Journal of Architecture and Construction
Volume 1, Issue 2, 2018, PP 37-63

Simulation of Hydrology in Ungauged Watersheds: SWAT Modeling in Kasillian Basin in Iran

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ABSTRACT

In order to design and construct hydraulic structures, such as dams, there is a need to determine the amount of river discharge. In ungauged watersheds, it is necessary to calculate their inflows through hydrological simulation. SWAT is one of the numerical models that is widely used for such purposes. For calculating the basin discharge, the model requires meteorological data, such as precipitation, temperature, wind speed, solar radiation and relative humidity, as well as physiographic data related to the basin surface, such as curve number and roughness coefficient.

In this research, the Kasillian watershed in Iran has been used for hydrological simulation based on the SWAT model and the river discharge has been verified using data from Valikben hydrometric station, located at the basin outlet. Furthermore, the impact of each input data on the calculation of water flow has also been examined. Specifically, with an increase of 13.43 percent in the curve number and 0.15 in the overland roughness coefficient of the basin the simulated value of the average monthly discharge 2.52 and 0.01 percent closer to the observed average discharge value. Using all the meteorological parameters, the average mean discharge of the period increased with an error of 14.32 percent.

Keywords: *SWAT, river discharge, curve number, roughness coefficient, meteorological parameters.*

INTRODUCTION

Watershed regionalization is an important step in estimating hydrological parameters of ungauged basins. Stream flow estimation is usually required for solving a number of engineering and environmental problems. There are several applications, such as design or dimensioning a water control structures, economic evaluation of flood protection projects, land use planning and management, water quality control, and stream habitat assessment, among others. When there are limited stream flow records at the site of interest, it is a common practice to apply regionalization techniques to derive the streamflow quantile estimates at the sites, where records are limited or in ungauged catchments (Kokkonen et al., 2003). In general, regionalization is considered the information transfer from one catchment to another (Blöschl and Sivapalan, 1995). This information may comprise characteristics describing hydrological data or models. To have greater confidence in extrapolating hydrological behavior from catchments with flow records to an ungauged site or catchment, these catchments should form a homogeneous group (Pilgrim et al., 1988; Post and Jakeman, 1999). The homogeneity is not only in terms of geographical contiguity, but also in terms of hydrological similarity. Some of the common approaches for regionalization in hydrology include: the method of residuals (MOR) (Choquette, 1988), the region of influence (ROI) approach (Zrinji and Burn, 1994), principal component analysis (PCA) (Singh et al., 1996), and cluster analysis and its extensions (Satyanarayana and Srinivas, 2011). There are reviews of regionalization methods for stream flow prediction in ungauged basins (Razavi and Coulibaly, 2013), as well as for broad and comprehensive catchment classification (Sivakumar et al., 2015).

In order to construct dams, the monthly and annual inflow of rivers is an important factor in determination of the dam reservoir volume. The input water flow can be computed from hydrometric stations. In some regions with the lack of hydrometric stations, numerical models, such as SWAT (Soil and Water Assessment Tool), can be used in order to estimate the runoff flowing into the dam. These models perform complex computations and provide accurate estimations in a very short time. In this research, the Kasillian watershed in Iran has been used for hydrological simulation based on the SWAT model and the river discharge has been verified using data from Valikben hydrometric station, located at the basin outlet. Furthermore, the impact of each input data on the calculation of water flow has also been examined.

The SWAT Model

Presentation of the SWAT Model

The SWAT model was developed by the Agricultural Research Service (ARS), the US Department of Agriculture (USDA), namely the Grassland Soil and Water Research Laboratory in Texas. The model consists of the integration of several physical or conceptual models (Neitsch et al., 2002) for the simulation of a series of physicochemical processes in a watershed, which are the following, along with the corresponding variables: (1) simulation of the climate, such as air-soil-water temperature, solar radiation, wind speed, rainfall, snowmelt, water droplets, relative humidity, weather conditions and climate change; (2) simulation of hydrological processes, such as discharge estimation based on the widely used SCS (Soil Conservation Service) method, evapotranspiration based on the Penman-Monteith method, actual evapotranspiration, water movement in the unsaturated and saturated zone; (3) simulation of sediment materials for erosion and discharge; (4) simulation of crop growth and cultivation methods and practices; and (5) simulation water movement and pollution in water bodies. The unit of the spatial scale is the watershed, whereas the temporal unit is essentially the day with a possibility for monthly or annual outputs. The required input data for the hydrological processes include geographical and physiographic data, digital elevation model (DEM), land use, time series of meteorological data, hydrographic network and climatic features.

The SWAT model simulates the river discharge, among others. In order to estimate the river discharge, meteorological data are used, such as precipitation, temperature, solar radiation, wind speed and relative humidity. The software program requires at least temperature and precipitation data. The rest of the data can be simulated by the software program itself. The necessary maps in the software include soil, land use and Digital Elevation Model (DEM) maps, respectively. The SWAT model performs through the Arc GIS (Geographic Information System) software. Among the existing hydrological models, the SWAT model is one of the most comprehensive models for the simulation of the prevailing processes at the surface of a watershed. The SWAT is a conceptual-distributive model, which has been initially designed for large basins and has gradually been expanded to various applications. The SWAT model consists of three main components, namely model inputs, model outputs and model main program. The SWAT model includes 9 main parameters and about 22 secondary parameters, which simulate the following six hydrological and biological variables and processes (Arnold et al., 1990).

