Biological Forum – An International Journal **7**(1): 836-846(2015)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Analyzing Kriging and CoKriging Methods by using ArcGIS Software in Preparing SP map of Farahan Plain Soil

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(Received 07 January, 2015, Accepted 15 February, 2015)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Soil and water conservation is one of the most fundamental bases of sustainable development. Knowing the distribution manner of soil physical and chemical properties is one of the most important factors in recognition, management and exploitation of water and soil resources. Estimating the soil moisture curve plays an important role in modeling water and solutes movement through soils. Soil saturated moisture is among the most significant parameters in soil studies that is used for estimating the soil moisture curve and soil unsaturated hydraulic conductivity. This investigation was done with the purpose of investigating spatial variation of soil sp parameter by geostatistical methods and then selecting the most suitable method in estimating the above-mentioned parameter in Farahan area. For this purpose, at first, 54 soil samples were taken from the given area. Then, the soil samples were transferred to the lab for determining the soil saturated moisture (sp). After determining the sp values, data were inserted to GIS software. Afterward, the interpolation map of soil saturated moisture was prepared by interpolation and ordinary kriging. The results obtained from interpolation method showed that among the various models, Spherical model with nearest RSS value to number 1 was chosen as the best map. According to the map prepared by this method, the spatial variation of soil saturated moisture in the direction of westnorth-eastsouth of the area was more. While in the direction of eastnorth-southwest there were gradual changes.

Keywords: Soil saturation moisture, GIS, Interpolation, Kriging, Farahan.

INTRODUCTION

Investigating the structures by considering interaction effects of soil and structures can help us in correct understanding of structure`s behavior. However, the issues associated with soil and structure interaction are usually handled by considering the foundation which is fixed to soil.

The force which caused water to be absorbed by the soil is called soil moisture suction force and the more water in the soil, the less suction force. If a soil is saturated with water, this force will reach to zero, and by increasing the dryness of soil, this force will increase. Under the same suction force, clayey soil can hold much more water than sandy soils. Also, under the same moisture percentage, sandy soil can hold water by much less suction force than clayey soil. Engineering properties of soil depends on complicated and mutual effect of several factors. These factors can be classified into two groups as composition and environment. The first group shows the potential soil properties like the type and amount of minerals, the kind of adsorbed cations, the shape and size of soil particles. The second group includes real and actual soil properties like soil water, density, structure and temperature. Forecasting soil behavior in different conditions according to the environmental and soil factors is difficult. However, the mail factors which affect soil behavior are clay activity (the ratio of plasticity index to the amount of clay), pH, exchange cations, leaching, and diffusion factors.

The significance of forecasting soil behavior in establishing soil structures in places like Water spreading stations in which soil embankment, torkinsts for obtaining and distributing water are used in conditions that used soils are diverged or sensitive to divergence, the stability of these structures will be questionable.

Among the chemical properties of diverged soils and their sensitivity to demolition and slackening, we can mention the amount of sodium, calcium and magnesium, lime, gypsum, exchange cations, texture and the kind of clay minerals. One of the most obvious cases of cation effects is sodium and/or its salt compounds like sodium carbonate which cause pasty, diffusion and divergence of soil, and in the opposite side there is neutralizing factors of sodium like calcium and magnesium that have the role of balancer and converging in soil.

Irrational use of land by human is applicable in two aspects of management and exploitation manner. Therefore, in order to use soil and water in an optimum way and making the least environmental consequences, evaluating the environmental power can be used as a solution (Zarei and Mirsepas 2007). Soil is one of the valuable capitals the plays a principle role in agricultural production, natural resources and environment. Soil is a suitable place for growth and development of plants and creating vegetation, and if this valuable capital is not protected, the shortage of food, soil erosion and destruction of natural resources will happen (Nosratpour *et al.*, 2010).

The first experiences for using statistical methods based on geostatistics in soil science was started by analyzing pH and sand in soil by using a variugram function by Campbell (1978) (Mohammadi1998). In the previous two decades, several studies were conducted about spatial investigation of soil salinity and its interpolation by using geostatistical methods (Kaydani and Delbari 2012). Accordingly, in this part a summary of investigation results about preparing soil salinity map is provided.

