AN INVESTIGATION ON SPATIAL CHANGES OF PARISHAN INTERNATIONAL WETLAND USING REMOTE SENSING METHODS

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Abstract. Wetlands as one of the most fragile ecosystems worldwide have been seriously affected by different natural and anthropogenic factors such as global climate change, land use change, and excess resource consumption. To investigate such adverse effects, we studied Parishan International Wetland situation over 25 years from 1991 to 2015. In order to detect the change trend and processes of the wetland, Landsat Satellite images were used over the time duration mentioned above. Supervision and maximum likelihood methods were used in the process of image classification. We used logistic regression analysis to investigate the relation between the volume of water in the wetland and the parameters of temperature, evaporation, precipitation, underground water levels, and water withdrawals from wells surrounding the wetland. We found that agricultural lands and residential areas were increased around the wetland compared to 25 years ago at a rate of %10.43 and %47.8, respectively. Our analysis revealed that the wetland water volume significantly correlated with the level of underground water and water uptake from the wells surrounding the wetland.
Keywords: *land use changes, remote sensing, Parishan Wetland, satellite imagery, wetland services and functions*

Introduction

Assessment of land use change is a process that leads to an understanding of the interaction between human and the environment (Singh, 1989; Lu et al., 2003). Changes in land use and land cover are some the most important environmental issues in different levels ranging from global to local levels. Patterns of land use changes are the consequence of land cover changes which bring about a cumulative impact on the global climate change and ecosystems degradation (Riebsame et al., 1994; Lambin and Geist, 2006). Changes in land cover and land use have a direct influence on climate changes in a way that there is complex interaction between climate changes and land cover changes (Dale, 1997). Human activities such as changes in land use

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also affect climate (Feddema et al., 2005). The problem of land use changes is more important in biologically sensitive and fragile areas such as wetlands (Lambin and Geist, 2006). Accordingly, evaluation of such changes taking place in wetlands and lakes can be very important and effective in the management and remediation of such valuable ecosystems and in making better decisions (Ozesmi and Bauer, 2002). Wetlands as intermediate areas between land and water ecosystems, provide diverse ecosystem services such as flood control, protection of water quality, wildlife habitat, and erosion control (Sugumaran et al., 2004). Change detection is a process that provides the possibility of identifying differences in the status of an object, phenomenon, and pattern on the Earth's surface at different times (Lu et al., 2004; Singh, 1989). Usually, data related to change detection is achieved by specifying the changed areas using two images at two different times (Xiaolu and Bo, 2011). Using remote sensing techniques is one of the most accurate tools to carry out such monitoring (Ozesmi and Bauer, 2002).

Mistry and Conway (2003) have studied the climatic parameters affecting the fluctuation of Lake Victoria in East Africa. In 2006, changes in coastal line of Ionian area in Southern Italy were survived using satellite data and TM based on multitemporal and multisource approaches (Guariglia et al., 2006). In 2013 a study entitled 'The impacts of climate change and land cover/use transition on the hydrology in the upper Yellow River Basin, China' was conducted (Cuo et al., 2013). In East Sudan, the effects of climate and land use changes on themigration paths of livestock have been studied using multi-temporal satellite images (Sulieman and Elagib, 2012). Kurt et al. (2010) investigated coastline changes in the coastal region of Istanbul, Turkey using Landsat satellite data and showed the expansion of the coastline up to 32 km over 20 years from 1987 to 2007. In 2012, changes in the coastline of the Aral Lake have been studied using the Landsat images (Singh et al., 2012). Duan et al. (2013) studied changes in the water volume of Mead Lake in America, Tana Lake in Ethiopia, and Ijssel Lake in the Netherlands by remote sensing methods (Duan et al., 2013). Most of the researches carried out with this method in Iran focused on Urumia Lake (Al-sheikh, et al., 2005; Rasouli et al., 2008; Shayan and Jannati, 2007; Rasouli and Abbasian, 2009; Jalili et al., 2011; Yarahmadi, 2014). For instance Sima and Tajrishi (2013) investigated factors of volume, area, and height of Uremia Lake using remote sensing data and analytical models. The aim of our research was to assess the changes in Parishan International Wetland in Fars Province in Iran and to study the factors responsible to those changes during 1990 to 2015.

Materials and Methods

The Study Area

Lake Parishan, an Iranian Ramsar Site in Fars Province, is one of the two sites nominated for the UNDP/GEF Conservation of Iranian Wetlands Project. As a part of Arjan Parishan Protected Area, Parishan Lake was registered by UNESCO as a Biosphere Reserve (Fars DOE/Department of Environment, 2010). This wetland is located in the eastern part of Kazeroun City surrounded by Parishan Protected Area (29˚ 34' 48" N and 51˚ 54' 36" E) with an area of about 60000 hectares in southwest Iran (*Fig. 1*). Parishan Wetland with an arid and desert cold climate at an average elevation of 820 m above sea level receives an annual rainfall of about 430 mm (Dolakhani et al., 2014). The evaporation capacity in the area is high (2470 mm/yr on average) ranging

