Flood Forecasting in Upper Zab River Using SWAT hydrological Model

استخدام الموديل الهيدرولوجي SWAT
في حوض نهر الزاب الاعلى لاغراض التنبؤ بالفيضانات المستقبلية

Oday Tamween Ajeel AL-Heetimi (1) , Luct. Wisam Abidalabbas Abidalla (2)

Asst. Prof. Dr. Jabbar Abbas Jaber (3)

(1) State Commission for Dams and Reservoirs , Iraq , (2 , 3) Mussaib Technical Institute - Babylon , Iraq

Abstract: -

Flood forecasting is linked to a prior knowledge of future probable precipitation amounts. Hydrological models are a way that can enable transforming observed precipitations into stream flow. In this work a GIS based hydrologic model, SWAT is used in an Upper Zab River basin at Eske Click for flood forecasting. The importance of this work comes due to Upper Zab River is an uncontrolled river (has no dam yet); therefore it is discharged impacts of Tigris river discharges due to it is supplying about 33% from all over discharges also; impacts of amounts of sediment load comes on it. The catchment area for this watershed has an approximate drainage area of 19350.17 km2, which is divided into 9 sub basins. Results showed that the annual mean flow discharge for the period 1976 to 2006 was 392.32 m^3/s which agreed with the model result which is shows that the average annual basin simulation values was 390.2 m^3/s for the same period. While result simulation for the period 2015 to 2075 gave 333.70 m^3/s which mean there is a reduction in mean flow discharge between two periods about 15%. Moreover, annual average basin simulation precipitation amount reduced from 1057 to 1038 mm which mean decrease about 2% between same periods .Also climate change impact was so clear in simulation results as one of climate parameters which is evapotranspration (ET) was increased from 378.3 mm to 450.2 mm which mean there is an increase about 19% between two periods simulations due to temperature increased.

Keywords: SWAT Model, Hydrological model, Flood Forecasting, Upper Zab River

الخلاصة :

ترتبط احتمالية تساقط الأمطار والثلوج بموضوعة التنبؤ بالفيضانات . ويعتبر الموديل الهيدرولوجي إحدى طرق تحويل القراءات الحقيقية للسقيط إلى كميات جريان . تم تطبيق احد أدوات برنامج نظم المعلومات الجغرافية (GIS) والمسمى الموديل الهيدرولوجي (SWAT) على تصاريف نهر الزاب الاعلى عند اسكي كلك لغرض التنبأ بالفيضان. اهمية هذا العمل تأتي من خلال ان نهر الزاب الاعلى هو نهر غير مسيطر عليةاي لم يتم تشييد سد عليه لغايه الان.لذا فان تصاريف النهرلها تأثير اساسي بتصاريف نهر دجلة كونه احد روافد نهر دجلة المغذية الرئيسية حيث يجهز ما يعادل 33% من واردات نهر دجلة إضافة إلى التأثير السلبي للأحمال الرسوبية المنقولة بواسطة تلك التصاريف. تبلغ مساحة حوض التغذية لمنطقة الدراسة حوالي 19350.17 كم^2 ومقسمة إلى 9 أحواض ثانوية. ان المعدل السنوي للتصاريف المائية لنهر الزاب للفترة الممتدة من 1976-2006 بمقدار 392.32 م^3/ثا والتي توافقت مع نتائج الموديل الهيدرولوجي التي اعطت قيم مقاربة حيث كان المعدل السنوي بمقدار 390.2 م^3/ ثا لنفس الفترة الزمنية. بينما نتائج المحكاة للموديل للفترة من 2015 - 2075 اعطت معدلات تصاريف سنوية بلغت 333.7 م^3/ثا هذا يعني وجود تناقص بمعدلات التصاريف بين الفترتين بمقدار 15% إضافة إلى نقصان في المعدلات السنوية للسقيط من 1057 إلى 1038 ملم سنويا أي بمقدار تناقص 2% بين نفس الفترات. وبرزت بشكل واضح تأثير التغيرات المناخية عند تشغيل النموذج الهيدرولوجي لفترات مستقبلية على المعاملات المناخية كالتبخر النتح (ET) حيث بلغت الزيادة من 378.3 ملم إلى 450.2 ملم اي بمقدار 19% نتيجة توقع زيادة درجات الحرارة .

1. Introduction

Several models were developed in the past century and are currently applied for the water resource management. SWAT model (Soil and Water Assessment Tool) is one of those models. SWAT model was developed by United States Department of Agriculture-Agricultural Research Service (USDA-ARS) to forecast the impact of land management practices on water, sediment and agricultural chemical yields in large occupied basins [1]. SWAT consists of many components like soil water percolation, interception, surface runoff, infiltration, lateral flow, evapotranspiration, sediment loading, groundwater flow and channel routing processes which is creating major water budget. The model runs on a daily time step for short or long term predictions and operates in a semi-distributed manner to account for spatial differences in topography, soils, land use, crops, channel morphology, and climate conditions. The data are processed spatially using GIS tools, Arc SWAT interface, which is an ArcGIS extension, was used. Due to the simplicity of the model algorithm and less number of data requirement, leads to choose the Soil and Water Assessment Tool. Also; there are many advantages regarding SWAT model such as model is computationally efficient, it is able to study long-term impact, it can simulate many and specialized (bacterial growth) physical processes compared to any other single physically based model, it can work with small number of input data. The objective of this study is to build up a hydrological river basin model for the Upper Zab River basin at Eske Kelek to estimate and forecast flood discharges river basin as Upper Zab river considered as an important resource for Tigris river due to limited resource for it and this this tributary is an uncontrolled river (has no dam yet). The discharge amount supplies by Upper Zab to Tigris represents about 33% from all over Tigris river discharges which is large percentage. Upper Zab flows along 462 km length; so estimation of river discharge is so important for Tigris river supplies and quantity amounts of sediment loads for the river.

