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Research Article

Groundwater Recharge Evaluation on The Duhok Dam Reservoir by Using (SWBAPP) Model

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Abstract

Groundwater recharge has been calculated of Duhok Dam District, Kurdistan region of Iraq by using soil water balance parameters, because of limited sources of water. The study area of 228.96 km^2. The main purpose of this paper is to apply a water balance concept with using (https://livingatlas.arcgis.com/waterbalance/) website data models in the Duhok dam basin to describe the groundwater recharge. The influence of groundwater recharge on the rainfall-run-off process was investigated in order to have a better knowledge of the storage runoff water in the Duhok dam lake, the annual groundwater change is (0.4mm, 1mm, -1mm, 12.3mm and -1.3mm) for the since (2016-2017, 2017-2018, 2018-2019, 2019-2020 and 2020-2021) (respectively); depending on the rainfall- runoff amount and the soil moisture content (19.75%, 19.41%, 29.33%, 6.5%) above average for the since (2016-2017, 2017-2018, 2018-2019, 2019-2020) (respectively) which lead to be water surplus, but at since (2020-2021) soil moisture content was below average (-8.3%) lead to decrease groundwater storage (deficit water is happen), Finally, all of the results of water balance parameters indicate the reservoir of Duhok dam basin need to more rainfall to renewable (2021-2022) hydrological year.

1. Introduction

Dams are one of the most important human interventions in the water cycle, delivering massive amounts of water for a number of cultural needs such as irrigation and power generation (drinking water, agriculture, and recreation). They also make floods and droughts less likely [1]. Groundwater may be a critical source of water in semi-arid climates, since it is protecting from the tall vanishing rates that affect surface water bodies. The long-term viability of groundwater bodies is therefore critical, and induced groundwater recharge is one of the most common strategies for enhancing a groundwater body's long-term supply [2]. Overseen aquifer revive frameworks may be more viable than expanding surface store capacities, especially under climate change conditions [3], and may moreover be the foremost financially and socially doable arrangement for coordinates water asset administration [4].

Water balances are used to guide water management in all population gatherings in different cities and villages, including those that do not have water scarcity. We found all the analyzed recharge rate over a twenty-one-year period from (2000 to 2021) concluded in the relationships that prominent of monthly average of rainfall amount between different water balance parameters by collection the database from water balance application with 0.25-degree spatial resolution (~30 km) for NASA: which approved by (Ersi, USGS: Esri, HERE, Garmin, FAO, NOAA, USGS).

Many types of hydrologic assessments, including assessments that concern water availability, water quality protection, streamflow and riparian-ecosystem management, aquifer replenishment, groundwater-flow modeling, and contaminant transport, require accurate estimates of groundwater recharge's spatial and temporal distribution. These recharge estimates are often key to understanding the effects of land-use change in urban, industrial, and agricultural regions. As the demand for science-based hydrologic management grows, so does the need for reliable and practical methodologies to calculate groundwater recharge rates [5].

The first Goals of this research are to evaluate groundwater storage within the reservoir. The second objective is to evaluate the average Rainfall-Runoff rate which flow towards within the Duhok Dam Lake. The last one is to observe the temporal variation of water balance parameters and identify effect everyone on the groundwater storage.

2. Material and Methods

2.1. Study Area

Duhok Dam could be a tall soil fill dam with a central clay center and rock shell on Duhok Waterway, 2 km in a north of Duhok, between 36°52′35″ and 36°54′21″N, and 42°59′51″ and 43°00′40″ E as shown in Figure1. The Dam was built in 1988 with the mainly goal for irrigate the agricultural lands inside Duhok city and surrounding areas until a tunnel connected them to Semel city. Today, the dam's reservoir area is used to deliver water to Duhok city while also serving as a tourist attraction. The greatest and smallest reservoir surface areas throughout the (2001 to 2012) were roughly 2492603.2 and 1014851.12 m^2, respectively. In these circumstances. The most extreme and least admissions water volumes were 2365947 and 0.0 m^3, individually, whereas the greatest and least surge volumes were 108000 and 500 m^3. It stands 60 meters (197 feet) tall and can hold 52 million m^3 (42,157 acres) of water. A bell-mouth spillway with a greatest release of 81 m^3/s (2,860 cu ft/s) is introduced on the Dam [6].

