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Investigating the Relationship between Land Use Changes and Physicochemical Characteristics of Groundwater

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ABSTRACT

Background: This study was conducted to investigate the relationship between land use changes and physicochemical characteristics of groundwater in the Dalaki watershed in Bushehr province, Iran from 2006 to 2016.
Methods: In this study, changes in the amounts of chlorine, calcium, sodium, sulfate, and total dissolved solids were investigated. In the first step, the spatial relationships of the aforementioned parameters were evaluated and the optimal models were selected for mapping. Then, using Landsat satellite images, the land use classification was done. Finally, the relationships between land use changes and the physicochemical characteristics of groundwater were surveyed.
Results: According to the analysis of the results, the highest concentration of groundwater in the studied years was observed in rainfed agriculture, palm groves and orchards land uses.
Conclusion: A significant relationship can be established between agricultural uses and the increase in the concentration of groundwater physicochemical characteristics. In other words, agricultural use caused groundwater resources salinity and reduced their quality. Because of the vastness of land use, a large amount of groundwater is taken to irrigate crops. Moreover, rainfed agriculture increased and decreased the number of quality characteristics, however using planting palm trees only increased them.

1. Introduction

Undoubtedly, water is an essential element for the survival of living organisms generation. Unfortunately, in recent decades the expansion of industry and the development of agriculture have reduced the amount of water or have contaminated it in various ways. Groundwater is an essential part of the world's renewable water. Calculating the world's water resources shows that underground resources have allocated about 0.6% of total water resources and 60% of renewable resources [1]. Therefore, investigating water quality is of great importance. A considerable increase in ion concentration in water, severely restricts the agriculture and water consumption [2].

Generally, using and developing groundwater resources in a way that expose extreme vulnerabilities in quality, quantity, and related ecosystems in the future, is defined as the sustainability of groundwater resources [3]. The change in the quality of groundwater which usually occurs due to the mismanagement of exploiting it, is an introduction to

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destroy other resources, both directly and indirectly [4]. Studying the quantity and quality of these resources and their relationship with the characteristics of the earth's surface will be the slightest effort to protect these valuable resources [5].

One of the crucial reasons for the change in the quality of groundwateris the land use change which changes the physicochemical characteristics of it in various ways including the water table drop and the entrance of different materials into these resources. Land use change in the world can be considered because of development in various fields such as economic, social, political, technology, and changes in the environment. The type of impact of these changes is strongly dependent on the governing policies [6]. Land use can affect the production and concentration of runoff due to the change in hydrological factors such as permeability, interception, and evaporation. Thus, it causes a change in the intensity and frequency of floods. Land use also affects water storage in the basin by changing hydrological processes such as groundwater supply, surface runoff, and base flow [7, 8]. In addition, land use changes cause variation in the type and amount of contamination leading to changes in groundwater quality by changing the amount of waste production and waste type [9]. Although surface water is more in contact with contaminants than groundwater due to availability and becomes contaminated more quickly, groundwater is not safe from mixing with contaminants. The most critical groundwater contaminants are municipal wastewater, various industrial effluents, pesticides, and chemical fertilizers which are found abundantly in agricultural uses [9].