2. Literature Review

Numerous of models were developed in the past century and are currently applied for the water resource management. SWAT model is one of them and been used by several researchers. [2] used the SWAT model to predict runoff and sediment loss in India for Nagwan basin. They also developed a decision support tool to identify the priority areas for soil and water conservation measures. [3] have evaluated SWAT model for flow simulation and forecasting in the upper Bernam humid tropical river basin which is the main water source in aimed area. The historical records between 1981 to 2007 were used. The period between 1981 to 2004 used for calibration whereas between 2005 to 2007 for validation of both simulation and forecasting. The model has shown a good performance in forecasting and simulating. Five scenarios used to discover stream flow with the individual effect of mixed land use change. Results illustrated that the land use changes are responsible for an increase in the annual flow depth between 8% to 39% while 16% to 59% during high flow months whereas decreases by 3% to 32% in months which have low flow. Flow forecasting for 2020 using 30 forecasting cycles which found to be the optimal for the study area. Also; they showed that SWAT model have capability to simulate and forecast flow in humid tropical condition effectively. [4] applied SWAT model in Philippines to investigate the impact of land use such as cover of grasslands and forestland to agricultural lands on runoff and sediment yield. In their research of the Manupali watershed, result showed that if 50% of the pasturelands and grasslands will be converted to cultivated lands there will be a drastic increase in sediment yield, and will consequently decrease the base flow from 2.8% to 3.3%. Regarding [5] are used the Model to evaluate the hydrologic sensitivity of the San Joaquin Watershed to climate change. The results indicated that the watershed is very sensitive to potential future climate scenarios. The study revealed that a 37.5% decrease in evapotranspiration (ET) will lead to an increase in water yield (36.5%) and stream flow (23.5%), and that increased temperature can cause temporal shifts in plant growth patterns which will affect ET and irrigation water demand. However, increase in precipitation by ±10% and 20% generally changes the stream flow and water yield, so will have negligible effects on predicted ET and irrigation water use. [6] used soil and water assessment tool in simulating stream flow for the Chi River Sub basin II which is located northeast of Thailand. The calibration and validation for the results were done by comparing predicted stream flows with equivalent in-stream measurements from four gauging stations within the watershed for four years (2000-2003). Statistical comparisons between the simulated results and the observed data for the calibration year gave a realistic agreement for both monthly coefficient of determination (r^2) and Nash-Sutcliffe Coefficient (E), in other hand the validation results showed lower values of E and r^2. The model has the capability to predict stream flows within the Chi River Sub basin II in northeast Thailand. Indeed. [7] applied SWAT for simulating the hydrologic pattern of Paraopeba river basin which is located in Minas Gerais state under different land use and occupation scenarios. The model parameters were calibrated and validated, for observed data from 1983 to 2005. The model was found to be highly sensitive to base flow, its main calibration variable. Statistical analyses produced a Nash-Sutcliffe coefficient above 0.75, which is considered good and adequate. SWAT model presented satisfactory results in simulating hydrologic pattern under different scenarios of land use change, also indicating it can be applied for forecasting discharge in the aforesaid basin. [8] used SWAT model to evaluate the sensitivity of model simulated stream flow to climate change within the Eastern Nile River basin .The model was run with daily station based on precipitation and temperature data for whole Eastern River basin including three sub basins the Abbay (Blue Nile), BaroAkobo and Tekeze. The daily and monthly stream flows were calibrated and validated. The model performed very well in simulating the monthly variability while the validation against daily data discovered a more varied performance. [9] was simulated the stream flow in Beijing River Basin. The SWAT model used to assess changes in stream flow in the Beijing River Basin using 15 sets of climate change scenarios. Results show that water yield decreases when temperature increases while, evapotranspiration (ET) will increase but rainfall does not change. Furthermore, water yield and ET will increase more or less when rainfall increase while temperature does not change. So, the model showed good results. Also, [10] assessed the impacts of climate change on the hydrological regime of Cauvery River Basin in India by using the hydrological model SWAT. On the other hand. For the purpose of flood forecasting, [11] used SWAT and GIS technology. Their study focused of quantifying the impact of land use, topography, soil and climate condition on water discharge in Be river basin in Vietnam. Results simulation in the period 1979 to 2007 represented fluctuation of discharge relatively well with both R^2 and NSI values were above 0.7 in the period 1979 to 1994. The results showed that the flood season on both sub-basins was defined as lasting from June to November with an average water discharge was ranged from 224.55m^3/s at Phuoc Long to 458.53m^3/s at Phuoc Hoa. On the contrary the dry season which is December to May water discharge was low, ranged 30.85m^3/s at Phuoc Long to 60.49m^3/s at Phuoc Hoa . The results showed that integrate GIS technology and SWAT model was suitable for simulating the water discharge in Be river basin and can be applied for other river basins.[12] examined the material transfer and identify critical sub-basins in Layawan watershed, Mindanao Philippines using SWAT model .The model used to investigate changes in land use. From the study the results indicates that a 4% reduction in sediment concentration and sediment yield in the critical sub-basins will be achieved if the community-based watershed management plan is preformed. On the other hand, sediment concentration and sediment yield increased about 106% in case of forests are cleared for utilization for agriculture in the critical sub-basins. [13] used hydrological modeling of a SWAT with the application of three days weather forecast from the numerical weather prediction (NWP) which provided temperature, rainfall, relative humidity, sunshine and wind speed. Both data from NWP and SWAT were used to simulate the runoff from the Nan River in the last 10 years (2000-2010). The results shows that the simulated flow rate for the main streams using the NWP data was more than the observations at N64 and N1 stations and the ratios of maximum simulated flow rate to the observation were about 108% and 118% respectively . In contrast the tributaries flow rate simulated were lower than observations, but within the acceptable values not more than 20% and the ratio of maximum simulated were 90.0%, 83.0% and 86.0%, respectively. The reason for the rainfall from NWP model being higher than measured rainfall is due to the rainfall distributed over all area, but the measured data was in specific points.

