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Hydrological Survey and Determination of Ecological Water Requirements in Parishan Wetland

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ABSTRACT

Wetlands are one of the most important aquatic ecosystems that play a significant role in modifying the quantity and quality of water, providing economic and tourist opportunities as well as drinking water and livelihood for aboriginal people. Establishing and maintaining a suitable water regime as well as wise use of wetland ecosystems in such a way to preserve their functions and values are considered as the most important management issues in wetlands. The basin of the Parishan International Wetland is located between 51° and 44' and 51° and 51' of east longitude and 29° and 32' and 30" of north latitude of Fars province. The purpose of this study was to evaluate the hydrology and determine the Ecological Water Requirements of Parishan Wetland to preserve and rescue this international wetland. Aiming at this goal, remote sensing techniques and the data recorded by related organizations were used. The results of the study showed that the currents of water entering the wetland over the solar year of 1380 consisted of runoff (20.06 million cubic meters), rainfall (14.75 million cubic meters), springs (5.487 million cubic meters) and groundwater leakage to the wetland (34.663 million cubic meters); the output of the wetland was also subject to evaporation (85.1 million cubic meters). Also, the amount of ecological water required by the wetland is equivalent to 110.96 million cubic meters.

Introduction

Wetlands are one of the most important aquatic ecosystems that play a significant role in modifying the quantity and quality of water, providing economic and tourist opportunities; as well as drinking water, and livelihood for aboriginal people (Dyson, 2003). Increasing demand for water in different sectors has increased the importance and sensitivity of resource management. Meanwhile, the establishment and maintenance of a proper water regime as well as wise use of wetland ecosystems in such a way to preserve their functions and values are considered as the most important management issues of wetlands (King, 2001). To maintain the natural function of the wetland and ensure its long-term health, it is necessary to determine and allocate the amount of water that is close to its natural regime, called the environmental water requirement (Bagherzadeh Karimi, 2008; Ramsar, 2010).

Simultaneous studies carried out on the environmental water requirement in the United States by the US Wildlife Service from 1940 to 1970 focused on clarifying the negative effects of dam on aquatic ecosystems (Niakani, 2010; Torabi Pelat kale, 2010).

In recent years, the discussion of studies performed on the determination of environmental water requirement in Iran has also been considered as a necessity. For example, in the long-term developmental strategies adopted for the country's water resources, besides increasing the extraction of surface water resources in the next 20 years, provision of the minimum requirements of permanent natural water resources are mentioned (Modaberi, 2008; Babran, 2008).

Due to the lack of sufficient studies on environmental water requirements in wetlands, this study is a step towards such applied studies including the necessity of water resources management as well as conservation and improvement of wetland habitats and their biodiversity in Iran.

Creating and maintaining a proper water regime is the most important management issue for most wetlands. Human activities can lead to an increase or decrease in flooding and changes in the seasonal floodwater regime of wetlands (ANCA, 1996). Therefore, identifying and allocating the environmental water requirement of wetlands will play an important role in protecting ecosystem functions. The International Wetlands Convention defines the water allocation of wetlands as follows: "The quantity and quality of water needed to maintain an ecological feature of water resource that sustains the functions of the given wetland" (Ramsar Convention Secratariat, 2004).

The main objective of this research is to collect and analyze climatological information and hydrology of part of Parishan wetland and to determine the ecological water requirement of Parishan wetland. In this study, hydrologic and comprehensive methods have been used to determine the required water (environmental abonne) to maintain part of vita of this wetland.

