Using Data of Remote Sensing and Arc-SWAT Model to Assessment Water Availability and Generation Surface Runoff of the Abbasan Watershed in Northeastern of Iraq

Ammar Abd Jasim* **Mustafa Ali Hasan****

* Ministry of Science and Technology/ Space and Communication Directorate- Remote Sensing Research Center, Baghdad-Iraq

** Ministry of Higher Education and Scientific Research/Baghdad University-College of Science, Baghdad-Iraq

E_mail: ammory.1977@yahoo.com

Abstract

The surface runoff is a very significant component of the hydrological cycle. The main objectives of this study the employed Soil and Water Assessment Tools (SWAT) model to assess the surface runoff and water balance in the Abbasan watershed (864 Km^2) in the northeastern of Iraq. The remote sensing data were used as the primary input for the SWAT model. This data included digital elevation model (STMR); Land Used Land Cover (LULC) map generated from the Landsat 8 classification for the year 2019. The climate data were collected from Prediction of Worldwide Energy Resource (POWER) project funded by the NASA Earth Science. The map soil was sourced from the Food and Agriculture Organization (FAO). The results revealed that about 32 % and 48% of the annual precipitation is lost by percolation and evapotranspiration respectively. The annual runoff volume for the period 1991-2019 was estimated at about 38 million m^3. These results demonstrated that the SWAT model can estimate the runoff volume and description all water balanced elements. Also, it has been found that the LULC and soil classes have an important impact in generated the surface runoff.

Keywords: SWAT, Landsat, Water Balanced and Surface Runoff.

توظيف بيانات الاستشعار عن بعد ونموذج Arc-SWAT لتقييم توافر المياه وتوليد الجريان السطحي لحوض عباسان في شمال شرق العراق

عمار عبد جاسم* **مصطفى علي حسن****

*وزارة العلوم والتكنولوجيا\ دائرة الفضاء والاتصالات- مركز التحسس النائي، بغداد-العراق

**وزارة التعليم العالي والبحث العلمي\ جامعة بغداد - كلية العلوم، بغداد-العراق

الخلاصة

الجريان السطحي هو عنصر مهم للغاية في الدورة الهيدرولوجية. الهدف الرئيسي لهذه البحث هو استخدام نموذج SWAT لتقييم الجريان السطحي وتقييم توافر الموارد المائية في حوض عباسان (864 كم^2) في شمال شرق العراق. تم استخدام بيانات الاستشعار عن بعد كمدخلات أولية مع نموذج SWAT. تضمنت هذه البيانات نموذج الارتفاع الرقمي STMR، وخريطة LULC تم إنشاؤها من تصنيف صور القمر الصناعي لاندسات8 2019. البيانات المناخية تم جمعها من مشروع التنبؤ بمصادر الطاقة العالمية الممول من قبل وكالة ناسا. تم الحصول على خريطة التربة من منظمة الأغذية والزراعة (الفاو). أوضحت النتائج أن حوالي 32% و48% من الهطول السنوي يُفقد بالترشيح والتبخر على التوالي. قدر حجم الجريان السطحي السنوي للفترة 1991-2019 بحوالي 38 مليون متر مكعب. أظهرت النتائج أن نموذج SWAT لديه القدرة على تقدير حجم الجريان السطحي ووصف جميع عناصر المياه المتوازنة. وكذلك وجد ان نوع الغطاء الارضي والتربة لها تأثير مهم في توليد الجريان السطحي.

الكلمات المفتاحية: سوات، لاندسات، الموازنة المائية والجريان السطحي.

Introduction

Natural water resources in the world and in Iraq in particular face many challenges, some of which are due to the prevailing global conditions represented in the scarcity of rain and the high rates of evaporation as a result of high rates of temperatures and the expansion of drought and desertification phenomena (Al-Ansari, 2013). Seasonal runoff water is considered one of the basic resources of water. Therefore, it is important to study its quantities, frequency, and probabilities in the presence of information and data provided by available field measurements, as well as by predicting them using hydrological models. There are a few numeral models that have the ability to simulation hydrological processes at the watershed scale and a sensible time scale to assess the surface runoff and describe the water balanced elements (Boithias, *et al*., 2017). Several solutions and models have been developed that are relevant to runoff estimation. One of the most important of these models is the SWAT (Soil and Water Assessment Tool) model, which is physically based distributed model (Ngo, *et al*., 2020) based on mathematical models of the continuous simulation type. The surface runoff is a very significant component of hydrological cycle (Byakod, *et al*., 2017). The SWAT model was chosen in this study in order to rainfall runoff simulation and assessment the availability of water, because it is a promising simulation model that ongoing to evolve day after day and can be greatly benefited from, especially in the study of cross-border and ungauged basins such as Abbasan watershed. In addition, the SWAT model has been evaluated by many researchers under different circumstances and around the world at different basin-scales range from about 1 to 630000 km^2 (Ezz-Aldeen, *et al*., 2012; Rossi, *et al*., 2009; Tyagi, *et al*., 2014) Therefore, the SWAT model has emerged as one of the most common models for the study of water basins and has been widely used in addressing many problems in the hydrological and/or environmental field (Gassman, *et al*., 2014).

The aim of this study is to assess the availability of water resources and evaluate the surface runoff for the period 1991-2019 using SWAT model.