3. Study Area

Upper Zab river basin at Eski Kelek located between Turkey and Iraq outlet of the watershed is at Latitude 36° 16′ 00″ N, Longitude 43° 39′ 00″ E. The total drainage area of Upper Zab River at Eski Kelek is approximately covers 19325.170 km^2 which is calculated by the model. The majority of the catchment is located in Iraq which is covers about 60% of the total area and the remaining of the basin located in turkey as shown in Figure 1. The model automatically divided the watershed into 9 sub basins and the description of each sub basin illustrated in Table 1. Upper Zab River collects the water from many tributaries. The river and its tributaries are primarily fed by rainfall and snowmelt as a result of which discharge fluctuates highly throughout the year.

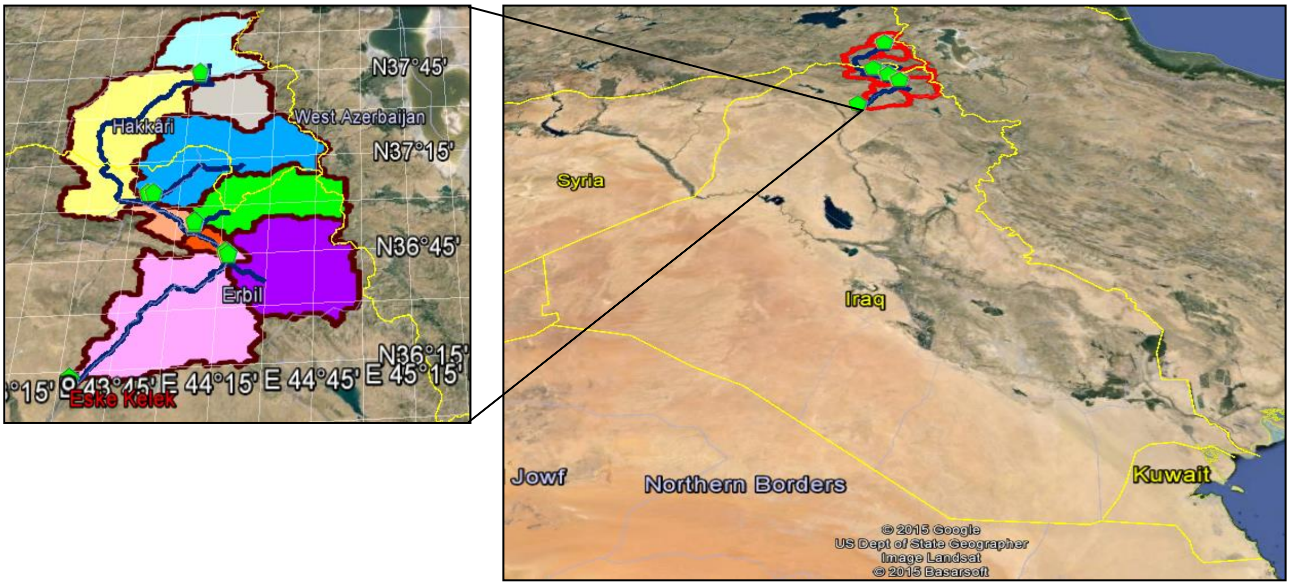


Figure 1. Watershed of Upper Zab River at Eske Kelek.

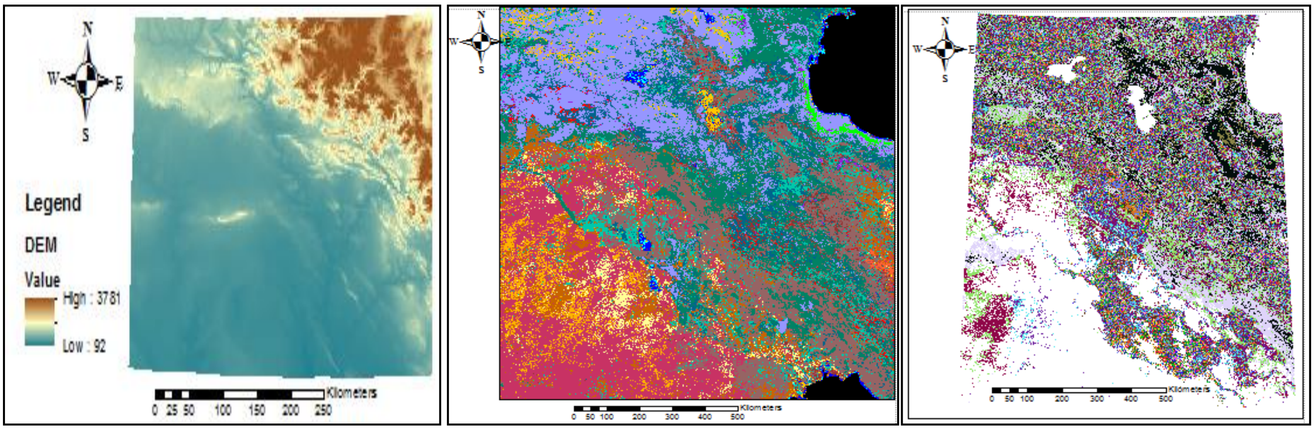
Table.1 Watershed Sub basins Description.

