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Geostatistical Analysis of Saline Condition and Development of Counter Measures Regarding Irrigation and Drainage in Bukhara, Uzbekistan

Aziz Omonov[1], Hirotaka Saito[2]

[1]Senior Environmental Specialist of the Agency for the implementation of projects in the field of agro-industrial complex and food security under the Cabinet Ministry of the Republic of Uzbekistan

[2]Professor of Tokyo University of Agriculture and Technology, Department of Ecoregion Science, Laboratory of Environmental Soil Physics and Engineering

1. Introduction

Central Asia was one of the first irrigated farming centers in ancient times. The largest water resources in Central Asia are Syr-Darya (length 3019 km, basin area 390 thousand.km²) and Amu-Darya (length 2540 km, basin area 219 thousand.km²) rivers that are flow to the Aral Sea Lake (Fig. 1). The water resources of Central Asia are important to five countries (Uzbekistan, Kazakhstan, Tajikistan, Turkmenistan, and Kyrgyzstan) in economic activities. Although the achievements of irrigation in ensuring food security and improving rural welfare have been impressive,past experience indicates problems and failures in irrigated agriculture. Environmental concernsare considered as a threat to sustainability in the irrigation sector. Environmental problems include excessive water depletion, water quality reduction, water logging, and salinization (OECD, 1998).

Figure 1: Map of Central Asia and Aral Sea basin

Moreover, inappropriate irrigation practices, accompanied by inadequate drainage, have often damaged soils through over-saturation and salt accumulation. The United Nations Food and Agriculture Organization (FAO) estimates that 60-80 million hectares are affected to varying degrees by waterlogging and salinity (FAO, 1996). Since the times of the Tsarist Russian Empire and in times of soviet power, a role of the chief supplier of "white gold" (cotton) waspredetermined for Uzbekistan because the most favorable conditions for its cultivation exist here - a large number of sunny days per year, vast areas available for irrigation, and a large number of country people (Khamraey Sh., Dukhovny V. et al., 2011). Prior to independence fromthe Former Soviet Union, the economies of the Central Asia interdepended upon a centrally managed Soviet economy. In each nation, agriculture was classified according to specific agro-climatic zones, with production and marketing distributed through the entire Soviettrade system. Agriculture still remains an important sector of the economy, employing between 20%-50% of the national labor force (Paroda et al., 2004).Nowadays, irrigated farming remains one of the most important economic sectors in Uzbekistan, which provides 17.5% of GDP and 20% of foreign currency earnings; besides the most significant point social stability under ensuring 40% of employment (as of 2010). Key crops (about 30% of the total irrigated area) are cotton that ensures about 10% of export receipts and wheat that is the basis for the national food security. (Khamrayev Sh., Dukhovny V. et al., 2011). The land of Uzbekistan mainly consists of deserts, semi-deserts, grassland as well as mountains that are predominantly in the eastern part of the country. In rural areas, irrigated farming and processing of agricultural production are chief sources of employment and revenues of local population. Secondary salinization is an important factor in land degradation and is largely brought about by the over-use of irrigation water and affects up to 47% of the total irrigated area, with slightly saline land accounting for 25%, medium-level saline land - 15% and strongly saline land - 7%. Unless measures are taken to reduce water losses on this land and improve the evacuation of surplus water and salts, it is inevitable that the land will continue progressively deteriorate. Environmental problems include excessive water depletion, water quality reduction, water logging, and salinization.

Research objectives are Geostatistical analysis on the current saline conditions of irrigated lands in Bukhara Province, Uzbekistan. Understanding of the salinization process, especially topographic features by overlay analysis.

Methodologies of the research are as follows:

a) Data collection of agricultural land and water management based on the current condition of the study area;
b) Understanding on salinization process and Geostatistical analysis;
c) Proposals and recommendations will be given for the measures to be taken in order to improve the crop productivity and incomes from agriculture in this area.

Research framework

Research asconducted by using GIS (Geostatistical analysis) and an understanding of the causes and further impacts of salinization, and dataanalysis was performed. Research methodology was applied in Bukhara province, as a case study. A Geostatistic model was applied to the study area of cotton field where it's quite influenced by salinization. Analyzing field condition, interpolating methodology of geostatistics were applied. This research will proceed to develop preventive counter measures for the analysis by Geostatistical modeling. There will be a preliminary step towards decision making for agricultural policy, such as the saline areas or identification of zones that are suitable for crop growth.

