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Estimate the actual evaporation of Lake Habbaniyah under conditions of changing climatic conditions

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Abstract:

Given the limited water imports resulting from the establishment of dams on river streams under conditions of climate change, which has had a significant impact on dam operating policies and the difficulty of meeting both agricultural and industrial human use requirements. The aim of this study is to estimate the losses from Habbaniyah Lake as a result of annual water evaporation by applying SWAT model and relying on MODIS satellite data. Annual climate information was collected and through the digital height model, Al-Habbaniyah Lake's enclave is planned. In addition, soil and land uses of the study area were classified to determine the values of the curve number. Climate data were use for 2021 until 2023. By simulating the SWAT model results, the annual evaporation rate of Lake El Habbaniyah was observed at approximately 2,000 mm. It was also seen by calibrating the evaporation values derived from the model with the values obtained from the MODIS satellite converging to a value of 94%. The results illustrated that an increase in evaporation values in the recent years due to the lack of large quantities of rain as well as high temperatures. Finally, the study concluded that there has been a shortage in water in recent the years for the period from 2021 to 2023. This loss causes the deprivation of 177 ha of agricultural land with water revenues, which needs to be addressed and strengthened in times of flooding and used to fill the deficit of water needs in time of the drought.

Keyword :Lake Habbaniyah's, (SWAT) Model ,and MODIS, DEM

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تقدير التبخر الفعلي لبحيرة الحبانية في ظل الظروف مناخية المتغايرة

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الملخص

بالنظر إلى محدودية واردات المياه الناتجة عن إقامة سدود على مجاري الأنهار في ظل التغيرات المناخية، مما كان له أثر كبير على سياسات تشغيل السدود وصعوبة تلبية متطلبات الاستخدام الزراعي والصناعي. الهدف من هذه الدراسة هو تقدير الخسائر من بحيرة الحبانية نتيجة التبخر السنوي لمياه البحيرة من خلال تطبيق نموذج SWAT والاعتماد على بيانات القمر الصناعي MODIS .تم جمع المعلومات المناخية السنوية ومن خلال نموذج الارتفاع الرقمي، تم التخطيط الجابية بحيرة الحبانية. بالإضافة إلى ذلك، تم تصنيف التربة واستخدامات الأراضي لمنطقة الدراسة. تم استخدام بيانات المناخ لعام 2021 حتى 2023. من خلال محاكاة نموذجSWAT ، لوحظ نتائج معدل التبخر السنوي لبحيرة الحبانية حوالي 2000 ملم. كما لوحظ عند مقارنة قيم التبخر المستحصلة من النموذج بالقيم التي تم الحصول عليها من القمر الصناعيMODIS متقاربة جدا. وأوضحت النتائج حصول زيادة في قيم التبخر في السنوات الأخيرة وذلك بسبب نقص كميات كبيرة من الأمطار فضلا عن ارتفاع درجات الحرارة. أخيرًا، خلصت الدراسة إلى وجود نقص في المياه في السنوات الأخيرة للفترة من 2021 إلى 2023. وتتسبب هذه الخسارة في حرمان 177 هكتارا من الأراضي الزراعية .واوصت الدراسة بضرورة تعزيز الخزين في أوقات الفيضانات واستخدامه لسد العجز في الاحتياجات المائية في وقت الجفاف.

