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Sensitivity Analysis of Meteorological Parameters in Runoff Modelling Using SWAT

(Case Study: Kasillian Watershed)

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ABSTRACT

Determination of river runoff is essential in design and construction of most hydraulic structures including dams. In rivers with no measurement stations, the hydraulic models can be used for data estimation. SWAT is one of the most widely-used numerical models. In this model, input influential meteorological data as precipitation, temperature, wind speed, solar radiation and relative humidity as well as watershed data including the curve number and roughness coefficient are required to calculate the watershed runoff. The lack of weather stations in some watersheds increase the risk that the registered data in a station do not represent the whole watershed. Consequently, runoff estimation error should be determined. This research evaluates the sensitivity of the river runoff estimation to variations of the meteorological parameters such as precipitation, solar radiation, wind, humidity and temperature using SWAT numerical model. The results indicated that with a 30% decrease in the average monthly precipitation, solar radiation, relative humidity, wind and temperature, a 64.27% decrease, 114.67% increase, 45.93% decrease, 126.12% increase, and 39.21% increase was observed in the modeled runoff, respectively.

Keywords

Meteorological parameters, rainfall runoff, sensitivity analysis, SWAT, watershed yield

1. Introduction

In order to build a dam, it is vital to determine the monthly and annul yields of the river to calculate the volume and the height of the dam. A gage station can measure the input water to the dam. In the absence of the gage station, a numerical model, e. g. SWAT, can be used to estimate the flow and the input runoff. The numerical models can perform precise and complicated calculations in a short time. In order to calculate the watershed runoff, the model requires the influential meteorological data such as precipitation, temperature, wind speed, solar radiation and relative humidity on one hand, and the watershed basin information including the curve number and the roughness coefficient on the other hand. Because of the limitation in the number of weather stations in some watershed basins, and the registered values in a station may not represent the whole watershed, calculation of the runoff estimation error is needed. The wind speed and the solar radiation are the most sensitive parameters and temperature is the least sensitive parameter in runoff estimation. This

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research investigates the sensitivity of the river runoff estimation to changes of the most prominent meteorological parameters including precipitation, solar radiation, wind, humidity and temperature using SWAT.

2. Literature Review

Behtarinejad (2012) investigated the sedimentation and the waste of nutrients in the east of Gorganrood watershed using SWAT. The model was applied and verified from 1999 to 2006. Data from 2007 to 2010 was used to validate the model and satisfactory results were obtained in both of the verification and validation stages. The SWAT model is capable of creating different scenarios to study different managerial issues. Gholami (2004) used SWAT to stimulate the average monthly discharge of Emameh watershed (a sub-basin of Jajrood watershed). The results indicated a higher sensitivity of the model to the land roughness coefficient (S. Gholami, 2004; Nejad B., 2012). Omani et al. (2007) used SWAT to stimulate the river flow in the Gharesar sub-basin in northwest of the Karkheh River. Their research showed a higher analytical sensitivity for the curve number parameter (Nejad B., 2011; Omani N., Tajrishy M., Abrishamchie A., 2007).

Saadati (2003) stimulated the daily discharge, water balance and land application in Kasillian watershed. The model results showed sensitivity to the water periods so that more reasonable results were obtained for the annual and monthly periods in comparison to the daily period (Saadati H., 2003). Alavinia and Nasiri-saleh used the SWAT model to estimate the discharge and concluded that the model can accurately estimate the discharge (Nejad B., 2012; Alavinia M., Nasiri Saleh F., 2010). Omani et al. (2008) used this model to model Ghareh-sar watershed and concluded that the SWAT model is a capable tool in stimulation of the hydrologic components (Nejad B., 2012; Omani N., Tajrishy M., and Abrishamchie A., 2008).

Rostamian (2006) stimulated the runoff in Behestabad watershed (one of the sub-basins of Northern Karoon) using SWAT and concluded that the model is not able to stimulate the maximum flows (Rostamian R., Mousavi S., Heidarpour M., Afyuni M., and Abaspour K., 2006).

Poorabdollah and Tajrishi (2009) employed SWAT in Emameh (a sub-basin of Latian Dam watershed) to estimate runoff and concluded that the model is efficient in estimation of the runoff (Nejad B., 2012; Pourabdullah M. and Tajrishy M., 2009).

Chu and Shirmohammadi (2004) used SWAT to estimate the surface flow in a 33.4 square kilometers watershed in Maryland. The results indicated that the estimations made by the SWAT model were not so accurate during very wet years. By omission of the wet year, the monthly estimations of the surface runoff of the base flow were more accurate (Nejad B., 2012; Chu T. W. and Shirmohammadi A 2004).

Hatou et al. (2004) concluded that the estimations of runoff made by SWAT were in agreement with the measurements in Lershi watershed (Nejad B., 2012; Hao F. H., Zhang X. S. and Yang Z. F., 2004). Schuol et al. (2006) claimed that SWAT is highly capable of making realistic stimulations of hydrological balance (Nejad B., 2012; Schuol J., Abbaspour K. C., Yang H., Reichert P., Srinivasan R., Schar Ch. and Zehnder A. J. B., 2006).

Santhi et al. (2001) employed SWAT to stimulate the discharge of in Bask river watershed and concluded that the model provides satisfactory results in prediction of the flow (Talebizadeh M., 2009; Santhi C., Arnold. J. G., Williams J. R., Dugas W. A., Srinivasan R. and Hauck L. M., 2001).

3. Materials and Methods

The study area was Kasillian watershed (located in Northern forests of Alborz mountain in Iran) including Sangdeh, Darzikela, Sootkela, Valikchal and Valikbon villages. The area of Kasillian watershed is approximately 66.81 square kilometers and the main river length is 16.8 kilometers. The geographical coordinates of the rivers are as follows: latitude from 36˚-02’ to 36˚-11’ N, and longitude from 53˚-10’ to 53˚-26’ E. There is a gage station on Kasillian River at Valikbon. The station, built in 1970, is located at the longitude of 53˚-17’ and the latitude 36˚-10’ to measure the river discharge. Figure 1 shows the location of Kasillian watershed.

