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The Effect of Climate Changes on The Fluctuation of The Water Level of Al- Razzaza Lake, Iraq

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Abstract

One of the serious environmental challenges that Iraq faces is climate changes and impacts of changing weather patterns and extreme global weather events. This paper addresses changes in the temporal and spatial characteristics of water levels of Razzaza Lake and response to climatic changes using archived series of Multispectral satellite images Landsat. TM, ETM+ and OLI images acquired on 1990, 2000 and of 2016. In order to extract, mapping the water surface area of the Razzaza Lake, Multispectral spectral band rationing the Normalized Difference Water Index (NDWI) technique was adopted, and the climatic elements data for the period (1990-2016) were analyzed which provide significant information of surface water. The results show that Razzaza Lake has a particularly sharp change rate in the water level and there are significant fluctuations on lake level and water surface area over the time.

Keywords: Climate changes, Razzaza Lake, satellite images, NDWI, meteorological parameters

تأثير التغيرات المناخية على تذبذب منسوب المياه في بحيرة الرزازة، العراق.

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الخلاصة

من التحديات البيئية الخطيرة التي يواجهها العراق هي التغيرات المناخية واثار تغير انماط الطقس والاحداث المناخية العالمية المتطرفة. تتناول هذه الورقة التغيرات في الخصائص الزمنية والمكانية لمستويات المياه في بحيرة الرزازة والاستجابة للتغيرات المناخية باستخدام سلسلة من صور الاقمار الصناعية متعددة الاطياف. تم استعمال الصور الملتقطة من TM، ETM+ و OLI في عام 1990، 2000 و 2016 ومن اجل استخراج ورسم الخرائط لمساحة سطح المياه لبحيرة الرزازة من النطاق الطيفي متعدد الاطياف بالاعتماد على تقنية مؤشر مياه الاختلاف الطبيعي وتم تحليل بيانات العناصر المناخية للفترة (1990 – 2016) والتي

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توفر معلومات هامة عن المياه السطحية وتظهر النتائج ان بحيرة الرزازة لديها معدل تغير حاد بشكل خاص في مستوى المياه وهناك تذبذب كبير في مستوى البحيرة ومساحة سطح المياه على مر الزمن.

1. Introduction

This study focuses on the Second-Largest Iraq's Lake (Al-Razzaza Lake) which is located west of Karbala between longitudes ($43^{\circ} 27 - 43^{\circ} 53$) eastern and latitudes ($32^{\circ} 33 - 32^{\circ} 50$) northern Figure 1. In dry and semi-dry climate such as Iraq where the prevailing continental climate is typically a long season of hot summer and short season of cold winter [1], water resources play an important role in maintaining ecological balance, which faced a big challenge and damages due to both natural and the man-made activities that have caused decline in water supply of our country since last century. That is reflected clearly on lakes surface area, specially there is extensive shrinkage of the Razzaza lake started by early 2000, which was observed through a reliable electronic record of previous and current situation of the study area by a series of satellite images. Razzaza Lake is a water body located in the central of Iraq between the province of Karbala and Al-Anbar [2]. Its water fed from Euphrates river through Al-Habbanya Lake by Al-Majarrah channel in the northern lake, but in the present time no supply to the lake from Al-Habbanya lake. Drainage channel from northern Karbala contains mixed: agricultural, industrial, and domestic wastewater which poured into Al-Razzaza lake [3], as well as rainfall and surface water flow of valleys from north to south: Thoulib, Abukreel, Foadh and Al- Ubaiydh in addition, the ground water flow toward the lake [4]. The volumes of supplied water to the Al-Razzaza Lake from surface water and ground water flow depended on amounts of precipitation in the area. The area of Al-Razzaza Lake in 2012 faced a real dangerous drought where estimates shows an area of 270.578 km^2 was affected while the almost dry land area reaches 14.434 Km^2 [5]. The geology of study area represented by tertiary sediments of different ages and rock units such as Damman, Euphrates, Nfayil, Injana and Dibdiba formations. Quaternary sediments cover vast area near Al-Razzaza Lake, which represented by gypcrete, inland sabkha, depression fill, flood plain and Aeolian sediments [2]. The climate plays an important role in water quality and change of water level [6].

