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Research article

ASSESSMENT OF THE GROUNDWATER QUALITY FEASIBILITY ZONES FOR IRRIGATIONAL PURPOSES (CASE STUDY; SOUTHWEST PART OF KERMAN PROVINCE, IRAN)

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ABSTRACT: Recently as the result of irregular use of ground water, static surface of water has been reduced in most parts of Iran, which is prevented using alternative approaches of pressurized irrigation instead of traditional methods. An obstacle in expansion of pressurized irrigation in arid regions is water quality. The purpose of this study is to identify the areas which have the potential of being pressurized irrigated using Geostatistics and GIS in Shahr-e-Babak plain. Between geostatistics methods of IDW and Kriging in terms of data cluster, kriging method is rarely chosen due to less RMSE and MAE. Then by putting the layers together based on Boolean simulator, regions with suitable water quality identified for the operation of pressurized irrigation systems. The results show that 35 percent of region is suitable for sprinkler irrigation and 48 percent is good for drip irrigation and neither is suitable and applicable in some areas. Wells that are utilized for drip irrigation are located in wide range of lands. Moreover in a vast part of the understudy areas, drip irrigation systems are applicable and sprinkle irrigation systems are operational in limited areas of north, northeastern and east of the plain.

Keywords: Pressurized irrigation, Ground water quality, Geostatistics, Boolean, Shahr-e-Babak plain.

INTRODUCTION

Irrigation typically results in doubled to quadrupled crop yields compared to dry land production levels, making irrigated agriculture a vital component of the regional economy [4]. Large-scale irrigation first became practical in the 1930s–1940s when internal combustion engines, turbine pumps, right-angle gear drives, and rotary well drilling became available for pumping ground water [19]. According to the statistics more than 80% of water is used in agriculture, therefore to save and increase the irrigation efficiency aids to overcome the water scarcity in the country [3]. In spite of the progression made in agronomy, the average efficiency of surface and traditional irrigation does not exceed from 25% worldwide [12]. Therefore pressurized irrigation instead of surface irrigation is appropriate to increase the efficiency of irrigation [2].The suitability of irrigation water depends upon many factors including the quality of water, soil type, salt tolerance characteristics of the plants, climate and drainage characteristics of the soil [17]. Water quality plays an important role in the management of irrigation and leaching fractions, as well as in the treatment of water itself, so as to achieve an optimal level of production in situations where irrigation systems are used [6]. The longtime effects of irrigation water on soil's physical properties and crop productivity depend on the total salt, sodium, bicarbonate and carbonate concentrations of the irrigation water, and also the soil's initial physical properties [22].

Therefore, the principal variables to be evaluated in the classification of water quality are EC (electrical conductivity), SAR (sodium adsorption ratio) RSC (residual sodium carbonate), and the concentration of other specific ions, such as chlorine [26]. In many countries located in arid and semi-arid regions ground water includes more than 80% of water resource [4]. Considering Iran is locate in arid and semi-arid regions that the average annual rain is 250 mm [18].

Natural resources and environmental concerns, including groundwater, have benefited greatly from the use of GIS. Typical examples of GIS applications in groundwater studies are site suitability analyses, managing site inventory data, estimating vulnerability of groundwater to pollution potential from nonpoint sources of pollution, modeling groundwater movement, modeling solute transport and leaching, and integrating groundwater quality assessment models with spatial data to create spatial decision support systems [9].

Using Geographical Information System (GIS) and geostatistics it is possible to map water pollutants and improve qualitative and quantitative management of water resources [5]. The basic idea in geostatistics is that data closer to each other are more similar than those farther apart [12]. The most advanced techniques which can be used for secluding the groundwater quality, according to its chemical compositions, in clusters or zones can be performed by implementing geostatistical methods such as inverse distance weighting (IDW), Kriging and Co-Kriging [16, 24, 13]. The spatial correlation between data points can be quantified by calculating a semivariogram. A semivariogram model is then used in kriging to interpolate the property of interest over the study region. Geostatistical approaches have been used for modeling the spatial distribution of many regional variables including groundwater quality parameters [7].