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Materials and Methods

Range of Study

The basin of the Parishan lake is located between 51 °, 44' and 51°, 51' east longitude and 29°, 32', 30" northern latitudes in Fars province (Kazeroun city). The area of this basin is (using topographical maps of 1: 25000) equal to 225 km^2, of which 40%, i.e. 90 km^2 is covered with altitudes and 60%, i.e. 135 km^2, is covered with plains and lakes. Parishan wetland is located at 12 km southwest of Kazeroon and at the end south-east of the Zagros ghaut. The size of this wetland varies, depending on the annual rainfall and drought and wet years, between 0 to 50 km^2 (1 or 2 months of the year). The average area of the Parishan Lake is 20 km^2, but due to the drought in 1386-87, its size was reduced to 10.8 km^2.. The Parishan Lake is a tectonic pit with a fault source. Due to the age, natural and geographical location, and entrance of types of agricultural wastes, this is Eutrophe Lake, providing a suitable environment for the growth of several fish species due to the presence of aquatic plants and unicellular algae and various foraminifera (Jahanbakhsh Ganjeh et al, 2017). Figure 1 shows the position of Parishan Lake and the Arjan plain.

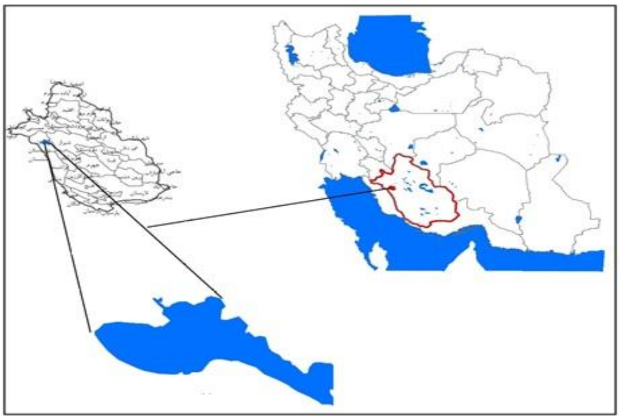

Figure 1. The location of Parishan basin on Iran map (Jahanbakhsh Ganjeh et al, 2017).

In general, permanent surface currents in the Parishan basin are dependent on the existing springs, especially in wet years. Season streams, especially in the north and northeastern regions of the basin, run the runoff towards the lake in the rainy season.

Analysis Method

Parishan Lake Hydrology

Landsat satellite imagery and wetland depth maps were used for analysis. To this end, two images of the lake were taken in the same month of two different years, and after the initial processing performed on the images, the water range of the lake was calculated for these two years. Then, based on the depth map of the wetland and its water range, a high altitude digital map (DEM) was prepared for these two years and the average volume of wetland water was calculated along with the difference of water volumes in the wetland between the time period of taking the two images by the ARC gis Software using the Surface Volume tool. After this stage, based on the difference in water volume of the wetland at different times and the data related to water input (rainfall, runoff and spring) and water output (evaporation and water withdrawals from the lake), the amount of water penetration from underground water sources to the wetland or water leakage of wetland to the underground water sources was estimated based on the following formula: (Formula One).

$$\Delta V=[(R + P+S) - (E + \text{Intake})] \pm GI; \qquad (1)$$

ΔV = Difference in volume of wetland water in m^3;
R = Surface flow into the wetland in m^3 / Year;
S = Entrance flows from springs to wetland in m^3 / year;
GI = Entrance leakage currents from underground water to wetland or from wetland to underground water in m^3 / Year;
P = Entrance flows into the wetland through annual direct rainfall in m / Year;
E = Average annual evaporation in m / Year; and
Intake = Water withdrawals from the wetland in m^3 / Year.

Formula 2 is used to calculate the surface water entering the wetland, considering that the source of surface waters is limited to occasional outbursts after heavy rainfall.

Formula 2: Equation for calculating the water entering the lake through runoff

$$R_{mcm} = \frac{A_{m^2} \times P_{mm} \times \lambda}{1000000000}$$

R = The amount of water entering the wetland through the runoff (million cubic meters);
A = Area of the basin (m^2);
P = Rainfall (mm); and
λ = Runoff coefficient.

According to Fars province Environmental Protection Agency studies, the runoff coefficient for Parishan watershed including plains and heights is equal to 0.12 (Lotfi, 2010) and for the lake water level it is equal to 1.

