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The Strategy of Sustainable Agricultural Development, Identifying and Zoning Certain Indices of Environmental Pollutants in the Underground Water (A Case Study: Sarvestan Plain)

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Abstract. The efficient and appropriate use of basic resources in agriculture and considerations of environmental requirements not only it helps in producing healthy crops but also lead to sustainable agriculture. Planning for optimal use of water and soil resources on one hand and on the other hand, moderate consumption of inputs in other agricultural areas is a fundamental and important principle. This study is done based on the data of physic-chemical parameters including pH, electrical conductivity, bicarbonate and sodium absorption ratio in 29 water wells of the area located in Sarvestan Plain from 2005 to 2011 analyzed by Excel and GIS (Surfer10 version) applications. As the last step, the results of data analysis, diagrams, and zoning and geological maps as well as land use and GIS were compared with FAO standards in regard to irrigation water quality so as to enable further review and inferences. According to the results of data analysis and their comparison with FAO standard, it is estimated that electrical conductivity in 75% of wells have very high degrees of restrictions, the sodium absorption ratio of 65% of wells were of high and very high restrictions, bicarbonate content and acidity of 28 water wells were respectively had low to moderate restrictions and normal range of irrigation water quality as codified in FAO standards. The maximum value of parameters of sodium absorption ratio and electrical conductivity in wells 7 and 9 were respectively (45/6 – 49/7) decisiemens/m and (46/5 – 70/5) milliequivalents/liter. Due to recent droughts, reduction of precipitations, increase in temperature and evaporation intensity along with usage of chemical agricultural fertilizers and the kind of formations surrounding the plain bed as well as locations of wells 7 and 9 in the evaporative area of salty Maharloo Lake, the diffusion phenomenon and migration of salty water of the Lake towards the plain and its influence on underground water of plain are seemingly the most important factors of increasing electrical conductivity and sodium absorption ratio. Therefore, planning for continuous monitoring of water resources seems essential.

Keywords: Sustainable development, environmental pollutants, zoning, FAO standard

1. INTRODUCTION

Now, more than three decades of international attention to the issue of environmental protection and approximately two decades of debate about sustainable development have passed. Before it and in all development projects, mere economic viewpoints and earning money and greater economic efficiency attracted more attention. World Commission on Environment and Development (WCED, 1987) has defined sustainable development as “A development that satisfies the needs of the present generations without endangering the ability of the future generations”. This concept was more accurately defined for the food and agriculture sections by the following definition and it was accepted by the FAO Council in 1988. The latter definition states that sustainable development is “the management and maintenance of natural resources, directing the changes and administrative structures so that they guarantee the continuous satisfaction of human needs and satisfy the present and future generations (Rahmani, 2010: 14). Regarding the issues of controlling, storing and timing of water resources, examining and analyzing such a large volume of data requires using specific software and hardware facilities which the geographic information systems provide in an appropriate manner (Almasari and Kalurachchi, 2007). In regard to the assessment and zoning of the environmental pollutants in the underground water, different studies have been done including Moghami et.al (2011)

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evaluated different interpolation methods of zoning interpretation of water quality using the GIS and Schuler chart in Abadeh Town and expressed that the northern, eastern and central regions had unfavorable conditions in terms of drinking water. Banezhad and Mohbzadeh (2012) did an evaluation of the quality of underground water used as the water supply for agriculture of Razan-Qahavand. They used GIS and after the analysis of 49 wells, during the 4 years and in terms of parameters of electrical conductivity, total dissolved solids, pH, chloride, sodium absorption ratio concluded that 43.7 percent of the region area has an inappropriate concentration of sodium ions. The region studied which is located in the east of Maharlou Lake lacks permanent surface water current and satisfies almost all water resources needs (agricultural, drinking and industrial) from the underground water supplies. So, determining the quality of underground water of the region is more important and more control and investigation are needed. The purpose of this study is to determine the quality of certain influential factors and environmental pollutants of the water wells of the region through GIS and FAO standard so as to determine the quality of irrigation water as a strategy for the sustainable development of agriculture.