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between 1600-3350 mm/yr. The surface area of the water body changes seasonally according to the hydrological condition and generally varies from more than 2500 to almost 5000 ha. The Lake does not have a natural outflow and its main source of water loss is through evaporation and consumption by vegetation cover. However, a large number of deep wells (more than 800) have been dug around the Lake exploiting significant volume of groundwater for agricultural uses resulting in wetland discharge (Fars DOE, 2010). The wetland is almost surrounded by agricultural farms in all directions; however, further on the northern elevations, there exists a semi-dry type of forest cover consisting mainly of scattered oak trees. The water body of the Lake as well as different patterns of vegetation cover around and inside the lake provides diverse habitats which supports the rich biodiversity of the wetland. The Lake hosts significant number of migratory water birds specially wintering population which breed there. At least, five globally threatened species such as *Pelecanus crispus*, *Marmaronetta angustirostris*, *Aythya nyroca*, *Oxyura leucocephala* and *Aquila heliacal* (Fars DOE, 2010) are usually present on the lake, occasionally in large population.

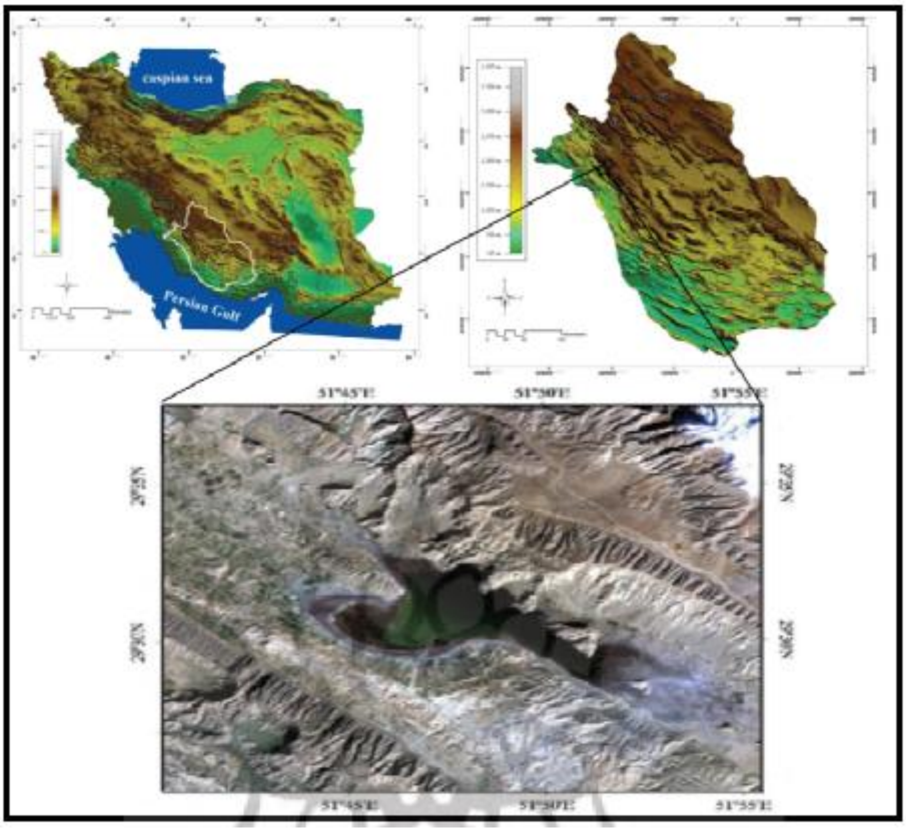

Figure 1. *Study area and TM-5 Image of Parishan Wetland (adopted from Maghsoodi et al., 2015)*

Data Preparation

The aim of this study was to investigate the changes of land use in the area around Parishan Wetland and to investigate the relation of the volume of wetland water with human, and natural factors from 1990 to 2015 through the following steps:

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1. Assessment of Changes in the Land Use and Land Cover

First, the required satellite images and data were prepared and multitemporal images were processed. In this study, satellite images of Landsat were used to review the changes (*Table 1*) at appropriate time intervals (from March 1991 to March 2015). On May 31, 2003, the Scan Line Corrector (SLC) installed on Landsat satellite stopped working and caused the scanner mirror of the sensor to move forward and backward when taking the picture and continuous movements of the mirror created parallel scanned bands (Gap) of the scene (Mobasheri, 2007). This damage brought about gaps of one pixel in the image center up to 12 pixels in the edges. To improve the satellite images (ETM +), the software provided by the Geological Survey and America's Space Agency (called Gap-Fill) was used. Then, radiometric and geometric corrections were applied to all images using software ENVI 5.1 and false color images were made using compounds of bands 2, 3, 4, 5, and 7 to identify different land uses. Then the training points were taken according to the land use map on a scale of 1: 100,000 (Produced by the Department of Forests and Rangelands of Iran) and according to IRS pictures and field Sampling operations. Then, several known pixels were used to identify each class. In the next step, supervised classification method and maximum likelihood (ML) were used for classification. In the first step of this method, the mean and covariance were calculated for the bands used in the classification on the basis of the training samples of classes. In the second step, the probability of the pixels for each class was calculated and based on the highest likelihood, the classification and allocation of pixels to different classes were done. In order to assess the accuracy of the classification, a specified threshold was considered for the probability of correct classification. Classification accuracy was assessed by Kappa coefficient and overall accuracy using random sampling in the ENVI 5.1 Software.

