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Physico-Chemical Analysis and GIS Based Study of Soil for District Swat, Khyber-Pakhtunkhwa, Pakistan

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ABSTRACT

The current research was carried out in November 2020 in order to determine the Physico-chemical properties of the agricultural lands of District Swat. The data were contrasted with the standard parameters for classifying these properties as low, medium, and adequate. Samples from 43 different agricultural lands were collected for the study area keeping in mind the variation in altitudes. The data showed that the soil is slightly acidic to alkaline (6.57 – 8.66). EC from (0.03 - 0.403 dSm^{-1}) showing the soil non-saline (<4 dSm^{-1}). The texture of the soils was mostly silt loam and loamy sand. The soil in the study area was found to be moderate calcareous. Geo-statistical and GIS-based analysis was also conducted which revealed a strong dependency for phosphorus and clay, while moderate spatial dependency for the remaining attributes. Ordinary kriging successfully interpolated each of the soil attributes. Different degrees of heterogeneity were observed via spatial correlation depicting different field management factors. Predicted maps can better guide agricultural workers to conduct better soil management practices and updated fertilizers application rates for upcoming seasonal crops. This study recommends a detailed management plan based on site-specific soil tests. Apart from this. awareness programs should be arranged for the farmers. Low phosphorous products like bone meal, pine mulches and gypsum should be applied to the study area.

Keywords: Physico-chemical, Geographic Information System, soil, swat, fertilizer management

1. INTRODUCTION

Pakistanis largely an agrarian nation and the majority of the people derive their livelihood from agriculture. Through understanding soil, it is, therefore, important to ensure sustainable crop yield. Soil is a fundamental natural resource that is important for the development of crops. Soil productivity plays a significant role in every country's economy. A nation's prosperity and development depend to a large extent on the fertility of its land, water supplies, and management of its productivity. The preservation of these resources provides the long-term security and advancement of society, but their destructive misuse gradually drains the vitality of the nation and jeopardizes its future [1]. The soil varies greatly in its ability to provide plants with one or more nutrients. Supplementary nutrients in the form of fertilizers are generally added by farmers. Due to a lack of the application of adequate doses of fertilizers, farmers are unable to attain the requisite nutrient status where required. Application of fertilizer is often done without soil testing, which leads either to an inadequate supply of nutrients for uptake by plants or losses of excess nutrients. The nature and application of fertilizers are suggested as per the soil fertility status, nutrients deficiency, field fertilizers experiments and soil testing. The sustainability of agricultural ecosystems is dependent primarily on the soil's Physico-chemical properties. Good management practices can lead to its viability and how it affects the usage of soil-crop-water relations [2]. Physico-chemical properties of soils are an important aspect of land management and are dependent on agricultural production. It is, therefore, essential to understand the Physico-chemical attributes of the soil as they influence agricultural productivity. Nutrient solubility and bioavailability are regulated by the Physico-chemical properties. Hence, it links agricultural production and soil components. There is very limited access to soil testing in the farming community. Without proper soil analysis, farmers apply inadequate fertilizer or an overdose, which goes to waste, both of which affect the production profitability. Spatial variation is an important aspect associated with the Physico-chemical analysis of soil. Closers' sample points will have similar properties in compared with samples taken from far [4]. The spatial variation shows us the intrinsic and extrinsic soil processes which eventually affect its Physico-chemical properties [5]. The spatial dependency varies from soil type, physiographic location, micro-climate, crop rotation, and other human activities which form the spatial distribution for the soils. Specific management of fertilizers is very important to study before the plantation of crops. An updated recommended application is better analyzed from the geospatial distribution behavior of the soil properties. This research has two objectives, namely, to analyze the present Physico-chemical properties of the soil and to implement GIS techniques (Geo-Spatial, Geo-statistics and Geo-Mapping) for the study area, i.e., District Swat.

2. MATERIALS AND METHODS

A research study was carried out to evaluate the Physico-chemical properties of the soils. The altitude was considered a key factor for the sampling of soils in the study area. The study area was divided into two main divisions i.e., Lower Swat and Upper Swat based on their altitude variation.

2.1. Soil sampling

23 soil samples from Lower Swat while 20 soil samples from Upper Swat were collected from various agricultural fields. A sampling of soil was carried out during November. The soil samples were taken a depth of 0-15 cm.

Soil sample Analysis: Soil samples after collection were labelled and stored in specialized containers. A total of 43 soil samples were then transported to the soil testing laboratory of The University of Agriculture, Peshawar, Pakistan. The samples were then air dried, ground, and sieved from a 2mm sieve. The analysis was carried out for different soil properties including soil texture, soil pH, Electrical Conductivity (EC), Lime, Organic Matter (O.M), AB-DTPA extract of soil for Phosphorus (P), and

Figure 1. Study Area

Potassium (K). The standard operating procedures were followed during the analysis as described by [6].

2.2. Analytical Procedures

2.2.1. Soil pH

1:5 soil Suspension was used to measure the soil pH with the aid of a digital pH meter.

The first 10g of air-dried soil was the weight on a digital balance. After weighing the soil, 50mL distilled water was added to the samples with the help of a measuring cylinder. The soil-water suspension was kept on a digital stirrer machine for a while. This was later filtered to beakers where the pH was measured with the help of an already calibrated digital pH meter (Hanna HI9813-6 pH meter).