الكلمات المفتاحية: بحيرة الحبانية، نموذجSWAT ، و MODIS، DEM

1. Introduction

Variations in evaporation significantly impact the energy and water budgets of lakes. Water resource management and forecasting future changes in Lake Hydrology due to climate change depend on an understanding of these variances and the role of climate **(Mahmood, 2023)**. In water-stressed regions of the world, where demands exceed the available water supply **(Boretti and Rosa, 2019; Dolan et al., 2021; Huns, 2020; Wada et al., 2016)**, global warming and rising water demands increase the strain on finite freshwater resources, resulting in a state of "water bankruptcy" and its associated socioeconomic. **(Abiodun, O et al,2018)** compared the values of ET computed from two models - the Soil and Water Assessment Tool (SWAT) and the MODIS remote sensing ET product (MOD16) - over a complex terrain at different spatial scales in the Sixth Creek Catchment. The study provided a comprehensive comparison of SWAT, AWRA-L, and MOD16 ET models in a complex terrain, which is important for improving our understanding of ET estimation in such environments. **(Cherednichenko A, 2019)** considered the dynamics of the level of Lake Balkhash in conditions of climate change. It is shown that the undisturbed runoff—the rise and decline of the level—occurs during the entire time that the annual amount of precipitation is above or below the normal level. **(Talak A et al, 2020)** defined the reasons the expanding and contraction in the Habbaniyah's lake's area, and understand the factors behind these changes using satellite imagery and GIS tool. This study is one of the rare, comprehensive investigations of Lake Habbaniyah's spatial characteristics and changes. It highlights the importance of continuous monitoring and analysis of water bodies, especially in regions facing water scarcity, to ensure their sustainable management. **(Hani L,2021**) focused on the application of the Soil and Water Assessment Tool (SWAT) model to simulate the monthly runoff in the Yarmouk River Basin (YRB) located in Jordan. The YRB is an important basin that contributes significantly to the annual water budget of Jordan. The calibrated SWAT model satisfactorily predicted the mean monthly runoff values in the calibration and validation periods, with R^2 values of 0.95. The SWAT model was able to capture the hydrological processes in the arid and semi-arid YRB, despite the limited data availability. **(Naji T et al,2023)** concentrated on using remote sensing technology to determine the water depth in lakes and water bodies, specifically in the western region of Iraq. It explored an appropriate way to monitor and assess water depths using satellite remote sensing techniques. The ArcGIS 10.8, ENVI 5.6 software, and MATLAB R2020a language were used to conduct the study. They selected three lakes in Iraq, Al Habbaniyah, Al Qadisiya, and Al Mosul, as regions of interest. The researchers successfully developed a method to determine water depths in the Al Habbaniyah Lake using satellite remote sensing data and experience conditions. The study concluded the approach is useful for monitoring and assessing water bodies, especially in regions where traditional field studies are challenging. This study presents a 3-year dataset (2021-2023) estimating the actual evaporation of Lake Habbaniyah under conditions of changing climatic conditions annually and determining the effects of water shortage due to the lack of the lake level.

2. SCS- Curve Number Method

SCS Curve Number (CN) is method for estimating direct runoff volume response from Rainstorms was developed to fill technological niche in the 1950. It is a simplified model that considers four catchment properties: soil type, land use/treatment, surface condition, and antecedent condition. SCS Curve Number method is an infiltration loss model, although it may else account for interception surface storage losses through its initial abstraction feature (**Chow, 1988**). Also, the method is developed for intended to account evaporation and evapotranspiration.
Watersheds have a certain group of soil and fair cover can be classified by various curve numbers. These relationship obtained between rainfall and runoff, such that **(Mahmood, 2015)**:

$$\text{Losses} = \text{Rainfall} - \text{Runoff} \quad (1)$$

ET=P-Q: is actual retention (mm)

ET: evaporation (mm)

P: total rainfall (mm).

Q: is actual runoff (mm)

3. Lake Habbaniyah

Lake Habbaniyah located in the North West of Iraq republic. It lies in the South of Anbar City between (43̊ 18′ -43̊ 36′) E and (33̊ 12′ -33̊ 21′) N. Before it was connected to the Euphrates River, Al-Habbaniyah Lake was an ancient natural lake with highly salinized water that was utilized to retain floodwater and supply agricultural water. It is located southeast of Ramadi, on the right bank of the Euphrates River, 70 km West of Baghdad and 15 km West of Al-Fallujah City. The lake's average depth is only 1.8 meters, making it shallow. At full extension, its length and width measure 26 km and 16 km, respectively. Al-Warrar Canal, which is managed by AlWarrar Regulator, is used to redirect water from the Euphrates River to Al-Habbaniyah Lake. The Euphrates River and Al-Razazza Lake are the intended destinations for the two outflows of the Al-Habbaniyah Lake system **(Al-Ansari et al, 2021)**. Water is released back into the Euphrates River via the Al-Thiban Canal, which is managed by the Al-Thiban Regulator. Additionally, through the Al-Majjarrah Canal, which is managed by the Al-Majjarrah Regulator, Al-Habbaniyah