The model inputs include precipitation, temperature, solar radiation, wind speed and relative humidity data of the January 1978 till January 1989 period to stimulate the runoff. The mentioned statistical parameters were retrieved from Pol-e-sefid cineoptic, Sangdeh and Darzikela climatology, Valikchal precipitation-gauge, and Valik hydrometer stations.

4. SWAT Model

SWAT was developed by the agriculture ministry of the US and the agriculture research service of Grassland water and soil research laboratory in Texas. This model stimulates the river discharge using climatic data such as precipitation, temperature, solar radiation, wind speed and relative humidity. At least the temperature and precipitation data is needed to run the software and other data can be stimulated. Required maps by the model include land map, land application, and the digital elevation model. The SWAT model is run in Arc GIS software.

Fig. 1. Location of Kasilian Watershed up to Valik hydrometer Station.

4.1 Formulas and Tables

The number of SCS curve is a function of soil permeability, land application and the humidity already retained in the soil. Different curve numbers were considered considering the humidity condition II in the study area from 67 to 76 based on the SWAT formulas tables as well as different land vegetation and soil types and the optimum curve number of 67 was obtained for the region (Soil Conservation Service Engineering Division, 1986; SWAT Theoretical Documentation, Version 2009).

SCS runoff equation is an empirical model developed in 1950 upon 20 years of studying the relationship between rain and runoff in a small village watershed in America. The model was developed to estimate the runoff in various land applications and different soil types (Rallison & Miller 1981, SWAT Theoretical Documentation Version 2009).

Eq. (1) shows the curve number (SCS 1972; USDA 1972):

$$Q_{surf} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)} \qquad (1)$$

where Q_{surf} is the accumulated runoff or the excess precipitation (mm), R_{day} is the water height per day (mm), I_a is the initial leakage of the surface reserve, the penetration before runoff (mm), and S is the water saving parameter (mm). A change in saving parameter will change the soil type, land application, management, slope and temporary changes in soil content. Saving parameter is defined as Eq. (2) (SWAT Theoretical Documentation Version 2009):

$$S = 25.4\left(\frac{1000}{CN} - 10\right) \qquad (2)$$

where CN is the Curve Number of the day. The initial value of I_a in Eq. (1) was estimated as 0.25 and Eq. (3) was obtained (SWAT Theoretical Documentation Version 2009):

$$Q_{surf} = \frac{(R_{day} - 0.2s)^2}{(R_{day} + 0.8s)} \qquad (3)$$

Runoff occurs only if $R_{day} > I_a$. The graphical solution of Eq. (3) for different curve numbers is presented in Fig. 2 (SWAT Theoretical Documentation, Version 2009). It can be seen in Fig. 2 that the higher curve numbers will lead to higher runoff and the precipitation runoff varies as a curve with the Curve Number.

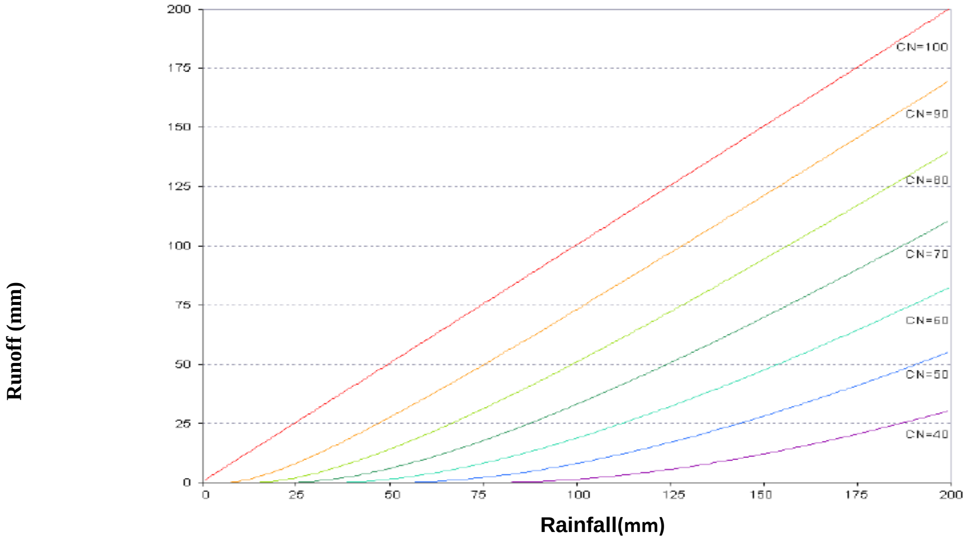

Fig. 2. Runoff-precipitation relation in SCS Curve Number method (SWAT Theoretical Documentation, V. 2009)

SCS curve defines three humidity conditions of dry (wilting point), Average humidity, and wet (soil capacity). The first humidity condition (dry) involves the lowest daily curve number. The curve numbers for the next two humidity conditions are calculated using Eqs. (4) and (5) (SWAT Theoretical Documentation, Version 2009):

$$CN_1 = CN_2 - \frac{20.(100 - CN_2)}{(100 - CN_2 + \exp[2.533 - 0.0636.(100 - CN_2)])} \quad (4)$$

$$CN_3 = CN_2.\exp[0.00673.(100 - CN_2)] \quad (5)$$

where CN_1, CN_2 and CN_3 are the curve numbers 1, 2 and 3 of the previous humidity, respectively.