Sub Basin	Area [ha]	Elevation[m]	Land Description	Water [%]
1	183013.56	1599-3666	Forest Evergreen , Row Crops	9.47
2	121478.57	1688-3666	Forest Evergreen, Generic	6.29
3	379642.63	594-3651	Forest Evergreen, Row Crops	19.64
4	341094.85	624-3781	Forest Deciduous, Row Crops	17.65
5	46504.89	462-2170	Forest Deciduous, Row Crops	2.41
6	197336.36	522-3304	Forest Deciduous, AGR Land	10.21
7	25109.10	419-1707	Forest Evergreen - Row Crops	1.30
8	272133.21	400-3514	Forest Evergreen - Row Crops	14.08
9	366203.95	228-1938	Forest Deciduous	18.95

4. Materials and Methods

4.1 Materials

The spatial data which include the digital elevation maps (DEM) for the study area is acquired from the CGIAR-CSI website. The CSI is Consortium for Spatial Information and the CGIAR is the community of geo-spatial scientists. The CGIAR-CSI is able to provide 90(m) digital elevation data for the entire world. The digital elevation data, produced by NASA originally. The DEM for the entire globe, covering all of the countries of the world, are available for download on their site and have a resolution of 90(m) at the equator .The other spatial data is land cover map for study area. The land cover maps were obtained from the website of European commission's Joint Research Center (JRC). The presented map is part of project called Global land cover 2000 maps is a collaboration of partners around the world with the general objective to provide for the year 2000 a harmonized land cover database over the whole globe. The global data was at resolution 1km. Also, spatial data include the soil maps which are taken through the website World Soil Information. It is an independent science-based foundation. The soil maps produced Soil Grids with resolution 1km for soil properties and soil classes by taking a global soil mask using automated global soil mapping. Figure 2. (a, b, c) illustrates sets of required spatial data for SWAT hydrological modeling input.



(a)Digital Elevation Map data (b) Digital Land use data (c) Digital Soil Data

(Source: http://srtm.csi.cgiar.org) (Source: http://bioval.jrc.ec.europa.eu) (Source: http://soilgrids1km.isric.org/)

Figure 2. The spatial data for SWAT model.

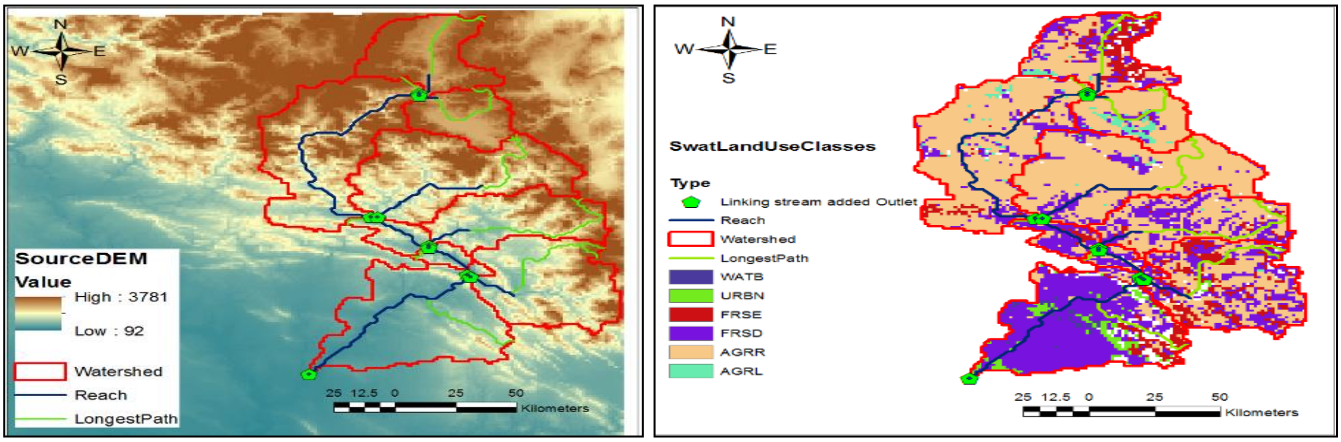
4.2 Method

The SWAT model simulates hydrology as a two-component system, composed of land hydrology and channel hydrology. The land portion of the hydrologic cycle is based on a water mass balance. Soil water balance is the primary consideration by the model in each hydrological response unit (HRU), which represent as follow[1]:

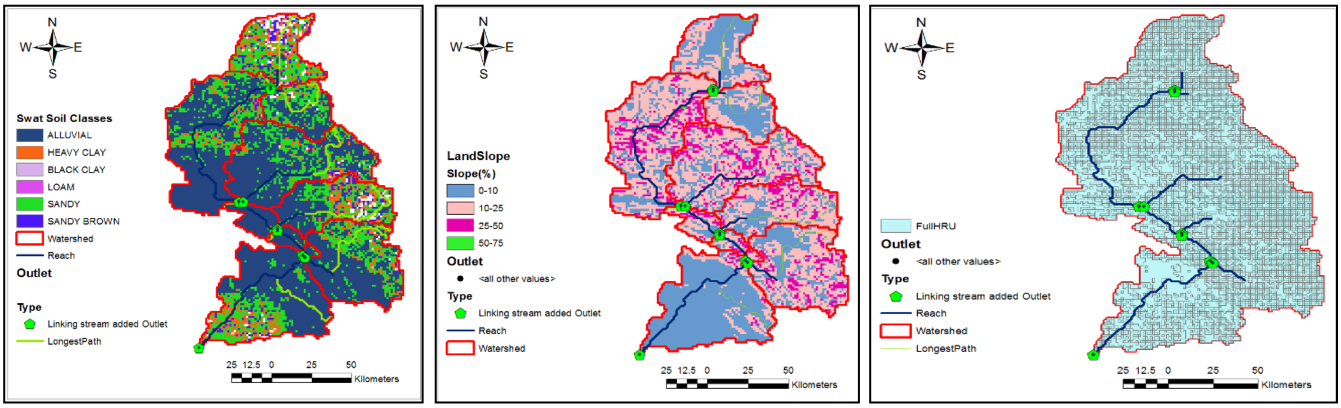
$$SW_t = SW + \sum_{i=1}^{t} (R_i - Q_i - ET_i - P_i - QR_i)$$

Where *SW* is the soil water content; *i* is time in days for the simulation period *t*; and *R*, *Q*, *ET*, *P* and *QR* respectively, are the daily precipitation, runoff, evapotranspiration, percolation and return flow.

