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Evaluating Physical Changes in Aquatic Zones and Their Relation with Precipitation in Fars Province

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ABSTRACT

Given the recent droughts, it has become increasingly valuable to plan for water resources management and conservation as well as the protection of local communities. Investigating the trend of water resource changes, especially those that are restricted and have undergone transformations over a short period of time, is applicable for optimal resource management. The present study aims to evaluate physical changes in Fars province's aquatic zones, i.e. Bakhtegan, Tashk, Maharloo, and Parishan lakes, using the MODIS (Moderate Resolution Imaging Spectroradiometer) service and its relationship with precipitation over the period 2001-2017. Due to land-use and precipitation changes, the areas of these aquatic zones have decreased dramatically. As the results show, the area of the province's water surface along with the wetland class was 1346.31 km^2 in 2001, comprising 1.09% of the total land use of the province, while the amount of water in the province (wetland and aquatic land-use classes) was 99.59 km^2 (about 0.75%) in 2017. This indicates a decline of more than 25%. Then, using precipitation data, the relationship between the area of aquatic zones and the precipitation rate was measured. The results indicated a direct and positive correlation between these two factors as 0.76. The highest precipitation concentration was observed in the studied aquatic zones. The reverse was also true in the years when the lakes reached their minimum areas.

1. Introduction

Iran is located in a dry and semi-arid region where dryness is an integral part of life. Appropriate water resources management should be implemented during droughts in such areas (Moghimi and Babies, 2016). Among the concerns about global environmental change, issues related to land-use changes have become increasingly important over time. User change is a term that describes human works (Meyer and Turner, 1994).

Land-use and land cover changes are one of the most important environmental change problems at the local and global levels (Riebsame et al., 1994; Lambin and Geist, 2006). Land cover and land-use changes have a direct effect on climate change. There is also a complex relationship between climate change and land cover change (Dale, 1997). Moreover, human factors such as land-use change the climate (Feddema et al., 2005).

Climate change is now widely recognized as a global problem with adverse effects on the natural and man-made environments (IPCC, 2007). Evaluating land-use change trends is a process that leads to a better understanding of how humans and the environment interact (Lambin and Gesit, 2006). Wetlands and lakes are useful for local communities because of the many services that they provide (Bagheri et al., 2016). These services are sometimes referred to as wetland ecological functions. Examples of these services and functions include flood control, erosion control, water purification, vital habitat provision, migration, recreational, economic, educational, research, and other uses (Rabbani, 2012).

Remote sensing techniques have been employed to track and detect the effects of climate change events, droughts and their effects, changes in riverbanks and their effects, alteration of river delta vegetation, and changes in protected areas (Rahdari et al., 2016). Providing land-use and land cover maps to inform land uses and planning for arbitrary land uses are essential measures for optimal resource utilization. This is especially important in sensitive areas, especially wetlands. One of the most important steps taken in planning and implementing integrated water resources management is evaluating water resources (Fussel & Klein, 2006). In fact, awareness of the poor quality of water resources and how it evolves is one of the key prerequisites for rational planning and management of water resources (Rahdari et al., 2012). The system is also monitored to determine the success rate of projects after execution (MacDonald et al., 1991). Monitoring land use in an ecosystem and their dynamics in order to understand the system in question helps to respond to actions such as regeneration, restoration, and protection of ecosystems

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(Wang, 2009). Assessment and monitoring techniques are precise and regionally relevant systems that are flexible in scale and combine economic, social, and biophysical aspects to plan various projects such as resuscitation (Dregne, 1994). Nowadays, employing remote sensing technology in field studies (water, soil, vegetation, etc.) is increasingly expanding, and the variety of precision techniques used in this field is growing (Mainguet, 1994).

Remote sensing techniques and the resulting data have a high speed and accuracy in surveying and interpreting applications (Roberts et al., 2003). That is why remote sensing techniques play key roles in determining the availability of wetlands, monitoring and assisting their conservation and management (Garg, 2015), and completing conventional approaches to conserving and monitoring lakes (Bukhara, 2013).

