Modeling Earth Systems and Environment (2020) 6:1427–1437
https://doi.org/10.1007/s40808-020-00759-0

ORIGINAL ARTICLE

Check for updates

Assessment of climate change impacts on streamflow through hydrological model using SWAT model: a case study of Afghanistan

Taha Aawar[1] · Deepak Khare[2]

Received: 22 October 2019 / Accepted: 21 March 2020 / Published online: 19 April 2020

Abstract

Hydrological models always forecast variable status and, therefore, need further studies in models to make more real the management of the water resources. Analysis and execution of the watershed model are essential to carry out the valid assessment of water resources, individually in Kabul river sub-basin, where the modeling is a challengeable issue due to the lack of data. In this research, the Kabul river sub-basin watershed located at the Istalif station is modeled through the Soil and Water Assessment Tool (SWAT) to predict the future streamflow and climate change impacts on it. The model is calibrated with monthly discharge data for 2003–2010 and validated for 2010–2018. SWAT-CUP, which recently has developed with the capacity of providing the decision making for using manual and automated calibration and incorporating sensitivity and uncertainty analysis through (SUFI2) algorithm, is used for calibration and validation. According to coefficient of determination (R^2), Nash Sutcliffe efficiency, and present bias parameters, the calculation indicates an excellent performance for both calibration and validation periods and acceptable agreement between measured and simulated values of monthly scale discharge. Results show the importance of climate change effect on water resources, where it does not have only an effect on precipitation and temperature, but the streamflow is also directly influenced by climate change. The impact of climate change on the surface flow as well as land use/land cover change and other different scenarios is evaluated using calibrated SWAT model for further investigation.

Keywords Hydrological model · Climate change · SWAT model

Introduction

A hydrological cycle is the combination of water resources, natural hazards, hydropower, and environmental aspects. To find out the impacts of changes in climate, land use/land cover, and population, a hydrological model is highly recommended, which, through the model, can get the right answer for many questions. Hydrological models are used for simulating the rivers and providing valuable information (Viviroli et al. 2009). Climate change has been recognized as a critical environmental issue in the twenty-first century that has a very significant effect on the hydrological cycle, ecology, and environment. Recently, many researchers have focused on climate change and its impact on hydrological issues and water resources (Zhang et al. 2015). Graham et al. (2007) have focused on climate variation on the hydrological models, where other changes by human activities have not been considered. The authors used multiple regional climate models to find out the impacts of climate change scenarios in different dynamical hydrological models.

The impact of climate change, land use in river hydrology, and surface water availability can be directly related to the discharge as well as rainfall–runoff model application (Stehr et al. 2008). Two fundamental components that have a significant role in water resources planning and management are climate and land use/land cover (Setegn et al. 2008). Due to human activities, the increasing global population, and climate change as well as land use, the water shortage

✉ Taha Aawar
maawar@wr.iitr.ac.in

Deepak Khare
kharefwt@iitr.ac.in

[1] Water Resources Department, Afghanistan National Water and Environmental Research Center (ANWERC), Kabul, Afghanistan

[2] Indian Institute of Technology Roorkee, Roorkee, India

has become a severe crisis in the world as a critical resource of sustainable economic and environmental development (Vilaysane et al. 2015). Discharge is one of the most crucial parameters in water resources, which plays a significant role in the planning and management of the catchment area. To estimate the discharge value, a model is needed that can realistically simulate the runoff. Runoff is a characteristic of resolution for hydrologic modeling (Duvvuri 2018). Surface water is the case of erosion; therefore, by increasing the surface runoff, landslide and erosion increased in a catchment area, and this has a direct effect on agricultural production (Nursugi and Windari 2016). Due to integrated management and adequate allocation of water under climate change and LULC change, many societies faced challenges; therefore, for analysis of the impacts of these two major factors on water resources and river hydrology, the model application is essential (Stehr et al. 2008). The study of water resources management would be helpful when it uses the methods and technologies for combining the parameters that have a direct impact on water resources such as topography and climate change. Moreover, the management of water resources is required to approach technology, which is robust to analyze the effect of the human being as well as global change on it (Semlali et al. 2017). Global warming is the case of a change in precipitation as well as climate variations, which can be the reason for increasing streamflow, where a change in runoff has a significant role in water resources planning and management (Teng et al. 2012). It is expected to appear the scarcities of freshwater almost overall the world due to the utilization of water, and this issue would be a very concerned point in the future (Abseno 2013). Most of the hydrological and ecological models need daily weather data, which are not easily accessible. In the world, around 40,000 stations of weather data are available, which are quickly distributed as uneven from the few stations over the world. Moreover, another essential issue is the quality of these data, which often large scales of these data are missing; therefore, using a model like SWAT is useful (Schuol and Abbaspour 2007). Water and land are the two significant parts of ecology that have a direct effect on the persistence and decadence of a watershed. The SWAT model is used for a different purpose, like evaluating the water quality, flood warning due to the simulation of flow, and assessing the effect of climate change on the water resources. Studies have shown the efficiency and potential of the SWAT model for the simulation of hydrology in a watershed (Quyen et al. 2014). SWAT model has been used in several case studies to find out the impact of climate change in water resources (Fohrer 1999; Setegn et al. 2008; GITHUI et al. 2009; Easton et al. 2010; Kushwaha and Jain 2013; Quyen et al. 2014; Duvvuri 2018; Gashaw et al. 2018; Singh et al. 2018).

Study area

Afghanistan is a central Asian country surrounded by Iran in the west, Turkmenistan, Uzbekistan, and Tajikistan in the north, China in the east, and Pakistan in the south. This country has 650,000 km^2 area with dry continental climate as a mountainous country (Aawar et al. 2019). This country has five major river basins, as shown in Table 1. Kabul river basin is located in the southeast part of Afghanistan after 700-km-long loin to the Indus river in Pakistan (<i> Scoping Strategic Options for Development of the Kabul River Basin </i>, n.d.). Figure 1 shows the study area location.

The study area is divided into four sub-watersheds, as shown in Fig. 2. The total area of the watershed is 7005 km^2 which the main outlet (gauged) watershed area is 2819 km^2 in this model for the simulation of the streamflow.

Methodology

In this study, a flow simulation of the hydrological conditions is done through a model. The impacts of climate change, LULC change, and soil condition on surface runoff of Kabul River are analyzed by using ArcSWAT 2012. SWAT is one of the powerful watershed models for the simulation of the hydrological conditions to find out the impact of climate change on water resources. As hydrological response is affected by many variables such as soil characteristics, soil moisture, land use, and land cover, it is essential to use the hydrological model.