Materials and Methods

Location of the Study Area

The watershed of Abbasan is sub-basin located in the northeastern of Iraq at the Iraq-Iran border between 34°35'27" to 34°56'50" N and from 45°36'4" to 46°7'36" E as shown in Figure (1) with total area about 864.7 Km^2, it extends within the Iranian land for a distance of approximately 45 Km with an approximate area of 713.345 Km^2 (82% of the Watershed Area), while it extends within the Iraqi land for a distance of 14 Km and covers an area of 151.382 Km^2 (18% of the Watershed Area) until its meeting with a river of Diyala near the city of Maidan in the northern part of the Diyala government. Diyala River is one of the branches of the Tigris River in Iraq. On the Iraqi side, the waters of Abbasan basin drain from the drainage of basins and mountains located south, southeast and east, in addition to steeply sloping foothills of the Bammu Mountains onto the Diyala River. The runoff waters of the Abbasan basin follow the original paths towards the north and northwest and reaching its intersection with the Diyala River.

Data Collection

Remote sensing supplies the significant data for mapping of water resource (AbdelRahman, *et al*., 2016). Four major file's datasets required by the SWAT model: (1) Digital Elevation Model (DEM) was acquired from Shuttle Radar Topography Mission (SRTM) version3 with 30m spatial resolution (Ferretti, *et* *al*., 2007), and were download from SRTM website http://srtm.csi.cgiar.org/ Fig. (2.a). (2) Soil map, the map soil is shown in Fig. (2.b) was sourced from the Food and Agriculture Organization (FAO), Digital Soil Map of the World (DSMW) version 3.6 (FAO, 2007). This data comes with about 7000 types of soil for the whole world at a spatial resolution of 10km and a database for the properties of two soil layers, the upper layer at a depth of 0-30cm, and the subsequent layer at a depth 30-100cm. (3) the map of Land-use Land-cover LULC was produced by utilizing the Landsat8 satellite image, free of cloud which acquiring on March 3, 2019. The LULC result of Abbasan basin contains 6 classes Fig. (2.c). (4) The climate data were collected from the NASA Langley Research Center (LaRC) Prediction of Worldwide Energy Resource (POWER) project funded by the NASA Earth, science/applied science program for three stations; Fig. (2.a) shows the location of these stations; and for 31 years starting from January 1, 1989, to December 31, 2019. The POWER data can obtain through the POWER website (https://power.larc.nasa.gov/). The ArcSWAT extension is a graphical user interface for the SWAT model (Srinivasan, *et al*., 1998). The ArcSWAT extension has many functions necessary to generate and run a SWAT model, for example, watershed delineation, and generator of the input file, edit modules, and others. The ArcSWAT extension is freely available and has won international recognition because of its performance and reliability. In addition, the SWAT model developed to work in much other software such as GRASS, MapWindow GIS, and QGIS. The SWAT model also underwent extensive validation.

Methodology

SWAT Hydrological Component and Assessment the Surface Runoff

There are two main methods for estimating surface runoff (The Flow that Happens Along Sloping Surfaces) in the SWAT model depending on the type of rainfall data: the first method is the modified SCS curve number (USDA, 1972) with daily precipitation data while the second method is the Green and Ampt method (Green and Ampt, 1911) which requires hourly or sub-daily precipitation data. Due to the lack of almost sub-daily data, the SCS-CN method was utilized in estimating the volumes of runoff for the Abbasan basin.

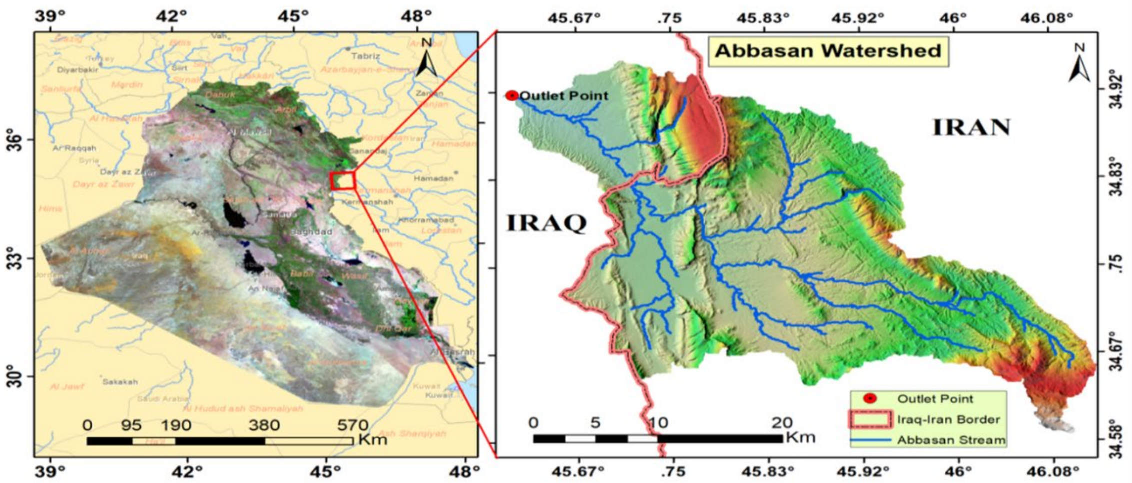

Figure (1) The location of Studied Area.

