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Journal Of Radar and Optical Remote Sensing

JRORS 1 (2020) 55–66

Modeling Spatial and Temporal Changes in Water Resources Quality by Cultivating a Variety of Agricultural Products

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Received 16 December 2019; revised 7 February 2020; accepted 10 March 2020

Abstract

Groundwater resources are considered as the main and most important sources of drinking water, agriculture and industry. It is necessary to study the quality change and decline in the balance of these resources as a result of improper drawing, inappropriate temporal and spatial distribution of water resources in Iran and low irrigation efficiency in agriculture, has made water the most limiting factor of production in agriculture. In the present study, the fields under cultivation with various crops were studied in terms of the effect of cultivating different plants on groundwater resources in the lands of Moghan Agriculture, Industry and Animal Husbandry Company at different time period according to the type of crop cultivated. For this purpose, spatial and temporal modeling of the change process was carried out. The results showed that due to successive cultivation and the use of crops that need a lot of water for cultivation, water in two wells in the region has become saline and the water level has decreased.

***Keywords**:* Groundwater, Moghan Plain, Modeling, Agriculture

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1. Introduction

Water used in agricultural production comes from different sources such as rivers, wells, qanat and springs and other similar cases. Each of them has different characteristics depending on the geographical location. Since plants have different reactions to solutes in water, care must be taken to select the cultivation of plants based on how the solutes are in the water (Soleimani et al., 2015). Some halophytes, other groups of lime and other plants are placed in different categories in relation to these cases. But what is important is to be careful in choosing the cultivation of the plant in relation to soil and water. Nowadays one of the major human concerns is the contamination of agricultural soils with a variety of chemical contaminants, especially heavy metals. These pollutants can potentially hamper agricultural development by using a variety of organic and chemical fertilizers, municipal effluents, pests, insecticides, herbicides, and many other agricultural processes that affect the local soil. On the one hand, in order to gain more economic benefits, human beings have increasingly used pesticides and chemical fertilizers, and on the other hand in order to achieve industrial development or disposal of chemical waste and industrial effluents, factories have polluted them in natural environments. All agricultural chemicals contain additives and although the toxicity of such additives is not high, but they can have side effects in nature (Piri et al., 2013). In this regard, many studies have been conducted to investigate the quantity and quality of water resources in agricultural use. Examining the amount of nutrients in agriculture and managing the reduction of other effective pollutants in 2017, Duncan concluded that worldwide, the cumulative effects of pollution from a wide range of human activities, decreases the quality and capacity of ecosystems of lakes, rivers, and oceans. Effective ways to regulate the causes and effects of published pollution is a legal, political and managerial challenge.

Osati, and Nahvinia (2016) have studied the quality of groundwater resources in terms of agricultural use in Birjand plain. The results showed that more than 85% of the drawn groundwater resources of Birjand plain are used in agriculture. Due to the importance of water quality in irrigation, sampling of pH and EC values in forty-seven piezometric wells in Birjand plain was done to determine the quality of groundwater resources in terms of agricultural use. The kriging method in interpolating the values of the mentioned parameters has a better estimate than the inverse distance weighted method (IDW) and the spline functions (RBF: Radial Basis Function). In another study, Alipour and Keli (2013) investigated the number of chemical factors in irrigation water of agricultural lands in Ramhormoz city. In order to investigate the current status of irrigation water in agricultural lands of Ramhormoz city, 120 samples of irrigation water of agricultural lands were collected; Salinity, bicarbonate and sodium, calcium and magnesium cations were measured in the soil and water laboratory. The results of sample analysis were compared using SPSS 18 software. According to the obtained results and their comparison with existing standards showed that these waters do not have a problem in terms of irrigation. Kourgialas et al. (2017) investigated the effects of fertilizers used in agriculture on groundwater quality in the Crete region of Greece with the aim of introducing a spatial information system as a suitable method for evaluating the effect of chemical fertilizers on drinking water quality and groundwater protection. To estimate the spatial distribution of groundwater pollution for each fertilizer element, 8 factors / maps were considered. The results showed that a small part of the study area, about 8 square kilometers (3.72%), with excessive use of fertilizer, is contaminated or partially contaminated. Due to the fact that in this area was the source of drinking water (wells), this study identified an analytical method for the protection of wells. According to the research records, it can be acknowledged that the cultivation of different crops according to the method of fertilization, uptake of soil elements, etc. can have different effects on the level of groundwater pollution. Meanwhile, water wells are a good option for studying water quality. The spatial location of water resources in agricultural lands as well as the period when water resources are affected is very important. Therefore, in this study, it is hypothesized that the spatial and temporal of different types of agricultural crops have a significant effect on the water quality of wells in the study area. Accordingly, the present study has been conducted with the aim of spatio-temporal study of agricultural water quality in terms of products in regions with diverse vegetation. In this research, modeling of changes in the GIS environment using remote sensing data, ground sampling, etc. has been done.

