International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 07 Issue: 04 | April - 2023 Impact Factor: 8.176 ISSN: 2582-3930

Sensitivity Analysis and Multi-Site Calibration of KRS Catchment using SWAT

Deepthi B P[1], Pushpa Tuppad[2] and K S Lokesh[3]
[1]Assistant Professor, Dept. of Civil Engineering, DSATM, Bengaluru, India deepthi.phalanetra@gmail.com
[2]Associate Professor, Dept. of Environmental Engineering, JSS Science and Technology University, Mysuru, India. ptuppad@gmail.com
[3]Former Professor and Registrar, Dept. of Environmental Engineering, JSS Science and Technology University, Mysuru. India. lokeshkaggere@yahoo.com

Abstract

Hydrological modelling offers itself as a crucial instrument for the management of water resources, as it aids in understanding the streamflow, sediments, and pollutants in a hydrographic basin. The KRS catchment in Karnataka, India has undergone a significant change driven by the growth of agricultural regions in the area, necessitating the adoption of tools for studies that analyze the environmental consequences primarily on surface water resources. The current study aim was to calibrate and validate at multi sites using the SWAT-CUP. Statistical performance coefficients attested the model's capacity for hydrological simulations in this basin on a monthly time scale, Pbias, NSE and R^2 showing values in the good acceptable range for calibration and validation.

Introduction

To depict the temporal and geographical components of the hydrological cycle at the basin size, hydrological models are utilised. These models are helpful for locating sensitive variables that affect how a basin responds to a sub-hydrological event. For estimating the various components of a watershed's water balance, a range of distributed hydrological models are available, some of which are incorporated into a GIS context ((Arnold et al., 1998, Raju and Nandagiri, 2015). A large number of hydrological models have been developed over the past several decades to simulate catchment-scale processes and thereby serve as tools for water resources planning and management. Models differ in the manner in which key hydrological processes are represented and parameterized. Despite large differences in input data requirements, model parameterizations and resulting model complexities, it has been found that the ability of models to simulate quantity and quality of runoff at the catchment outlet does not differ much (Refsgaard and Knudsen, 1996). In other words, complex models appear to be only marginally better than simpler models in simulating catchment-scale hydrologic responses. Among these, the Soil Water Assessment Tool (SWAT) has been effectively applied at spatial scales ranging from tiny watersheds to major river basins, and it has been widely employed in many parts of the world and in diverse climatic zones at daily, monthly, and yearly time steps (Tripathi et al., 2003; Xu et al., 2011). Using alternate input data to quantify the proportional influence on the water balance is another use for SWAT. This study aims at identifying sensitive parameters which govern water yield of the basin and helps calibrating and validating the model for the hydrological response.

Materials and methodology

Study Area

The study area, KRS Catchment is shown in fig 1. Deepthi et al., 2021 mentioned that "there are three main tributaries - Harangi, Hemavathi and Lakshmanatheertha within the KRS catchment study area. The upper Cauvery basin is mainly irrigated agriculture land; nearly 66.21% of the total area is covered with agricultural land and 4.09% is covered by waterbodies and remaining area is covered with forest". The catchment area is the main source of food production served to larger population. The Basin is a highly valuable resource for the people of Karnataka because they directly depend upon it for irrigation, drinking and industrial needs (Empri, 2017)