2.2.2. Electrical Conductivity (EC)

EC level was measured for the total soluble salts in a ratio of 1:5. In order to find out the EC of soil samples, the first 10 g of soil was treated with 50 mL of distilled water. The suspension was later kept on a stirrer machine and then filtered. The filtrate was used for EC analysis using a digital EC meter (HI9813-6 pH meter)

2.2.3. Lime Content

Treatment of 5 g soil with 0.6 N HCl was carried out followed by titration with 0.025 N NaOH in the presence of phenolphthalein as an indicator. The titration was stopped after the appearance of pink color.

$$LC(\%) = \frac{[(HCl \times N) - (NaOH \times N) \times 0.05]}{weight\ of\ soil(g)} \times 100 \qquad ...eq.1$$

Where:
LC= lime content
HCl and NaOH in ml

2.2.4. Soil Texture

Soil texture was determined using the Hydrometer method [7]. 50 grams of soil (air-dried) from each soil sample was placed in dispersion solution followed by 5 minutes of shaking via an electrical shaker. After dispersion, the soil solution was transferred and filled with distilled water to 1 Litre. A hydrometer was inserted after thoroughly shaking in the suspension and the readings were measured after 40 sec for silt+clay and after 2 hours for clay. The temperature was also recorded in order for hydrometer correction. The textural class of the USDA triangle was made after the calculation of the silt, clay, and sand ratio.

$$(silt + clay)\% = \frac{40\,\text{sec} * HR \pm TC}{weight\ of\ soil(g)} \times 100 \qquad ...eq.2$$

$$\%\ clay = \frac{2\ hrs\ HR \pm TC}{weight\ of\ soil(g)} \times 100 \qquad ...eq.3$$

$$\%Sand = 100 - \%(silt + clay) \qquad ...eq.\ 4$$

$$\%Slit = 100 - sand - clay \qquad ...eq.\ 5$$

Where:
HR=Hydrometer reading
TC= Temperature correction

2.2.5. Phosphorus Content (P)

Soil phosphorus content was determined by the AB-DTPA method following [8]. 5g of each soil sample was taken to which 20 ml AB-DTPA solution was later added. The solution was kept in the mechanical shaker for 15 minutes. The solution, after shaking was filtered through Whatman42-filter paper and P concentration was determined using a spectrophotometer. Standards of 0, 2ppm, 4 ppm, 6 ppm, 8ppm and 10 ppm were used for the calibration curve.

2.2.6. Potassium content (K)

Potassium content in the soil was determined by the AB-DTPA method [8]. 5g of each soil sample was taken followed by 20 ml AB-DTPA solution. The solution was kept for shaking on a mechanical shaker. After shaking for 15 minutes, the solution was filtered through Whatman42-filter paper and K concentration was determined through flame photometry. Different standards like 2 ppm, 4ppm, 6ppm, 8ppm, and10 ppm were used for the calibration curve.

2.3. GIS-Based Study

GIS (Geographic Information System) based study was carried out for the study area i.e., the district swat from where the soil samples were collected. The GIS-based study is carried out in order to better understand the trends and relationships geospatially for the Physico-chemical attributes of the soil. Following are some of the approaches studied: Geospatial and Geo-statistical Analysis: After the analytical approach, the data was subjected to statistical analysis which included Descriptive Statistics and Pearson Correlation for each variable. For Geostatistical Analysis, ArcMap 10.4, a GIS software, was used. The geostatistical approach included Variograms models and Kriging Mappings for each parameter of soil. The geostatistical analyst wizard extension was used in the whole process.

2.4. Statistical Analysis

All the parameters for soil Physico-chemical analysis were subjected to descriptive statistics followed by Pearson Correlation in order to determine the relationships among these parameters.

2.5. Spatial Auto-correlation

Evaluation of spatial variability was done using the kriging technique. Kriging is a dominant spatial interpolation technique that is used to estimate the values for unknown sample areas based on the values measured at sampled areas [9].For spatial correlation of the study area, the main component of kriging i.e., semi-variogram is used. It is used to describe the components' structural spatial structure. Furthermore, it is used to provide possible progressions which affect data distribution. The variogram function for the study is expressed as models of semi-variograms. In the geo-statistical analysis for the sample area, Gaussian and K-Bessel models were used. According to literature, the majority of the soil attributes exhibit non-zero variance known as the "Nugget Effect" [10]. The Nugget Effect shows us the random variance mostly occurred by errors in the variability while sampling. In the present study, Gaussian and K-Bessel appeared to be the best-fitted models for the selected Physico-chemical properties for soil.

2.6. Prediction Method

For the prediction method, Interpolation for the selected Physico-chemical soil properties was followed. Kriging Interpolation technique was followed as it shows the geo-statistical approach (Linear) for the space-dependent variable. Kriging represents the weighed sums of adjacent sampled areas. Ordinary kriging is the most common method as it estimates the un-sampled values in a sufficient way.

$$Z*(x_0) = \sum_{i=1}^{N} \lambda_i \; Z\,(x_i)$$

$$\sum_{i=1}^{N} \lambda_i = 1 \qquad \text{... eq. 6}$$

Where

Z*(x_0) = the estimated value for Z for location x_0;

λ_i = the weight measured at location i.

Weights are measured in order to minimize the variance of estimated errors. Values of λi are forced to ∑λi =1 expressing N as number of estimated values used in estimation of neighbourhood of i

2.7. Cross Validation

Cross-validation of the mapped models represents the predicted values of the model left unsampled. It performs the diagnostics in order to evaluate the model.

Mean Error: The predicted values should be impartial.

$$ME = \sum_{i=1}^{n} \frac{z*(x) - z(x)}{n} \quad \text{...eq.7}$$

Root Mean Square Error: The predicted values should be close to the measured ones.

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}\left(\frac{z*(x) - z(x)}{n}\right)^2}{n}} \quad \text{...eq. 8}$$

Root Mean Square Standardized Error: This represents the standard errors predictions which are closer to 1.

$$RMSSE = \sqrt{\frac{\sum_{i=1}^{n}\left[\frac{\sum_{i=1}^{n}(z*(x) - z(x))^2}{n} \Big/ \sigma^*(x)\right]^2}{n}} \quad \text{...eq.9}$$

Average Standard Error: This refers to the smallest possible standard error.