Another source of water supply for the Parishan Lake is groundwater. The flows of more than ten springs are drained into the lake after providing the irrigation needs of the arable lands. There are also two springs below the water surface that drains their water directly into the lake.

Also, water leakage from the two aquifers of Famor and Mullahare to the lake is another source of water supply of the lake that can't be directly measured; it can be estimated on the basis of the volume of water in the lake and the calculation of the output and input of other waters to the lake.

To calculate the output water from the lake surface by evaporation, the mean value of the evaporation of the Parishan basin is multiplied by a coefficient of 0.7 evaporation pan so that the evaporation rate is calculated from the free water surface. Then, by multiplying the evaporation rate from the free water surface in the mean area of the lake over one year, the evaporation rate from the water surface of the lake for one year is calculated.

Determination of the environmental water requirement of the wetland

To this end, census data of birds from 1990 to 2013 have been investigated and threatened species have been identified. Then, marble duck was considered as the endangered species. The census statistics of this species were reviewed over the years and the year of average abundance of this species at best was considered as a desirable year; the level and volume of the wetland was also considered as the desired level and volume; then, based on the technology of remote measuring, the surface and water volumes of the wetland in the year under consideration was calculated. The input and output water of the wetland were then estimated and according to Formula 2, the environmental water requirement of the wetland was estimated.

$$NW=GV - V; \qquad (3)$$

NW = Required environmental water in m^3;
GV = Desirable water volume of the wetland in m^3; and
V = Current water volume in m^3.

Results

1. Hydrological Examination

Aiming at this goal, images from the interval of 24/3/2001 to 11/3/2002 were used. At first, initial processing was performed on images and the water range of the wetland was extracted; then, using a bathymetry map, the DEM layer of the wetland was prepared (Figures 2 and 3). The difference in volume of wetland water over these two times (ΔV) was estimated (Table 1). Regarding the fact that there was a 12-month time difference between the two images, the difference between the entrance of the rainfall in the spring and runoff to the wetland as well as the output of water by evaporation and direct withdrawals during this period was calculated (Table 1). Then, based on the volume difference of the wetland over the time period studied and the calculation of the input and output difference of water to the wetland through rainfall, runoff, spring, and evaporation, the amount of water entering the wetland through underground resources was calculated (Table 1).

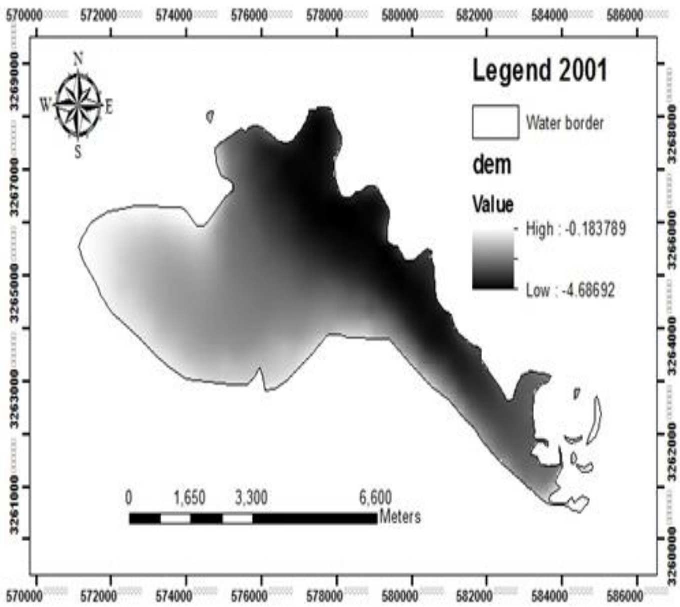

Figure 2. The DEM layer of the Parishan Wetland in 2001.

