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Estimating the Volume of Sediments and Assessing the Water Balance of the Badra Basin, Eastern Iraq, Using Swat Model and Remote Sensing Data

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Abstract

The primary objective of this study is to employ the remote sensing data and Soil & Water Assessment Tool model to estimate sediment volume and assess the water balance of the Badra Basin (2,615km²) in eastern Iraq. Remote sensing data was utilized as the main input with the Soil & Water Assessment Tool model. These data involved a land use-land cover map that was constructed by the classification of the Landsat-8 satellite imagery for the year 2020, STMR digital elevation model, soil map was acquired from the Food and Agriculture Organization and climatic data were sourced from the NASA-funded prediction of Worldwide Energy Resource. The results discovered that about 40 % and 18% of the yearly rainfall are losing by evapotranspiration and filtration. The average amount of annual sediment transported was predicted at 120.47 tons /ha, 2018 recorded the highest value of transported sediment which is about 360 tons /ha. The volume of annual runoff was assessed at about 340.74 million m³. These results proved that the Soil & Water Assessment tool model has the ability to estimation the sediment and runoff volume. The climatic elements, especially rainfall, in addition to soil classes, topography, and land use-land cover had a significant impact on the amount of transported sediments and the volume of runoff.

Keywords: Badra Basin; Water balanced; Sediment volume; Remote sensing

1. Introduction

The study and estimating of the volume of the sediment are some of the important studies that cannot be overlooked (Shendge et al., 2018). Ackermann et al. (1973) analyzed approximately 1,100 lakes in the United States of America and stated that most of these small reservoirs were filled with sediments during periods of less than 30 years. While Rădoane & Radoane (2005) analyzed about 138 water reservoirs in Romania with storage capacity ranged between 1–1230 million cubic meters and determined that there are about 30 water reservoirs that will lose more than 30% of its capacity in periods between 2–10 years. Thakkar & Bhattacharyya (2006) reported that India suffers from losing approximately 1.3 (billion cubic meters) of the total capacity of the storage due to reservoirs filling with sediment. The eastern region of Iraq, including the study area, is a very important source for water harvesting and storage, but the main problem is the high rates of sediment carrying, which caused many

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dam reservoirs to fail (Abdullah et al., 2019). Therefore, the accumulation of sediments in the reservoir is a dangerous problem that maybe threatens the sustainability of the reservoir and has dire consequences for the productivity of the reservoir during its operation period.

On the other hand, water resources in the world and Iraq, in particular, suffer from many problems, the most important of which are global conditions represented in the lack of rainfall and high levels of temperatures, which led to an increase in the phenomenon of drought and the expansion of desertification (Al-Ansari, 2013; Awadh, 2018; and Awadh et al., 2021). Surface runoff water is one of the primary water resources. Therefore, studying their quantities, frequency, and probabilities is one of the most important studies, especially through the availability of field information or space data. There are few numerical models that have the ability to simulate hydrological processes, describe the water balanced elements, and estimate sediment volumes on a watershed scale and at a reasonable time scale (Boithias et al., 2017). One of the very important of these models is the SWAT (Soil & Water Assessment Tool) model, which is a physically distributed model (Ngo et al., 2020) based on mathematical models of the continuous simulation type.

The model of the SWAT was chosen in this work for estimating the volume of sediments and rainfall-runoff simulation, 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 ungauged and cross-border basins such as Badra Basin. Furthermore, many researchers around the world evaluated the SWAT model and with various conditions with basin areas ranging from 1 to 630,000 km² (Rossi et al., 2009; Ezz-Aldeen et al., 2012; Tyagi et al., 2014). Consequently, the SWAT model has arisen as one of the most widespread and had been broadly utilized in the environmental and/or hydrological field (Gassman et al., 2014). The main problem in the Badra Basin is the high rate of sediment load during the rainy seasons, which threatens the failure of the dam that was built in the Badra Valley in Wasit governorate. It is a concrete weir 800 meters long and 3m high (Saeed, 2018). The aim of this study is to estimate the volume of sediments and assessing the water balance of the basin of Badra for the period 1991-2020, the SWAT model has been used.