The aim of the research is to monitor changes and fluctuations of the lake's water level using a time series of multispectral satellite images (Landsat) extended between the ninetens of the last century to the present time (1990, 2000, and 2016), and to highlight the meteorological parameters which affecting the changes and the fluctuations of water level. This research will track evidences of climatic changes in Razzaza Lake by correlated, comparison and analyzing the spatial temporal changes of Razzaza Lake in the period (1990 -2000 -2016)series of multispectral satellite images from Landsat TM, ETM+ and OLI data. Climate parameters and calculations of water balance for more than twenty years of Karbala meteorological station during the period (1990–2016) will be discussed. The global climate change in the last century shown an influence on regional water resources through changes in temperature, evaporation and precipitation [7].

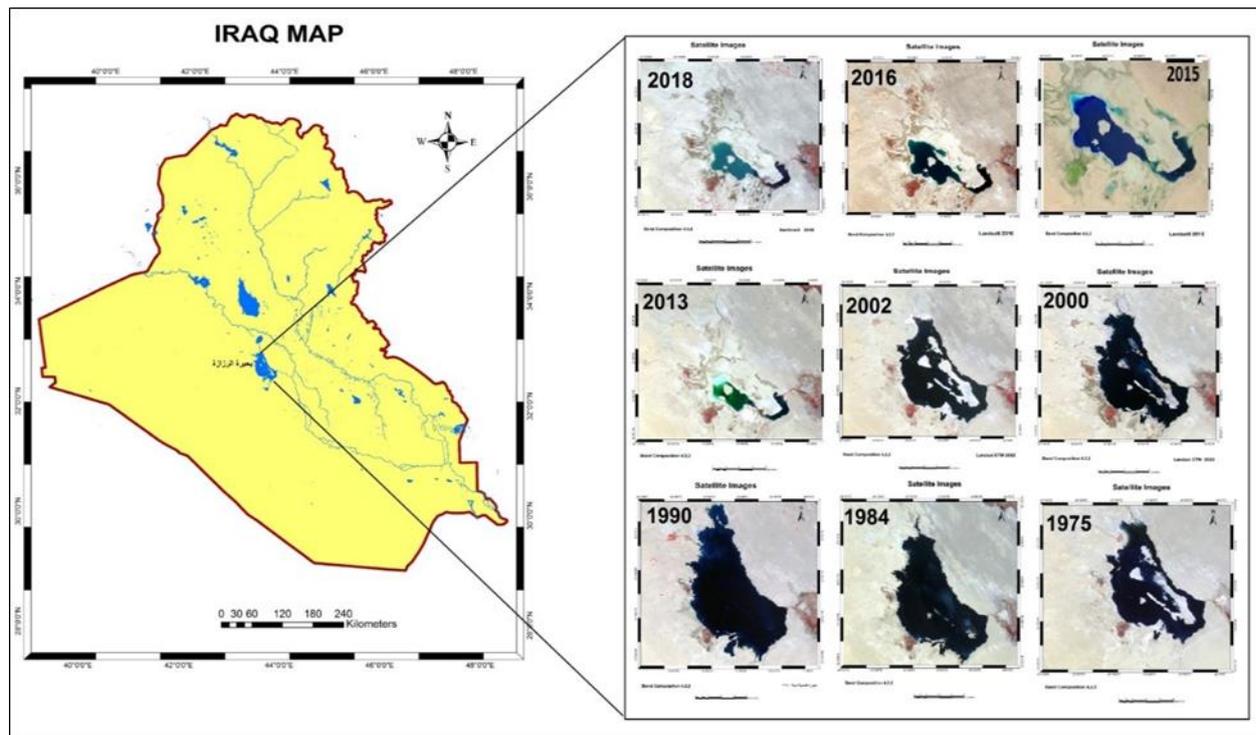


Figure 1- Location map of the study area with satellite images view of Razzaza Lake

2. Data and Methods

Multispectral Landsat satellite images (spatial resolution of 30 meters, TM, ETM+ and OLI) from the Nineties of the last century to present time covering the study area were used. Those images lies within (path 168, row 38) were downloaded from the United States Geological Survey (USGS) official website [8]. Modern software packages have been used for digital image processing and for producing thematic maps in standard cartographic format. Those packages are:

1. ERDAS IMAGINE 2014.
2. The Geographical Information System (ArcGIS 10.2.2).

Main purpose of digital processing of input satellite data(images) is to prepare this data in a format for further processing and different feature extraction techniques. For the phenomena under study, ERDAS IMAGINE 2014 have been used. Those procedures were:

1. Data and bands were imported in TIF format then converted to be suitable for processing by ERDAS as an image.
2. For each type of satellite images (visible and infrared bands, i.e., electromagnetic spectrum), a Layer Stack was used to obtain a colored image (natural colors or false colors (FCC)) in three spectral bands (RGB).
- 3 - Subtraction the region of interest by forming (a shape file) for the study area for each date using (ArcMap).
- 4 - Perform various image enhancements, including:

Color mixing technique: Color is often required while visualizing multi-attribute information, mixing many spectral bands and production of several colors composited images, or visible green and red, plus near infrared bandwidths combined to make a standard false-color composite. The images which a representation of a multispectral image created using ranges other than visible red, green and blue, such as near infrared can increase spectral separation and enhance interpretability of data as well as amount of information that can be obtained.