The principles governing the chemical characteristics of groundwater and location of irrigation are well documented in many parts of Iran [1, 15, 25, 20]. In this study we evaluated the applicability of pressurized irrigation systems in Shahre-Babak plain, mean while the different methods of interpolation used for the best zoning.

MATERIALS AND METHODS

Case study

The study area (Shahr-e-Babak plain) with area about 600 km^2 with longitude 55˚ 8´ E and latitude 30˚ 7´ N located at western part of Kerman province. The average of above sea level in the region is 1845m, and mean annual precipitation, temperature and evapotranspiration in the catchment are 140 mm, 15.5 ˚C and 2462.5 mm, respectively. Rainfall shortage has resulted in poor condition of vegetation and rangelands, and also wind erosion occurs. In an overall conclusion about rainfall and temperature diagrams in Shahr-e-Babak according to ambro-thermic curve diagram in a period from 1989 to 2009, it was found that dry season in this town prolongs from May to November (low rainfall and high temperature), and only in five months of year (December to April) there is not condition of dry season, thus based on this results climate in Shahr-e-Babak plain is classified as cool-dry climate. The location of study area has been shown in Fig1.

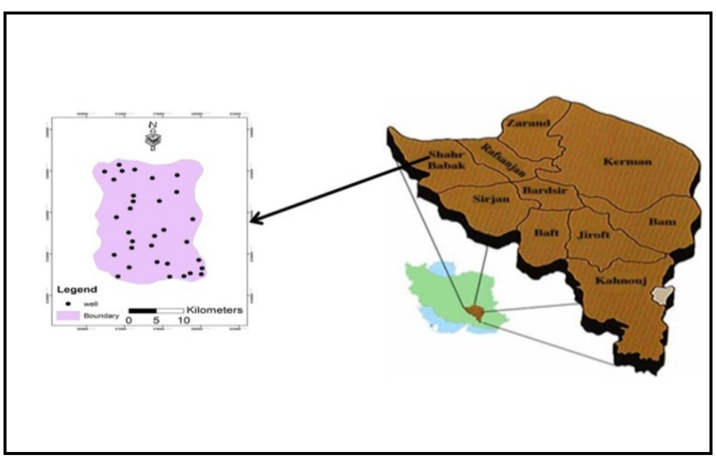


Fig1. Geographical location of study area and sampling wells

Methodology

For locating the suitable areas for sprinkler and trickle irrigation in Shahr-e-Babak plain, we used the data of 32 wells of 2009 statistical year which were taken from locale water organization of Shahr-e-Babak and then they were used for quality analysis.

After standardization of the data in order to describe the variable spatial continuity, the best Variogram model was drawn with two criterions of MAE[1] and RMSE[2] and the appropriate method of interpolation was determined and quality parameters diagram was drawn in Arc GIS9.3. In next step zoning maps was done based on permissible parameter's value for each sprinkle and trickle irrigation systems. Different zones were separated after the overlapping the layers using Boolean simulator and suitable lands were indicated for performance of pressurized irrigation systems. Determining the prone areas for sprinkle and trickle irrigation and implementing the systems prevent the decline of water tables and the reduction of quantity and quality of water.

For evaluation of error rate and choosing the best interpolation method, different criterions are considered such as MAE, MBE[3] and RMSE.

In this paper MAE and RMSE methods were used. Siska and Kuai Hung (2001), have considered the RMSE as the most important parameter to show the accuracy of spatial analysis.

$$RMSE = \left(\sum (Z^*(xi) - Z(xi))^2 / n \right)^{1/2}$$

$$MAE = \frac{1}{n} \sum_{i=1}^{n} \left| Z^*(x_i) - Z(x_i) \right|$$

$Z^*(x)$: estimated value of the variables, $Z(x_i)$: measured value of the variable and n: number of the data.

In Boolean simulator the logical combination is Yes or No. In other words, in this method the membership of the set is shown with one and zero is assigned to show not being a member of the group. The result of logical operation of AND for several maps is multiplication and the logical operation of two mentioned maps can be shown as the sum of data mathematically. In general, for choosing a place in which a special operation would take place, the location can be found using the simulator in which One and Zero can indicate, respectively, the appropriate and inappropriate spots and there would be no other possible state. Considering the parameters and their permissible value (Tab1 and Tab2) is on the basis of Land Drainage book (2).