Lake releases its excess water to Al-Razazza Lake during a flood. At a maximum water surface elevation of 51 m.a.m.s.l., the lake's maximum surface area and water storage are 426 km^2 and 3.28 billion m^3, respectively. There are 2.61 billion m^3 of live storage and 0.67 billion m^3 of dead storage. The lake's ground surface height is around 36 meters above mean sea level .In June 1993, the lake's maximum recorded water surface elevation was 50.64 meters above mean sea level (**CEB, 2011**).

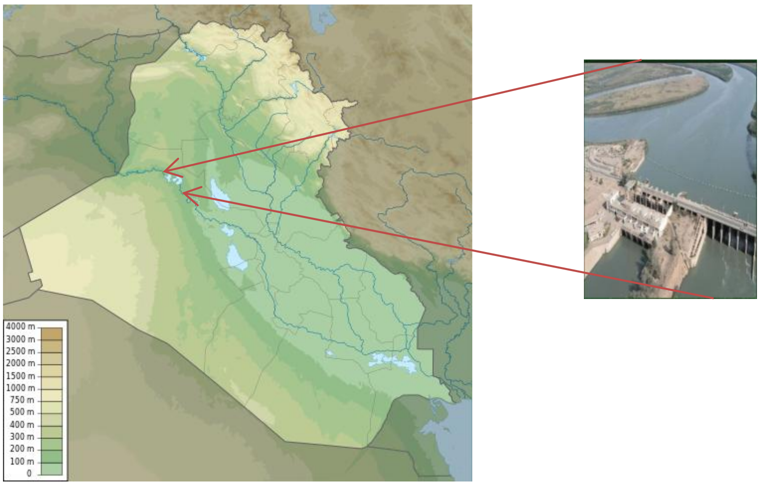


Figure (1): illustrated of the study area **(Isam M,2022)**

4. Methodology

1- Collect hydrological information representing projected water revenues, climate data, digital - elevation models, soil data, and land surveys that represent the inputs to the model.

2- Classified the soil and land use types based on satellite image and GIS tool.

3-Planning and delineating the watershed based on the digital elevation model and satellite images by SWAT model.

4-Dividing the watershed into basins to extract the values of the curve number by reclassifying the soils and land uses for each basin.

5-Proving climate data and simulating the SWAT model .

6-Comparison of the actual evaporation results obtained from the SWAT model with the evaporation values obtained from the MODIS satellite.

5. Data Collection

5.1. Climate Data

Climate data such as (rainfall, minimum and maximum temperature, relative humidity, solar and wind speed) were obtained from **Iraq Meteorological Organization and Seismology at Haditha station, and the Ministry of Water Resources**, MoWR (2021 to 2023). The geographic location of Anbar Governorate imposed a dry and warm summer for the period June, July, and August, with temperature of 31.5 °C as an average summer temperature for the studied period. The city is usually windy during winter extends from December till February. However, the temperature in the winter season is about 7.6 °C. The average relative humidity for summer and winter are 25.5% and 65.6% respectively, while the evaporation reached 329.5 mm in summer and 53 mm in winter where the average wind speed in winter 1.2 m/sec and little bit more in summer 1.8 m/sec. Sunshine duration reaches 5.1 hour and 10.6 hour in winter and summer respectively.