2. MATERIALS AND METHODS

The region under study is Sarvestan Plain with an area of 1641 square kilometers in the longitude of 17′ and 20° north. This plain is consisted of a mountainous platform at the fringes of which a low-lying alluvial plain exists and the salinity of it water streams is affected by climate conditions. The average temperature, evaporation and rainfall are respectively 17/1°C, 2222/8 and 379/8 mms. Based on Demarton classification, the climate of the region is dry. The maximum height of this region is 2970m in the mountain range of south west plains of Kouhdan and the minimum height (i.e. 1460 m) is observed at the outlet towards Maharlou Lake. According to the same-level curves of underground water, the direction of underground waters is from the highlands of eastern and southern plains towards the west of Maharlou Lake. Figure 1 shows the location of Sarvestan Plain along with the wells under study. In this area, 1 residential well, 8 pasture wells and 19 agricultural wells existed.

Figure 1. Location of the area under study; East of Sarvestan Plain on the map of Iran.

In the present study, the detection of environmental pollutants in the underground water of Sarvestan Plain for agricultural purposes is done through the parameters of pH, electrical conductivity, and bicarbonate and sodium absorption ratio. These parameters were collected during 7 years (i.e. 2005 to 2011) from 28 wells that covered the entire plain. The statistical analysis of mean, variation coefficient, standard deviation and upper and lower limits were done using the Excel Software. In order to provide the map of assessment of underground water for agricultural purposes, the topographic, geological, and land-use maps were initially added to ArcGIS10 Software and the zoning map of mean of each parameter was drawn and the location of all the wells on the map were specified and numbered. Then, the results of analyzing the parameters of 28 wells were attributed to each well in GIS Environment. Finally, by comparing the results of data analysis and zoning maps with FAO standard, the mean value of each

parameter was analyzed and interpreted. Electrical conductivity measurement was done by EC meter device (Aqualytic, Germany) with the accuracy of 0.01, pH was measured through pH-meter device (Meter Ohm, Switzerland), and determination of bicarbonate values was done by spectrophotometer (DR 5000). In the American Wilcox classification, the proportion of Na to (Ca + mg) is determined and the output quantity is called the sodium absorption ratio or SAR in which concentration of ions is described in terms of milliequivalent per liter.

$$SAR = \frac{Na}{\sqrt{\frac{Ca+mg}{2}}} \quad (1)$$

3. RESULTS AND CONCLUSION

Underground water is an important source of water for domestic, industrial and agricultural uses. For example, about 20% of the water consumed in the country of America is supplied from the underground resources and around 50 % of the people use underground water to meet some of their needs. Shallow aquifers whose storages are annually renewed provide the water needed for the farms and rural houses. Larger underground water reserves in deeper aquifers that takes decades or even centuries to renew their storage are usually pumped to meets the urban, industrial and irrigation needs (Shahouyi, 2006: 234).

Examining Changes in Electrical Conductivity

The total solute concentrations in the irrigation water are the most important water quality assessment criteria for the crops. Electrical conductivity is often used as an estimate of the total solute concentrations. Water quality assessment guidelines provided by FAO is universally accepted. The parameter of saltiness and its comparison with FAO standard of irrigation water showed that 25% of the wells had the moderate restriction, 75% had high and very high restriction degrees and the maximum salinity parameter was observed in wells 7-9 with respective values of 49.7 and 45.6 Siemens/m (Figure 2).

Figure 2. Zoning map of mean electrical conductivity.

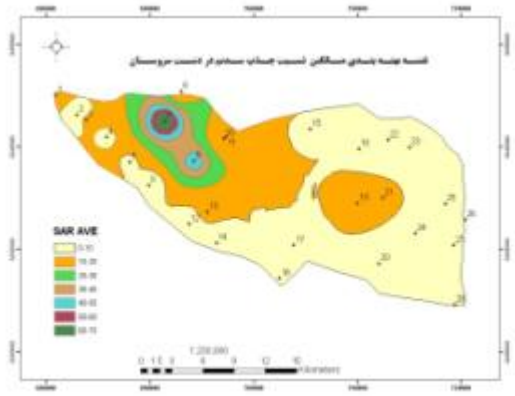

Figure 3. Zoning map of mean sodium absorption.

