Mapping Soil Salinity in Arid and Semi-Arid Soil by Geostatistic Theory (Esfahan Province)

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Received 8 August 2012
Accepted 30 November 2013

1. Introduction

Salinity is a highly important problem in arid and semi- arid region. In Iran, about 235,000 km ^{2} (or 14.2% of the total area of the country) area is salt-affected, which is equivalent to about 50% of irrigated lands in Iran (Pazira 1999). Irrigating of these lands causes to transfer salts to the area of root growth and thus increases the osmotic pressure and reduces the absorption of the nutrient elements and product. Some of researchers believe that this process is one of the disasters that threats development of human societies. Esfahan province is exposed to the danger of salinity. Esfahan province is located in the central arid region of Iran. Of 105,000 km 2 total area, an area of 5000 km ^{2} is used for crop and fruit production. Soil and water salinity is the major limitation to achieve optimum crop yields. However, the classical soil survey methods of field sampling, laboratory analysis and interpolation of these field data for mapping, especially in large areas, are relatively expensive and time-consuming but to get informed about distribution of salinity in soil is very important for recognizing critical threshold, planning, management, operation of source, and suitable distribution of water to correct the soil saline. Soil chemical properties commonly have spatial dependence at regional scale (Yost et al., 1982). Regional assessment of soil properties requires evaluation of their spatial distribution. In recent years, environmental scientists have come to appreciate the merits of geostatistics and kriging for investigating and mapping Soil chemical properties in un-sampled areas. There are a large number of reports to natural resource distributions. Geostatistic method such as Ordinary Kriging is a class of statistics used to analyze and predict the values associated with spatial or spatiotemporal phenomena. It incorporates the spatial (and in some cases temporal) coordinates of the data within the analyses. Many geostatistical tools were originally developed as a practical means to describe spatial patterns and interpolate values for locations where samples were not taken. Three functions are used in geostatistics for describing the spatial or the temporal correlation of observations: these are the correlogram, the covariance and the semivariogram (hasani pak, 1999). The last is also more simply called variogram. The following parameters are often used to describe variograms:

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nugget: The height of the jump of the semivariogram at the discontinuity at the origin, sill: Limit of the variogram tending to infinity lag distances and range: The distance in which the difference of the variogram from the sill becomes negligible. In applied geostatistics the empirical variograms are often approximated by model function ensuring validity (Chiles and Delfiner 1999). Some important models are (Chiles and Delfiner, 1999; Cressie, 1993): The exponential variogram model, the spherical variogram model and The Gaussian variogram model. In assessments of some variables, spatial correlation structure is the same in all directions, or isotropic. In this case the variogram depend only on the magnitude of the lag vector, h = h , and not the direction, and the empirical variogram can be computed by pooling data pairs separated by the appropriate distances, regardless of direction. Such a variogram is described as omnidirectional. In many cases, however, a property shows different autocorrelation structures in different directions, and an anisotropic variogram model should be developed to reflect these differences. The most commonly employed model for anisotropy is geometric anisotropy, with the variogram reaching the same sill in all directions, but at different ranges. However some Geostatistical methods such as kriging need valid variograms. Cross validation is used to find the best model among the competitors. "Cross Validation" allows us to compare estimated and true values using the information available in our sample data set (Houlding, 2000).

2. Study area

This research was conducted in Isfahan province (Fig1). It is located in the center of Iran in a predominantly arid or semiarid climate condition and is about 6800 km^2 around Zayandehroud River. Mean annual precipitation and temperature are 120 mm and 14.5 Co and Annual evapotranspiration is 1500 mm. The soils are classified as Aridisols. The area covers different land uses including agricultural, industrial, urban and uncultivated lands. In this study, soil sampling strategy was random stratify. In this method, the region was stratified in to regular- sized grid cells of 4 × 4 km and within each cell a sampling location was chosen randomly. A total of 255 soil samples (0-20 cm) were collected (Fig 2). At each sampling point the coordinates were obtained using a portable GPS and its land use was recorded. After calculation, 46.5% of the sampling locations occurred in agricultural lands, 43.5% in uncultivated lands and 10% in industrial and urban area (Fig2). Soil samples were air dried and ground to pass through a 2 mm sieve, Electrical conductivity was measured in a 1:2.5 soil-water ratio suspension.