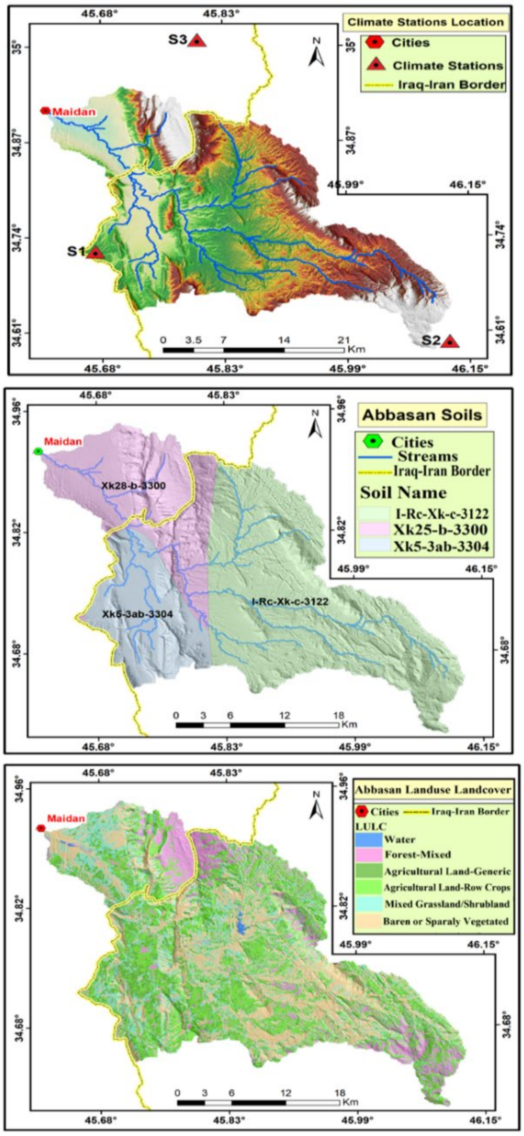

Figure (2) The Spatial Data for SWAT Model: a. SRTM DEM 30m (Farr, *et al.*, 2007) Superimposed on a Hillshaded with the Locations of Climate Stations (https://power.larc.nasa.gov/); b. Soils Map of the Abbasan Basin (FAO, 2007); and c. LULC Map of the Abbasan Basin.

According to the SWAT model, the hydrological cycle that the model simulates is the basis upon which to accurately estimate the amount and volume of runoff water and sediments. The hydrologic cycle simulation through the SWAT model depends on the equation of water balance (Neitsch, *et al.*, 2011):

$$SW_t = SW + \sum_{i=1}^{t}(R_t - Q_t - ET_t - P_t - QR_t) \quad \ldots\ldots\ldots\ldots (1)$$

Where SW_t is the final soil moisture content (mm); SW is the initial soil moisture content on a day i (mm); t is the time (Days); R_t is the rainfall volume on a day i (mm); Q_t is the surface runoff on a day i (mm); ET_t is the Evapotranspiration on a day i (mm); P_t is the percolation on a day i (mm); and QR_t is the amount of return flow on a day i (mm).

The SCS-CN method was developed to become a suitable basis to assess runoff amounts under different land-use with varying soil types. This method is often known as the Curve Number CN method, the soil properties and land-use are lumped in one parameter (White, *et al.*, 2008). The SWAT model predicted the volumes of runoff and the rates of peak runoff for each HRUs (Hydrologic Response Unit) used SCS-CN equation:

$$\boldsymbol{Q}_{surf} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)} \;, R_{day} > I_a \quad \ldots\ldots\ldots\ldots (2)$$

Where the $\boldsymbol{Q}_{surf}$ is the daily runoff or rainfall excess in millimeters, R_{day} is the daily rainfall depth in millimeters, S is the retention parameter (mm). I_a is the initial abstractions which is usually approximated as 0.2S Usually, I_a approximated as 0.2S, thus the equation becomes:

$$\boldsymbol{Q}_{surf} = \frac{(R_{day} - 0.2\,S)^2}{(R_{day} + 0.8\,S)} \quad \ldots\ldots\ldots\ldots (3)$$

The retention parameter changes spatially due to variations in soils, land-use, slope, management, and temporally from the changes in soil water content. The retention parameter is defined as:

$$S = 25.4\left(\frac{1000}{CN} - 10\right) \quad \ldots\ldots\ldots\ldots (4)$$

CN = the curve number for the day.