Changes in sodium absorption ratio. Another important measurement is related to water quality, the relative amounts of sodium in water. Irrigation water containing sodium prompts the formation of soils with high levels of exchangeable sodium. According to the zoning map of mean sodium absorption ratio in Figure 3 and its comparison with the FAO standard, it could be stated that 25% percent of water in wells have low restriction limits, 10 % of the wells face medium degree of restriction, 14% of the wells have high degree and 51% of the wells could be assigned very high degrees of restriction which in total shows that 65% of the wells had high and very high degrees of restriction for application as irrigation water source. The maximum values of these parameters were observed in wells 7-9 with respective values 5.5 to 46.70 milliequivalent per liter.

Examining changes of bicarbonate: Carbon dioxide is one of the components of the carbonate balance in the water. The amount of carbon dioxide in the water depends on the pH and its alkalinity. The dissolved carbonic anhydride in the water combines with the elements present in it or in combination with the water, a part of it changes into acid carbonic and the other part changes into carbonate and bicarbonate ions. The water present in 100% of the wells (28 wells) had low to moderate degree of restriction in comparison with the FAO standard and in accordance with the zoning map in Figure 4.

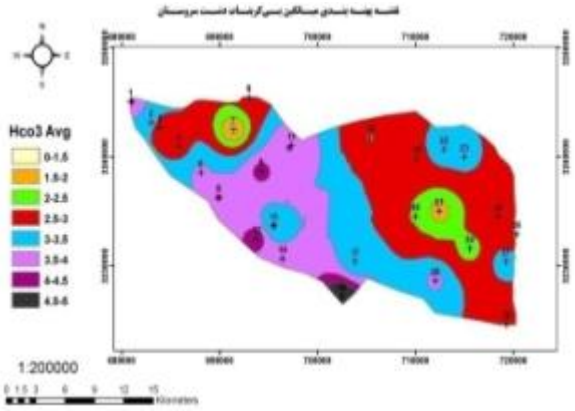

Figure 5. Map of average acidity zoning.

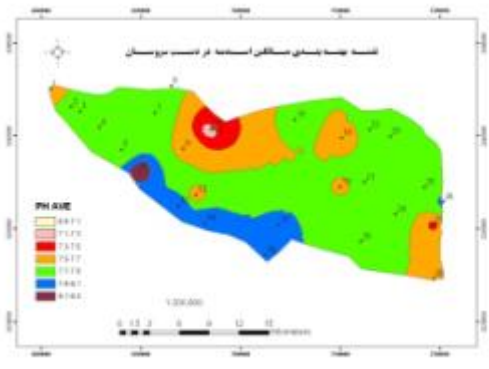

Figure 4. Map of average bicarbonate zoning.

Analysis changes in the acidity. Acidity is the amount needed to bring the pH to the neutral level and its unit is CaCO3mg/1. The acidity in the unpolluted water is usually caused by the weak carbon dioxide dissolved in water which creates carbonic acid. Hemic acid and folic and other organic acids which are derived from the decomposition of plants, can also be the causes

of water acidity. By examining and studying the zoning map of average acidity as shown Figure 5, one can understand that the amount of this parameter in 28 wells (100% of all the wells) was within the normal standard range of 4.8-6.5 of irrigation water quality guidelines for interpreting the quality of FAO standard.