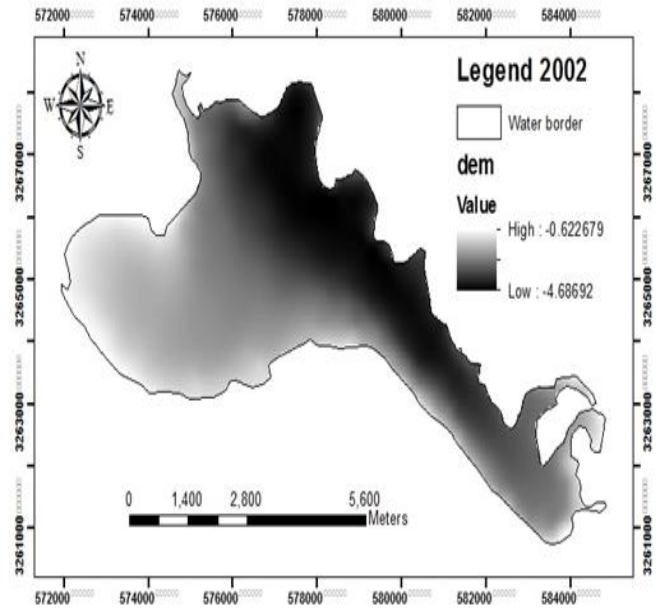

Figure 3. The DEM layer of the Parishan Wetland in 2002.

Table 1. Input and Output flows to Parishan Wetland in the first time period of April 2001 to March 17.

ΔV_{mcm}	P_{mcm}	R_{mcm}	S_{mcm}	E_{mcm}	$Intake_{mcm}$	GI_{mcm}	$\overline{A_{Km^2}}$
-10.14	20.06	14.75	5.487	-85.1	0	34.663	38.58

ΔV = Difference in water volume of the wetland in m^3;

R = Surface flows of the entering runoff into the wetland in m^3 / Year;

S = Entering flows from springs into the wetland in m^3 / Year;

GI = Leakage flows entering from underground water to the wetland or from wetland to groundwater in m^3 / Year;

P = Entering flow into the wetland through direct annual rainfall of the wetland in m / Year;

E = Average annual evaporation in m / Year; and

Intake = Water withdrawals from the wetland in m^3 / Year.

1.1The volume of direct entering of water to the wetland through rainfall

To do this end, the rainfall data and the average water level of the lake are required. To calculate the average water surface of the lake, 4 images of the lake were obtained during the interval of 24/3/2001 to 11/3/2002. The water surface area of the wetland over these 4 periods was calculated as 38.58 km2 and was considered as the average area of the wetland. The amount of rainfall in the Parishan basin during this period was reported to be 520 mm. Therefore, the amount of water entering the wetland during this period is equal to:

$$\boldsymbol{P} = \frac{\mathbf{38.58 \times 1000000 \times 520 \times 1}}{\mathbf{1000000000}} = \mathbf{20.06}_{\boldsymbol{mcm}}$$

1.2 The volume of water entering the wetland through the runoff

The area of the watershed of Parishan wetland is 275 km^2 (Environmental Protection Agency, 2015) and over the period under review, 38.88 km^2 of the area belonged to the water level of the lake. Therefore, the dry land was considered to be 236.42 km^2. Therefore, the amount of water entering the wetland through the runoff during this period is equal to:

$$\boldsymbol{R} = \frac{\mathbf{236.42 \times 1000000 \times 520 \times 0.12}}{\mathbf{1000000000}} = \mathbf{14.75}_{\boldsymbol{mcm}}$$

1.3 The volume of water entering the wetland through the springs

During the time interval between the two images, the drain of springs was 9.145 million cubic meters (regional water organization of Fars province, 2015). Therefore, the amount of water entering the wetland through springs during this period is equal to: $\boldsymbol{S} = \mathbf{9.145 \times 0.6 = 5.487}_{\boldsymbol{mcm}}$

1.4 Water output from the wetland through evaporation

During the time interval between the two images, the total evaporation rate was equal to 3150.3 (regional water organization of Fars province, 2015). The average area of the lake over this interval was estimated to be 38.58 km^2. According to the coefficient of 0.7 evaporation pan, the evaporation rate from the lake surface is 2205.21 mm. Therefore, the rate of water output from the wetland through evaporation is equal to:

$$\boldsymbol{E} = \frac{\mathbf{2205.21 \times (38.58 \times 1000000)}}{\mathbf{1000000000}} = \mathbf{85.1}_{\boldsymbol{mcm}}$$