Numerous studies have been conducted to evaluate the impact of land use changes on groundwater quality. Regarding the changes in soil profiles due to land use changes on groundwater quality [10] it was concluded that land use changes led to changing in soil profiles and then changes the physicochemical characteristics of water in various ways including manipulating the chlorine volume balance in the water. In this study, the water sample of ten wells was collected from all over Negatingara city. TDS, EC, pH, sulfate, and carbon dioxide parameters were measured for four months from March 2012 to June 2012 using standard methods. EC and pH, sulfate, and carbon dioxide parameters were in the permitted WHO range, but the TDS level was higher than the permitted limit at some stations [11]. Another study investigated land use changes using remote sensing and GIS techniques in the Giroud River Basin in India over 20 years (1990-2010). The results showed that about 30% of the study area was covered by agriculture in 1990 and its value increased by 9.8% in 2010 [12]. In another study, remote sensing techniques were used in the west of the Bengal region during 1990-2001 to model the land use change. The results of this study showed that many changes have taken place in the use of surface water and agricultural lands; so that 4.42% has been added to the area of water zoning and 27% of agricultural lands have been destroyed [13]. Shi Zhang showed that land uses on different scales have different effects on water quality size, density, accumulation, and diversity of land uses are essential factors that affect water quality [14]. Furthermore, groundwater supply in different land covers was examined by SWIM numerical model [15]. The results showed that this nutrition was mainly dependent on precipitation patterns and land use changes. As a result, groundwater supply is relatively higher in the forested areas compared to destroyed agricultural lands. In Iran, some of the related studies also have been conducted on the relationship between land use changes and groundwater characteristics. For example, in a study conducted by Dizaj *et al.* (2015) about investigating the impact of land use on groundwater quality with emphasis on significant cations and anions in the Islamshahr area, it was observed that the concentration of chemical parameters in the northwest, southwest, and south of this area has the maximum amount and much higher than the standard limit [16]. Finally, they concluded that the geological structure, agricultural activities, urban development, and population density are the most important sources affecting the quality of groundwater in Islamshahr city. The results of the study about investigating the land use changes on the groundwater quality resources in Ardakan plain in Yazd indicated that groundwater level has been dropped by land use changes such as the conversion of rangeland lands to urban and residential lands and caused an increase in the water salinity and reduce its quality [17]. Mahmoud Hassan carried out a study on land use changes on groundwater quality in the Lajan region of West Azerbaijan. It was revealed that changes in water quality in the two years had not been related to land use changes in both years [18]. In a study conducted titled zoning groundwater quality variables in Sarvestan plain using geostatistics, it was found that the lowest amount of electrical conductivity is in the suburbs of southern heights and most in the central areas of the plain because the groundwater level is high in this range and speed of groundwater movement is low due to the presence of fine granular alluvium with saline salts [19]. Moreover, Skndari Dameneh *et al.* (2019) found that increasing (13%) in groundwater level has been occurred by increasing extent in urban and agricultural land use [20]. Using geostatistics and remote sensing are affordable in terms of time and cost by reducing the number of sampling and providing more accurate estimates compared to traditional methods on a regional scale, and facilitating data collection [21-27]. Due to the importance of groundwater quality, the purpose of present study is to investigate the land use changes during the study period and then to examine the relationship between these changes and the concentration of physicochemical characteristics of groundwater in the study area.

2. Materials and Methods

2.1. Study area and sampling

Dalaki watershed is one of the basins of the Persian Gulf and Oman Sea, located between the Fars and Bushehr provinces. The basin is bounded to the Shapur watershed from the north to the Dalaki watershed from the west (in Bushehr province), to the Shoor Firoozabad river from the south, and to the Qara Aghaj watershed from the east. The catchment area of this basin to the upstream of Cham Chit water metering station (located in Fars province) is about 3900 square kilometers, its highest point with a height of 2900 meters is located in Bahim Mountain and its lowest point with a height of 545 meters above sea level is located in Cham Chit water metering station (Figure 1). Withdrawal of well water in Dalaki watershed is approximately 48.114 million m^3. Soil type in Dalaki catchment is more Alkaline and sand clay with low loam that is suitable for wheat and barley agriculture. Although the soil quality in Dalaki catchment is good, in the case of heavy irrigation due to the possibility of rising drainage, both water and soil are exposed to salinity and contamination. In this study, data were obtained from Bushehr Regional Water Organization. In the present study, chlorine, calcium, sodium, sulfate, and the total dissolved solids (TDS) were used. These data are related to 109 wells in Dalaki watershed sampled in 2006-2016 (Figure 1). The position of the sampling points is shown in Figure 1. From each station, three replicate samples were selected for analysis per year (2006, 2011, and 2016). Glassware and vessels were treated in 10% (v/v) nitric acid solution for 24 h and were washed with distilled and deionized water. However, in the sampling site the vessels were washed several times with a water sample then after ensuring the cleanliness of the container, a water sample was taken. TDS of water samples were measured at the sampling stations using a portable digital multimeter (Hach HQ 40d). In the laboratory, analyzing the samples was immediately done for determining chlorine and sulfate by using a Hach spectrophotometer DR 5000. The colorimetric method was used to determine chlorine and sulfate, method 10102 (Linear range 0.09 to 5.00 mg/L) and method 8051 (Linear range 2 to 70 mg/L), respectively. Complexometric titration by ethylenediaminetetraacetic acid (EDTA) was applied to find the calcium content (Standard method 3500 Ca, B; Linear range 3-250 mg/L). A flame photometer instrument (Jenway PFP7) was used to determine sodium (Standard method 3500 Na, B; LOQ 2 mg/L). The reference standard materials were selected based on the used standard method and a value of 5% error was accepted to accuracy. In order to prepare land use maps, the classification method and Envi software were used. In the first step, satellite images were prepared in 2006, 2011, and 2016. Landsat7 ETM+ satellite was used to receive images in 2006 and 2011 and TIRS/OLS Landsat 8 satellite was used to receive images in 2016. Then,

