Investigating the effects of water transfer from Karkheh Dam on the physico-chemical properties of soil in Dasht-e Abbas plain, Ilam

Elham Karami[1], Haji Karimi[1]*, Mohsen Tavakoli[1], Gholamreza Banparvari[2]

[1] *Agriculture Faculty, Ilam University, Pajohesh Blv., Ilam, Iran*

[2] *Ilam Water Organizations, Iran*

*Corresponding author, e-mail:haji.karimi@gmail.com

Abstract

This research investigates the changes of soil properties in Dasht-e Abbas plain due to the Karkheh water transfer to this plain. In this study, the maps of groundwater level changes before and after the utilization of irrigation system were prepared. Furthermore, to investigate the changes of soil characteristics, soil samples were collected from various project implantations and control areas and their parameters were determined and compared. The results showed that the groundwater level has been increased more than 15 meters during the study period and the depth of groundwater in some areas reached to less than 5 meters. The results indicated that the highest salinity belonged to the network coverage areas and evaporating zone having a saturation extract electrical conductivity of 10.62 and 9.26 ds/m respectively, while dry land areas have the lowest salinity with electrical conductivity of 0.8- 4.0 ds/m. The results further demonstrated that the water transfer of Karkheh Dam to Dasht-e Abbas due to the absence of drainage in 3 and 4 sub-networks, high volume of agricultural return water from flood irrigation, and inadequate development of groundwater exploitation has reduced the quality of soil in marsh area and flooding lands, and generally a "desertification" process after "combat to desertification" has occurred.

Keywords: *Dasht-e Abbas, Physical and Chemical Properties of Soil, Water Level Change, Water Transfer.*

Introduction

Historical evidence shows that soil salinity coincided with the rise of sedentary and agricultural development in the world, and it goes back to around 10 thousand years ago. The effects of soil salinization are evident in Mesopotamia, Hwang Ho Valley of China, and the Nile Valley, which are among the most ancient lands on earth; researchers have proven and reported that the salinity of these oldest samples of soils is due to irrigation (Szabolcs, 1995). The phenomenon of salinity may be a combination of climatic factors, mineralization of irrigation water and soil texture, and the changes in ground water level. Four factors, namely irrigation system type, topography and drainage, agricultural activities, and soil composition and structure hasten the accumulation of salt in the ground and are effective in increasing the level of the aquifer and the quantity of water available for evapotranspiration (Valenza *et al.,* 2010). The irrigation of agricultural lands in arid and semi-arid areas is accompanied by the risk of salinity and alkalinity (FAO, 1973). Various factors justify the cause of this phenomenon, e.g., capillaries which due to the evaporation bring salts to the ground surface, and also marshy conditions which occur due to the rise in the level of the water table and salinize the lands. The climate of these areas plays an important role in land degradation, since it causes too much evaporation (Tickell, 1997). In order to reduce the risk of salt accumulation and damage to farming and local ecosystems, several studies were conducted in different parts of the world (Singh *et al.,* 2010; Hen *et al.,* 2011; Ibrakhimov *et al.,* 2011). In general, human beings greatly exacerbate soil degradation and desertification by improper water irrigation, failure to perform proper leaching cycle, and drainage issues. With the increased level of groundwater in an area, in accordance with the change in hydrodynamic coefficients, evaporation and drainage zones are provided which leads to the growth of different plant species and reeds and the creation of new ecosystems which can be called temporary desertification. At the same time, the long continuous raise of groundwater in the soil profile along with the destruction of its physical and chemical properties decreases the yield of the garden and cultivated crops (Karami, 2013). Soil salinity reduces plant growth, impairs the activities of microorganisms, decreases water quality, ceases metabolic processes of soil compositions, harms the hydrosphere, and finally leads to a failure in the nutrient requirements of the biosphere (Abbasi, 2001). Abbasi and Darwish (2001) studied the role of soil salinity and water quality reduction in

exacerbating desertification in the Mand Drainage basin of Shiraz. In this study, through using the existing data and collecting field data, two methods, including measuring the maximum electrical conductivity or maximum percentage of exchangeable sodium (depending on the region) have been considered as an indicator of salinity spread assessment in four categories and desertification status map was prepared at the scale of 1:250000 for Mand watershed. The role of water as a salinity transfer agent to determine the natural desertification inclination was also studied. The present study aims to investigate the effects of changes in the soil quality of Dasht-e Abbas in Ilam Province due to the water transfer from Karkhe Dam to the area and exploitation of irrigation and drainage network and its impacts on groundwater levels.

Materials and Methods
Location and characteristics of the study area
The study area, Dasht-e Abbas plain (32°15 25 - 32°28 30 N; 47°43 11 -47°59 41 E) having an area of 221 km^2 is located in the south of Ilam province, Iran (Fig. 1). The average annual rainfall and temperature of this area is about 250 mm and 24.5°C, respectively. This area covers the western catchment of the Rofaeieh seasonal river. Geologically the study area is located in the simply folded zone of the Zagros mountain range.