William (1995) developed the curve number equation for different slopes as Eq. (6) (SWAT Theoretical Documentation Version 2009):

$$CN_{2s} = \frac{(CN_3 - CN_2)}{3}.[1 - 2.\exp(-13.86.slp)] + CN_2 \quad (6)$$

where CN_{2s} is the curve number of the previous humidity II set for the slope, CN_3 is the curve number III for 5% slope, CN_2 is the curve number of the previous humidity II for 5% slope and SLP is the average slope of the sub-basins. SWAT does not set the curve numbers for the slopes. Slope settings should be done before entering the curve number through the input file management. SWAT input variables that affect the surface runoff calculations using the curve number method are listed in Table 1 (SWAT Theoretical Documentation, Version 2009).

Table 1. SWAT input variables that are dependant upon surface runoff calculations using the SCS curve number method (SWAT Theoretical Documentation Version, 2009)

Variable	Definition	Input File
IEVENT	Rainfall, runoff , routing options.	.bsn
ICN	Daily curve number calculation method: 0 will caculate daily CN as a function of soil moisture; 1 will calculate daily CN as a function of plant evapotranspiration	.bsn
CNCOEF	Cncoef: Weihghting coefficient used to calculate the retention coefficient for daily CN calculations dependent upon the plant evapotranspiration	.bsn
PERCIPITATION	R_{day}: Daily precipitation (mm H_2O)	.pcp
CN_2	CN_2: Moisture condition CN II	.mgt
CNOP	CN_2: Moisture condition CN II	.mgt

Manning roughness coefficient of the surface flow for the desired watershed and considering the SWAT tables was in the range of 0.05 to 0.2 and the optimum value of 0.1 was obtained considering the area conditions (Engman E. T., 1983; USDA, 1983; SWAT Theoretical Documentation, Version 2009).

The land flow concentration time, t_{ov}, was calculated as Eq. (7) (SWAT Theoretical Documentation, Version 2009):

$$t_{ov} = \frac{L_{slp}}{3600.v_{ov}} \quad (7)$$

where L_{slp} is the length of sub-basin slope, v_{ov} is the land flow velocity (m/s) and 3600 is the unit conversion factor. The land flow velocity was estimated using Eq. (8) (Manning equation) (SWAT Theoretical Documentation Version 2009):

$$v_{ov} = \frac{q^{0.4}{}_{ov} slp^{0.3}}{n^{0.6}} \quad (8)$$

where q_{ov} is the average land flow (m^3/s), slp is the mean slope of the sub-basin and n is the Manning roughness coefficient of the sub-basin. Average flow velocity of 6.35 mm/h was considered and unit conversions were done through Eqs. (9) and (10) (SWAT Theoretical Documentation Version 2009).

$$v_{ov} = \frac{0.005.L_{slp}^{0.4}.slp^{0.3}}{n^{0.6}} \quad (9)$$

$$t_{ov} = \frac{L_{slp}^{0.6}.n^{0.6}}{18.slp^{0.3}} \quad (10)$$

5. The effect of Soil Type

In this study, the optimum Curve Number and Overland Roughness coefficient of watershed were investigated. The precipitation data was chosen from the different meteorological parameters to obtain the optimum Curve Number and the Overland Roughness coefficient of the watershed. SWAT model was initially run considering CN_2=67 and the Overland Roughness coefficient of 0.1. The results are presented in Fig. 3.

To optimize the parameters, different *CN* and roughness coefficient values were used. Changes of the discharge with these parameters are presented in Tables 2 and 3 are Figs. 4 to 7. In comparison with the recorded runoff values in the hydrometer station and the calculated flow values, the optimum Curve Number of 67 and the Roughness coefficient of 0.1 was obtained for the watershed. Subsequently, considering the obtained values, changes of the SWAT input parameters in simulation of the river discharge were investigated. The effects of changes in each of the meteorological parameters on simulation of the river discharge were studied and compared with the observed results. It should be mentioned that in this stage of the calculations only the precipitation input data was used in the model.

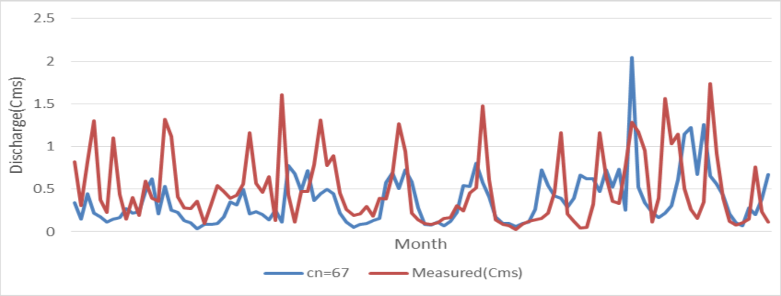

Fig. 3 . Comparison of the simulated monthly discharge using SWAT with the measured discharge.

Table 2 . The effect of *CN* on the average calculated discharge

CN	**67**	**69**	**72**	**76**
Average Calculated Discharge (m^3/s)	0.375787	0.377227	0.38084	0.388203
Average Measured Discharge (m^3/s)	0.498953	0.498953	0.498953	0.498953
Calculation Error (m^3/s)	0.123166	0.121726	0.118113	0.11075
Percent of the variable changes	0	0.3992%	1.3574%	3.3271%

Table 3. The effects of overland roughness coefficient on the average calculated discharge

Manning Overland Roughness coefficient	**0.05**	**0.1**	**.15**	**0.2**
Average Simulated Discharge (m^3/s)	0.375787	0.375787	0.375784	0.375774
Average Measured Discharge (m^3/s)	0.498953	0.498953	0.498953	0.498953
Difference between the Average Measured and Simulated Discharges (m^3/s)	0.123166	0.123166	0.123169	0.123179
Percent of the variable changes	0	0	-0.0007%	-0.0034%