Remote sensing data have been used to evaluate environmental models and theories as well as change factors in a large number of aquatic ecosystems (Palmer et al, 2015). Sima and Tajrishy (2006) used remote sensing to determine changes in the Shadegan wetland surface and its vegetation cover as a part of the wetland water requirement calculation process. Alesheikh et al. (2007) used Landsat imagery to monitor the shores of Lake Urmia and to determine the reduction of lake area between 1976 and 2009. Mozaffari and Narrangi Fard (2014) investigated the effect of precipitation on Lake Manalo's water level changes using remote sensing data. The findings showed that the lake area in 2009 was 107 km^2 lower than that in 1999, mainly due to a 200-mm decrease in precipitation over the same period. Conditions indicate that the lake is heavily influenced by the precipitation rate. Samiei et al. (2017) investigated the impact of climate change on Lake Manalo's surface changes using satellite image processing. To achieve this, they used the Blue Index (NDWI) for an 18-year period. The results showed that in spite of some fluctuations in the lake area, it has been decreased in the long run.

Using a maximum likelihood algorithm, maps of land-use and land cover changes in northwestern Egyptian coastal regions were obtained via remote sensing techniques, geographic information systems, and Landsat imagery during a period from 1987 to 2002 (Shalabye & Tateishi, 2007). Rimal (2009) examined changes in vegetation and urban land use in Nepal. The results showed a high level of urban land-use development as opposed to reduced vegetation cover from 1976 to 2009. Hwang et al. (2016) investigated changes in the level of 23 lakes in the Quaternary Plateau from January 1993 to December 2014. The results showed that the lake levels were mainly increased in the eastern lakes and decreased in the western part. The surface of the lake was affected by the monsoons and the location of the lakes.

In recent years, due to the influence of human and natural factors, aquatic zones in Fars Province have dried up, while Bakhtegan, Parishan and Maharloo wetlands are among the 22 wetlands in Iran listed on the Ramsar Convention. As a result of the destruction of the aforementioned aquatic zones, lake ecosystem services are being destroyed, becoming salt marshes. Subsequent saline dust storms also pose a serious threat to human health and other local organisms. In addition, dusts rising from salt marshes are effective in reducing the yield of the region's crops, so it is essential to maintain, revitalize, and manage lake ecosystems. Due to the increasing number of studies conducted today, the use of remote sensing technology is increasingly used in studies of terrestrial phenomena (water, soil, vegetation, etc.) and the use of various techniques. And exactly this branch is expanding. The purpose of this study is to investigate physical changes in and areas of water zones in Fars province (2001, 2010 and 2017) as well as the possible relationship between physical changes in water zones and the rate of precipitation in the studied years.

2. Study site

Fars province covers an area of about 122,608 km^2 between the latitudes of 27°02' and 31°42' N and the longitudes of 50°42' and 55°36' E. The most important water resources in Fars province include Bakhtegan, Tashk, Maharloo and Parishan lakes which have undergone significant changes in water potential and land use due to the weather conditions in the last decade. The average temperature in Fars province is between 15 and 23°C and the average monthly rainfall is 48.45 mm, with a maximum of 184.2 mm in December and a minimum of zero mm in July, October, and November.

3. Materials and Methods

The materials used in the present study were the MODIS Land Cover Type product and two Terra and Aqua satellites. The Land Cover product is available with the acronyms MCD12Q1 and MCD12C1, whose difference is in the size of their pixels. It shows a great variety of spatial characteristics.



Fig.2. Land cover flowchart

The pixel size of the first product is 500 × 500 m and that of the second product is 5600 × 5600 m. But, in terms of time, both the annual data and the available data are from 2001 onwards. In terms of location, it covers the whole planet. The positions and coordinates defined for the Earth's surface are based on the sinusoidal coordinate system. The HDF-EOS file format and each data layer contain 13 datasets. Each data is known as a tile with a width of about 1200 × 1200 km.