The theory of geostatistics in Iran, in the fist time was used by Hajrasuliha *et al.* (1980) for analyzing spatial variations of soil salinity in which a comparison was done between classic statistical methods and geostatistics for salinity studies in sugarcane fields of Haft tappe, Khoozestan province, Iran. According to the results, spatial dependency of soil salinity data that naturally occurs in some fields, provides a better estimation of salinity by using geostatistical methods.

Darvishsefat and Damavandi (2000) investigated the possibility of using satellite data in recognition and classification of saline land by numerical method in a small part ofHoz-Soltanlake in Ghom province, Iran. The results showed that if in time data is available, then this data can be used for classification of saline land to various categories.

Abdi and Abdi (2001) investigated the variation trend and development of saline land in Ghazvin plain in Iran by using RS-GIS. The results showed that fertile plains such as Ghazvin plain are exposed to the risk of being saline.

Pishkar (2004) prepared a soil salinity map by using geostatistical method. In this method, after sampling and by using geostatistical method, interpolation and preparing the map of soil pH and EC were done. This method was performed by fitting a mathematical model to the model obtained from variance variation relation as a function of points distance from each other (variography) and then by performing the kriging practice (that is actually a kind of interpolation) the salinity map was prepared.

Pashazadeh and Zeynali (2011) prepared the map of soil pH and salinity by using GIS and geostatistics in the east of Khoy in Azarbayjan-gharbi province, Iran. The results of this investigation showed that the least mean absolute error (MAE) for pH is related to discontinuous kriging with exponential model and for EC is related to simple kriging with spherical model.

Shahriyari *et al.* (2013) investigated the spatial variations of soil salinity in different depths by using geostatistical methods in Gharve in Kordestan province, Iran. For estimating salinity, kriging methods, IDW and GIS and GS+ were used. Results showed that in the depth of 0-30 cm and 60-90 cm, the best model for variogram analysis is gossy model, and in the depth of 30-60, the best model is spherical model, and in the depths 0-30 and 60-90 cm, the IDW method has more accuracy in comparison to kriging method, and in the depth of 30-60 cm, the kriging method has more accuracy than IDW method in estimating points with known coordinate and preparing soil salinity map of the given study area.

Hosseini *et al.* (1993) used the methods of the nearest neighbor, kriging, mobile mean, reverse distance and TPSS for preparing maps of iso-salinity. The results showed that the accuracy of all the models is low because of high ratio of piece effect to threshold. Nevertheless, TPSS and common kriging methods are the most accurate methods, while the nearest neighbor method has the lowest accuracy.

Tarr *et al.* (2005) prepared a salinity map by cokriging method. They examined various helping variables including clay, soluble calcium, soluble magnesium, Argilic horizon depth and bed rock depth, and finally, introduced the amount of clay as the appropriate helping variable for forecasting salinity in Cokriging method.

Eldeiry and Garcia (2009) compared the capability of cokriging and regression kriging methods in preparing soil salinity map. The results showed that the method of regression kriginghas higher efficiency than cokriging method, and the former method could anticipate small local variations in soil salinity properly.

Khaksaran *et al.* (2013) investigated the temporal and spatial variations in soil salinity in Orumiye, Iran by using geostatistical methods including kriging, cokriging and weighted mobile mean. The results showed that the method of kriging and semi-variogramgossy with correlation coefficient of 1 for 1967, and 0.97 for 2007 were the best anticipating models.

Akramkhanov *et al.* (2014) investigated the soil salinity by geostatistical monitoring by using electromagnetic induction and linear regression model in a region of Uzbikistan. Results showed that in 2008 to 2010 most parts of this region was not saline, and there is a low probability that critical threshold of salinity exceeds8 dSm^{-1}.

MATERIALS AND METHODS

A. The study area

Farahan plain has the surface area of 35297.87 hectare and geographical coordinate of 49° 35` 9`` to 49° 47` 27`` east and 33° 08` 24`` to 34° 24` 19`` north that occupies a relatively large part of the Mighan basin. Fig.1 shows the location of the study area.