2. Materials and Methods

2.1 Study Area

In the present study, the study area is the lands of Moghan Agriculture, Industry and Animal Husbandry Company, which is the largest company of its kind in the country and in the Middle East with the volume of agricultural, livestock and industrial operations. This company is located in Pars Abad city. Parsabad is one of the cities of Ardabil province in northwestern Iran (Figure 1). Moghan Company's agricultural and livestock products include cotton, sugar beet, corn, wheat, Hashemi rice, legumes, oilseeds, sesame, and fruits.

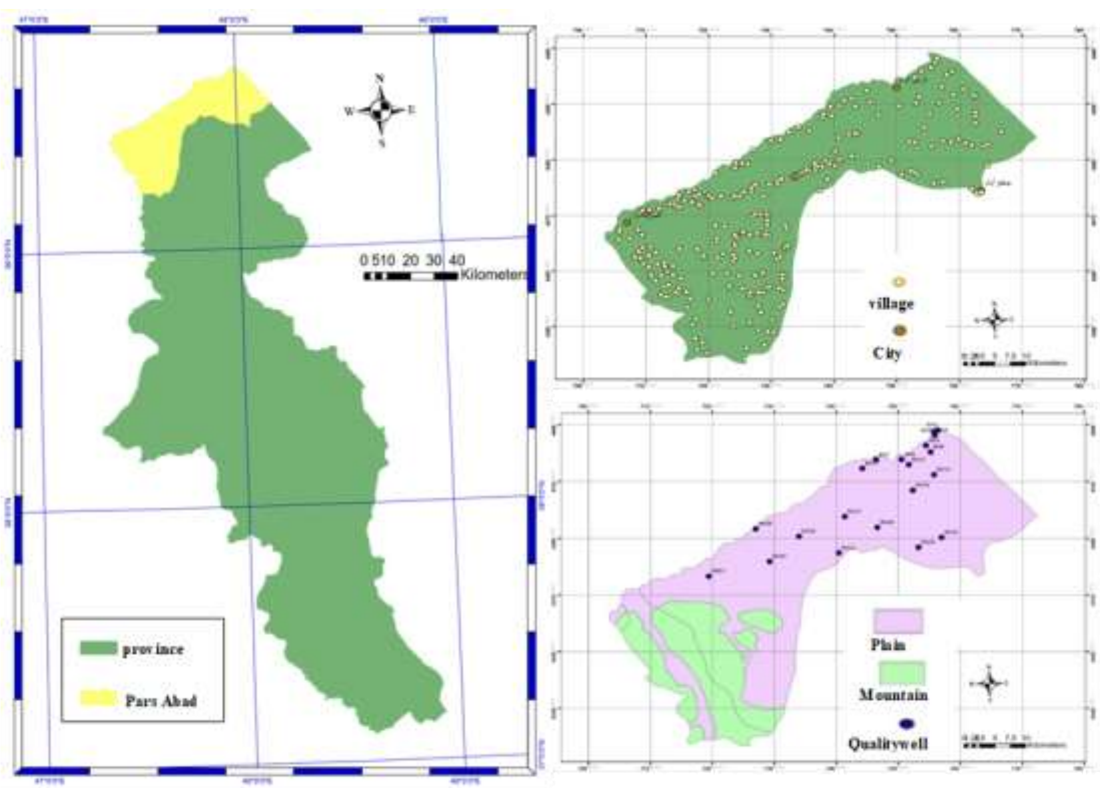

Figure 1. Limited map of Ardabil province and geographical location of Pars Abad city, the situation of the city and villages of the city and its features (location of wells, mountains, plains, etc.)

2.2 Method

The main stages of the implementation of the current research method began with the collection of information on the distribution of crop cultivation in the study area. Therefore, the qualitative information of wells dispersed in the study area and the lands under cultivation of each crop was collected and then entered in the Geographic Information System (GIS). In the next stage, land surveying map and quality maps of water resources in the study area were prepared. Topographic maps of the study area were also prepared and used in order to use them in the modeling process. Recent maps have already been prepared by relevant organizations and made available to researchers in this study. All the mentioned information was recalled in GIS environment and processed using modeling techniques. Therefore, first the bugs and errors of the implemented model were fixed and then the output was extracted and the type of product and the amount of water pollution were compared. It should be noted that there were 18 wells in the area in question that the water quality information of these areas in 1year period and during 4 years from 2011 to 2014 was reviewed. Figure 2 shows the cultivation status of each crop, considering the adjacent well for a period of 4 years.