2. Study Area

The Bukhara province is located in central and southwestern part of the country and was selected as a case study area (Fig. 2). The province consists of 11 rural districts: Olot, Bukhara,Vobkent, Gijduvon, Jondor, Kogon, Korovulbozor, Karakul, Peshku, Romiton, Sbofirkon; 11 towns: Bukhara, Vobkent, Gazly, Galosiyo, Kogon, Olot, Gijduvon, Karakul, Romiton, Korovulbozor, Shofirkon; 3 town-type-settlements: Jondor, Zafarobod and Yangiobod; as well as 121 villages. The city of Bukhara is the administrative center of the province (616 km from Tashkent, 259,0 thousand people) (FAO, 2008). Use of land Bukhara province and agriculture: cotton, grain crops, fruit and vegetables, etc in 2008.

Figure 2: Bukhara province boundary map

The limited water resources of arid zones are a main constraint on economical development. This is especially true for the Aral Sea disaster zone. Some 1.2 million people are living in the Bukhara oasis, the oldest irrigated zone of Uzbekistan. Irrigation practice in the more than 230,000 ha of land consumes more than 5 km 3 of Amu Darya river water. Reduction of runoff by the re-use of saline drainage water for irrigation, deserves special care. Extending of irrigated lands on the basis of available freshwater resources is very problematic under deficit conditions. But all the same time, all regions of Uzbekistan like Bukhara province has significant volumes of saline drainage water which is not used for further development. Considerable amounts of this drainage water discharges to the rivers, deteriorating water quality and the environmental situation in the region (G.Bos, V. Dukhovny. 1996).

3. Method

3.1 Geostatistical method

3.1.1 Definition of Geostatistics

Geostatistics is a group of interpolation methods for statistical analysis of data which is measured with limited of sample points to continuous spatial variation. And, also provides a set of statistical tools for incorporating spatial and temporal coordinates of observations in data processing (P. Goovaerts, 1998). Geostatistics is the study of phenomena that vary in space and/or time. Geostatistics can be regard as collection of numerical techniques that deal with the characterization of spatial attributes, employing primarily random models in a manner similar to the way in which time series analysis characterizes temporal data. Geostatistics originated from the mining and petroleum industries, starting with the work by DanieKrige in the 1950's and was further developed by Georges Matheron in the 1960's. In both industries, geostatistics is successfully applied to solve cases where decision concerning expensive operations has since been extended to many other fields in or related in space. Geostatistics is a specialized branch of statistical analysis concerned with the spatial relationships among data situated. It is originally developed to predict probability distributions of ore grades for mining operations, but it is currently applied in diverse disciplines including *(petroleum geology, hydrogeology, hydrology, meteorology, oceanography, geochemistry, geometallurgy, geography, forestry, environmental control, landscape ecology, soil science, and agriculture)*. Geostatistical algorithms are incorporated in many places especially Geographic Information System (GIS) and R statistical Environment. The goal of geostatistics is to predict the possible spatial distribution of a property.Such prediction often takes the form of map or a series of maps. There are two basic form of prediction exist: estimation and simulation. Estimation form provides producing a statistical assessment of the spatial occurrence.

3.1.2 Application of Geostatistical

The regionalized variable theory has been applied successfully to soil property interpolation for nearly 30 years (Matheron, 1971). The theory provides a convenient summary of soil variability in term of semivariogram and an interpolation technique which is in term of kriging (Goovaerts, 1999). To obtain the accurately soil properties, more sample points are required as many as possible. Measure of: average dissimilarity between observations as a function of separation *distance + direction*. Simple Kriging (SK), Ordinary Kriging (OK) and Universal Kriging (UK) three methods for interpolating soil properties. UK has been the commonly used method to accommodate the trend or the changing drift, as it is sometimes known, in a soil variable (Matheron, 1971).

4. Results and Discussion

4.1. Field survey results (SK) and (OK) variants

The field survey was donein August-September 2014, inJandor district, Bukhara province, Uzbekistan. Taking soil samples, ground water samples, and irrigation water samples, level of ground water, rural areas condition, crops and real current condition of the area were observed. Meeting with local irrigation specialists and WCA of the project area was held. Also,land use and water use of local farmer were observed.

