Journal of Soil Science and Environmental Management Vol. 3(2), pp. 36-41, February 2012
Available online at http://www.academicjournals.org/JSSEM
DOI: 10.5897/JSSEM11.031

Full Length Research Paper

Preparing of the soil salinity map using geostatistics method in the Qazvin Plain

M. T. Nezami[1]* and Z. T. Alipour[2]

Department of Agriculture, Karaj Branch, Islamic Azad University, Karaj, Iran.
[2]Department of Agriculture, Damghan Branch, Islamic Azad University, Damghan, Iran.

Accepted 12 July, 2011

In land evaluation, soil salinity is a limiting factor of plant growth in most suitable land systems. In order to prepare map salinity of south Qazvin Plain with sampling topsoil sample of 0 to 30 cm, electrical conductivity (EC), clay and pH of soil samples were measured. Finally, to provide the salinity map of topsoil, the accuracy of the several common methods of interpolation including Kriging, CoKriging, Spline, and Inverse Distance Weighted was evaluated. The results showed that Co-Kriging method by using auxiliary variable like clay had the lowest mean absolute error (MAE) (0.5) and root mean square error (RMSE) (108) compared to the other methods.

Key words: Kriging, salinity, interpolation, Qazvin Plain.

INTRODUCTION

A review on studies shows that the saltiness of the soil and water resources is a pandemic problem in more than 100 countries and more than 20% of irrigated lands of the world are inclined to be salty. Each year 50 to 100 thousand hectares of arable land turns to waste land as a result of sodic saltiness. The saltiness has negative environmental impacts besides direct reduction on agricultural production. The saline soils are widespread in a wide area of the country. Saline soils are scattered in different areas and places over the country and are able to threaten the adjacent lands to be salty. The issue of saltiness and saltiness of the adjacent arable lands is one of the most important problems in agriculture sector which must be controlled by appropriate and accurate scientific management methods and policies. In this way, the initial step is the identification of salty regions and providing the saline land map of the country.

Climate, natural drainage, topography, geological structure and distance to the sea are natural factors and inappropriate methods of irrigation. Inappropriate drainage and poor land management are other cropping factors which impact on land saltiness. Surveying the soil saltiness maps is recognized as an important toll in decision making in macro level and can help policy makers to adopt appropriate management systems with consideration of economical aspects. Nowadays researchers are trying to utilize the different methods in identification, estimation and preparing of saltiness maps. Certainly, lowering the cost and time spent besides maximizing the accuracy of the maps is the most important objectives of the researchers.

In this way, satellite images and geostatistic techniques can be utilized as an efficient tool in land saltiness surveying. Researchers can utilize a variety of different geostatistic methods to estimate consistent variables such as saltiness, hydraulic conductivity and precipitation in places where sampling is not feasible. Hosseini et al. (1994) used average techniques to analyze soil saltiness and plotting land saltiness maps. In this study they assessed four average techniques to imply saltiness as a map, ordinary Kriging, moving average of inverse distance, thin plate smoothing splines (TPSS). For appraisal of accuracy, the cross sectional technique was used. The results showed that TPSS and Kriging methods provided more accuracy. Mohammadi (1387) used geostatistics to study the saltiness of Ramhormoz Region. In this study, 600 samples were collected in 500 m distance and in 3 different depths of 0 to 50, 50 to 100 and 100 to 150 cm.

To determine the displacement of the saltiness in

*Corresponding author. E-mail: eliaskhajavi@yahoo.com.

different depths of soil, a Variogram has been used which is a statistical function for analyzing the structure of geographical variables displacement. The comparison between saltiness maps is derived from Kriging and open geodesy methods in the study area performed by criteria data. Results show that the general similarity between criteria data and results of Kriging technique was about 40% whereas it was about 36% for the saltiness that resulted by open geodesy.

Besides, the results confirm that the maps derived by Kriging method are more reliable to determine the S_0 and S_1 saltiness classes (75%) in comparison with saltiness maps derived from Open geodesy (about 50%). The results confirm that we can use statistical methods derived from Geostatistics theories besides ordinary methods to survey the saltiness maps. Moustafa and Yamato (1998) utilized different geostatistics methods to analyze the saltiness and hydraulic conductivity of soil.