Table 1 Afghanistan river basin

River basin in Afghanistan			
Name of river basin	Catchment area percentage	Water percentage	Rivers
Amu Darya	14	57	Amu Darya, Panj, Wakhan, Kunduz, Kokcha
Hari Rod–Murghab	12	4	Hari Rod, Murghab, Koshk
Helmand	41	11	Helmand, Arghandab, Tarnak, Ghazni, Farah, Khash
Kabul (Indus)	11	26	Kabul, Konar, Panjshir, Ghorband, Alinigar, Logar
Northern	11	2	Balkh, Sar-i-Pul, Khulm
Non-drainage area	10		

Fig. 1 Study area

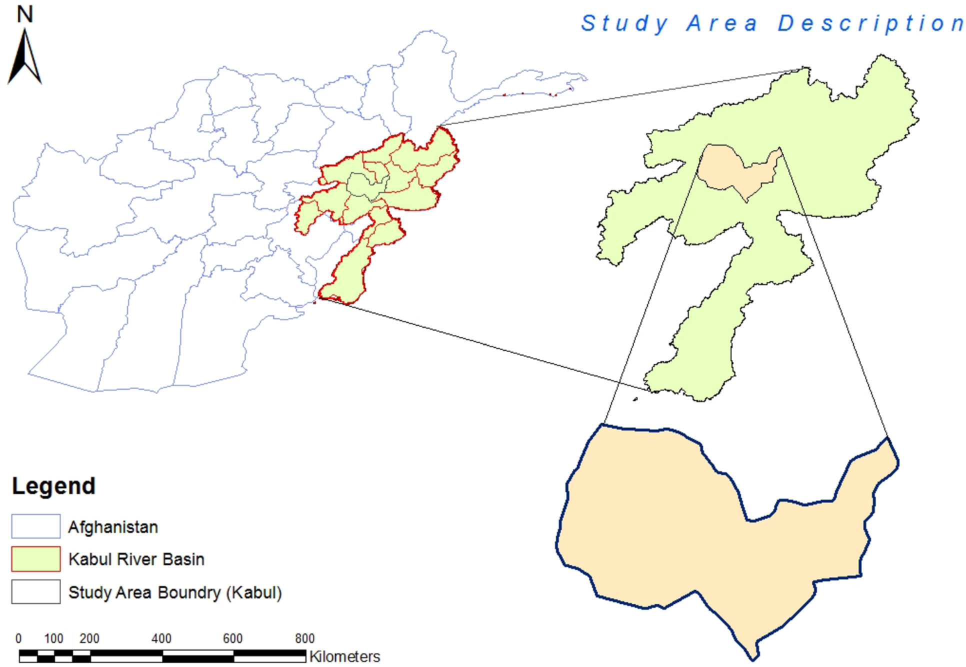
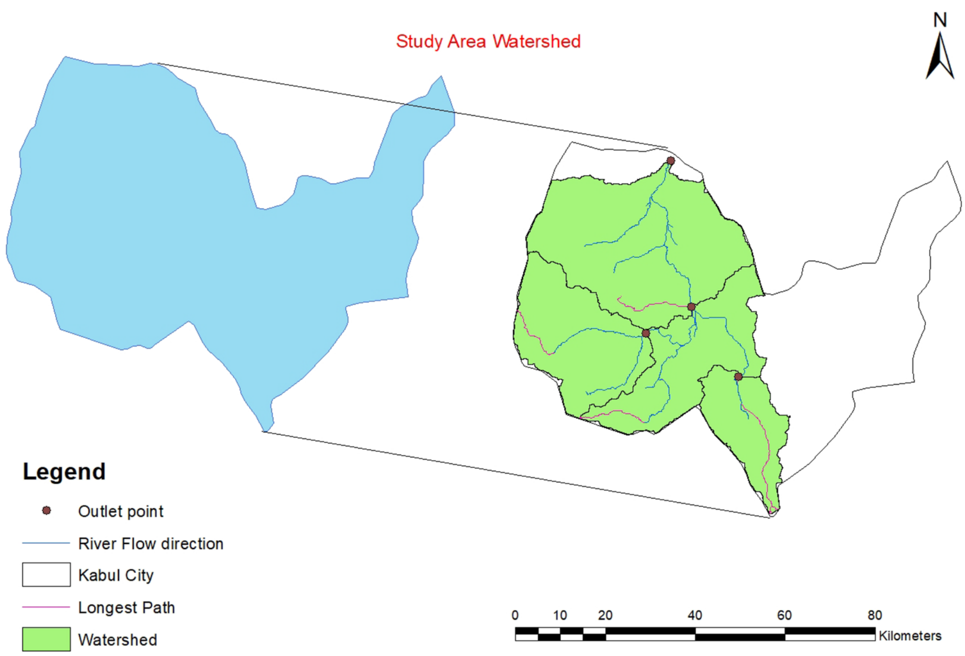


Fig. 2 Watershed of study area



As illustrated in Fig. 3, the methodology embraces three steps. The first step includes creating watershed, the second stage consists of identifying hydrological response units, and the third part includes determining general weather station data.