2. Study Area

The basin of Badra is a water basin sited in the Wasit (Eastern part of central Iraq) and at the Iraqi-Iranian border between latitudes 32°47'44" and 33°38'44" North and longitudes 45°48'42" to 46°41'18" East (Fig. 1), with a total area of about 2,616 km², extends into Iranian territory for a distance of approximately 81 km, with an approximate area of 2,319 km² (88% of the basin area), while it extends into the Iraqi territory for an approximate distance of 48 km and covers an area of about 296 km² (12% of the basin area) until its meets with the Shuweijah Marsh. On the Iraqi side, the Badra Basin water flows from the drainage of the basins and the mountains located on the northern and northeastern sides, including the slopes of the Bashtako Mountains.

3. Materials and Methods

3.1 Data Set

The data of remote sensing supply important data for water resource mapping (Abdel Rahman et al., 2016). Four major file's datasets required by the SWAT model: (a) Digital Elevation Model (DEM) was acquired from SRTM (Shuttle Radar Topography Mission), version3 with 30m spatial resolution (Ferretti & Guarnieri, 2007), and were download from the website of SRTM (<http://srtm.csi.cgiar.org/>), Fig.2. a. (b) The soil map, map of soil is shown in Fig.2.b was sourced from the FAO (Food-and-Agriculture-Organization). Digital-Soil Map of the World (DSMW), version 3.6, (Sanchez et al., 2009). 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 layers of the soil, the upper layer at a depth of 30cm, and the lower

layer at a depth 30-100 cm. (c) the map of Landuse-Landcover (LULC) was produced by utilizing the Landsat8 satellite image, free of cloud which acquiring on March 3, 2019.

Fig.1. Location map of the study area

The LULC result of the Badra basin contains 5 classes (Fig. 3 and Table 1). (d) The climate data were collected from the NASA Langley Research Center (LaRC) Prediction of Worldwide Energy Resource (POWER) project funded by the NASA (the Program of the Earth Science/Applied Science) for three stations; Fig. 3 shows the location of these stations; and for 31 years starting from 1 January 1989 to 31 December 2019. Five climatic elements are required to implement a SWAT model which are rainfall, minimum & maximum air temperature, wind speed, solar radiation, and relative humidity (Manhi & Al-Kubaisi, 2021). The extension of the ArcSWAT is a graphical user interface for the model of SWAT (Srinivasan et al., 1998).

The extension of the Arc SWAT contains various functions required to create and run the SWAT model, the most important of which are watershed delineation, input file generator, editing modules, and others. The Arc SWAT extension can be obtained for free and has been developed to work within the environment of many programs, the most important of which are Map Window GIS, GRASS, and QGIS.

Table 1. The Landuse-Landcover (LULC) classification of the Badra basin

Class Name	Arc SWAT Code	Area KM ²	Area%
Water	Water	17.21	0.7
Agricultural Land-Row Crops	AGRR	663.60	25.4
Grassland	GRAS	291.59	11.1
Baren or Sparsly Vegetated	BSVG	225.77	8.6
Barren Land	BARR	1417.87	54.2
	Total	2616.04	100%

Fig.2. The datasets for SWAT Model: (a) SRTM DEM 30m (Farr et al., 2007); (b) Soils map of the Badra Basin (FAO, 2007)

Fig.3. LULC map of the Badra Basin. The yellow triangles show the locations of the climate stations

3. 2 Materials and Methods

3.2.1. Sediment Volume Estimation

To estimate the volume of the sediment to every HRU, the model of SWAT uses the Modified Global Soil Loss Equation (MUSLE). This equation was developing by Williams, (1975) through

replacing the rain-fall factor (R) with a surface runoff factor and considers both sediment movement and surface erosion in the basin to improve the prediction of the sediment yield. Models based on physical processes such as the SWAT model depend on erosion calculation utilizing mathematical representations of basic hydrologic and erosion operation involving soil separation and transport (Foster, 1990).