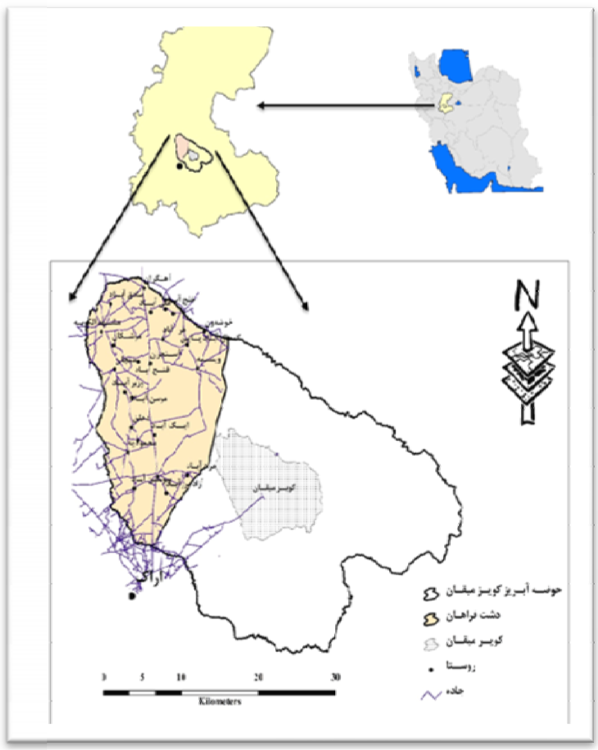

Fig. 1. Location of study area.

B. The method of investigation

(i) Geostatistical methods: One of the methods of investigating spatial variations in qualitative variables is using geostatistical method. The main difference of this method with classic statistic is that in classic statistic, the samples taken from a statistical community are independent from each other, and the presence of one sample does not show any information about the next sample. But geostatistical methods investigate the presence of spatial correlation among the amounts of a variable in a region. Totally, it can be said that geostatistics investigate those group of variables that has spatial structure, or in other words, there is a spatial relation among different amounts of them, distance and the direction of arrangement (HasaniPak 1998). Therefore, geostatistics is a combination of technics and accidental models that analyses the properties of spatial data. This technic has the capacity and power of estimation, and also can express the estimation error.

Developing new technics like geostatistics solves the problem of collecting data in precision agriculture, and makes it possible to prepare maps of logic accuracy by collecting less data (Burgess and Webster 1980). Geostatistical methods like kriging has a lot of usages in soil science studies because of providing the best linear non-skewed estimation for determining the unknown values on regions which taking samples is not done in them (Odeh *et al.* 1995).

(ii) Kriging geostatistical estimator: Estimating the variable values with spatial structure and distribution and evaluating the error associated with this estimation is called Kriging (Davis 1973).

Kriging is a geostatistical estimator that Mathron called it kriging in the honor of D.G. Krige (Bagheribedaghabadi *et al.* 1384).

Kriging method is based on the weighted mobile mean and is the best non-skewed estimator that determines the estimated values and also estimation error in each point. In the last decade, kriging was introduced as a powerful technic for interpolation and is used in various fields of earth science including hydrology, soil science, and mineralogy (Xu *et al.*, 2006). One of the most important characteristics of kriging is that it pays attention to the spatial structure of points in the process of estimation, and in each estimation, the associated error can be calculated (Hasanipak1998).

This estimator which is also called BLUE (Best Linear Unbiased Estimator) has the following properties (Bagheribedaghabadi *et al.* 2005):

1. The estimated values for unknown points are linear combinations of adjoining samples. It means that:

$$\hat{\mu}_k = \sum_{i=1}^{n} \lambda_i x_i \quad (1)$$

Where $\hat{\mu}_k$ is the kriging estimation and λ_i is the vector of weights assigned to samples. In other words, an estimated or kriged value is obtained by attributing weights of λ_i to known values measured in adjoining point.