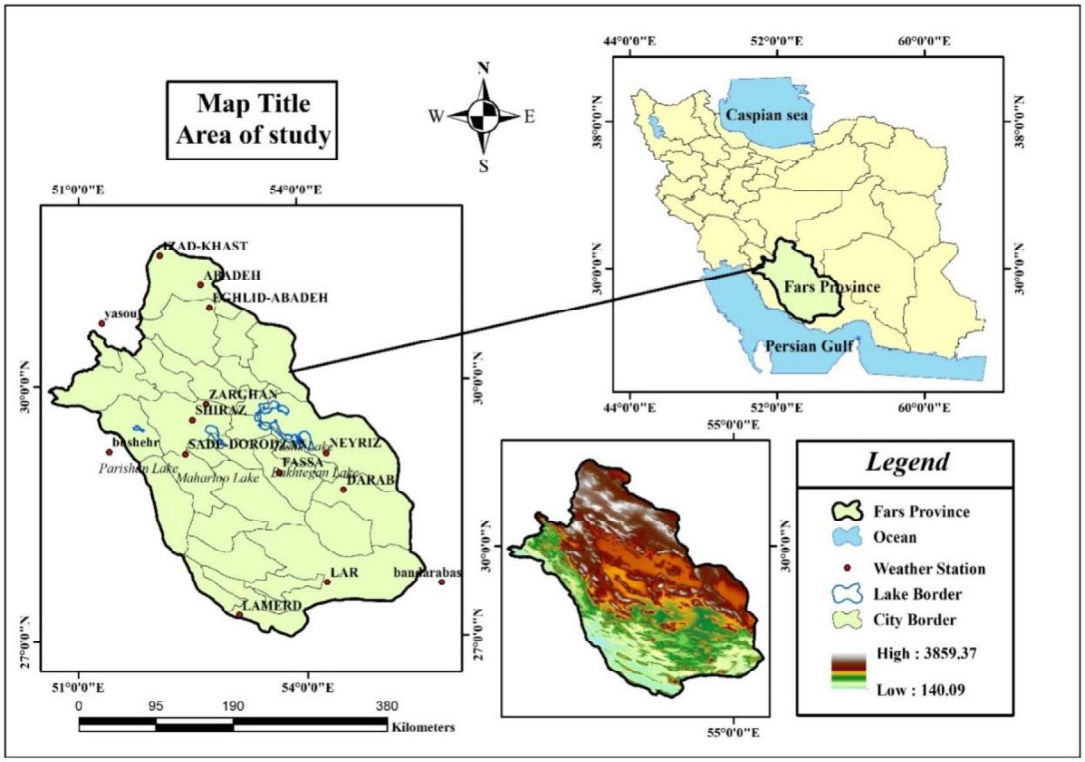


Fig.1. The location of the study site

Table 1. Properties of land cover data properties

Characteristic	Description
Temporal granularity	Yearly
Temporal extent	2017-12-31 to 2001-1-1
Spatial extent	Global
File size	75KB
Coordinate system	Sinusoidal
Datum	N/A
File format	HDF-EOS
Geographic dimensions	1200 km × 120 km
Pixel size	500 m
Number of science dataset (SDS) layers	13

Five types of land cover classification based on MODIS sensors are as follows (Zhang et al., 1998):

1. IGBP Land Classification
2. LAI Classification
3. PFT Classification
4. BGC Classification
5. UMD Classification

This research uses the IGBP Land Classification by default, including 17 land-use classes. It should be noted that due to the characteristics of the study site, some of these land uses may not be available in the area.

Table 2. Land-use classes in IGBP Land Classification

Value	User
1	Evergreen coniferous forest
2	Evergreen broadleaf forest
3	Needle leaf forest
4	Broadleaf forest
5	Combined forest
6	Dense shrubs
7	Scattered shrubs
8	Savanna is dense
9	Savannah
10	Grassland
11	Permanent wetland
12	Agriculture-agronomy
13	City and man-made
14	Compound farming with natural lands
15	Snow and ice
16	Arid
17	Water

The received data covers a size of about 1200 × 1200 km. The number of images is represented by the number of rows and columns.