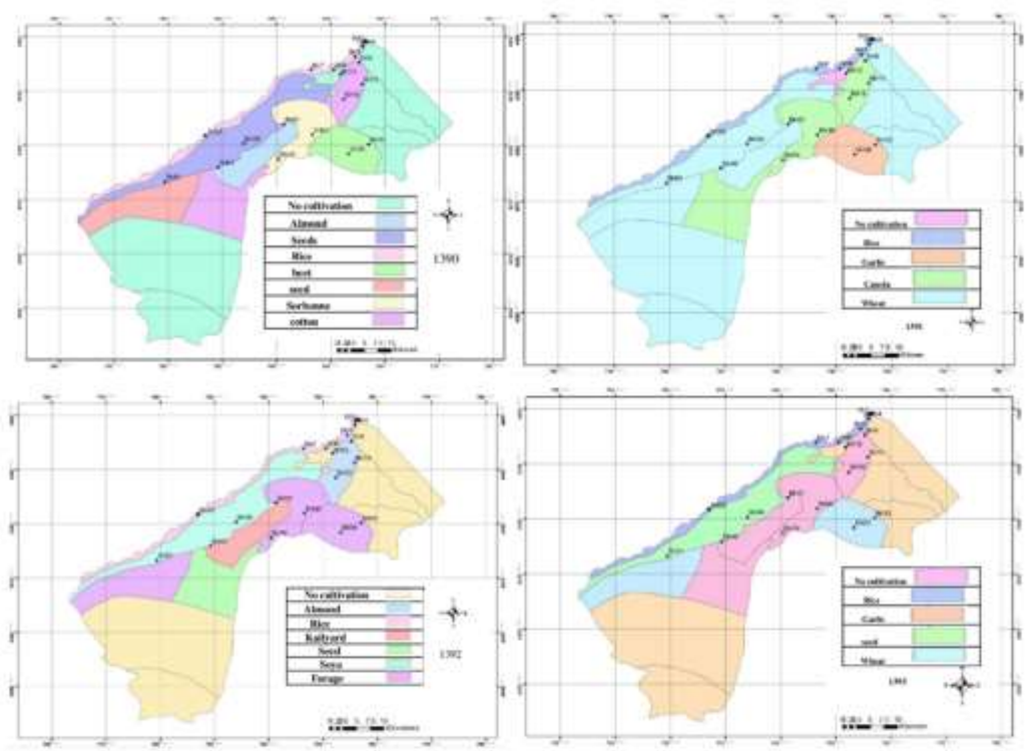

Figure 2. Dominant cultivation map of each crop to study the water quality of each well in the region

Naturally, there are many salts in the water, but in addition to these salts, some chemicals are added to the water during the refinement process, so they must be qualitatively controlled at the end of the refinement or generally before the water is consumed. The chemical quality of water is very important in agriculture and drinking. In order to study the chemical quality of water in agricultural use, more attention is paid to two important parameters which are the Sodium Absorption Ratio (SAR) and Electrical conductivity (EC). Parameters studied in the chemical quality of water include soluble TDS, electrical conductivity EC, alkalinity (PH), concentration of anions including CO3-2, HCO3-, CL and SO4¨, density of cations including Ca ++, Mg ++, Na + and K + and finally thickness (TH). Most of these data do not have a sufficient record period for analysis. Therefore, to evaluate the chemical quality of water for irrigation, mainly two parameters of sodium adsorption ratio (SAR) and electrical conductivity (EC) are used. Sodium uptake ratio indicates the amount of sodium hazards for plants and soil (Panahifard et al., 2017).

Also, in almost pure water, the relationship between electrical conductivity and total solute concentration is EC = 2 TDS. When the concentration of impurities in water increases, the ions have a negative effect on each other's motion and the electrical conductivity of the solution will no longer have a linear relationship with the ion concentration. In fact, the relationship between TDS and EC is different for each water sample and depends on the concentration and type of impurities in the water. There are appropriate interpolation methods to evaluate the status of these elements. Interface methods in GIS are both statistical and deterministic. Basically, statistical methods are used for topics such as pollution, and definitive methods are used to prepare DEM and rate curve mapping. Kriging method has been one of the common statistical methods to check the quality and contamination in most researches and in this method the second Root-Mean-Square Error (RMSE) less indicates the desirability of this method. Therefore, due to the low density of sampling points in the area of quantities close to each other, the simple kriging method (Calirad et al., 2013) was used for interpolation. In the continuation of statistical data analysis, using water quality tables, each of the considered parameters during the 4-year period was reviewed and analyzed. In this process, Thysson polygons were used to determine the effective level of each well (Valizadeh et al., 2016) (Figure 3).