First step in build up the model is to delineation of the watershed this was performed by using the automatic watershed delineation option in Arc Swat interface, which was based on the DEM of study area where pour points were automatically selected from where the grid drains at its edges, and watershed were delineated. It involved DEM-set up, stream definition, outlet and inlet definition, main watershed outlet selection and calculate sub-basins parameters. Land use and soil type data were loaded and then reclassified; also slope of the watershed has been defined. We used multiple classes slope for the watershed and then overlaid to represent the study area conditions. So, the distribution of hydrologic response units (HRUs) within the sub basin was determined based on the land use, soil and slope data layers specified in the previous step. SWAT has the ability to divide the watershed into smaller sub-basins and subsequently into Hydrologic Response Units (HRU) which is a unique combination of a land use, a soil type and slope that are overlapped in each sub-basin. More the catchment is homogenous (big number of HRU) more easy to manipulate the model. [14] said that 'the water balance of each HRU is represented by four storage volumes: snow, soil profile (0-2m), shallow aquifer (typically 2-20 m) and deep aquifer (>20m)'.So, HRUs can be used to assess the varying hydrologic conditions between sub-watersheds. Subdividing the watershed into areas having unique land use, soil and slope combinations enables the model to reflect differences in evapotranspiration and other hydrologic conditions for various crops and soils. With SWAT model, runoff is predicted separately for each HRU and routed to obtain the total runoff for the watershed. This increases accuracy and gives a much better physical description of the water balance.. After defining HRU's we found number of HRU's for watershed is 101 for 9 sub-basins .Figure 3.Illustrated Delineation of the watershed, Land Use, Soil, Slop and HRUs maps for the watershed.



(a)Delineation Watershed. **(b) Swat Land Use Classes.**



(c) Swat Soil Classes **(d) Swat Slope Classes** **(e) Hydrologic Response Units (HRUs)**

Figure 3. Illustrated (a) Delineation of the Watershed (b) Land Use (c) Soil (d) Slope and (e) Hydrologic Response Units (HRUs) Maps for the Watershed.

5. Results and Discussion

Simulation has carried out for the watershed in different scenarios. The first period of simulation which covered the years between 1976 to 2006 which is the available data records and the second period of simulation were for the period 2015 to 2075. The monthly simulation scenarios result is shown in table 2(a,b) for two periods. From the results noticed that the model has been calculated many parameters, but since the model developed for flood forecasting, so in this research will focus and analyzing the influence of hydrologic parameters on the stream flow variability and estimation of monthly and average annual basin value at the outlet of the watersheds that will effect on the river discharges. Data observed discharges for the river were, between January 1976 to the end of December 2006. Some missing data were found which are January, February, March and April 1991; also from February to September 1992 as shown in table 3. Discharge measurements were made from the bridge at Eske Kelek. The extremes and statistics measurements for monthly and annual mean discharge at stream flow-gaging station, Upper Zab River at Eski Kelek for water years 1976 – 2006 illustrated below in table 4. Moreover; figure 4 shows monthly discharge mean, maximum and minimum at stream flow-gaging station, Upper Zab River at Eski Kelek, for water year's 1976–2006. Figure 4 illustrated that the mean extreme discharge values concentrate between March to June which agrees with model simulation results shown in table2 (a, b) which is the extreme values of surface discharge between March to June.Also; table 2 (a, b) indicated that the maximum precipitation values also obtained from March to June consequently the surface runoff. Furthermore, from the table 4 the annual mean flow discharge was 392.32 m^3/s which agreed with the average annual basin simulation values for the period 1976 to 2006 which was 390.2 m^3/s as shown in table 5(a) .As well the annual average basin simulation precipitation amount was 1057 mm by comparing this amount with Hakkari weather station in Turkey which is the station that used in the model that has a historic records between (1960-2012) precipitation was 900 mm, the location of weather station on the watershed illustrate in figure 5. Although the annual average participation is higher, but the mean monthly was about 897.23 mm. The reason for the simulation of annual average value being greater than the observed value that because the rainfall from the SWAT model being higher than measured rainfall is due to in the model the rainfall distributed over all areas, but the measured data was on specific point.Therefore, the rain from the SWAT model is very useful especially in the watershed areas which give more safety as the most designer design on the worst case scenario which increase factor of safety. This result agrees with [12]. Their results show that the simulated flow rate for the main streams was more than the observations and the ratios of maximum simulated flow rate to the observation were about 108% and 118% respectively. In contrast the second simulation results illustrated in table 5(b) which covered years between 2015-2075 shows that the annual mean flow discharge was 333.70 m^3/s. It is mean there is a reduction in mean flow discharge between 1976 to 2006 and 2015 to 2075 about 15%. In addition the annual average basin simulation precipitation amount was 1038 mm which means decrease about 2% between 1976 to 2006 and 2015 to 2075. Even though precipitation redaction was small in future period simulation, but the flow has affected more than precipitation due to climate change impact as temperature will increase and all climate parameters will also change as the simulation results show there is an increase in evapotranspration (ET) between current and future simulation scenario. ET increased from 378.3 mm to 450.2 mm which mean there is an increase about 19%.

Table 2(a): Average Monthly Basin Simulation Values for the Watershed in 1976 to 2006.