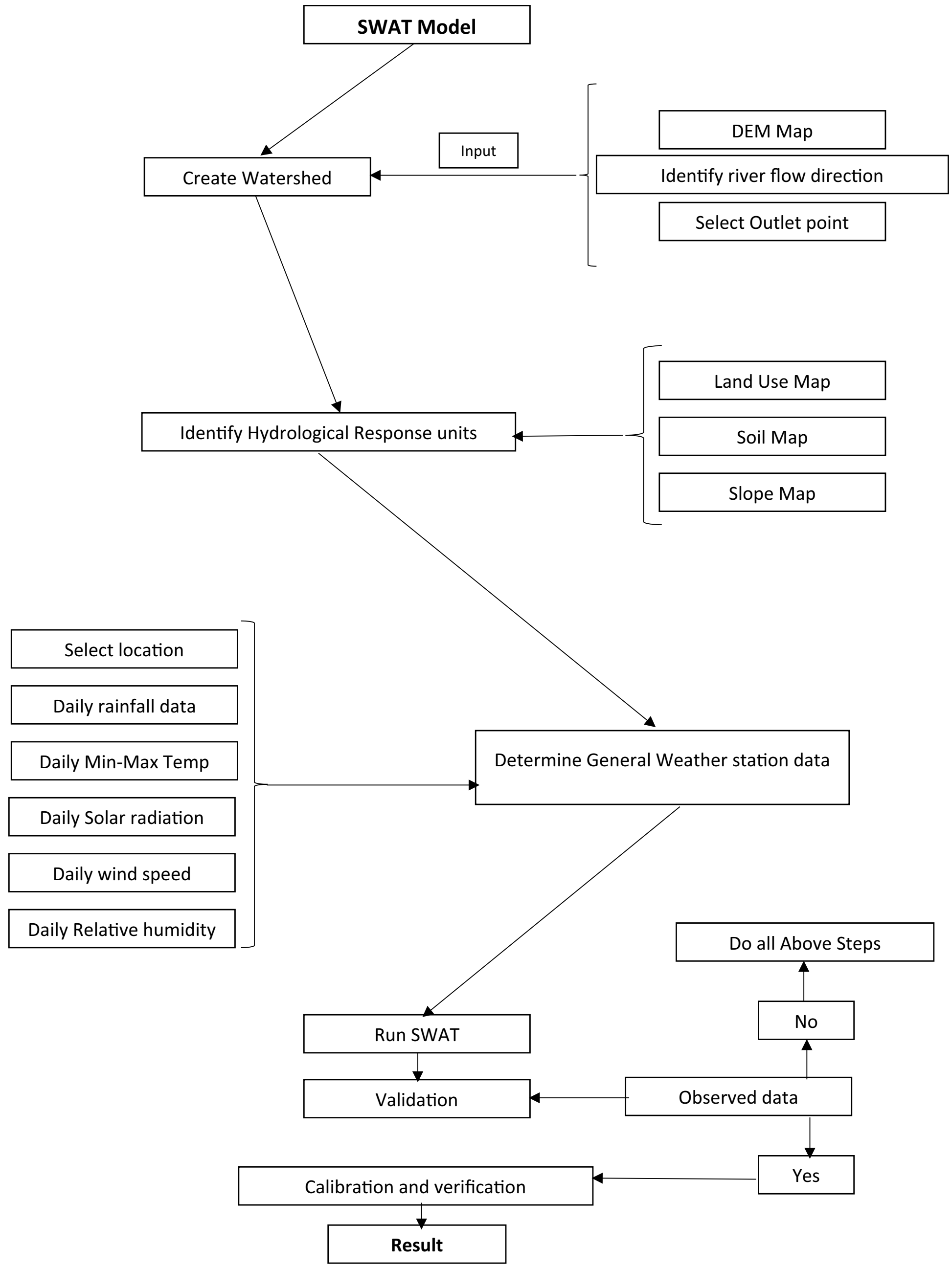


Fig. 3 Methodology flowchart

Description of the SWAT model

Soil and Water Assessment Tool (SWAT) is a model designed on continuous time and spatially distributed for the simulation of water, sediment, and nutrient and pesticide transport at a catchment scale on a daily time step (Setegn et al. 2008; Winchell et al. 2007). The SWAT model is used to predict the influence of land use and land cover change on water in a vast watershed over a long time with different conditions (Gashaw et al. 2018).

In 1990s, the first version of SWAT 94.2 is developed and released, and for the first time, Arnold in 1994 published a peer-reviewed description of a geographic information system (GIS) interface for SWAT. United States Department of Agriculture (USDA) has developed the SWAT model in the Agricultural Research Service (ARS), which has over 30 years of experience in modeling. The current SWAT model contains the key elements contributed by the USDA-ARS model (Arnold 1998; Hansen et al. 2013).

The purposive use of the SWAT model is to predict the impact of climate on water resources, as well as sediment and chemical yield in a large scale of the ungauged basin Holeček (2001).

The SWAT model is based on a water balance equation in the soil profile where the simulation process contains the surface flow, runoff, evapotranspiration, precipitation, infiltration, and percolation, as shown in Eq. 1 (Arnold 1998; Gashaw et al. 2018; Holeček 2001; Quyen et al. 2014; Setegn et al. 2008; Tibebe and Bewket 2011; Ghoraba 2015).

$$SW_t = SW_0 + \sum_{i=0}^{t} \left(R_{day} - Q_{Sur} - E_a - W_{Seep} - Q_{gw} \right) \quad (1)$$

where SW_t is the final soil water content (mm), SW_0 the initial soil water content (mm), R_{day} the rainfall amount on day i (mm), Q_{Sur} the surface runoff on the day i (mm), E_a the evapotranspiration amount on day i (mm), W_{Seep} the seepage water amount on the day i (mm), and Q_{Gw} the return flow on day i (mm), t time (days).

In this research, the Soil Conservation Service (SCS)–Curve Number (CN) method has been used in the SWAT model for assessing the surface runoff in the watershed.

SCS–CN equation is one of the powerful and efficient methods for predicting the runoff from the given daily precipitation data, as shown in Eq. 2 (Arnold 1998; Gashaw et al. 2018; Setegn et al. 2008; Tibebe and Bewket 2011; Ghoraba 2015).

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

where Q_{Sur} is a daily surface runoff in (mm) and R_{day} is the depth of daily rainfall (mm).

S is the retention parameter in (mm), which can be found out by Eq. 3.

$$S = 254 \left(\frac{100}{CN} - 1 \right) \quad (3)$$

where CN is the curve number, which has a range of $100 \geq CN \geq 0$, where CN = 100 value represents the zero potential retention and CN = 0 represents an infinitely abstracting catchment with $S = \infty$.

Data input

DEM map

The 90 m digital elevation model (DEM) image is downloaded from (https://srtm.csi.cgiar.org) for making the watershed delineation in ArcSWAT 2012. ArcGIS 10.4.1 is used for generating the DEM map, as shown in Fig. 4.