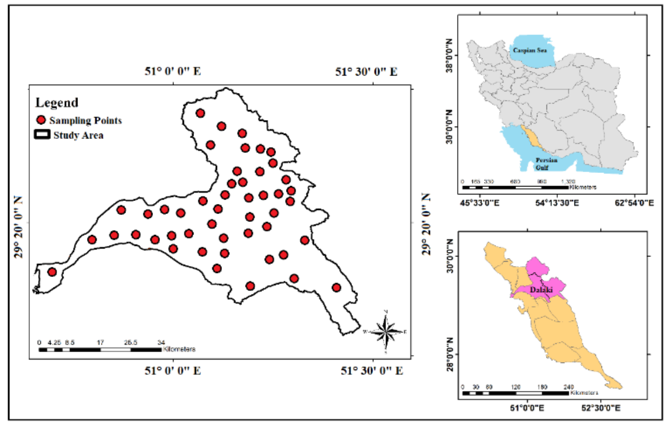

Figure 1: The location of the study area and position of sampling points

atmospheric, geometric, and radiometric errors were eliminated in the software environment and the spatial resolution of images was increased to 15 meters by using a combination of panchromatic and thermal bands. The classification process was performed using the Maximum Likelihood technique and the monitored classification method and using educational examples.

3. Results and Discussion

In the first step, land use map of the study area was prepared in 2006, 2011, and 2016 which were classified in 7, 6, and 10 classes, respectively (Figure 2). According to this figure, in 2011, low-dense rangelands were removed from the existing uses in 2006. Further, the area of semi-dense rangelands and forests have been reduced by 2237151 Km^2 and 4442769 Km^2, respectively, and 122667, 154529, 947033 and 591216 Km^2 have been added to the area of rainfed agricultural uses, orchards and palm groves, residents, and riverbeds, respectively.

Using the petrochemical site, industrial area, shrimp farming, and dense rangelands had been calculated that did not exist in 2016 compared to 2011 and 2006. In 2016, the rainfed agricultural area, semi-dense rangelands, orchards, and palm groves have been decreased by 1171436, 1804942, 730964, and 2081545 Km^2 compared to 2011. In this year, residential and riverbed areas have been increased by 232626 and 113681 km^2, respectively. Generally, during the study years, semi-dense and forested rangelands have been faced with decreasing rate and rainfed agricultural, orchards and palm groves, residents, riverbed, and low-dense rangelands faced with increasing rate. In other words, the land use of semi-dense and forested rangelands has been reduced by 4.02% and 68.46%, respectively, and the rainfed agricultural, orchards and palm groves, residents, riverbed, and low-dense rangelands have been increased 87.87%, 67.1%, 37%, 51.7%, and 15.9%, respectively.