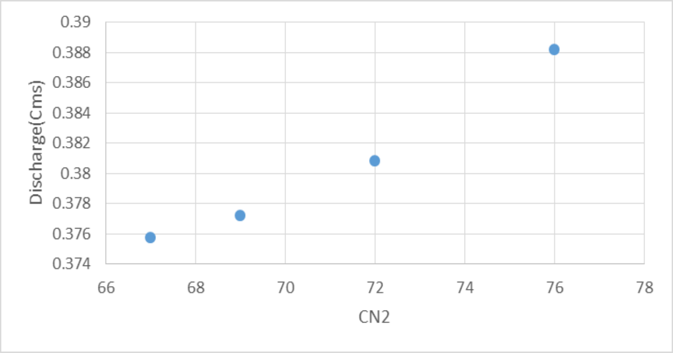

Fig. 4. CN_2 versus the simulated discharge

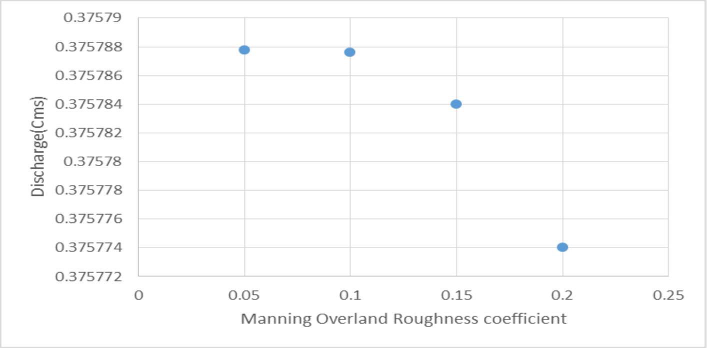

Fig. 5. Manning overland roughness coefficient versus simulated discharge

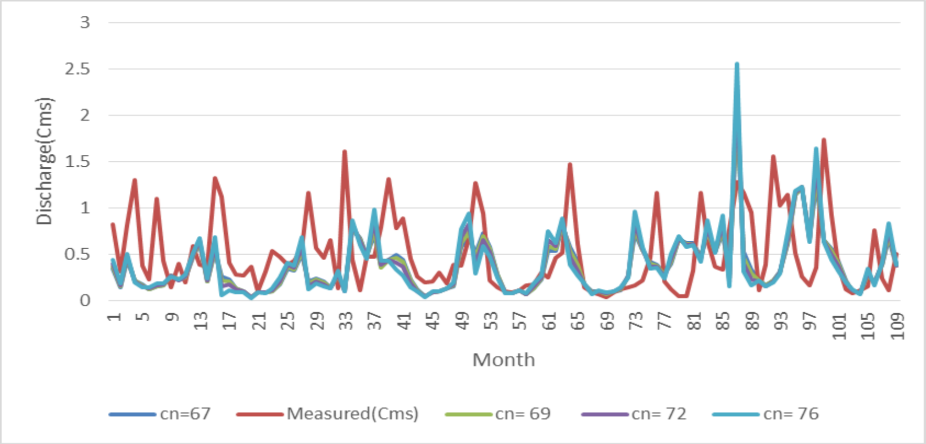

Fig. 6. Simulated river discharge using different CN values versus measured discharge

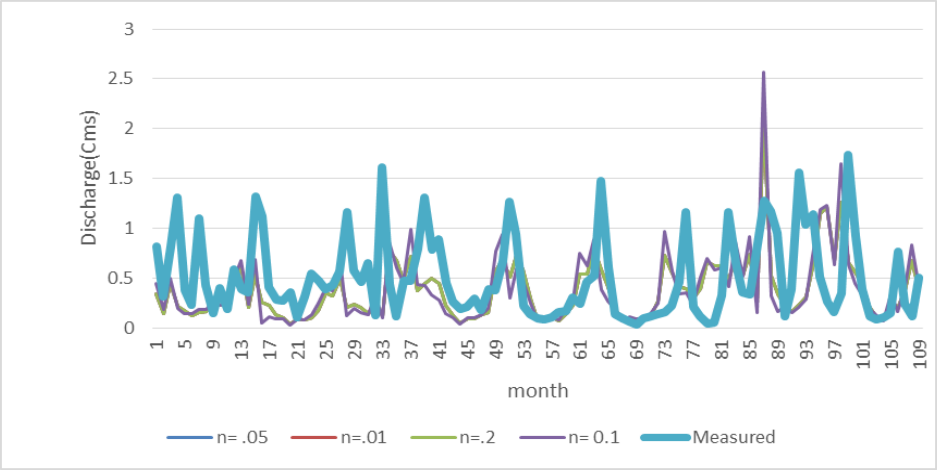

Fig. 7. Simulated river discharge using different Manning Overland Roughness coefficients versus measured discharge

6. Sensitivity analysis of the meteorological parameters in calculation of river runoff

In this stage, other required meteorological parameters including temperature, relative humidity, wind speed and solar radiation as well as precipitation were fed to SWAT and the average discharge was calculated as 0.5704 m3/s, as shown in the third row of Table 4.

6.1 The effect of Precipitation

In order to study the sensitivity of the estimated discharge to precipitation, first all the precipitation values were multiplied by 1.5 and the discharge was calculated. Using the real precipitation values, the average long-term discharge of the river was obtained as 0.5704225, while by increasing the precipitation by 50%, the river discharge increased to 1.285224074 (a 125% increase). With a 30% decrease in precipitation, the average discharge decreased by 64% (0.203889444 m^3/s). Consequently, a 0.7148 increase and a 0.3666 decrease occurred in monthly runoff. As can be seen from Fig. 8, the monthly discharge has an ascending trend versus precipitation. By a 50% increase and a 30% decrease in precipitation input data, the stimulated discharge was 0.79 higher and 0.29 lower than the measured average monthly discharge, respectively.

