Evaluation of the Accuracy of Regression Kriging and Cokriging Models to Determine Soil Salinity

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Abstract: Desertification phenomenon and loss of land potential are caused by one or a combination of desertification processes such as, salinization of land, destruction of plant resources, waterlogging, water erosion, wind erosion and etc that intensify by natural and human factors. The purpose of this study is to evaluate changes in soil salinity using geostatistical methods. The research was carried out in Ardakan region to assess soil salinity (electrical conductivity) using geostatistical techniques (Regression Kriging model and Cokriging model). 150 points were taken to determine the amount of electrical conductivity by electromagnetic inductor device. The results showed that the northern parts have less salinity and the southern parts have more salinity. According to the results, the Regression Kriging method is more accurate than the Cokriging model.
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Introduction

Human factors have the main and key role in appearing of desertification factors, because, in addition to their direct role, these human factors stimulate and strengthen the potential environmental factors and accelerate the speed of desertification [6]. As mentioned, salinization of lands is one of desertification processes. Salinity and soil salinization are among the environmental risks and problems that have been considered in recent years and have to be restrained by plan and accurate science management. The first step in this way is to identify the saline areas and preparing soil salinity maps of the country. In developing countries, especially in arid and semi-arid climates, modification of soil salinity is important in the first place because in these countries, the natural resources, especially soil, are used unscientific and regardless of its capabilities and limitations (Krista, 1993). To portray the location changes of soils with lower cost and shorter time, so that an acceptable soil map would be prepare, quantitative methods are presented to estimate the soil location with an emphasis on available data resources (McBratney et al., 2003: Mercer et al., 2011). So far, different models such as SoLIM (Soil Land Inference Model) and SCORPAN have presented for digital zoning of soil. The SCORPAN model was introduced by (Hasheminejhad, 2010 & Rahimian) for the first time.

Electromagnetic machine (EM) allows monitor soil salinity without direct contact with it and to spend less time and cost is providing compared to other desert methods (Zolfaghari, 2010).

From electromagnetic induction sensors (especially EM-38) can be used to measure the salinity of the surface layer (30-0 cm) or deeper (90-0 cm). This sensor can be used if combined with global positioning to determine soil salinity map (Walter et al, 2001: Minasny and McBratney, 2006: Daempanah et al, 2011).

2. Materials and methods

2.1 The study area

This study was conducted in the city of Ardekan in Yazd province (Figure 1). Expanse of the study area is 62 hectares, that in between longitude 54 ° and one minute to 54 ° and three minutes east and latitude 32 degrees 20 minutes to 32 degrees 22 minutes north is located. Most of soil texture in different parts of this region is sandy loam, clay loam and loam. Irrigation source in this area is a deep well with flow rates about of 25 liters per second, which is located near pistachio gardens.

The results chemical properties of irrigation water indicates that the electrical conductivity its 6.12 dS/m and sodium absorption ratio of water is 04/33, which is represents the sodium salt of irrigation water in this region (Ayubi et al, 2007: Siasar and shojaei, 2017).

2.2 Sampling

For suitable sampling of study area, at first by using electromagnetic induction device, numbers 150 readings were taken. After sample preparation (drying and sifting) was measured electrical conductivity in the saturation extract (Shojaei, 2014).

Cokriging: in Cokriging method one or more secondary variables are used as covariates to improve the estimation. Cokriging equation is as equation (1): (McKenzie and Ryan, 1997).

$$Z^*(x_i) = \sum_{\acute{e}=1}^{n} \lambda_{\acute{e}i} . x_i \sum_{k=1}^{n} \lambda_k . y(x_k) \quad (1)$$

Where Z*(xi): is the estimated value for xi point, λ i is the weight of the variable Z, λk is the weight of the covariate y, z(xi) is observed value of the main variable and y(xk) is observed value of the covariate. To estimate by using this method and to calculate the weights, we have to calculate the mutual variogram as follows (Equation 2):

Y(zy)h = 1/2 n[z(xi + h) – z(xi)]×[y(xk – y(xk))] (2)

Where Y(zy)h is mutual variogram between Y and z, z(xi) is observed variable and y(xk) is covariate (Tajgardan et al, 2009).