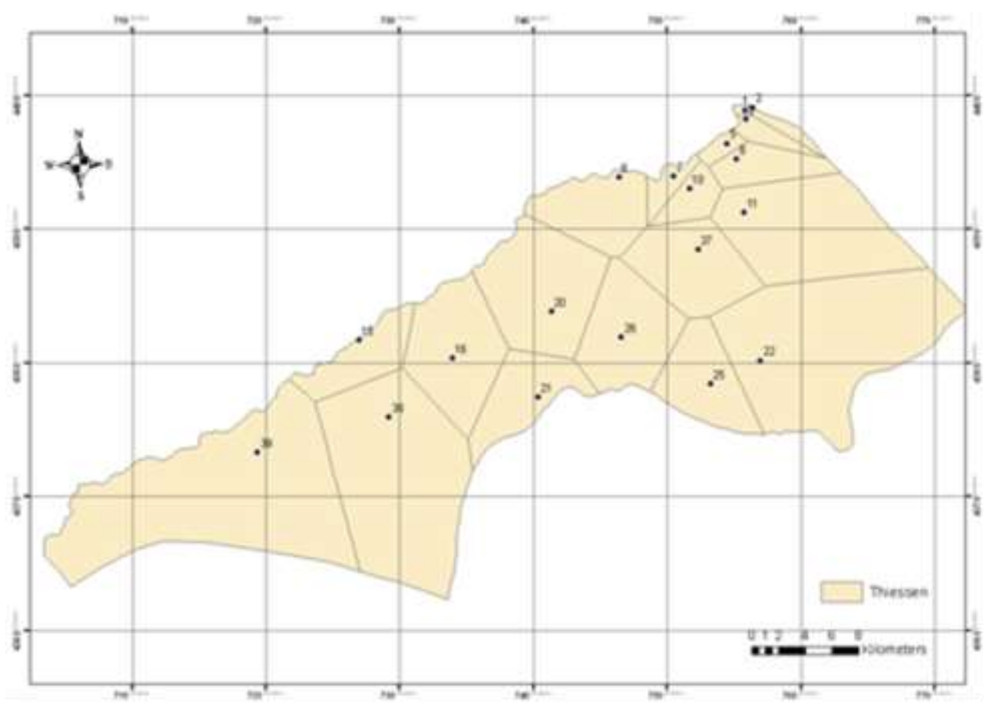

Figure 3. Thiessen Polygon map

3. Results

The results of the study of different parameters in the water are as follows. The results for each parameter, well in the desired year are shown in the form of a graph in Figure 4 to 6.

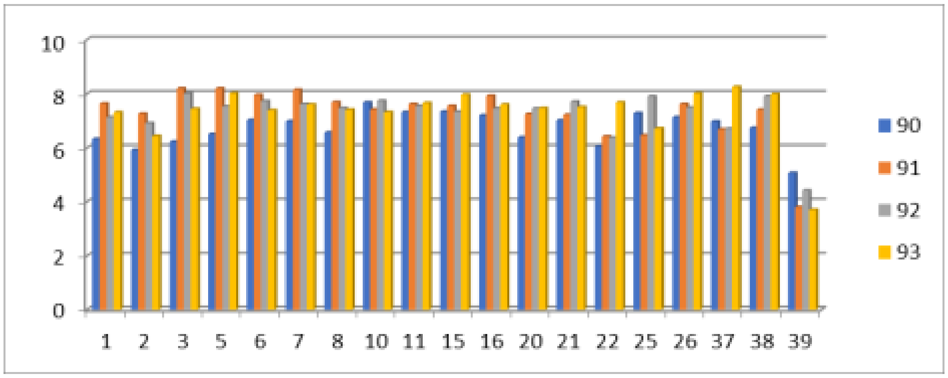

Figure 4. Comparison diagram of water pH hardness in 4 time periods of the study area.

The status of the two parameters of electrical conductivity and total dissolved solids (EC and TDS) are shown in Figures 5 and 6.