5.2. Digital Elevation Model

A Digital Elevation Model (DEM) is a three-dimensional representation of a terrain's surface created by digitizing and storing elevation data. DEMs are crucial in various fields such as cartography, urban planning, environmental modeling, and engineering **(Alwan et al, 2018)**. They provide valuable insights into landscape features, including terrain roughness, slope, and elevation variations. This section explores how DEMs are generated and their specific applications in this study. Figure (2) illustrates the DEM at 12m resolution of case study that obtained from the website glovis.usgs.

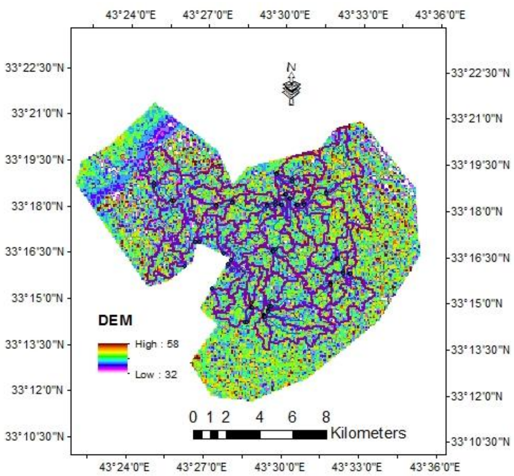


Figure (2): Habbaniyah DEM

6. Land use/land cover and Soil digital maps

The land use (LU) and soil properties of study area can be obtained from satellite imagery; Land sat 8 and the Website. Three Land sat images; acquired in 08 jun 2022, were used to cover the study area. These images were geometrically and atmospherically corrected and digitized in GIS software **(Mohamed et al, 2018)**. Then, these images were mosaic processed and the study area masked up from the mosaic image. Thematic mapping of different (LU), soil classes and Land-use map at scale 1,000,000 were achieved through supervised classification using technique of (GIS) software and analyzing texture of soil was done.

7. Runoff Modeling by Soil Water Assessment Tool (SWAT)

The model selected for the application to the Habbaniyah watershed, is the Soil and Water Assessment Tool (SWAT) version (2012) and it was operated through the interface Arc SWAT developed by the United State Department of Agriculture and Texas University 2012. It simulates the different surface and ground hydrological components as well as crop yields. A distributed rainfall-runoff model – such as SWAT – divides a catchment into smaller discrete calculation units for which the spatial variation of the major physical properties are limited and hydrological processes can be treated as being homogeneous. The soil map and land use map within sub-basin boundaries are used to generate unique combinations, and each combination considered as a homogeneous physical property Hydrological Response Unit (HRU).The water balance for HRUs is computed on a daily time step. SWAT divides rainfall into different components which include evaporation, surface runoff, infiltration, plant uptake, lateral flow and groundwater recharge. Surface runoff from daily rainfall is estimated with a modification of the SCS curve number method from the United States Department of Agriculture Soil Conservation Service (USDA-SCS). First step required to build a SWAT model is defining the elevation related properties such as: elevation above sea level, slope, aspect, stream flow network, and distance to nearest stream, and dividing the basin in sub-catchments. And the resulting of number of Sub-basins: 59, Number of HRUs: 60, 10106 ha sub-catchments by DEM.land use/soils/slope reclassification incorporation and distributions for the watersheds delineated and all respective sub-watershed. Figure (3), (4), (5) and (6) illustrate delineated, slope, land use and soil analysis by the DEM.

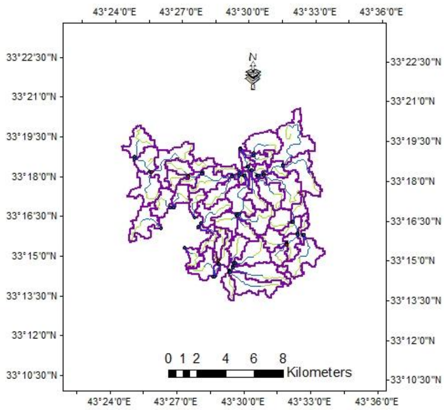
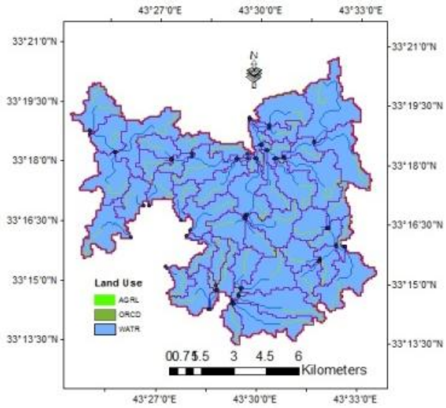