$$ASE = \sqrt{\frac{\sum_{i=1}^{n}\sigma^*(x)}{n}} \quad \text{...eq. 10}$$

Where,

z(x) =the measured value,

z*(x)=the predicted value

σ *(x) =the variance observed in the predicted value

3. RESULTS AND DISCUSSION

3.1. Soil Physico-chemical Analysis

Table 1. Soil Physiochemical Data for Lower Swat

S. No	Village name	pH	EC (dSm1)	Lime Cont. (%)	P (mgkg1)	K (mgkg1)	%Clay	%Sand	%Silt	Texture class
1	K.shanglo	6.62	0.18	8.59	5.237	71.4	7	33.6	59.4	Silt loam
2	K.Garonai	8.32	0.06	14.9	4.2134	131	13	33.6	53.4	Silt loam
3	K.Chail	6.82	0.15	22.22	2.6936	53.6	11	21.6	67.4	Silt loam
4	Dangram	8.22	0.13	12.37	4.0148	106.8	13	41.6	45.4	Loam
5	Khwajabad	8.14	0.07	5.81	12.0918	79.2	7	37.6	55.4	Silt loam
6	Marghuzar	6.57	0.34	12.63	8.5062	78.4	11	33.4	55.6	Silt loam
7	M.stream	7.14	0.24	9.6	5.8616	50.2	11	37.6	51.4	Silt loam
8	Salampur	8.31	0.12	3.28	11.4032	159	11	33.6	55.4	Silt loam
9	Guligram	6.57	0.11	17.17	15.361	75	11	29.6	59.4	Silt loam
10	Saidu sharif	7.2	0.32	12.63	12.557	135.2	9	25.6	65.4	Silt loam
11	Qambar	8	0.14	17.17	23.45	96.2	7	31.6	61.4	Silt loam
12	Takhtband	7.67	0.03	12.63	7.557	88.4	11	33.6	55.4	Silt loam
13	Ghazibaba	7.27	0.3	12.63	13.0968	93.2	11	37.6	51.4	Silt loam
14	Odigram	7.12	0.34	13.13	10.0322	138.6	11	27.6	61.4	Silt loam
15	Gogdara	7.27	0.4	12.63	24.146	169.8	13	37.6	49.4	Loam
16	Tindodaag	8.27	0.25	18.94	19.5298	159.8	15	37.6	47.4	Loam
17	Manyaar	8.13	0. 12	15.66	15.125	87.4	15	33.6	51.4	Silt loam
18	Ghalegy	8.09	0.08	12.37	13.0968	167.8	11	57.6	31.4	Sandy loam
19	Balogram	6.85	0.19	4.8	8.5434	87.8	13	33.6	53.4	Silt loam
20	Ingaroderai	7.05	0.14	12.63	3.7482	113.2	11	37.6	51.4	Silt loam
21	Chinar bagh	7.18	0.24	11.11	1.887	62.4	13	41.6	45.4	Loam
22	Lokmaira	8.13	0.1	9.6	2.2532	65.8	13	27.6	59.4	Silt loam
23	Jambil	8.38	0.08	14.65	2.2732	59.2	9	45.6	45.4	Loam

Table 2. Soil Physiochemical Data for Upper Swat

S. No	Villages	pH	EC (dSm1)	% Lime	P (mg kg-1)	K (mgkg-1)	% Clay	% Silt	% Sand	Texture Class
1	Malam Jabba	7.04	0.069	5.38	1.4352	83	3	19.2	77.8	Loamy sand
2	Shin Kadd	7.56	0.072	6	1.8482	80.4	3	14.4	82.6	Loamy sand
3	Kanju	7.67	0.078	4.88	8.623	81.2	4.2	12	83.8	Loamy sand
4	Ningwalai	7.36	0.075	4.88	5.2268	90.6	6	12.6	81.4	Loamy sand
5	Sheer Palam	7.71	0.067	4.75	6.0868	116.6	6	15.6	78.4	Loamy sand
6	Ronyal	7.76	0.12	6.125	3.3578	110.8	4.2	18.6	77.2	Loamy sand
7	Shawar	7.46	0.068	6	1.8442	60.8	5.4	16.8	77.8	Loamy sand
8	Gaht Peochar	6.85	0.037	6.25	2.2766	73.2	3.6	12	84.4	Loamy sand
9	Biha	7.66	0.126	5.25	3.6744	77.4	4.8	9.6	85.6	Loamy sand
10	Chupriyaal	8.60	0.153	7.625	4.1584	99.6	7.2	11.4	81.4	Loamy sand
11	Matta	8.46	0.123	6.25	3.7084	155.4	7.8	14.4	77.8	Sandy loam
12	Allam Ganj	7.88	0.122	5.25	9.441	129	5.4	12.6	82	Loamy sand
13	Fizaghat	8.32	0.19	5.25	1.6924	30	0.6	3.6	95.8	Sand
14	Sangota	8.66	0.215	17.25	3.3168	75.2	6.6	26.4	67	Sandy loam
15	Chaarbagh	7.02	0.403	5	3.9714	80.8	7.2	10.8	82	Loamy sand
16	Khwazakhela	8.62	0.179	5.625	2.5162	116.8	6.6	23.4	70	Sandy loam
17	Baghderai	7.58	0.053	5	1.4702	44777	6	12.6	81.4	Loamy sand
18	Madyan	7.57	0.082	10.125	2.8962	112.8	6.6	15.6	77.8	Loamy sand
19	Kalam	7.46	0.094	6.25	1.9448	85.2	3	20.4	76.6	Loamy sand
20	Bahrain	7.89	0.074	5.5	1.6514	97	3	19.2	77.8	Loamy sand

Soil samples comprised of 43 samples i.e., 23 samples from Lower Swat and 20 samples from Upper Swat were collected from various agricultural sites. The sites were owned by local farming communities. Soil samples carried a variation in altitudes i.e., low, medium and high. After storing in containers, all the 43 soil samples were then subjected to the Physico-chemical analysis, the results (table 1 and table 2). Twelve classes of soil have been made based on the particle size by USDA which are present in different ranges i.e., sand (0.05 to 2.0mm), silt (0.002 to 0.05mm), clay (<0.002mm). Soil analysis for lower Swat showed seventeen soil samples (74%) as silt loam, five soil samples (22%) as loam, and one soil sample (4%) as sandy loam, while the results for Upper Swat, showed sixteen soil samples (80%) were loamy sand, three soil samples were sandy loam (15%), and one soil sample (5) was sand. The ideal soil texture for optimum agricultural production is lacking in the study area. pH values ranged from 6.57 to 8.38 and 6.85 to 8.66 for the lower Swat and Upper Swat respectively representing the soil status as "Neutral to Alkaline".