AVE SIMULATION MONTHLY BASIN VALUES						
MON	RAIN(mm)	SNOW FALL(mm)	SURFACE(Q) m^3/sec	ET(mm)	SEDIMENT (ton/ha)	PET(mm)
1	64.6	22.66	24.01	18.72	3.83	55.52
2	67.77	14.72	25.17	20.47	7.08	61.62
3	89.65	6.81	30.47	35.81	8.36	124.07
4	105.8	0	39.99	42.51	12.39	147.56
5	127.57	0	65.53	62.79	18.75	170.8
6	82.46	0	38.059	75.08	8	201.23
7	7.03	0	10.71	69.36	1.29	229.44
8	18.17	0	23.31	38.16	1.41	214.96
9	88.47	0	22.29	24.08	3.26	171.37
10	80.29	0	31.07	26.94	3.47	123.86
11	83.68	1.38	28.44	21	3.85	81.29
12	81.74	23.94	25.76	18.77	3.19	56.58

Table 2(b): Average Monthly Basin Simulation Values for the Watershed in 2015 to 2075.

AVE MONTHLY BASIN VALUES						
MON	RAIN(mm)	SNOW FALL(mm)	SURFACE(Q) m^3/sec	ET(mm)	SEDIMENT (ton/ha)	PET(mm)
1	57.46	21.19	18.19	18.59	3.97	55.18
2	73.38	22.53	22.53	20.55	6.85	63.77
3	88.79	2.53	27.46	35.84	9.15	123.66
4	110.8	0	38.87	43.11	14.99	148.66
5	153.22	0	58.65	62.08	16.44	169.33
6	107.36	0	39.64	75.25	8.29	203.76
7	5.24	0	10.97	67.75	1.57	227.99
8	9.82	0	11.56	36.98	1.5	218.4
9	64.18	0	18.39	24.53	2.6	172.46
10	66.91	0	28.37	25.63	3.18	127.25
11	75.99	1.7	27.44	20.96	3.56	81.98
12	77.29	20.29	27.37	18.78	4.11	56.63

Table 3: Monthly and annual mean discharge at stream flow-gaging station, Upper Zab River at Eski Kelek, Iraq, water years 1976 to 2006 .

Water Year	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sept.	Annual mean *(m^3/s)*
1976	110	110	171	232	510	439	1170	1138	715	478	257	162	**458**
1977	206	223	230	253	408	609	698	728	589	394	242	178	**397**
1978	171	161	403	519	621	727	831	747	689	445	225	167	**476**
1979	156	155	289	362	535	524	766	678	566	300	164	130	**385**
1980	196	264	320	320	384	631	759	924	679	379	228	180	**439**
1981	136	257	204	390	564	838	900	899	725	449	229	179	**481**
1982	169	209	250	350	424	522	909	1004	682	367	209	183	**440**
1983	217	231	197	228	321	613	859	932	612	235	173	161	**398**
1984	130	174	240	168	289	545	671	653	570	266	131	105	**329**
1985	106	336	229	352	780	852	1252	1055	546	227	149	130	**501**
1986	114	133	204	308	438	455	701	587	425	230	102	91	**316**
1987	130	289	366	366	580	757	1215	1727	670	357	199	144	**567**
1988	182	264	799	693	696	1635	1690	1559	700	404	173	97	**741**
1989	67	83	103	82	110	242	313	243	96	38	34	35	**121**
1990	45	122	271	145	261	355	667	553	322	118	57	50	**247**
1991	49	55	82	_	_	_	_	411	184	117	67	50	**127**
1992	44	45	350	138	_	_	_	_	_	_	_	_	**145**
1993	140	253	481	364	509	510	1694	2282	1030	282	148	105	**650**
1994	122	220	165	306	320	438	1036	665	773	210	145	102	**375**
1995	130	375	590	483	765	801	1728	1379	710	329	163	105	**630**
1996	131	160	133	318	383	503	868	849	389	195	110	100	**345**
1997	105	125	307	365	325	635	1279	1253	696	355	189	130	**480**
1998	145	170	325	300	525	645	1360	790	435	210	110	100	**426**
1999	108	124	104	123	245	231	440	336	179	84	66	65	**175**
2000	87	75	105	165	205	285	513	347	162	102	73	71	**183**
2001	66	80	235	155	200	440	520	345	240	160	115	80	**220**
2002	85	85	225	485	365	600	1375	1085	560	260	150	123	**450**
2003	107	135	270	315	454	1150	-	1600	850	232	152	110	**489**
2004	140	275	255	525	550	900	595	750	480	275	180	145	**423**
2005	120	280	190	270	50	700	650	620	370	225	165	135	**314**
2006	130	150	160	265	1025	560	1100	915	400	200	175	135	**434**

Table 4.: Extremes and statistics for monthly and annual mean discharge at stream flow-gaging station, Upper Zab River at Eski Kelek, Iraq, water years 1976 to 2006 .

Month	Maximum		Minimum		Statistics		
	Flow(m^3/s)	Water Year of Occurrence	Flow(m^3/s)	Water Year of Occurrence	Mean Flow (m^3/s)	Standard Deviation	Coefficient of variation
October	217	1983	44	1992	124	44.64	0.36
November	375	1995	45	1992	181.22	85.61	0.47
December	799	1988	82	1991	266.22	148.9	0.56
January	693	1988	82	1989	311.5	137.4	0.44
February	1025	2006	50	2005	442.82	211.8	0.48
March	1635	1988	231	1999	625.58	281.4	0.45
April	1728	1995	331	1989	948.53	387.2	0.41
May	2282	1993	243	1989	901.8	460.7	0.51
June	1030	1993	96	1989	534.8	224	0.42
July	478	1976	38	1989	264.1	114.5	0.43
August	257	1976	34	1989	152.66	57.93	0.38
September	183	1982	35	1989	118.26	41.21	0.35
Annual	741	1988	121	1989	392.32	152.8	0.39