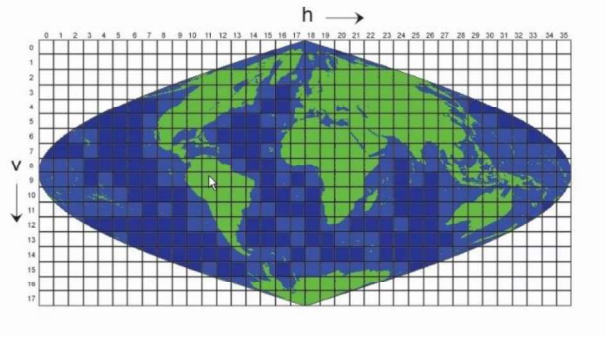


Fig. 3. MODIS Grid Title

The characteristics and investigations are monitoring of land-use changes that will occur when and where geometric computations occur. In addition, land-use area changes and temporal changes are calculated and graphed. Finally, a layout based on the data we have is applied.

In order to study precipitation in the studied years, the monthly precipitation data were obtained from www.irimo.ir and a precipitation zoning map was prepared for each year in the GIS software via the inverse distance weighting (IDW) method. Finally, the relationship between aquatic zones and precipitation was investigated using statistical software.

4. Results and Discussion

The results of the land-use classification are illustrated in Figs. 4 to 9 and Table 3. The present study was aimed at investigating the physical changes in aquatic zones during 1986-2017. Given that there are two aquatic land-use and wetland classes in the land-use classes of IGBP Land Classification, to calculate the area of the aquatic zones, these two land-use classes were summarized and the results were analyzed. According to Fig. 4 and Table 3, the area of the province's water surface along with the wetland class was 1346.31 km^2 in 2001, accounting for 1.09% of the province's total land use. The largest land-use area was related to the scattered shrub class (covering 56401.96 km^2) and then to the class of arid lands (covering 51747.57 km^2) accounting for 45.97% and 42.18% of the total province area, respectively. There is no snow cover throughout the year in the province. The smallest land-use area is related to permanent wetland and savannah with areas of 22.53 and 4.07 km^2, respectively.

