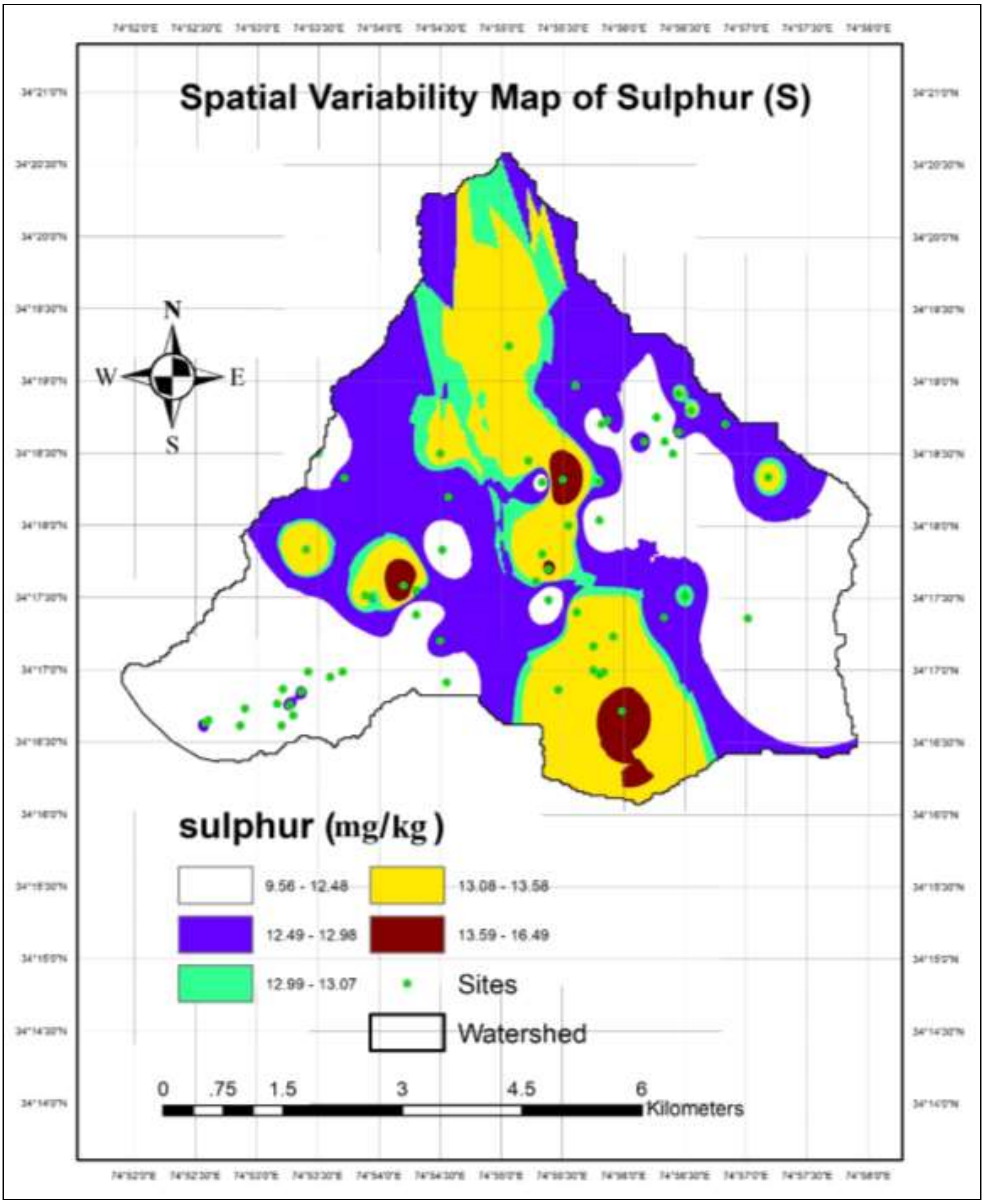

Fig 12: Available sulphur content in soils of Wangath watershed

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