Plant Archives Vol. 20, Supplement 2, 2020 pp. 1038-1043 **e-ISSN:2581-6063 (online), ISSN:0972-5210**

MONITORING OF WATER LEVEL FLUCTUATIONS OF DARBANDIKHAN LAKE USING REMOTE SENSING TECHNIQUES

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Abstract

Darbandikhan Reservoir /Dam is located on the Sirwan (Diyala) River, about 230 km northeast of Baghdad and 65 km southeast of Sulaimaniyah-Iraq. Its borders extend from latitude 35° 06' 58 "- 35° 21' 07 "N and longitude 45° 40' 59 " -45° 44' 42 " E. In order to monitor the fluctuation in the level of this lake, Landsat Satellite images were collected for 10 years included, 1984, 1990, 1995, 2000, 2005, 2010, 2015, 2017, 2018, and 2019 for the same time period. Next, the classification of satellite images and the measurement of areas were done using ArcGIS 10.2. In order to study the effect of droughts and wet conditions on water levels in the lake, the standardized precipitation index (SPI) method proposed by Mckee, 1993 was used. In the current study, the 12 months' time scale SPI values (SPI-12) that was considered individually for the years 1984-2017 were estimated. Each period starts from January and ends in December. It was found that the water level in Darbandikhan Lake has experienced periodic changes during the period from 1984 to 2018. The results also showed that there were some gradual drought trends in the study area according to precipitation changes during the years studied, where severe drought dominated several parts of the study area, and the worst were in the years 1995, 2000, 2915 and 2017

Keywords **:** Water-Level Fluctuation; water crisis; SPI; Darbandikhan lake

Introduction

Water is an environmental element that plays a fundamental role in development in all its aspects. The need for it has increased due to population growth and economic development, offset by a decrease in this resource due to climate change resulting from greenhouse gases, and this has negatively affected the variation and distribution of rain amounts and their fluctuations in multiple regions of the world, including Iraq (Khatab, 2018).

Various investigations indicate the relative dependence between the environmental situation of lakes and climate changes. Kebede, 2006 found about 20% of changes in climate variables over the Lake Tana basin during a 50-year period, although the lake's water level remained constant. In the case of Lake Aral, the impact of climate is estimated at 14% versus 86% of man-made impact on water level changes (Benduhn and Renard, 2004; Beek *et al*., 2010) .Studies by Lofgren *et al*. 2002, through a hydrological modeling set using input data from CGCM1 (the first version of the Canadian Global Coupling Model) predicts large drops in lake levels, up to a maximum of 1.38 meters in the Michigan and Huron lakes by 2090.

Agriculture in Iraq depends on surface water resources (rivers) and groundwater to provide irrigation water for agriculture. These water resources are limited and most of them are shared with the neighboring countries of Iraq (Yaseen *et al*., 2018).

Lake Darbandikhan brings water from Iran by 70%, through the Sirwan River and other tributaries. Expectations indicate a rapid decline in the water level in the lake, due to Iran building several dams on the tributaries that supply it with water before reaching the lake, which threatens to decrease the level of the lake, so there are expectations of a water crisis in the dam in the coming years.

The water level in the lake decreased by about 300 cubic meters. Environmental organizations note that there are major impacts on life in these areas due to the low water levels. So Darbandikhan Lake has been studied by many researchers in term of physical and chemical properties, poisoning event, earthquake effect, infection and others (Abdulla, 2005; Abdullah and Abdullah, 2013; Toma, 2013). However, there are limited studies on the assessment of the lake in terms of climate change (Abdullah, 2005). It is important and necessary to study the impact of climate change on this lake (Yaseen *et al*., 2018). Satellite imagery analysis shows that a wide range of seasonal/cyclic changes in the surface of the lake have changed in recent decades. Extreme changes occurred due to the lake's water level being reduced or raised to several meters above the normal rate (Khatab, 2018).

The periodic changes in the climatic and hydrological variables that cause extensive climate changes as well as drought throughout the world and Iraq seem to have a decisive impact on the water crisis in Lake Darbandikhan.

Therefore, this study was conducted with the aim of knowing the climatic changes in the lake level during the previous years.