- Daily stream flow [discharge]
- Daily sediment yield
- [Monthly and Yearly] Water balance
- Water [quality] pollution
- Producing the agricultural product
- Estimation of the production of pasture plant coverage through application of management of cattle grazing systems (Gholami, 1998)

For modeling purposes, one basin might be divided into many sub-basins. By dividing one basin into many sub-basins, SWAT model simulates the spatial details. In this model, each basin is divided into many sub-basins and each of the sub-basins into many Hydrologic Reaction Units (HRU), which are homogenous from the land use viewpoint and the soil features. For measuring the monthly discharge in the SWAT method, there is a need to the measured monthly quantities in Synoptic Climatology and raingauge and hydrometric stations (such as daily rain, daily minimum and maximum temperature, sun ray, wind speed, and relative humidity, which in these cases in SWAT it is read in dbf).

Background on SWAT Modelling Applications

There are several modeling efforts based on SWAT. The SWAT model has been used in Zayandehrood watershed modeling (Babaei and Sohrabi, 2006). Similarly, the SWAT model has been used for the simulation of the river flow in Qareh Sar sub-basin in the North-West of Karkheh River and showed a higher sensitivity for the curve number parameter (Omani et al., 2006; Akhavan et al., 2010; Behtari Nejad, 2011). Moreover, the runoff rate has been simulated by the SWAT model in a basin in the north of Mississippi for 10 years and the SWAT model showed acceptable results in the simulation of daily and annual runoff in some sub-basins with the exception of one sub-basin full of affluent trees (Bingner and Parcla, 2006). The SWAT model was also applied in a watershed near Nashra (Khalil et al., 2002) and the results showed that the model has a high potential to forecast groundwater flows under different climatic and soil conditions. Moreover, the SWAT model was used to estimate runoff under changing weather conditions for three sub-basins in the experimental watershed of Little Washita river in south-west Oklahoma (Van Liew and Garbrecht, 2003) and the results showed that SWAT can forecast the rate of runoff satisfactorily under dry, average or humid conditions. Similarly, the SWAT model was also used to simulate the monthly average discharge at the Emameh basin, one of the sub-basins of Jajerood river (Gholami, 2003; Bazrkar et al., 2013) and the results showed that the model has a high sensitivity to the roughness of the land surface. The SWAT model was also calibrated for Atrova river basin in Kaneon with an area of 1680 km^2 (Lin and Radcliffe, 2005) and the calibration results of the daily and monthly flows were satisfactory and the results showed that the model has a good performance in flow prediction.

Recently, the SWAT2009 model was tested in Kordan river and achieved acceptable results for river simulation and understanding the basin’s behavior (Bastani Allah Abadi et al., 2012). Similarly, the Xedone river basin in an area of 7,224.61 km^2 in the southern part of Laos was used to test the SWAT model for the prediction of stream flow in the river basin (Bounhieng Vilaysane et al., 2015). Specifically, the model was tested for two periods (1993-2000 and 2001-2008) and the result were satisfactory for the simulation of monthly and daily runoff in both calibration and validation phases. Moreover, in another SWAT model application, the main focus was on the runoff responses to land use change with daily measurement. Specifically, Jinjiang, a natural area for collecting rainwater in southeast China with a humid sub-tropical climate, was used for simulation with three stations for the reproduction of annual, monthly and daily runoff processes over nine years (2002-2010) and the result were satisfactory (Bingqing Lin et al., 2015). In addition, Simly Dam watershed in Saon basin in the north-east of Islamabad was another region for application of the SWAT model (Shimaa, M. Ghoraba, 2015). The model was calibrated from 1990 to 2001 and evaluated from 2002 to 2011. The aim of the whole process was to simulate stream flow. The results for both annual and monthly discharge were very good for calibration, as well as validation periods. Similarly, Ye Tuo et al. (2016) tested the same model. The outcome of the study indicated that precipitation is the main source of uncertainly and different precipitation datasets in the SWAT model lead to different estimated ranges for the calibration parameters. In another study, the SWAT model was used in Haean highland agricultural catchment (62.8 Km^2), an upland area above 600 m of elevation (Sun Sook et al., 2016). The results indicated a sediment reduction of 3.0% for 6.0% runoff reduction up to 14.1% for 17.0% runoff reduction, respectively, and T-P reduction of 1.3% for 6.0% runoff reduction up to 6.8% for 17% runoff reduction along with negative effect of total nitrogen (T-N) up to -3.7% for 12% runoff reduction (Ostad-Ali-Askari et al., 2017; Talebi Zadeh, 2008).

Application of SWAT model to Kasillian basin, Iran

This section presents the application of the SWAT model to the Kasillian basin in Iran. At first, the study area and data sets are described, which is followed by the model implementation procedure.

Study Area and Data Set

The study area is located in the northern forests of Alborz in Iran, which includes the villages of Sangdeh, Darzikol, Soutkola, Valik Chal and Valik Ben. Kasilian basin is itself one of the sub-basins of Haraz basin, where there are installed hydrometric and meteorological stations by the Ministry of Energy in Iran. The area of Kasillian basin is about 66.81 km^2 and the length of the main river is 16.8 km. The basin of this river is located between the geographic coordinates of 36°-02´ to 36°-11´ of latitude and 53°-10´ to 53°-26´ of longitude. The gradients being used in this study in percent include -2, 1, 2-5, 8-12, 12-20, 30-60 and >60. Figure 1 shows the geographical location of the Kasillian basin.