Soil pH is considered a master variable in the soil as it affects many chemical processes. Lime in the study area ranged from 3.28% to 22.22% and 4.75 to 17.25 for

Table 3. Descriptive Statistics for Selected Physio-chemical Properties of Soil

Variable	Minimum	Maximum	Mean	S.D.	Skewness	Kurtosis	CV (%)
pH	6.57	8.66	7.63	0.60	-0.05	-1.04	7.86
EC	0.03	0.40	0.15	0.09	1.16	0.52	60
Lime	3.28	22.22	9.66	4.7	0.68	-0.46	49.61
P	1.88	155.4	47.12	45.12	0.64	-0.95	95.75
K	1.43	169.8	55.82	54.56	0.59	-0.94	97.74
Clay	0.6	15	8.30	3.73	-0.01	-1.01	44.92
Sand	3.6	57.6	25.85	11.99	0.28	-0.47	46.40
Silt	31.4	95.8	68.83	14.97	-0.10	-0.97	22.73

Table 4. Pearson Co-relation Coefficient between soil properties

	pH	EC (dS/m)	% Lime	P (mg/kg)	K (mg/kg)	% Clay	% Sand	% Silt
pH	1							
EC (dS/m)	-0.28	1						
Lime Cont.%	-0.03	0.25	1					
P (mg/kg)	0.24	-0.25	-0.55	1				
K (mg/kg)	-0.03	0.35	0.54	-0.74	1			
% Clay	-0.04	0.35	0.61	-0.67	0.78	1		
% Sand	0	0.18	0.54	-0.72	0.78	0.73	1	
% Silt	0	-0.23	-0.59	0.745	-0.82	-0.84	-0.98	1

lower and Upper Swat, respectively. The results showed that 83% and 95% of the soil were moderately calcareous in lower Swat while 17% and 5% in Upper Swat were analyzed as strongly calcareous. The quantity of soil lime content is most important from a soil fertility point of view. Electrical conductivity, a measure of soil salinity for the soil of Swat was mostly non-saline. Results have shown a range from 0.06 to 0.34 dsm1 and 0.037 to 0.403 dsm1 for lower and Upper Swat respectively. Phosphorus was found at 17% and 50% in low range, 26% and 40% in the medium while 56% and 10% in the high range for lower Swat and Upper Swat respectively. Phosphorus is an integral part of soil nutrition and helps in certain physiological and metabolic processes. Data for Potassium in lower Swat and Upper Swat depicted 13% and 80 in the low range, 52% and 35% in the medium while 56% and 10% in the high range respectively. Potassium is also an important soil nutrient and helps in certain functions like enzyme activation, photosynthesis, protein and starch synthesis, crop quality, resistance against disease, regulate water stress in plants, cold, and other adverse conditions.

3.2. Geospatial and Geostatistical Analysis

3.2.1. Statistical Analysis

The attributes of soil Physico-chemical characteristics were statistically analyzed, values of which are present in Table.3. The study area differed in the elevations due to which the attributes depicting the variation. The difference in the variance is also due to difference in samples of collection in field management techniques.

Application of fertilizers, irrigation systems, different depositional processes, etc., are responsible for the caused variation in the study area. Coefficient of variation (C.V) was determined which showed the dispersed distributed values for the samples. C.V for pH and Silt was calculated as least i.e., 7.86 and 22.73, respectively while other attributes showed the highest variation.

Table 5. Semi-variogram models and model parameters

Variable	Best Fitted Model	Nugget Effect	Sill	Dependency of Correlation (%)	Degree of Dependency
pH	Gaussian model	0.7	0.9	77	Moderate
EC	K-Bessel	0.10	0.15	66	Moderate
Lime	Gaussian model	0.5	1.4	35	Moderate
Phosphorus	Gaussian model	0.1	0.7	14	Strong
Potassium	K-Bessel	0.3	0.9	33	Moderate
Clay	K-Bessel	0.03	0.99	3	Strong
Sand	K-Bessel	0.59	1.01	58	Moderate
Silt	Gaussian model	0.50	0.97	51	Moderate