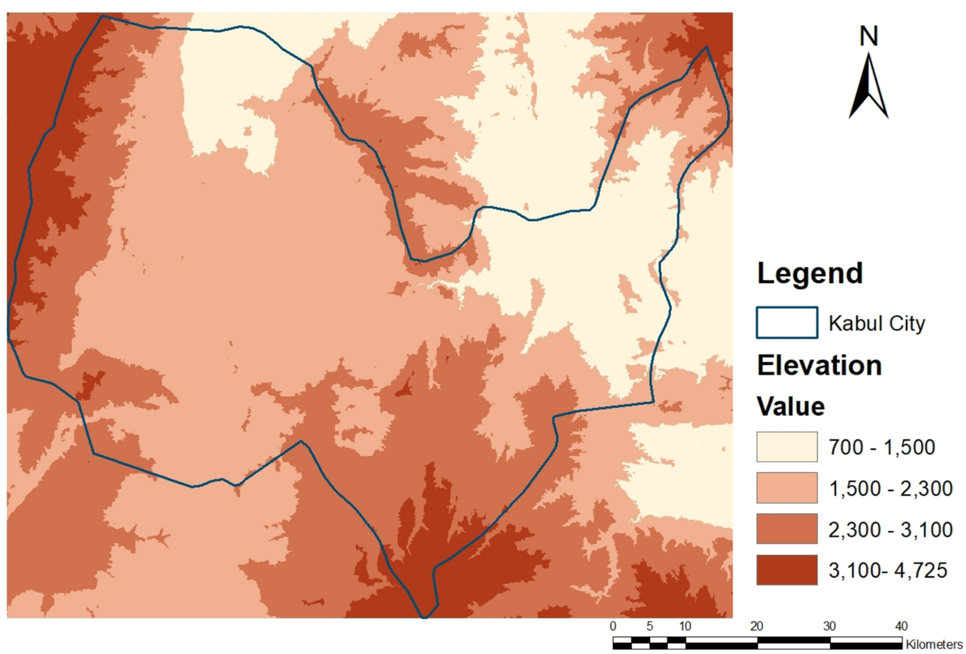


Fig. 4 Kabul DEM map

Table 2 Satellite image source

SI/No.	Sensor/satellite	Date	Path and row	Source
1	Landsat 8 OLI/TURS C1 Level1	May/7/2018 Jul/13/2018	164/036	USGS

Land use/land cover map

Landsat data are downloaded from the website (https://earthexplorer.usgs.gov/) as given in detail in Table 2 for the study area. ArcGIS 10.4.1, Google Earth Pro, and ERDAS Imagine 2018 are used for generating the LULC map. The classification process is done through ERDAS Imagine 2018 with a hybrid classification, which is the combination of supervised and unsupervised classification. Accuracy assessment showed 86.67% and kappa coefficient 0.84 for the Kabul LULC map. Figure 5 shows the Kabul LULC map of 2018.

Soil map

World soil map is downloaded from the United Nations Food and Agriculture Organization (FAO) (https://www.fao.org/geonetwork/srv/en/metadata.show%3Fid=14116). ArcGIS 10.4.1 is used to create the study area soil map. Kabul soil map has three different types of soils, as shown in Fig. 6.

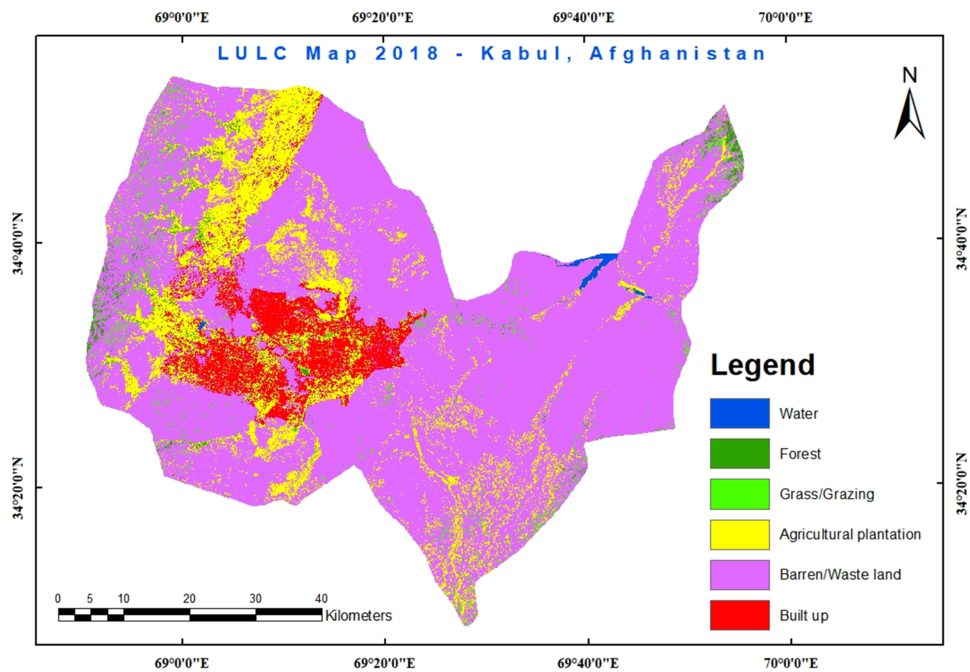


Fig. 5 Land use/land cover map

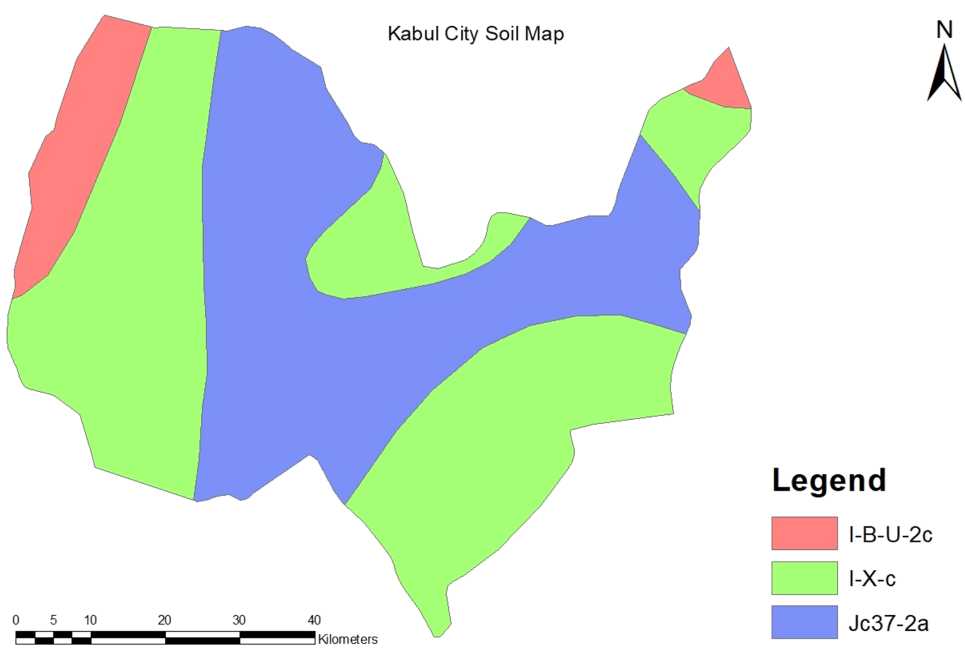


Fig. 6 Kabul soil map

Soil type has a direct impact on streamflow due to the physical and chemical properties of soil, such as water content availability, hydraulic conductivity, texture, and bulk density in each layer of earth which determine surface runoff factors.