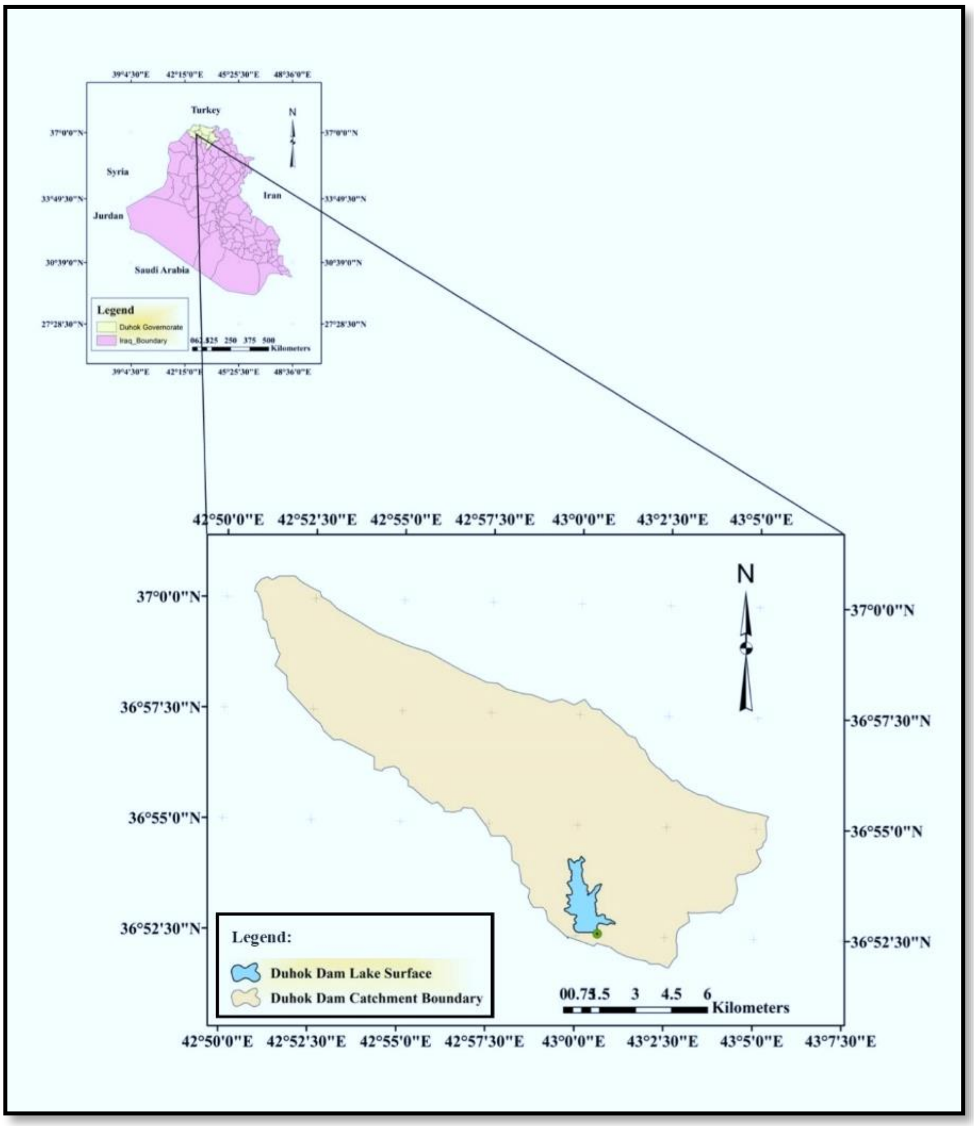

Figure 1. Duhok Dam Basin and its lake

2.2. Data Collection

The climatic data for the study area which covered the period (2016-2021) of Duhok Dam Basin was drawn from the GLDAS' high-quality global land surface fields assist a variety of current and proposed weather and climate forecasting, water resource applications, and water cycle studies. The project produced a huge library of modeled and observed global surface meteorological data, parameter maps, and output, including 1-degree and 0.25-degree resolution Noah, CLM, VIC, Mosaic, and Catchment land surface model simulations from 1948 to the present. Because one degree (1°) near the equator equals roughly 111 kilometers, travelling to the south or north poles of both longitude and latitude, despite a tiny difference of about 1 kilometer, is a viable option. As a result, 0.25° by 0.25° gridded degree is approximately 27.75 km, while 0.5° by 0.5° is around 55 km.

Data Calibration; Output is available online at the National Center for Atmospheric Research (NCAR) webpage on NLDAS: North American Land Data Assimilation System; the NASA webpage on LDAS Land Data Assimilation Systems and the Goddard Earth Sciences Data and Information Services Center (GES DISC) data collection of GLDAS (https://livingatlas.arcgis.com/waterbalance/).

2.3. Climate

According to the increasing ratio of rainfall in Iraq's northern area, the mean annual summation of rainfall appears to have a symmetrical increasing trend from southwest to north-east. In these places, terrain, atmospheric depression, and the kind of air masses flowing in from the surrounding areas all play a part in the variation of yearly rainfall values. Iraq's climate is categorized as continental and subtropical semi-arid, including mountains sections in the north-east and north classified as Mediterranean [7]. With the surrounding high mountains exerting an expressed influence. Summers are dry and hot, while winters are wet and rainy; however, cold weather prevails in the winter, with snowfall on the high mountains. The rainy season lasts in October until May, and the year rest is dry in mostly. Every year, the region receives about 535 mm of rains. The temperature contrast between summer and winter is critical. The yearly average temperature is 19.5°C, with sand and silt brought in by north-west winds in the summer. While. North-east winds prevail in the winter. Table 2. illustrate the soil moisture and meteorological data of the Duhok dam basin.

2.4. Land Cover

Scattered oak trees, open forest, and bushes on unstable slopes make up around 23% of the area covered by poor forest and woodland. Due to soil erosion and severe erosion, lands in the Sindor and Bajlor sub-basins, which cover 19 percent of the region, are currently in very poor condition near the communities. Agricultural land makes up around 10% of the total area, and it is mostly found near large rivers with moderate slopes. Irrigation is accessible along the Duhok stream, in Garmava, and in the Sindor village, which is the main wine-growing area, on moderate slopes as shown in figure (3), where vineyards are commonly cultivated, rainwater agriculture can be found [8].

The soil around the lake is generally unstructured and easily eroded when it rains. This creates silt issues and has a negative impact on vegetation degradation. Dam coverage due to illegal logging, overgrazing, shifting cultivation, forest fires, and unsuitable farming methods on river slopes causes basin soil erosion. Burlap, bare rock, shale, sand, and Red Clay are all common in the area. As a result, the soil's water storage capacity fluctuates, and runoff is rather considerable. As a result, soil erosion is present in most basins, particularly in the Garmava and Linava sub-basins, Soil erosion is a serious constraint for the dam, reducing the storage capacity of the dam reservoir significantly each year if no measures of soil conservation, protection, and management of the dam's basin are taken, according to various field observations and studies conducted within the Duhok dam basin [9].