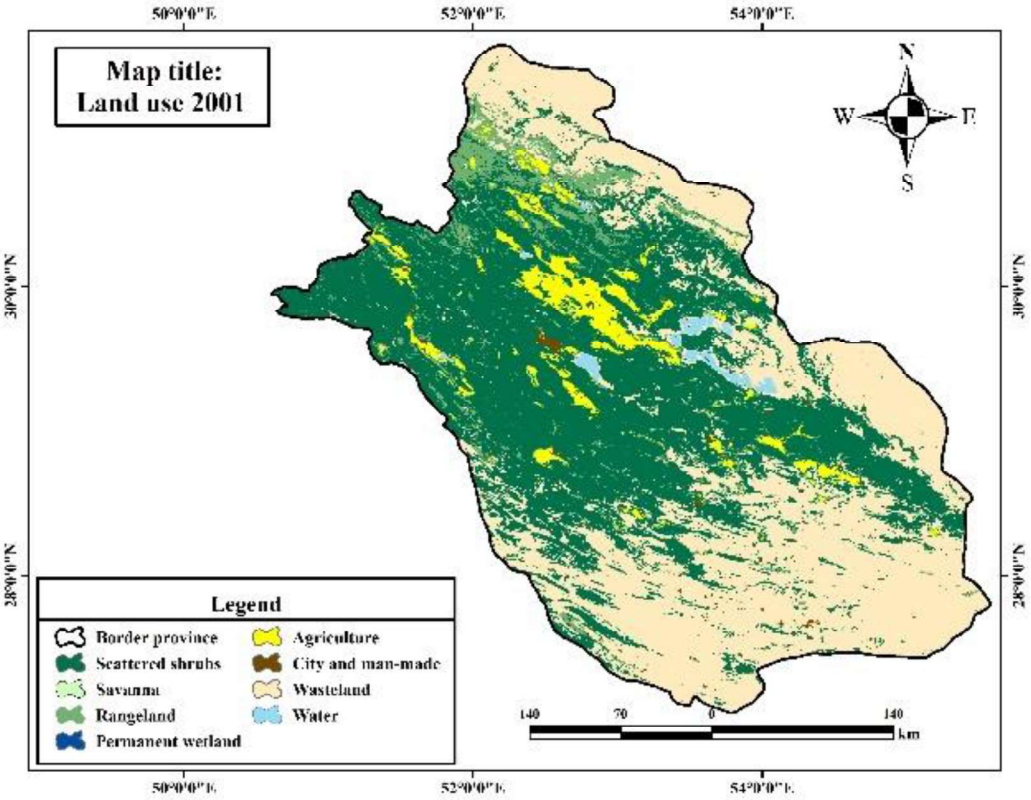


Fig. 4. The land-uses in 2001

In order to compare and analyze changes in different land-use classes, the results of 2017 were analyzed. The total area of the province's aquatic zones (wetland and aquatic land-use classes) was 999.59 km^2 (0.75%) in 2017. The area of permanent wetland in the same year was less than 1 km^2, while the area of the class in 2001 was 22.53 km^2. The area of the aquatic land-use class was 1345.89 km^2 in 2001. It reached 915.07 km^2 in 2017.

The smallest and largest land-use classes of IGBP Land Classification for 2017 were related to the scattered shrub and savanna classes covering areas of about 56401.96 km^2 and 4.07 km^2, respectively.

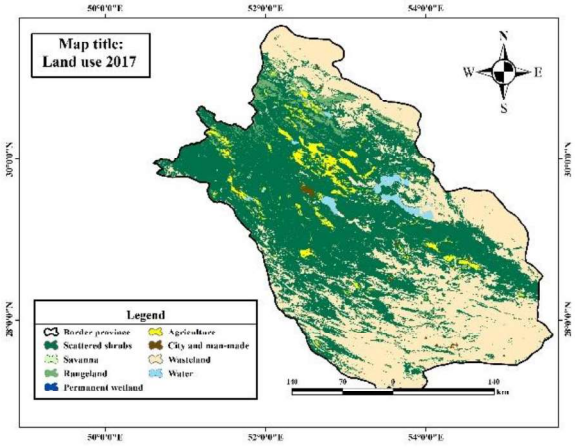


Fig. 5. The land-uses in 2017

Then, based on the results of the IGBP Land Classification, the class area was compared in different years and the year with the smallest class area (permanent water and wetland) was selected and analyzed. In 2010, this class had the smallest area during 2001-2017, and the sum of both classes was 327.39 km^2.

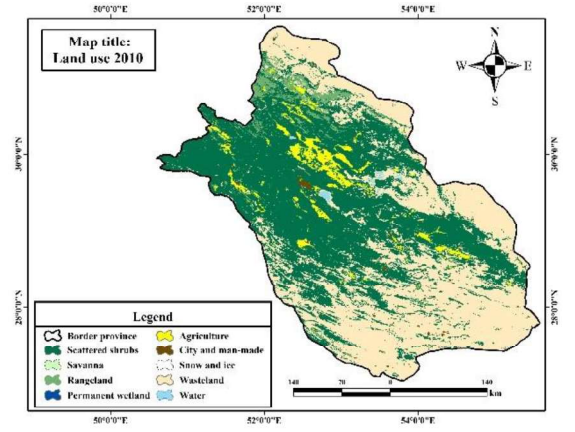


Fig. 6. The land-uses in 2010

In the second part of the study, to determine the relationship between land use and precipitation, the precipitation rate was calculated during 2001-2017. To this end, the precipitation data for the studied years were obtained from www.irimo.ir and precipitation zoning maps were prepared for each year in GIS software.

To calculate the 2001 and 2017 precipitation as the first and last year, as well as the lowest rainfall in the studied years (2001-2002) and map the spatial distribution, the zoning maps were developed for the studied years by the IDW method in GIS software. The average precipitation was 222.09 mm covering an area of about 995 km^2 in 2001. The study of precipitation distribution shows that the wider the areas of Taskh and Bakhtegan lakes are, the lower the precipitation rate is. Regarding Maharloo and Parishan lakes that have lower area than the two other lakes, have similar conditions to the precipitation rate recorded around Bakhtegan and Bakhtegan lakes.