2.1. Normalized Difference Water Index (NDWI):

Water is easily distinguished from other targets by high reflectance in visible portion while

less reflected in near-infrared portion of the spectrum. Spectral rationing are enhancement techniques in which a raster pixel from one spectral band is divided by the corresponding value in another band. [9], (NDWI) the most important and more suitable index for enhancing and extracting water information which is used to monitor changes related to water content in water bodies, using Green and NIR wavelengths defined by [10].

The NDWI is computed as follows:

$$[NDWI = (X \text{ Green} - X \text{ NIR}) / (X \text{ Green} + X \text{ NIR})]$$

Where X Green refers to the green band and X NIR refers to the NIR band. This formulation of NDWI produces a new image in white and black (gray scale), where the value of positive (+1) refers to water and appearance of White color in satellite images. Negative values are typically non-water features. NDWI has a native scaling of -1 to +1 Figure 2. The equation above was applied to all the Landsat images which used in the study and calculated the lakes surface water as, 2185.17 km², 1480.76 km², 338.79 km² for the periods (1990, 2000, 2016) respectively.

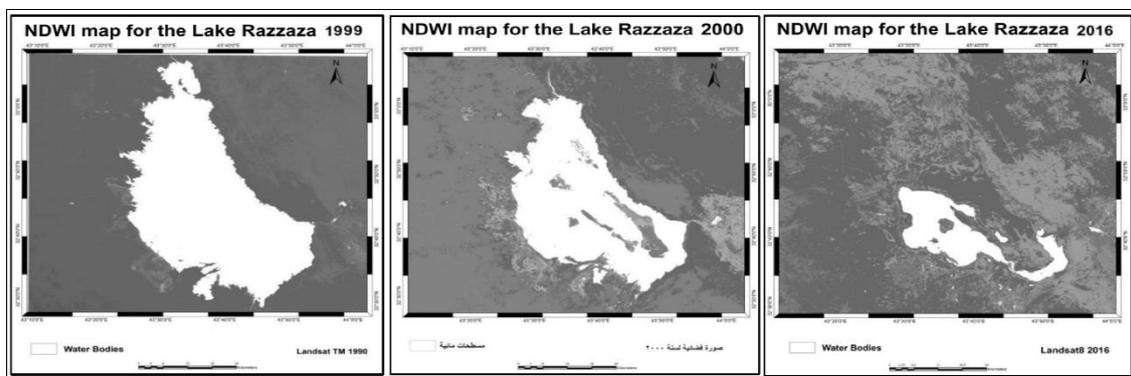


Figure 2- Special distribution images for NDWI of the Period (1990 -2000–2016) (White color represents the water body).

2.2. Hydro-meteorological data

In order to discover commonly evidences effecting climatic change in Razzaza Lake, a study and analysis of ground-based measured data of climatic elements by calculating climate water balance for more than twenty years of Karbala meteorological station during the period (1990–2016) were used. These measurements (using direct measurement instruments) provided a ground truth when analyzing Ground -based climatic elements data at specific station which included data of water availability and water losses. The water availability elements were containing rainfall and relative humidity whereas the water losses elements are: temperature, sunshine, wind speed, evaporation and evapotranspiration. Karbala meteorological station was selected to analyze the climatic elements for the period (1990 - 2016). Values of evapotranspiration were determined by utilizing Thornthwait equation. Lerner method was applied to computation water balance in the study area. Razzaza used to be a large, deep lake, but it is now characterized by very high salinity levels, which had increased during the past ten years due to the shortage in water it receives and increased evaporation during Iraq's very dry and hot summers.