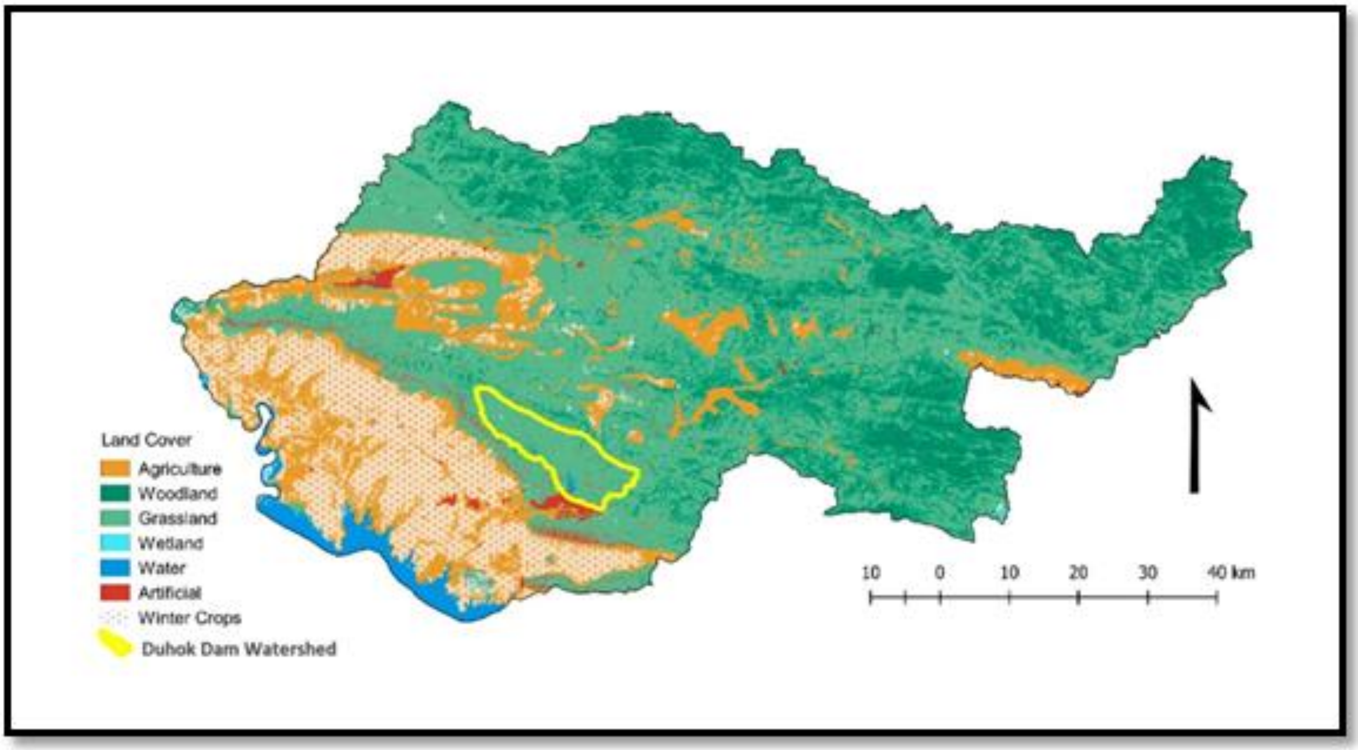

Figure 2. Land cover in the Duhok governorate by 2010 based on Globeland30 (provided by National Geomatics Center of China, DOI:10.11769/GlobeL and 30. 2010.db). Winter crop areas for the period 1998–2014 are superimposed on the land cover classification

2.5. Hydro-geomorphology

The area is characterized by a mountainous nature, with steep mountain slopes making up the bulk of the terrain, show Figure 3. covered by a large number of valleys and corridors, which are rich in springs, and the (Germava) sub-basin containing a number of mineral springs, and the basin consists of rocky layers, and is directed northwest. The basin is positioned within the northern edge of the Bekhair fold and slopes northwest to southeast [10]. The highest point on Bekhair Mountain is (1381) meters above sea level, and the lowest point is (560) meters above sea level, where the city's basin entry is located, as well as the drainage of pattern in the study area is dendritic, shown in Figure 4.