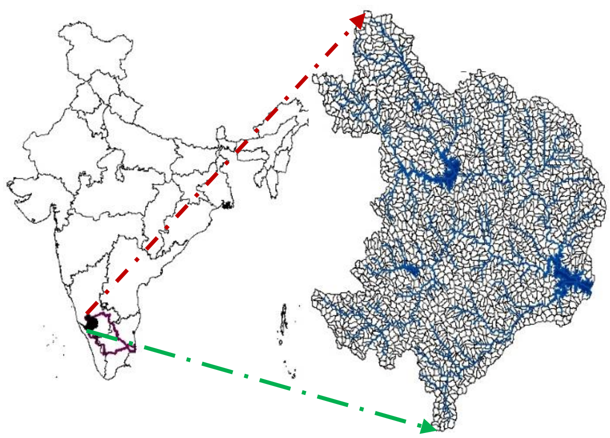

Fig 1: Study area showing KRS catchment

Input data

The SWAT model requires meteorological data like precipitation, humidity, solar radiation, windspeed and temperature data and topographical data like land use, soil and man-made structures like reservoirs etc for assessment of water resource availability at the desired locations of the drainage basin. Topographic data was obtained in the form of DEM (Digital Elevation Model) of 90 m resolution from the SRTM (Shuttle Radar Topography Mission) and it was used to delineate a basin into multiple sub basins and calculate topographic related parameters such as slope class, stream length and locate monitoring points. 1:50,000 scale land use data and soil data were collected from Karnataka State Remote Sensing Application Centre (KSRSAC). Daily rainfall data and weather were collected from IMD Pune.

SWAT Modeling

The essential above-mentioned data were input to the model using QGIS as an interface. Hargreaves and SCS-CN were used to determine the evaporation and flow routing in the basin. The methodology adopted by

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Deepthi et al., 2021 was considered in which " model was run for the period 1987 to 2014 excluding first 5 years (1982-1986), which was considered as warmup period for proper adjustment of hydrological parameters. Calibration and validation periods considered were 2002 to 2011 and 2012 to 2014, respectively. Prior to the calibration process, sensitivity of hydrological parameters was analyzed using the Latin hypercube one factor-at-a-time technique and subsequently ten sensitive parameters were considered for calibration which were further optimized by using SUFI2 algorithm of SWAT-CUP (Abbaspour et al., 2007; Abbaspour et al., 2015). The sensitive parameters are Sol_AWC.sol, EPCO.hru, GW_DELAY.gw, RCHRG_DP.gw, CH_K2.rte, ESCO.hru, SOL_K.sol, CN2.mgt, ALPHA_BF.gw, SHALLST.gw. The uncertainty in the simulation of flow in the basin is assessed statistically by the model". The calibration range used are as shown in table 1. The multi-site calibration was performed at six flow gauging stations as shown in fig 2.

Table 1: Calibration Specifications

Parameter Name	Min Value	Max value
Sol_AWC	-20	20
CN2	-0.2	0.2
ESCO	0	1
EPCO	0	1
GW_DELAY	0	100
RCHRG_DP	0	1
SOL_K	-20	20
SHALLST	0	5000
ALPHA_BF	0	1
CH_K2	0	200