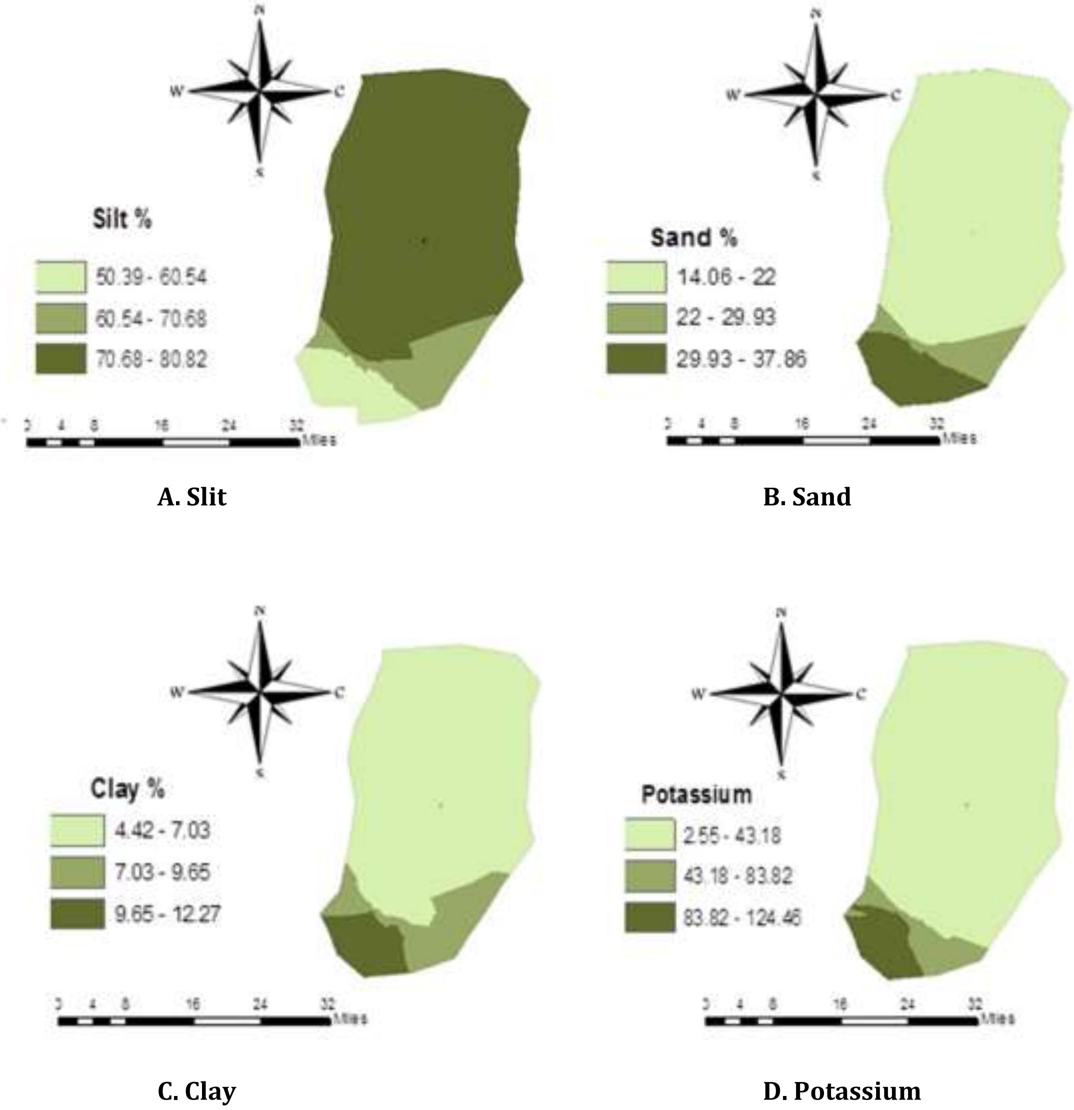


Figure 2. Interpolation Maps of Selected Physico-chemical Parameters of Soil. Distribution Maps of (A) Silt (B) Silt (C) Clay (D) Potassium

It is concluded from the study that pH and Silt of the study area are not affected while other attributes of the soil are affected including EC, Lime, P, K, Clay and Sand ratio. The lowest variance for pH is reported by many researchers like [11-13]. and hence this study is coinciding with other studies. While studying the range of variance, it was found that clay (CV= 44.92%) and sand (CV= 46.40%) were almost stable to each other while Lime (CV= 49.61), P (CV=41.93), K (58.62) were different among each by less than 10 %.

Pearson correlation illustrated in table 4 revealed significant correlation among various attributes. pH was found to be significant correlated with EC-K-clay-sand, lime with K-clay-sand, P with silt, K with clay-sand, clay with sand.

3.2.2. Spatial Dependency

Geostatistical analysis showed several semi-variograms and best-fitted models (table 5 and figure 3) for various Physico-chemical properties of the soil. Among the attributes, pH, Lime, and P were characterized by Gaussian Models while others were fitted in K-Bessel Models.

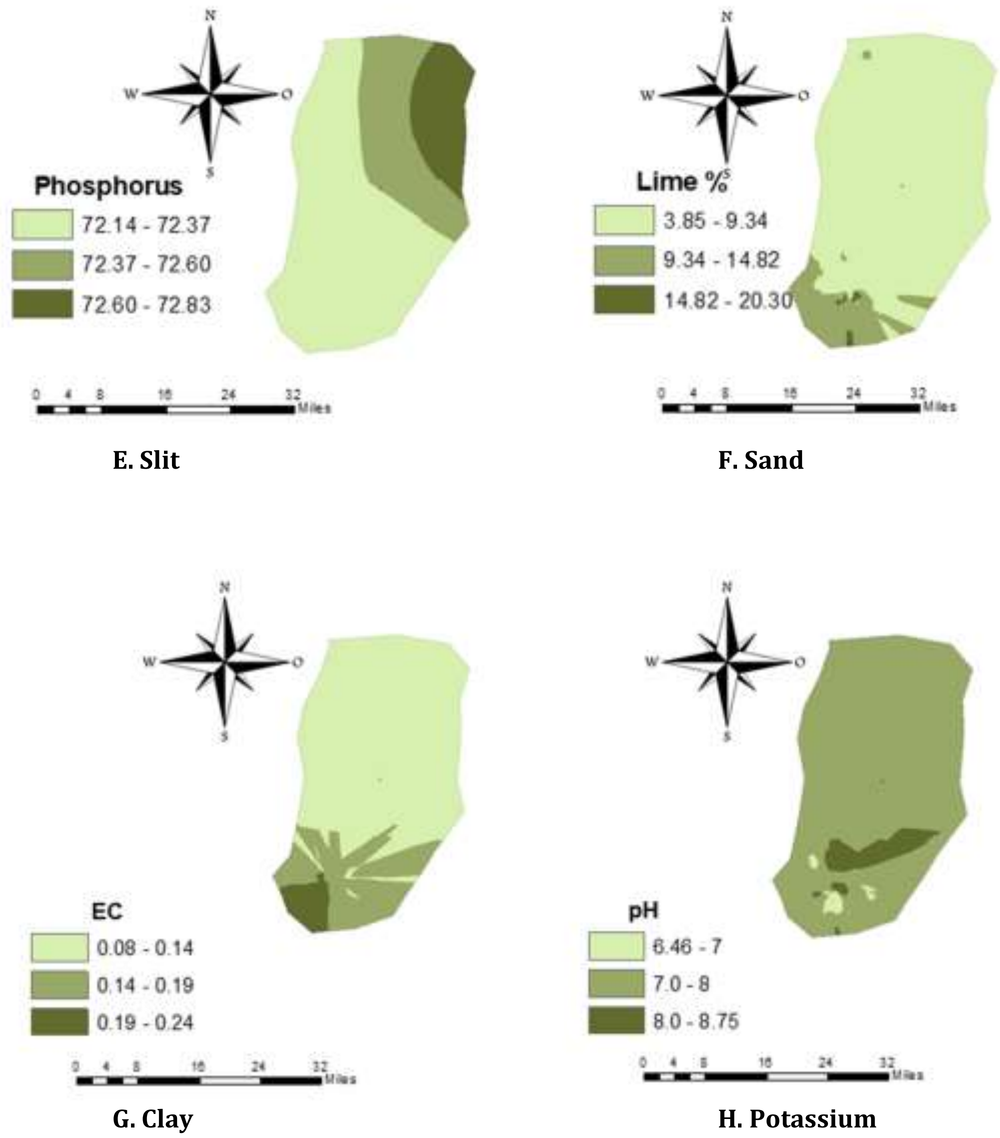
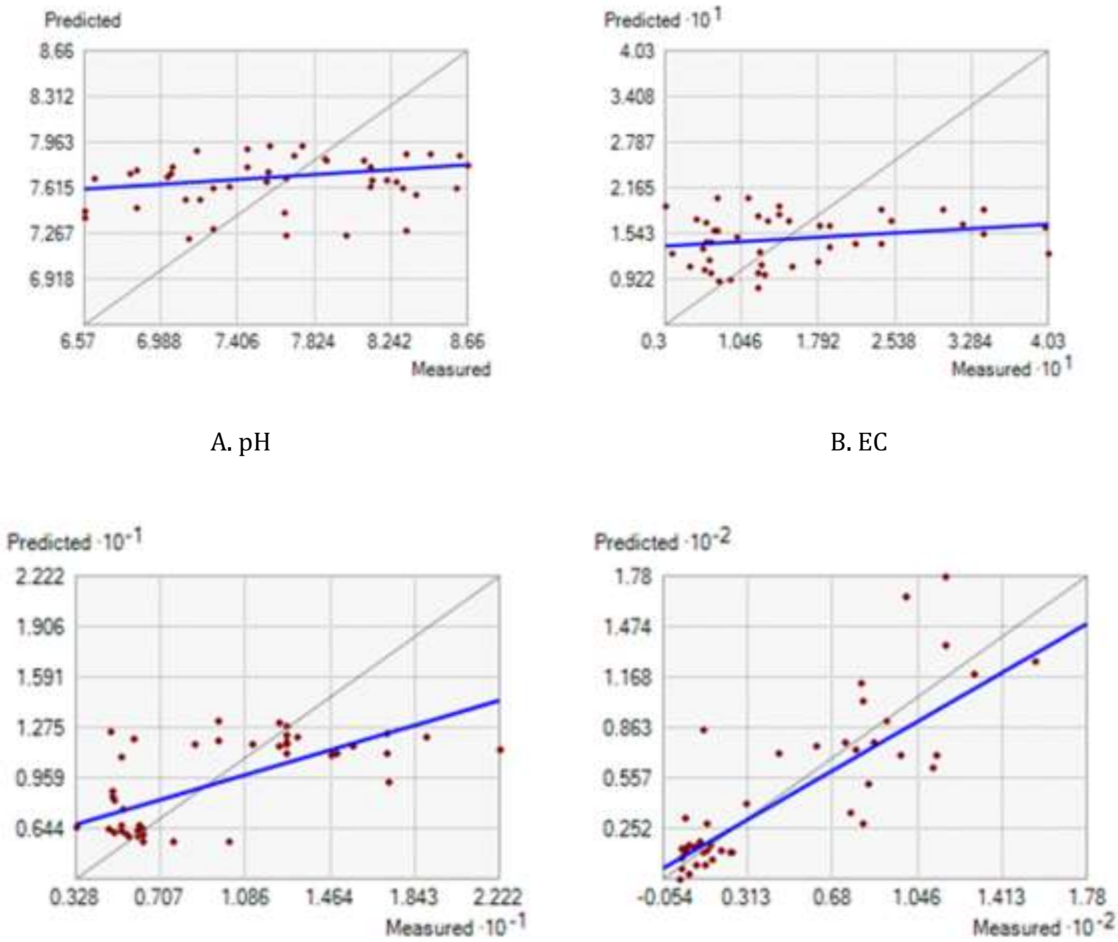