Table 1. *Satellite images used for the study*

Sensor	Path/row	Acquisition date	Spatial resolution (m)	Source
LT5	163/40	1991/3/21	30	USGS
LT5	163/40	1995/4/17	30	USGS
LE7	163/40	2000/3/21	30	USGS
LE7	163/40	2005/4/20	30	USGS
LE7	163/40	2010/4/2	30	USGS
LC8	163/40	2015/3/23	30	USGS

2. Investigation of the Relation of the Volume of Parishan Wetland Water with Human and Natural Factors

For this purpose, factors including precipitation, temperature, and evaporation were considered as the natural factors; since there was no direct withdrawals of wetland water by humans, the water taken from the wells surrounding the wetland resulting in the groundwater level changes was considered as the human factor (*Table 2*). Fars Regional Water Organization has recorded the parameters of temperature, evaporation, precipitation, groundwater level, and water withdrawals from wells around the wetland since 1996; the data were obtained from Fars Regional Water organization. To calculate the annual water volume of the wetland, the bathymetric maps of the wetland was obtained from the Environmental Protection Agency of Fars province and on the basis

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of bathymetry map, the DEM layers of wetland area in different years were prepared by the ARC gis 10.2 Software. In the next step, water surface area was calculated for each year. For this purpose, due to the lack of multiband images of the study area in all the years, Landsat Look Images with Geographic Reference of the study area were taken from the USGS website for all the years. After geometric corrections of images, annual water surface of the wetland was manually extracted for each year with high accuracy. Then, the DEM layer of wetlands was cropped for each year according to the water surface area of the wetland. Finally, these layers were entered into the ARC gis Software environment and the volume of water in the wetland was calculated for each year using the Surface Volume tool.

Table 2. *Natural and human factor descriptions and abbreviations*

Factors	Abbreviation	Measuring unit
The wetland water volume	WV	Million cubic meters
Precipitation	P	mm
Evaporation	Ev	mm
Temperature	T	^{0}c
Water uptake from the wells surrounding the wetland	DW	Million cubic meters
Groundwater level	GWL	Meters

After assessing and determining the factors, the data were entered into the SPSS Software and data analysis was performed.

The Shapiro-Wilk test was used to test for normality on all variables analysed (SPSS 18.0); and if non-normal variables transformed logarithmically or trigonometrically (Jobson, 1992; Atmar and Patterson, 1993; Sokal and Rohlf, 1994). The Pearson's Correlation Coefficient (r) was used for simple relation analyses with the variables. Then, a backward multiple regression test was employed for modeling the relation between the volume of the wetland water as the dependent variables and the precipitation, temperature, and harvesting water from wells around the wetland and the groundwater level as the independent variables.

In this method, all variables are first entered into the model and then, the least important variable is removed according to removal criteria; this process continues until all the less important variables are gradually removed. Finally, the final model will be calculated based on the main variables. Therefore, all the remaining variables have an acceptable and significant correlation with each other. Models obtained by backward method are superior than those made by *Enter* and *Stepwise* methods in terms of the number of variables. That is to say, the number of variables is not as many as that in the Enter models and not as few as that in the Stepwise models. Also in these models, higher correlation between the calculated performance and actual performance is observed compared to the Stepwise model (Amiri, 2012). Logistic regression is used for modeling the relation between binary dependent variable and one or more environmental predictor variables. In other words, logistic regression can be used to predict the dependent variable based on the predictor variables (Bahadori Nezhad, 2012). Formula of Backward Model is given in formula 1.

Formula 1:

$$Y_i = \beta_{0i} + \beta_{1i}X_{1i} + \beta_{2i}X_{2i} + \beta_{3i}X_{3i} + \beta_{4i}X_{4i} + \ldots + \beta_{(p-1)\,i}\, X_{(p-1)\,i}$$

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Y_i= the linear predictor

β_{0i}= Constant coefficient

β_{1i} - β_{4i}= the coefficients of the variables

X_{1i} - X_{4i}= Variable values

Results

Filling Gaps in Landsat ETM+ SLC-off Images

In this study, the gap errors in images for 2005 and 2010 have been modified using Gap-Fill Software (*Fig. 2*). It is observed that there are no errors in the center of the images, and as we come closer to the edge of the images, gaps become wider. Fortunately, since the wetland area is located in the center of the image, therefore the images have been used with the appropriate reliability and accuracy.