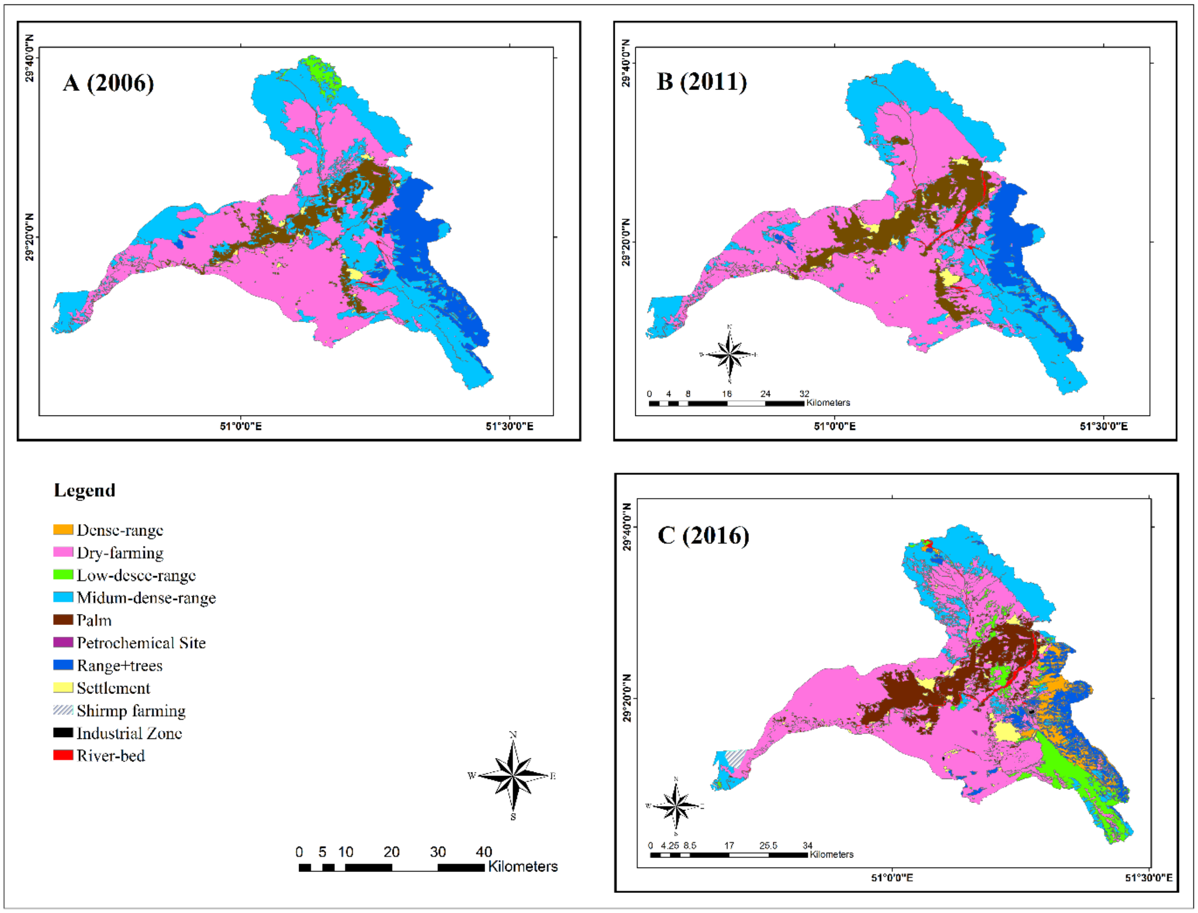

Figure 2: Land use classes in 2006 (A), 2011 (B), and 2016 (C)

A zonal statistical tool was used to investigate the relationships between land uses and spatial distribution of parameters. For this purpose, the mentioned command was called in the Arcmap environment and the zoning and land use layers were defined as the raster layer and the vector layer per year and for each parameter. Figures 3-7 show statistical information related to parameters studied during the study period.

As shown in Figure 3, the highest chlorine concentrations in 2006, 2011, and 2016 are related to rainfed agricultural uses, semi-dense rangelands, and semi-dense rangelands, respectively. As a result, it is possible to make a logical relation between chlorine concentration increase and the presence of vegetation-covered uses, especially those in which agriculture occurs. The lowest chlorine content is seen in rainfed agricultural use in every three studied years. Observing the highest and lowest level of chlorine in the rainfed agricultural use means a broader range of chlorine values in this land use. The amount of chlorine in the areas where the sampling was done in this land use is very different from each other. The maximum concentration of chlorine during 2016 in forest, riverbeds, shrimp farming, residents, orchards and palm groves, rainfed agriculture, low-dense and semi-dense rangelands land uses exceeded the defined standard limit and it is on the verge of alert. Additionally, in this year, the chlorine concentration in the petrochemical site is very close to the standard threshold. Iran national standard organization (ISIRI 1053) announces that the amount of chlorine must be in the range of 200-600 mg/L (for drinking water) [28]. In 2011, the amount of this parameter in all uses was higher than the standard. The amount of chlorine in the uses of dense rangelands and industrial areas in 2016 and all uses in 2006 did not exceed the standard limit and it is always lower than the permitted level and has a desirable situation.