3. Materials and Methods

Statistics including mean, variance, maximum, minimum, coefficient of variation (CV) and comparison average EC in different land use were calculated. The results of factor analysis were used to calculate the autocorrelation value between observed points and produce a minimum unbiased variance estimate. This variance is calculated as a function of variogram model. Variogram is calculated using the relative location of the samples (Soderstrom, 1998). The experimental variogram is calculated for several lag distances this is then generally fitted to a theoretical model and the parameters in *suitable model are then used in the kriging procedure (Mohamadi, 2007).* The next step is cross validation of the prediction models. The cross-validation technique is used to choose the best variogram model among candidate models and to select the search radius and lag distance that minimizes the kriging variance. Cross-validation is achieved by eliminating information, generally one observation at a time, estimating the value at that location with the remaining data and then computing the difference between the actual and estimated value for each data location. To compare different interpolation techniques, we examined the difference between the known data and the predicted data using the Mean Square Reduced Error (MSE). Correlation coefficient (Pearson) computed between real and estimated data with ordinary kriging. Distribution map of EC was produced using the ordinary kriging and use from maximum 16 point and minimum 3 point in estimation. The descriptive statistical parameters were calculated with Microsoft EXELE and SPSS (version 11). Maps were produce with Surfer (version 8) and ILWIS (version 3.0) and geostatistics analyses were carried out with VARIOWIN and WINGSLIB.

4. Result and discussion

The average EC was 6.9 dSm^{-1} with range of 1-74 dSm^{-1} in Isfahan surface soils (Table 1). EC values don't follow a normal distribution and had a strongly skewed distribution (Fig 4a) therefore these values were transformed to logarithm and the log-transformed data fit an approximately normal distribution (Fig 4b). The average EC between different land uses was compared by using one-way ANOVA. The results showed that there is a significant difference in the soil salinity between uncultivated and agricultural area, but there is no significant difference between uncultivated and urban-industrial area. Soil salinity mean in the uncultivated area is at least three times higher than other land uses (Fig 3). The study of the spatial variability of EC is begun with the computation of directional variograms for EC in different directions. The best variograms was fitted in directions of 45 degrees, and a spherical theoretical covariance model fitted on variogram (Fig 6). The next step, cross validation of the prediction models computed with MSE and Pearson coefficient. MSE was minimum and Pearson coefficient was high (77%) and this parameter is identifier. Therefore valid variogram parameters (sill= 21000, rang= 0.6 and nugget effect =0.127) use for kriging and mapping (Table 2). According to the map of salt distribution in the top soil of study area (Fig 7), all lands are saline (Ec> 4$dS.m^{-1}$) but critical accumulation of salt is in the eastern region, especial Segzi plain. Segzi plain is located in the Eastern part of Isfahan province in the center of Iran and is about 40 kms from Isfahan center. The climate of the area according to the Gowsen method is found to be dry and semi-desert, respectively (Mojiri et al., 2011). In Segzi plain are gypsum mines and wind can transport particles of chalk and sand that cause erosion and air pollution in Esfahan. Rainfall in east of Esfahan in comparison with center and west are lower and temperature is higher so there are more salt in compare to central and west parts. Moreover comparison of maps (salt distribution and land use) delineate, agricultural lands have lower salinity. Because irrigation and leaching are continued and transfer salt to deeper part. Moisture regime in study area is aridic. In this regime evapotranspiration is high and suction gradient transfer salinity solution to soil surface (Richards, 1954).

5. Conclusion

The important result of this research was obtain concentration map of salt with this hope that this survey can be effective step in chose best decision in management of salinity lands to intention improvement and reformation this land. According result of this research, to be near with Lut deserts, low average rainfall, high annual temperature and high evaporation in eastern parts than western parts, are the most important parameters in accumulation of salt in this part of study area.

Key Words: Electrical conductivity- Variogram- kriging- Spatial variability