Regression Kriging: Regression Kriging or Kriging after the process removal is a hybrid method consists of a Regression model and simple Kriging. In this study, for soil electrical conductivity zoning the Regression Kriging model with local variogram was used. For this purpose, first, all of the information layers converted to the cell. Then, a neuro-fuzzy relationship was created between outward electrical conductivity data and electrical conductivity data and residual values were used to provide continuous error map using local variogram (process removal). Implementation of local variogram consists of four phases: 1) Finding the nearest neighbor points to the spot where the prediction is made. 2) The creation of experimental variogram using neighbor areas. 3) Fitting the appropriate model to the experimental variogram. 4) Predicting the amount of salinity in the intended spot. Consider that in the global variogram only one variogram is calculated for the entire region. In recent years researchers have widely used the local variogram in the studies of soil digital mapping. Finally, we combined the resulting error map with the obtained map from neuro-fuzzy model (Quinlan, 2001) to obtain the final soil salinity map (Shojaei, 2014).

This method is based on the assumption that with increasing the data distance, the data effect on each other would decrease. Therefore, the weight coefficient has inverse relation with distance. The relationships are as follows:

$$\hat{Z}_J = \frac{\sum_{i=1}^{N} \frac{Z_i}{h_{ij}^{\beta}}}{\sum_{i=1}^{N} \frac{1}{h_{ij}^{\beta}}} \quad (3)$$

$$h_{ij} = \sqrt{d_{ij}^{2} + \sigma^2} \quad (4)$$

Where hij is the effective distance between network node (j) and node neighboring point (i), $\hat{Z}_J$ is the estimated value of the parameter Z, Zj is the actual value of the parameter Z neighboring node, dij is the distance between network nodes (j) and node neighboring point (i), β is the given weight power, σ is leveler coefficient (Zolfaghari et al, 2011: Shojaei et al., 2017).

Assessment models

Assessment models of geostatistical models' methods.

$$RMSE = \left[\frac{\sum(X_0 - X_e)^2}{n}\right]^{1/2}$$

$$R^2 = \left[\frac{\sum((X_e - \bar{X}_e)(X_0 - \bar{X}_0))}{\sqrt{\sum((X_e - \bar{X}_e)^2(X_0 - \bar{X}_0)^2)}}\right]^2$$

$$ME = \frac{1}{n}\sum_{i=1}^{n}(X_0 - X_e)$$

3. Results and discussion

Electrical conductivity values obtained from Co-kriging model and kriging regression method shown in Table 1. According to obtained results from electrical conductivity mean value estimate Co-kriging model at a depth of 0-30 cm is equal to 16.1 dS/m. Also mean value electrical conductivity is obtained from kriging regression method equal to 16.9 dS m.

Table 1 summarize statistical of electrical conductivity values (dS/m)

Coefficient of variation	SD	mean	depth	method
53.28	5.1	16.1	0-30	**Co-kriging**
44.11	4.0	16.9	0-30	**kriging regression**

In this research kriging with spherical model was used. Root Square Error and mean error soil salinity arising from both kriging models and inverse distance weighted method results shown in Table 2 (Siasar and shojaei, 2017).