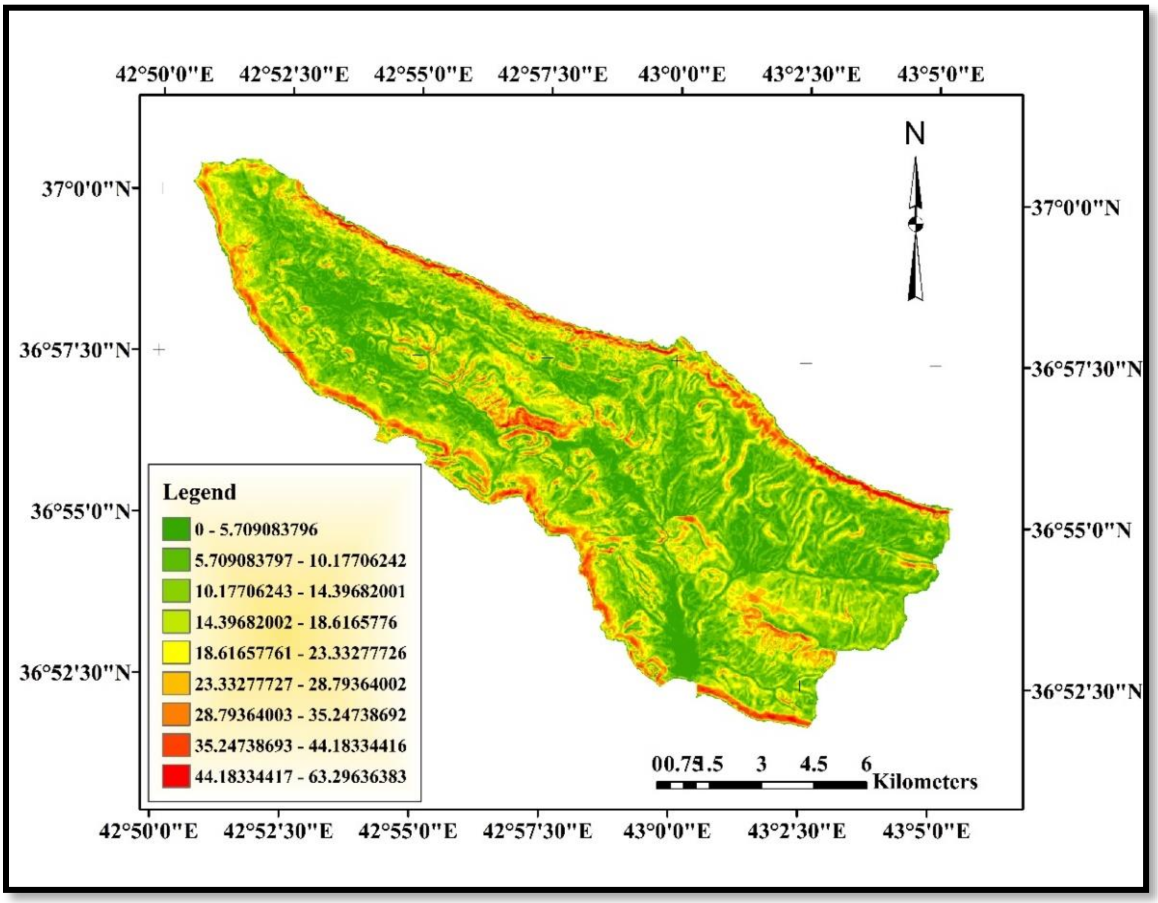

Figure 3. Slope of Duhok Dam Basin.

Both the Garmava and Linava rivers in the Garmava Catchment have modest and narrow banks. The rocky slopes are fairly steep, falling more than 80% of the way to the river, where they are in the range of (20 to 30%). The northern part of the Sindor Spring is comparable to the remainder of the stream, with a few moderately sloping ravines around Sindor towns. The hills between the Sindor and Bajlor streams are also very steep, with few troughs. According to Jamel et al, 1999; the morphometric analysis effect on geological and hydrological characteristics, example of morphometric properties of Duhok dam basin in Table 1.

Table 1. Show some morphometric properties Duhok dam basin

Basin	Area (km^2)	Maximum Length (km)	Maximum Width (km)	Average Slope %
Duhok Dam Basin	130	4	1.7	23

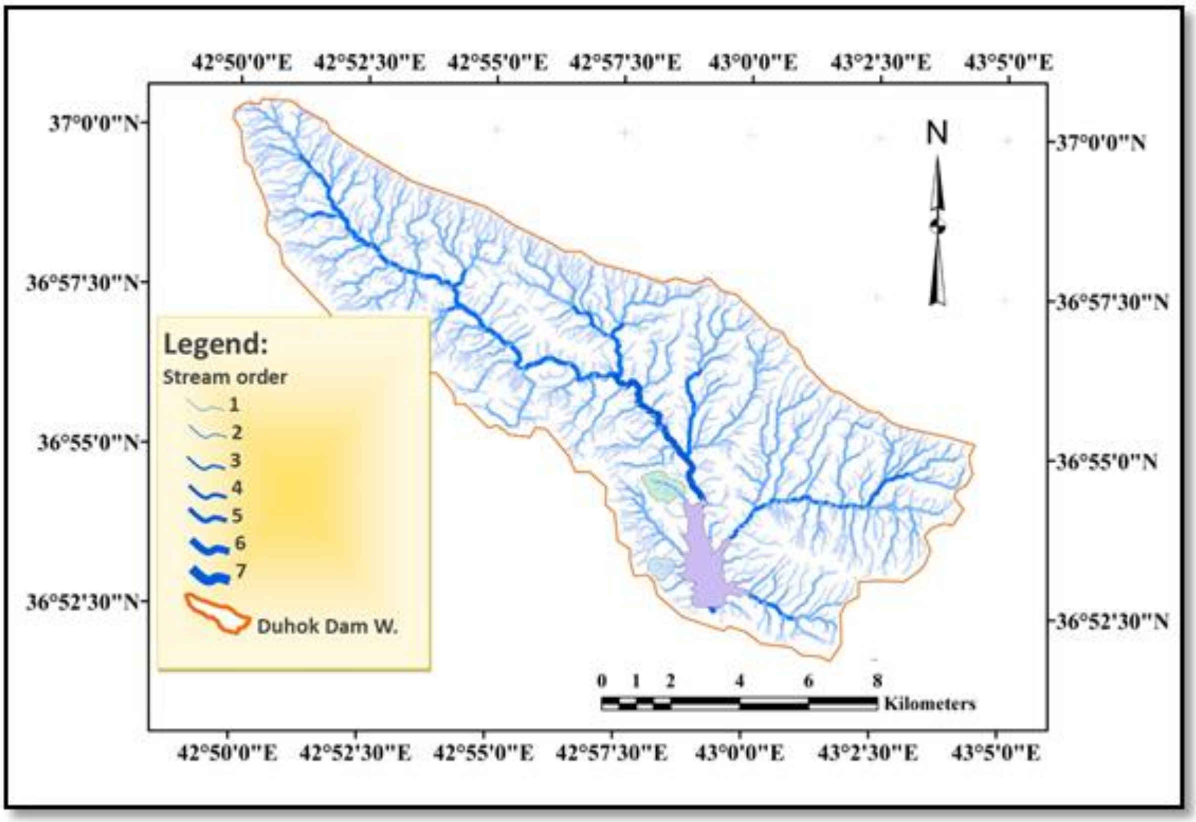

Figure 4. Duhok dam and its stream (Drainage Pattern)

