Agricultural Water Management 178 (2016) 215–224

Contents lists available at ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

Assessment of groundwater salinity risk using kriging methods: A case study in northern Iran

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ARTICLE INFO

Article history:
Received 20 September 2016
Received in revised form 28 September 2016
Accepted 29 September 2016

Keywords:
Ordinary kriging
Cokriging
Indicator variables
Guilan Province

ABSTRACT

The suitability of groundwater for paddy field irrigation in the alluvial plains of Guilan Province, northern Iran, was investigated using ordinary kriging and ordinary cokriging of continuous and indicator quality variables. The cross validation values of error measures showed that ordinary cokriging provides more accurate estimates of the quality variables of interest. Maps showing the spatial variability of electrical conductivity (EC) and sum of major cations and anions (SCA) were generated for the years 2010 through 2014, using ordinary cokriging. Based on the estimated values of EC and SCA, four groundwater salinity classes (excellent, good, risky, and unsuitable) were considered and the proportion of the study area covered by each class was obtained. Results showed that the portion of the study area covered by the risky class, in which the groundwater salinity is expected to reduce the rice yield, is located in the eastern part of the study area and has an average value of 25.4% in the period 2010–2014. The results also showed that the western part of the study area has excellent or good groundwater quality for rice irrigation. The probability maps of EC were also obtained using ordinary cokriging of EC indicator variable. Five probability classes were considered and the proportion of the study area covered by each class was obtained. It was observed that the probability that the rice yield is reduced more than 10% is above 0.4 in 6.2% of the study area. The maps generated in this study can be used to identify the regions in the province where groundwater could be allowed to be extracted and utilized by farmers to reduce the bad effects of the scarcity of surface water. Also, in the regions with a risk of rice yield reduction, conjunctive use of groundwater and surface water could be planned and advised to farmers.

1. Introduction

Groundwater constitutes a major part of the global renewable freshwater resources (Döll, 2009). In many countries, groundwater is important in terms of supplying domestic, industrial, and agricultural water (Nayak et al., 2006). For many agricultural production areas in Iran, groundwater is the main source of irrigation water supply and its availability and reliability has an important role in the food security of the country. In recent decades, a large volume of water has been depleted from the groundwater basins across the country, and as a result, the water table has declined notably in many regions (Taheri Tizro and Voudouris, 2008). Reducing the amount of water stored in aquifers can result in saline water intrusion, which consequently leads to deterioration of groundwater quality, reduction in crop yield, salinization of irrigated lands, and even long term economic and social issues.

The suitability of groundwater quality for irrigation is assessed based on the observed values of groundwater's hydrochemical variables (Jang et al., 2008). These observed values are used to quantify the salinity, sodicity, and toxicity hazards of irrigation water. The groundwater quality of aquifers is usually monitored through a network of monitoring wells from which water samples are taken. Consequently, the values of groundwater quality variables are known only at a few discrete locations within aquifers and an interpolation technique is required to estimate the values at unsampled intermediate locations.

Kriging is a geostatistical interpolation technique which attempts to incorporate the spatial autocorrelation among the measured values of a spatial random variable to estimate a value for an unsampled location. In recent years, different forms of kriging have been widely used in a variety of problems in geohydrology, including evaluating and optimizing groundwater quantity and quality

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http://dx.doi.org/10.1016/j.agwat.2016.09.028
0378-3774/

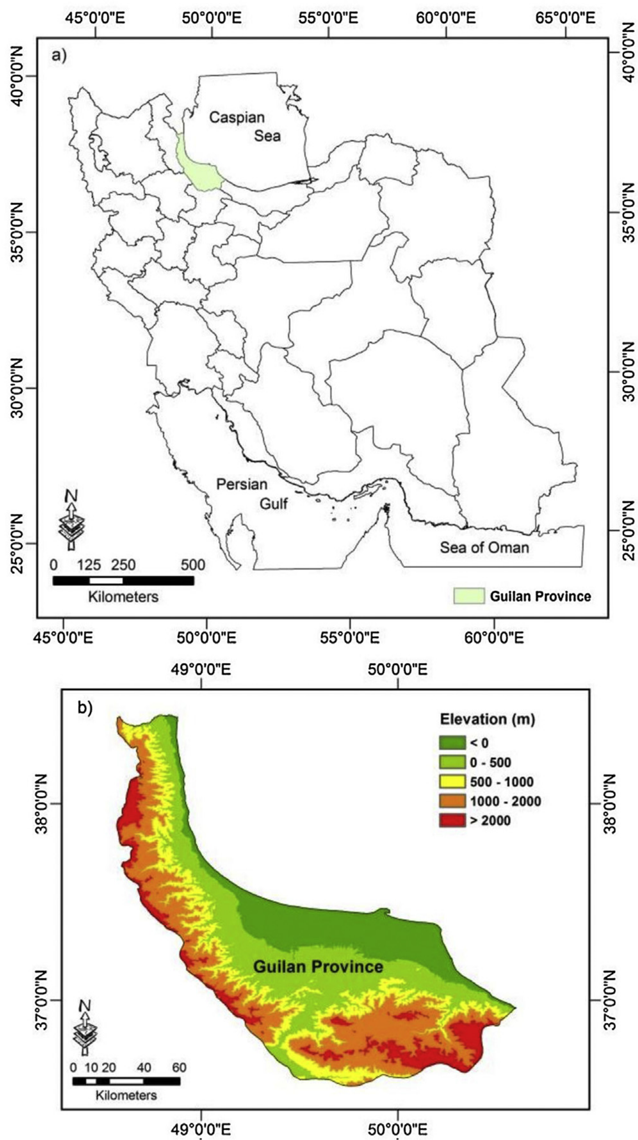

Fig. 1. Guilan Province, Iran (a), Topography of Guilan Province (b).