Materials and Methods

Lake Location and Geography

Lake Darbandikhan was formed from the construction of a dam, also called the Darbandikhan Dam. It is confined to latitude 35° 06' 58" -35° 21' 07" N, and longitudes 45° 40' 59" -45° 44' 42" E, 285 kilometers northeast of the city of Baghdad and 65 kilometers southeast of the city of Sulaimaniya (Fig.1). The dam was built on the Diyala River in 1956 and officially started operating in 1961. The height of the dam is 128 meters and its length is 445 meters, while the maximum width of the dam is about 17 meters. The dam catchment area is approximately 17850 km^2 and the maximum height of the main building is 128m. When the water height is 485mabove sea level, The reservoir area is 113 km^2 and its volume is 3000 Mm^3 of which 2500 Mm^3 direct storage and 500 Mm^3 dead storage. The storage capacity of the dam is three billion cubic meters at a level of 485 m and the resulting lake area at storage is 114 km^2. The height of the dam above sea level is 532 m.

The type of dam is a dam with a central mud core and a shoulder filled with rocks. It feeds from two major tributaries including the Tanjero River, which flows from north/northwest inside Iraqi territory, and the Sirwan River, which flows in from the east (Iran).

In winter, the study area is under the influence of Mediterranean cyclones that move from east to northeast on the region. Cyclones of the Arabian Sea move north through the Gulf and carry large amounts of moisture, causing large amounts of rain.

In summer, the region is under the influence of semi-tropical high-pressure belts and anti-Mediterranean hurricanes. The daily maximum temperature may approach 40 °C in hot summer periods, while the minimum daily temperature can drop to below zero in the cold winter.

The precipitation system is also subject to the Mediterranean system, which means that it occurs in the winter, spring and autumn, while summer is characterized by drought (Khatab, 2018).

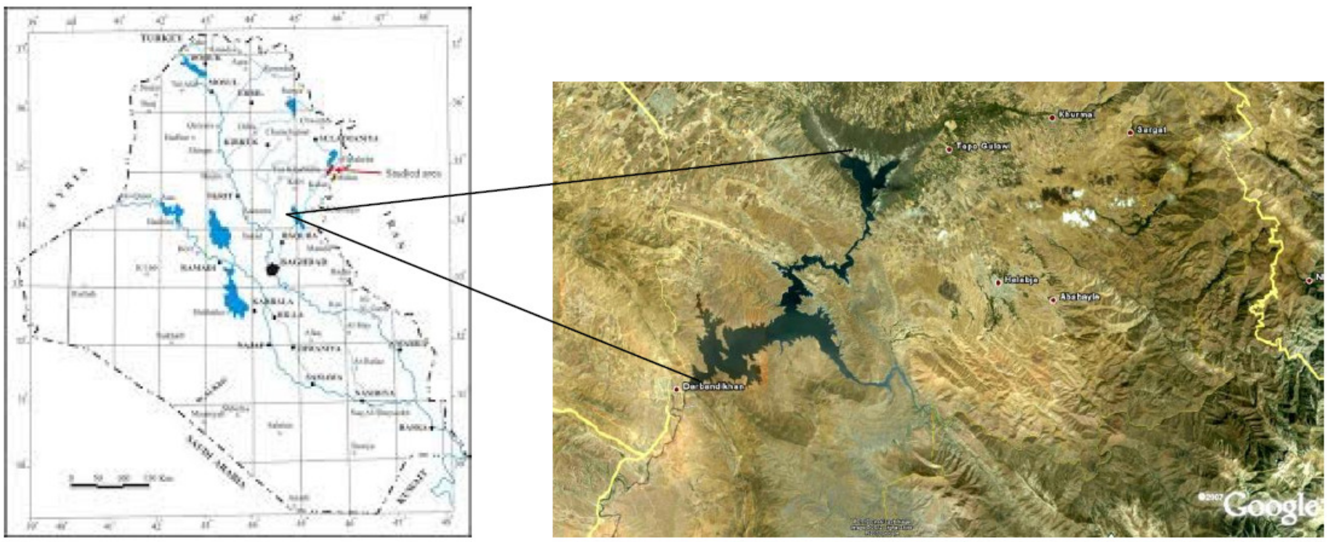

Fig. 1 : Study area location (Darbandikhan Lake)

In order to study the differences in the extent of the lake's water area, landsat 4(TM), 5(TM) and 8(OLI) satellite images were collected for 10 years included, 1984, 1990, 1995, 2000, 2005, 2010, 2015, 2017, 2018, and 2019 (Fig. 2) for the same time period. Next, the classification of satellite images and the measurement of areas were done using ArcGIS version 10.2.