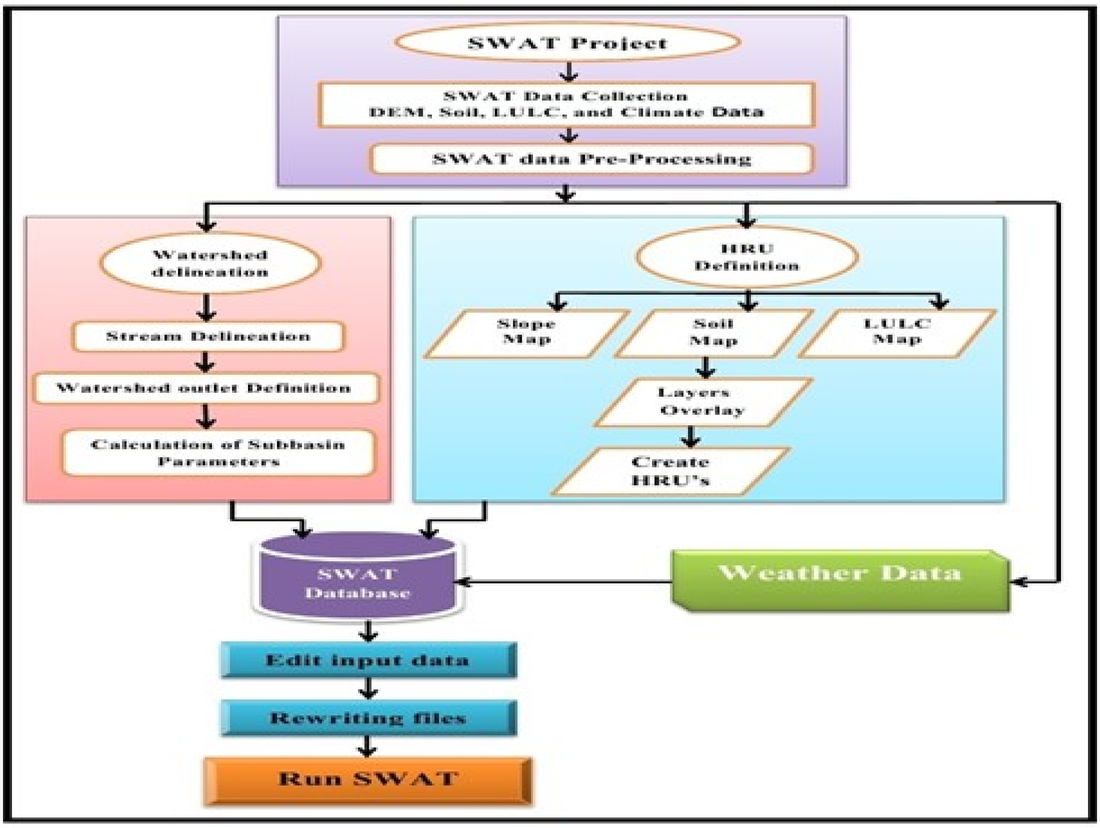

Figure (3) A Schematic Diagram Shows the SWAT Model Setup.

Setup of SWAT Model

After collecting and pre-processed all data required for the SWAT model as the first stage. There are four main steps for the SWAT model setup. A schematic diagram illustrated in Fig. (3) which showed these main steps. It is important here to point out that before running these steps, all data must be in the same projection. It is preferable to use UTM projection because it consists of metric units and more accurate than the geographic projection. The first step in the SWAT model setup is the watershed delineation into sub-basins from a DEM (Tolosa, 2015). The sub-basins size can be determined through editing outlet and inlet points manually. Once the process of the watershed delineation is completed, the creation of Hydrological Response Units HRUs is the next step. HRUs are lumped ground areas within a sub-basin generated by overlaying the LULC layer, soil layer, and slope of the DEM layer as represented in Fig. (4) with various thresholds to recognize unique homogenous individual areas.

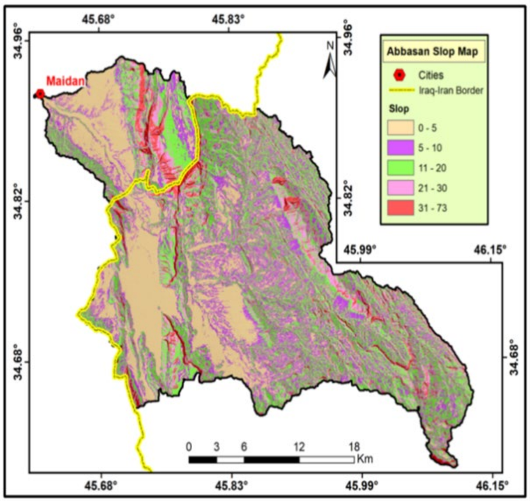

Figure (4) Slop Map of the Abbasan Basin.

The estimate of the runoff separately per each HRU and directed to calculate the runoff total of the watershed improves the accuracy of the model and presented the best physical explication for the balance of water. Thresholds must set when generating HRUs to facilitate computational efficiency and enhance simulation operability (Srinivasan, *et al.*, 2010). After the definition of HRU, all watershed weather data should be loaded into the SWAT. The SWAT-weather generator was used to calculate all the required statistical data from the watershed weather stations, in addition to the locations table, temperature, precipitation, relative humidity, solar radiation, and wind speed were prepared in text format. Then, all loaded and written into the SWAT model (Tolosa, 2015). The database of ArcSWAT will be connected to all layers of data to get all the necessary parameters for assessing the runoff for every HRU.

Results and Discussions

Watershed Delineation

Automatic delineating the total watershed and the catchment of each sub-basin is the first step in building a SWAT model. In the delineation step, the DEM had been used to tracking the initial flow direction and the number of outlet points for each sub-basin. To increase model reliability, the delineation process of the Abbasan watershed was based on the main outlet point which is located at the confluence of the basin with the Diyala River as reoresented in Fig. (5.a). While sub-basins have been delineated based on the area threshold of 3000 ha (30km^2) and manual adjustment of the sub-basins outlets sites illustrated in Fig. (5.b). The results of the Abbasan watershed delineation shown the overall drainage area was 864.7 km^2 with 9 outlets and 9 sub-basins named as sub-basin1 to sub-basin9. The elevation ranges from 312 meters in the southeast to 2566 meters in the northwestern of the Abbasan watershed, nearly 79% of the watershed area is below 1000 meters. The parameters of sub-basins calculation with the path of longest flow, Table (1) showed the information of stream geometry.

HRUs

After delineation of the Abbasan watershed, the area of each sub-basin is subdivided into various HRUs which are the calculated smallest unit in the SWAT model that is defined as unique groups of land use, soil, and slope. The separate analysis for each HRU will improve the SWAT model accuracy that enhances the precision of the forecast of sub-basin loadings, but the outcomes will be lumped per sub-basin and in the final report the averaged for the whole watershed will be calculated. The Abbasan basin subdivided into 217 HRUs based on LULC, slope, and soil layers. Table (2) showed the summary of HRUs data for each sub-basin.