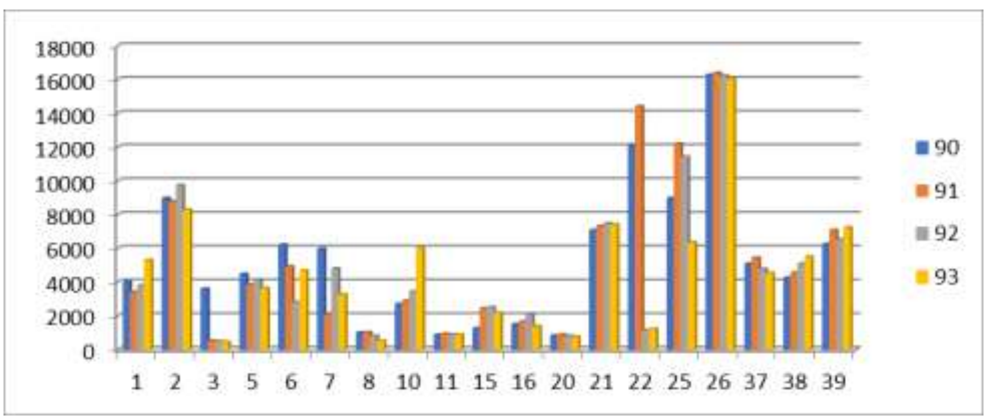

Figure 5. Diagram of changes in electrical conductivity

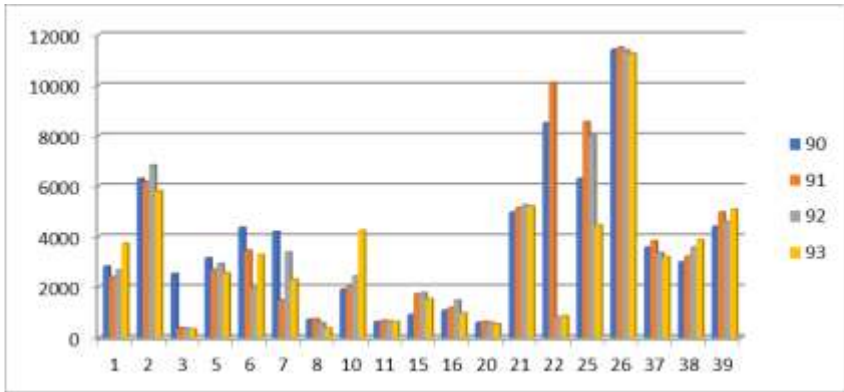

Figure 6. Chart of residual TDS changes

Interpolation maps of 3 parameters of pH, electrical conductivity and residual TDS produced using kriging method are also shown in Figures 7, 8 and 9.