Determination of Land Use Changes

The land cover/land use maps generated by image classification for 1991, 1995, 2000, 2005, 2010, and 2015 are presented in *Figs. 3 to 8*. Initially, the study area was classified into 10 distinct classes. Then, based on similarity of land use, subclasses were combined and reduced to 5 classes. The final classes included: 1- arable land (cultivated and ready to cultivation); 2- bare soil, sand, and rock; 3- residential area; 4. Wetland vegetation; and 5. Water. The land cover proportions are shown in *Table 3*. Also, in order to assess the classification accuracy, overall accuracy and kappa coefficient were calculated; the results are presented in *Table 3*.

The processing of data shows that farming lands and residential areas from 1991 to 2015 have increased at a rate of %10.43 and %47.8, respectively. During these years, the wetland has completely dried up. The changes of land use and land cover in the study area from 1991 to 2015 are presented in *Table 3* and *Diagram 1*.

Table 3. *The changes land use and land cover during the years 1991 to 2015*

Kappa Coefficient	Overall Accuracy (%)	Residential Area (Km^2)	Bare soil, sand, rock (Km^2)	Wetland vegetation (Km^2)	Water (Km^2)	Farmland (Km^2)	Land cover classes Year
0.865	89.65	0.909	150.4629	9.4068	28.746	75.2697	1991
0.776	82.95	1.0089	150.3723	8.379	34.6599	53.8605	1995
0.925	94.15	1.121	157.224	10.3914	36.9873	59.0418	2000
0.896	92	1.169	138.8647	7.0353	35.8029	85.2543	2005
0.761	82.7	1.203	169.0158	4.6386	1.7649	89.1261	2010
0.792	85.71	1.3438	166.8644	9.7938	0	83.1231	2015

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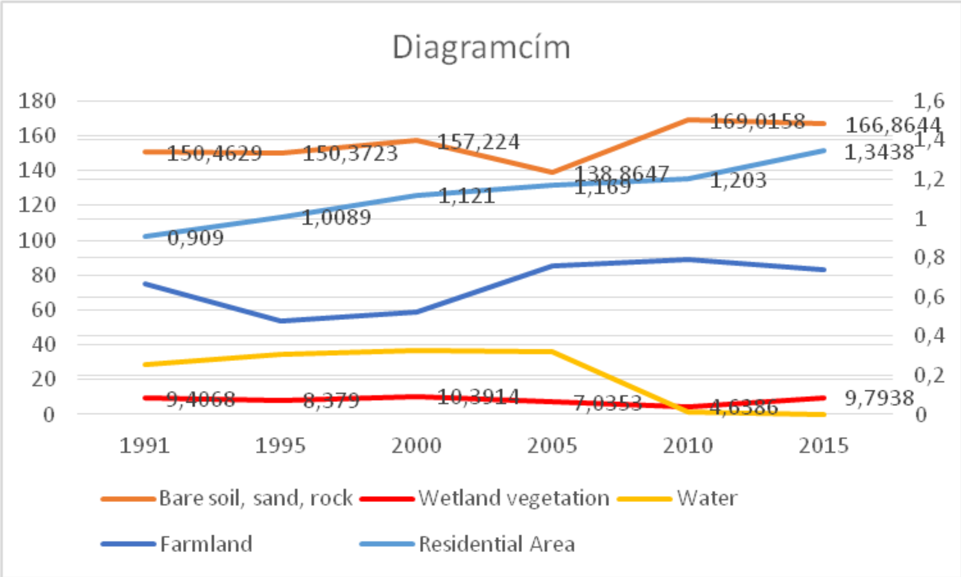