By comparing the measured quantities and estimated quantities, they found that the Kriging method provided more logical maps for drainage studies. In this study, to provide the saltiness map of some part of Qazvin Plain, soil samples were collected from 0 to 30 cm depth. Electrical conductivity (EC), texture and pH of soil samples were measured and the accuracy of different geostatistics methods such as Kriging, Co kriging, Spline and inversion of weighted distance were assessed to provide the most accurate saltiness map of the Qazvin Plain.

With the advent of geographic information system (GIS) packages and the generalization of spatial interpolation techniques, maps of environmental parameters such as those relevant for soil erosion have become frequent. For example, several authors have used GIS techniques to map the factors of the RUSLE equation by means of interpolation methods (Shi, 2004; Lim, 2005; Mutua, 2006; L´opez-Vicente et al., 2008). There are a number of statistical methods available such as regression models; local interpolators such as the inverse distance weighting (IDW) or thin plate splines, or geostatistical techniques such as kriging (Borrough and McDonnell, 1998). Recent studies, mostly in the field of Climatology (Ninyerola and Pons, 2000; Vicente-Serrano et al., 2003; Beguer´ıa and Vicente- Serrano, 2006) highlighted the interest of finding the method with the best adjustment to the observed data.

MATERIALS AND METHODS

The study area is about 15000 ha of eastern part of the Qazvin Plain which is located between 50° 7' 4'' to 50° 28' 27'' of Eastern longitude and 35 49' 57'' to 36° 3' 19'' Northern latitude.

The total area of Qazvin Plain is about 450000 ha. This plain is a wide alluvium plain which is formed by sedimentation of superficial flows of neighboring mountains. The elevation of the plain varies from 1150 to 1500 m where the elevation of the mountainous regions varies from 2600 m in south to 2900 m in eastern north. As a result of flatness and gentle slope of the plain, there is no significant drainage performed. General slope of the plain is toward east and the magnitude of the slope is 3% in outskirt of the mountain and less than 1% in marshlands. The annual average temperature of the plain is 13.2°C and annual average precipitation is about 304.4 mm.

At first, the limits of the study area were determined by using the numerical maps of the elevation, the boundaries of the area and digital map of rural districts and the coordinates of the sampling points were determined. Then the locations of sampling points were identified by global positioning system (GPS) and samples were collected from 0 to 30 cm depth. Total number of 50 samples were collected and transferred to the laboratory. The saltiness, the ratio of argil and pH of the samples were measured.

RESULTS AND DISCUSSION

To study the distribution of the data and to give a summary of the statistical information and distribution of frequencies, such as average, mean, minimum, maximum, deviation, skewness and elongation were analyzed by SPSS software.

Variable distributions were performed by Smirnof colmograph to study the normal tests. Statistical descriptions of the variables of this study are summarized in Table 1. The normality test of data by Smirnoph kolmograph test showed that the saline variables have normal distribution but the distribution of argil ration and soil reaction are not normal.

To compile the map of saltiness, various interpolation methods were assessed. These methods include inverted weighted distance with 1, 2 and 3 powers, Spline, Kriging and co kriging. The results of different methods of interpolation are compared in Table 2.

The comparison of different methods showed that the invert of weighted distance method with 2 powers and root mean square error (RMSE) and resulted in the least error (132) and on the contrary, the invert of weighted distance method with 1 power resulted in the biggest error (145.7).

The mean biased error (MBE). of aforementioned errors are 0.7 and 0.3, respectively (Table 2). With this method, the least saltiness belongs to northern east of the study area which shows 4.5 for electrical conductivity (EC).

Less than 2% of the area includes less than 8 dS/ m^2 of EC and more than half of the area shows more than 200 dS/ m^2 as EC. The average (Mean) of EC in the area is 143 dS/ m^2 (Figure 1).

Among the different Spline methods, the Spline with tension method and abstract mean error of .82 and r^2 of 128.8 has the biggest error. In Figure 2, the rain erosive map that resulted by different Spline methods are demonstrated. Based on this map, in about 6% of the area the salinity is 4 to 16 and in 70% of the area the salinity is more than 16. Based on this method, the average salinity of the area is 150 dS/ m^2.