4. CONCLUSION

There are several definitions for sustainable agriculture such as the one which defines sustainable development as "a kind of farming which is ecologically proper and economically prosperous, socially equitable, culturally acceptable and agreeable and scientifically holistic. In sustainable agriculture, the available human and natural resources including soil, water, and vegetation and so on are optimally exploited in which optimal and correct use of pesticides and fertilizers as well as the suitable use of crop rotation and proper agricultural operations using organic fertilizers and agricultural milling losses among other factors, ideal conditions will be provided for the agriculture and the farmers (Environmental Protection Agency, 2008: 4). There are noticeable amounts of soluble ions in the irrigation water which affects the plants and farming soil in physical and chemical aspects and reduces the productivity and efficiency. Because of the physical effects of these ions, the osmotic pressure inside the cells is reduced which prevents the water to reach the leaves and the branches. Chemically, such ions also disrupt the metabolism of the plant (Moghimi, 2006: 94). In general, the quality of surface or underground water depends on the geological, hydrological, and biological conditions on the one hand and the quality variation in different places and times on the other. The underground waters destroy the minerals of the rocks which they pass through or into which they gather. By studying the formation of ground of the bed of the plain which contain abundant limestone and gypsum, the normal pH of the underground plains is justifiable in comparison with the FAO standard. The studied parameters of the wells present in the Plain of Sarvestan, in terms of electrical conductivity and sodium absorption ratio had respectively a high degree and very high degrees of restrictions in using the irrigation water. This high amount of saltiness and sodium absorption ratio leads to observing the detrimental effects in the plants susceptible to such effects and on many of the sensitive farming crops. This water can also be used for water-resistant plants or impermeable soil through careful management operations. After studying the existing plans, and analyzing the data and comparing them with FAO standard, it is noteworthy that the kind of the geological structure around and at the plain's bed made of Asmari-Jahrom, Pabedeh-Guryi, Sachoun, Razak and Aghajari formations, presence of evaporative minerals, limestone and gypsum formations and droughts in the recent years leading to reduced the rainfall and increased temperatures, demographic density and increase of demand for water resources as well as overuse of chemical fertilizers have led to contaminated groundwater of the Plain of Sarvestan and high levels of its electrical conductivity and the sodium absorption ratio. On the other hand the groundwater flow direction which should be towards areas with lower elevation (i.e. Maharlu Lake) is now from the salt lake area into the plain. Usually in the areas with coastal aquifers of low topographic slope, the high withdrawal of underground water leads to reversal of hydraulic gradient and as a result, the flow direction tends towards the coast which leads to the phenomenon of diffusion and migration of the saltwater of Maharlou Lake towards the plain and the dramatic increase in the electrical conductivity and the sodium absorption ratio in most of the wells of the plain, especially wells 7 and 9 due to being located in evaporative area of Maharlou Lake. Underground water level during the years 2005-2011 shows a noticeable decline which is consistent with the relative increase of electrical conductivity and sodium ratio absorption. The concentrations of the above factors show increase toward the main reservoirs of underground water (from the eastern heights to the west of the plain). The high levels of underground water and poor water quality and its resulting high evaporation has caused the poor quality of the water the effect of which can be observed in a vast part of the plain. The primary sources of bicarbonate ions in the underground water are CO2 molecules present in snow, rain water and soil. The origins of CO_2 gas in the soil are the roots of plants,

the creatures' breath and the decomposition of organic matter. The increase in the temperature and evaporation intensity along with the decrease in the precipitation causing the low dissolution of carbonate structures present in the geological structures of the region seem to be major factors reducing the average amount of bicarbonate in the underground water of the 28 wells of Sarvestan Plain to the the standard level of FAO. The results of present study are consistent with the results of the research by Haghighat and Muhammadi (2005) on the study of 31 samples of sodium, potassium, calcium, magnesium, sulfate, chloride, bicarbonate, nitrite, nitrate and phosphorous ions. They stated that according to the maps, a high underground pollution in the residential areas compared with other areas could be observed. The findings of present study are also consistent with the results of the study done by Aali et al., (2013) who studied underground water in the areas of Riyadh and Al-Ahsa in Saudi Arabia and stated that no problems with the sodium in the water were expected to be found in Riyadh while in Al-Ahsa a minority (14%) of the studies on water problems showed serious problems due sodium-containing water. The underground water in most of the areas of Riyadh Al-Ahsa were on average salty and contained large amounts of chloride. In addition, the amount of pH and biocarbonate in both studies were in a safe and natural range.

5. SUGGESTIONS

For optimal productivity and protecting the environment based on premises of sustainable agricultural development, one can farm products or crops such as cotton which is an industrial product and can handle electrical conductivity (EC) of about 7700 micromhos/cm. Wheat, barley, hay and pistachio can be farmed with regard to the climatic conditions, the soil and hydrological conditions of the region, dryness and saltiness of the water. Growing these crops is significantly important and the following solutions could be used in this regard.

- Utilization of modern irrigation methods in accordance with the climatic conditions of Sarvestan Plain.
- Organic farming to significantly reduce the agricultural inputs.
- Prevention from taking excessive amounts of water from the wells and drilling new unauthorized wells.

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