Journal of Hydrosciences and Environment
ISSN: 2345-5608

Spatial and temporal variation of the water yield in the highly managed Zayandeh Rud basin using SWAT model

Z. Mesmarian*[1] , T.Omidinia[1] , M. Malekmohammadi[1] , I.Chakraei[1]

[1] *Water resources expert, Isfahan regional water company, Isfahan, Iran*

ARTICLEINFO

Article history:

Received: 27 Sep 2023
Accepted: 1 Oct 2023

Keywords:
SWAT
Calibration
Validation
Water yield

ABSTRACT

The integration of urban services is one of the most important achievements of the urban geographic information system (GIS), which will clarify, unify and facilitate services by creating a database in GIS, and it will be a step in the direction of reaching the urban information management system and decision support of senior city managers, which can be used as a new and powerful tool for better city management. Gathering information (spatial and descriptive) of all aspects of green space in the region, elements, furniture and urban facilities in Qochan city is one of the main operations to achieve better management in the region. Using Quick Bird satellite images and evaluating the potential of these data in producing a number of green space information layers such as linear, point and surface complications and the ability to update area information is one of the activities that makes it easy for managers to access information.

1. Introduction

Sustainable management of water resources at the watershed and basin levels needs prerequisites such as water yield knowledge influenced by climate conditions (Adeogun et al., 2014, olofintoye et al., 2022). According to the literature, climatic variables of temperature and precipitation were the main parameters that affect water yield (Liang et al., 2020). Hydrological models can be used to investigate the effects of climatic conditions on water yields in this respect. In addition, models could accurately describe natural processes that lead to improved management of rivers by sustainable water resource management because of the complicated nature of hydrological processes. The Soil and Water Assessment Tool (SWAT) is a hydrological model that could satisfactorily simulate hydrological processes within a river catchment, considering the region's geophysical catchment characteristics and climatic conditions. (Besalatpour et al., 2020) investigated the impact of spatial and temporal changes in water resources within the Zayandeh Rud basin to determine changes in water resource components over four periods from 1995 to 2014. Another study demonstrates the effect of climate change on water supply and availability in the Zayandeh Rud Basin and the optimal water allocation of the Zayandeh Rud Reservoir using the SWAT model (Saeidi et al., 2021). The impact of land uses on nitrate loading and water catchments for Jebba Dam in Nigeria has been investigated through a research project by the Atlantic Canadian Agricultural Watershed,

*Corresponding author's email : zmesmarian@gmail.com
DOI: 10.22111/jhe.2023.46795.1100

with SWAT modeling. As a decision support tool, the "SWAT" model might prove to be an excellent instrument for predicting water balance and yield and its potential usefulness in sustainable water management, according to the study results (Liang et al., 2020).

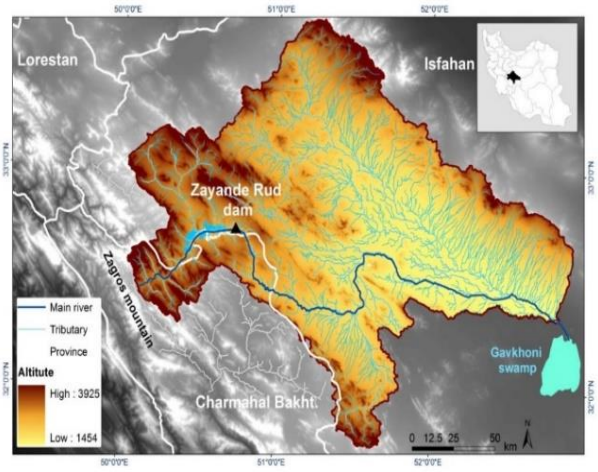
Despite the frequent use of SWAT in the hydrological modeling of different river basins in Iran, more attention should be given to investigating water yield. In this regard, this study investigates the applicability of SWAT in the Zayandeh Rud basin, Isfahan-Iran, to estimate the water yield as an essential factor for effectively managing water resources using the calibrated model.

2. Materials and Methods

2.1. Description of the case study area

The Zayandeh Rud basin is located in the central part of Iran, with an area of about 28,193 km2, located 50°24′–53°24′ East and 31°11′–33°42′ North. The Zayandeh Rud originates from the Zagros Mountains, west of Isfahan, and flows 350 kilometers eastward before ending in the Gavkhouni swamp, a seasonal Salt Lake, southeast of Isfahan city. The climate is semi-arid in the uplands (west) and the lowlands (east). The annual rainfall ranges from 84.7 mm to 1270 mm, and the average annual temperature ranges between 3.02°C to 29.14°C from 1992 to 2018. Fig. 1 shows the geographic location of the Zayandeh Rud basin.