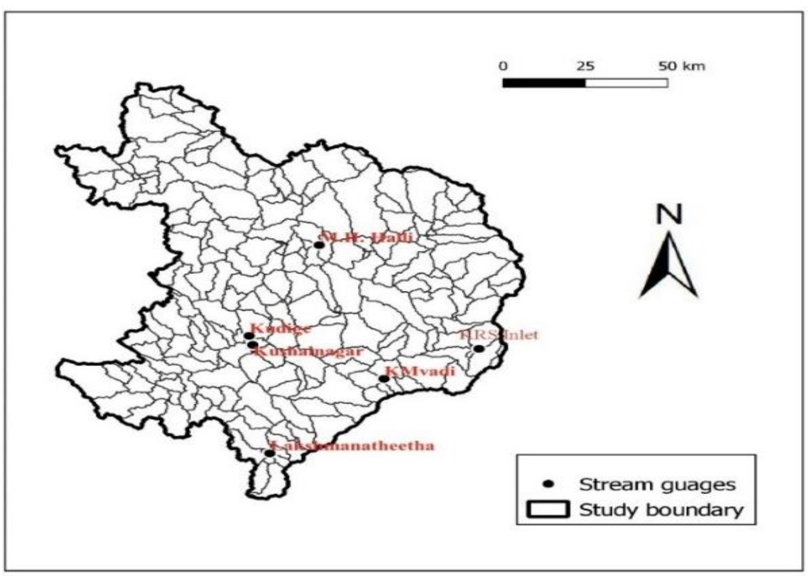

Fig 2: Calibration points in the study area

Result and discussion

Streamflow was estimated based on calibrated model parameters. The SWAT model was calibrated using the daily observed streamflow data of gauging station. The calibration and validation period were chosen between 1/1/2002 to 31/12/2011 and 1/1/2012 to 31/12/2014 respectively. The time series and a of simulated and observed flows (m^3 /s) for the SWAT model at the gauging site of the basin is shown in fig 3 to fig 8. From these Figure it is noticed that observed streamflow are simulated well, which implies that the performance of SWAT model is good. The statistical values for calibration and validation are shown in table 2. Moriasi et al. (2007) mentioned that "the statistical performance of the model is accepted if NSE < 0.5, R^2 < 0.65, P-bias ± 25%". The obtained results are well within the suggested range.