According to Figure 4, the highest amounts of calcium in 2006, 2011, and 2016 are seen in the rainfed agricultural uses, orchards and palm groves, and rainfed agriculture. Therefore, it can be concluded that agricultural uses have increased the concentration of calcium in groundwater.

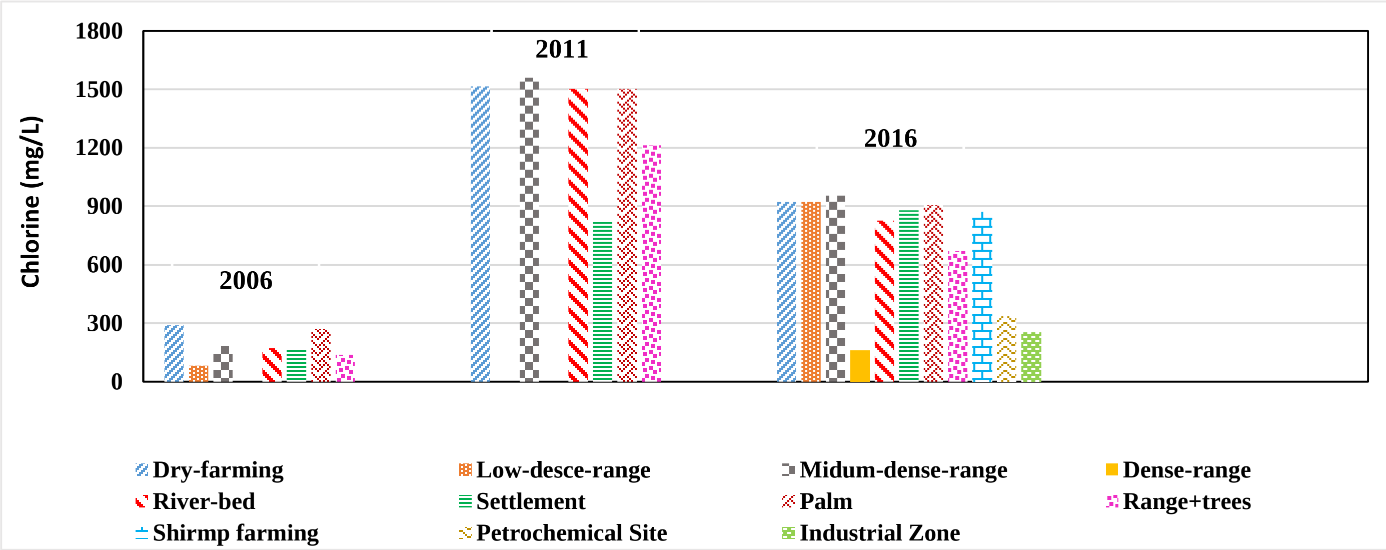

Figure 3: Chlorine concentration diagram for different land uses in 2006, 2011, and 2016

The lowest amount of this parameter in the mentioned years is related to semi-dense forest-rangelands and rainfed agriculture. In this parameter, like chlorine, the maximum range of changes is related to rainfed agriculture per three years. The concentration of this parameter in the mentioned three years and all uses in 2006 and 2011 is lower than the standard limit (75-200 mg/L; ISIRI 1053) and is in a desirable condition. Therefore the amounts of calcium in 2016 for dry farming, settlement, and Palm agriculture were higher than announced amounts.

According to Figure 5, the highest amount of sodium in rainfed agricultural uses is seen per three years. There is a significant relationship between increased sodium concentration and agricultural uses, especially rainfed agriculture.

Considering the standard defined for the permitted limit of sodium concentration in groundwater, the amount of this element in every three years is approximately higher than the permitted limit in most uses. These uses include rainfed agriculture, semi-dense rangelands, palm groves and orchards, residents and riverbeds per two years (2006 and 2011), and the petrochemical site, shrimp farming, and low-dense rangelands in 2016. The amount of this parameter in all land uses in 2011 is higher than the standard limit (200 mg/L; ISIRI 1053). The amount of this parameter in the uses of low-dense rangelands and forests in 2006 and dense rangelands and industrial areas in 2016 was lower than the permitted limit and did not exceed the standard limit.