Tab 1. Trigger of SISI[4]

Parameter	Trigger
EC(μmhos/cm)	>2500
PH	6.5 – 8.4
SAR	>0.2
Na(meq/lit)	>3
HCO3 (meq /lit)	>8.5
Cl(meq/lit)	>3

Tab 2. Trigger of DISI[5]

Parameter	Trigger
EC(mg/lit)	>50
TDS(mg/lit)	>2000
Cl(meq/lit)	>10
HCO3(mg/lit)	>6
PH	6 - 8

1- Mean Absolute Error
2- Root Mean Squar Error
3- Mean Bias Error
4- sprinkle irrigation system index
5- drip irrigation systems index

RESUALTS

For data analysis in classical statistics for every parameter, all the data histograms and statistical parameters were investigated. According to histograms forms and parameters, it was seen that all the variables of the study have skewness, therefore in order to standardization of data, logarithmic transformation of data was used in the results of each variables. The results are shown in Tab 3.

Tab 3. Results of statistical analysis conducted on the ground water data in study area

parameter	Year	mean	Std deviation	Min	Max	skewness
Na	2009	24.82	16.79	4.60	79.70	1.27
Na*	2009	2.98	0.71	1.53	4.38	0.27
PH	2009	7.32	0.37	6.40	8.00	0.76
PH*	2009	-	-	-	-	-
EC	2009	3691.66	2052.32	770	9150	0.59
EC*	2009	8.04	0.63	6.65	9.12	0.51
SAR	2009	8.29	3.34	2.58	14.67	0.74
SAR*	2009	2.02	0.44	0.95	2.69	0.10
Cl	2009	2	18.72	2.00	80.00	1.06
Cl*	2009	2.92	0.87	0.69	4.38	0.08
TDS	2009	2312.58	1379.10	472.00	6050	0.71
TDS*	2009	7.56	0.65	6.16	8.71	0.29
HCO3	2009	4.53	2.73	2.00	11.00	1.18
HCO3*	2009	1.36	0.53	0.69	2.40	0.58

*we used of the Log for normalized data

Also the results of fitting variogram model to experimental variogram shows that the best fitted model to Cl quality parameters is exponential model and to the other parameters, it is spherical model. In this case, the best variogram model for spatial structure of data can be indicated by the behavior of variogram near the origin of coordinates, residual sum of squares and the ratio of structural component to the total variance of model. The related variograms are shown in Fig 2 and Tab 4 shows the parameters.

Tab 4. Variogram model characteristic for qualitative parameters.

parameter	Years	model	C_0	C_0+C	C/C_0+C	A_0	R^2	RSS
Na(meq/lit)	2009	spherical	0.94	0.99	0.71	22290	0.001	0.02
PH	2009	spherical	0.11	0.41	0.71	61100	0.48	0.06
HCO3(meq/lit)	2009	spherical	0.01	0.38	0.96	30630	0.87	0.01
Cl(meq/lit)	2009	Exponential	0.84	0.99	1.22	3950	0.01	0.02
SAR	2009	spherical	0.01	0.17	0.17	19950	0.94	0.03
EC (µmhos/cm)	2009	spherical	0.12	0.50	0.99	16050	0.74	0.04
TDS(mg/lit)	2009	spherical	0.17	0.47	0.66	13970	0.67	0.52

The consequences correspond to the results obtained by Taghizadeh Mehrjerdi et al. (2008) and Adhikary et al. (2011). In order to choose the best interpolation method for zoning map of the area, among two interpolation methods of IDW and Kriging, the usual kriging selected as the best method for zoning all the quality parameters, based on less RMSE and MAE criterions (Tab 5 and Tab 6).

With combining the layers for each irrigation system based on Booleon simulator in Arc GIS9.3 In next step, the suitable and unsuitable places were indicated for different types of pressurized irrigation (Fig 3 and Fig 4). With kriging method, zoning maps of the area was prepared in Arc GIS9.3 software which the results can be seen in Fig 5. Also the areas consisting suitable and unsuitable lands were calculated for performing the pressurized irrigation (Tab 7).