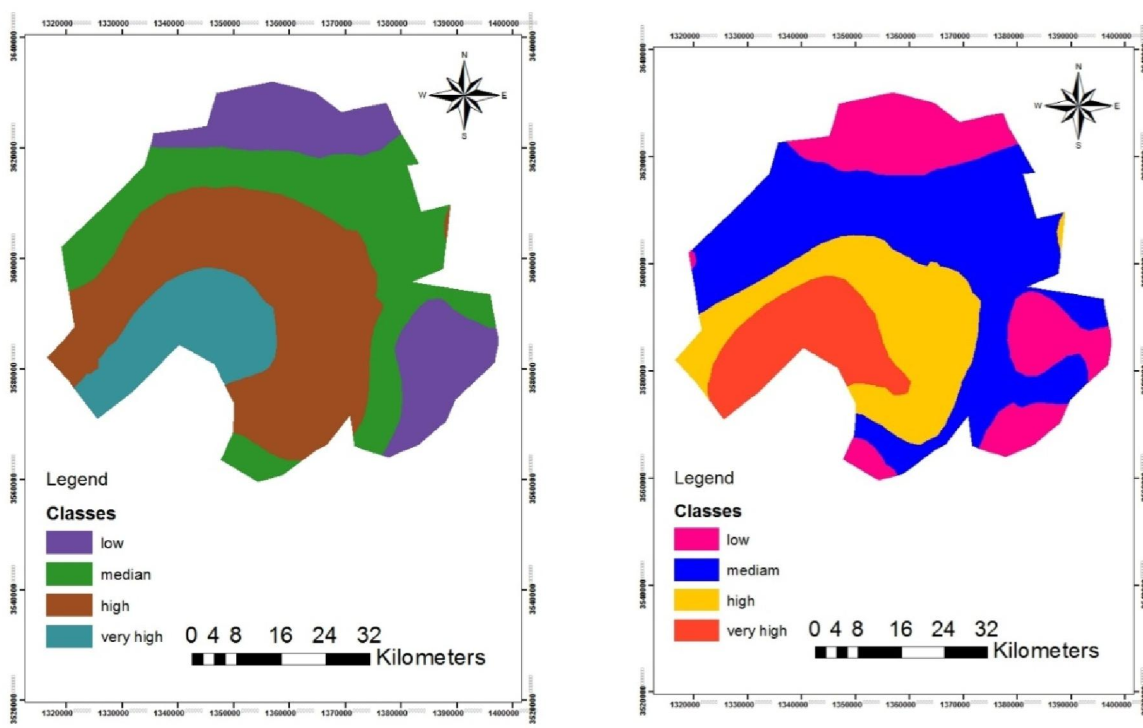
Table 2 shows the results of the evaluation criteria kriging model to predict the electrical conductivity

The sum square error	mean error	depth	method
5.7	0.22	0-30	**Co-kriging**
3.4	0.19	0-30	**kriging regression**

Soil salinity map of the study area for 0-30 cm depth was obtained by Co-kriging model and kriging regression method (Figure 2). The results showed that salinity is higher in north part and as possible south of this region are closer and is lower salinity. Rainfall less than 60 mm per year, reduction in dry climate and vegetation due to the expansion salinity and release large part of agricultural land from reasons spread of salinity can be expressed in Yazd (Zolfaghari, 2010).

In this Taghizadeh Mehrjardi et al (2012) dry area decreased the accuracy, but in this study due to the smaller region and more moisture in the soil, especially in its lower depths, the data variance is less. Of course, one of the defects of the electromagnetic inductor device is that it affected by moisture and clay content. In comparison, another study of (Rahimian et al., 2014) showed the results of salinity monitoring in two parts with different moistures of soil. In a similar study (Taghizadeh-Mehrjardi et al., 2014) carried out the digital zoning of outward electrical conductivity capability using Regression Kriging and local variogram in Ardakan region. The results show the high efficiency of Regression Kriging model with local variogram, so that, the Regression Kriging model has decreased the percentage of predicting error in a horizontal position 21% and 28% compared to Cokriging and Kriging, respectively.

In a similar study (Triantafilis et al., 2001) with comparing five geostatistical methods to estimate the salinity, found out that the Regression Kriging method presented better estimation than the ordinary Kriging method, three-dimensional Kriging and Cokriging.



Co-kriging model kriging Regression model

Figure 2. Maps of ability the electrical conductivity by using of regression kriging model and Co-kriging method

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