There is a hydrometric station at Valikben on the Kasillian river that has been established since 1970 with a longitude of 53°-17´ and a latitude of 36°-10´, which measures the river discharge. The meteorological data, which are used in this study, include precipitation, temperature, solar radiation, wind speed, and relative humidity and cover the period from February 1978 to February 1989. Specifically, data processing and statistical analysis is conducted for the data of the Pole Sefid synoptic station and the Sangdeh and Darzikola climatological stations, as well as the Valik Chal raingauge station and the Valikben hydrometric station.

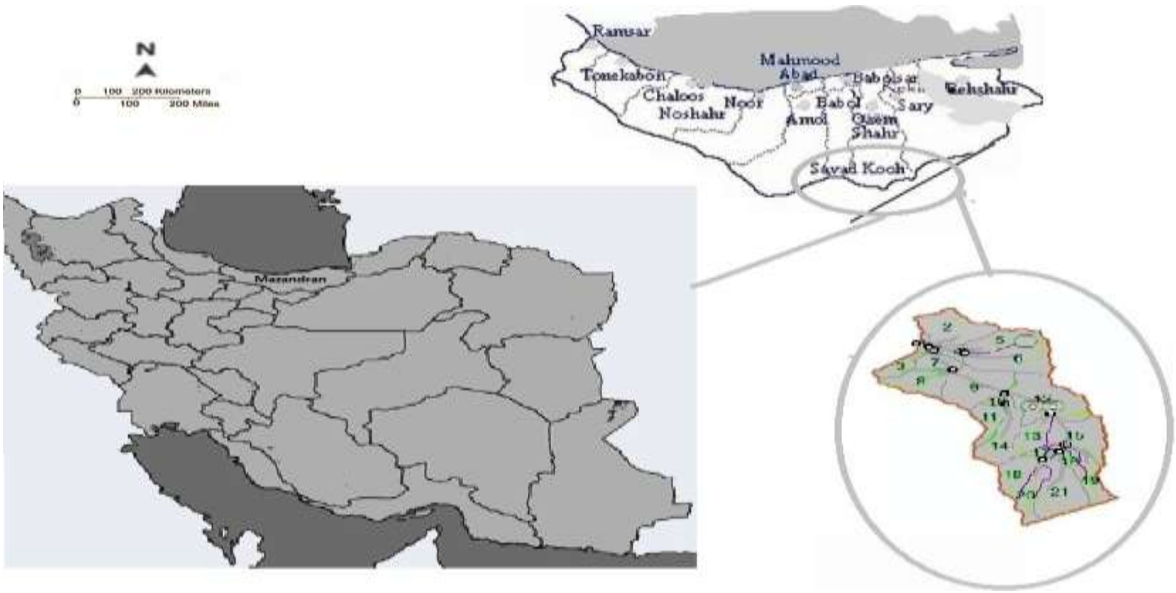

Figure1. *Geographical location of Kasillian Basin*

SWAT Model Implementation Procedure

The SWAT modeling procedure specifies the river zone, the river flow direction and the simulation of the river discharge. The SWAT model uses several GIS-based maps, such as topographic map and DEM map (Figure 2), land use map (Figure 3) and soil map (Figure 4). Similarly, figure 5 delineates the classification of the Kasillian river basin into zones. In addition, soil data for the watershed and meteorological data of the synoptic, climatological and raingauge stations, respectively, are also used through look up tables. Needless to say, the smaller the maps scale, the better the model performance. Similarly, the longer the meteorological data records, the better the model outcome. Moreover, all the three maps should have the same scale and units in order to be able to overlap through the SWAT modelling procedure. The meteorological data should be stored in the DATABASE of SWAT software and the other data could be stored in USERSOIL and WGN (SWAT 2009.mdb).

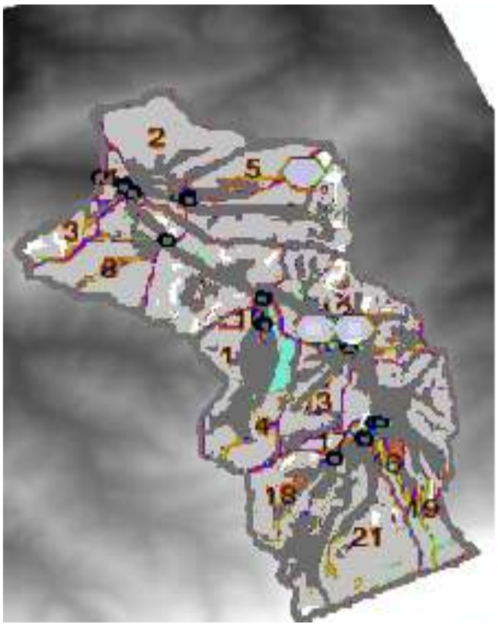

Figure2. *Digital Elevation Model for Kasilian River Basin of Savadkooh Region (DEM)*