The first step in using the Kriging method is to study the existence of spatial structure in data by using exponent

Table 1. Descriptive data of EC, pH and clay ratio.

	Mean	Standard deviation	Minimum	Maximum	Skewness	kurtosis
EC	142	164	4.5	400	0.86	1.96
pH	7.95	0.38	7	8.7	3.1	0.27
Clay (%)	25.6	11.8	14	45	2.06	0.66

Table 2. The result evaluation of inverted weighted distance way with various exponent.

Method		MAE	MBE	RMSE
	E1	5.26	0.3	145.7
Inverted weighted distance	E2	5.58	0.53	132
	E3	5.90	0.7	134.5
Thin plate spline		0.82	-0.05	128
Spline with tension		0.77	0.11	124
Normal Kriging		0.01	0.70	120.3
Co kriging		-0.01	0.5	103

change analysis. To study the existence of the spatial structure among data, the experimental semi exponential change was plotted. After assessing the different methods based on the mean of squared errors, the spherical and Gaussian models in Kriging and Co Kriging methods were adopted. The specifications of estimated models of Kriging and Co Kriging methods are demonstrated in Table 3.

The effect radius of estimated spherical model is 92 m. The amounts of estimated partial effect on data in Kriging and Cokriging are 13 and 22% respectively which express that the roles of structured elements are more significant in comparison to randomly elements and the model has stronger spatial structure.

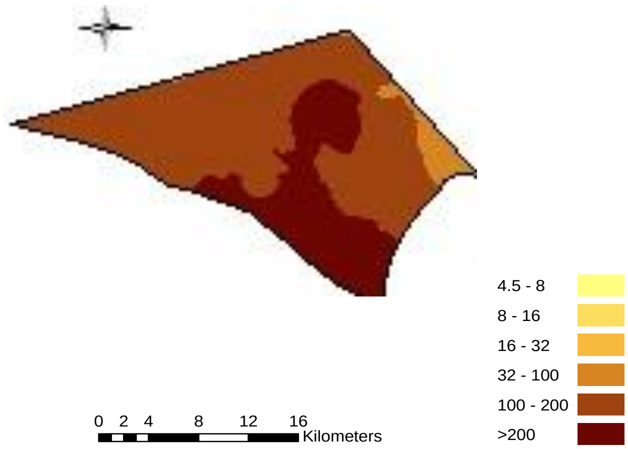
One of the striking problems in the estimation of exponential change and interpolation by Kriging model is its necessity of having a large number of soil samples. The use of auxiliary variables which has correlation with the definite parameter can help us to estimate the main parameter. In this study, the argil percentage is used as an auxiliary parameter in Co Kriging model to survey soil salinity map. The results shows that , where the argil percentage was used as an auxiliary parameter , the MAE and RMSE were 0.5 and 108 respectively which indicates that using the argil percentage as an auxiliary variable may reduce the errors.

The least salinity was 6.2 dS/m which belongs to point with the coordination of 50° 24’ ^{4}4’’ and 36° 0’ 24’’ in northern west of the region. The mean of salinity (average salinity) in the study area is 140 dS/m. Based on the estimated map, the salinity in 2.2% of the area is less than 8 dS/m and 74% of the area is more than 100 dS/m. The salinity shows increasing trends towards southern and eastern areas of the region (Figure 3).

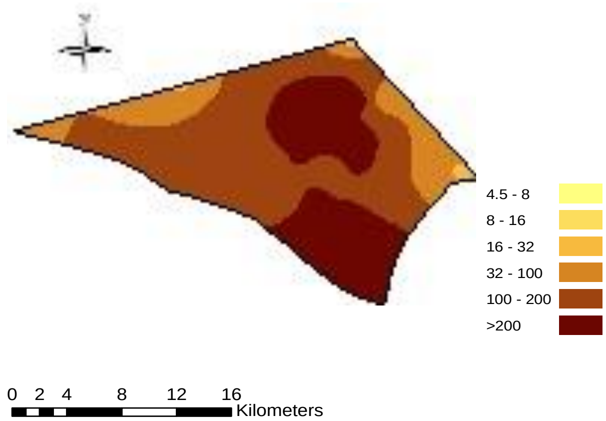
Results of this study showed that Kriging method (including Normal Kriging and CoKriging) is more accurate in estimating the saltiness of the soil in the study area. The survey results showed that Kriging method has higher accuracy than other methods of interpolation. Kriging method can be used as a valuable tool for improving soil quality as the traditional map. This is because the differences in soil specification such as saltiness, tissue, hydraulical conductivity are specially correlated. Considering the assessing criteria such as definite mean of errors, Co kriging method is more accurate in comparison to Kriging method. This is because of the high correlation between secondary variable of clay % and basic variable (EC) which results in reduction in estimated variance. This is similar to what other researchers such as Knotters et al. (1995), Horney et al. (2005) and Amini (1999) have found.