Figure 3. Interpolation Maps of Selected Physico-chemical Parameters of Soil. Distribution Maps of (E) Phosphorus (F) Lime (G) EC (H) pH

Similar models are proposed and reported by [13-15]. Nugget effect, an integral part of spatial variability depicted that neither additional sampling at a low range is required nor soil sample density is needed. Hence, the taken samples are appropriate and accurately mapped with [16-17]. In the present study, the highest nugget effect is measured for pH. Spatial dependency (nugget to sill ratio) in the present study (table 5) depicted that a large variance for Clay and P are introduced spatially while the rest of the attributes represented moderate variance except pH which showed a low spatial variance. The criteria for spatial variance are considered following [18]. As per Cambardella et al. (1994), a low ratio (< 25 %) indicates a stronger variance introduced to spatial analysis, while 25 % – 75 % shows a moderate and >75 % shows a low spatial variance [18]. Spatial Variance is influenced by certain intrinsic and extrinsic properties which include the formation of soil, application of soil, methods of farming, etc.



A. pH

B. EC

C. Lime

D. Phosphorus

Figure 4. Predicted Plots -Predicted values against soil attributes (A) pH (B) EC (C) Lime (D) Phosphorus

3.3. Kriging Models of Soil Physico-chemical Properties

In order to estimate the soil Physico-chemical properties for unsampled areas, optimum kriging techniques were used. Kriging Interpolation models are illustrated in Figure.1while the findings of cross-validation (table 6). Ordinary Kriging interpolation technique is widely used for soil attributes with minimum Root Mean Square (RMS) and Average Standard Error (ASE). It interpolates most of the variables for soil successfully [11]. In the given study, maximum error indicators were shown by potassium. The attributes for soil were cross-validated (table 6). The predicted values resulting after cross-validation against measured values (figure 2).

Kriging mapping represents the soil status i.e., the presence of silt in a higher ratio for the northern side, higher sand % in southern part while higher clay ratio in the southwest part of the study (figure 1). Other attributes like EC the pattern depicted low salinity in the study area (0.08 to 0.24) and hence doesn't affect the plant growth (figure 1, g). The study area is irrigated by River Swat flowing along. But the soil from the study is presented good drainage and aeration which washed out the salts and decrease the salinity. Mapping for soil pH showed an alkaline nature for the whole study area (figure 1, g). A few areas from the southern part of the study area (lower Swat) were slightly acidic while some areas situated in the eastern part were found strongly alkaline. Mapping for lime showed that the majority of the study area is moderately calcareous (3 % -15 %) while a couple of areas from the central and southern part are strongly calcareous (figure 1, f).