This plain was announced as a prohibited plain in 1977 due to uncontrolled water exploitation from the Dasht-e Abbas aquifer, and since then the groundwater level has gradually dropped. To compensate the deficit of the groundwater reservoir and supply the irrigation water, a water transfer plan from Karkheh Dam to Dasht-e Abbas plain was arranged which consists of a 6.7 km tunnel with a diameter of 5.5 m in the southwest of the dam reservoir, and irrigation and drainage systems including south and north development units were performed. Exploitation of the southern unit started in February 2005 and some parts of the northern unit also began to operate in August 2007 (Karami, 2013).

The total water volume required for the irrigation of the area under the irrigation and drainage network is estimated to be 270 Million Cubic Meter (MCM), 170 MCM of which is supplied from Karkheh Dam and 100 MCM is supplied from groundwater (Ilam regional water organization, personal communications).
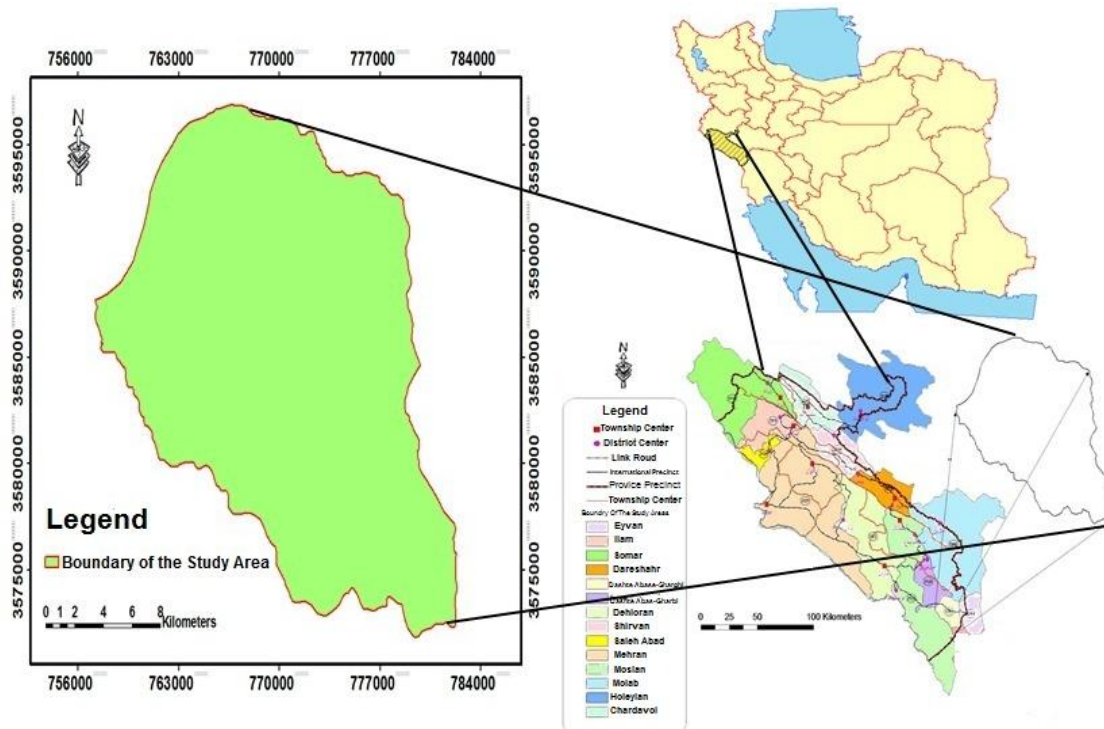

Figure 1. Map of the study area in Ilam province, Iran

Thus, concerning the inadequacy of drainage in the area, to prevent the changing of agricultural lands to marshes, it is necessary to increase the abstraction of the aquifer water at the same time when the water enters from Karkheh Dam to Dasht-e Abbas plain. However, since the northern phase of drainage is not completed, the amount of water which enters the southern phase is high, so the agricultural wells in the area are semi-active because of highly accessible water. Thus, the water level of observation wells in the southern areas has risen quickly; consequently, the level of water table has also increased and some agricultural lands have changed to the marshes (Karami, 2013).

The process of desertification and degradation of soil's physical and chemical properties exists due to the creation of the evaporated zone in the south of the Rofaeih River. Also, this trend exists in the area under the coverage of irrigation and drainage network of the north side of Dasht-e Abbas due to the flooding of lands because of overfeeding from the Karkheh water and lack of proper surface and underground drainage; this trend will persist and develop if the necessary measures are not implemented.