Climate change components

Daily precipitation data

Daily precipitation data with time intervals from 2000 up to 2018 have been collected from the Ministry of Energy and Water of Afghanistan. Table 3 and Fig. 7 show the details and location of rainfall data stations in the study area.

Table 3 Metrological station properties

Geographic characteristics of the weather station sites				
No.	Name of station	Longitude	Latitude	Elevation (m)
1	Payan-I-Qargha	69° 2′ 8.68″	34° 33′ 9.14″	1970
2	Pul-I-Surkh	69° 17′ 19.26″	34° 22′ 0.63″	2216
3	Tang-I-Sayedan	69° 6′ 15.88″	34° 24′ 32.31″	1870
4	Shakardara	69° 0′ 13.03″	34° 41′ 7.75″	2168
5	Istalif	69° 17′ 19.26″	34° 49′ 42.06″	1821
6	Teng-e-gharo	69° 17′ 19.26″	34° 34′ 11.57″	1775
7	Balay-I-Qargha	69° 17′ 19.26″	34° 33′ 21.93″	2007
8	Sang-I-Naweshta	69° 17′ 19.26″	34° 25′ 5.48″	1813

Daily maximum and minimum air temperatures

Daily maximum and minimum air temperature [(T_{max}) and (T_{min})] data with the time interval of 2000–2018 have been collected from MoEW of Afghanistan.

Solar radiation, relative humidity, and wind speed

Due to the three-decade civil war in Afghanistan from 1980 up to 2004, the meteorological and hydrological data were not recorded; therefore, the missed data such as solar radiation, relative humidity, and wind speed are obtained from NASA power data access (https://power.larc.nasa.gov/data-access-viewer/).

Monthly discharge flow

As daily discharge flow data were not available, monthly discharge flow is used for the validation of streamflow with the time interval from 2010 to 2018.

Sensitivity analysis

The method which indicates the significant parameter that has the most effect on streamflow in the calibration and validation process through the SWAT model is called sensitivity analysis (Arnold 1998; Zhang et al. 2009; Tang et al. 2012; Vilaysane et al. 2015; Khalid et al. 2016; Shrestha et al. 2016; Ang and Oeurng 2018). Accuracy assessment with selected ten different

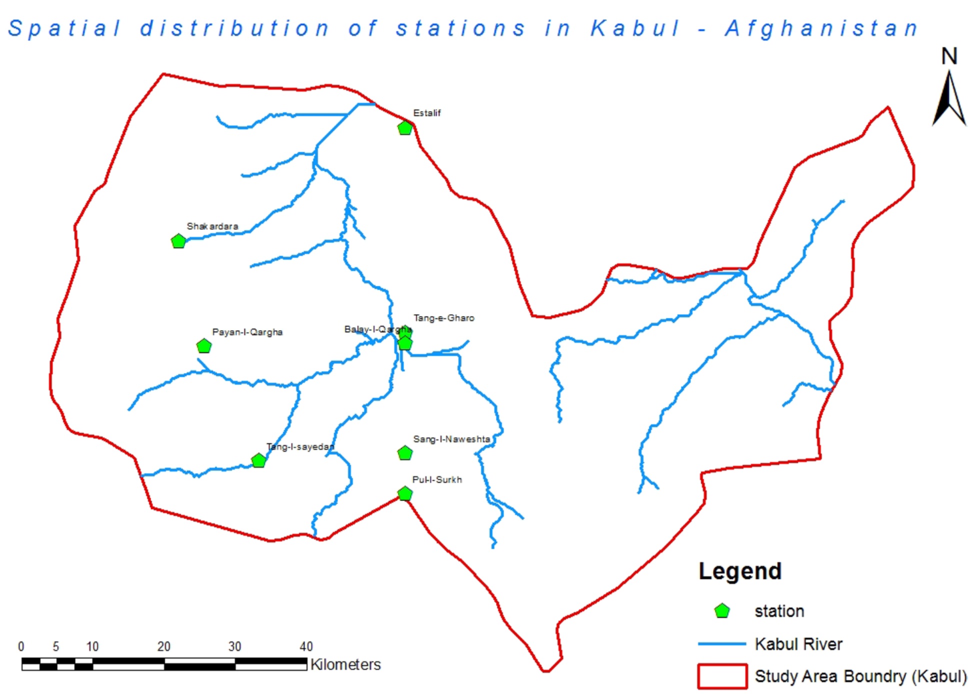


Fig. 7 Metrological stations of Kabul city

parameters that have a direct influence on streamflow was analyzed through SWAT-CUP 2012, as shown in Table 4.

Calibration and validation

The process which adapts or alters the model parameter following their range value based on observed data to confirm the same response over time is called calibration, where the validation is a process that indicates the relative between simulated and observed data in a specific time interval without adjusting the parameters (Abbaspour 2015). The simulated discharge data are created by using SWAT, based on Eqs. 1, 2, and 3.

Model performance list

The SWAT performance on surface flow simulation is analyzed with the coefficient of determination (R^2), Nash Sutcliffe efficiency (NSE), and present bias (PBIAS) parameters as recommended by several researchers (Abbaspour 2015; Leta et al. 2018; Meaurio et al. 2015; Moriasi et al. 2015; Yuemei et al. 2008). The coefficient of determination, Nash Sutcliffe efficiency, and present bias parameters are determined by using Eqs. 4, 5, and 6, respectively.

$$R^2 = \frac{\sum_{i=1}^{n}\left(Q_{o,i} - \overline{Q_o}\right)\left(Q_{s,i} - \overline{Q_s}\right)}{\sqrt{\sum_{i=1}^{n}\left(Q_{o,i} - \overline{Q_o}\right)}\sqrt{\sum_{i=1}^{n}\left(Q_{s,i} - \overline{Q_s}\right)}} \quad (4)$$

$$\mathrm{NSE} = \frac{\sum_{i=1}^{n}\left(Q_{s,i} - Q_{o,i}\right)^2}{\sum_{i=1}^{n}\left(Q_{o,i} - \overline{Q_{o,}}\right)^2} \quad (5)$$

$$\mathrm{PBAIS} = \frac{\sum_{i=1}^{n}\left(Q_{s,i} - Q_{o,i}\right)}{\sum_{i=1}^{n}\left(Q_{o,i}\right)} \times 100 \quad (6)$$

where R^2 is the coefficient of determination, NSE is the Nash Sutcliffe efficiency, PBAIS is the present bias, n is the period, Q_o and Q_s are the observed and simulated streamflow, respectively. $\overline{Q_o}$ and $\overline{Q_S}$ are the mean value of observed and simulated discharge, respectively.