2. It is non-skewed. It means that its mathematical expectation is equal to the real mean (μ_w) of samples.

$$E(\hat{\mu}_k - \mu_w) = 0 \quad (2)$$

3. Mean square of error has the lowest value possible. It means that:

$$E\left[(\hat{\mu}_k - \mu_w)^2\right] = \text{a} \quad \text{min} \quad (3)$$

The most common kriging method is ordinary kriging, and it is supposed that the mean value is constant, but its value is not known. Therefore, local variable in estimation space is an unknown value.

The generalized form of kriging is called cokriging. In some cases it is possible that sampling from one variable does not done adequately, and evaluating its distribution faces a problem. In this case, it is possible to correct the evaluation by considering the correlation and spatial relation of this first variable, with a second variable that has suitable samples. By using cokriging, evaluation is done in parts that has lack of sample by using the correlation among given local variables and also helping variable. From the theoretical point of view, cokriging is preferred to kriging method and it is a kind of generalizing one-variable kriging method. If the correlation among two variables is more than 0.5, then the estimation error is reduced significantly by this method.

(iii) Covariogram: Covariogram is a criterion for measuring the similarity between quantity values of two local variables with distance h from each other. The variation trend of Covariogram is opposite of variogram (Fig. 2). It means that in variogram, the difference of two points with small distance is zero, because the similarity of these two points is high, so in covariogram the highest value possible is shown.

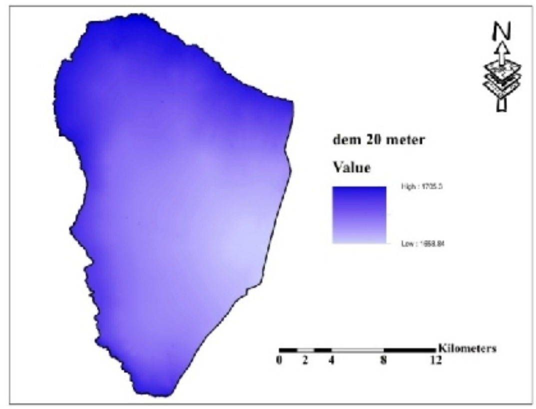

Fig. 2. The map of digital elevation model for study area.

The relationship between variogram and covariogram is as the following formula:

$$\gamma(h) + C(h) = S^2 \quad (4)$$

In the above formula, C(h) is equal to covariogram, and S^2 is equal to the variance of all data. According to this relation, the sum of variogram and covariogram is equal to the variance of all data.

The aim of semi-variogram/covariance modeling is determining the best fit for the model that passes through semi-variogram points. The process of fitting semi-variogram model for recording the spatial relations of data is called variography. Semi-variogram is a graphical demonstration for presenting an image of spatial correlation of data. In geostatistical analysis, at fist the delay dimensions suitable for grouped semi-variogram values are determined. The delay dimension is a dimension of distance class in every couple of grouped conditions for reducing the high number of possible combinations. According to Fig. 3, for having a clearer image from semi-variogram values, imperical semi-variogram values (red points) are grouped according to separation distance coincident to them. Therefore, points are splited in tow phases, and the delay dimension shows how extension of each distance occurs, and this process is called bining (Geostatistical Analyst Tutorial, 2010).

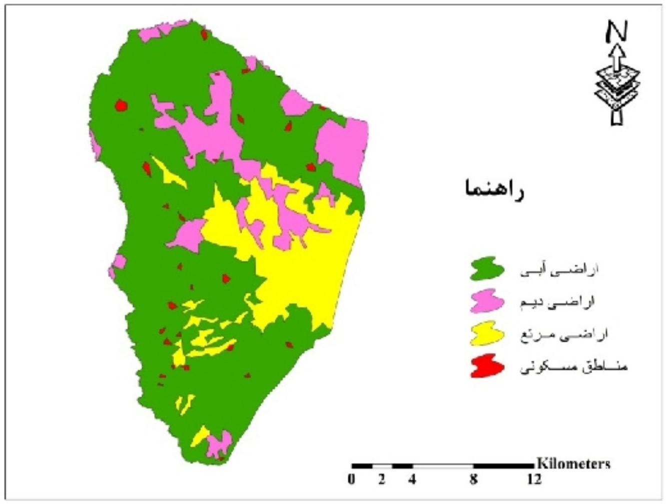

Fig. 3. The land use map.