Tab 5. Amount of RMSE measure of parameters for determination the best geostatistical method.

parameter	year	kriging	IDW Pow1	IDW Pow2	IDW Pow3
PH	2009	0.33	0.36	0.38	0.41
Na	2009	10.20	11.78	11.65	11.45
HCO3	2009	1.36	1.52	1.63	1.53
Cl	2009	12.49	14.81	14.91	15.02
EC	2009	1192	1531	1526	1515
SAR	2009	2.38	2.54	2.48	2.38
TDS	2009	1112	1218	1195	1177

Tab 6. Amount of MAE of parameters for determination of the best geostatistical method

parameter	year	kriging	IDW Pow1	IDW Pow2	IDW Pow3
PH	2009	0.02	0.03	0.04	0.05
Na	2009	0.33	0.70	0.50	0.37
HCO3	2009	0.09	0.16	0.11	0.20
Cl	2009	0.67	0.74	0.97	0.98
EC(μmhos/cm)	2009	70.27	88.10	125.00	143
SAR	2009	0.17	0.23	0.19	0.20
TDS(mg/lit)	2009	21.37	50.44	58.46	43.26

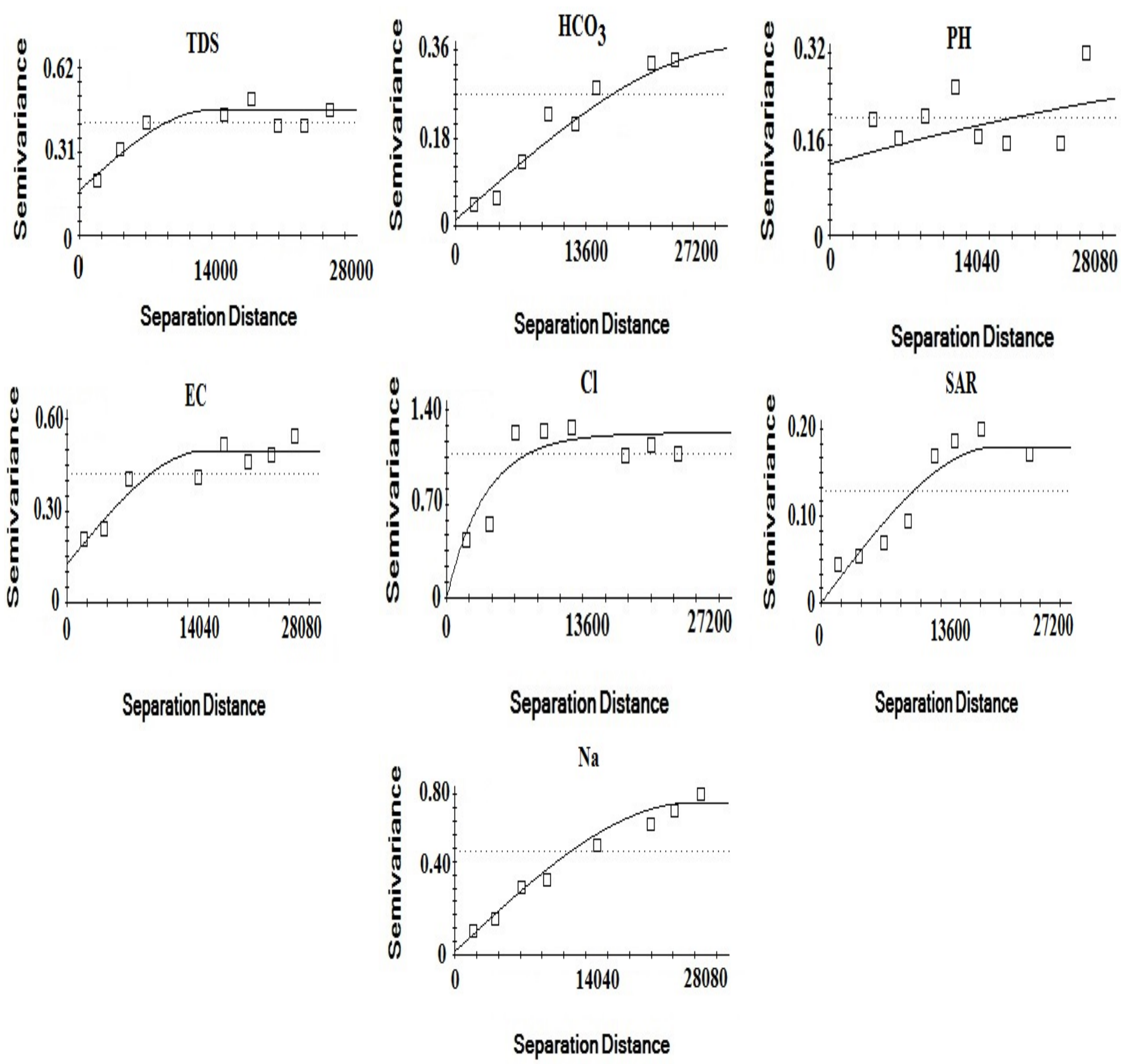


Fig 2. Variograms related to ground water qualitative parameters

Tab 7. Area of irrigation system

Water quality	Irrigation system			
	DIS		**SIS**	
	Area			
	Percent	Km^2	Percent	Km^2
suitable	48	288	35	210
unsuitable	52	312	65	390

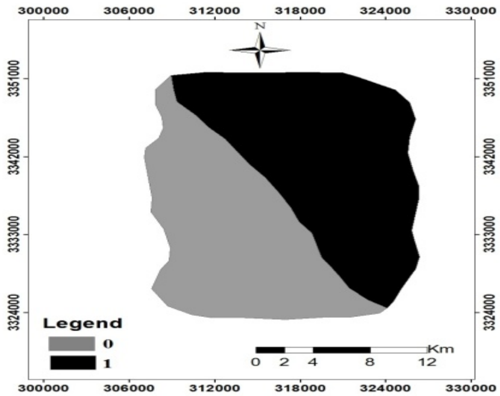


Fig 3. Zoning of DIS

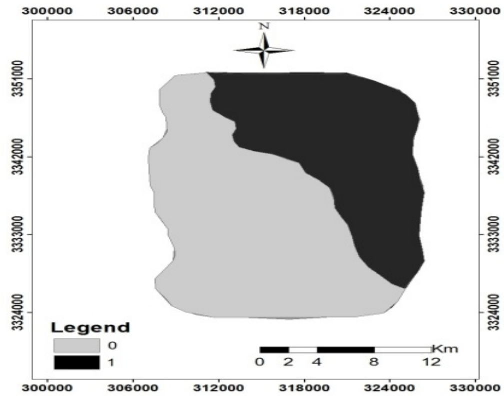
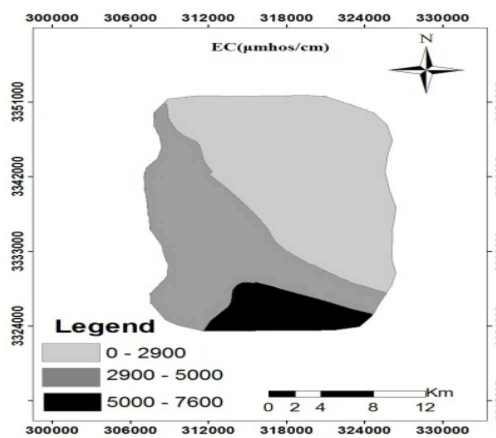
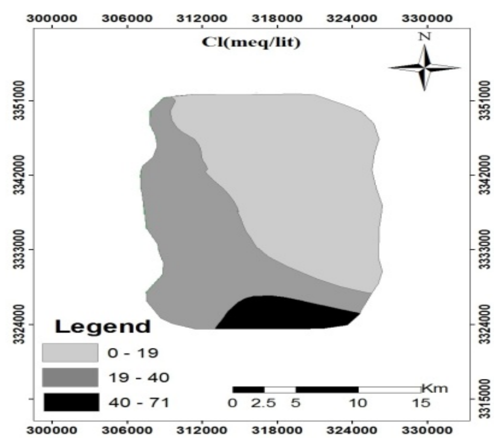
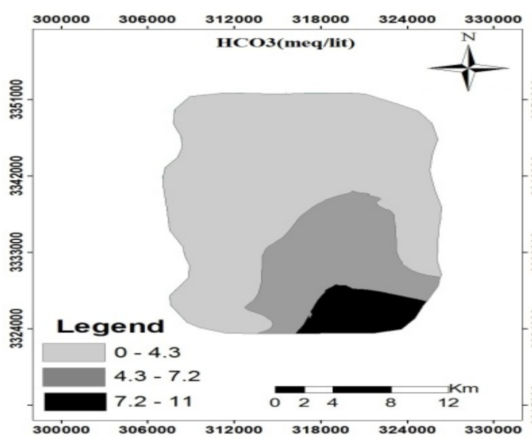
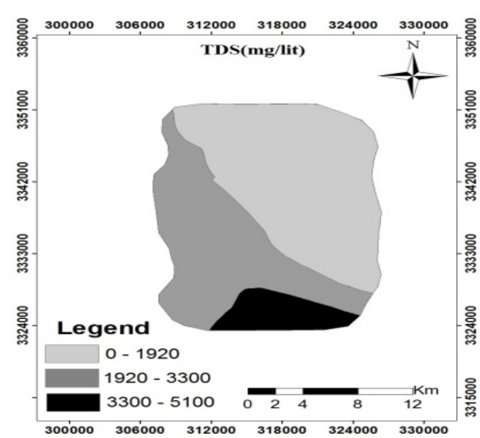