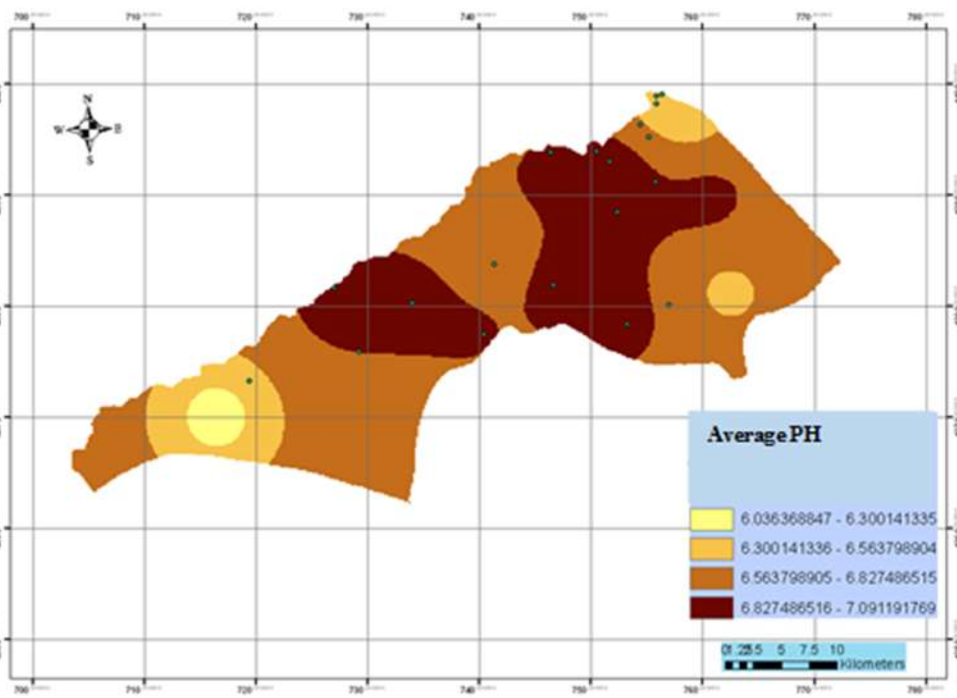

Figure 7. Intermediate map of average water hardness

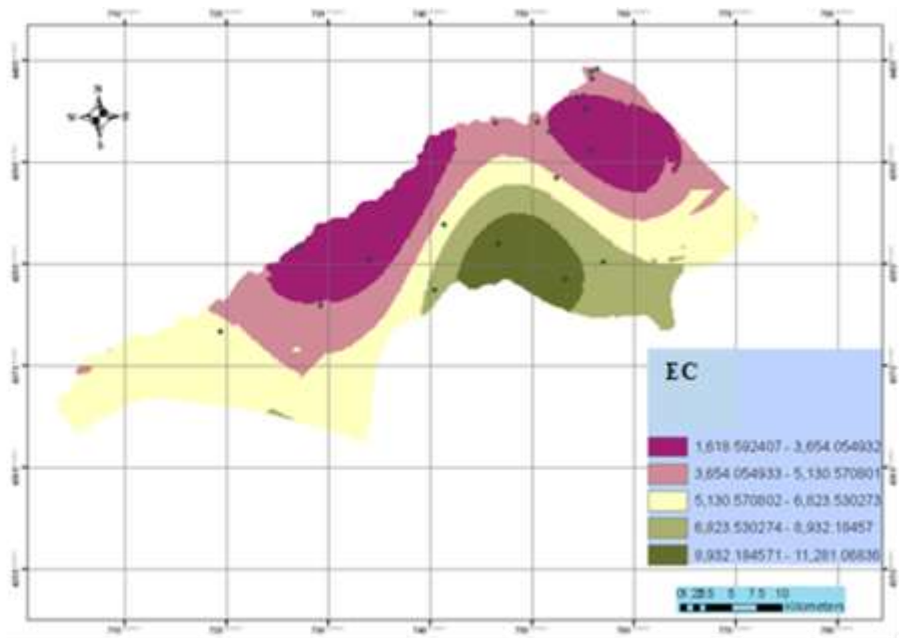

Figure 8. Electrical conductivity interpolation map

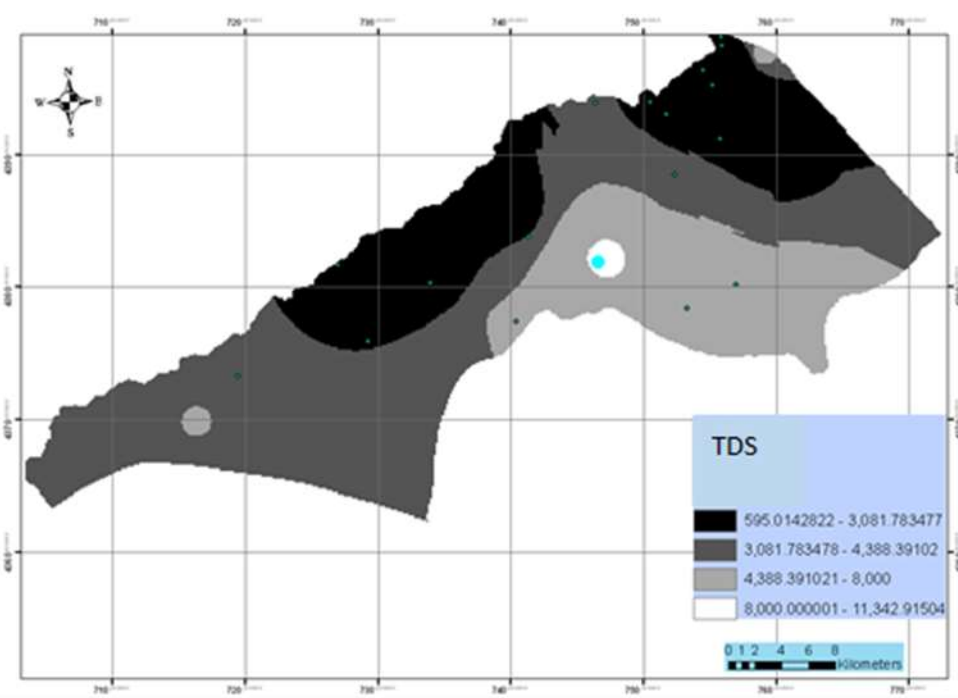

Figure 9. TDS interpolation map

According to the statistical information and interpolation in GIS environment, it was realized that well number 26 with code BH40 may have caused salinity and change in water quality due to successive cultivation in all 4 time periods and uncontrolled water abstraction. The high value in the electrical conduction table is quite evident for this well. In well number 25, code BH39, like well 26, has a lower quality than other wells due to annual cultivation. Cultivation of 4 periods of this well included beet, garlic, fodder and soybean. Also, in wells 8, 11, 37, BH13, BH19, BH9, despite the cultivation of crops in all 4 time periods, due to the cultivation of crops such as wheat, cotton, canola and almonds, water quality has been maintained at the desired level. In general, considering the location of the well, the best cultivation for the region in the central parts is wheat, and the northern parts, which are adjacent to the Aras River, the best cultivation is rice. In all 4 time periods in the northern areas of the city is allocated to rice cultivation.

4. Discussion

The most important elements affecting the yield of rice and wheat, which are the dominant crops in the region, are calcium, magnesium and sodium. These three elements affect the yield of rice and wheat in relation to each other. Wafakhah et al. (2011) in their study on the effect of ammonium and calcium on the release and absorption capacity of potassium and wheat yield found that the amount of calcium in soil water had an effect on straw yield. As calcium increases, straw yield increases compared to wheat and has a positive effect on straw yield. On the other hand, nitrogen is one of the important elements in wheat yield, which was zero in the wells we studied. Studies have shown that the behavior of potassium is correlated with various soil and environmental factors. These are the type of clay mineral, moisture regime, history of cultivation and fertilization, drying temperature and weathering (Hanan, 2008). At the test site, the usability of potassium is controlled by two factors: specific surface area and soil granulation status (Amini and Movahedi Naeini, 2013). For optimal plant nutrition, the amount of K + in soil solution is affected by the release of non-exchangeable potassium from clay minerals and organic matter. In the soil of the test site, due to the high specific surface area, the dual diffuse layer, the higher ratio of potassium in the electrical dual layer to the soil solution and the low diffusion rate of potassium from cation exchange sites into the soil solution, the exchange