Method of the Research
Groundwater level changes
To obtain information about the level and depth of the water table of Dasht-e Abbas, the monthly data of 29 piezometric wells having suitable distribution drilled in the plain were gathered. To investigate the groundwater level and fluctuation of the aquifer and groundwater level data of piezometers, Theissen network has been used. Moreover, to investigate the effects of exploitation of irrigation and drainage system of Dasht-e Abbas, the changes in the groundwater level of available piezometers have been investigated after its exploitation from February 2005 to the end of 2012 and compared to the groundwater level of piezometers before exploitation (October 1985 to February 2005). To investigate the depth of the studied aquifer water table, the map of 2011-2012 water levels of existing piezometers was drawn.

Checking the status of the studied area's soil
To evaluate the changes in the soil quality of the area, eight soil samples were collected from the areas covered by the irrigation and drainage system of Dasht-e Abbas and areas outside the coverage

area, as well as Rofaeih soil drains and sent to the lab. Then, a list of the physical and chemical parameters of samples such as acidity (pH), electrical conductivity of the saturation extract (EC), soil texture, organic matters, phosphorus, and potassium were determined in order to investigate the effect of Karkheh water transfer on the chemical chemical properties of soil samples.

Soil texture determination
30g of dry soil from each sample along with 25 ml of Sodium hexametaphosphate with two-thirds cup of water in one liter volume cylinder was mixed with a hand mixer. Then, the prepared suspension was measured using a hydrometer after 40 seconds for the first reading. The temperature was constantly under control. After 2 hours, the hydrometer was read again and finally the percentage of clay was determined. After determining the percentage of soil particles, the soil textural triangle was used to determine the soil texture.

Measurement of soil's chemical properties
The most common way to assess soil salinity is to measure the electrical conductivity of an extract of a saturated soil sample. This method involves collecting samples from the farm, drying, and grinding the soil and calculating the saturation of soil samples with distilled water and soil solution extraction of samples. After preparing the saturated mud, the electrical conductivity of extracts was measured using EC meter. Soil EC is a function of temperature and usually increases with an increase in each degree Celsius (at temperatures between 15 and 35°C) at a rate of 0.2 (Barzgar, 2000). Because EC is reported at 25°C (EC_{25}), an approximate temperature correction was performed as follows:

$$EC_{25} = EC_t . F_t \tag{1}$$

where EC_{25} is electrical conductivity at 25°C; EC_t is the read electrical conductivity and Ft is the temperature correction factor.

In order to determine acidity (pH), after saturating soil samples with distilled water, the amount of soil acidity was determined using a pH meter. The Measurement of SAR (sodium adsorption ratio) was performed in two phases: the first phase, the sum amount of calcium and magnesium ions was calculated using titration by

EDITA solution and secondly, sodium measurement was done through flame photometry, and eventually SAR levels were calculated using the following formula (Ehteshami *et al.,* 1999):

$$SAR = \frac{[Na]}{\sqrt{\dfrac{[Ca] + [Mg]}{2}}} \qquad (2)$$

where [Na], [Ca], and [Mg] are the concentrations of sodium, calcium, and magnesium respectively, which are expressed in meq /l.

To determine the soil's organic matters, different substances such as potassium dichromate 1 normal, concentrated sulfuric acid, orthophenanthroline iron reagent, and the green ammonium ferrous sulfate 0.5 normal were used (Ardekani *et al.,* 2007). The flame photometer method was used to measure soil potassium, and phosphorus was measured by the Olsen method. To analyze the percentage of nitrogen, organic matters, and organic carbon, as well as the values of potassium and phosphorus, three soil samples were used as representatives of sampling locations and only the results of their analysis were inspected.

Results
Groundwater level changes
To investigate the changes in the groundwater level in Dasht-e Abbas plain before the utilization of irrigation and drainage systems, the map of groundwater level changes (October 1985 to February 2005) has been drawn (Fig. 2). Based on this map, the groundwater level in different parts of the aquifer has dropped. The greatest decline in groundwater level has been observed in north-western and south-western margins due to the high density of wells, by 10 and 12 m respectively. The least decline has been observed in the central to the southwest region because of the lack of wells such that the reduction has been measured about 2 meters. Furthermore, to study the effects of exploitation of irrigation and drainage systems on the aquifer, the map of groundwater level changes has been drawn from February 2005 to the end of the study year (2011 to 2012) (Fig. 3). Concerning this map, in all aquifer areas, the groundwater level has increased by 15 meters in some parts of the aquifer.