Ahmadali et al. (2009) studied spatial variables of soil such as lime %, acidity and saltiness by using interpolation in Bookan Region. Then they used Normal Kriging , Co Kriging , IDW with 2,3,4 and 5 powers, TPSS with 2,3,4 and 5 powers and spherical model estimation to analyze data. Data were assessed by using average statistical criteria of mean absolute error (MAE) and mean biased error (MBE). The results showed that Co Kriging with minimum MAE for saltiness, acidity and lime % were more accurate (0.218, 0.156 and 7.353, respectively). Wu et al. (2006) estimated the amount of zinc in North Dakota by using Co Kriging method and found out that Co Kriging method is more efficient in comparison to Kriging method. Yanl et al. (2007), by using different geostatistics methods and data in estimation of saltiness in salty areas of Shankivi bank in China, found out that Co Kriging and regressed Co Kriging are more accurate in comparison to Kriging in saltiness estimation.

Results of this study proved that using auxiliary variables such as height and soil tissue which have



(a)



(b)

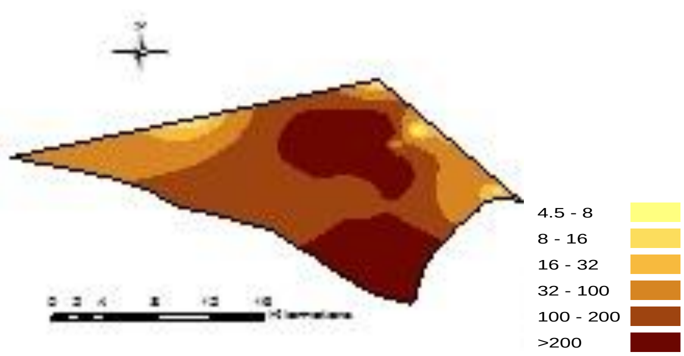
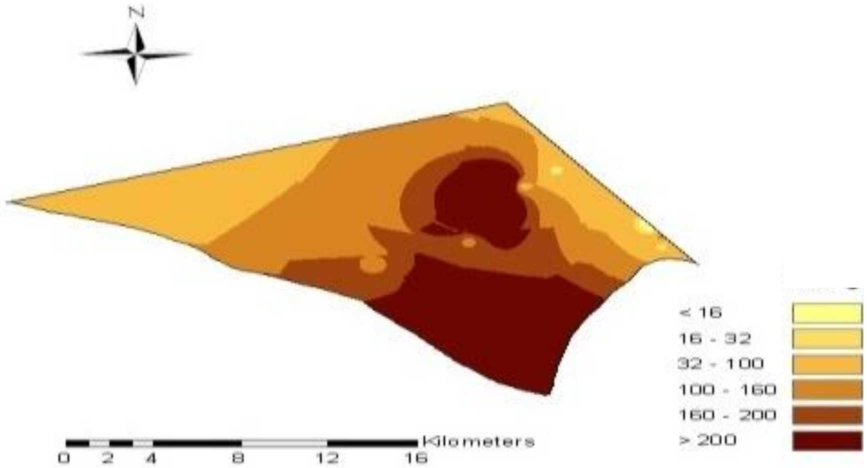
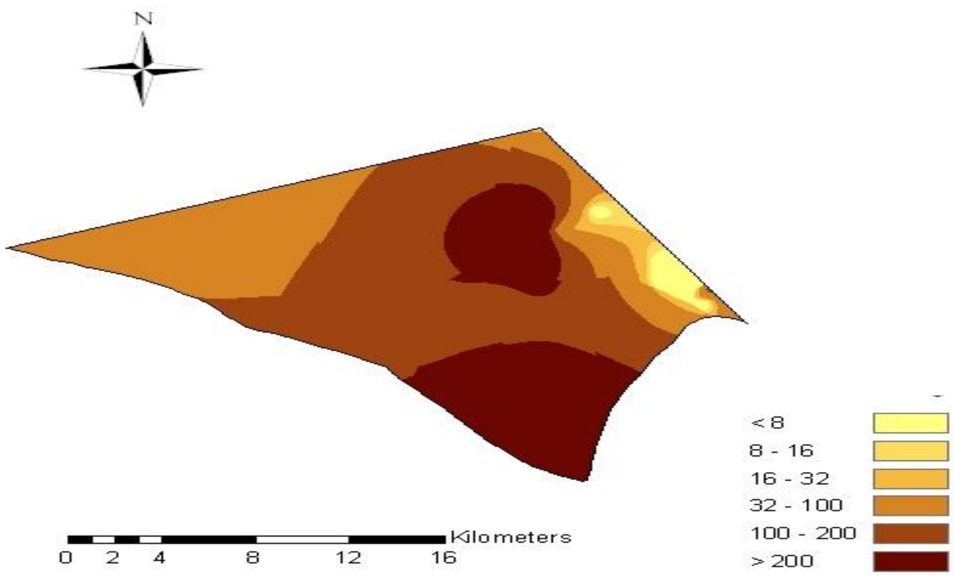