2.6. Water balance Parameters Assimilation

The water balance of the study area was calculated by using Lerner method, water surplus ratio from the yearly rainfall (Where the soil moisture considered = 0). The methodology used for the water balance in this research is well documented by [10] and [11]. As the following equation:

$$P = Q + ETc + \Delta S \ldots \qquad \ldots\ldots (1)$$

P: Precipitation (mm).

Q: Runoff discharge (mm).

ETc: Evapotranspiration (mm).

ΔS: Change in Water storage (mm).

The excess of rainfall values over corrected evapotranspiration values during specified months of the year is described as water surplus like (Winter), whilst the excess of corrected evapotranspiration values over rainfall values during the remaining months of the year is defined as water deficit like summer [12]. They can have calculated with Actual Evapotranspiration (ETc) by using the following equation [13]:

$$WS = P - ETc, \quad \text{when } P > ETc \tag{2}$$

While:

$$WD = ETc - P, \quad \text{when } P < ETc \tag{3}$$

WS: water surplus (mm)

WD: water deficit (mm)

P: Precipitation (mm).

ETc: Actual Evapotranspiration (mm).

In addition, the percentage of (WS% and WD%) calculated as follows [14]:

$$WS\,\% = WS/P \times 100 \tag{4}$$

While:

$$WD\% = 100 - WS\% \tag{5}$$

3. Results and Discussion

3.1. Rainfall

Annual rainfall has been fluctuating for the past 21 years (Figure 5). The yearly rainfall pattern has been fluctuating for the previous 21 years, according to the participant during focus group talks and key informant interviews. Similar to this conclusion, rainfall variability was particularly noticeable in the years (2015-2016 to 2018-2019); however, rainfall variability became relatively minor in the years (2020-2021), assuming the annual summing of all rainfall amounts is less than the 21-year average. This indicates that groundwater levels are declining as a result of rainfall, which is the main source of water, which flows into the Duhok Dam Basin by duhok river. In addition to this results, reduction of rainfall amount is also observed in both spring, surface of lake and ground water. For example, there is reduction of spring, surface of lake and ground water during (2015-2021), there was high lacking in (2021), show figure (5 and 9).

3.2. Runoff

Model SCS-CN The Natural Resources Conservation Service (NRCS) of the United States Department of Agriculture (USDA) (formerly known as the Soil Conservation Service (SCS)) developed a method for estimating runoff from rainfall in the early 1950s. The CN method is another name for this procedure (10). The water balance equation is used to calculate the SCS curve number. The SCS-CN approach, as seen in equation (6):