Figure (3):Watershed delination



Figure(5):Land use reclass

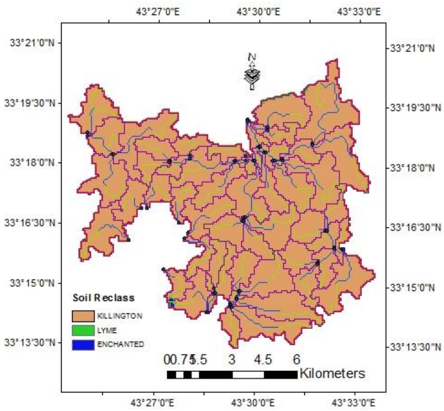


Figure (4):Soil reclass

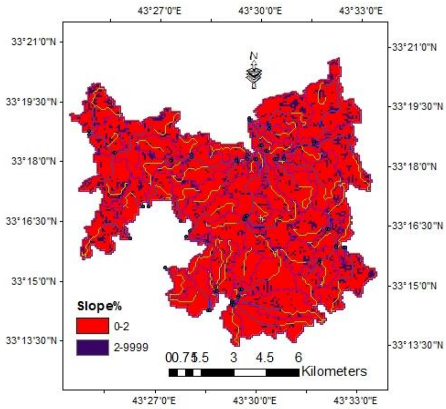


Figure (6):Slope reclass

8. Results

The average evaporation events in the catchment area with a net area of the watershed of 101.06 km² were simulated, in which Table (1) illustrated the number of sub basins and hydrologic responses unit distribution by SWAT. Hence, curve number values range between 80 and 90, and the total net annual losses for the period 2021-2023 are shown in Table (2).

Table (1): illustrated the elevation report for the watershed

Name	Area(km^2)	No of sub basin	No of HRU	Mean	Std
watershed	101.06	59	60	45.23	1.659

Table (2): illustrated the Et by SWAT& ET by MODIS

Date (2021)	5/1	5/2	5/3	9/4	8/5	9/6	8/7	9/8	7/9	8/10	7/11	8/12
ET(cm) by SWAT	3.5	4.4	4.1	3.1	0.21	0.41	0.017	0.009	0.42	0.9	3.5	3.6
ET (cm) by MODIS	2.9	3.7	3.444	2.604	0.1764	0.3444	0.01428	0.00756	0.3528	0.756	2.94	3.024
Date (2022)	5/1	5/2	5/3	9/4	8/5	9/6	8/7	9/8	7/9	8/10	7/11	8/12
ET(cm) by SWAT	6	3.7	4.8	3	1.1	0.098	0.007	0	0.044	0.53	1.84	5.7
ET (cm) by MODIS	5.1	3.12	4.03	2.52	0.924	0.082	0.006	0	0.037	0.45	1.55	4.78
Date (2023)	5/1	5/2	5/3	9/4	8/5	9/6	8/7	9/8	7/9	8/10	7/11	8/12
ET (cm) by SWAT	7.5	5.2	10.7	9.5	0.99	0.14	0.004	0.0034	0.05	0.67	2.6	4.5
ET (cm) by MODIS	6.3	4.36	8.98	7.98	0.831	0.1176	0.0033	0.0028	0.042	0.562	2.184	3.78

It showed the monthly maximum value of ET in 2021 to be 4.4 cm and 3.7 cm by the two models occurring in Feb, and the minimum value is 0.009 cm and 0.0075 cm in Sep. While in 2022, the height values are 6 cm and 5.1 cm in Jun, respectively. Finally, it showed that the maximum value in three successive years occurred in 2023, ranging from 10.7 cm to 8.98 cm in March.