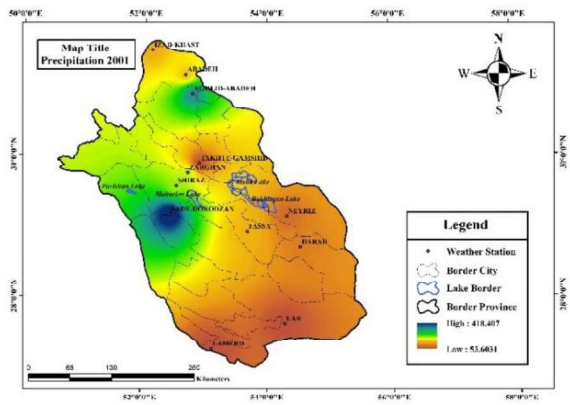


Fig. 7. The precipitation in 2001

Precipitation was increased dramatically in 2017 with an average precipitation rate of 308.42 mm. Years from 2001 to 2002 had the highest precipitation rate. The area of aquatic zones was calculated as to be 1346.31 km^2 in this year (2017), which was the largest area over the studied years. The concentration of the highest precipitation rate was observed around Lake Tashk and Lake Bakhtegan.

To clarify the relationship between aquatic zones and the precipitation rate, the lowest precipitation rate over the studied period was in 2010 with an average precipitation of 103.58 mm. Due to the precipitation distribution, the lakes around Bakhtegan and Tashk, which are wider than the Parishan and Maharloo, have experienced drought and lower precipitation rates. Lake Maharloo and Lake Parishan enjoyed higher precipitation rates than the other two lakes.

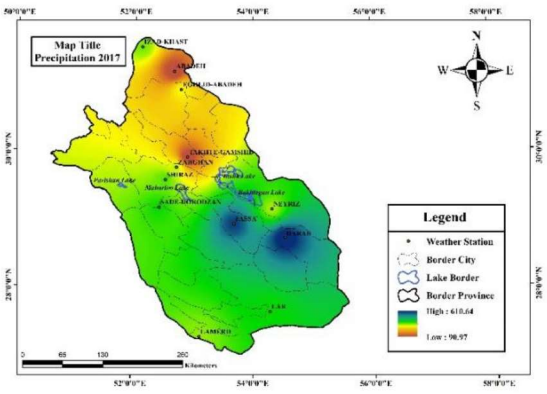


Fig. 8. The precipitation in 2017

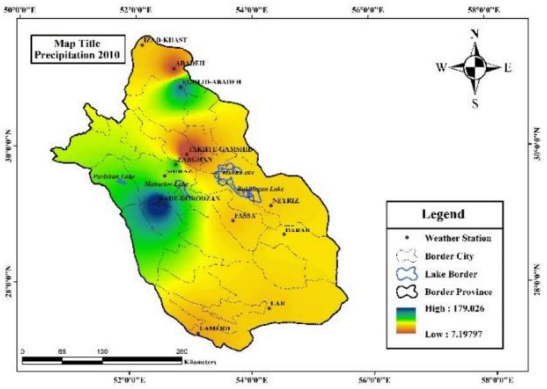


Fig. 9. The precipitation zoning in 2001

Table. 3. The precipitation rate and area of the aquatic zones

	2001	2010	2017
The average rainfall (mm)	222.09	103.58	308.42
Area of aquatic zones (km^2)	1346.31	327.39	915

Finally, with respect to the correlation between the precipitation rate and the area of the aquatic zones, it was found that the two factors were correlated throughout the studied years. The correlation coefficient of 0.76 indicates a direct relationship between the area of aquatic zones and the precipitation rate in the years 2001-2002 in the study site. In fact, as the precipitation rate increases, the area of the aquatic zones increases and as the precipitation rate decreases, the area of the water zones decreases.