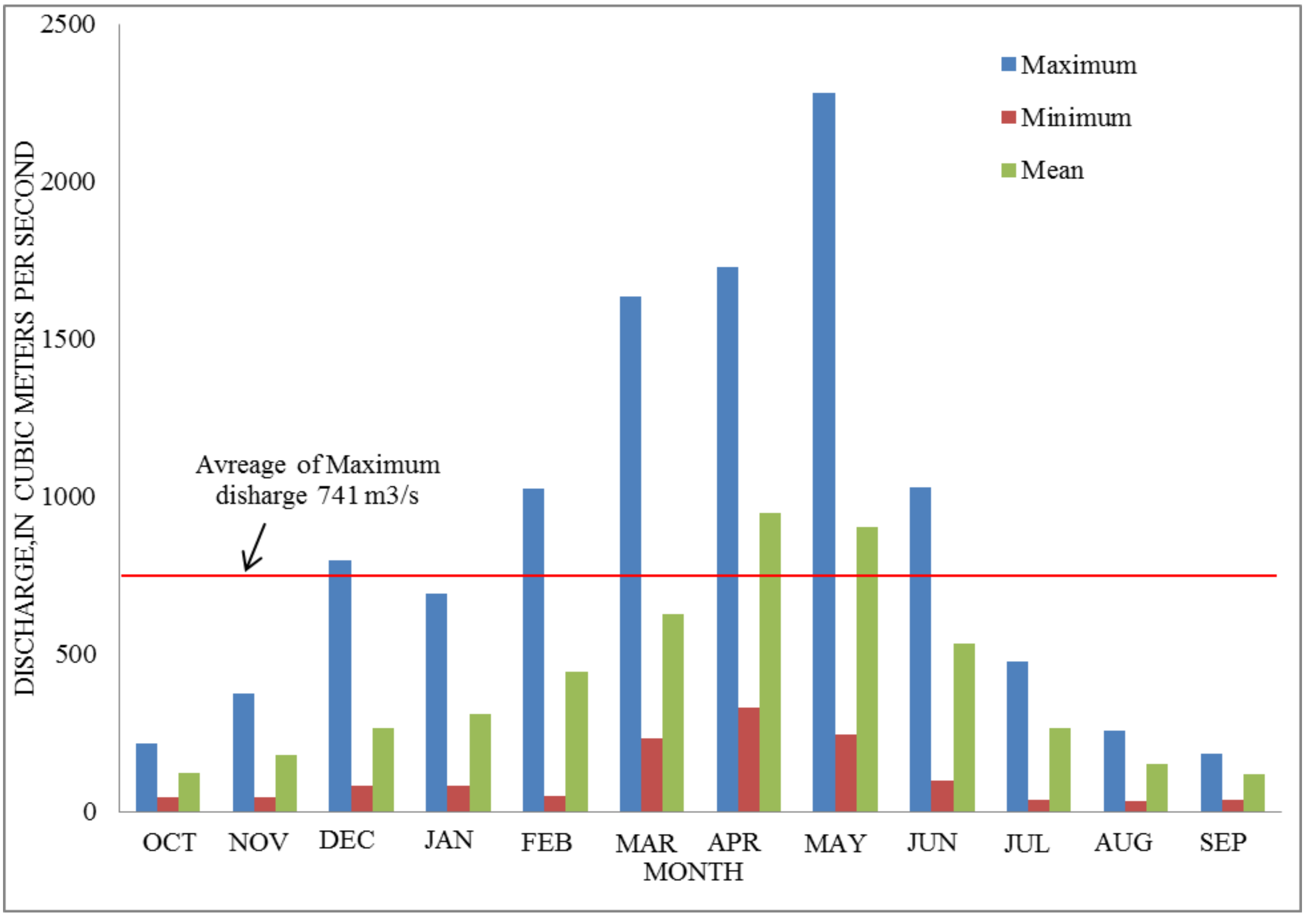


Figure 4. Monthly mean discharge with maximum and minimum Upper Zab River at Eski Kelek, water years 1976 to 2006.

Table 5(a): Average Annual Basin Simulation Values for Period 1976 to 2006

Ave. Annual Basin Values
Precipitation = 1057.8 mm
Snow Fall = 74.17 mm
Surface Runoff = 390.20 m^3/s
Ground Water (shallow aquifer) = 144.26 m^3/s
Ground Water (deep aquifer) = 9.20 m^3/s
Evapotransperation (ET) = 378.3 mm

Table 5(b): Average Annual Basin Simulation Values for Period 2015 to 2075.

Ave. Annual Basin Values
Precipitation = 1038.1 mm
Snow Fall = 68.89 mm
Surface Runoff = 333.70 m^3/s
Ground Water (shallow aquifer) = 116.06 m^3/s
Ground Water (deep aquifer) = 7.55 m^3/s
Evapotransperation (ET) = 450.2 mm