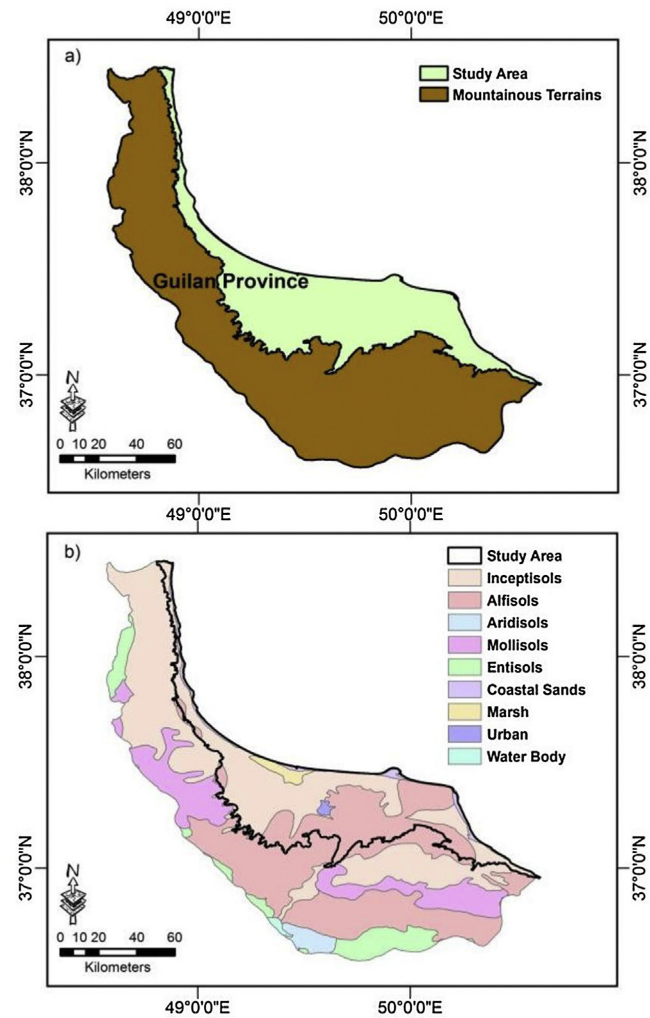

Fig. 2. Borders of the study area in Guilan Province (a), Soil order map of Guilan Province and the study area (b).

monitoring networks (e.g. Theodossiou and Latinopoulos, 2006; Yeh et al., 2006; Nabi et al., 2011), mapping groundwater levels (e.g. Kholghi and Hosseini, 2009; Nikroo et al., 2010; Moukana et al., 2013), and generating the maps of groundwater quality variables (e.g. Goovaerts et al., 2005; Chowdhury et al., 2010; Rivest and Marcotte, 2012; Gong et al., 2014).

Indicator kriging is used to generate the probability maps of different spatial random variables. These maps quantify the probability that the estimated values at unsampled locations exceed a specified threshold value. Probability maps could be utilized as an effective management tool in the regions with limited or contaminated water supplies. Jang et al. (2008) employed indicator kriging to assess the hazards of using groundwater for irrigation purposes in an area in western Taiwan. Dash et al. (2010), using the probability maps of groundwater quality variables generated by indicator kriging, evaluated the status of groundwater contamination in a high population urban area in India in which groundwater is a source of drinking water. Arslan (2012) used indicator kriging to assess the groundwater salinity in an agricultural plain in northern Turkey and estimated the temporal variation of the area that has the highest probability of exceeding a critical threshold of salinity. Jang (2013) determined the extents of pollutants in an aquifer

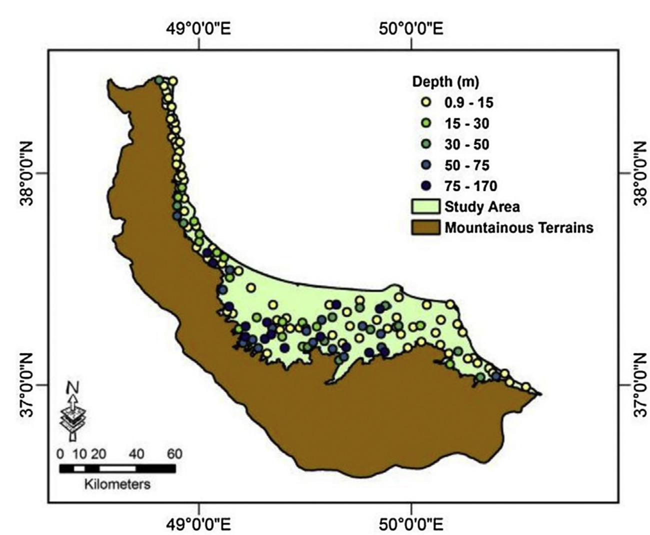

Fig. 3. Location and depth of all quality observation wells in the study area.