Results and discussion

Sensitivity analysis

Sensitivity analysis assessment with ten different parameters that have a direct influence on streamflow investigated through SWAT-CUP 2012, which is based on Eqs. 4, 5, and 6 as shown in Table 4. The result shows that out of these ten parameters, four are the most sensitive parameters shown in Table 5.

CN2 is a function of watershed properties, which is used to calculate the depth of runoff from total precipitation depth. Watershed properties are dependable on soil moisture conditions, soil type, and land use conditions (Gdp and Proceedings 2007).

The R^2 values were around 0.83% for calibration and 0.86% for validation, which represents more than ¾th of the observed variation illuminated by the model's inputs. The NS efficiency, whose value should ideally be one, was calculated to be 0.73 for validation and 0.57 for calibration, which shows approximately 60% match of modeled discharge to the observed data. PBIAS parameter presents the difference

Table 4 Sensitivity analysis parameters

No	Parameter	Description	classification	Range of initial value	
				Min	Max
1	R__CN2.mgt	SCS runoff curve number for moisture condition II	Surface runoff	35	98
2	V__SURLAG.bsn	Surface runoff lag time		0.05	24
3	V__GW_DELAY.gw	Groundwater delay (days)	Groundwater	0	500
4	V__GWQMN.gw	Threshold depth of water in the shallow aquifer required for return flow to occur (mm)		0	5000
5	V__ALPHA_BF.gw	Base flow alpha factor (days)		0	1
6	V__SOL_AWC(..).sol	Available water capacity of the soil layer	Soil	0	1
7	V__SOL_K(..).sol	Saturated hydraulic conductivity		0	2000
8	V__TLAPS.sub	Temperature lapse rate	Temperature	−10	10
9	V__EPCO.hru	Plant uptake compensation factor	Evapotranspiration	0	1
10	V__ESCO.hru	Soil evaporation compensation factor		0	1

V__ represents the parameter value which is replaced with the given value

R__ represents the parameter value that multiplied with the (1 + given value) between the simulated and observed amount, and its ideal value is 0. The positive value of the model represents underestimation, where the negative value shows overestimation. The 69.7% for calibration and 41.2% for validation show underestimation.

Calibration and validation

The observed discharge data were analyzed with simulation data for calibration and validation through SWAT-CUP 2012 by applying the most effective parameters on surface flow, where Table 6 presents the result of calibration and validation.

The graphical comparison of monthly observed data with simulated streamflow data for calibration and validation with the time interval of 01.01.2010 to 31.12.2017 and 01.01.2003 to 31.12.2013, respectively, is shown in Figs. 8 and 9.

Conclusion

In the present study, an effort has been made to pretend the impact of climate change, LULC, soil, and topographic condition on Kabul River sub-basin through ArcSWAT 2012, by the input of long-term metrological data, satellite images, soil data, and DEM image, correspondingly. Kabul River sub-basin model was calibrated and validated with the SUFI-2 algorithm of SWAT-CUP to optimize the output so that it matches the observed discharge, available at Istalif gauging station. Hydrological analysis of this research determined the efficiency and

Table 5 Most sensitive flow parameters

Rank of sensitivity	Parameters	T-state	P-value	Min value	Max value	Fitted value
1	1. CN2.mgt	22.66	0.00	−0.5	0.5	−0.02
2	10. ESCO.hru	1.02	0.31	0	1	0.88
3	5. SURLAG.bsn	0.58	0.56	0.05	24	20.766
4	4. GWQMN.gw	0.01	0.99	0	1000	517

Table 6 Model performance statistic for the calibration and validation periods

Name of watershed	Station	Period				Evaluated statistic parameter					
		Calibration		Validation		R^2		NSE		PBIAS	
		From	To	From	To	Cal	Val	Cal	Val	Cal	Val
Kabul river sub-basin	Istalif	2010	2017	2003	2012	0.83	0.86	0.57	0.73	69.7	41.2

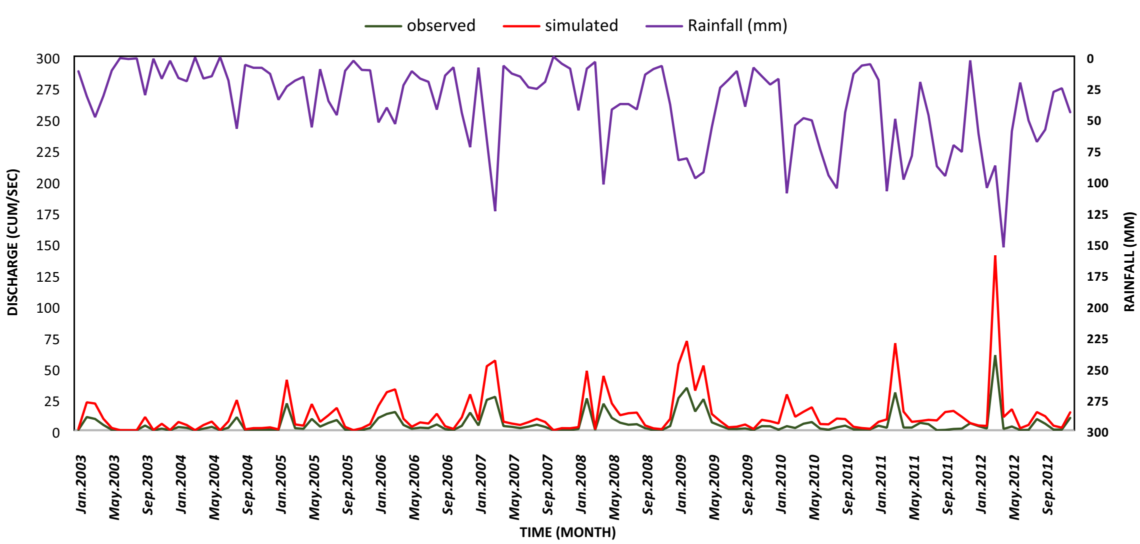


Fig. 8 Graphical comparison of monthly observed data with simulated stream flow data for validation as well as monthly rainfall data