The MUSLE is:

$$Sd = 11.8 (Q_{sur} * q_p * A_{hru})^{0.56} * C * K * LS * P * CF \quad (1)$$

Where the Sd represented the volume of the sediment (metric tons), Q_{sur} represented the volume of run-off (mm), q_p represented the peak of run-off rate (m³/sec), A_{hru} represented the area of the HRU (ha), K represented the factor of soil erodibility, C represented the factor of cover and management, P represented the factor of support practice, LS represented the factor of topographic, and CF represented the factor of course fragment.

3.2.2 Swat Hydrological Component and Assessment the Surface Runoff

There are two major approaches for assessing runoff (runoff is the flow that occurs along the sloping surfaces) within the model of SWAT based on the type of rain-fall data: the primary method is the modified SCS curve number (USDA, 1972) which requires daily rainfall data, and the second method is the method of the Green & Ampt (Green & Ampt, 1911) which needs sub-daily or hourly rainfall data. The SCS-CN method was applied in assessing the surface runoff volumes for the Badra basin. The hydrological cycle that will be simulated by the model of SWAT depends mainly on the estimation of the volume of both sediments and runoff. The model of SWAT usages the equation of water balance to simulate surface runoff (Neitsch et al., 2011), which is:

$$SW_f = SW_i + \sum_{i=1}^t (R_t - Q_t - ET_t - P_t - QR_t) \quad (2)$$

Where the SW_f represented the final moisture content (mm); SW_i represented the initial moisture content on a day i (mm); R_t represents the rain-fall volume on a day i (mm); t is the time (days); Q_t represent the surface runoff on a day i (mm); ET_t represent the Evapotranspiration on a day i (mm); P_t represent the percolation on a day i (mm), and QR_t represent the return flow quantity on a day i (mm).

The SCS-CN method was established to become an appropriate basis to evaluate runoff volume under diverse land use with variable soil types. This method is frequently recognized as the CN (Curve Number) method, the land-use, and properties of the soil are lumped in one parameter (White et al., 2008). The model of SWAT forecast the volumes of runoff and the rates of peak runoff for each HRUs (Hydrologic Response Unit) used SCS-CN equation:

$$Q_{sur} = \frac{(R_{day} - 0.2 S)^2}{(R_{day} + 0.8 S)} \quad Q_{sur} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)}, R_{day} > I_a \quad Q_{sur} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)}, R_{day} > I_a \quad (3)$$

Where the Q_{sur} is the daily run-off or rain-fall excess in millimeters, R_{day} represents the daily rain-fall depth in millimeters, S represents the retention parameter (mm). I_a represents the initial abstractions which are generally be similar to 0.2S, thus the equation turns into:

$$Q_{sur} = \frac{(R_{day} - 0.2 S)^2}{(R_{day} + 0.8 S)} \quad (4)$$

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

$$S = 25.4 \left\langle \frac{1000}{CN} - 10 \right\rangle \quad (5)$$

CN = the day curve number.

3.2.3 Setup of the SWAT Model

The initial stage in implementing the model of SWAT is to prepare and collect all the data required for the model, followed by a number of important steps. Fig. 4 is a schematic diagram of the most important of these steps. It is important to standardize the projection for all data collected. The metric projection (UTM) is better and more accurate than the geographical projection because it deals with metric units.

The watershed delineation of the main basin and sub-basins utilizing DEM data represents the first step in implementing the SWAT model (Tolosa, 2015). The size of the sub-basins can be determined more precisely by manually editing the inlet and outlet points of each sub-basin. The construction of HRUs is the second step after the watershed delineation process. HRUs are areas that are aggregated and constructed within each sub-basin by overlaying a number of layers namely soil layer, LULC layer, and slope layer which are derived from DEM (Fig.5) with the use of an appropriate threshold to enable the user to distinguish unique homogeneous lands. The use of appropriate thresholds in the process of building the HRUs will contribute to enhancing the operation of the simulation and facilitating the calculations processes (Srinivasan et al., 2010).