Groundwater level depth
The map of the depth of the groundwater level of the aquifer was drawn using the data of 2011- 2012 year of piezometers (Fig. 4). As can be seen from this map, the highest depth of the groundwater level is in the northern area and is more than 50 meters. In the eastern parts and southwestern margins, the depth is high and is 35 and 30 meters respectively.
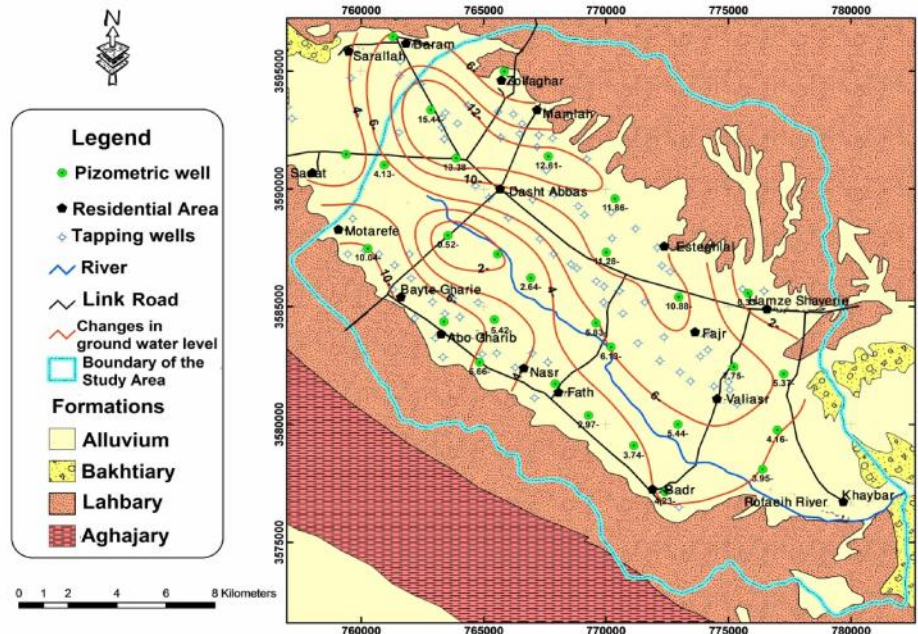

Figure 2. Spatial changes in groundwater level of Dasht-e Abbas plain before utilization of irrigation system (October 1985 to February 2005).
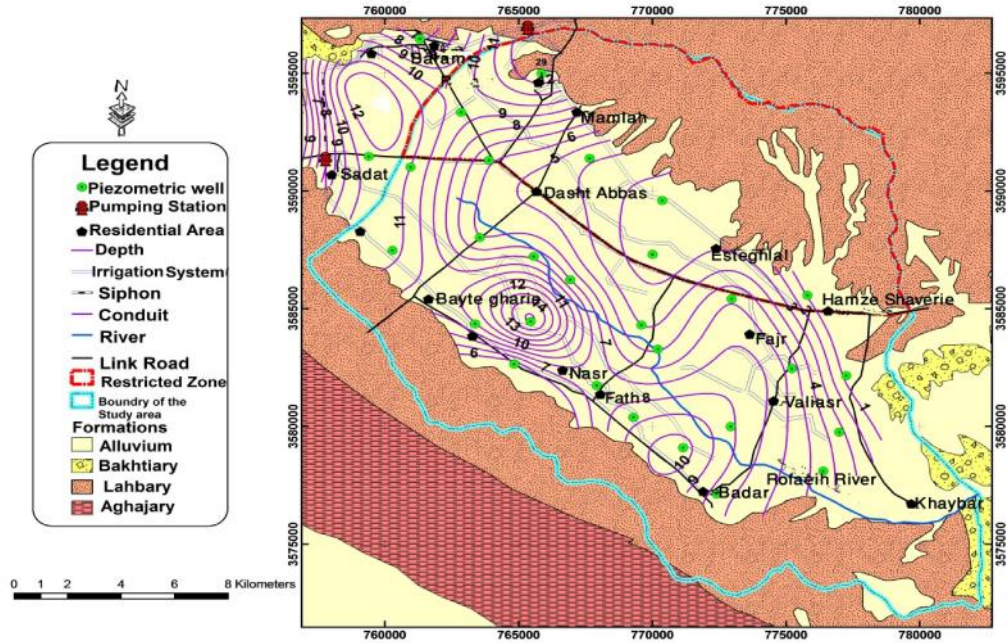
Figure 3. Spatial changes in groundwater level of Dasht-e Abbas plain after utilization of irrigation system (February 2005 to August 2011)
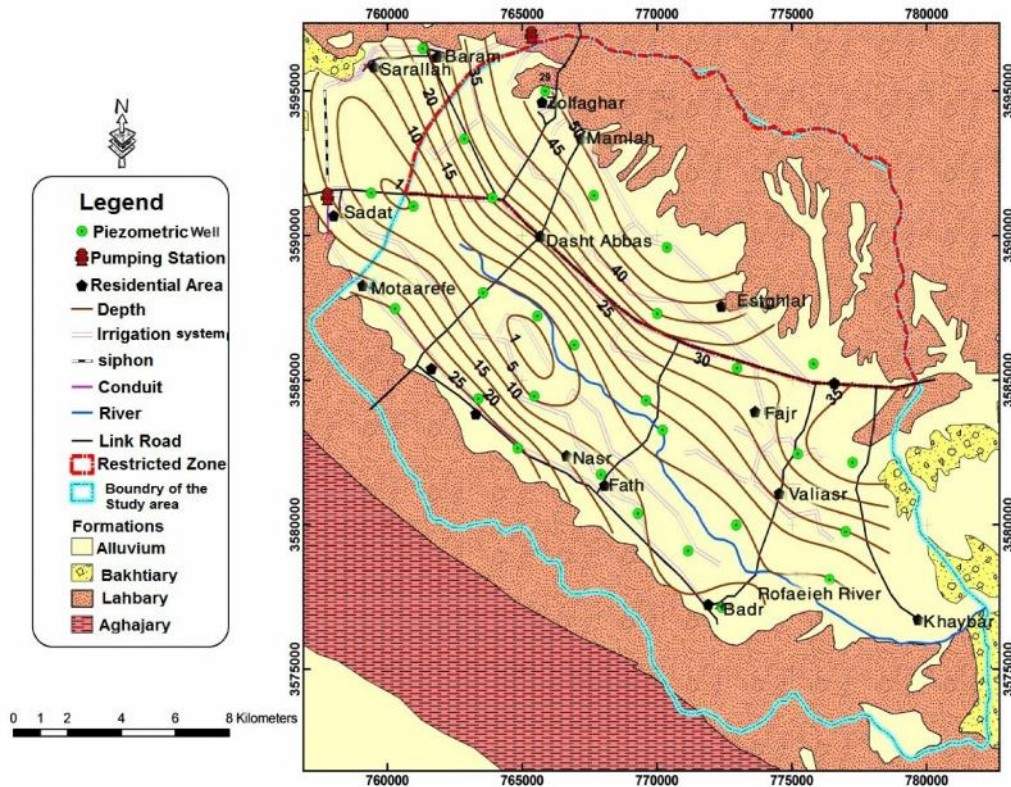