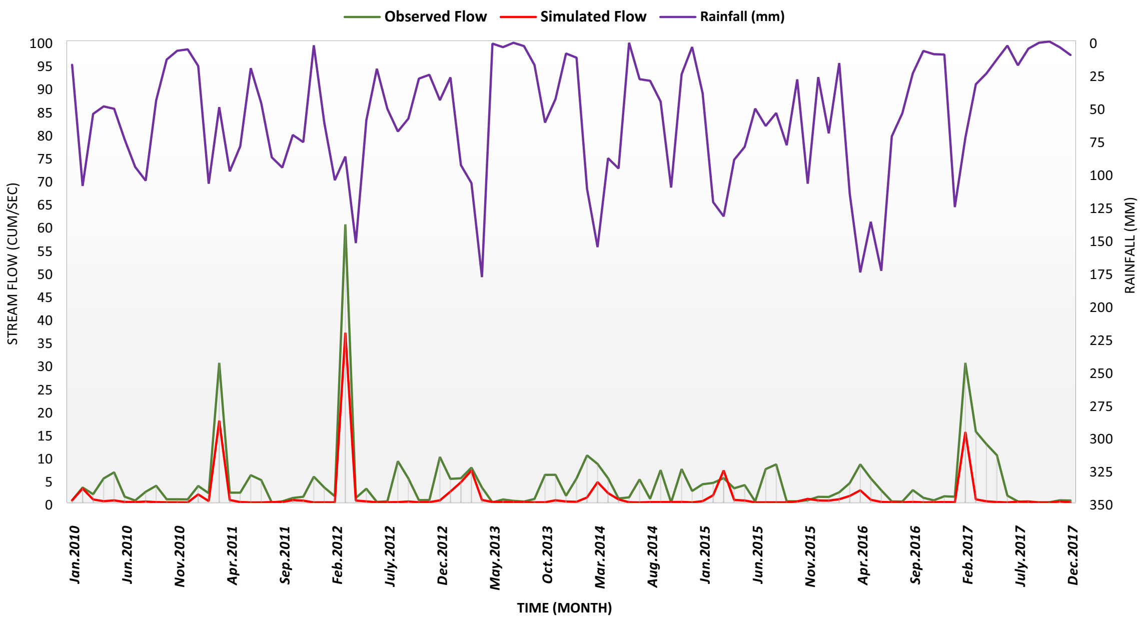


Fig. 9 Graphical comparison of monthly observed data with simulated stream flow data for calibration as well as monthly rainfall data

power of the SWAT model. The coefficient of determination (R^2), Nash Sutcliffe efficiency (NSE), and present bias (PBIAS) parameters are considered as main parameters to check the performance of the model. The R^2 value for validation is 0.86%, and calibration is 0.83%, which shows the symmetry regression of this model. The NS efficiency is 0.73 for validation and 0.57 for calibration representing a proper modeled discharge to the observed data. PBIAS parameter presents 69.7 and 41.2% for calibration and validation, respectively, showing underestimation. The model efficiency has been evaluated through a proper calibration from 2003 to 2014 and validation from 2010 to 2017 results. The calibrated model can be used for further investigation of the effect of climate change, land use change, and other different management scenarios on streamflow and soil erosion. The result of the simulated model indicates a small part of a basin which has a high impact on the water balances, while the uncertainty of the outcome is high. Illustration of calibration is realistic, but it would never be the best fit due to the non-uniqueness of valid parameters. The coefficient of determination (R^2), Nash Sutcliffe efficiency (NSE), and present bias (PBIAS) parameter have cleared that after climate change impacts on water resources, the soil type and land use/land cover have more effect on streamflow and hydrological regimes. The hydrological impact analysis shows an increase in monthly flow during January, February, March, and April.

Acknowledgements The authors would like to thank Dr. Wasim Iqbal and Lakhwinder Singh for check and the anonymous reviewers for their insightful suggestions and careful reading of the manuscript.

References

Aawar T, Khare D, Singh L (2019) Identification of the trend in precipitation and temperature over the Kabul river sub-basin: a case study of Afghanistan. Model Earth Syst Environ. https://doi.org/10.1007/s40808-019-00597-9

Abbaspour KC (2015) SWAT-CUP: SWAT calibration and uncertainty programs—a user manual. Department of Systems Analysis, Integrated Assessment and Modelling (SIAM), EAWAG, Swiss Federal Institute of Aqualtic Science and Technology, Duebendorf 10.1007/s00402-009-1032-4

Abseno MM (2013) Nile river basin. UN Watercourses Conv Force Strength Int Law Transbound Water Manag. https://doi.org/10.4324/9780203135365

Ang R, Oeurng C (2018) Simulating streamflow in an ungauged catchment of Tonlesap lake basin in Cambodia using Soil and Water Assessment Tool (SWAT) model. Water Sci 32(1):89–101. https://doi.org/10.1016/j.wsj.2017.12.002

Arnold MDJG (1998) Large area hydrologic modeling. J Am Water Resour Assoc 34(1):73–89

Duvvuri S (2018) Hydrological modelling of Cooum river basin using GIS and SWAT model, December, pp 306–311

Easton ZM, Fuka DR, White ED, Collick AS, Biruk Ashagre B, McCartney M, Awulachew SB, Ahmed AA, Steenhuis TS (2010) A multi basin SWAT model analysis of runoff and sedimentation in the Blue Nile, Ethiopia. Hydrol Earth Syst Sci 14(10):1827–1841. https://doi.org/10.5194/hess-14-1827-2010

Fohrer, N. (1999). Applying the SWAT model as a decision support tool for land use concepts in peripheral regions in Germany. … the Global Farm. 10 …, pp 994–999. https://topsoil.nserl.purdue.edu/nserlweb-old/isco99/pdf/iscodisc/SustainingtheGlobalFarm/P072-Fohrer.pdf

Gashaw T, Tulu T, Argaw M, Worqlul AW (2018) Modeling the hydrological impacts of land use/land cover changes in the Andassa watershed, Blue Nile Basin, Ethiopia. Sci Total Environ 619–620:1394–1408. https://doi.org/10.1016/j.scitotenv.2017.11.191

Gdp B, Proceedings C (2007) Communication à un colloque (conference paper), pp 1–6

Ghoraba SM (2015) Hydrological modeling of the Simly Dam watershed (Pakistan) using GIS and SWAT model. Alex Eng J 54(3):583–594. https://doi.org/10.1016/j.aej.2015.05.018

Githui F, Mutua F, Bauwens W (2009) Estimating the impacts of land-cover change on runoff using the soil and water assessment tool (SWAT): case study of Nzoia catchment, Kenya/Estimation des impacts du changement d'occupation du sol sur l'écoulement à l'aide de SWAT: étude du cas du bassi. Hydrol Sci J 54(5):899–908. https://doi.org/10.1623/hysj.54.5.899