Table 4. Simulated discharge versus precipitation changes

Precipitation(mm)	**Average Simulated Discharge (m^3/s)**	**Average Measured Discharge (m^3/s)**	**Difference between the Average Measured and Simulated Discharges (m^3/s)**	**Changes of the Simulated Discharge (%)**
PCP×1.5=3.11181	1.285224074	0.49895304	0.7863	125.31%
PCP×0.7=1.452178	0.203889444	0.49895304	0.2951	-64.27%
PCP= 2.07454	0.5704225	0.49895304	0.0715	0

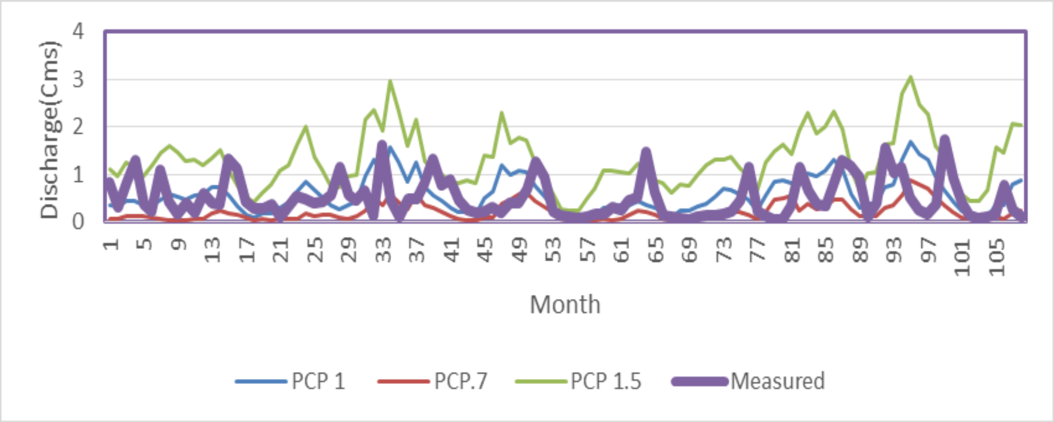

Fig. 8. Simulated discharge versus precipitation changes

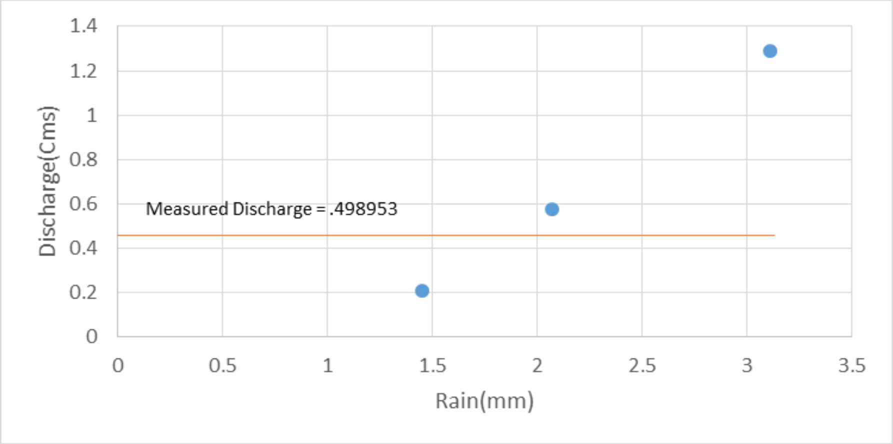

Fig. 9. Simulated discharge versus input precipitation data

6.2 The effect of Solar Radiation

By a 20% increase and a 30% decrease in the input solar radiation, the simulated discharge varied from 0.57 m^3/s to 0.59 and 1.22 m^3/s, respectively. The monthly changes are presented in Table 5 and Figs. 10 and 11. By a 20% increase and a 30% decrease in the input solar radiation, the simulated discharge was 0.09 and 0.73 m^3/s higher than the measured discharge, respectively.

Table 5. Simulated discharge using SWAT model versus input solar radiation data

Average Solar Radiation (MJ/(m^2/Day))	**Average Simulated Discharge (m^3/s)**	**Average Measured Discharge (m^3/s)**	**Difference between the Average Measured and Simulated Discharges (m^3/s)**	**Changes of the Simulated Discharge (%)**
solar ×1.2= 22.16	0.59279263	0.498653704	0.0938	3.9095%
solar ×0.7= 12.901	1.224596	0.498653704	0.7256	114.67%
solar= 18.43	0.5704225	0.498653704	0.0715	0