3. Results and discussion

It is important to use modern techniques in descriptive and quantitative methods of remote sensing and geographic information systems in the study of natural resources and environmental variables, because it provide accurate and reliable information in the study, monitoring and follow-up changes in resources of land of a dynamic nature over time because it represents a descriptive photographic record documenting the reality of land cover in nature. For the purpose of identifying and classifying cover of land, especially the water of

Razzaza Lake and its direct effects on the social and economic reality of the region, adopting the method of visual and digital interpretation of a time series of Landsat satellite data, which are intersected with multiple spectral bands (VIS, NIR) and the adoption of Multispectral band rationing (NDWI), which helped to extract and capture water bodies and produce thematic maps representing surface water cover areas where changes in water cover were observed from increases and decreases over time periods (1990,2000 and 2016). Through the analysis of the NDWI, the results showed there are many changes in area flooded with water Razzaza lake (increment and decrement), reaching its peak in 1990, while in 2016 a sharp decrease in water area as in Figure 3.

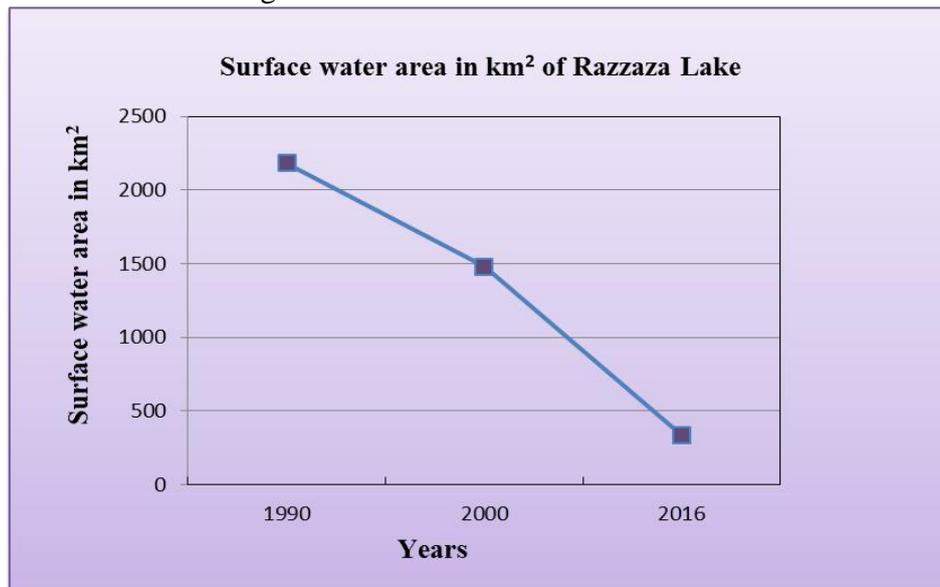


Figure 3- The changes of Razzaza surface water area in km² over the time (1990 -2000–2016).

The monthly average values of climatic elements in the study area for the period (1990-2016) were analyzed as following: The highest and lowest monthly averages of rainfall occur in January 17.84 mm and July 0.0 mm respectively. The total annual rainfall of the study area reached 91.36 mm. The average means of annual rainfall in mm for interval (1990-2016) are shown in Figure 4. It indicates that there were remarkable decreases in amount of rainfall for years (1990-2016) that reflects regional climatic change. The annual precipitation data of Karbala meteorological station were used to revising behaviour of time series of the Razzaz area. Figure 5 shows time series analysis and trend of the annual rainfall values for the years (1990-2016) and this proves that the Razzaz area is driven to dryness.