Figure (6) illustrated the calibration between the results of ET that were obtained by the SWAT model with the ET values given by the MODIS satellite image and showed that there was good agreement between the values with R^2 equal to 0.94.

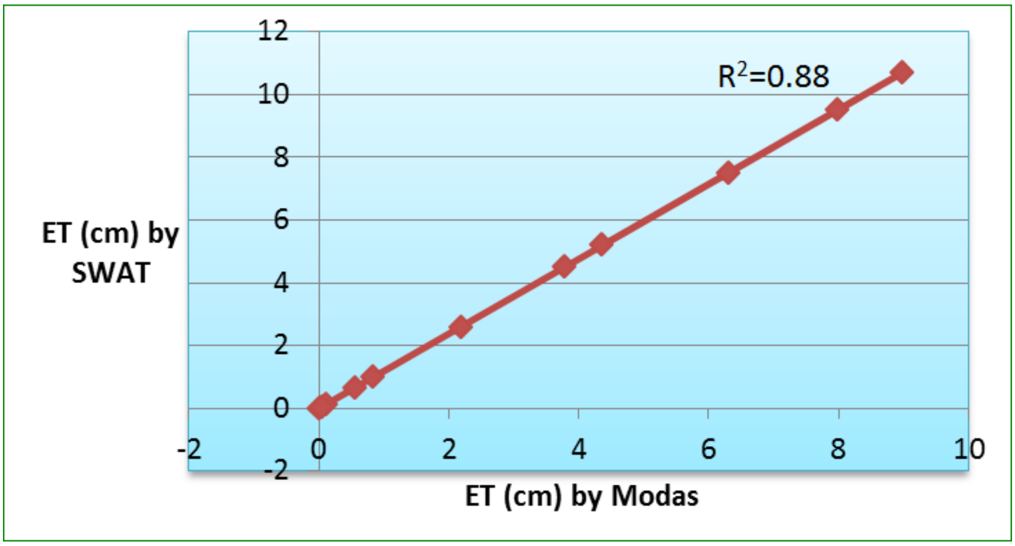


Figure (7): ET by MODIS crossponding ET by SWAT model

Generally, the maximum average annual quantity losses from Habbaniyah Lake is 5.7 * 106, which happened in 2022, and the average annual quantity losses for three successive years is 3.9 * 106 m³ As illustrated in the table (3). This value has a direct impacted on the agricultural areas and urban regions. Finally, **(Qasi and AlShammary ,2018)** established the consumption of the capita at nearly 260 L/c/d, and the annual urban water demand is 95 m³/c/year, while the water lost to evaporation each year from Habbaniyah Lake is equivalent to the urban water demand of over 42105 capita. At the same time, assuming the annual irrigation water demand is equal to 22,000 m³/ha, that means the water lost to evaporation each year could be used to irrigate over 177 ha of land.

Table (3): illustrated the average annual quantity losses from Habbaniyah Lake.

Year	Annual Quantity Losses ($10^6 m^3$)
2021	2.0
2022	5.7
2023	3.8

9. Conclusions

1. The Soil Conservation Service-Curve Number method was successfully applied to estimate surface runoff for the study area using the Soil Water Assessment Tool (SWAT). The model takes into account the land cover types and hydrologic soil groups together for estimating the Curve Number.

2. The comparison between the results of ET that were obtained by the SWAT model with the values of ET given by the MODIS satellite showed a good relationship with R^2 equal to 0.94.

3The maximum value in three successive years occurred in 2023, ranging from 10.7 cm to 8.98 cm in March.

4. The water evaporation for each year from Habbaniyah Lake is equivalent to the urban water demand of over 42,105 people. At the same time, the water lost to evaporation each year could be used to irrigate over 177 ha of land.

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