Diagram 1. *Land use and land cover changes in the study area*

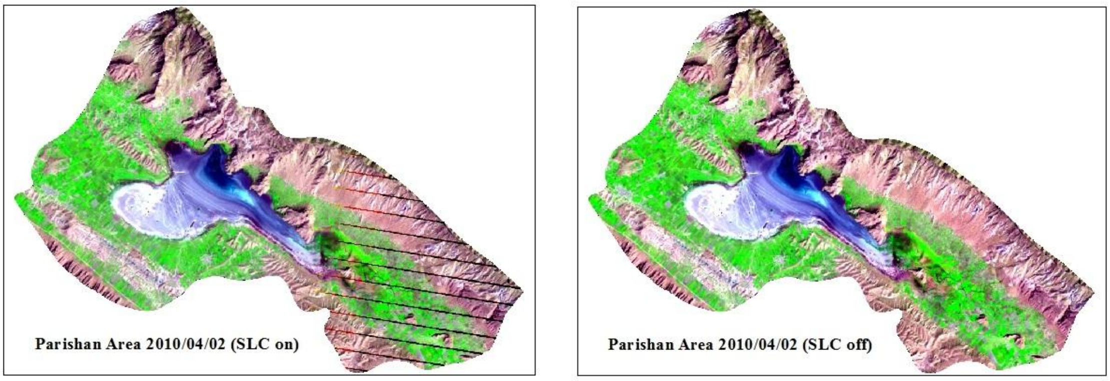

Figure 2. *Landsat 7 ETM + imagery before and after the error correction*

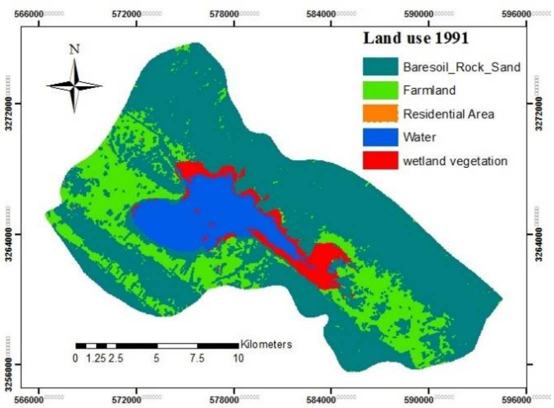

Figure 3. *classified image of 1991*

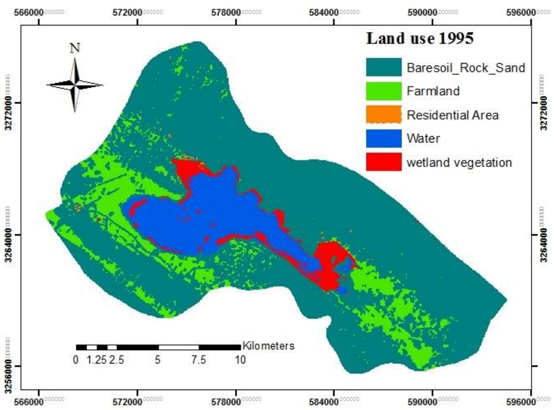

Figure 4. *classified image of 1995*

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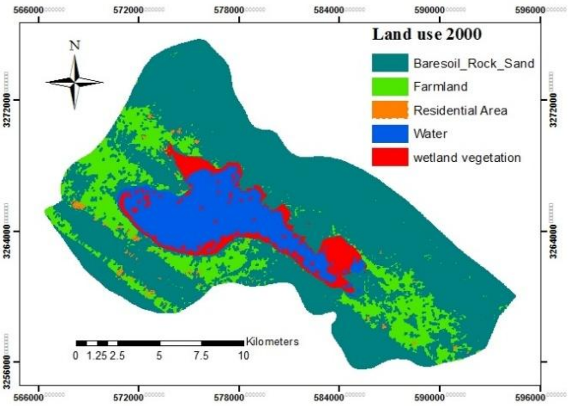

Figure 5. classified image of 2000

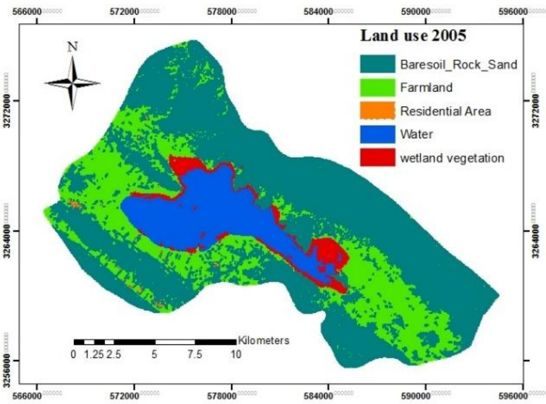

Figure 6. *classified image of 2005*

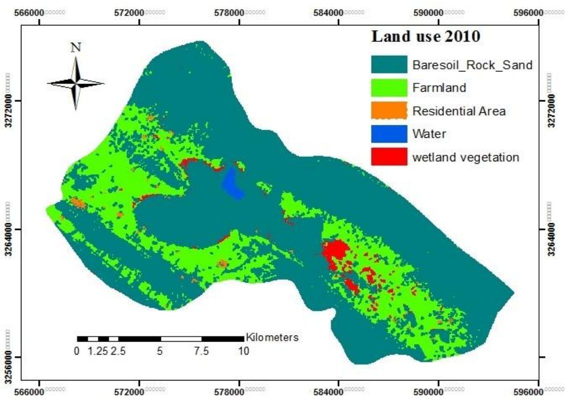

Figure 7. *classified image of 2010*

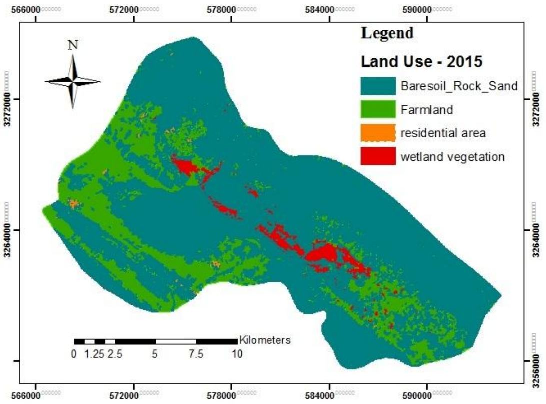

Figure 8. *classified image of 2015*

Investigation of the Relation of the Volume of Wetland Water with Human and Natural Factors

Since 1996, Fars Regional Water Organization has recorded underground water level and water withdrawals from wells around the wetland. Also, synoptic stations of Parishan Wetland affiliated with Fars Regional Water Organization have recorded the data related to temperature, rainfall, and evaporation. The data are presented in *Table 4*. The annual volume of water in the wetland is also presented in *Table 4*. Digital elevation layers of the wetland in different years are presented in *Figs. 9 to 16*.