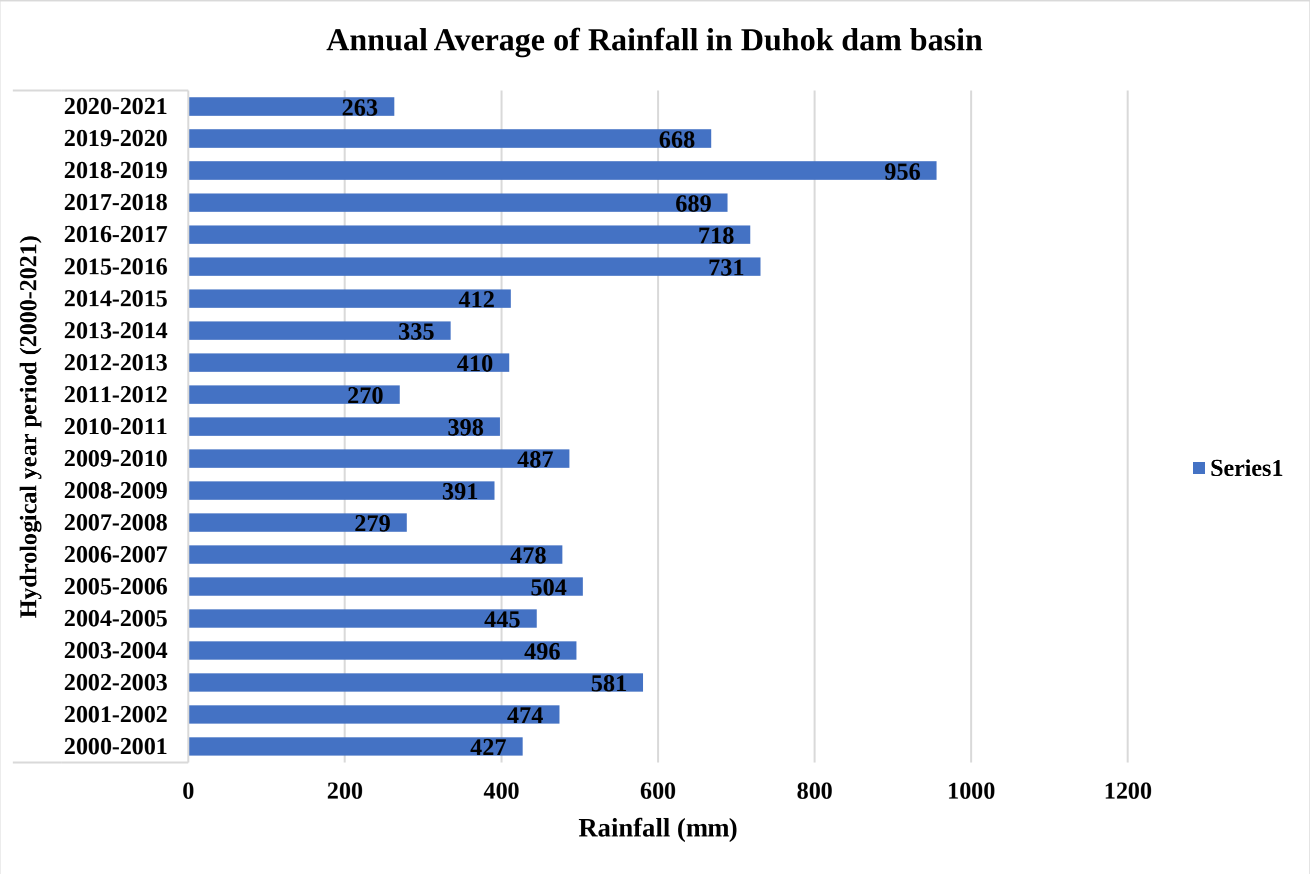

Figure 5. Annual Average of Rainfall in Duhok dam basin

$$Q = (PIa)\ 2\ PIa+S \qquad (6)$$

Ia = 0.2S

m = accumulated storm runoff (Q); Q = accumulated storm runoff; Q = accumulated storm runoff.

P = mm of accumulated storm rainfall

S = Maximum water retention potential of the soil,

Ia = Initial interception, depression, and infiltration quantity. Equation (6) becomes Equation (7) after substituting in equation (6).

$$Q = (P0.2S)\ 2\ P+0.8S \qquad (7)$$

* This is true if P > 0.2S; otherwise, the P - Q data can be used to determine Q = 0 S. S is obtained from a mapping equation written in terms of in practice.

Even though there are similar themes in hydrological works, our understanding of hydrological reactions is still changing, and the details will rely on experience, particularly the types of hydrological situations that a hydrologist has worked in. Different processes may occur in different ecosystems and catchments with varying terrain, soil, vegetation, and bedrock features. According to the slope, vegetation covers, type of soil and land use within the Duhok dam basin the results generally have the differentiation of Runoff during rainy season for example: from March and April during (2015-2016 to 2019-2020) increasing but the vice versa decreasing was appearing in the (2020-2021) for some months (show in figure 6). as the some, the annually average of runoff for (2020-2021) is below the annually average of runoff during all of the 5 years ago which is (32.38 mm) show in table (2). It indicates we cannot have harvested enough runoff water with in the Duhok dam basin due to lacking of main source in the region.

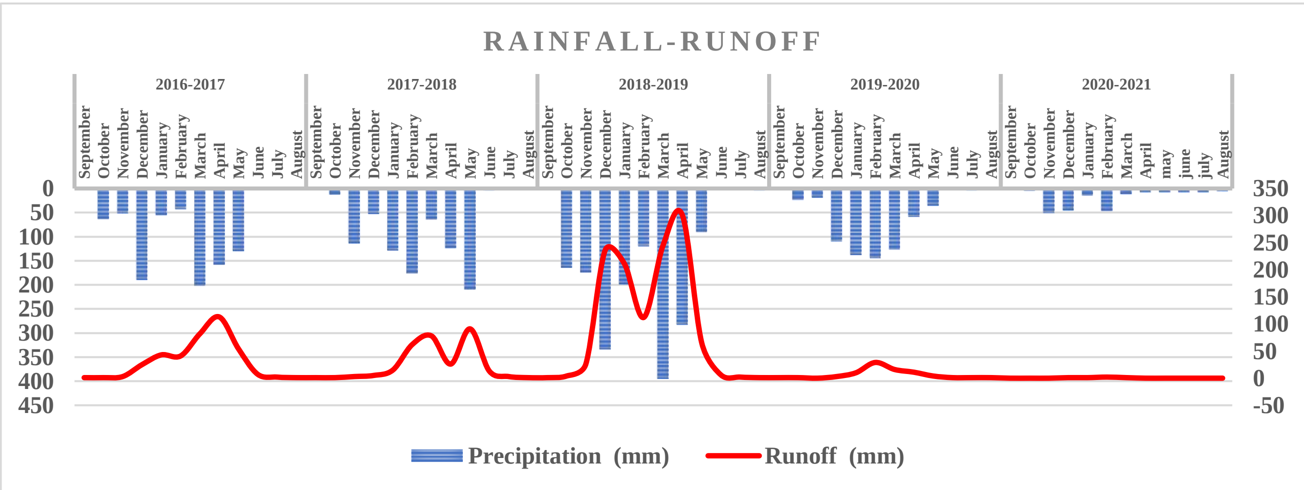

Figure 6. The rainfall-runoff relationship

3.3. Evapotranspiration

The potential evapotranspiration is a combined term of evaporation and transpiration is defined as the total loss of water through evaporation and transpiration from the soil-plant system [15]. Thornthwaite suggested an equation to calculate the potential evapotranspiration after conducting several experiments on semi-arid climate types depending on the temperature only [16]. The evapotranspiration in the study area is calculated for each month as follows:

$$PEc = 16\ [10tn/J]^{a} \quad (8)$$

$$J = \Sigma\ j\ 12\ j = 1 \text{ For the 12 month} \quad (9)$$

$$j = [tn/5]\ 1.514 \tag{10}$$

$$a = (675 \times 10\text{-}9)\ J^3 - (771\times 10\text{-}7)\ J^2 + (179\times 10\text{-}4)\ J + 0.492 \tag{11}$$

a = 0.016 J + 0.5

The value of (a) equals (1.68).