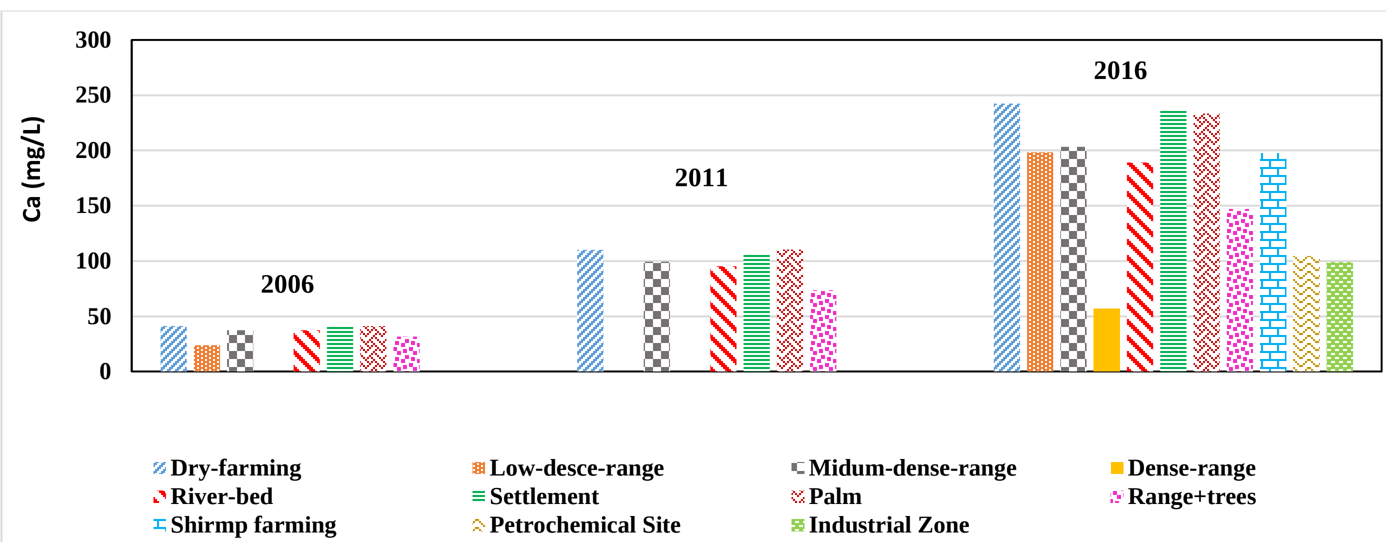

Figure 4: Calcium concentration diagram for different land uses in 2006, 2011, and 2016

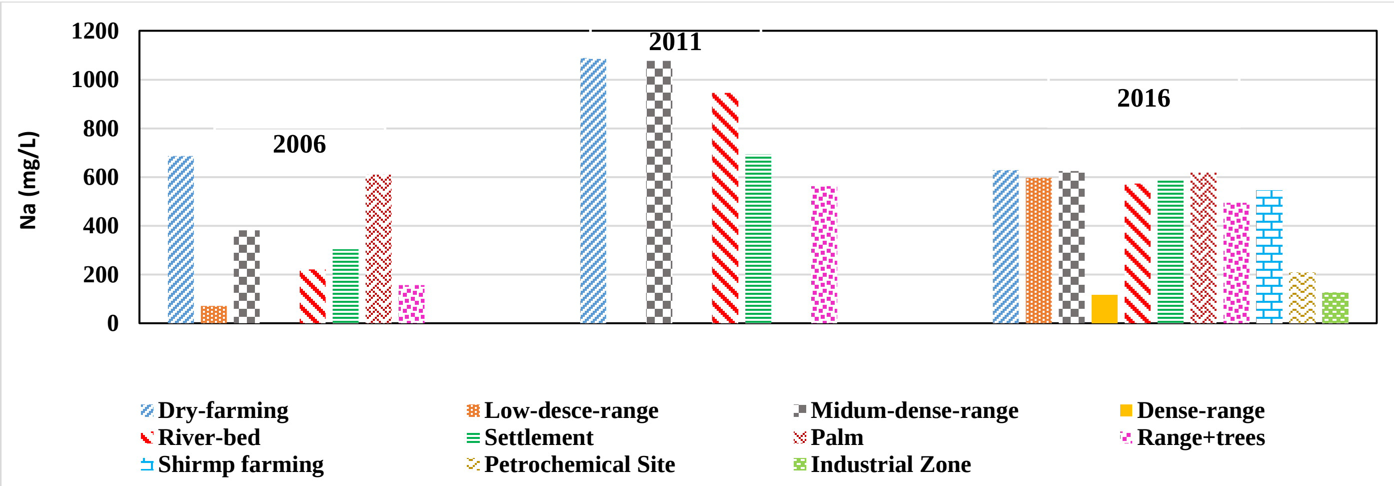

Figure 5: Sodium concentration: diagram in different land uses in 2006, 2011, and 2016