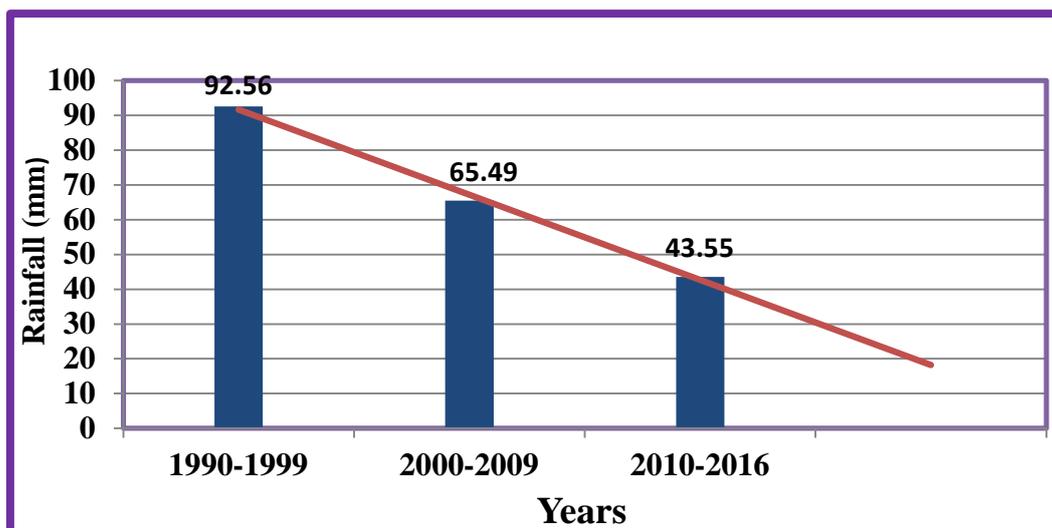


Figure 4- Annual average of rainfall in mm for interval for the period (1990-2016).

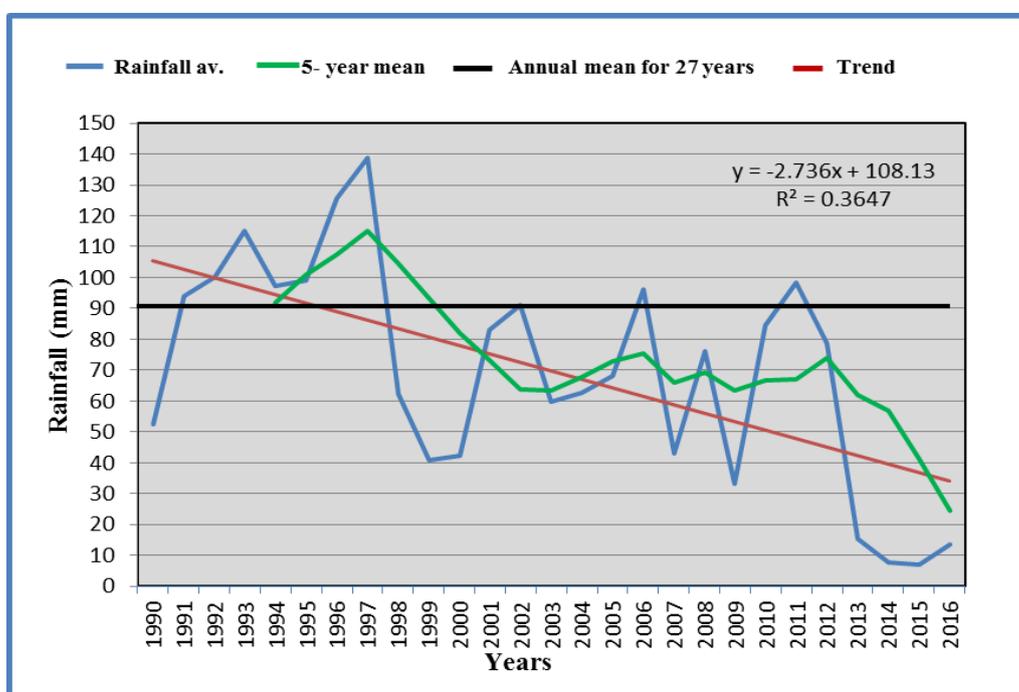
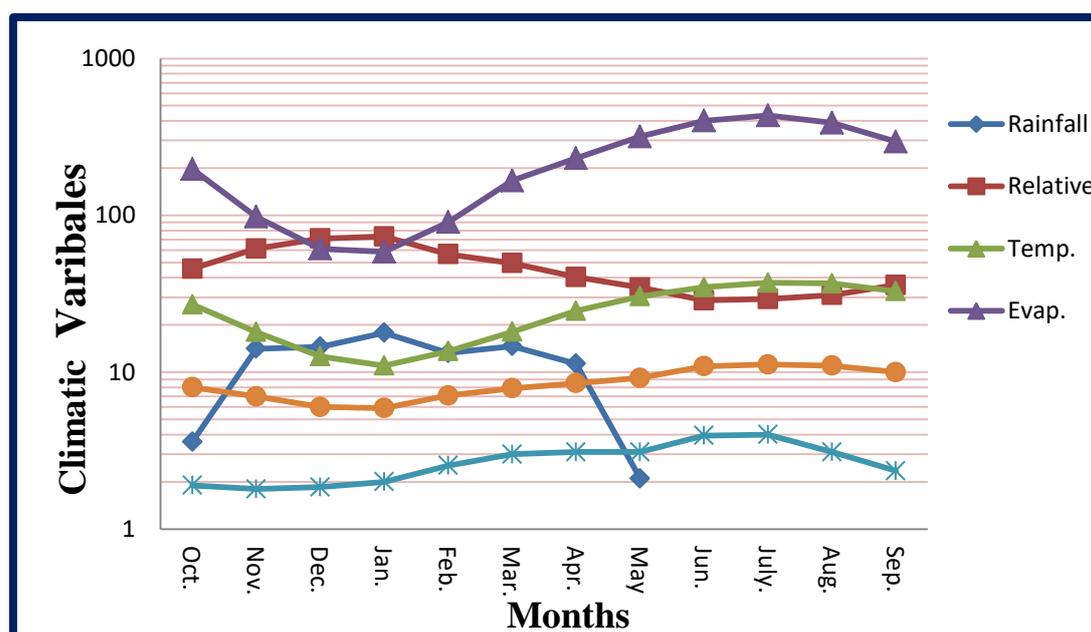