1.5 The flow entering the wetland from underground water resources or the flow draining into groundwater resources

In order to calculate this factor, it is necessary to have the output and input factors related to the wetland and change of the water volume in the wetland between the two time periods. So:

$$\mathbf{-10.14 = \{(20.06 + 14.75 + 5.487) - (85.1 + 0)\}} + \boldsymbol{GI}$$
$$\rightarrow \boldsymbol{GI} = \mathbf{34.663}_{\boldsymbol{mcm}}$$

1.6 Determination of the environmental water requirement of the wetland

The results of the study performed on the presence of *Marmaronetta angustirostris* in the Parishan Lake indicate that marble ducks have been present in the wetland for only 10 years over the past 25 years and in 1992 with 5500 pieces at best (Table 2). So, 1992 was the most desirable year for this species in the Parishan wetland and this year was considered as an ideal year in terms of water volume in the wetland. The basin conditions in this year (water in the wetland and groundwater level) were examined and compared to those of 2015, and the required volume of water was estimated to reach the desired conditions in 1992.

Table 2. *Marmaronetta angustirostris* census statistics in Parishan Wetland from 1991 to 2015.

year	1990	1992	1996	1997	2001	2002	2003	2004	2005	2008
number	4000	5500	33	20	60	23	14	17	5	5

After the DEM layer was prepared for the water surface of the wetland in February 1992 (Fig. 4), the amount of water in the wetland was calculated. The results indicates that the volume of water in the wetland in (1992) was 72 million cubic meters, but the wetland was dry in (2015).

In the Parishan basin, there are two aquifers of Famor with an area of 39.56 square kilometers and Mullahare with an area of 31.48 square kilometers (Ara Land surveyor engineers of Fars, 2010). According to information obtained from the regional water organization of Fars province, the average groundwater level of the Famor aquifer in (1992) was 835 meters, reaching 824.84 meters in 2015. Also, the average groundwater level of the Mullahare aquifer in (1992) was 822.5 meters, reaching 807.23 meters in 2015. Therefore, the difference in groundwater volume in 1992 and 2015 is calculated as follows:A) Difference in the water volume of Famor aquifer

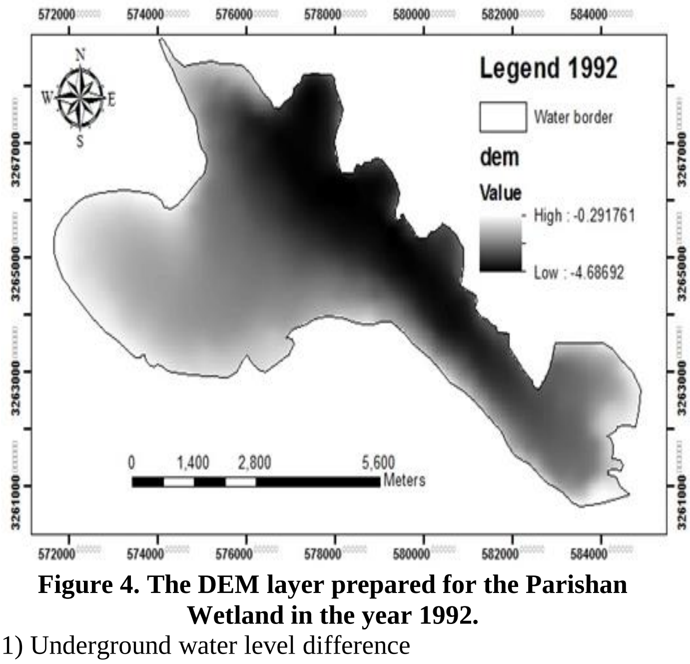

Figure 4. The DEM layer prepared for the Parishan Wetland in the year 1992.