Where:

PEc = Potential evapotranspiration for each month (mm / month).

t = Monthly mean air temperature (C°).

n = Number of monthly measurement.

J = Annual heat index (C°).

j = Monthly temperature parameter (C°).

a = Constant.

The values of potential evapotranspiration for each month are determined in Table (2). The correlation graph of each of the potential evapotranspiration PE, and Groundwater recharge are explained in Figure (7). Groundwater change with exchangeable of water from beneath the ground to the atmosphere in the happen of water source within the lake or in aquifers, there is significantly relations between them so when the evapotranspiration increases the ground water change will be decreasing. The monthly evapotranspiration average of May is (126 mm, 124 mm, 125 mm and 97 mm) for since (2017, 2018, 2019 and 2020) respectively as depth, is high in evaporation due to happen high amount of water with in reservoir but inversely for since 2021 was recorded (9 mm) as depth in May due to lacking of water as main source, show in figure (7). in the other hand; the average of change in storage for May is (-50 mm, -5 mm, -100 mm and -65) for since (2017, 2018, 2019 and 2020) respectively, but for May 2021 is (-1 mm) which recorded minimum amount of storage change due to the evapotranspiration is low during this month because of first reason, as in figure (7), as well as we can say the evapotranspiration rate directly effect on the groundwater storage after each event or in the presence of water source. The effect of evapotranspiration more appears in dry season, and dry hydrological year like (summer) for each year and more months of since (2020-2021) as a dry year within the all-hydrological year, show table (2).

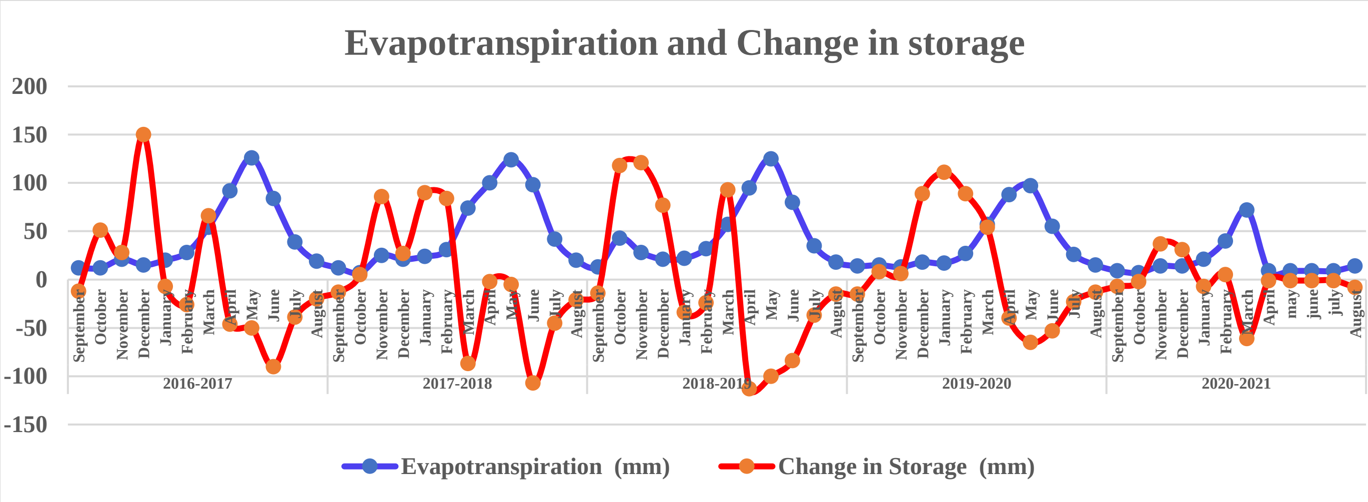

Figure 7. The effect of evapotranspiration on change in storage.

3.4. Groundwater recharge

All the water balance parameters affected on the groundwater recharge. Groundwater recharge depends on the amount of annual rainfall falling at the space area studied. to calculate the annual amount of water that recharges the groundwater, we use general equation of water balance (explained before).

Figure (8) shows the fluctuations of rainfall, Groundwater storage during the wet season (October to May). The water capacity underneath the Duhok dam supply is much subordinate on the precipitation sum. Within the dry season, the up-gradient surface water within the reservoir is emphatically connected with the down-gradient level within the supply. This demonstrates that the water level up-gradient of the supply specifically impacts the water level down-gradient of the supply. The degree of the up-gradient and down-gradient waters within side the reservoir isn't always properly correlated with the rainfall intensity, indicating that the discharge of the water within side the reservoir might not be stimulated through rainfall when you consider that it is able to be associated with the want of the water for irrigation [17]. The groundwater storage. This study is similar to the conclusion for the dry season. The change in storage significantly related to rainfall amount, but may be increasing in rainy season (September to April) inversely to dry season the groundwater storage is decreasing in (May to August). The reservoir's groundwater storage, on the other hand, is tied to the groundwater level. This discovery is crucial because it allows us to conclude that the groundwater level in the study region fluctuates as a result of rainfall rates but is not enhanced by irrigation or other sources of water, as shown in Figure (9).