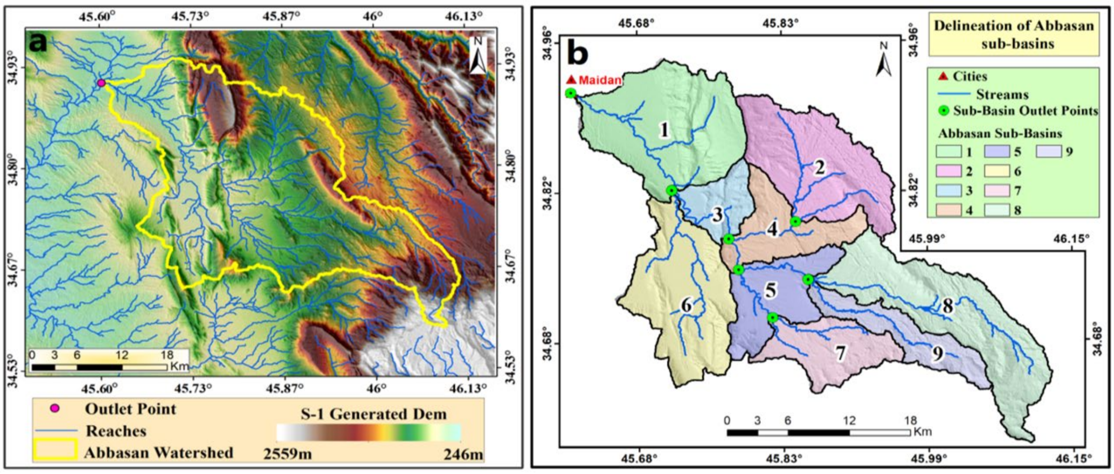

Figure (5) a. The Arc-SWAT Delineation of Abbasan Watershed Depended on the Main Outlet Point; b. Sub-basins Delineation of Abbasan Watershed.

Table (1) The Significant Characteristics of Abbasan Sub-basins.

Sub-Basin	Area Km^2	Perimeter Km^2	The Drainage Area Km^2	Longest Flow Path Km^2	Elevation Min-Max (M)	Average Slop (Degree)
1	156.60	75.58	864.76	30.7	316-1840	11.8°
2	129.10	78.52	129.1	20.9	555-1840	14.7°
3	38.22	39.20	576.35	17.3	404-1773	16.1°
4	64.66	66.59	538.13	17.6	483-1383	10.5°
5	68.87	64.78	344.36	15.1	503-1217	7.5°
6	131.82	81.24	131.82	30.6	405-1092	9.3°
7	63.92	58.89	63.92	18.2	560-1153	9.5
8	156.07	110.77	156.07	43.4	584-5228	15.7
9	55.50	71.11	55.05	29.9	587-1849	13

Table (2) The HRUs Data for Each Sub-basin of the Abbasan Watershed, TC Represent the Time of Concentration. The CN1, CN2, and CN3 Represented the Curve Number at Dry, average Moisture, and Wet Conditions Respectively.

Sub-basin	HRUs	CN1	CN2	CN3	TC(h)
1	23	67.06	82.39	92.96	8.98
2	21	66.33	82.12	92.69	4.96
3	24	69.07	84.17	93.69	8.67
4	37	68.06	83.62	93.32	12.1
5	38	67.81	83.32	93.24	15.4
6	20	68.2	83.15	93.38	9.28
7	20	68.2	83.05	93.38	8.02
8	15	66.9	82.53	92.9	4.65
9	19	67.17	82.41	93	5.98
	Total	Average			
	217	67.6	82.9	93.2	8.7

Quantification of Hydrological Components

There are huge data for many parameters computed by the SWAT model. However, this work use of the SWAT model for analyzing the hydrological components that influence the volume variability of water. The availability of water resources has been computed as an annual average for each sub-basin of Abbasan watershed for the period 1991-2019. Fig.6 (a, b, c, d, e and f) showed the interesting hydrological components including the annual average of potential evapotranspiration (PET), actual evapotranspiration (ETa), soil water content (SWC), surface runoff, groundwater runoff, and water yield (i.e., the amount of water which leaves the sub-basin and contributes to the flow of the stream during the period). Although all sub-basins of the Abbasan watershed have a close amount of the precipitation; the average annual precipitation is varied from 305 to 309 mm/year, but there is a spatial difference in the distribution of other hydrological components through the Abbasan watershed.

Fig. 6 (a, b, c, and d) showed the high value of PET, ETa, SWC, and surface runoff in the west of Abbasan watershed (Sub-basin6), this may be due to the sub-basin6 have the lowest value of mean elevation (405 m) compared with other sub-basins, less rocky outcrops, the wider spread of crop land, and moderate slope (An Average About 17). All of this led to less water yield in sub-basin 6 Fig. 6(f), but the increased surface runoff rate of sub-basin 6 is mainly due to high soil water content and less groundwater flow Fig. 6 (e). The lowest values of ETa were found in upstream sub-basins (Sub-basin 5, 7, 8, and 9) due to the high slope and more rock outcrops except the sub-basin5. The yearly average of surface runoff for the period of 1991 to 2019 varied from 33.63 mm/year to 73.15 mm/year for various sub-basins of the Abbasan watershed Fig. 6(d). The spatial map of runoff distribution indicates that the lower elevation basin has a higher rate of runoff. So, the sub-basin6 whose average height is 568m (The Lowest Average Height Compared to The Rest of The Sub-basins) has the highest surface runoff.