Also to study the succession of dry and wet periods for the study area, standardized precipitation index SPI values analysis, developed by McKee, 1993, was adopted. SPI is considered as one of the main criteria in assessing drought, that is requires calculation of average and long term standard deviation of precipitation quantities during the period under study (Bonaccorso *et al.*, 2003).

SPI was developed to estimate rainfall deficits over multiple time ranges, reflecting the impact of rainfall deficiency on the availability of different water resources. It is computed for 1, 3, 6, 12, 24 and 48 months to reveal the temporal effect of the impact (Awchi and Jasim, 2017).

This indicator is provided primarily for the identification and monitoring of droughts and rainfall (Tsakirist *et al.*, 2004) and also allows the analyst to determine the number of years of drought that occurred, in addition to the wet periods for any specific time (Mckee *et al.*, 1993).

Another advantage of this indicator is that it is possible to determine the prepared probability density function and frequency analysis for severe drought and wet conditions in the areas performed on it (Levida *et al.*, 2007).

The SPI values have been classified by Edossa *et al.* (2010) into eight classes ranged from extreme drought to extreme wet as shown in Table 1.

Table 1: SPI classes period classification (Edossa *et al.*, 2010)

SPI Classes	Period classification
Extreme drought	SPI≤-2
Severe drought	-2<SPI≤-1.5
Moderate drought	-1.5<SPI≤-1
Mild drought	-1<SPI≤0
Mild wet	0<SPI≤1
Moderate wet	1<SPI≤1.5
Wet	1.5<SPI≤2
Extreme wet	SPI >2

Results and Discussion

Fig. 2 : Shows that there is a clear fluctuation in the lake area during the study years.

Also as shown in figure 3 In 1984 the total area of the lake was 6758.72 ha. As it grew nearly to 8810.94 and 11671.08 in 1990 and 1995 respectively. In 2000, the area reached the lowest value, with the total area reduced to 4,100.32 ha. It increased again in 2005 to reach 10323.56ha then it decreased gradually during the years 2010 and 2015 to reach 9324.99 and 6017.76, respectively. In 2017 the water level in the lake rose to reach 10855.84 ha, and it decreased again to 5412.36 ha in 2018.In next year, 2019, there was a rainy year in all of Iraq, and this affected the amount of water in the lake, bringing the area to the highest values of 11237.52 ha.

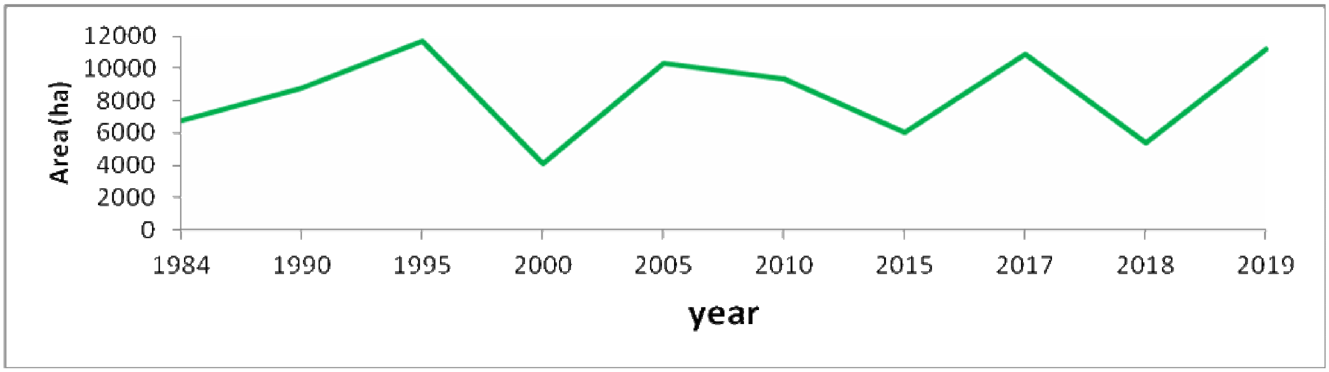

Fig. 3: Lake area changes throughout 1984-2018

Darbandikhan Lake receives water from precipitation directly above the lake, surface flows from Sirwan river, and runoff from the surrounding lands. All of these resources depend directly on the precipitation over the region and its vicinity. Consequently, the lake's hydrological condition directly reflects the climatic conditions in the lake, especially precipitation and temperature.