Once the HRUs are generated, the SWAT model must be supplied with all climatic data. Before loaded the climatic data, all the climatic statistical data required for all elements (precipitation, temperatures, wind speed, relative humidity, and solar radiation) were calculated using the SWAT weather generator program and then connected to the SWAT database.

Fig.4. A schematic diagram shows the SWAT Model setup

Fig.5. A slope map of the Badra Basin

4. Results and Discussions

4.1 Watershed Delineation

The main initial step in implementing the model of SWAT is the automatic delineation of the main Badra basin and each sub-basin. The digital elevation model was used to track the initial flow directions as well as the out-let point for individually sub basin. To increase the accuracy of the delineation process, the main outlet point was used at the confluence of the Badra basin with Hor Al Shuwaija, Fig.6. As for the sub-basins, they were identified based on a threshold boundary of 3000 hectares or 30 km² and with the help of manual adjustment of the locations of the main outlet for each sub-basin. The results of the delineation process of the Badra Basin showed that the drainage area of the basin amounted to 2,615.76 km² with 4 sub-basins were named sub-basin 1 to 4. The height of the sub-basins ranged from 312 meters in the southwest to 2566 meters in the northeast, and that about 79% of the basin area have an altitude of less than 1000 meters. Table 2 shows some of the most important morphometric properties with the longest flow path of the Badra sub-basins.

Table 2. The most important morphometric properties of the Badra 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	486.23	139.36	486.23	38.58	580-2584	22.45°
2	694.95	169.93	1181.18	38.82	273-1855	17°
3	992.3	239.95	992.3	82.67	128-2700	13.17°
4	442.3	302.97	2615.76	103.68	14-1105	4.7°

Fig.6. The Sub-basins delineation of the Badra Basin

4.2. HRUs

After the delineation process is completed, each sub-basin area is subdivided into small units named hydrological response units (HRUs). The hydrological unit is defined as the smallest unit that is calculated within the SWAT model and has unique characteristics in terms of the nature of each of the soil types, landuse, and degree of slope. The calculation and analysis of each hydrological unit will ensure the increased accuracy of the model of SWAT in predicting the volumes of each of the sediments and the runoff for each sub-basin. Then the results are collected for all sub-basins to calculate the average volumes for the entire main basin. The results demonstrate that Badra basin is separated into 29 smaller hydrological response units depended on landuse data, type of soil, and slope. Table 3 shows a summary of the HRUs data for each sub-basin. In addition to the concentration-time and curve number values for three possible states of soil moisture, namely, the dry state, the medium-moisture state, and the high-moisture state.

4.3. SWAT Predictive of the Sediment Volume

The model of SWAT was utilized to calculate the volume of sediment transported and deposited in the Badra Basin. The results of the sediment volume simulations conducted during the period 1991-2020 are shown in Fig. 7, While the most important results of the simulation elements are recorded in Table 4. The average annual of transported sediment of the Badra basin over the period 1991–2020 was assessed at 120.47 tons /ha, the year 2008 was the year in which the highest value of transported sediments was recorded. The highest value of transported sediments was recorded in 2008, which was estimated at 360 tons/ha due to a large volume of rainfall that was recorded through 2008, which amounted to about 705.5 mm. The lowest value recorded for the transported sediments was in 1999 and was estimated at 13 tons/ha. At the monthly level, the highest rates of transported sediment were recorded during the months from November to April, and the peak was in March. These high sediment

loads can be explained by the fact that these months have high levels of rain and runoff and thus an increase in the amounts of sediment carried.