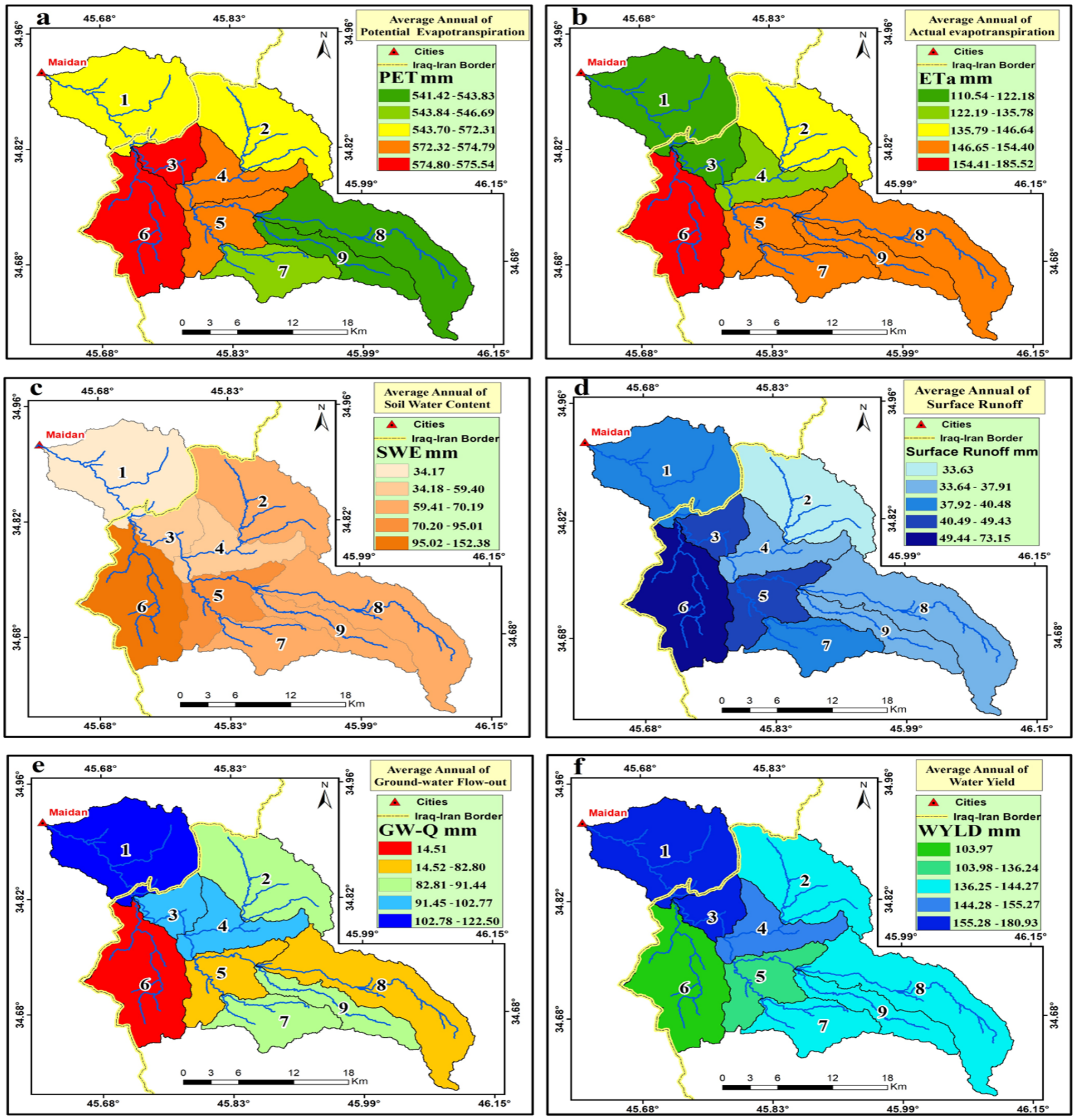

Figure (6) Spatial Distribution of Averages Annual of Hydrological Components in Abbasan Watershed for the Period 1991-2019, (a) Average Annual Distribution of Potential Evapotranspiration (PET); (b) Actual Evapotranspiration (Eta); (c) Soil Water Content (SWC); (d) Surface Runoff; (e) Groundwater Flow-Out; and (f) Water Yield.

Water Balance of the Abbasan Watershed

Hydrologic components are one of the SWAT model components. SWAT model can define the movement of water for each sub-basin, reservoir, pond, the river within the watershed. Three main hydrological parameters that leave the sub-basin and contribute to the streamflow which are surface runoff, lateral flow, and groundwater flow minus the losses of transport (The Water Lost as Re-evapotranspiration from the Shallow Aquifer and Deep Percolation). These three parameters form the water yield of the watershed. Groundwater flow is one of the water yield parameters and at the same time, one of the percolates parameters.

Table (3) and Fig.7 (a and b) summarized the annual water balance components for the period 1991-2019 on a monthly base at the Abbasan watershed outlet, which revealed that about 32 % and 48% of the annual rainfall was lost by percolation and evapotranspiration respectively. The simulation result of the hydrologic components indicated that the main contributor to the total flow of Abbasan watershed was the base flow (Lateral Flow Plus Groundwater Flow) with the percent of 69% of total streamflow, while the contributes the surface runoff about 31% of total streamflow. The results of an average annual basis show that more than 59% of the water in mainstream consequence from groundwater flow.

Fig. 7(b) shows the relationship between the average rainfall and water yield, percolation, and evapotranspiration. The highest value of rainfall takes place during the months from November to March. On the other hand, the average monthly of ET is very high during the summer season with a peak from May to July. Table (3) indicates that March has the highest surface runoff value with an average of about 10 mm/ month.

Table (3) Average Monthly Hydrological Components which Represent Water Balance of the Abbasan Watershed for the Period 1991-2019. Where the SURF-Q Represents Surface Runoff; LAT-Q Represents Lateral Flow; GW-Q Represents Groundwater Flow; REVAP Represents the Water in the Shallow Aquifer Returning to the Root Zone; D-RCHG Represents Deep Aquifer Recharge; and ET Represents Actual Evapotranspiration.