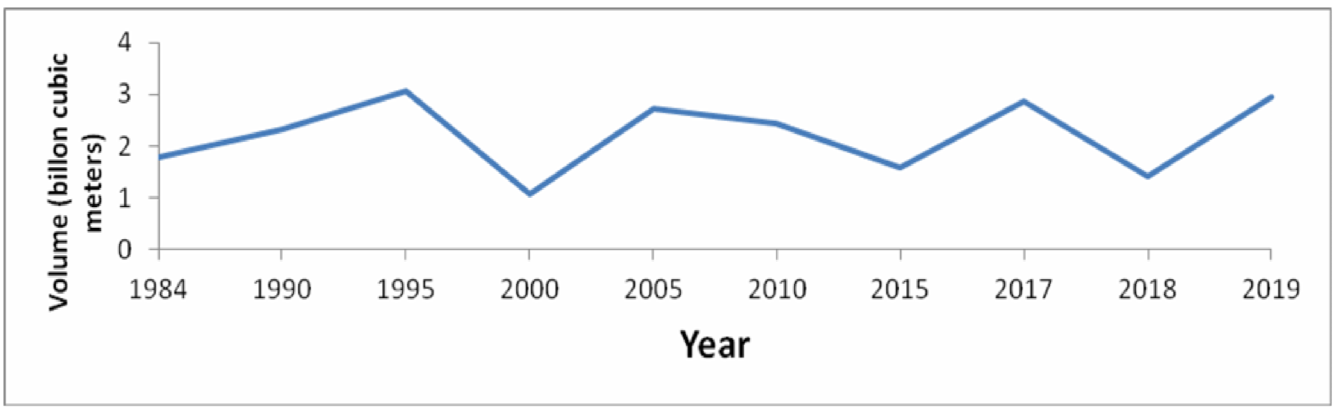

Fig. 4: Lake water volume changes throughout 1984-2018.

The last decline reached 472.36 meters above sea level in 2018 (Figure 5), and based on satellite imagery of the surface area (Figure 3), the trend continued through seasonal ups and downs as the current water level appears to be approaching 484.60 meters in 2019 from any time in more than 20 years.

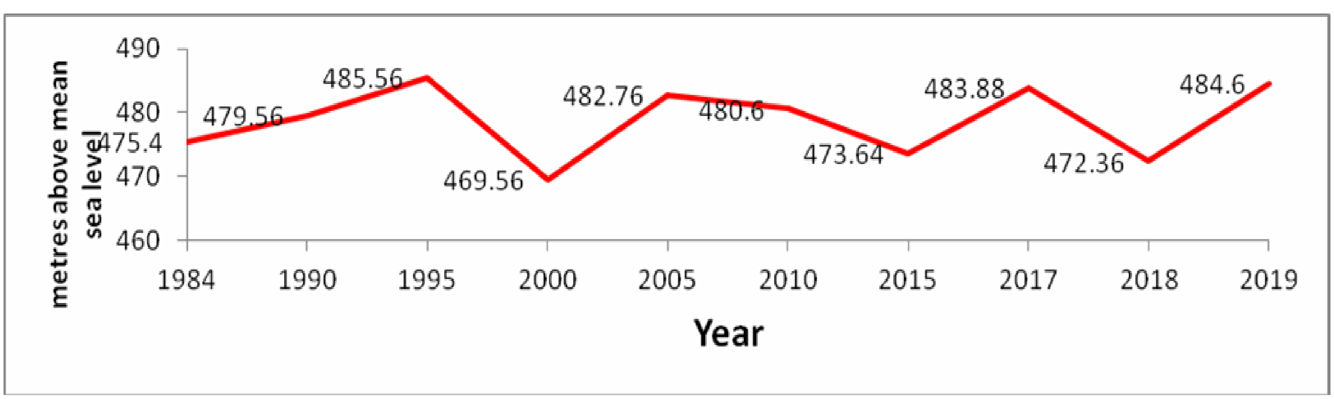

Fig. 5: Water level fluctuation of lDarbandikhan during 1984-2017

The study area was subjected to different years from dry to humid, in which periods of drought and humidity followed (Fig. 6), the percentage of dry years reached 47%, compared to 536% for wet years (Table 2), which led to the value of the SPI being different during the study years (Rasheed, 2010; Yenigün *et al*., 2018) and this in turn affects the amount of water and level of the lake.