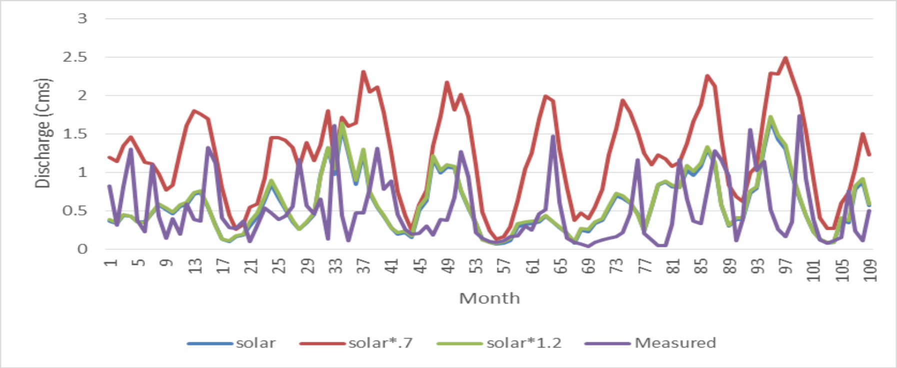

Fig. 10. Simulated discharges versus input Solar Radiation

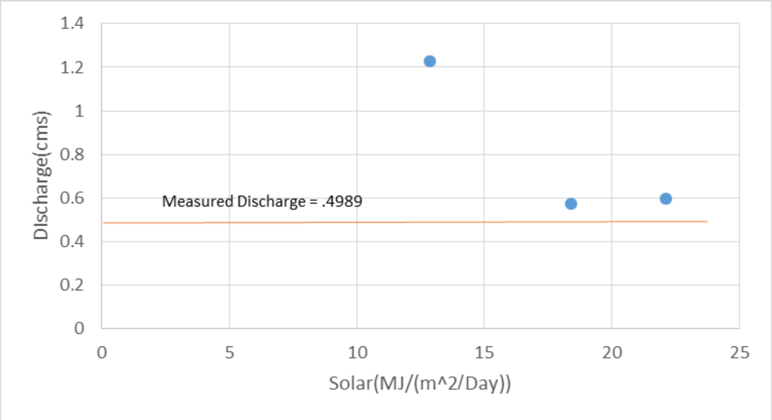

Fig. 11. Simulated average monthly discharge versus input Solar Radiation

6.3 The effect of Humidity

By a 20% increase and a 30% decrease in the input relative humidity, the average monthly discharge changed from 0.5704 to 0.6947 and 0.3084, respectively that shows a 21.79% increase and a 45% decrease that is presented in Table 6 and Figs. 12 and 13. With a 20% increase and a 30% decrease in input relative humidity, the simulated discharge increased by 39.25% and decreased by 38.18% from the average measured monthly discharge, respectively.

Table 6. Simulated discharge versus input relative humidity

Average Humidity (%)	**Average Simulated Discharge (m^3/s)**	**Average Measured Discharge (m^3/s)**	**Difference between the Average Measured and Simulated Discharges (m^3/s)**	**Changes of the Simulated Discharge (%)**
Rh =0.4591	0.5704225	0.498953	0.0715	0
Rh×1.2=0.5509	0.694742037	0.498953	0.1958	21.79%
Rh× 0.7=0.3213	0.308425093	0.498953	0.1905	-45.93%

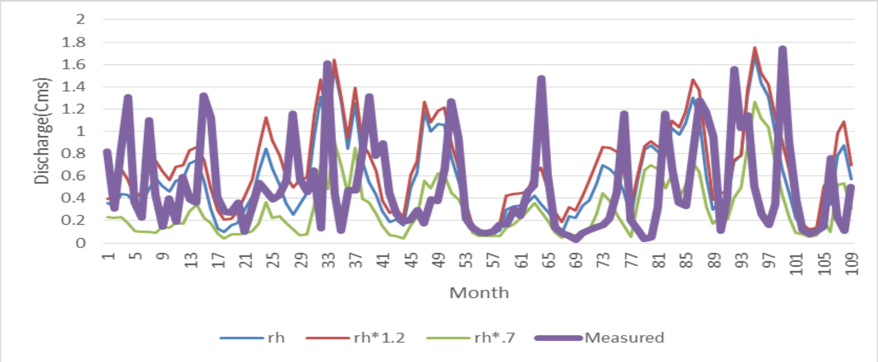

Fig. 12. Simulated average monthly discharge versus input Relative Humidity.

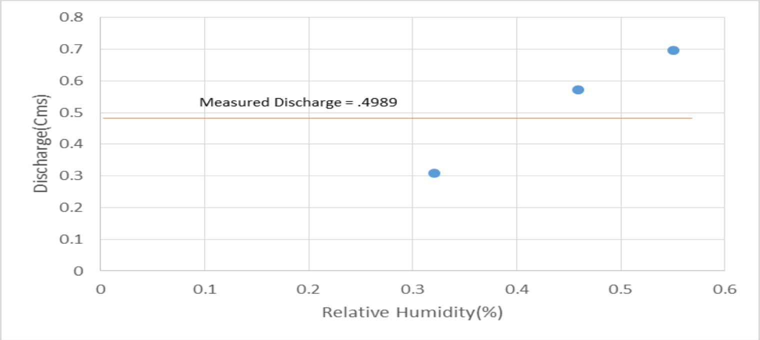

Fig. 13. Simulated discharge versus input relative humidity

6.4 The effects of Wind Speed

By a 50% increase and a 30% decrease in input wind speed, the average monthly discharge changed from 0.57 to 1.23 and 1.28 m^3/s, respectively that shows a 0.74 and 0.79 increase than the measured average monthly discharge (Figs. 14 and 15 and Table 7).