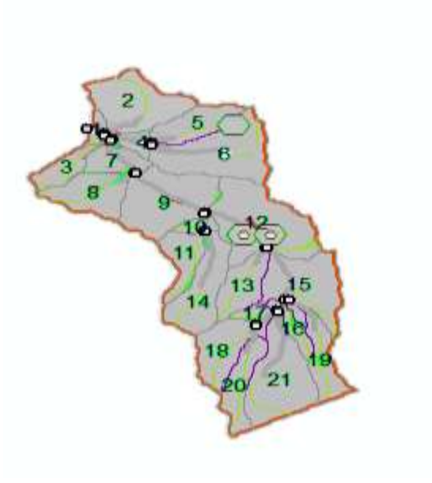

Figure3. *Land Use Map for Kasilian River Basin of Savadkooh Region (Land Use)*

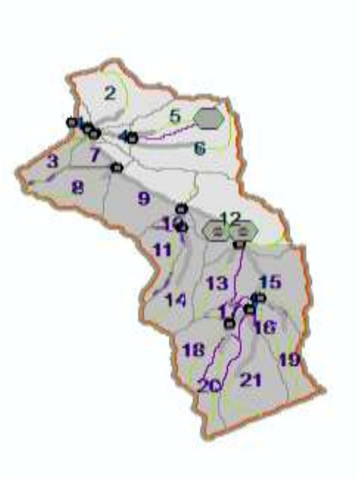

Figure4. *Soil map of Savadkooh Region in the Kasilian River Basin (Soil)*

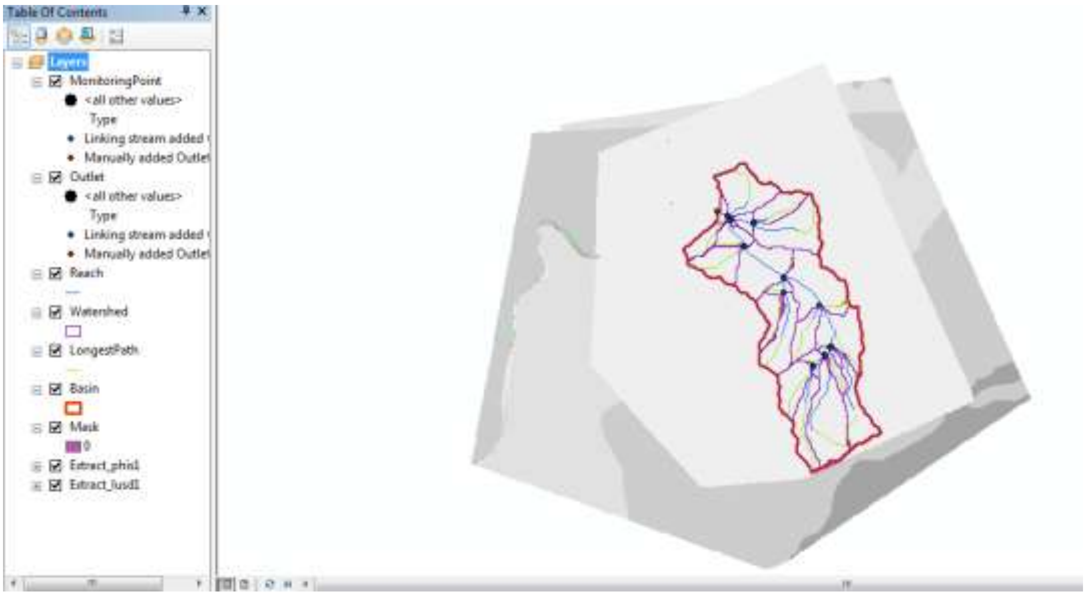

Figure5. *Zoning into regions for Kasillian River Basin*

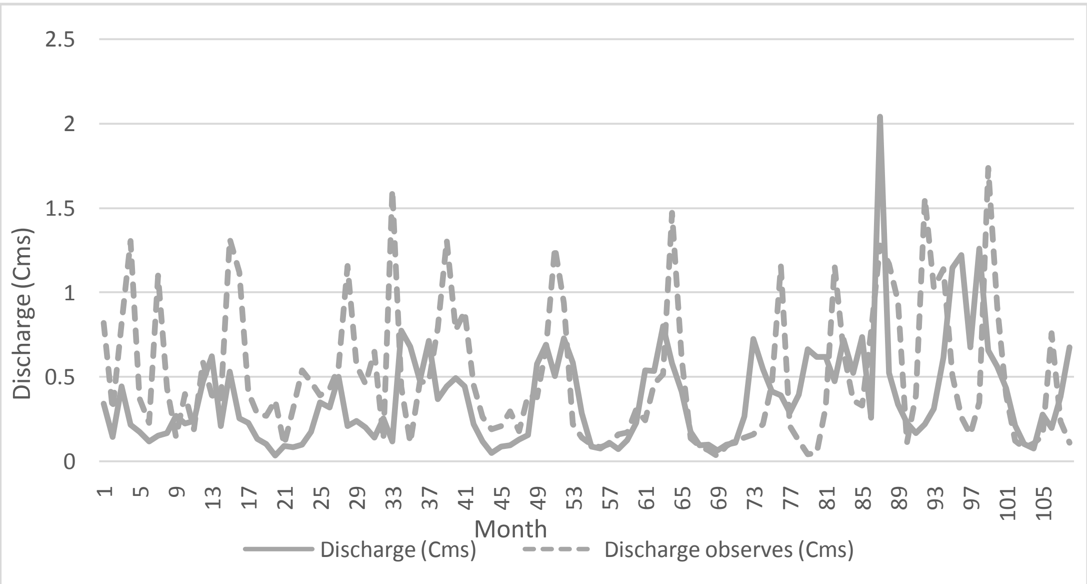

Figure6. *Simulated and observed average discharge of SWAT model in the Kasillian basin*

The followings steps are considered for the SWAT modeling procedure:

- Consideration of the method for inserting the input data into the model;
- Modeling stages in ARCSWAT;
- Model performance, data storage and output data.