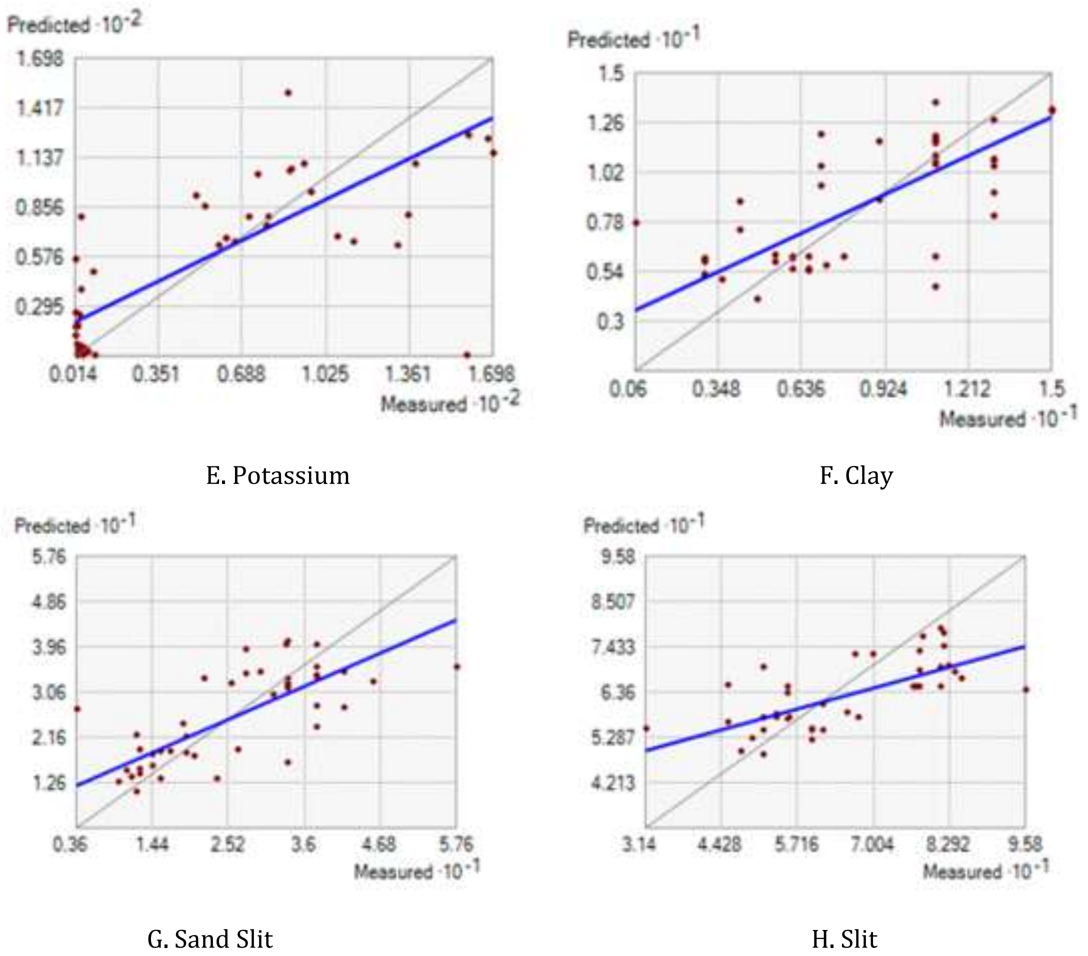


Figure 5. Predicted Plots -Predicted values against soil attributes (E) Potassium (F) Clay (G) Sand Slit (H) Slit

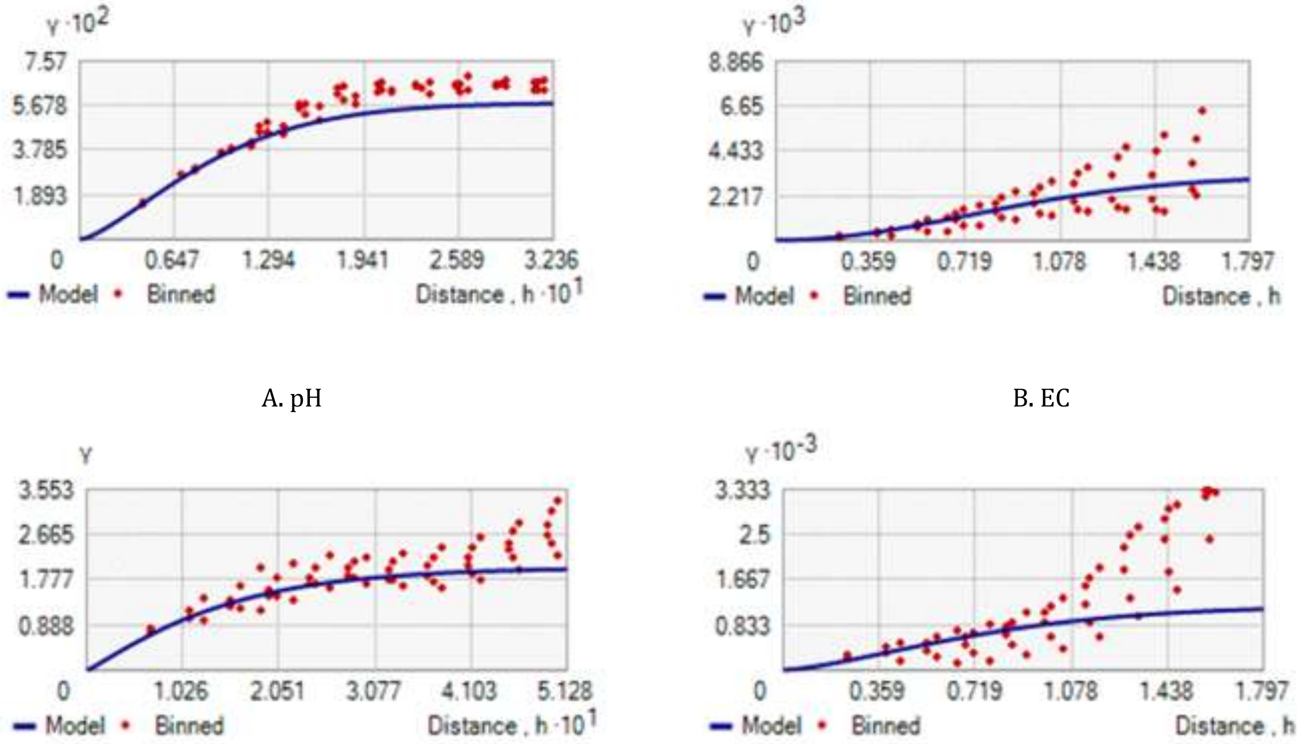
The soil is having lime in the moderate range and hence it represents no lime leaching. Distribution map for potassium exhibited low potassium concentration in soil for the northern side of the study area i.e., Upper Swat (figure 1, d). It can be due to the recent seasonal cultivation activities.