Table 4. *The annual average of natural and human factors in the study area*

YEAR	Precipitation (mm)	Temperature (C)	Evaporation (mm)	Discharge wells (mcm)	Wetland water volume (m^3)	Underground water level (m)
1996	652.5	22.10	1839.2	17.5	103452429.6	820.91
1997	255.5	21.40	1794.7	20.5	101896063.5	821.13
1998	684.5	20.90	1609.7	22.5	105240623.8	821.51
1999	454.5	22.60	1743.9	23.5	104345713.3	822.34
2000	226	22.00	2617.7	29.5	103555301.1	820.94

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2001	244	22.20	3078	31	81157976.0	817.8
2002	579	22.00	2072	29	77319160.5	817.2
2003	423	22.20	1718.3	27.5	72521104.2	816.75
2004	421.5	22.40	2713	33	70796177.8	816.59
2005	594.5	21.70	3329.8	34.5	76425078.3	818.55
2006	351.5	22.70	3205.3	39.5	76409447.8	818.4
2007	366.5	21.60	3328.2	41.5	64217068.6	817.03
2008	170	22.40	3818.1	39	30137468.0	814.82
2009	186.5	21.70	3559	32	2478169.6	812.21
2010	238.5	22.00	3208.4	23	699449.7	810.04
2011	235	22.00	3413.2	17	0	808.03
2012	338	21.10	3349.5	13.38	0	807.66
2013	409	21.80	2758.9	9.31	0	808.33
2014	356.5	21.50	2733.5	11.37	0	808.24
2015	224	22.40	2746.1	14.56	0	807.23