Figure 5: Gulistan-Namgoni WCA map

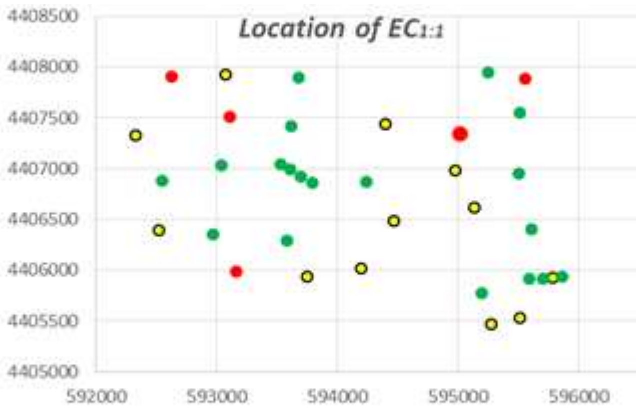

Figure 6: Location of EC of the study area

In Bukhara plain soil salinity is the major soil limitation factor for agricultural production. Spatial information on soil salinity is increasingly needed. To explore spatial variability of soil salinity in the study area **(Fig. 5 and Fig. 6)** grid sampling 512 ha consisting of 36 sample points. Using counter measure of soil salinity Texture of soil, Electrical conductivity (EC), Water quality (pH) and agrochemical composition of soil were determined by laboratory analysis and Electrical conductivity was determined by laboratory analysis from 1:1 soil-water suspension (EC1:1) and generated Geostatistical maps by SGeMS (Fig. 7 and Fig. 8).

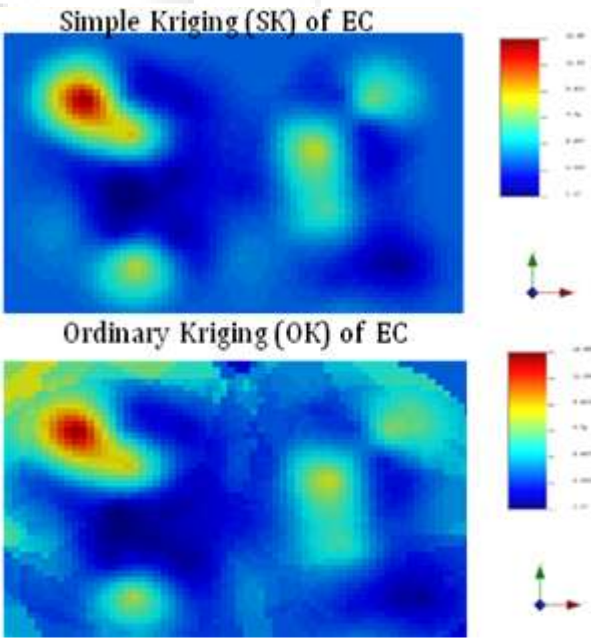

Figure 7: SK and OK of EC

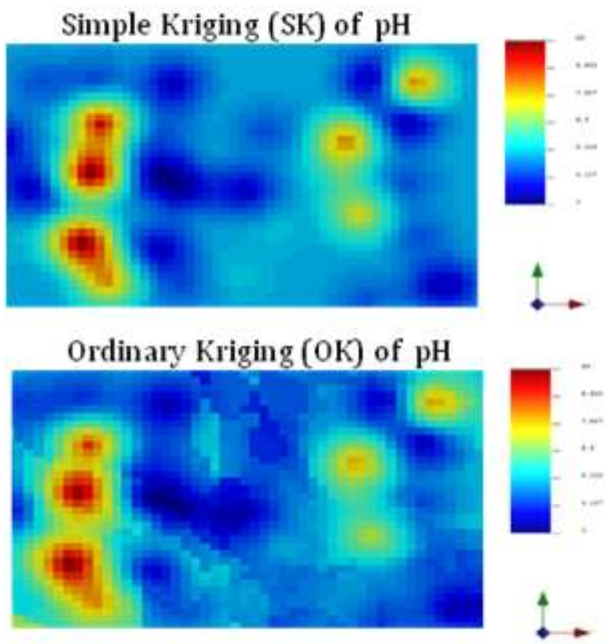

Figure 8: SK and OK of pH

Geostatistics is frequently used synonymously with kriging, which is the statistical version of spatial interpolation. There were two types of kriging used in the research: Simple Kriging (SK) and Ordinary Kriging (OK) with semivariogram (spherical) model. In this case, the Simple Kriging (SK) variant is more clearly illustrated the map than Ordinary Kriging (OK) (strong saline, moderate saline, slight saline and non-saline areas). The results may be suggested that a good model to be generate soil salinity map on Simple Kriging with spherical semivariogram model.

5. Conclusion

Results suggest that a Geostatistic method for statistical analysis on field scale data can be used in mapping/showing spatial variability in soil salinity. Those methods cananalyze the salinity area (small and large scale) and will be helpful for agriculture system. Using this model and making Geostatistical maps for each area, can give us a chance to analyze and make decisions for land use, land change and also supporting for governmental decision.

This research will proceed to develop preventive counter measures for the analysis by SGeMS and Geostatistical modeling. It will be a preliminary step as well, towards making a decision for agricultural policy, such as the saline areas or identification of zones that are suitable for crop growth.

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