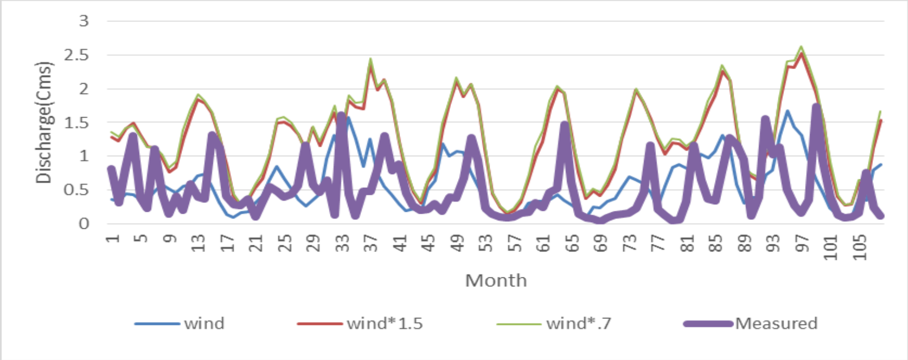

Fig. 14. Simulated discharge versus input Wind Speed

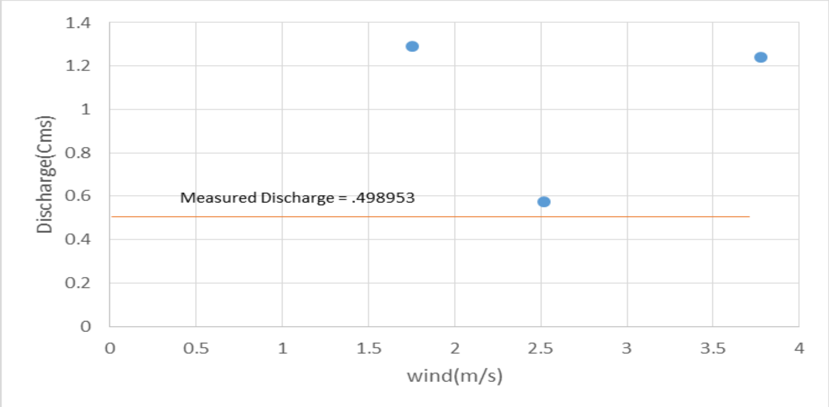

Fig. 15. Simulated discharge versus input wind speed

Table 7. Changes of the measured and simulated discharge by input wind speed

Average Wind Speed(m/s)	**Average Simulated Discharge (m^3/s)**	**Average Measured Discharge (m^3/s)**	**Difference between the average Measured and Simulated Discharges (m^3/s)**	**Changes of the Simulated Discharge (%)**
wind× 0.7 =1.764	1.2898388	0.498953704	0.7909	126.12%
wind× 1.5 =3.78	1.23933713	0.498953704	0.7404	117.26%
Wind=2.52	0.5704225	0.498953704	0.0715	0

6.5 The effects of Temperature

By a 50% increase and a 30% decrease in the input temperature, the average monthly discharge changed from 0.5704225 to 0.242062685 and 0.79410463, respectively that shows a 57.56% increase and a 39.21% decrease. The simulated discharges were 51% lower and 61.22% higher than the measured average monthly discharge (Figs. 16 and 17 and Table 8).

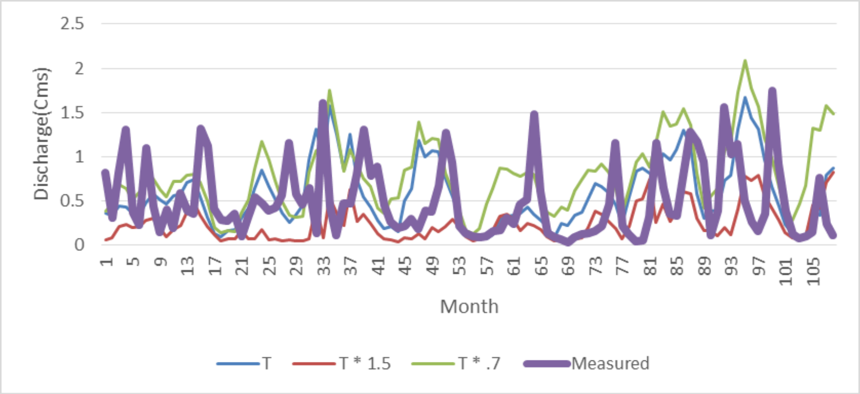

Fig. 16. Simulated discharge versus input temperature

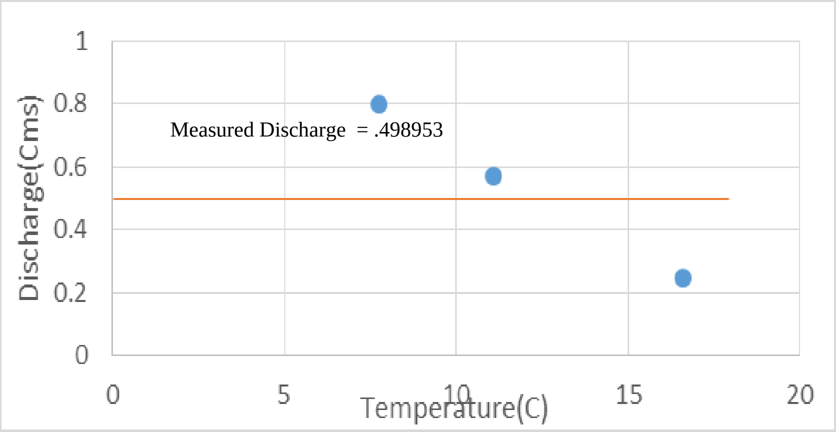

Fig. 17. Simulated average discharge versus input temperature

Table 8. Simulated discharge versus input temperature changes

Temperature(C)	**Average Simulated Discharge (m^3/s)**	**Average Measured Discharge (m^3/s)**	**Difference between the average Measured and Simulated Discharges (m^3/s)**	**Changes of the Simulated Discharge (%)**
T×0.7 =7.7627395	0.79410463	0.498953704	0.2952	39.21 %
T×1.5 =16.635587	0.242062685	0.498953704	0.2569	-57.57 %
T= 11.08963	0.5704225	0.498953704	0.0715	0

7. Conclusions

The followings were concluded from the present study:

1. By a 13.43% increase in the Curve Number, the simulated average monthly discharge got 2.51% closer to the measured average discharge. By a 0.15% increase in the roughness coefficient of the watershed, the simulated discharge got 0.01% closer to the measured discharge.
2. SWAT software is a good tool to estimate average monthly discharge using the precipitation, temperature and other required data. By a 30% decrease in the average monthly precipitation, solar radiation, relative humidity, wind and temperature, a 64.27% decrease, 114.67% increase, 45.93% decrease, 126.12% increase and 39.21% increase occurred in the simulated discharge, respectively. It is evident that the precipitation and the relative humidity decreased the most. The highest increases in discharge occurred for wind, solar radiation and temperature, respectively.
3. By a 50% increase in the average monthly precipitation, a 20% increase in the radiation and relative humidity and a 50% increase in wind and temperature, a 125.31% increase, 3.9095% increase, 21.79% increase, 117.26% increase and 57.57% decrease occurred in the simulated discharge, respectively. The highest increases in discharge occurred for precipitation, wind and relative humidity, respectively. Discharge showed the lowest sensitivity to the solar radiation.