The files of Arcswat_documentation in Arcswat help are used, which describe the performance methods and the files of swat-input-output.pdf are also used (SWAT 2009.mdb). The files should be in Excel form in order to be inserted into the SWAT database (swat2009.mdb). Specifically, for the implementation of the SWAT model, they should be used in form of dbf and txt files. The time period should be the same for all the input data files into SWAT model. The rainfall amounts are in millimeters and can be inserted in the form of daily (or less), monthly or annual data. The data of Abali synoptic station have been used instead of Pole-Sefid synoptic station, due to regional similarity. The images have been cut due to the high capacity of the main files of DEM, land use and soil data, respectively, resulting into better performance of the SWAT model. The cell-size of the map was considered as 50 for all three maps for reasons of consistency. The type of land use and their map numbers should be marked. Indeed, two types of land use in the examined basin are considered, namely: (1) FRSD and (2) FRSE.

Soil data should be taken from the regional Soil Lab and should be connected to the type of soil in the map. In the case of unavailable soil data, the world soil map was used. Table 1 presents a sample of soil general data. Moreover, Table 2 presents a sample of soil data for each soil horizon. Specifically, the data which are required for SWAT include the followings: number of layers= (NLAYERS); soil hydrological groups (using infiltration and use) =HYDGRP; soil depth related to all existing horizons (millimeter) (SOL_ZM); soil Texture=Texture. In addition, the following data should be provided for all existing horizons in the basin soil units: thickness of Horizon 1 in millimeter=SOL_Z1; soil volume density in horizon 1 (gram per cubic centimeter); water accessible capacity in horizon 1 (mm) =SOL_AWC1; saturation electrical conductivity in horizon 1 (mm per hour) =SOL_K1; organic materials in horizon 1 (%) =SOL_CBN1; clay in horizon 1(%) = CLAY 1; silt in horizon 1(%) =SILT1; sand in horizon 1(%) = SAND1.

Table1. *Sample of Soil General Data*

OBJECTID	MUID	SEQN	SNAM	S5ID	CMPPCT	NLAYERS	HYDGRP	SOIL_ZMX	ANION_EXCEL	SOL_CRK	TEXTURE
203			Soil_1			2	C	1000	0.5	0.5	LOAM
204			Soil_2			2	C	1000	0.5	0.5	LOAM

Table2. *Sample of Data related to each of the Soil Horizons*

SOL_Z1	SOL_BD1	SOL_AWC1	SOL_K1	SOL_CBN1	CLAY1	SILT1	SAND1	ROCK1	SOL_ALB1	USLE_K1	SOL_EC1
300	1.3	0.175	9.23	1.7	21	49	30	0	0.0184	0.3108	0
300	1.3	0.175	9.23	1.7	21	49	30	0	0.0184	0.3108	0

Table 3 presents the data related to Sputnik station and land use and soil. Then, the Abali synoptic station data were inserted, as explained above. In addition, the daily rain data and the daily maximum and minimum temperature of two climatological stations and two raingauge stations for 11 year (1979-1989) were inserted, along with the latitude and longitude of these stations. Then, the soil data, land use data and synoptic station data should be delineated into the map. Specifically, using SWAT 2009 INPUT-OUTPUT file, land use data was connected to SWAT. Then, synoptic station data was inserted, which should be in agreement with the geographical legends of the land use, soil and DEM maps, respectively. The corresponding files should be converted into dbf form in order to be inserted into SWAT.

For the drainage gradient of the basin, the SCS method was used, which classifies the gradients into 5 classes (Table 4). Soil and land use data and gradient in HRU should be in agreement with each other. Moreover, the synoptic station data, such as temperature and rain, was inserted in the proper input table in the weather station section. Specifically, daily rain and temperature data are inserted. In the sub-basin data part, all the changes related to sub-basins can be applied and other changes related to SWAT can also be applied in the SWAT input edit part. In the last part, SWAT simulation can be performed as long as the software data are completed and saved. All the saved data can be found in Table shoot at the SWAT output section.