Figure 1. The salinity map with inverted weighted distance. (a) The way of inverted weighted distance with E 1; (b) The way of inverted weighted distance with E 2; (C) The way of inverted weighted distance with E 3.



(a)



(b)

Figure 2. The salinity map with spline method. (a): Thin plate spline; (b) Spline with tension.

Table 3. The characteristics of the selective model saline data on kriging and cokriging.

Method	Model	Effect radius	Threshold (C_0 + C)	Partial effect C_0
Normal Kriging	Spherical	100	31600	13
Cokriging	Gaussian	50	26600	23

strong correlation with basic variable resulted in more accuracy in interpolation methods. Normal Kriging method results in less error in comparison to other interpolation methods such as inverted weighted distance and Spline methods. Particularly, the difference between normal Kriging method with roots of mean of squared errors of 120 and inverted weighted distance method with mean of squared error of 132 are evident. Considering 12% higher accuracy of Co Kriging method in comparison to Kriging methods and 24 and 20% differences in inverted weighted distance and Spline methods, using auxiliary variables which have strong

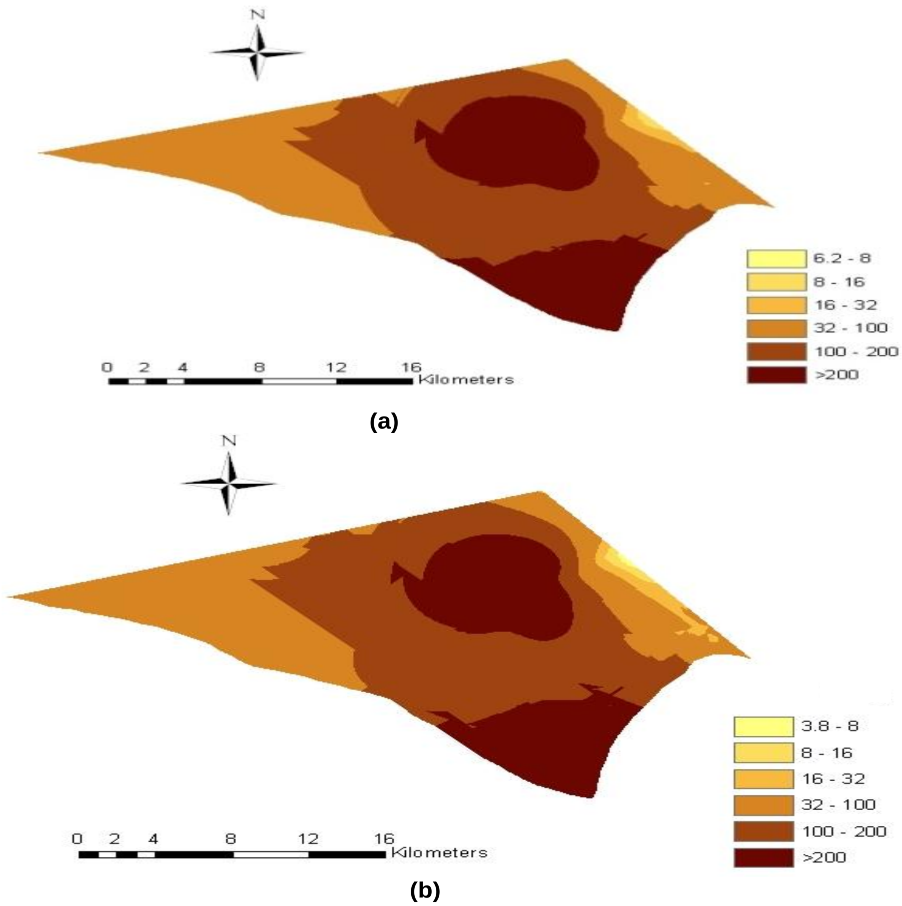


Figure 3. Salinity map of the region by using Normal Kriging (a) and CoKriging(b).

correlation with basic variables is recommended to convert point data to regional data.

Based on the results, inverted weighted distance method is more accurate in comparison to Spline method. Anderson (2000), in a research, found out that inverted weighted distance method is more accurate in comparison to interpolation methods in order to estimate thermal data. Based on the estimated map of average saltiness by using Co Kriging, the average saltiness of the study area is 140 dS/m. The eastern part of study region is less salty; on the contrary, western and southern areas of the study region are more salty.

REFERENCES

Amini M (1999). Assessment of soil salinity and alkalinity using geostatistic technique in a part of Rudasht district (Isfahan province). MS.C thesis. Isfahan University of Technology, College of Agriculture, Isfahan, Iran. p. 120.