DISCUSSION

A. The Geographical Information System

In the present study, physiological parameters of Farahan plain including area, circumference in GIS by using the technic of geographical information system and based on the map of Digital Elevation Model (DEM) was extracted and the results are shown in Table 1.

The maximum elevation of this area is 1705 m and the minimum elevation is 1658 m from sea level. Fig. 2 shows the map of digital elevation model in the study area with pixel sizes 20 meter. As can be seen in the map of digital elevation model, since this area is even and flat, there is not so much difference in elevations and it can be said that this area does not have much topography.

Table 1: The area of different land uses.

Type of land use	**Area (Km^2)**	**Percent of area**
Irrigation agriculture	232.97	66.28
Rainfed agriculture	51.02	14.51
Pasture	64.41	18.32
Residential land	3.12	0.89
Total	352	100

B. Land use map

The land use map was prepared from natural resources and watershed management organization in Markazi province, Iran. As can be seen in Fig. 3, most lands in the study area are assigned to water cultivation. Table 1shows the area of each category and land percentage related to that category for the study region.

C. Data of soil sp

Table 2 presents the data of soil saturated moisture (sp) in study region of Farahan. It also shows the indexes of explanatory statistics including minimum, maximum, mean and standard deviation of data.

Table 2: Data of spin study area of Farahan.

Code	X	Y	S_P_
1	376977	3791189	45
2	376389	3788791	41
3	387864	3795561	33
4	378857	3806204	36
5	387471	3798798	29

Code	X	Y	S_P_
6	371954	3800055	35
7	379531	3790371	41
8	371883	3798440	41
9	371453	3803545	39
10	373589	3798934	41
11	382599	3783916	37
12	379917	3785735	39
13	371639	3800491	37
14	384563	3800726	30
15	381999	3801538	35
16	380561	3803414	38
17	376621	3806791	37
18	374370	3805978	37
19	375183	3804102	37
20	372994	3802539	37
21	377809	3804790	36
22	377246	3802789	37
23	374808	3801351	38
24	379560	3801226	37
25	376684	3799537	39
26	378622	3799662	37
27	381499	3799412	36
28	384625	3797974	33
29	386439	3796161	32
30	383062	3796286	34
31	383625	3794222	36
32	386064	3793034	36
33	385626	3791220	37
34	380623	3796161	37
35	381561	3793284	38
36	382624	3791346	37
37	382874	3789094	37
38	382624	3786468	38
39	380748	3788469	38
40	381436	3783842	36
41	379372	3782403	36
42	378309	3779527	37
43	376496	3781215	37
44	377496	3784092	38
45	375183	3784279	39

46	376746	3786218	40
47	378685	3787594	41
48	373557	3787906	42
49	373369	3791721	45
50	376246	3793347	45
51	378434	3793284	43
52	374182	3795910	40
53	378372	3796161	40
54	375433	3798099	40
Maximum			29
Maximum			45
Mean			38
Standard deviation			3

Table 3: Results of index normality.

N		55
Normal Parameters[a]	Mean	38
	Std. Deviation	3
Most Extreme Differences	Absolute	.242
	Positive	.132
	Negative	-.242
Kolmogorov-Smirnov Z		1.798
Asymp. Sig. (2-tailed)		0.1003
a. Test distribution is Normal.		

D. The results of normality test

At first, the normality of data was tested in SPSS software. The results showing the normality of data is presented in Table 3. According to this table, if Sig for all indexes and also for land harvested data is more than 5 percent, then the zero hypothesis is failed and data are normal. As can be seen in Table 3, all parameters are in normal condition.

E. The results of examining spatial variation trend in soil sp

Fig.4 shows the trend in spatial variation of soil sp in Farahan region. About spparameter, results showed that the trend line in green with values in the furthest end of Y axis (west of region) has a gradual reducing trend and then it has an extraordinary reducing trend in X axis (east of region). But blue trend line from the furthest end of X axis (south of region) in Y axis (north of region) shows a gradual reduction.