Figure 4. The groundwater depth map of Dasht-e Abbas plain in 2011- 2012

The high depth of groundwater level in this area is due tothe high intensity of exploitation wells. The

The lowest depth of the water table is observed in the central to southwestern areas and is less than 5

meters (in some parts it reaches 1 meter). The low depth in these areas is due to the lack of wells, fine grained aquifer materials, lack of the drainage system, and recharge of the aquifer from the irrigation system. The average depth of groundwater in the central areas of Dasht-e Abbas plain is about 20 m.

Soil conditions
To evaluate the effect of Karkheh water transfer on the soil properties of the study area, multiple samples were taken from surface soil in the lands under irrigation network and rain-fed land areas, as well as pasture lands (in order to compare results and enhance the precision). The description and locations of collected soil samples are presented in Table 1 and Figure 5, respectively.

The percentages of clay, silt, and sand were measured and, using the soil textural triangle, the soil texture was determined (Table 2).

Salinity index is the electrical conductivity of soil saturation extract at a temperature of 25°C. Saline soil is a type of soil whose saturation extract electrical conductivity is 4 dS/m or more (Barzgar, 2000). The results of electrical conductivity in the study area are presented in Figure 5.

Table. 1. The geographic coordinates and soil samples collected location

| Soil sample No.	Geographic coordinates		Collected Location
1	"47 48'33	32 24'08"	The commissure of Rofaeih river and road (drain)
2	"47 46'32	32 22'36"	The road path to the south in the dry lands(outside the irrigation system of Dasht-e Abbas)
3	"47 49'15	32 26'15"	Irrigation network (Murmuri Abdanan road)
4	"47 47'55	32 27'38"	Dry land in the northwest area
5	"47 45'07"	32 23'41"	Pasture lands in the southwestern margin of the aquifer
6	"47 4500	32 22'29"	Pasture land in the extreme southwestern area
7	"47 48'14	32 24'24"	The commissure of Rofaeih river and road (drain)
8	"47 49'150	32 23'20"	network coverage area in South drainage area of Rofaeih
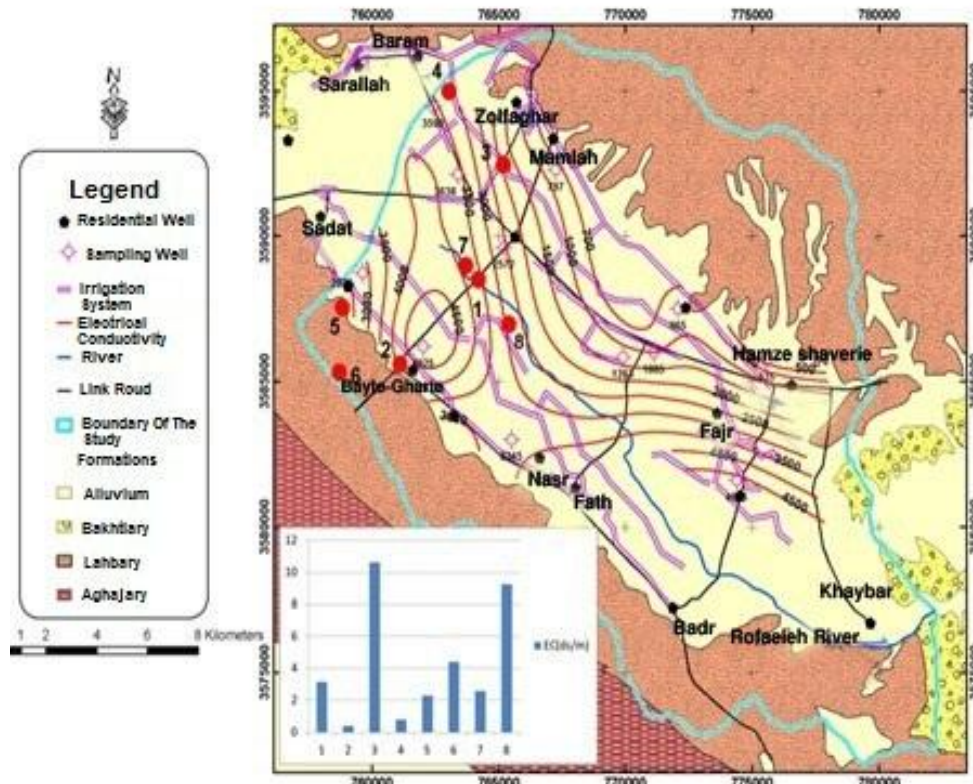
Figure 5. The electrical conductivity map of Dasht-e Abbas aquifer and soil sampling locations