The northern-West part of the study area showed a high concentration of potassium present in the soil. The mapping of Phosphorus depicted low concentration of P in the lower swat followed by moderate and higher levels in the northeast part of the study area (figure 1, e). The imbalance in the soil nutrient has been detected which is a key point in planning crop management. The soil texture differs while going towards the northern side. Hence, P depletion in the lower swat while K depletion in the upper swat should be considered. Studies have proven that a strong spatial dependency of soil attributes is often controlled by intrinsic variation while extrinsic factors can better deal with the weak spatial dependency [18].

4. CONCLUSION

It was concluded from the analysis that soil texture for the Swat region is medium to coarse textured soil i.e., silt loam and loamy sand for lower and upper Swat, respectively.

The pH of the soil was slightly acidic to alkaline for the region and was non-saline. The majority of the soil was moderately calcareous in nature. AB-DTPA extractable P for the majority of the soil was in the high and medium



A. pH

B. EC

C. Lime

D. Phosphorus

Figure 6. Best fit semi-variograms for soil parameters - Predicted values against soil attributes (A) pH (B) EC (C) Lime (D) Phosphorus

range while AB-DTPA extractable K was in the medium and low range for lower and upper Swat, respectively.

The lowest and highest variation was observed for pH and K respectively. Strong spatial dependency was measured for P and Clay while moderate spatial dependency for the rest of the attributes. Ordinary kriging successfully interpolated each of the soil attributes. Different degrees of heterogeneity were observed via spatial correlation depicting different field management including extrinsic factors like land-use patterns, crop irrigation behavior, application of fertilizers, and intrinsic factors like soil erosion, aeration, and drainage system. The predicted maps are focused on soil management practices the experts will follow and educate the farmer's community. This can only be done if the spatial heterogeneous behaviour of the soil is taken into consideration. In order to optimize the crop yield, specific site management techniques are followed. Considering the results of this study, updated recommended fertilizer application rates can be managed for upcoming seasonal crops. A cropping system has a modest effect on the geospatial soil properties.

5. RECOMMENDATION

Based on the analysis, a detailed management plan based on site-specific soil tests for the application of fertilizers should be made as well as providing better awareness programs for the farmers.

Low P products like bone meal and pine mulches should be applied by the farmer's community in lower Swat,

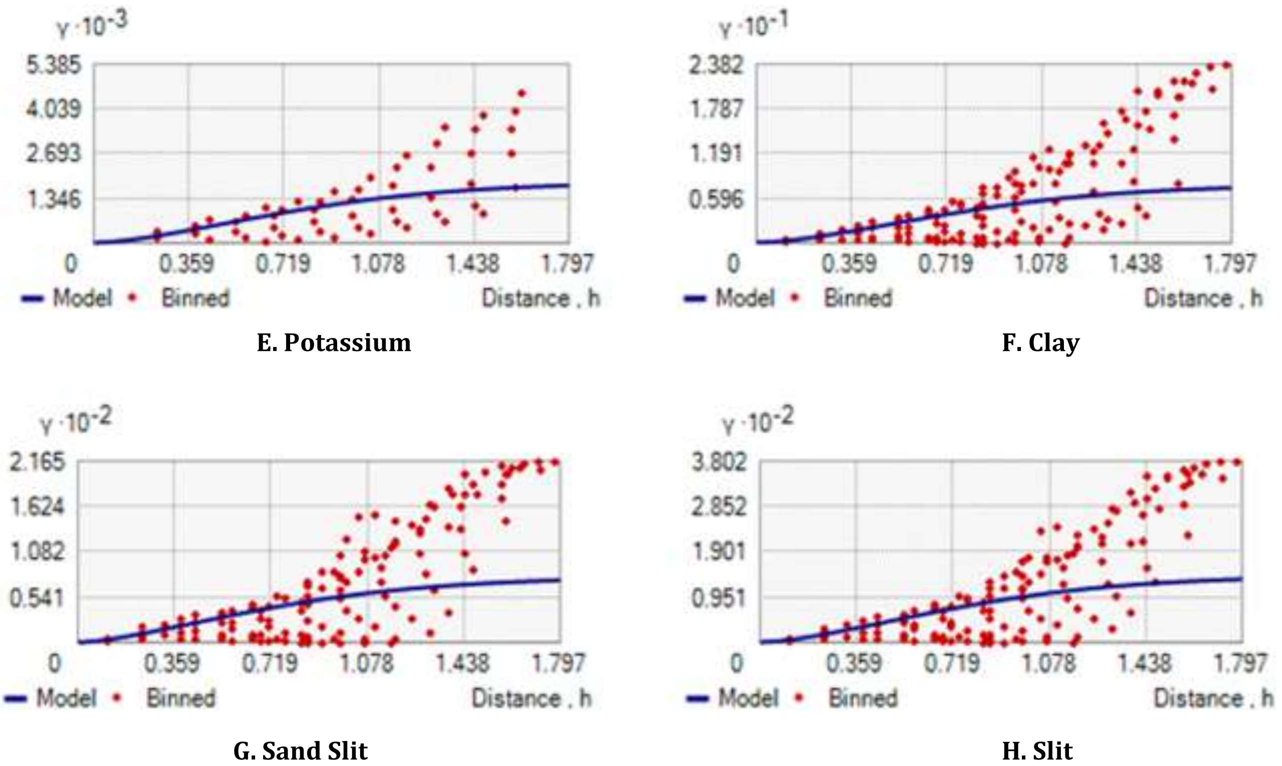


Figure 7. Best fit semi-variograms for soil parameters - Predicted values against soil attributes (E) Potassium (F) Clay (G) Sand Slit (H) Slit

while gypsum should be applied for the upper Swat areas.

6. ACKNOWLEDGEMENT

NA

7. CONFLICT OF INTEREST

The authors have declared that there is no conflict of interest.

8. SOURCE/S OF FUNDING

NA

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