Table 3. The summary of the HRUs data for each sub-basin, The CN1 represented the Curve Number (CN) at dry state, CN2 represented the CN at the average moisture, and CN3 represented the CN at wet conditions, TC represents the time of Concentration

Sub-basin	HRUs	Area Km ²	CN1	CN2	CN3	TC (h)
1	1	87.40	76.3	89	95.8	0.76
	2	88.06	76.3	89	95.8	0.45
	3	180.68	85.8	94	97.9	0.77
	4	130.09	85.8	94	97.9	0.91
	5	17.35	76.3	89	95.8	0.45
	6	11.49	76.3	89	95.8	0.21
	7	17.57	76.3	89	95.8	0.15
	8	57.93	76.3	89	95.8	0.26
	9	86.11	76.3	89	95.8	0.65
	10	141.96	68.4	84	93.5	0.80
2	11	60.44	85.8	94	97.9	0.26
	12	41.58	85.8	94	97.9	0.52
	13	87.32	85.8	94	97.9	0.96
	14	173.21	85.8	94	97.9	0.85
	15	27.76	76.3	89	95.8	0.54
	16	25.33	76.3	89	95.8	0.22
	17	24.2	76.3	89	95.8	0.21
	18	29.64	76.3	89	95.8	0.55
	19	40.44	76.3	89	95.8	0.28
	20	26.76	76.3	89	95.8	0.54
3	21	87.34	76.3	89	95.8	1.54
	22	82.17	85.8	94	97.9	1.11
	23	92.94	85.8	94	97.9	0.50
	24	103.30	85.8	94	97.9	0.86
	25	452.35	85.8	94	97.9	2.66
	26	160.30	76.3	89	95.8	4.19
	27	206.45	85.8	94	97.9	4.83
4	28	51.16	85.8	94	97.9	1.45
	29	24.36	85.8	94	97.9	0.63
The average			80.29	91.07	96.67

Fig.7. Sediment estimation of the Badra basin for the period 1991-2020.

Table 4. The results of simulations

Basin Stress (Average Annual)	Value (days)
Number of days for water stress	44.9
Number of days of temperature stress	12.88
Basin Values (Average Annual)	Value (Millimeters)
Rainfall	323.09
Snow fall	7.21
runoff	130.27
Ground water (Shallow Aquifer)	39.29
Total water yield	173.08
PET	924.1
ET	128.3
Total Transported Sediment	120.47 Tons/ha

4.4. Water Balance Predictive for the Badra Basin

The model of SWAT considered as one of the hydrological models that can simulate the movement of water at the level of sub-basins or reservoirs, ponds, and rivers within the main basins. There are a number of important hydrological elements that may affect the water flow within the boundaries of the main basin, and the most important of these factors are surface run-off, groundwater movement, and lateral flow minus the amount of water lost during the transport process. Therefore, the total water productivity of the basin consists of these hydrological elements. Although groundwater is considered one of the elements of the water productivity of the basin, at the same time it is considered one of the filtering (percolates) elements.

The results in Fig. 8 and Table 5 show the annual average of the elements of the water balance for the period from 1991 to 2020 and on a monthly basis for the Badra Basin. About 16% and 40% of rainwater are lost through both filtration and evaporation processes, respectively. The results demonstrate that surface run-off is the main contributor to the total flow within the Badra basin, with a percentage of up to 75% of the total flowing water. While both groundwater flow and lateral flow contribute about 25% of the total water flow. More than 59% of the water in the mainstream of the Badra basin is an outcome of groundwater inflow.