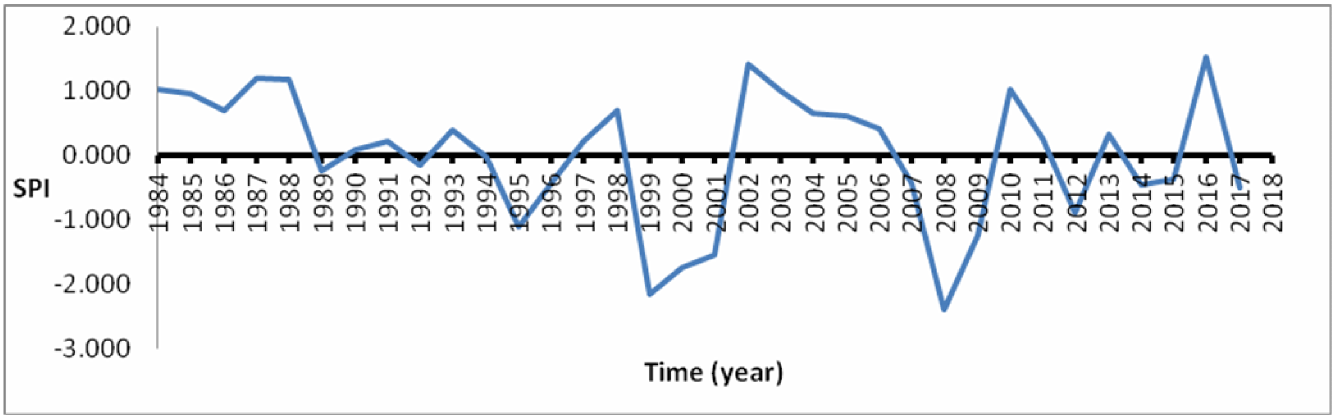

Fig. 6: Standardized precipitation index SPI for Darbandikhan weather station of 12 month time scale

The results in table 2 showed that of a total of408 months, 10 (2.45%) extreme droughts, 26(6.37%) severe droughts, 41(10.05%) moderate droughts and 115(28.19%) mild droughts events in the study area.

Table 2: Dry months and percentage of the SPI1, SPI3, SPI6 and SPI12 values of Darbandikhan 1979-2013. Source : Yenigün *et al.* (2018)

Months number	Percentage of dry	Number of dry months	Extreme drought		Severs drought		Moderate drought		Mild drought	
			Months number	Percent (%)	Months number	Percent (%)	Months number	Percent (%)	Months number	Percent (%)
SPI 1										
420	31	131	6	1.43	14	3.33	27	6.43	84	20.00
SPI 3										
408	38	155	9	2.21	21	5.15	25	6.13	100	24.51
SPI 6										
408	47	191	17	4.17	16	3.92	33	8.09	125	30.64
SPI 9										
408	48	196	14	3.43	20	4.90	40	9.80	122	29.90
SPI 12										
408	47	192	10	2.45	26	6.37	41	10.05	115	28.19

An irregular cyclic pattern of drought /wet periods was observed during the period 1984-2018. Droughts were observed on seasonal basis often during historical years, especially in the years 1995, 2000, 2015 and 2017, where SPI value was declined to -1.119, -1.756, -0.369 and -0.512 respectively . It should be noted that the highest value of SPI-12 during the study period was -2.398 in year 2008. According to the SPI 12 values, the longest dry period is 142 months.

It is also clear that the storage efficiency of the lake began to decline due to negligence in removing sediments, especially in the course that connects the northern and southern part of the lake on the one hand and the accumulation of deposits near the body of the dam, which may cause disaster at any exceptional flood.

The current hydrological climatic information in this region is extremely short and in some cases inconsistent with facilitating comprehensive analysis. for example although the lake water level and SPI value in 1995, 2000, 2015 and 2017 indicates a previous drought, rainfall data in Darbandikhan does not confirm this.

Conclusion

There was fluctuation in the amount of rainfall during the study years, and this affected the area, volume and level of the lake's water in almost the same pattern .The calculated SPI-12 ratio for the studied station ranged between dry and moderate humidity according to the SPI classification, and the percentage of years of drought reached 47%, which means that half of the study period years were suffering from drought.

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