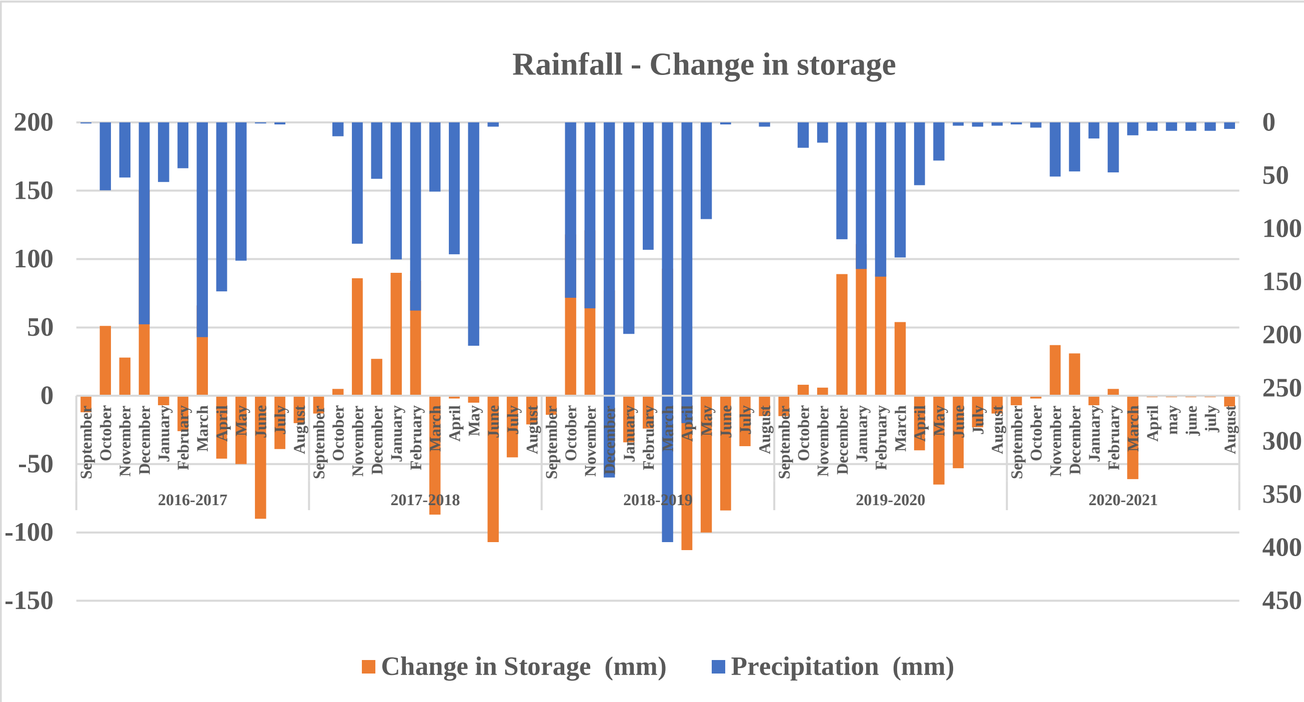

Figure 8. The effect of rainfall amount on the change in storage

The annual average of ground water storage in the study area during hydrological years is influenced with changing rainfall amount, so that; the annual average of ground water storage is (31.2 mm, 25.9 mm, 99.9 mm, 18.8 mm and 1.41 mm) for since (2016-2017, 2017-2018, 2018-2019, 2019-2020 and 2020-2021) respectively, these results indicated to water table become very low, shown the bed of the Duhok Dam Lake in figure (9).

In the first case (water surplus period), annual averages of ETc, WS and WD. The annual average of Rainfall amount for since (2015-2016, 2026-2017, 2017-2018, and 2019-2020) is greater > than the evapotranspiration is mean that the water surplus is happen which (58.21%, 54.05%, 77.66%, 62.23%) respectively.

In the last case (water deficit period), annual averages of ETc, WS and WD. The annual average of Rainfall amount for since (2020-2021) is less < than the evapotranspiration is mean that the water deficit is happen which (-8.3) respectively, it represented the groundwater storage become below the average this indicate that the level of the groundwater with in the basin appear very little, all are shown in figure (9), Table (2).

Table 2. Show the annual average of water balance parameters of Duhok dam basin during (2016-2021).

Hydrological Year	Rainfall (mm)	Runoff (mm)	Ground- water change (mm)	Evapo-transpiration (mm)	Soil Moisture Content %	WS (%)	WD (%)
2016-2017	75	31.0	0.4	43.5	19.75	58.21	
2017-2018	74	24.0	1	48.1	19.41	54.05	
2018-2019	147.3	100.9	-1	47.4	29.33	77.66	
2019-2020	55.6	6.5	12.3	36.8	6.5	62.23	
2020-2021	18	0.41	-1.3	18.9	-8.3		-58.33

Figure 9. Duhok dam level for dry season during (2015-2021)

4. Conclusion

The lake conceptual model was redefined and adjusted according to hydro-meteorological interpretation. The using of the water balance equation to assimilate groundwater recharge is a simple, quick, and effective way for interpreting hydrological studies in a given area, particularly when the region is experiencing a water crisis (2020-2021). Furthermore, the data reveal that a water shortage has occurred. Since the soil moisture content and groundwater storage as a percentage have been below average during (2020-2021). Using hydro-climatic characteristics (soil–water–balance approach), an aquifer recharge estimate of (-58.33 percent) of total rainfall was calculated. They permitted estimating a natural outflow of infiltrated water for soil moisture content (-8.3%) to the Duhok Dam Lake by specifying the volume by percent of the aquifer. Nevertheless, while the model contained different assumptions and limits, these results should be interpreted with caution. Rather than validating the data, we are attempting to make use of it. The study's key limitations include how these projected recharge values relate to groundwater age dating and the validity of the storability values.

Declaration of Competing Interest: The authors declares that they have no conflict of interest.

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