Table3. *Data related to Sputnik station and land use and soil*

ID	NAME	LAT	LONG	ELEVATION
1	POLSEFID	36.05	53.10	1350
VALUE	LANDUSE			LANDUSE
19	Mix(bagh lowforest)			FRSD
24	Dense forest			FRSE
VALUE	NAME			
13	SOIL_1			
24	SOIL_2			

Table4. *Gradient classification in SCS suggested method*

Gradient in percent	Gradient class
5-0	1
10-5	2
20-10	3
40-20	4
>40	5

The effect of soil type. In this application, the optimum curve number (CN) and overland roughness coefficient of the basin surface have been considered. Initially, only precipitation data have been used to obtain the optimum curve number and roughness coefficient of the flow in the basin. Similarly, SWAT model was ran initially by considering a curve number of CN2= 67 and an overland roughness coefficient of OV_N=0.1. The results are delineated in Figure 6, where the observed and simulated average discharges are plotted. Moreover, in order to optimize the SWAT parameters, different curve numbers (CN) and overland roughness coefficients have been used. Specifically, Table 5 presents the impact of curve number (CN) on the computed average discharge. Similarly, Table 6 presents the impact of roughness coefficient on the computed average discharge. Moreover, Figure 7 shows the changes of curve number as compared to the simulated discharge and Figure 8 presents the changes of roughness coefficient as compared to the simulated discharge.

In a comparison to the recorded discharges in the gauging station and the calculated discharge, an optimum curve number of 67 and an overland roughness coefficient of 0.1 was obtained for the basin. Then, considering the two mentioned values, other input parameters of SWAT model in river discharge simulations were considered. The effect of meteorological parameters on the simulated discharge using the SWAT model was investigated and the results were compared to the observed discharges. It is worth noting that only the precipitation data have been used as model input. Figure 9 delineates the average discharge from different curve numbers as compared to the observed discharge and Figure 10 shows the average discharge from different roughness coefficients as compared to the observed discharge.

Table5. *The impact of curve number (CN) on the computed average discharge*

Curve Number	67	69	72	**76**
Simulated discharge average (m3/s)	0.475787	0.477227	0.38084	0.388203
Observed discharge average (m3/s)	0.4989532	0.4989532	0.4989532	**0.4989532**
Calculations errors (m3/s)	0.123166	0.121726	0.118113	**0.11075**

Table6. *The impact of roughness coefficient on the computed average discharge*

Basin Over land roughness coefficient	0.05	0.1	0.15	0.2
Simulated discharge average (m3/s)	0.375787	0.375787	0.375784	0.375774
Observed discharge average (m3/s)	0.498953	0.498953	0.498953	0.498953
Difference between the observed and simulated discharge average (cubic meter per second)	0.123166	0.123166	0.123169	**0.123179**

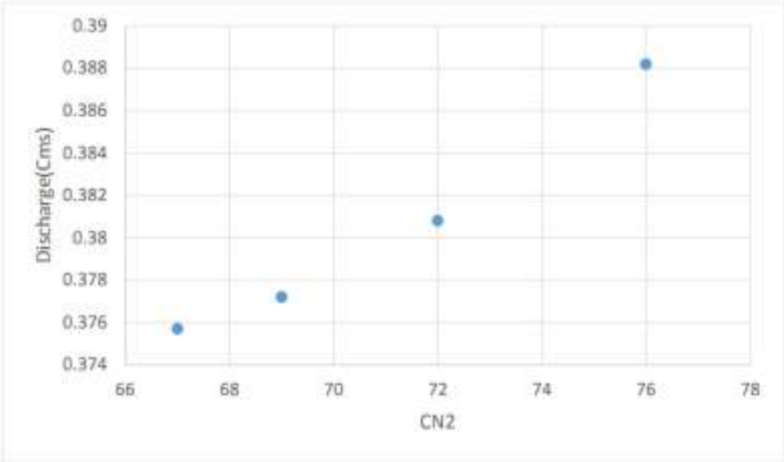

Figure7. *Changes of curve number as compared with the simulated discharge*

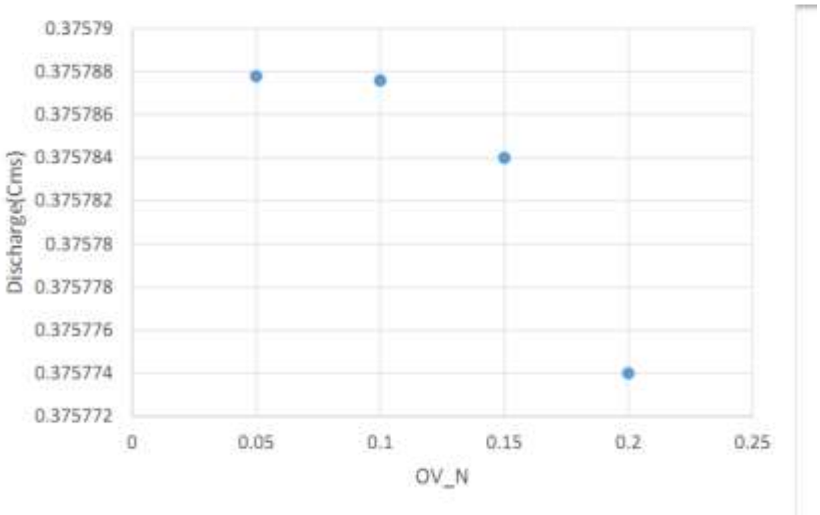

Figure8. *Changes of roughness coefficient as compared with the simulated discharge*