Figure 5- Time series and trend of the annual rainfall values for the period (1990-2016).

The highest average of Relative humidity in January 73.28 mm and the lowest average in July 28.73 mm and the monthly average is 46.45 %. The monthly average of temperature is 24.73 C°, sun shine average 8.6 h/day, wind speed average 2.72m/sec and the total of the Evaporation 2737.2 mm, the results are listed in Table 1. Different relationships are occurring between climate elements. Rainfall is directly proportional to relative humidity and inversely proportional to temperature, sunshine, wind speed and evaporation Figure 6.

Table 1- Monthly annual averages of the climatic elements for the period (1990-2016) in the studied area.

Month	Rainfall (mm)	Relative Humidity %	Temp. C°	Evap. (mm)	Wind speed (m/s)	Sunshine (h/day)
Oct.	3.6	45.65	27	197	1.9	8.0
Nov.	14.1	61.39	18	97.8	1.8	7.0
Dec.	14.5	71.12	12.6	61.2	1.85	6.0
Jan.	17.84	73.28	11	58.5	2.0	5.9
Feb.	13.24	56.44	13.6	90.31	2.54	7.1
Mar.	14.66	49.6	18.1	166.3	3.0	7.9
Apr.	11.32	40.39	24.6	231.1	3.1	8.5
May	2.1	34.58	30.4	317.7	3.1	9.2
Jun.	0.01	28.73	34.8	401.1	3.94	10.9
July.	0	29.23	37.1	432.9	4.0	11.2
Aug.	0	31.0	36.8	388.4	3.1	11.0
Sep.	0.4	35.96	32.8	294.9	2.35	10.0
average		46.45	24.73		2.72	8.6
Total	91.36			2737.2		

**Figure 6-** The relationships between the climate parameters during months for period (1990-2016) in the study area.

3.1. Potential Evapotranspiration

The potential evapotranspiration is a combine term of evaporation and transpiration, defined as the total loss of water through evaporation and transpiration from the soil plant system [11]. Evapotranspiration was computed by [12] through making a number of experiments on different types of climate based on temperature only. Evapotranspiration is computed for each month in the year.

$$PE_x = 16 [10t_n / J]^a \text{ mm/month} \tag{1}$$

$$J = \sum_{j=1}^{12} j \text{ for the 12 months} \tag{2}$$

$$j = [t_n / 5]^{1.514} \tag{3}$$

$$a = 0.016 J + 0.5 \tag{4}$$

$$PE_c = PE_x \times \frac{DT}{360} \tag{5}$$

Where:

PE_c: Corrected potential evapotranspiration (mm).

PE_x: Actual potential evapotranspiration (mm).

D: number of days in the month.

T: average number of hours between sunrise and sunset in the month.

t = Monthly mean air temperature (C°).

n = Number of monthly measurements.

J = Annual heat index (C°).

j = Monthly temperature parameter (C°).

a = Constant.

Then: The value of (a) equals 2.78432 and according to the values of evaporation Table 2, the following correlation was recognized:

The period from January to December is characterized by the following relation Epan >PE_x >PE_c, Figure 7. The total evaporation from E pan is 2737.2 mm and the total of the corrected potential evapotranspiration (PE_c) is 1008.8 mm, while the total of potential evapotranspiration (PE_x) is 1192.7mm. The observed difference between the three values refers to the differences in the measuring ways (field and calculated values) [13].

Table 2- Corrected potential evapotranspiration in the studied area using Thornthwiat method (1948).