According to above couple curves (green and blue), order to trend removal was interpolated as Fig. 1-5. About the parameter sp with the goodness of fitting equal to 1.789, the results showed that spatial variations in the direction of westnorth-eastsouth were more. But there is a gradual variation in the direction of eastnorth –westsouth.

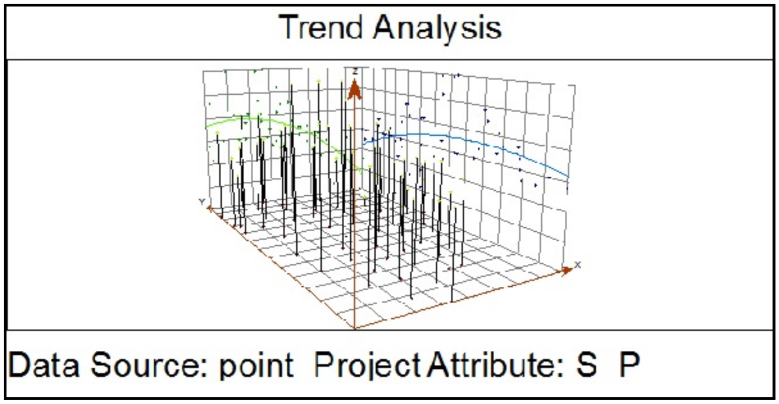

Fig. 4. The experiment of spatial variation trend in hydraulic conductivity of soil saturated moisture.

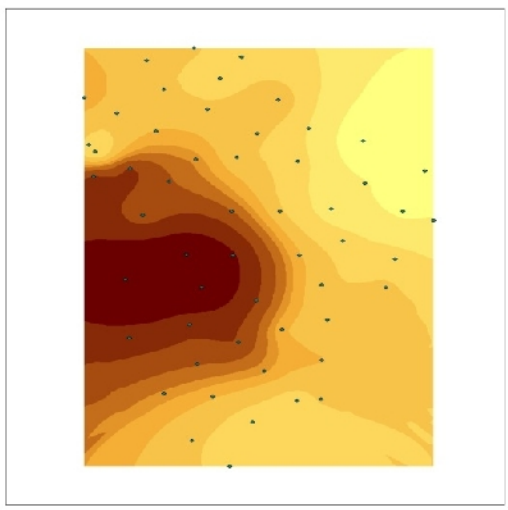

Fig. 5. Spatial variation trend in soil saturated moisture.

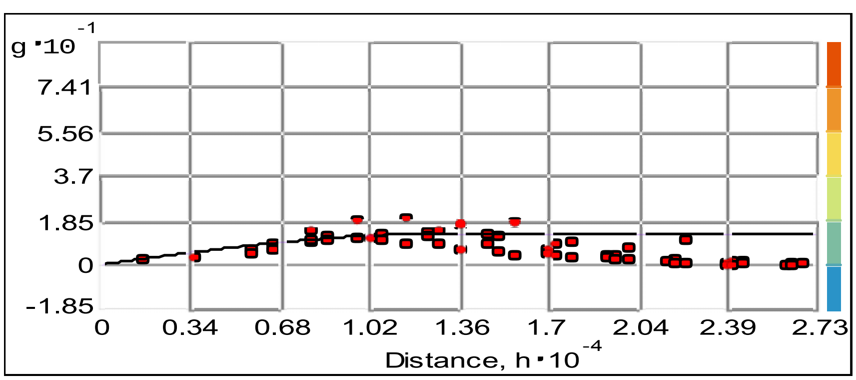

Fig. 6. The semi-variogram model of soil saturated moisture in Farahan region.

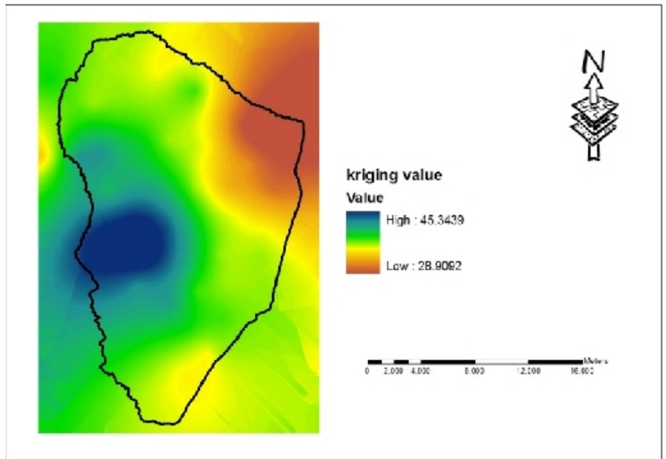

Fig. 7. Interpolation map of soil sp in study region by using Spherical model.