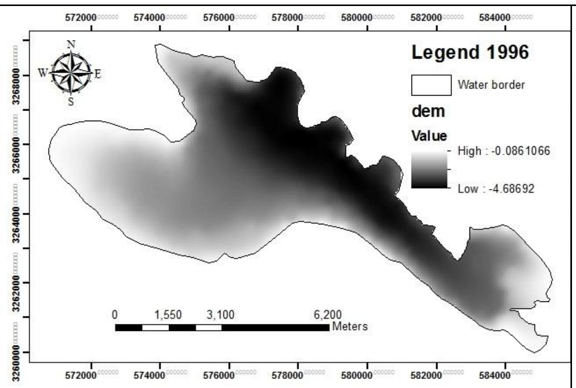

Figure 9. *The DEM layer of water level in 1996*

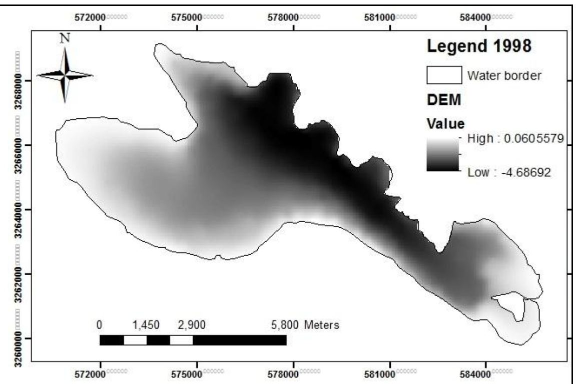

Figure 10. *The DEM layer of water level in 1998*

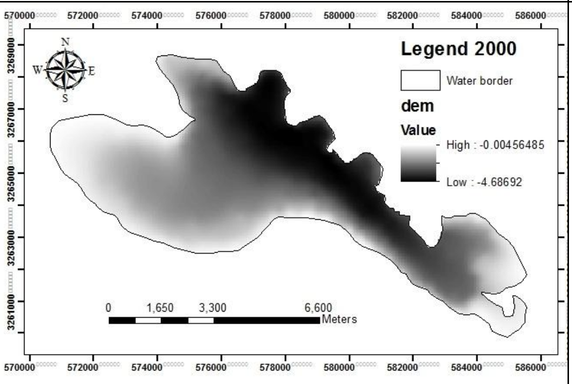

Figure 11. *The DEM layer of water level in 2000*

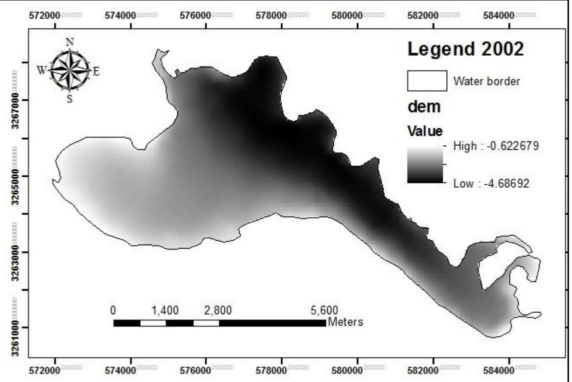

Figure 12. *The DEM layer of water level in 2002*

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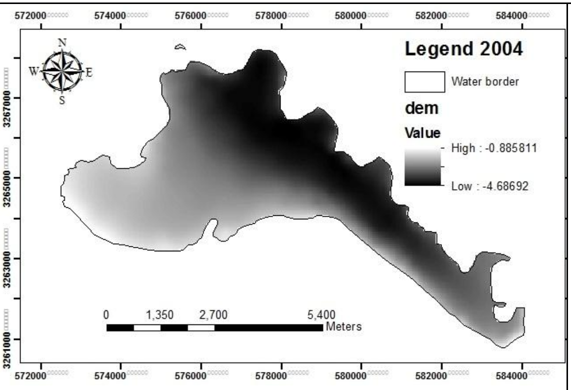

Figure 13. *The DEM layer of water level in 2004*

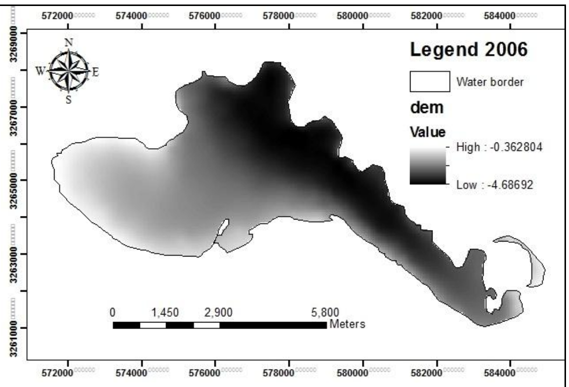

Figure 14. *The DEM layer of water level in 2006*

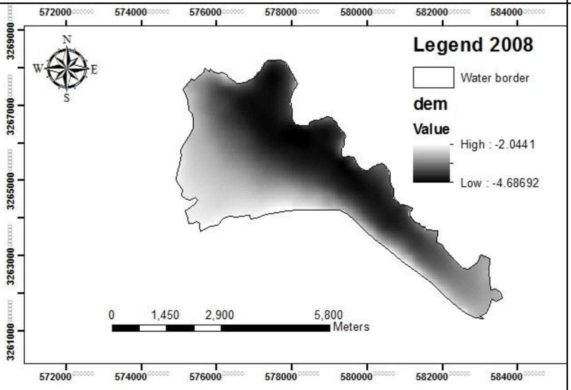

Figure 15. *The DEM layer of water level in 2008*

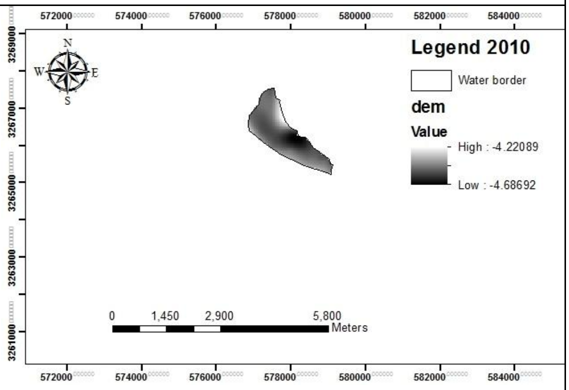

Figure 16. *The DEM layer of water level in 2010*

Three independent variables were significantly correlated with the water volume of the wetland (Ground water level ($p < 0.01$, r = 0.0.970), Discharge wells ($p < 0.01$; r = -0.788) and evaporation ($p < 0.01$; r = -0.733)). They were entered in backward multiple regression tests for modeling to predict the water volume of the wetland. The Resulting models of the backward multiple regression test indicated that the ground water level ($p < 0.01$) and discharge wells ($p < 0.01$) were good predictors of the water volume of the wetland (*Table 5*).

Table 5. *The models resulting from the backward multiple regression test using the water volume of the wetland as the dependent variables and ground water level, discharge wells, and evaporation as the independent variables*

Parameters included in the model	**R^2**	**Coefficient**	**F**	**p**	**Excluded Variables**	**p**
Model	0.965		165.236			
Constant		-5777.105		0.000		
Underground Water level		7.161		0.000	Evaporation	0.991
Discharge wells		-0.891		0.013		

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As is evident from *Table 5*, backward method eliminated unimportant variables with the use of removal criteria and calculated the final model according to the original variables of the underground water level and the amount of water extraction from the wells. Therefore, the underground water level and discharge wells are the predictors for the volume of wetland water.

Furthermore, to investigate the factors affecting the groundwater level, initially the correlation between the groundwater level and independent variables (evaporation, temperature, discharge water wells, and precipitation) were investigated using Pearson's correlation coefficient. Two independent variables were significantly correlated with the ground water level (discharge wells ($p = 0.004$; $r = -0.697$) and evaporation ($p = 0.008$; $r = -0.656$)). They were entered into the backward multiple regression tests for modeling to predict the ground water level. The resulting models of the backward multiple regression test indicated that the discharge water wells ($p < 0.01$) were good predictors of the ground water level (*Table 6*).