kinetics of exchangeable potassium to In solution is slower than the kinetics of non-exchangeable potassium release and the controlling factor of potassium concentration in soil solution and its absorption capacity (Amini and Movahedi Naeini, 2013). A study by Bajwa and Rahman (1996) showed that in Pakistani soils, when Ca ++ was added in large amounts to gypsum, K + was replaced by Ca ++. Due to the adsorption of Ca ++ in exchange sites, the increase in Ca ++ caused K + leaching. Jalali (2006) showed that Ca ++ due to its larger hydrated size expands the spaces inside the illite clay layer and causes the release of potassium in the calcareous soils of Hamedan. Jalali (2008) investigated the Ca / Mg ratio of irrigation water on the release of potassium in calcareous soils in the west of the country and stated that calcium and magnesium in irrigation water, during the process of ion exchange and substitution, could be effective in release of potassium in the mineral in soil solution and the release of potassium in saline irrigation water containing these elements increases with increasing magnesium ratio.

Farhangi and Movahedi Naeini (2010), in a study showed that in clay soils with high specific surface area due to the dual distributed layer, mixing potassium fertilizer with calcium fertilizer (from gypsum and calcium chloride sources) can be due to calcium replacement instead of Potassium in exchange sites increases the mobility of potassium and reduces its stabilization. According to the research of Amini, Movahedi Naeini and Mashayekhi (2012) in the tested soil (Typic Haploxerepts), N + P + K treatment (if phosphorus fertilizer is triple superphosphate) reduced wheat yield compared to N + K treatment. Therefore, calcium with superphosphate fertilizer may reduce the K / Ca ratio in soil solution and reduce potassium uptake. Talebizadeh, Movahedi Naeini, Pahlavani and Zeinali (2009) in investigating the effect of fertilizer treatments with potassium fertilizer on grain yield and potassium harvest in wheat plant in a soil with a high specific level, reported that the highest amount of potassium is related to fertilizer mixing Urea + potassium sulfate + diamonium phosphate and also the increase in potassium in the mixture of ammonium and potassium fertilizers, increases the root uptake of potassium in wheat. In the study of Kourgialas et al. (2017), which had a similar purpose to the present study, the parameters determining the contamination of water wells were zoned by kriging method and the results showed that a small part of the study area, about 8 square kilometers, with excessive fertilizer use is Infected or moderately infected. In map number 10 of the present research, according to the amount of pollution in the study area, it has been zoned and the amount of lethality has been shown according to the situation.