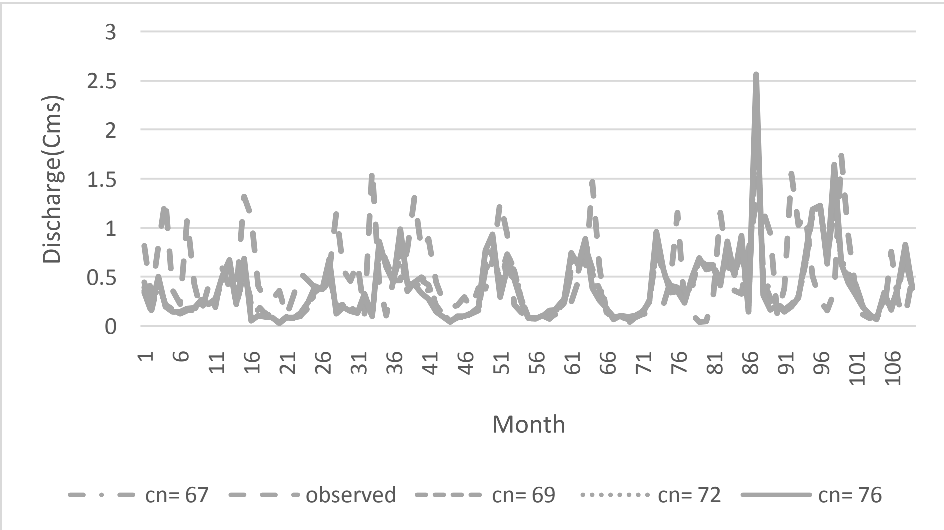

Figure9. *River discharge average from different curve numbers as compared with the observed discharge*

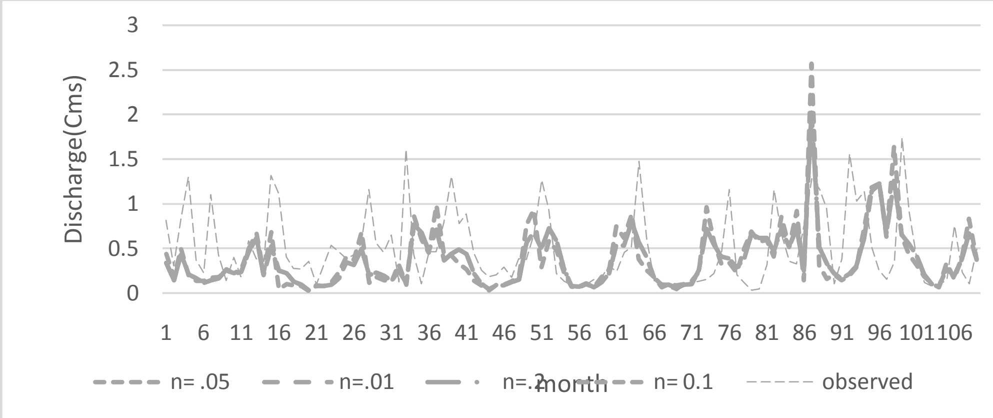

Figure10. *River discharge average with different basin over land roughness coefficient as compared with the observed discharge*

Results and Discussion of SWAT Modeling Application

At this stage, in addition to precipitation data, other meteorological parameters including temperature, relative humidity, wind speed and solar radiations have been entered to SWAT model and an average discharge of 0.5704 m^3/s has been obtained, as can be seen in the first row of Table 7. Moreover, the recorded discharge in the gauging station in the modeling period (February 1998 to February 1989) has been 0.4989 m^3/s and the calculation error was 0.0714 m^3/s corresponding to 14.32% (Table 7).

In order to study the effects of all the required meteorological parameters on the calculated discharge in SWAT model, the input parameters to the model have been removed. Model results are presented in other rows of Table 7. For example, row 2 of Table 7 shows that when solar radiation data are not inserted into the model, the average calculated discharge is 0.588 and the calculation error increases to 17.89 percent. The third row of Table 7 shows that when relative humidity data are not inserted, the average discharge of the period decreases and the calculation error is 41.16 percent. Moreover, the fifth row shows that when temperature data is not inserted to the model, discharge significantly increases and the error is 89.75 percent compared to the calculated value. The sixth row shows that when precipitation data are not inserted, the average discharge of the period decreases and the error is 82.65 percent. The seventh row shows that when precipitation and wind speed data are not inserted to the model, the average discharge of the period decreases and the error is 36.48 percent. The eighth row shows that when precipitation and relative humidity data are not inserted, the average discharge of the period decreases and the error is 94.4 percent. The ninth row shows that when precipitation and temperature data are not inserted, the average discharge of the period decreases and the error is 70.06 percent.

Similarly, in the eleventh row, by omitting solar radiation and wind speed data, the average discharge is computed with an error of 16.72 percent. In the twelfth row, by omitting relative humidity and wind speed data, the average discharge decreases and the error is 41 percent. The thirteenth row shows that by inserting precipitation and temperature data, the average discharge of the period decreases and the error is 39 percent. In the fourteenth row, by omitting temperature, solar radiation and wind speed data, the average discharge of the period increases and the error is 33.61 percent. In the fifteenth row, by the omitting temperature, relative humidity and wind speed data, the average discharge of the period decreases and the error is 13.28 percent. In the eighteenth row, by inserting temperature and solar radiation input data, the average discharge of the period decreases with an error of 94.8 percent. In the twentieth row, by inserting temperature and solar radiation input data, the average discharge of the period decreases with an error of 4.66 percent. In the twenty-third row, by inserting precipitation data, the average discharge decreases with an error of 22.08 percent. In the twenty-fourth row, by inserting temperature data, the average discharge of the period decreases with an error of 75.68 percent. In the twenty-seventh row, by inserting relative humidity input data, the average discharge of the period decreases with an error of 3.26 percent. The negative and positive values of the column before the last column show the decreased and increased simulated discharges in comparison to the observed values, respectively.