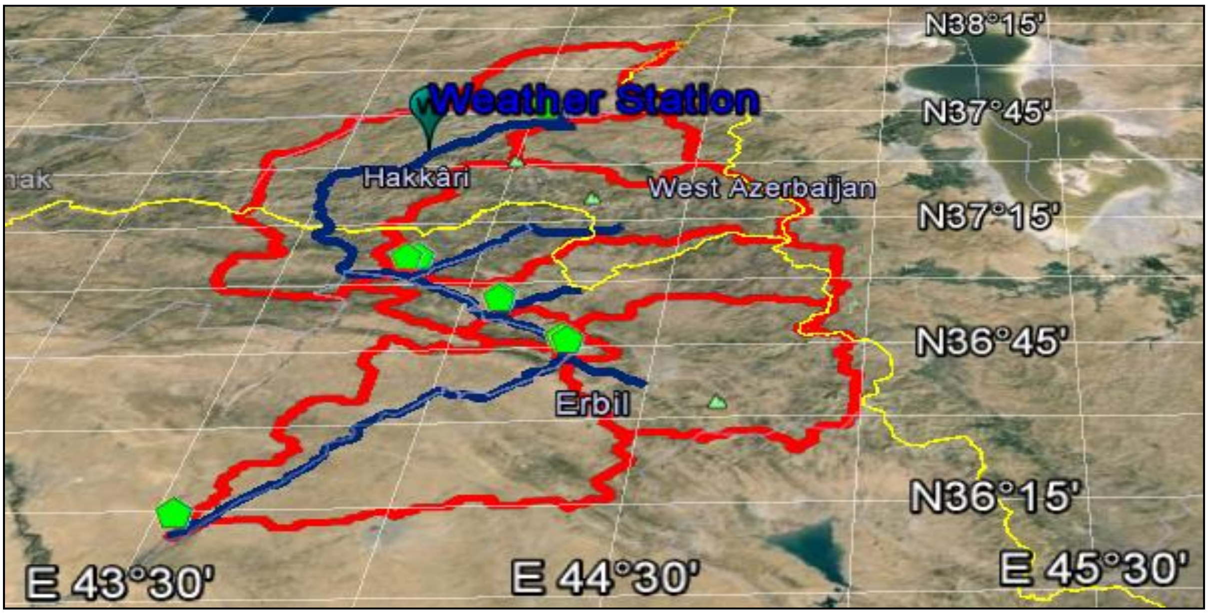


Figure 5. Illustrated Hakkari Weather Station on The Upper Zab River Basin.

6. Conclusion

Hydrological models a good way to convert the precipitation into the flow. The SWAT model considered one of the most efficient hydrological models in this study.SWAT used Upper Zab river basin to forecast the flow and the model was able to simulate and forecast flow in Upper Zab river watershed efficiently and this results will help to study and expects the future amounts of resource discharges in comes on Tigris river and it is effects .results shows there is a redaction on the precipitation and flow on the river basin on the future which will cause impact on the Tigris river resources and a major impact on hydrological regimes. In result this impact will have a direct impact on ecological, economical, social systems and human life.

7. Recomandation

The upper Zab river is uncontrolled tributary on the Tigris basin and this may cause unexpected flow discharges in the future, which may cause economic and social losses so; the good suggestion to the ministry of water resource and the Iraqi government to fasten to implement Bekhme dam which is the suggested dam on the Upper Zab basin. This dam in addition to it is facility to prevent flooding on the Tigris river, it will supply more than 1536 MW of electricity which the Iraq desperately in need.

REFERENCES

1. Arnold J, Williams J, Srinivasan R, King K. SWAT – soil and water assessment tool – documentation and user’s manual. USDA-ARS, Temple, Texas; 1996.
2. Kaur R, Srinivasan R, Mishra K, Dutta D, Prasad D, Bansal G. Assessment of SWAT model for soil and water management in India. Land use. Water Resource Vol, 3, pp 1–7, 2003.
3. Alansi A. W., Amin ,M. S. M., Abdul Halim G., Shafri1,H. Z. M., and W. Aimrun. Validation of SWAT model for stream flow simulation and forecasting in Upper Bernam humid tropical river basin, Malaysia. Hydrol. Earth Syst. Sci. Discuss., Vol 6, pp 7581–7609, 2009.
4. Alibuyog, N. R., Ella, V. B., Reyes, M. R., Srinivasan, R., Heatwole, C., & Dillaha, T. Predicting the effects of land use change on runoff and sediment yield in Manupali River Sub-watersheds using the SWAT Model. International Agricultural Engineering,Vol18(1-2), pp 15-25, 2009.
5. Ficklin, D. L., Luo, Y., Luedeling, E., & Zhang, M. (2009). Climate change sensitivity assessment of a highly agricultural watershed using SWAT. Journal of Hydrology, 374, pp 16-29, 2009.
6. Reungsang, P, Kanwar, R.S, Srisuk, K. Application of SWAT Model in Simulating Stream Flow for the Chi River Sub basin II in Northeast Thailand. Trends Research in Science and Technology .Vol 2, No1, pp 23-28, 2010.
7. Matheus Fonseca Durães MG., Carlos Rogério de Mello, Mauro Naghettini. Applicability of the Swat Model for Hydrologic Simulation in Paraopeba River Basin. Cerne, Lavras, Vol 17(4), pp.481-488,2011.
8. Mengistu1,2 D. T. and A. Sorteberg. Sensitivity of SWAT simulated stream flow to climatic changes within the Eastern Nile River basin Hydrology and Earth System Sciences, 16, pp 391–407, 2012.
9. Lirong, S and Jianyun, Z . Hydrological Response to Climate Change in Beijiang River Basin Based on the SWAT Model. Journal of Procedia Engineering.Vol 28, pp 241-245, 2012.
10. Singh A. and Gosain A. K. GIS Based Hydrological Modelling for Climate Change Impact Assessment Greener Journal of Science, Engineering and Technology Vol. 3 (7), pp 210-219, August, 2013.
11. Palao, L.K.M; Dorado, M.M; Anit, K.P.A.; Lasco, R. D. Using Soil and Water Assessment Tool to assess material transfer in Layawan Watershed and its implications on payment for ecosystem services. Journal of Sustainable Development Vol 6(6), pp 73-87, 2013.
12. Pongput K, Wangpimool. W, Supriyasilp T, Kamol P, Sakolnakhon N, and Vonnarart O. Hydrological Evaluation with SWAT Model and Numerical Weather Prediction for Flash Flood Warning System in Thailand. Journal of Earth Science and Engineering. Vol 6, pp 349-357, 2013.
13. Dechmi. F, and Skhiri. A. Evaluation of Best Management Practices under intensive irrigation using SWAT model. Journal of Agriculutral Water Management.Vol 123,pp 55-64,2013.