5. Conclusion

From quantitative and qualitative perspectives, access to water resources is essential to human life and activities. Therefore, conservation of these resources, especially freshwater, is one of the most important factors in maintaining the health and overall development of

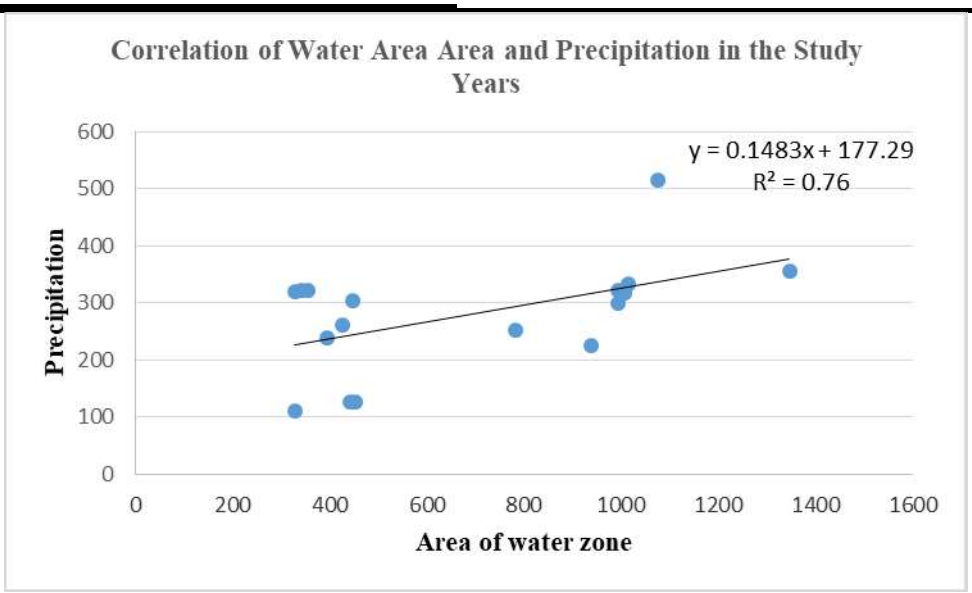


Fig. 10. The correlation between water area and precipitation over the studied period

communities. It is clear that in the first step for the optimal conservation and exploitation of these resources, we need to have detailed knowledge of the potentials of these important resources by conducting continuous monitoring and gaining comprehensive awareness, especially of their qualitative changes, and presenting them for users.

Precipitation can be considered the most important parameter directly affecting groundwater issues. The evaporation rate is 0.77% of precipitation, soil penetration rate is 0.1% of precipitation, and water runoff is 0.12% of precipitation; as a result, 233 million m^3 of precipitation evaporates back into the atmosphere. 33.28 million m^3 penetrates into the earth, and 36.3 million m^3 per year runs as runoff. The present study aimed to investigate the relationship between physical changes in aquatic zones to obtain precipitation in Fars province. MODIS sensors for years 2001-2017 were used to study and evaluate the physical changes in the aquatic zones in the study site.

In this regard, using Land Cover product, 17 land-use floors were determined as follows: evergreen coniferous forest, evergreen broadleaved forest, fine coniferous forest, broadleaf forest, mixed forest, dense shrubs, scattered shrubs, dense savannah, savannah, rangelands, permanent wetlands, agree-farming land uses, urban and man-made land uses, compound land, snow and ice, waste, and water. Given that there are two water and wetland classes in the classes of the IGBP Land Classification, to calculate the area of the aquatic zones, the two land-use classes were summarized and the results were analyzed.

During the studied years (2001–2011), the first and last year, i.e., 2001 and 2017, as well as 2010 as the year with the lowest area, were investigated as case studies. According to the results, the areas of aquatic zones in 2001, 2010 and 2017 were 1346.31, 327.39 and 915.07 km^2, respectively. In order to study physical changes in the zones and, the relationship between this factor and precipitation, the precipitation rate was solicited for the mentioned years and the zoning maps were drawn accordingly. Based on the results for the years 2001, 2010 and 2017, the average precipitation rates were 229.92, 103.58 and 308.42 mm, respectively. As the results showed, in the years when the area was smaller, the precipitation rate was lower, and vice versa. The results of the present study are consistent with those of Mozaffari and Narrangifard (2014) on the effect of precipitation on Lake Manalo's water level change using remote sensing data, indicating a decrease of 107 km^2 in the area of the lake in 2009. This is mainly due to the 200-mm decrease in precipitation in the aquatic year compared to the same period.

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