Month	Rain (mm)	SURF-Q (mm)	LAT-Q (mm)	GW-Q (mm)	REVAP (mm)	D-RCHG (mm)	ET (mm)
Jan	43.62	6.42	1.75	6.54	0.07	0.51	2.90
Feb	40.88	8.27	1.86	9.95	0.13	0.74	5.33
Mar	49.22	10.27	2.15	14.87	0.27	0.96	10.23
Apr	42.55	7.82	2.12	17.39	0.41	1.00	14.94
May	18.29	1.65	1.54	17.15	0.74	0.77	23.34
Jun	1.59	0.01	0.57	10.23	1.99	0.34	43.50
Jul	1.13	0.00	0.22	3.20	2.77	0.16	30.32
Aug	0.79	0.00	0.10	0.17	2.77	0.06	5.22
Sep	1.06	0.00	0.06	0.07	1.54	0.03	2.83
Oct	21.18	1.09	0.15	0.10	0.41	0.02	2.31
Nov	44.78	4.48	1.17	0.36	0.12	0.09	3.19
Dec	41.89	4.21	1.77	3.10	0.06	0.31	2.12
Total	306.9	44.23	13.45	83.15	11.27	4.98	146.23
		The Water Yield 140.83			Percolates 16.25		

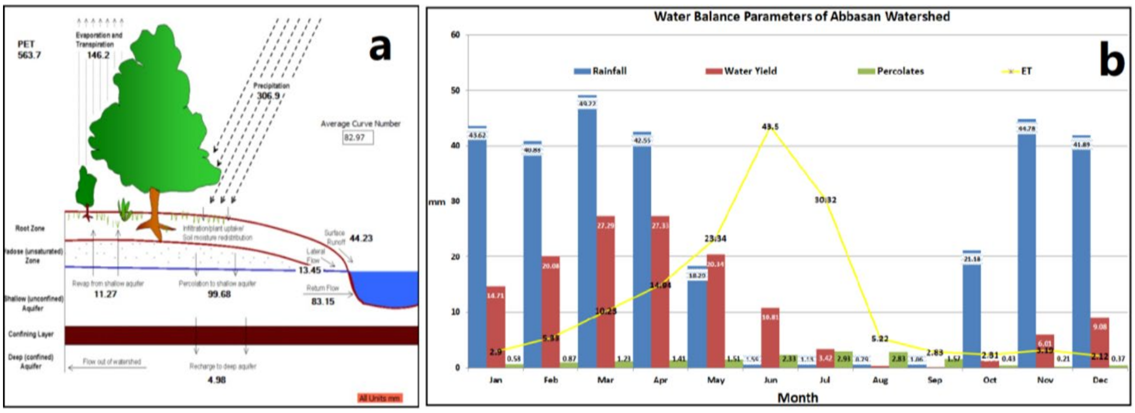

Figure (7) a. Schema Shows the Water Balance of the Abbasan Watershed; b. Histogram of the Abbasan Water Balanced.

Surface Runoff Estimation

The water movement within the basins such as surface runoff and interflow is driven by topography, gravity, and area of contributing that then play role in concentrated the water flow which finally to create the saturated lands where runoff is produced. Other topographic factors with a hydrological effect consist of solar radiation, precipitation, and local temperature. These factors have direct roles in the accumulation of snow, snowmelt, transpiration, evaporation, and hence plant productivity.

Table (4) showed the simulation average annual of rainfall, surface runoff, and water flow with the total water volume of Abbasan watershed the period (1991-2019). The Abbasan watershed is exemplary of mountainous catchments sited in semi-arid climates where dominant surface runoff takes place as a land flow from impervious areas (Average CN about 83) and saturated valleys, the contribution of the hill slope is characterized by the flow. Surface runoff dominates on the area of low slope and bottoms of valleys in Abbasan watershed, especially in the wet time.
From Table (4), the average annual of flow discharge was about 1.43 m^3/s with the average annual of water volume was about 45 million cubic meters, while the average annual of water volume calculated from runoff was about 38 million cubic meters. There is a difference in the average annual volume of water calculated from surface runoff and discharge, and this is because there are other sources involved in increasing discharge, including lateral runoff and groundwater runoff towards the main channel, adding that not all surface runoff water reaches the main channel, some of which are trapped in ponds and behind the spreading barriers Inside the Abbasan basin.

Conclusions

The paper refers to the runoff simulation of the Abbasan watershed located at Iraq-Iran border utilizing SWAT model. The SWAT model was found to give encouraging results for runoff generation and prediction availability of water in watersheds. Also, it has been found that the LULC and soil classes have an important impact in generated the surface runoff.

There is a difference in the average annual volume of water calculated from surface runoff and discharge, and this is because there are other sources involved in increasing discharge, including lateral runoff and groundwater runoff towards the main channel, adding that not all surface runoff water reaches the main channel, some of which are trapped in ponds and behind the spreading barriers inside the Abbasan watershed.

Table (4) Annually Average of Rainfall, Surface Runoff, and Water Flow with the Total Water Volume of Abbasan Watershed for the Period 1991-2019.