Table 6. *The models resulting from the backward multiple regression test using the ground water level as the dependent variable and Evaporation and Discharge wells as the independent variables*

Parameters included in the model	**R2**	**Coefficient**	**F**	**p**	**Excluded Variables**	**p**
Model	0.486		12.281			
Constant		827.749		0.000		
Discharge wells		-0.324		0.004	Ev	0.769

Discussion and Conclusion

The results show that the area around Parishan Wetland has been changed from 1991 to 2015. Viewing the changes by using processing satellite images shows that the farmlands surrounding wetlands have increased at a rate of %10.43 from 1991 to 2015 and on average, they have increased by %0.52 per year. Agricultural sector imposes huge pressures on the region with excessive withdrawal water from wells, digging water wells, and more use of fertilizers and pesticides to raise productivity. Therefore, drying up of springs, reduction of the level of underground water, an increase in organic and inorganic contaminants, and finally drying up of wetland are all resulted from uncertain effects of land use changes along with climate changes. Also, residential areas have increased at a rate of %47.8 during this period and on average, they have increased by %2.39 per year. Increase in human settlements and tourist sites in the region shows a series of pressures including occupation and land use changes; rape and destruction of wetland; change of the landscape structure for excavation and embankment operations; and an increase in sewage and garbage without creating the appropriate infrastructure for sanitary disposal. On the other hand, wetland has completely dried up from 2011 onwards. According to *Table 3*, along with the increased discharge of water from the wells surrounding wetlands, the underground water level and the volume of wetland water also have declined and the wetland has completely dried up in 2011. Most of the wetland water is supplied through precipitation and spring water and a portion is supplied through groundwater flow, while the amount of annual precipitation in the region is very small compared to the rate of evaporation from free surface of the

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wetland. According to *Table 3*, the average evaporation in the area under study during this period has been equal to 2731.8 mm and considering the coefficient of evaporation pan (0.7) (Zamin Ara Consulting Engineers of Fars, 2011), evaporation from the wetland surface has been equal to 1912.26 mm. Now, given that the average area of the wetland during the period under study was 24 square kilometers, it follows that the average annual evaporation from the wetland surface has been equal to 38.245 million cubic meters, while the average rainfall has been equal to 8.892 million cubic meters. On the other hand, the water of the springs around the wetlands is consumed by farmlands before reaching the wetland; in recent years, most springs have dried up due to drought and low levels of underground water. Meanwhile, digging a large number of wells around the wetlands (*Fig. 17*) and depletion of groundwater have caused the groundwater level go down by 13.68 meters. Now, there is no possibility of providing water for the wetland by underground water flows. According to studies carried out by the Zamin Ara Consulting Engineers of Fars in 2011, the direction of groundwater flow is in direction of the tilt of the study area. According to *Figs. 17 and 18,* in addition to groundwater depletion, the wells in the direction of the groundwater flow towards the wetland, prevent groundwater flow from reaching the wetland.

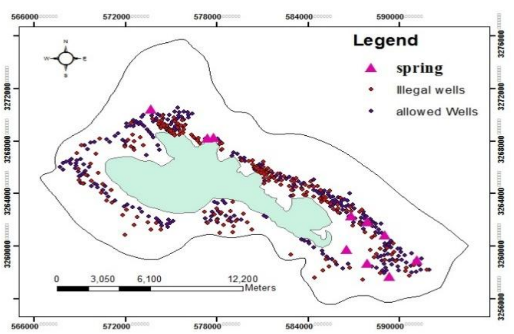

Figure 17. *Location of water wells*

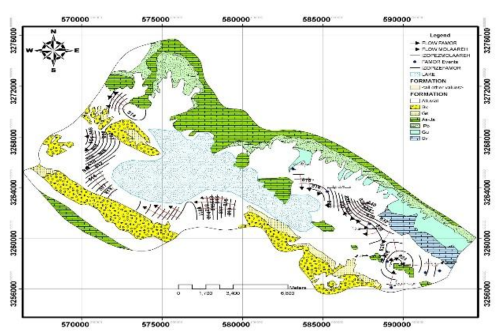

Figure 18. *Groundwater flow in the plain of Parishan. Source: Zamin ara Consulting Engineers of Fars, 2011*

Based on the backward model results, reduction of the underground water level and drainage of the water in wells surrounding the wetland have high correlation at 0.01 level with a decrease in the volume of wetland water. Therefore, withdrawals of underground water resources require serious monitoring, because the number of wells has increased from 425 rings in 1992 to 940 rings in 2011 (Ghazali, 2012). The results of backward regression model confirm the bilateral relationship between the volume of wetland water and underground water level. The result of this paper is consistent with the result of the studies performed by (Simonit et al., 2005; Ghazali, 2012) in the area of interaction of the surface water with groundwater. Also, the results of the studies carried out by (Amini and Ranjbar, 2014; Ghahari and Pakparvar, 2007; Velayati, 2003) are in line with the results of this study. All of them have expressed that harvesting water from the wells has the greatest impact on the groundwater levels.

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