Anderson S (2000). An Evaluation of Spatial Interpolation Methods pn Air Temperature in Phoenix. A Z. Beguer´ıa, S. and Vicente-Serrano, S. M.: Mapping the hazard of extreme rainfall by peaks over threshold extreme value analysis and spatial regression techniques, J. Appl. Meteorol., 45: 108-124.

Borrough PA, McDonnell RA (1998). Principles of geographical information systems, Oxford University Press.

Horney RD, Taylor B, Munk DS, Roberts BA, Lesch SM, Richard EP (2005). Development of practical site-specific management methods for reclaiming salt-affected soil. Comput. Electr. Agric., 46: 379-397.

Hosseini E, Gallichand J, Marcotte D (1994) Theoretical and experimental. Performance of spatial interpolation methods for soil salinity analysis. ASAE, 37(6): 1799-1807.

Knotters M, Brus DJ, Oude Voshaar JH (1995). A comparison of kriging, co-kriging combined with regression for spatial interpolation of horizon depth with censored observations. Geoderma, 67: 227-246.

Moustafa MM, Yomota A (1998). Spatial modeling of soil properties fir subsurce drainage projects. J. Irrig. Drainage Eng., 124 (4): 218-228.

Ninyerola M, Ponss X, Roure JM (2000). A methodological approach of climatological modelling of air temperature and precipitation through GIS techniques, Int. J. Climatol., 20, 1823-1841.

Shi ZH, Cai CF, Ding SW, Wang TW, Chow TL (2004). Soil conservation planning at the small watershed level using RUSLE with GIS, Catena, 55: 33–48.

Vicente-Serrano SM, Saz-S´anchez MA, Cuadrat JS (2003). Comparative analysis of interpolation methods in the middle Ebro Valley (Spain): application to annual precipitation and temperature, Climate. Res., 24: 161-180.

Wu J, Norvell WA, Welch RM (2006). Kriging on highly skewed data for DTPA-extractable soil Zn with auxiliary information for pH and organic carbon. Geoderma, 134: 187-199.

Yanl LI, Zhou SHI, Ci-fang WU, Hong-yi LI Feng, LI (2007).Improved Prediction and Reduction of Sampling Density for Soil Salinity by Different Geostatistical Methods. Agricultural Sciences in China, 6(7): 832-841.