Fig. 1. Geographic location of the Zayandeh Rud basin



2.2. Input data collection and processing

To model Zayandeh Rud stream flow, the hydrologic model Soil and Water Assessment Tool (SWAT) (Arnold et al., 1998) in combination with the Sequential Uncertainty Fitting program (SUFI-2) (Abbaspour, 2011) was used to calibrate, validate, and perform uncertainty analysis based on the available measured river discharge data. SWAT mainly uses the hydrologic response units drawn from slope characteristics, soil, and land use maps. The DEM was used to delineate the basin into sub-basins and river networks. A total of 370 sub-basins were delineated. Climate information, including the precipitation and maximum and minimum temperature data, was used with the HRUs as input to the SWAT model to determine the catchment's hydrological response. A weather generator embedded in SWAT, developed by (Schuol and Abbas, 2007), was used to estimate the missing data when there were gaps within the dataset. The SCS curve number was used for simulating surface runoff in this study. Potential evapotranspiration (PET) was simulated using the Hargreaves method (Hargreaves et al., 1985). Based on a methodology developed by Roger (Ritchie, 1972), the actual evapotranspiration AET was predicted. In order to partition PET into potential soil evaporation and possible plant transpiration, a daily value of the leaf area index LAI was used. LAI and root development were simulated using the "crop growth" component of SWAT. This component represents the interrelation between vegetation and hydrologic balance.

2.3.SWAT Model Parametrization and Simulations

Several parameters were refined via calibration and validation during hydrological simulation via the SWAT model. For this purpose, sensitivity analysis of the model parameters was carried out before simulation to identify and rank the parameters that significantly impact specific model output. The sensitivity analysis for 32 model parameters was done via auto calibration based on the parameter solution optimization method. The SUFI-2 correspondent algorithm was considered for the calibration and validation analyses. Model calibration followed sensitivity analysis. At first, a 3-year warm-up period (1992–1995) was considered. In the next step, the model was calibrated for sensitive parameters (1995-2009) and validated monthly for the next period (2009-2018). Water yield is one of the critical outputs of the model, which is the total amount of water leaving the HRU and entering the main channel during the time step. It is one of the critical parameters that must be estimated for the sustainable management of water resources in the study area. The water yield of a river catchment is estimated by Eq (1):

Eq (1): $Wyld = Qsurf + Qgw + Qlat - Tloss$ (1)

Where Wyld is the measure of water yield (mm), Qsurf is the surface runoff (mm), Qlat is the lateral flow contribution to stream (mm), Qgw is the groundwater contribution to streamflow (mm), and Tloss is the transmission losses (mm) from tributary in the HRU by means of transmission through the bed.

3.Results and discussion

The calibration processes are considered the 28 most sensitive flow parameters Table 1. Their values were varied iteratively within the allowable ranges until a satisfactory agreement between measured and simulated streamflow was obtained. The autocalibration processes significantly improved model efficiency. Statistical model efficiency criteria generally fulfilled the requirement of (correlation) r2 > 0.6 and (Nash-Sutcliffe Efficiency) ENS> 0.5, which the SWAT developer recommends. The model calibration results for monthly flow Table 2 generally indicate a good fit between measured and simulated output in each hydrometric station. Since the model performed well in the validation period, the output parameters can be taken as the representative set of parameters for the watershed.

As a result, the water yield was simulated for 24 years (1995 to 2018) on monthly time steps Fig. 2. The lowest water yield was received from the eastern and northern regions of the basin, including the Koohpayeh-Segzi, Isfahan-borkhar, Moorcheh Khort, Meimeh, and Mahyar Shomali. This is mainly due to the absence of permanently flowing rivers, low rainfall, and excessive consumption in these regions. Further analysis of the results also revealed that the western part of the study area, including Ghaleshahrokh-Chelgerd study area, a mountainous area with a high precipitation and high slope, contributed a more significant percentage of the water yield in the area.

4. Conclusion

This study investigated the use of SWAT to estimate water quantity by simulating river basin hydrologic processes and responses. This model was calibrated and validated using monthly flow data of the Zayandeh Rud gauge, meteorological and hydrological data, slope characteristics, and soil and land use maps before being used for estimating water yield in the river basin. Close approximation between simulated and observed streamflow data can be considered as a contributing factor for model performance after calibration and validation.

Table 1. Sensitive parameters

Parameter	Lower and upper bounds
r_CN2.mgt	-0.4 to 0.4
r_SOL_BD.sol	-0.4 to 0.4
r_SOL_AWC.sol	-0.5 to 0.5
r_SOL_K.sol	-0.8 to 0.8
r_SOL_ALB.sol	-0.5 to 0.5
v_ALPHA_BF.gw	0 to 1
v_GW_DELAY.gw	0 to 400
v_REVAPMN.gw	0 to 100
v_GW_REVAP.gw	0.02 to 0.2
v_SHALLST.gw	0 to 1000
v_RCHRG_DP.gw	0 to 1
v_GWQMN.gw	0 to 500
v_EPCO.hru	1 to 0.01
v_ESCO.hru	1 to 0.01
v_SLSUBBSN.hru	10 to 150
v_OV_N.hru	0 to 0.8
v_CH_N2.rte	0 to 0.3
v_CH_K2.rte	0 to 150
v_SFTMP.bsn	-5 to 5
v_SMTMP.bsn	-5 to 5
v_SMFMX.bsn	0 to 10
v_SMFMN.bsn	0 to 10
v_TIMP.bsn	0.01 to 1
v_MSK_CO1.bsn	0 to 10
v_SURLAG.bsn	1 to 24
r_PCPMM.wgn	-0.5 to 0.5
r_PCPSKW.wgn	-0.5 to 0.5
r_PCPSTD.wgn	-0.5 to 0.5