As shown in Figure 6, the highest level of concentration of sulfate in 2006, 2011, and 2016 are in the orchards and palm groves, and rainfed agricultural land uses. The lowest rate of this parameter is observed in rainfed agriculture per three years. In this land use, the value of sampling points is very different from each other and a wide range of the amount of this element can be seen in this use. The concentration of this parameter in all uses and all studied years is not only much lower than the permitted limit (200-400 mg/L; ISIRI 1053), but also it has a significant difference from the threshold limit. As a result, the amount of this parameter in all uses is at a desirable level.

According to the results of Figure 7, the highest concentration of total dissolved solids in 2006, 2011, and 2016 are observed in residential uses, rainfed agriculture and orchards, and palm groves, and the lowest amount is seen in the palm groves and orchards, rainfed agriculture and rainfed agriculture. Also, the highest rate change for all three years is related to rainfed agriculture. Unfortunately, the concentration of this parameter in all uses and all the years under review is higher than the permitted limit, but also it is very different from the defined standard. Therefore, its amount reaches 5000 mg/l in the use of semi-dense rangelands while its standard rate (WHO) is 1000 mg per liter [29].

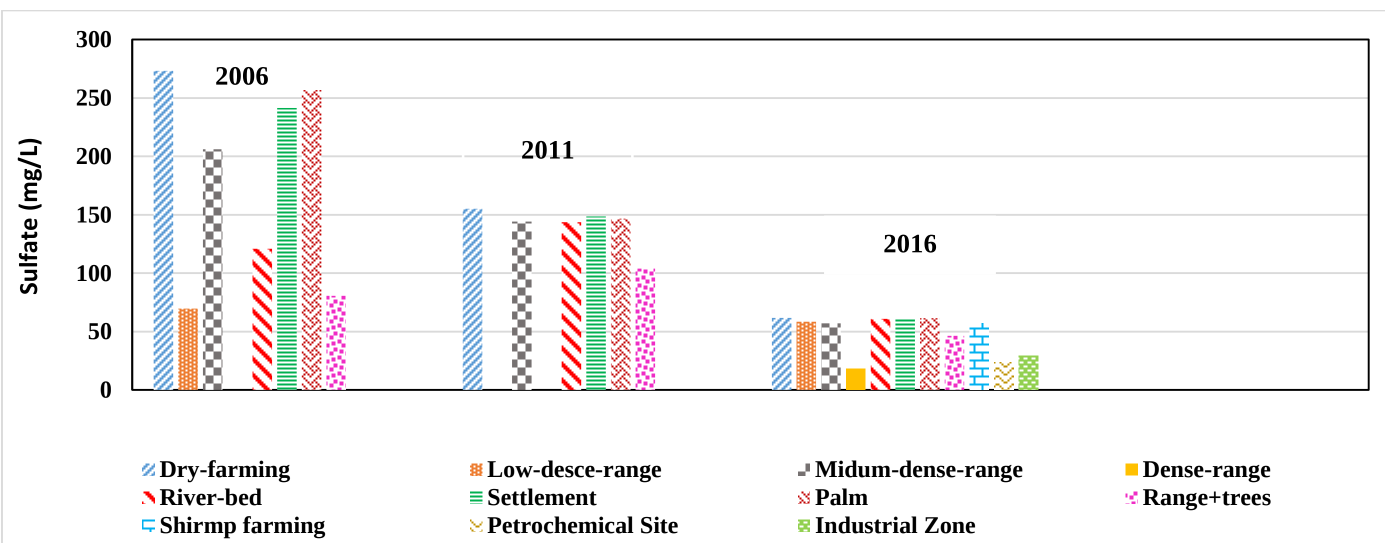

Figure 6: Sulfate concentration diagrams for different land uses in 2006, 2011, and 2016