Table. 2. The qualitative characteristics and texture of soil samples

Number of soil samples	Soil texture	EC(dsm⁻¹)	SAR	PH
1	Silty Clay Loam	3.17	3.5	7.65
2	Sandy Loam	0.40	2.1	7.85
3	Silty Loam	10.62	2.3	7.42
4	Loam	0.8	1.9	7.80
5	Silty Loam	2. 3	2	7.89
6	Silt Clay Loam	4.4	2.2	8.10
7	Silt Loam	2.6	3.4	7.68
8	Silty Loam	9.26	2.7	7.52

Investigating the pH values of the collected soil samples showed that the soil of areas covered by the irrigation network had lower pH which can be due to the leaching of soil's basic cations. Rates of Sodium Absorption Ratio (SAR) were also determined in taken soil samples whose values were changed from 1.9 to 3.5 The range of SAR values shows that soil samples have a lot of similarities in terms of sodic; soil samples 1 and 8 are on the sodic-threshold while the other samples had no problem in terms of sodic.

While investigating the results of the samples, it was observed that soil sample No. 1 in the natural Rofaeih drainage area had the most organic matters, potassium, and phosphorus compared to the other places due to the leaching of organic matters in areas under drainage network and its transfer to the Rofaeih drain. Furthermore, soil sample No. 2 located in dry land had more organic matters than sample No. 3 located within the irrigation network because of the less leaching of the transfer of topsoil humus to the lower side.

Since the mentioned values in soil No. 3 were transferred out of the area due to the transfer of materials by irrigation network and, more importantly, due to land smoothing operations and soil surface layer (humus) removal which contained organic matters, this place was the one which had less organic matters in the study area. Potassium and phosphorus levels in soil samples also followed up the above conditions. In Table 3, the amounts of organic matters, phosphorus, and potassium of the samples are given.

Discussion

Fluctuations in soil sample No.1:
According to the results of the map of the groundwater level changes in the location of this sample, the water table increased about 8 m after the entrance of Karkheh water and the depth of the water table reached 5 meters. However, due to the relatively good drainage of location caused by the topography of this area and the compatibility of the longitudinal slope of this location with Rofaeih river axis, the irrigated water has been drained with relatively more appropriate speed than any other low slope of the basin which caused the leaching of soil minerals. Thus, despite the entrance of water from irrigation network, the electrical conductivity of soil saturation extract of sample reached 3.17 dS/m which was on the salinity threshold.

It should be noted that the electrical conductivity of the groundwater at the mentioned sample location was 3500 µmhos/cm and electrical conductivity of water network and river (irrigation wastewater) was 1241 and 1452 µmhos/cm, respectively. Thus, the salinity change in water network is much smaller than agricultural wastewater (water). Thus, soil sample No. 1 was not too salty due to the relatively good drainage in the longitudinal direction of the river and the short period of exploitation from network (Fig. 6).

Changes in soil sample No. 2:
The groundwater level of this sampling location increased nearly 20 meters according to the water level changes map, but this rise in water level was not caused by the direct recharge of water into the sampling area and it was due to the regional groundwater gradient of plain to the sampling location. On the other hand, the depth of water table at sampling site was more than 25 meters and the electrical conductivity of groundwater was 4000 µmhos/cm. The amount of electrical conductivity of the saturation extract sample was 0.40 dS/m which represents no change in soil quality due to its being out of the irrigation network coverage area and the absence of wells.