Fig.8. Schema shows the water balance of the Badra Basin

Table 5. Average monthly of the elements of water balance for the Badra Basin for Period 1991 to 2020. Where the LAT lateral flow; SURF surface runoff; GW the flow of the groundwater, ET actual evapotranspiration, and PET evapotranspiration in mm

Mon.	Rainfall	SURF	LAT	GW	ET	PET
Jan	52.98	20.93	0.47	5.06	3.54	4.08
Feb	47.59	21.8	0.53	8.64	5.98	7.06
Mar	52.89	25.37	0.56	6.34	10.15	13.66
Apr	41.05	17.36	0.52	7.25	14.6	20.98
May	14.33	3.75	0.38	6.78	21.33	46.7
Jun	0.7	0.04	0.17	3.64	39.1	169.56
Jul	0.31	0.4	0.09	0.52	16.17	244.34
Aug	0.53	0.05	0.05	0.03	5.74	234.53
Sep	1	0.17	0.03	0.03	3.24	141.95
Oct	21.53	6.59	0.06	0.08	2.35	30.61
Nov	47.36	18.35	0.25	0.15	3.41	6.96
Dec	43.63	15.46	0.41	0.77	2.7	3.69
Total	323.9	130.27	3.52	39.29	128.31	924.12
Average	26.99	10.86	0.29	3.27	10.69	77.01

5. Conclusions

This work aimed to simulate water behavior, monitor sediment volume, and estimate the water balance of the Badra Basin for a period of 30 years, extending from 1991 to 2020 utilizing the SWAT model integrated with GIS (ArcGIS, version 10.5). The first conclusion that can be reached is the efficiency of the model of the SWAT in simulating processes of sediment transport and the water behavior of basins. Although integrating different data for a long period is complicated, the coupling of the model of SWAT with GIS software has allowed the management and automation of various data, which facilitated the integration and manipulation phase, and thus the accuracy of the simulation results. The average annual of transported sediment of the Badra basin is estimated at 120.47 tons/ha –1, 2018 recorded the highest value of transported sediment which is about 360 t /ha due to a large amount of rainfall that was recorded during this year, which amounted to about 705.5 mm. While the minimum sediment volume was about 13 t /ha in 1999. The water balance product is calculated through the SWAT model gives a good visual representation of the behavior of rainfall and how is partitioned within the hydrological cycle. The SWAT model showed that the climatic factors, especially rainfall, in addition to soil classes, topography, and LULC had impact on the transported sediments and surface runoff.

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References

- Abdel Rahman, M. A. E., Natarajan, A., 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.
- Abdullah, M., Al-Ansari, N., Laue, J., 2019. Water resources projects in Iraq: Medium and small storage dams. Journal of Earth Sciences and Geotechnical Engineering, 9(4), 283-289.
- Ackermann, W. C., White, G. F., Worthington, E. B., Ivens, J. L., 1973. Man-made lakes: their problems and environmental effects. Washington DC American Geophysical Union Geophysical Monograph Series, 17.
- Al-Ansari, N., 2013. Management of water resources in Iraq: perspectives and prognoses, 5(6), 667-684.
- Awadh, S.M., Al-Mimar, H. and Yaseen, Z.M., 2021. Groundwater availability and water demand sustainability over the upper mega aquifers of Arabian Peninsula and west region of Iraq. Environment, Development and Sustainability, 23(1), 1-21.
- Awadh, S.M., 2018. A preliminary assessment of the geochemical factors affecting groundwater and surface water quality around the rural communities in Al-Anbar, Western Desert of Iraq. Environmental earth sciences, 77(3), 1-18.