Years	Rainfall (mm)	Surface Runoff (mm)	Volume (m^3)	Flow water (Discharge) (m^3/s)	Volume (m^3)
1991	236.08	6.58	5689726	0.164	5175668
1992	272.93	20.56	17778232	0.995	31461585
1993	351.43	39.17	33870299	1.308	41286691
1994	391.89	56.53	48881491	2.030	64056286
1995	221.41	36.39	31466433	1.658	52313103
1996	302.31	20.26	17518822	0.931	29454506
1997	338.5	41.09	35530523	1.299	40998627
1998	271.44	47.09	40718723	1.879	59282326
1999	34.44	0.58	501526	0.020	618600
2000	196.9	3.00	2594100	0.068	2135587
2001	229.94	15.81	13670907	0.502	15847364
2002	270.53	39.27	33956769	1.193	37634263
2003	289.15	18.84	16290948	0.553	17454829
2004	299.83	31.05	26848935	1.514	47881712
2005	371.01	101.22	87524934	2.224	70192901
2006	359.19	52.99	45820453	1.510	47644127
2007	324.08	67.68	58522896	2.190	69118666
2008	250.86	12.59	10886573	0.452	14294837
2009	316.1	38.58	33360126	1.204	38007752
2010	221.36	16.94	14648018	1.133	35747632
2011	292.68	32.44	28050868	1.272	40124854
2012	306.35	27.11	23442017	0.817	25835852
2013	293.68	40.47	34994409	1.401	44212682
2014	305.1	31.66	27376402	1.257	39678291
2015	382.78	78.4	67792480	1.922	60647051
2016	364.15	82.78	71579866	2.935	92814081
2017	286.42	50.64	43788408	1.686	53199758
2018	623.56	144.2	124689740	3.269	103149869
2019	495.01	128.76	111338772	4.021	126885722
Average	306.9	44.23	38,245979	1.428	45,056906

References

AbdelRahman, M., Natarajan, A., and Hegde, R. (2016). Assessment of Land Suitability and Capability by Integrating Remote Sensing and GIS for Agriculture in Chamarajanagar District, Karnataka, India. The Egyptian Journal of Remote Sensing and Space Science, 19(1), 125–141.

Al-Ansari, N. (2013). Management of Water Resources in Iraq: Perspectives and Prognoses. Engineering, 5(6), 667–684.

Boithias, L.; Sauvage, S.; Lenica, A.; Roux, H.; Abbaspour, K. C.; Larnier, K.; … and Sánchez-Pérez, J. M. (2017). Simulating Flash Floods at Hourly Time-step Using the SWAT Model. Water, 9(12), 929.

Byakod, K.; Shivapur, A. V., and Venktesh, B. (2017). Application of Swat Model for Generating Surface Runoff and Estimation of Water Availability for Balehonnuru Catchment Area for Badhra River Basin. International Research Journal of Engineering and Technology (IRJET), 4(8), 1143–1148.

Ezz-Aldeen, M.; Al-Ansari, N., and Knutsson, S. (2012). Application of SWAT model to estimate the runoff and sediment c from the Right Bank Valleys of Mosul Dam Reservoir. In International Conference on Scour and Erosion: 27/08/2012-31/08/2012.

FAO (Food and Agriculture Organization of the United Nations). (2007). Digital Soil Map of the World (DSMW). Retrieved December 20, 2019, http://www.fao.org/geonetwork/srv/en/metadata.show?id=14116

Farr, T. G.; Rosen, P. A.; Caro, E.; Crippen, R.; Duren, R.; Hensley, S.; … and Roth, L. (2007). The Shuttle Radar Topography Mission. Reviews of Geophysics, 45(2).

Ferretti, A.; Monti-Guarnieri, A.; Prati, C.; Rocca, F., and Massonet, D. (2007). InSAR Principles-guidelines for SAR Interferometry Processing and Interpretation, TM-19. The Netherlands: ESA Publications.

Fuka, D. (2013). Simplifying watershed modeling.

Gassman, P. W.; Sadeghi, A. M., and Srinivasan, R. (2014). Applications of the SWAT Model Special Section: Overview and Insights. Journal of Environmental Quality, 43(1), 1–8.

Green, W. H., and Ampt, G. A. (1911). Studies on Soil Phyics. The Journal of Agricultural Science, 4(1), 1–24.

Ketelaar, V. B. H. G. (2009). Satellite Radar Interferometry: Subsidence Monitoring Techniques (Vol. 14). Springer Science & Business Media.

Neitsch, S. L.; Arnold, J. G.; Kiniry, J. R., and Williams, J. R. (2011). Soil and Water Assessment Tool Theoretical Documentation Version 2012. Texas Water Resources Institute.

Ngo, S.; Hoang, H.; Tran, P., and Nguyen, L. (2020). Application of SWAT Model to Assess Land Use and Climate Changes Impacts on Hydrology of Nam Rom River Basin in Vietnam.

Rossi, C. G.; Srinivasan, R.; Jirayoot, K.; Le Duc, T.; Souvannabouth, P.; Binh, N., and Gassman, P. W. (2009). Hydrologic Evaluation of the lower Mekong River Basin with the Soil and Water Assessment Tool Model.

Srinivasan, R; Arnold, J. G., and Jones, C. A. (1998). Hydrologic Modelling of the United States with the Soil and Water Assessment Tool. International Journal of Water Resources Development, 14(3), 315–325.

Srinivasan, Raghavan, Zhang, X., and Arnold, J. (2010). SWAT Ungauged: Hydrological Budget and Crop Yield Predictions in the Upper Mississippi River Basin. Transactions of the ASABE, 53(5), 1533–1546.

Tolosa, D. (2015). Modeling Sediment Yield Using Arcswat and Analyzing the Most Prominent Remedial Measures: Cases of Melka Wakena Reservoir, Ethiopia. Addis Ababa University.

Tyagi, J. V; Rai, S. P.; Qazi, N., and Singh, M. P. (2014). Assessment of Discharge and Sediment Transport from Different Forest Cover Types in Lower Himalaya Using Soil and Water Assessment Tool (SWAT). International Journal of Water Resources and Environmental Engineering, 6(1), 49–66.

USDA, S. C. S. (1972). National Engineering Handbook, Section 4: Hydrology. Washington, DC.

White, E.; Easton, Z.; Fuka, D.; Collick, A.; Adgo, E.; McCartney, M. and Steenhuis, T. (2008). Adapting the Soil and Water Assessment Tool (SWAT) for the Nile Basin. CGIAR Challenge Program on Water and Food, 22.