Nomenclature

Q_{surf}	accumulated runoff (mm)
$R\ day$	height of water per day (mm)
I_a	the initial leakage of the surface reserve, the diffusion before runoff (mm
S	the water saving (mm)
CN_1	the number of previous humidity I
CN_2	the number of previous humidity II
CN_3	the number of previous humidity III
.pcp	precipitation
.mgt	management
.bsn	basin
CNOP	Moisture condition II curve number
t_{ov}	land current concentration time
L_{slp}	the length of sub-basin slope
v_{ov}	the velocity of land current (m/s)
q_{ov}	the average of the land current (m^3/s)
slp	the mean slope of sub-basin
n	Manning roughness coefficient for the sub-basin.

References

Alavinia M., Nasiri Saleh F., (2010), Comparsion Of HSPF and SWAT Model to simulate Sediment ;(Case Study: Watershed Abro). Fifth

National Congress On Civil Engineering Ferdowsi University Of Mashhad (in Persian).

Chu T. W. and Shirmohammadi A., (2004), Evaluation of the SWAT model's hydrology component in the piedmont physiographic region of Maryland. Trans. ASAE. 47, 1057-1073.

Engman E. T., (1983), Roughness coefficients for routing surface runoff. Proc Spec. Conf.

Geza M., McCray J., (2007), Effects of soil data resolution on SWAT model stream flow and water quality predictions.

Gholami Sh., (2004), Simulation of Daily Sediment using Distribuation SWAT Model in Mountain Catchment (Case Study: Catchment Emameh). Quarterly Research and Development (in Persian).

Green C., Griensven, (2007), Autocalibration in hydrologic modeling: Using SWAT2005 in the small-scale watersheds.

GUO J., GUO S. LI. T., (2011), Daily runoff simulation in Poyang Lake Intervening Basinbased on remote sensing data.

Hao F. H. , Zhang X. S. and Yang Z. F., (2004), A distributed nonpoint-source pollution model in Calibration and validation in the Yellow River basin. J. Environ. Sci. 16(4), 646-650.

Kannan N. , White S., Worrall F., Whelan M., (2006), Hydrological modelling of a small catchmentusing SWAT-2000 – Ensuring correct flowpartitioning for contaminant modelling.

Kannan N., White S., Worrall F., Whelan M., (2006), Sensitivity analysis and identification of the best evapotranspiration and runoff optionsfor hydrological modelling in SWAT-2000.

Kim N., Chang I., Won Y., Arnold J., (2008), Development and application of the integrated SWAT-MODFLOW model.

Milewski A., Sultan M., Yan Eugene, Becker R., Abdeldayem A., Soliman F., Abdel K., (2008), A remote sensing solution for estimating runoff and recharge in arid environments.

Nejad B., Behtari (2011), Estimation of erosion, sedimentation and nutrient loss in Gorganrood catchment with SWAT model. A Thesis Presented for a Degree Master of Science (M.Sc) in Soil Physics & Conservation (in Persian).

Omani N., Tajrishy M., Abrishamchie A., (2007), Streamflow Simulation Using Of SWAT and GIS Model. Seventh International Seminar Of River Engineering. Shahid Chamran University Of Ahvaz (in Persian).

Pourabdullah M., Tajrishy M., (2009), Erosion Catchment Model with SWAT & Rusle Model (Case Study: Emameh Sub-Catchment). Seventh International Conference Of Civil Engineering (in Persian).

Romanowicz A., Vanclooster M., Rounsevell M., Junesse I., (2005), Sensitivity of the SWAT model to the soil and land use data parametrisation: A case study in the Thyle catchment Belgium.

Rostamian R., Mousavi S., Heidarpour M., Afyuni M., Abaspour K., (2006), Apllication Of SWAT 2000 Model For Estimating Runoff and Sediment in Beheshtabad Sub-basin of Northern Karun. A Thesis Presented for a Degree Master of Science (M. Sc.) in Geology, Faculty Of Agriculture, Isfahan University Of Technology (in Persian).

Saadati H., (2003), Effect Of Land Use On Simulating Daily Discharge Flow Using SWAT Mathematical Model (Case Study: Kasilian Catchment Area). A thesis presented for the degree of Master in Watershed Management. Tarbiat Modares University, Natural Science Faculty (in persian).

Santhi C., Arnold J. G., Williams J. R., Dugas W. A., Srinivasan R., and Hauck L. M., (2001), Validation of the SWAT model on a large river basin with point and nonpoint sources. Journal of American Water Resources Association, 37, 1169-1188.

Schuol J., Abbaspour K. C., Yang H., Reichert P., Srinivasan R., Schar Ch., and Zehnder A. J. B., (2006), Estimation of freshwater availability in the west Africa subcontinent. J.

SCS. (1972), Soil Conservation Service, Section 4: Hydrology In National Engineering Hand-book. SCS.

Soil Conservation Service Engineering Division. (1986), Urban hydrology for small watersheds. U. S. Department of Agriculture, Technical Release 55. U.

Talebizadeh M., (2009), Daily Sediment Load Estimation Using The SWAT Model and Artificial Neural Network, Case Study: Kasilian Watershed. Tarbiat Modares University, Natural Science Faculty (in Persian).

Tolson B., Shoemaker C., (2006), Cannonsville Reservoir Watershed Swat 2000 Model development, calibration and validation.

USDA (1983), USDA Soil Conservation Service. In National Engineering Handbook, Section 4 Hydrology, Chapter 19.

USDA (1972), USDA Soil Conservation Service. National Engineering Handbook, Section 4 Hydrology, Chapters 4-10.

Yang J., Reichert P., Abbaspour K., Yang H., (2007), Hydrological modeling of the Chaohe Basin in China: Statistical model formulation and Bayesian inference.