Fig 3. Pre and Post Calibration of Lakshmanathirta stream flow

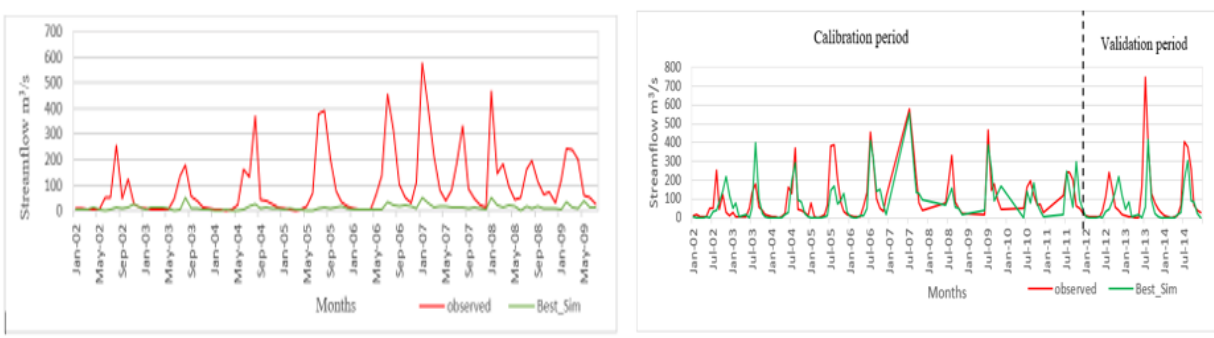

Fig 4. Pre and Post Calibration of Kudige stream flow

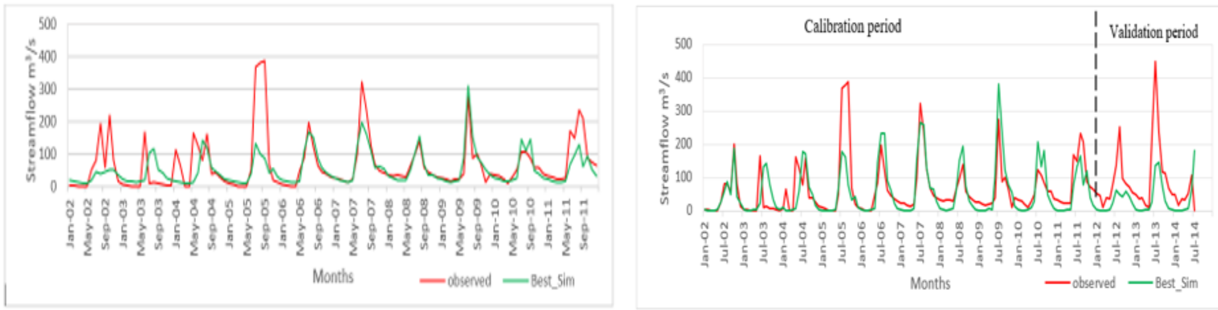

Fig 5. Pre and Post Calibration of Kushalanagara stream flow

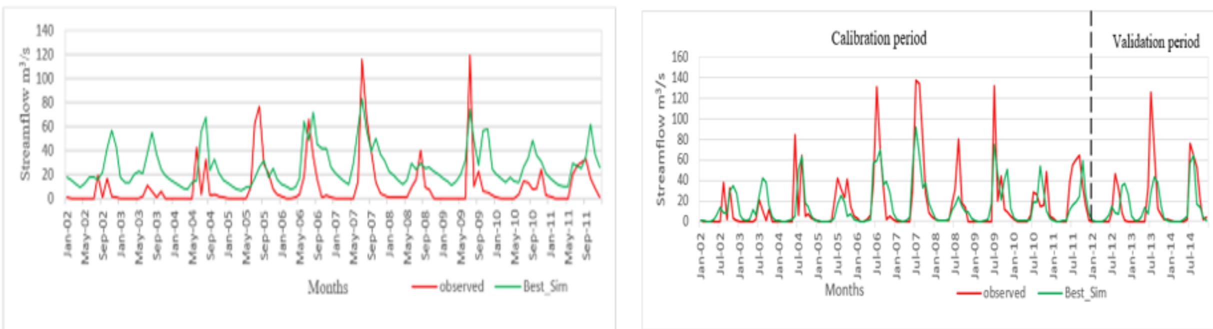

Fig 6. Pre and Post Calibration of KM Vadi stream flow

Fig 7. Pre and Post Calibration of MH Halli stream flow

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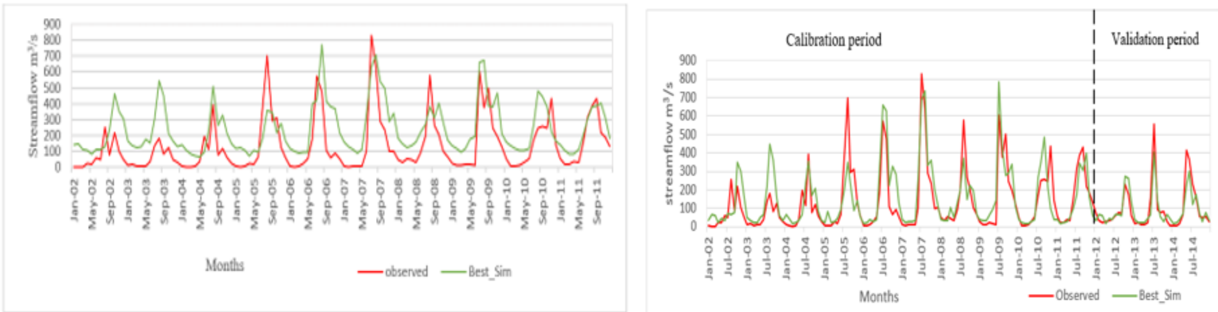

Fig 8. Pre and Post Calibration of KRS stream flow

Gauging station	Calibration			Validation		
	NSE	R^2	P-bias	NSE	R^2	P-bias
Lakshmanathirtha	0.62	0.73	3.4	0.66	9.3	0.54
Kudige	0.55	0.74	9.6	0.58	3.9	0.68
Kushalanagar	0.60	0.66	4.2	0.62	7.0	0.50
KM Vadi	0.59	0.60	-8.3	0.58	-9.2	0.59
MH Halli	0.52	0.71	9.4	0.56	-13.4	0.72
KRS	0.62	0.67	-15	0.60	3.5	0.63

Conclusion

The present study was able to interpret the physically based SWAT model for the KRS catchment area. The behavior of the basin in terms of response to streamflow at the gauge site was successfully assessed by identifying the sensitive parameters. The model was successfully calibrated using observed daily flow data at multi-sites. The statistics of model performance in simulating flow at multi-site are good. In view of the results obtained in this study, it may be concluded that SWAT is an effective modeling tool for hydrologic analyses and water resources management in the study area.

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