- Boithias, L., Sauvage, S., Lenica, A., Roux, H., Abbaspour, K. C., Larnier, K., Dartus, D., Sánchez-Pérez, J. M., 2017. Simulating flash floods at hourly time-step using the SWAT model. *Water*, 9(12), 929.
- Ezz-Aldeen, M., Al-Ansari, N., Knutsson, S., 2012. Application of SWAT model to estimate the runoff and sediment load from the Right Bank Valleys of Mosul Dam Reservoir. *International Conference on Scour and Erosion*.
- FAO (Food and Agriculture Organization of the United Nations), 2007. Digital Soil Map of the World (DSMW).
- Farr, T. G., Rosen, P. A., Caro, E., Crippen, R., Duren, R., Hensley, S., Kobrick, M., Paller, M., Rodriguez, E., Roth, L., 2007. The shuttle radar topography mission. *Reviews of Geophysics*, 45(2).
- Ferretti, A. M., Guarnieri, A. P., 2007. In *SAR Principles: Guidelines for SAR Interferometry Processing and Interpretation*. AGNoordwijk: ESAPublications.
- Foster, G. R., 1990. Process-based modelling of soil erosion by water on agricultural land. *Soil Erosion on Agricultural Land. Proceedings of a Workshop Sponsored by the British Geomorphological Research Group*, Coventry, UK, 429-445.
- Gassman, P. W., Sadeghi, A. M., Srinivasan, R., 2014. Applications of the SWAT model special section: overview and insights. *Journal of Environmental Quality*, 43(1), 1-8.
- Green, W. H., Ampt, G. A., 1911. Studies on Soil Physics. *The Journal of Agricultural Science*, 4(1), 1-24.
- Manhi, H. K., Al-Kubaisi, Q. Y. S., 2021. Estimation annual runoff of Galal Badra transboundary watershed using Arc Swat Model, Wasit, East of Iraq. *Iraqi Geological Journal*, 54 (1D), 69-81.
- Neitsch, S. L., Arnold, J. G., Kiniry, J. R., Williams, J. R., 2011. Soil and water assessment tool theoretical documentation version 2009. Texas Water Resources Institute.
- Ngo, S., Hoang, H., Tran, P., Nguyen, L., 2020. Application of SWAT model to Assess Land Use and Climate Changes Impacts on Hydrology of Nam Rom River Basin in Vietnam.
- Rădoane, M., Radoane, N., 2005. Dams, sediment sources and reservoir silting in Romania. *Geomorphology*, 71(1-2), 112-125.
- Rossi, C. G., Srinivasan, R., Jirayoot, K., Le Duc, T., Souvannabouth, P., Binh, N., Gassman, P., W. 2009. Hydrologic evaluation of the lower Mekong river basin with the soil and water assessment tool model.
- Saeed, F. H., 2018. Optimum utilization of Iraqi eastern streams. *Water Scarcity in Iraq, Current Situation and Future Challenges*. Iraqi Forum for Intellectuals and Academics.
- Sanchez, P. A., Ahamed, S., Carré, F., Hartemink, A. E., Hempel, J., Huising, J., Lagacherie, P., McBratney, A. B., McKenzie, N. J., de Lourdes Mendonça-Santos, M., 2009. Digital soil map of the world. *Science*, 325(5941), 680-681.
- Shendge, R. B., Chockalingam, M. P., Saritha, B., Ambica, A., 2018. Swat modelling for sediment yield: A case study of Ujjani reservoir in Maharashtra, India. *International Journal of Civil Engineering and Technology*, 9 (1), 245-252.
- Srinivasan, R., Arnold, J. G., 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, R., Zhang, X., & 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.
- Thakkar, H., Bhattacharyya, S., 2006. Reservoir siltation: latest studies-revealing results, a wakeup call. *Dams, Rivers & People*.
- Tolosa, D., 2015. Modeling sediment yield using Arc swat and Analyzing the most prominent remedial measures: cases of Melka Wakena reservoir, Ethiopia. Addis Ababa University.
- Tyagi, J. V, Rai, S. P., Qazi, N., 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, Hydrology. Washington, DC.
- White, E. D., Easton, Z. M., Fuka, D. R., Collick, A. S., Adgo, E., McCartney, M., Awulachew, S. B., Selassie, Y. G., Steenhuis, T. S., 2008. Adapting the soil and water assessment tool (SWAT) for the Nile Basin. CGIAR Challenge Program on Water and Food, 22.
- Williams, J. R., 1975. Sediment routing for agricultural watersheds, *JAWRA Journal of the American Water Resources Association*, 11(5), 965-974.