Graham LP, Hagemann S, Jaun S, Beniston M (2007) On interpreting hydrological change from regional climate models. Clim Change 81(SUPPL. 1):97–122. https://doi.org/10.1007/s10584-006-9217-0

Hansen S, Abrahamsen P, Petersen CT, Styczen M (2013) Daisy: model use, calibration, and validation. Trans ASABE 55(4):1317–1335. https://doi.org/10.13031/2013.42244

Holeček M (2001) The BCAA-BCKA cycle: its relation to alanine and glutamine synthesis and protein balance. Nutrition 17(1):70. https://doi.org/10.1016/S0899-9007(00)00483-4

Khalid K, Ali MF, Rahman NFA, Mispan MR, Haron SH, Othman Z, Bachok MF (2016) Sensitivity analysis in watershed model using SUFI-2 algorithm. Procedia Eng 162:441–447. https://doi.org/10.1016/j.proeng.2016.11.086

Kushwaha A, Jain MK (2013) Hydrological simulation in a forest dominated watershed in Himalayan region using SWAT model. Water Resour Manag 27(8):3005–3023. https://doi.org/10.1007/s11269-013-0329-9

Leta OT, El-Kadi AI, Dulai H, Ghazal KA (2018) Assessment of SWAT model performance in simulating daily streamflow under rainfall data scarcity in Pacific island watersheds. Water (Switzerland) 10(11):1–31. https://doi.org/10.3390/w10111533

Meaurio M, Zabaleta A, Uriarte JA, Srinivasan R, Antigüedad I (2015) Evaluation of SWAT models performance to simulate streamflow spatial origin. The case of a small forested watershed. J Hydrol 525:326–334. https://doi.org/10.1016/j.jhydrol.2015.03.050

Moriasi DN, Gitau MW, Pai N, Daggupati P (2015) Hydrologic and water quality models: performance measures and evaluation criteria. Trans ASABE 58(6):1763–1785. https://doi.org/10.13031/trans.58.10715

Nursugi NDK, Windari EH (2016) Hydrological modelling using swat model case study Cimanuk watershed hydrological modelling using SWAT model, September. https://doi.org/10.13140/RG.2.2.31372.92801

Quyen NTN, Liem ND, Loi NK (2014) Effect of land use change on water discharge in Srepok watershed, Central Highland, Viet Nam. Int Soil Water Conserv Res 2(3):74–86. https://doi.org/10.1016/S2095-6339(15)30025-3

Schuol J, Abbaspour KC (2007) Using monthly weather statistics to generate daily data in a SWAT model application to West Africa. Ecol Model 201(3–4):301–311. https://doi.org/10.1016/j.ecolmodel.2006.09.028

Scoping strategic options for development of the Kabul river basin (n.d.)

Semlali I, Ouadif L, Baba K, Akhssas A, Bahi L (2017) Using GIS and SWAT model for hydrological modelling of Oued Laou Watershed (Morocco). ARPN J Eng Appl Sci 12(23):6933–6943

Setegn SG, Srinivasan R, Dargahi B (2008) Hydrological modelling in the lake Tana basin, Ethiopia using SWAT model. Open Hydrol J 2(1):49–62. https://doi.org/10.2174/1874378100802010049

Shrestha MK, Recknagel F, Frizenschaf J, Meyer W (2016) Assessing SWAT models based on single and multi-site calibration for the simulation of flow and nutrient loads in the semi-arid Onkaparinga catchment in South Australia. Agric Water Manag 175:61–71. https://doi.org/10.1016/j.agwat.2016.02.009

Singh L, Saravanan S, Jennifer J (2018) Assessing impact of land use/land cover changes on stream flow in Noyyal river catchment using ArcSWAT model. In: SWAT international conference, pp 10–12

Stehr A, Debels P, Romero F, Alcayaga H (2008) Hydrological modelling with SWAT under conditions of limited data availability: evaluation of results from a Chilean case study. Hydrol Sci J 53(3):588–601. https://doi.org/10.1623/hysj.53.3.588

Tang FF, Xu HS, Xu ZX (2012) Model calibration and uncertainty analysis for runoff in the Chao River Basin using sequential uncertainty fitting. Procedia Environ Sci 13(2011):1760–1770. https://doi.org/10.1016/j.proenv.2012.01.170

Teng J, Chiew FHS, Vaze J, Marvanek S, Kirono DGC (2012) Estimation of climate change impact on mean annual runoff across continental Australia using Budyko and Fu equations and hydrological models. J Hydrometeorol 13(3):1094–1106. https://doi.org/10.1175/JHM-D-11-097.1

Tibebe D, Bewket W (2011) Surface runoff and soil erosion estimation using the SWAT model in the Keleta Watershed, Ethiopia. Land Degrad Dev 22(6):551–564. https://doi.org/10.1002/ldr.1034

Vilaysane B, Takara K, Luo P, Akkharath I, Duan W (2015) Hydrological Stream Flow Modelling for Calibration and Uncertainty Analysis Using SWAT Model in the Xedone River Basin, Lao PDR. Procedia Environ Sci 28(SustaiN 2014):380–390. https://doi.org/10.1016/j.proenv.2015.07.047

Viviroli D, Zappa M, Gurtz J, Weingartner R (2009) An introduction to the hydrological modelling system PREVAH and its pre- and post-processing-tools. Environ Model Softw 24(10):1209–1222. https://doi.org/10.1016/j.envsoft.2009.04.001

Winchell M, Srinivasan R, Di Luzio M, Arnold J (2007) ArcSWAT interface for SWAT 2005. User's guide, pp 1–436

Yuemei H, Xiaoqin Z, Jianguo S, Jina N (2008) Conduction between left superior pulmonary vein and left atria and atria fibrillation under cervical vagal trunk stimulation. Colomb Med 39(3):227–234

Zhang L, Nan Z, Yu W, Ge Y (2015) Modeling land-use and land-cover change and hydrological responses under consistent climate change scenarios in the Heihe river basin, China. Water Resourc Manag 29(13):4701–4717. https://doi.org/10.1007/s11269-015-1085-9

Zhang X, Srinivasan R, Bosch D (2009) Calibration and uncertainty analysis of the SWAT model using genetic algorithms and Bayesian model averaging. J Hydrol 374(3–4):307–317. https://doi.org/10.1016/j.jhydrol.2009.06.023