Table7. *The observed and simulated monthly average discharge changes in the application of SWAT model with each of the input data*

Row	Input data	Simulated discharge average (cubic meter per second)	Observed discharge average (cubic meter per second)	Difference of observed and simulated discharge average (Cubic meters per second)	Error Percentage
1	(Pre.,Temp., Rad., Win., RH)	0.5704225	0.498953704	0.071468796	14.32
2	(Pre., Temp, Win, RH)	0.588334	0.498953704	0.089271	17.89
3	(Pre. Temp, Rad., Win)	0.293554	0.498953704	-0.205399	41.16
4	(Pre., Temp., RH, Rad)	0.569122407	0.498953704	0.070168703	14.06
5	(Pre., Rad., Win., RH)	0.722399	0.498953704	0.447829	89.75
6	(Temp, Rad, Win, RH)	0.086537	0.498953704	-0.412416	82.65
7	(Temp, Rad, RH)	0.090831	0.498953704	-0.182043	36.48
8	(Temp, Rad, Win)	0.0254080	0.498953704	-0.473545	94.9
9	(RH, Rad, Win)	0.149367	0.498953704	-0.349586	70.6
10	(Pre., Temp, Win.,)	0.298773889	0.498953704	-.200179815	40
11	(Pre., Temp., RH)	0.582392315	0.498953704	0.083438611	16.72
12	(Pre, Temp, Rad)	0.296394444	0.498953704	-0.20255926	41
13	(Pre, Temp)	0.300483333	0.498953704	-.198470371	39
14	(Pre. , RH)	0.666655	0.498953704	0.167702	33.61
15	(Rad, RH)	0.154092	0.498953704	-0.344861	69.12
16	(Rad., Win)	0.04151318	0.498953704	-0.457439	91.68
17	(Pre.)	0.388740926	0.498953704	-.110212778	22.08
18	(Temp.)	0.121320904	0.498953704	-0.3776328	75.68
19	(Rad.)	0.044181033	0.498953704	-0.4547719	91.14
20	(Win)	0.251754	0.498953704	-0.247199	49.54
21	(RH)	0.482683	0.498953704	-0.01627	3.26

The application of SWAT model in the Kasillian basin in Iran has provided the possibility for a number of useful results, as well as fruitful discussions and comments. Some of the results and findings can be summarized in this section. In particular, with an increase of 13.43 percent in the curve number, the simulated value of the average monthly discharge was 2.52 percent closer to the observed average discharge value. Similarly, with an increase of 0.15 in the overland roughness coefficient of the basin, the simulated discharge was 0.01 percent closer to the observed discharge. Moreover, the SWAT software has presented satisfactory results in the estimation of the average monthly discharge with regards to rain, temperature and other required input data.

Precipitation, temperature and relative humidity data have a greater impact on the computed discharges as compared to solar radiation and wind speed data. Specifically, there was an effect of inserting relative humidity as input data into the average discharge as compared to other parameters. By applying the (RH) and (Wind, RH) parameters, the simulated average discharge was closer to the observed value. Similarly, the effect of inserting temperature as input data was a decrease in the average discharge. On the other hand, using all the meteorological parameters, the average discharge of the period increased with an error of 14.32 percent.

The use of the temperature, rain, relative humidity, solar radiation and wind speed as inputs has resulted into a decrease of the average observed monthly discharge by 16 percent as compared to the simulated average monthly discharge. Moreover, the insertion of only temperature and rain as inputs has resulted into an increase of the average observed monthly discharge by 38 percent as compared to the simulated average monthly discharge. Similarly, the use of only temperature, rain and wind speed as inputs has resulted into an increase of the average observed monthly discharge by 40 percent as compared to the simulated average monthly discharge. Furthermore, the use of only temperature, rain and relative humidity as inputs has resulted into a decrease of the average observed monthly discharge by 18 percent as compared to the simulated average monthly discharge. On the other hand, the use of temperature, rain and solar radiation as inputs has resulted into an increase of the average observed monthly discharge by 40 percent as compared to the simulated average monthly discharge. Similarly, the use of only temperature as input has resulted into an increase of the average observed monthly discharge by 75 percent as compared to the simulated average monthly discharge. Finally, the use of only rain input has resulted into an increase of the average observed monthly discharge by 22 percent as compared to the simulated average monthly discharge.

Summary and Conclusions

Hydrological simulation based on the SWAT model in the Kasillian basin was conducted for the time period between February 1978 to February 1989 and the results fulfil the accuracy and scaling expectancy. The SWAT modeling application shows successful results in the simulation of monthly discharge at watershed scales, as well as the capability of addressing climatic land-use change issues. Moreover, the results in the Kasillian basin also indicate that the SWAT model could be successfully used in dam design for flood protection and water resource management. As a result, the SWAT model could be effectively used for sustainable development at regional or national scales.

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