Months	Temp.(C°)	$j=(t_n/5)^{1.514}$	PE _x (mm)	DT/360	PE _c (mm)	Epan (mm)
Oct.	27	12.85	94.32	0.69	64.98	197
Nov.	18	6.95	30.5	0.58	17.79	97.8
Dec.	12.6	4.1	11.3	0.52	5.84	61.2
Jan.	11	3.3	7.82	0.51	3.97	58.5
Feb.	13.6	4.55	13.98	0.55	7.72	90.31
Mar.	18.1	7.01	30.98	0.60	18.67	166.3
Apr.	24.6	11.16	72.79	0.71	51.56	231.1
May	30.4	15.38	131.23	0.79	103.96	317.7
Jun.	34.8	18.87	191.2	0.91	173.67	401.1
Jul.	37.1	20.8	228.5	0.96	220.38	432.9
Aug.	36.8	20.8	223.39	0.94	209.68	388.4
Sep.	32.8	17.3	156.71	0.83	130.59	294.9
Total	24.73	J= 142.77	1192.7	8.59	1008.8	2737.2

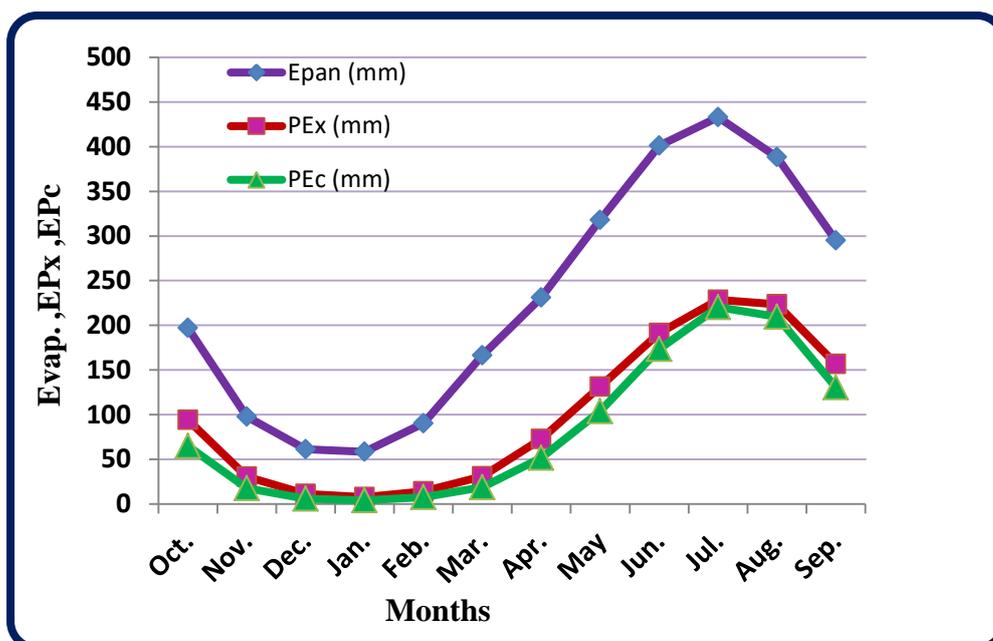


Figure 7- Evaporation, PEx and PEc correlation graph.

3.2. Water surplus (WS) and water deficit (WD):

Water surplus (WS) is defined as the excess of rainfall over the corrected potential evapotranspiration (PEc) values during specific months of a year ($WS = P > PEc$), while water deficit (WD) is the excess of corrected potential evapotranspiration values over the rainfall during the remaining months of that year ($WD = P < PEc$), according to [14]. The actual Potential evapotranspiration (PEx) could be derived as follows:

$$WS = P - PEc \quad (6)$$

$PEx = PEc$ when $P \geq PEc$

$$WD = PEc - P \quad (7)$$

$PEx = P$ when $P < PEc$

Where:

WS: Water surplus (mm).

WD: Water deficit (mm).

P: Rainfall (mm).

PEx: Actual potential evapotranspiration (mm).

PEc: Corrected potential evapotranspiration (mm).