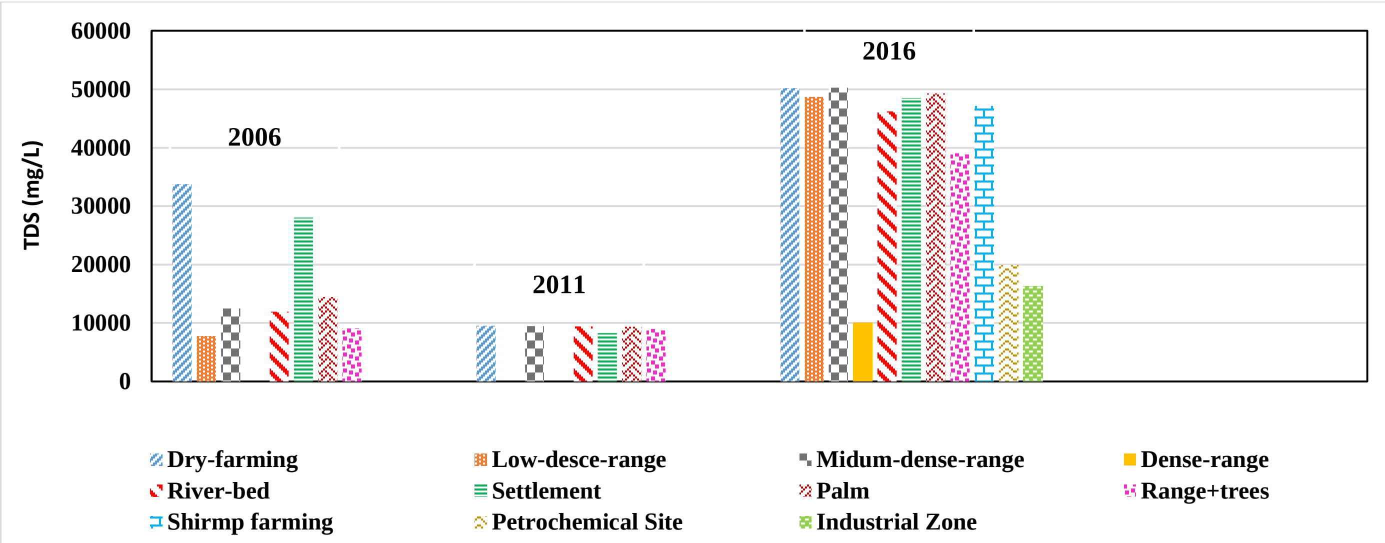

Figure 7: Total dissolved solids concentration diagram in different land uses in 2006, 2011, and 2016

4. Conclusion

Today, overpopulation, unprincipled agriculture, industrial expansion, increasing urbanization, and such cases led to the water shortage crisis. On the one hand, lack of water, and the high quality of groundwater compared to surface water caused these resources to be taken more than the capacity. As a result, their quality must be monitored regularly to minimize the amount of damage to them. However, it should be noted that the monitoring should be affordable in terms of cost and time. In other words, sampling is not possible in all parts of an area to control the quality of groundwater in a particular basin. Accordingly, it can be reached from the values of points that have not been sampled using interpolation methods. In the present study, land uses in the Dalaki watershed were classified into different classes in 3 years, 2006, 2011, and 2016 by satellite images related. The relationship between land use changes and chlorine, calcium, sodium, sulfate, and total dissolved solids shows that the highest concentration of the aforementioned parameters is in the use of rainfed agriculture, orchards, and palm groves. Therefore, a significant relationship can be established between agricultural uses and the increase in the concentration of groundwater physicochemical. In other words, agricultural use caused salinity of groundwater resources and reduced their quality because a large amount of groundwater is taken to irrigate crops causes the water level to be dropped and the remaining water to become saline. On the other hand, by the entrance of toxins and chemical materials intowater, the concentration of parameters will be increased and their salinity will be intensified.

Authors' Contributions

Fatemeh Zahra Takin: Methodology; software and Collected the data; Writing-original draft. **Younes Khosravi:** Design of methodology; Wrote the paper; Methodology; Software; Project administration; Writing-review and Editing. **Abbasali Zamani:** Data analyzing; Methodology; Writing-review and Editing.

Conflicts of Interest

The authors affirm that there is no conflicts of interest that may have influenced the preparation of this manuscript.

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