Table. 3. Analysis of organic matters, potassium and phosphorus of representative samples

Number of soil samples	Nitrogen (%)	Organic compound (%)	Organic matters (%)	Potassium (ppm)	Phosphor (ppm)
1	0.024	0.409	0.24	240	31.5
2	0.015	0.263	0.15	180	29.5
3	0.008	0.146	0.08	160	23.5

Figure 6. Photo of Rofaeih drainage margin and accumulation of salts on the soil surface

Figure 7. Photo of salt accumulation on soil surface of pound irrigation lands of Dasht-e Abbas

Changes in soil sample No. 3:
Ground water depth of 40 m with a conductivity of 2000 µmhos/cm indicates that this location was not located within the evaporation zone. Among the typical characteristics of this place was its very low slopes; therefore, large volumes of irrigation water were pounded at the surface, and despite recharging the groundwater and the rise of the water table more than 20 m, some of this water evaporated and mineralized the soil cover and increased the electrical conductivity of the soil samples' saturation extract at a rate of 10.62 dS/m which is the main cause of soil salinity in this issue.

As stated above, the electrical conductivity of the groundwater around this sampling site is 2000 µmhos/cm and the electrical conductivity of irrigation network water is 1241 µmhos/cm which can be expected in such normal irrigation, and efficient use of irrigation water had less destructive effects on the lands. According to local research taken from local farmers, it was observed that production efficiency had a decreasing trend in recent years.This indicates that the soil salinity in the past few years was lower than the current amount and the rate of soil qualitative deforestation of this area will continue in the absence of the implementation of sub-irrigation and drainage network and optimal use of irrigation water and finally suitable agricultural lands change into barren lands and the process of desertification will begin. Figure 7 shows a view of salt accumulation

on the soil surface of pound irrigation lands of Dasht-e Abbas.

Changes in soil sample No. 4:
In this location, the soil minerals do not change much due to leaching and carrying from the basin on the other hand, due to the lack of irrigation water from network, its conditions were quite different from the sampling location No. 3. Thus, its soil quality was secured against marsh water conditions. Depth of groundwater in the area was 35 m with an electrical conductivity of 3000 µmhos/cm and the amount of electrical conductivity of the saturation extract soil samples were determined as 0.8 dS/m in the lab.

Variations of soil samples No. 5 and 6:
In these areas, soil quality does not have any influence on the water transfer from Karkheh project. From the viewpoint of groundwater impact, since the sampling site of No. 5 was not covered by irrigation of wells and also since the groundwater level in the area was at the depth of about 30 meter and this area had no evaporation zone, it can be concluded that the soil quality can be affected solely by the geological formations of the region. At a glance, by comparing the quality of soil samples 5 and 6, both of which were collected in pasture lands, the difference in the electrical conductivity of the saturation extract in both soil samples was because of the leaching of some soil

minerals at the site of sample No. 5 by sub-waterways which were passing this area.

Because sample No. 6 with the electrical conductivity of 4.4 dS/m was located in an area with no drainage, the soil leaching is weak in this location and has agreater electrical conductivity than location No. 5 with an electrical conductivity of 2.3 dS/m. It is worth noting that the quality of the sampling location No. 6, as well as sample No. 5, was not influenced by the irrigation network and groundwater of the area, and soil quality is mainly controlled by the geological conditions of this area.

Changes in soil sample No. 7:
This sample was collected from the intersection of the road and Rofaeih River with a small distance of sample No. 1 and its characteristics, e.g., being influenced by groundwater sources and irrigation water network are the same as sample No. 1. Thus, the qualitative characteristics of this sample with an electrical conductivity of 2.6 dS/m have great similarities with sample No. 1.

Changes in soil sample No. 8:
One of the major causes of soil salinization in arid and semi-arid areas is the existence of shallow underground saline aquifers which usually contain large amounts of minerals due to their specific climate conditions and the process of evaporation which increases their concentration. The evaporation intensity of these aquifers depends on their depth from the soil surface and the ambient temperature. The lower the depth of these aquifers is, the higher the amount of evaporation becomes for a given soil type.

The depth of groundwater, which causes soil salinity, varies at different climatic conditions. This depth which is called the crisis depth varies according to the evaporation severity and the type of soil and varies between 1 to 3 meters. Capillaries cause groundwater and, consequently, the minerals to come to the surface, so salts accumulate at the surface by evaporation. Sample No. 8 has been located in an evaporative zone with a depth of about one meter of the earth's surface. Conductivity curve value of 4000 µmhos/cm has passed it and the lack of proper drainage and abundance of network entrance water since the onset of utilization have increased the level of groundwater more than 12 meters and caused the water level to reach near ground level (depth of one meter). Thus,

investigating the above sample soil quality parameters shows that soils with an electrical conductivity of 9.26 dS/m have been totally salinized. Obviously, soil salinity is influenced by the salinity of drainage area groundwater due to the capillary and the evaporation of the region; therefore, if this trend continues and the necessary measures are not implemented, this phenomenon will develop in the surrounding areas. Figure 8 indicates a view of the pounded area under the irrigation system of Dasht-e Abbas.