Table 2. Statistical parameters of calibration period for hydrometric stations

Stations	LAT	LONG	NS	R2
Ghaleshahrokh	32.66	50.46	0.83	0.85
Eskandari	32.82	50.43	0.39	0.44
Sadtanzimi	32.72	50.78	0.83	0.87
PolZamankhan	32.50	50.90	0.76	0.82
Polkale	32.38	51.23	0.7	0.75
Lenj	32.39	51.55	0.27	0.60
Diziche	32.37	51.52	0.76	0.81
GhaleNazer	32.85	50.82	0.66	0.90

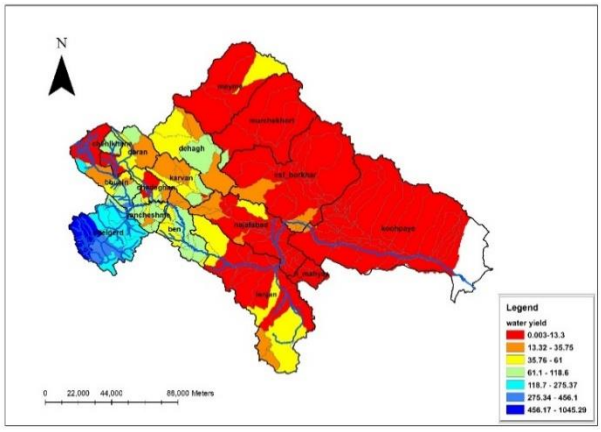


Fig. 2. Average Annual Water Yield contributed by each of the subbasins to Zayandeh Rud basin for the simulation period 1995-2018

The values of the standard test statistics NSE>0.65, RSR>0.5, and R2>0.75, which are within the acceptable range, were further confirmed. Overall, estimates of water yields based on this model were satisfactory in the study area.

5.References

1. Adeogun, A.G., Sule, B.F., Salami, A.W., & Daramola, M.O. (2014). Validation of SWAT Model for Prediction of Water Yield and Water Balance: Case Study of Upstream Catchment of Jebba Dam in Nigeria. World Academy of Science, Engineering and Technology, International Journal of Mathematical, Computational, Physical, Electrical and Computer Engineering, 8(2), 264-270.

2. Abbaspour, K.C. (2011). User Manual for SWAT-CUP: SWAT Calibration and Uncertainty Analysis Programs. Eawag: Swiss Fed. Inst. of Aquat. Sci. and Technol., Duebendorf, Switzerland, 103 pp.

3. Arnold, J.G., Srinivasan, R., Muttiah, R.S., & Williams, J.R. (1998). Large area hydrologic modeling and assessment–Part 1: Model development, Journal of the American Water Resources Association 34: 73–89.

4. Besalatpour, A. A., Heydarpour, G. H., Kazemi, A., & Afshar, A. H. A. (2020). Hydrological Modeling of Spatial and Temporal Changes of Blue and Green Water Resources in the Zayandeh Rud River Basin. Standing up to Climate Change: Creating Prospects for a Sustainable Future in Rural Iran. 141-173.Springer.

5. Hargreaves, G., Samani, Z.A. (1985). Reference crop evapotranspiration from temperature. Appl. Eng. Agric. 1: 96–99.

6. Ijaz, M.A., Ashraf, M., Hamid, S., Niaz, Y., Waqas, M.M., Tariq, M.A.U.R., Saifullah, M., Bhatti, M.T., Tahir, A.A., Ikram, K., Shafeeque, M., Ng, A.W.M. (2022). Prediction of Sediment Yield in a Data-Scarce River Catchment at the Sub-Basin Scale Using Gridded Precipitation Datasets. Water, 14(9), 1480.

7. Liang, K., Jiang, Y., Qi, J., Fuller, K., Nyiraneza, J., & Meng, F. (2020). Characterizing the impacts of land use on nitrate load and water yield in an agricultural watershed in Atlantic Canada. The Science of the Total Environment, 729.

8. Olofintoye, O., Ayanshola, A., Salami, A., Idrissiou, A., Iji, J. & Adeleke, O. (2022). A Study on the Applicability of a Swat Model in Predicting the Water Yield and Water Balance of the Upper Ouémé Catchment in the Republic of Benin. Slovak Journal of Civil Engineering, 30(1), 57-66 .

9. Ritchie, J.T. (1972). A model for predicting evaporation from a row crop with incomplete cover. Water Resour. Res. 8: 1204–1213.

10. Saedi, F., Ahmadi, A., & Abbaspour, K. (2021). Optimal water allocation of the Zayandeh-Roud Reservoir in Iran based on inflow projection under climate change scenarios. Journal of Water and Climate Change, 12 (5), 2068–2081.

11. Schuol, J., Abbaspour, K.C. (2007). A daily weather generator for predicting rainfall and maximum–minimum temperature using monthly statistics based on a half degree climate grid. Ecological Modelling. 201: 301–311.