1) Underground water level difference

$$\Delta \boldsymbol{H} = \mathbf{816.03} - \mathbf{828.5} = -\mathbf{12.47}_{\boldsymbol{m}}$$

2) Changing the storage volume of the aquifer

$$\Delta \boldsymbol{V} = -\mathbf{12.47} \times \mathbf{0.04} \times \mathbf{39.56} = -\mathbf{19.73}_{\boldsymbol{mcm}}$$

Thus, the storage volume of the Famor aquifer in 2015 compared to that in 1992 decreased by 19.73 million cubic meters.

B) Difference in the water volume of the Mullahare aquifer

1) Underground water level difference

$$\Delta \boldsymbol{H} = \mathbf{807.23} - \mathbf{822.5} = -\mathbf{15.27}_{\boldsymbol{m}}$$

2) Changing the storage volume of the aquifer

$$\Delta \boldsymbol{V} = -\mathbf{15.27} \times \mathbf{0.04} \times \mathbf{31.48} = -\mathbf{19.23}_{\boldsymbol{mcm}}$$

Thus, the storage volume of the Mullahare aquifer in 2015 compared to that in 1992 decreased by 19.23 million cubic meters.

Therefore, the groundwater of the Parishan plain in total has been decreased by 38.96 million cubic meters from 1992 to 2015.

Discussion and Conclusion

The results of the nutrition survey and drain of Parishan (Table 1) showed that the highest water input to the wetland was through the springs and groundwater leakage into the wetland (40.15 million cubic meters), while the amount of water entering through the rainfall and runoff was equal to 34.81 million cubic meters and the flow out of the wetland by evaporation alone was 85.1 million cubic meters. On the other hand, the results indicated a 12.47- meter drop in underground water level in the Famor aquifer and 15.27 meters drop in underground water level in the Mullahare aquifer. It is clear that the groundwater level is lower than the surface of the wetland, and no water from the underground sources reached the wetland, but the reverse case took place in practice. This means that the water entering the wetland through rainfall and runoff is fed to groundwater (apart from the evaporation rate), and these water currents are also extracted from water wells and used for agriculture. The study shows that the hydrologic cycle of the lake is disordered and the present trend has caused the death of the lake. The studies of Ganjah et al in 2017 also stated that extraction of water from wells around the wetland would reduce groundwater levels, penetrating all the water entering the wetland into groundwater.

The results also show that the water volume of the wetland in (1992) was 72 million cubic meters, and in (2015) the wetland was dry. The groundwater of the Parishan plain has also been affected by a decline of 38.96 million cubic meters in total from 1992 to 2015.

According to these interpretations, the Parishan Lake needs a water volume of 1106.9 million cubic meters to meet the conditions in 1992, while other input and output of water to and from the lake are considered zero. But in practice, water drainage of the wells around the wetland reduces the water level of aquifers; the water enters the wetland through the rainfall, runoff, and springs penetrating into the earth and feeding the groundwater. On the other hand, evaporation is also another cause of the decrease of the water entering the wetland. However, the long-term average of rainfall and evaporation must be estimated in the long run, and the water balance should be calculated within the range; therefore, managerial solutions should be presented to return the conditions to optimum.

Wetland Management Solutions

• In order to reduce the irregular utilization of wells and to compensate for the decline in groundwater levels and to balance the water in the lake, unauthorized wells should be filled.

• Apportionment of water withdrawal from authorized wells around the wetland for irregular withdrawal.

• Implementation of an artificial feeding plan (construction of a penstock for collecting rainwater, the construction of small underground dams), aquifer and watershed for feeding groundwater.

• Implementation of drop irrigation plans in agricultural lands around the wetland

• Dredging of the lake floor to increase depth and reduce evaporation

• Creating alternative jobs for farmers to prevent groundwater depletion

•Native ecotourism and tourists to protect the wetland

• Planting drought resistant trees in the basin to counteract excessive evaporation

• The transfer of wetland management to the private sector under the supervision of the Environmental Protection Agency

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