Former studies and comparison of the results obtained from this research show that based on the information obtained in this study, we find that in areas where well water quality is severely reduced, planting should be reduced or that the product is appropriate to the quality of the well. Cultivated area. According to the characteristics of wheat, the dominant crop of the city can be assigned to wheat in general. By proper planning and management, the water quality of wells in the region can be maintained at the desired level. According to the conditions of the region, with the studies conducted, the agricultural jihad of the region has presented a map entitled the cultivability of the region. In this map, unfortunately, cultivation capability has been allocated to BH40 well area again. With optimal water consumption management, the water quality of the well can be kept constant and crops that are capable of operating with this water quality can be cultivated (Figure 10).

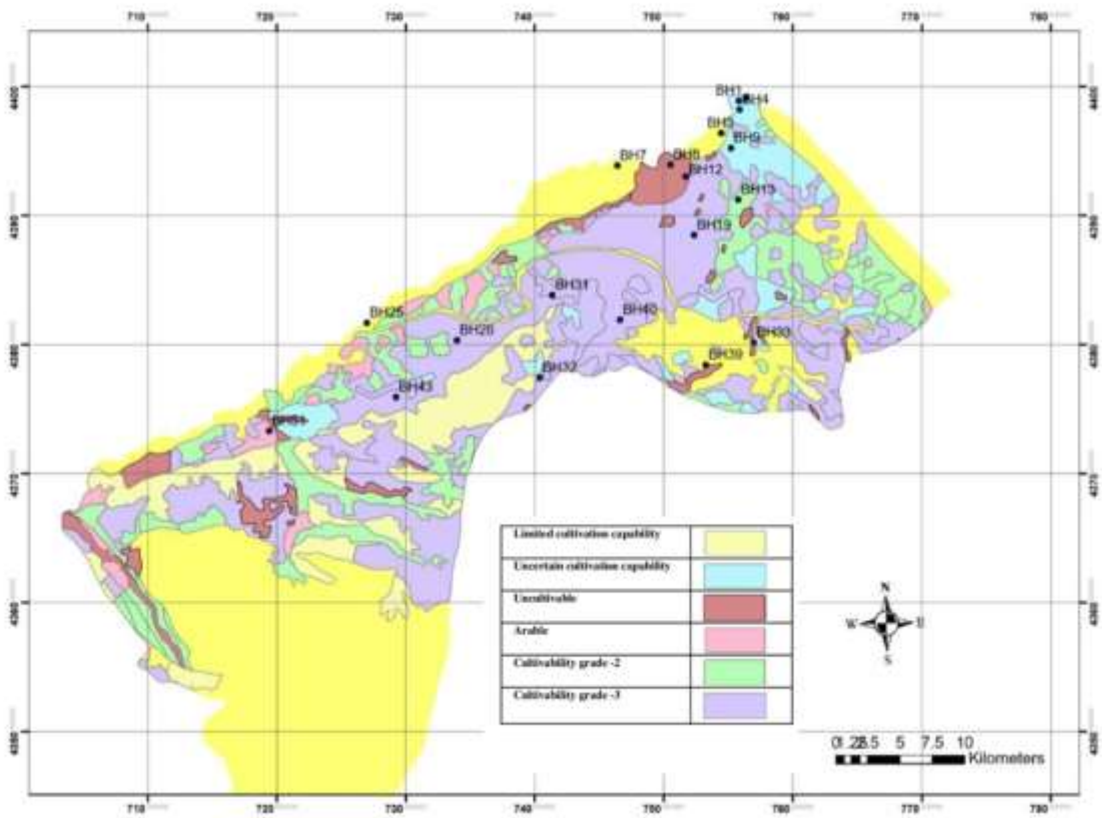

Figure 10. Map of the Cultivation capability presented

5. Conclusion

One of the most important effects of water hardness on crop cultivation is its direct effect on agricultural pesticides. Because spraying of agricultural products requires a mixture of water and pesticides and the desired water is supplied from agricultural wells, the water that often comes out of agricultural wells is very alkaline and its pH is very high. Studies in other research by researchers have shown that the high pH of water used for spraying and filling sprayer tanks breaks down the formulation of the toxins used and reduces their impact on the pest. At pH above 7, the effect of many organophosphate and carbamide toxins on the pest is reduced. Reducing the effect of toxins by the pH of water is called alkaline hydrolysis or refraction. Pesticides usually perform very well in aqueous solution with a pH below 7.

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