Fig 4. Zoning of SIS









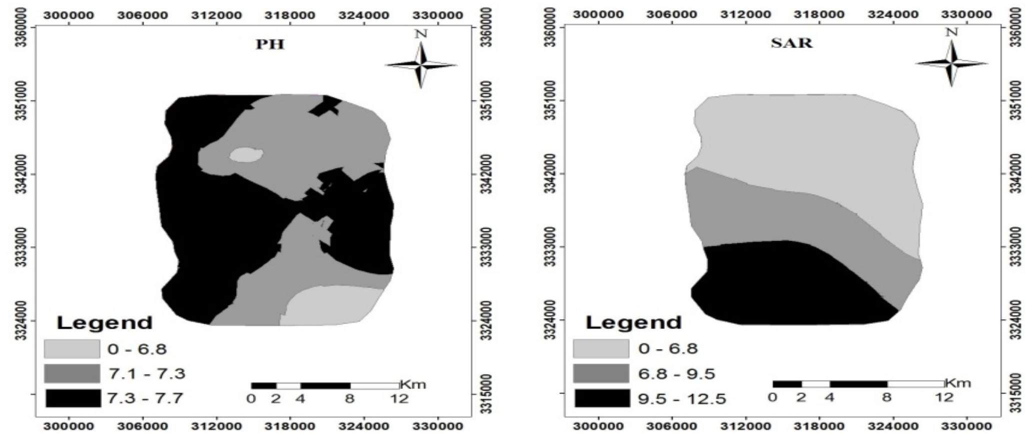


Fig 5. Zoning maps qualitative parameters.

DISCUSSION AND CONCLUSIONS

Exponential model was considered as the best fitting model of variograms for Cl parameter and spherical model for other parameters. Then between the different methods of geostatistics, the kriging method was chosen according to RMSE and MAE criterions (which were less than IDW method) to provide the zoning maps. The results corresponded to Nazari Zadeh et al (2006), Taghizadeh Mehrjerdi et al (2008), Ahmed (2002) and Albaji (2008) researches. In the next step the zoning of the maps were done according to permissible value of important materials in water for sprinkle and trickle irrigation. Then by combining various layers for each irrigation system based on Boolean simulator in Arc GIS9.3 software, proper regions were identified for all kinds of pressurized irrigation and those with optimal water quality were determined for trickle irrigation in wider range of lands. According to the results, trickle irrigation systems are applicable in large portion of this plain and in limited parts of north, northeastern and east of the plain sprinkle systems are applicable. Of course it should be noted that in almost half of the lands in this region –South and west- none of these approaches are practicable. Due that the main product of this region is pistachio and this plant is resistible against saltiness, it is possible to increase the water efficiency and transference by reforming the irrigation approaches which decreases the water consumption as well. Considering growing trend of saltiness in Shahr-e-Babak plain groundwater, it is recommended to prevent the reduction of ground water quantity and quality in the region through the development and accurate selection of irrigation approaches.

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