F. The model of semi-variogram

The model of semi-variogram for data of soil saturated moisture of Farhan region is shown in Fig.1-6. According to the semi-variogram model, the values of model parameter are presented in Table 4. Based on these results, in the model of sp semi-variogram, the partial threshold is zero and the line is without slope. It shows that the phenomenon is relatively regular and there is not sp monotony in the region. In fact the reason is related to the following factors:

(i) The errors arising from sampling, preparation and sample analysis.

(ii) The dimensions of harvest network and scale effect.

(iii) Weak or lack of spatial structure.

Table 4: The anticipated error values obtained by kriging method.

Type of error	**Value**
mean	0.0128
Root mean square error	0.1519
Mean standard error	0.1764
Standardized mean square	0.017
Standardized mean square error	0.9969
Number of samples = 52	

Table 5: The results of using different interpolation methods.

Method type	Model type	Sector type	Anisotropy	RMSS
	Circular	Four	No	0/9792
	Spherical	Four	No	0/9969
	Tetraspherical	Four	No	0/9612
	Pentaspherical	Four	No	0/9532
	Exponential	Four	No	0/9782
Ordinary Kriging	Gaussian	Four	No	0/9552
	Rational Quadratic	Four	No	0/9862
	Hole Effect	Four	No	0/9679
	k-Bassel	Four	No	0/9572
	J-Bassel	Four	No	0/9604
	Stable	Four	No	0/9271

G. Preparing soil salinity map by using geostatistics

In order to obtain the interpolation of soil saturated moisture, kriging method by using changing pattern of all direction sight was used. The map of soil sp in Farhan region in GIS space was interpolated by using kriging approach and ordinary kriging. The results are shown in Fig.7 as aninterpolation map.

In this part for selecting the best approach and consequently for selecting the best model, the RMSScriterion was used. For each model, more close the parameter to number 1, the better the interpolationmodel is. Table 4 shows the anticipated error values obtained by kriging method for data of soil electrical conductivity.

As can be seen in Table 5, Spherical model from the ordinary kriging was chosen as the best method according to RMSS which has the most closeness to number 1.

CONCLUSION

A. Investigating the indexes of data descriptive statistics

In this investigation, by sampling from 50 points from a 500 hectare area in Farahan region, the soil saturated moisture was measured and used for preparing interpolation maps. But at the beginning of the research, the indexes of data descriptive statistics were investigated. In investigating the normality of data it became clear that data has more skewness and pull relative to sp data. The skewness and pull for data were 0.698 and 9.03 respectively and for sp data were 0.3 and 1.95 respectively. Therefore, they are in the range of +2 to -2, and sp is normal. So they can be used with definiteness in other steps of statistical analysis.

B. Investigating the special variation trend in soil sp

About the special variation trend in sp, the results showed that in the direction of west-eats, soil sp in the west of region is low and by moving to the east, the values increase. But in the direction of north-south, soil sp reduces by moving toward the south. About the parameter spatial variation trend, results showed that in the direction of west-east, soil has gradual increasing trend and then gradual decreasing trend. Therefore, the highest soil saturated moisture is found in the middle of region. In the direction of north-south, soil spis reduced by moving toward the south.

Based on the overlap seen in the sp and soil parameters spatial variation trend it can be concluded that the highest recorded values are related to the north of region, and by moving toward the south of region, the soil quality will be better. Moreover, the results of couple curves showed that spatial variation of soil sp in the directionof westnorth-eastsouth is more. But spatial variations show that the direction of eastnorth-westsouthhas more variations than the direction of westnorth-eastsouth.

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