Figure 8. A view of drainage area covered by the irrigation system of Dasht-e Abbas

Conclusion
Soil and water salinization is arguably the most important cause of desertification, which largely takes place in the arid and semi-arid regions of the world. The results of soil qualitative examinations in this research showed that the maximum amount of soil salinity belonged to the soil sample location No. 3 (the area under irrigation network) whose lands had become absolutely pounded due to the failure of the implementation of sub-networks, the lack of proper drainage, the existence of excess water, and the very low slope of the sampling place. Consequently, the soil of this area had the highest

salinity with 10.62 dS/m electrical conductivity of the saturation extract.

In addition, the results of the analysis of soil sample No. 8 suggested that the evaporation zone with crisis depth led to soil salinization due to the influence of transferred water to the area and the absence of an effective drainage system. Soil samples N. 2 and 4 which were taken from the area of rain-fed lands with 0.4 to 0.8 dS/m electrical conductivity had the lowest salinity. These sites are located out of the irrigation system network; therefore, it can be concluded that the continued incorrect use of network water and lack of sub-network implantation and continued poor drainage, will degrade the quality of soil cover of the lands which are irrigated by the network, and desertification will occur in them in the future.

Finally, it can be concluded that although the implementation of the Karkheh water transfer project and the construction of Dasht-e Abbas irrigation and drainage networks have developed the agricultural lands as a step to combat desertification in the region, considering the lack of efficient water management practices due to the lack of implementation in 3 and 4 sub-networks and the qualitative degradation of land soil due to the surface pounding of lands with improper drainage and groundwater level uplift caused by lack of proper usage of groundwater from wells, it is shown that the phenomenon of desertification is taking place.

Therefore, now, in spite of the plenitude of water in a previous desert area, the concern about its turning into desert exists because by the continuation of the current trend, the capability of lands will decrease rapidly and a "desertification" process will occur after the "combat of desertification".

References

Abbasi, H., 2001. Investigating the most significant limitations of Dag in Kerman province from agrology perspective. Journal of Range and Desert Research, No. 4, Research Institute of Forests and Rangelands. 268.

Abbasi, H., Darwish, M., 2001. Role of soil salinity and water quality in intensifying the desertification process of Mand watershed, Iranian Journal of Range and Desert Research, Volume 11, Issue .2: 163-178.

Ardekani, M.,Rezvani, M.,Zfryan, P., 2007. Experimental methods in plant ecology, first edition, Tehran: Tehran University (In Persian).

Barzgar, A., 2000. Saline and sodic soils: Recognition and Productivity, First Edition, Ahvaz Shahid Chamran University Press (In Persian).

Ehteshami, M., Ashktorab, C., Siyahi, M., 1999. Concepts of drainage and soil and water salinity, first edition, Iranian National Committee of Irrigation and Drainage.

FAO Organization, 1973. Irrigation, Drainage and salinity, an international source book. FAO/UNESCO, London, 510pp.

Han, D., Song , X.,Currell, M.J., Cao, G., Zhang, Y., Kang, Y., 2011. A survey of groundwater levels and hydrogeochemistry in irrigated fields in the Karamay Agricultural Development Area, northwest China: Implications for soil and groundwater salinity resulting from surface water transfer for irrigation, Journal of Hydrology, 405(3–4): 217–234.

Ibrakhimov , M., Martius, C., Lamers, J.P.A., Tischbein, B., 2011. The dynamics of groundwater table and salinity over 17 years in Khorezm, Agricultural Water Management. 101 (1): 52–61.

Karami, E.,2013. Effect of water transfer from Karkhe Dam on desertification of Dashte-Abbas, Dehloran Township, Ilam province, Master's thesis, Ilam University. Iran,

Ilam Office of Regional Water Company, 2007. Statistics of groundwater and surface water resources.

Singh, A., Krause, P., Panda, S.N., Flugel, W., 2010. Rising water table: A threat to sustainable agriculture in an irrigated semi-arid region of Haryana, India, Agricultural Water Management. 97 (10): 1443–1451

Szabolcs, I., 1995. Global overview of sustainable management of salt-affected soils, Proceedings of the international workshop on integrated soil management for sustainable use of salt affected soils. Manila, Philippine.

Tickell, S.J., 1997. Mapping dry land salinity hazard, Northern Territory, Australia. Hydrogeology Journal. 5:109-117.

Valenza, A., Grillot, J.C., Dazy, J., 2010. Influence of groundwater on the degradation of irrigation soils in a semi-arid region, the inner delta of the Niger River, Mali. Hydrogeology Journal, 8(4): 417-429.