In the first case (water surplus) values of rainfall is more than corrected potential evapotranspiration (PEc), actual potential evapotranspiration (PEx) is equal to the corrected potential evapotranspiration (PEc) values, whereas in the second case (water deficit) values of rainfall is less than corrected potential evapotranspiration (PEc), actual potential evapotranspiration (PEx) is equal to rainfall values. The water surplus and water deficit are calculated without using the soil moisture (equal to zero). The monthly averages of WS and WD is shown in Table 3. The total value of annual water surplus is 28.05 mm from annual average rainfall 91.36 mm and it is limited between December and February because rainfall exceeds PEc; therefore, the water surplus ratio from the annual rainfall represented as:

$$WS \% = WS/P \times 100 \quad (8)$$

$$WS\% = 28.05 / 91.36 \times 100 = 30.7\%$$

This percentage represents the ground water recharge and surface runoff. While the total value of water deficit is 945.09 mm from PEc, which equals 69.3 % from annual average rainfall as the following equation:

$$WD\% = 100 - WS\% \quad (9)$$

$WD \% = 100 - 30.7 \% = 69.3 \%$

The relationship between monthly averages of rainfall and corrected potential evapotranspiration is shown in Figure 8, which is led to determine water surplus and water deficit periods.

Table 3- The calculations of water surplus and water deficit for the studied area.

Months	P (mm)	PEc (mm)	PEx (mm)	WS (mm)	WD (mm)
Oct.	3.6	64.98	3.6	0	61.38
Nov.	14.1	17.79	14.1	0	3.69
Dec.	14.5	5.84	5.84	8.66	0
Jan.	17.84	3.97	3.97	13.87	0
Feb.	13.24	7.72	7.72	5.52	0
Mar.	14.66	18.67	14.66	0	4.01
Apr.	11.32	51.56	11.32	0	40.24
May	2.1	103.96	2.1	0	101.86
Jun.	0.01	173.67	0.01	0	173.66
Jul.	0	220.38	0	0	220.38
Aug.	0	209.68	0	0	209.68
Sep.	0.4	130.59	0.4	0	130.19
Total	91.36	1008.8	1192.7	28.05	945.09

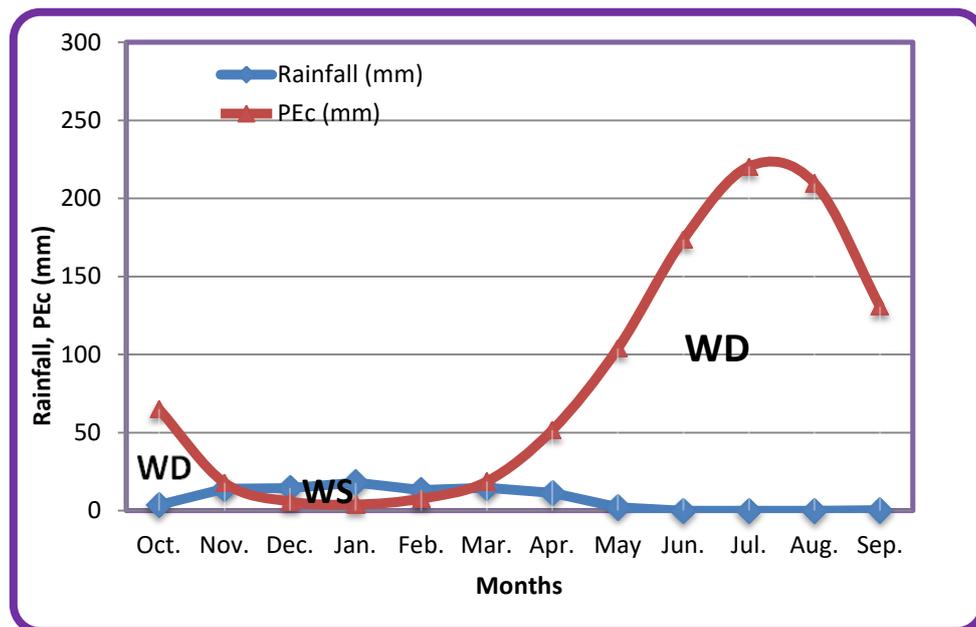


Figure 8- The monthly fluctuation of rainfall and corrected potential evapotranspiration to determine the WS and WD.

4. Conclusions

- The results of the NDWI analysis, showed there are many changes in the submerged areas by Razzaza lake, reaching its peak in 1990, while in 2016 a sharp decrease observed in water area.
- The analysis of climate parameters for Karbala meteorological station showed a remarkable decrease of average annual means of rainfall and relative humidity for the period (1990-2016).

- The average annual rainfall for intervals (1990-2016) is decreasing. This proves that the Razzaza area is driven to dryness.
- Remarkable increase in average annual of temperature, wind speed, sun shine and evaporation.
- The Razzaza area is under water deficit (WD) which equals 69.3% and the water surplus (WS) which equals 30.7%.

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