



Calibration and validation of the SWAT model for the Sani River basin, Gujarat

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ARTICLE INFO	ABSTRACT
<p>Original Review Article Received on February 18, 2026 Revised on February 26, 2026 Accepted on March 19, 2026 Published on March 27, 2026</p> <p>Article Authors Wandre Sarika S., H. D. Rank, Shinde Vinayak B.</p> <p>Corresponding Author Email sarikawandre@gmail.com</p>	<p>A simulation study using the Soil and Water Assessment Tool (SWAT) model has been initiated to assess current and alternative nutrient, cropping, and management practices in the Sani River Basin in an effort to help mitigate climate change impact in the basin. The SWAT software system has been constructed to manage the input and output data for the SWAT simulations, and the execution of the model for each scenario. An overview of the modeling structure that has been developed for the basin is presented, including the spatial representation of the region within SWAT. Initial results for the baseline simulation are also presented for monthly stream flows near the outlet of the basin, and for annual stream flows for the basin. Overall, the model demonstrated good performance in capturing the patterns and trend of the observed flow series, which confirmed the appropriateness of the model for future scenario simulation. Therefore, SWAT model can be taken as a potential tool for simulation of the hydrology of watershed which behaves hydro-meteorologically similar with Sani basin. Future studies on Sani watershed modeling should address the issues related to water quality and evaluate best management practices.</p>
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Understandings on hydrological processes to develop suitable models for a watershed are the most important aspect in water resource development and management programmes. Water resource development is the basic and crucial infrastructure for a nation's sustainable development. To utilize water in a sustainable manner, it is necessary to understand the quantity and quality in space and time through studies and researches. Major hydrological processes can be quantified with the help of water balance equations (Arnold *et al.*, 1996). The component of water balance of a watershed is influenced by climate, and the geophysical characteristics of the watershed such as

topography, land use and soil. Consideration of the relationship between these physical parameters and hydrological components is very essential for any water re-source development related work. Since the hydrologic processes are very complex, their proper comprehension is essential and therefore, watershed based hydrological models are widely used. To test the capability of the model in determining the effect of spatial variability of the watershed on streamflow, SWAT 2012 with ArcGIS interface was selected. The time series data on climate and runoff yield were available at the gauging stations of the watershed and these were used to calibrate and validate the SWAT model.

To assess its applicability in simulating runoff yield from the Sani watershed. The objective of this study was to perform calibration and validation of SWAT model at the outlet of Sani watershed to estimate water balance components of the watershed.

Simulation Methodology

Description of Study Area

Devbhumi Dwarka district is located in Southern region of Gulf of Kutch of Gujarat state with 21°12' to 22°72' N latitude and 68°90' to 69°80' E longitude. On 15th August 2013, this district was bifurcated from Jamnagar district. It's headquarter is located in the city of Khambhalia. Dwarka has its pilgrimage importance due to Dwarkadheesh Temple built in 6th to 7th century. Devbhumi Dwarka district has a population of around 7.5 Lac and area of 4,051 km². It is connected to the coastal area; the most of the land is saline. The district has 4 talukas namely Dwarka, Bhanvad, Kalyanpur and Khambhalia consisting of 429 villages. It has 2.5 lakh ha cultivable land.

The district has 13 river basins among them 5 are west flowing and remaining north flowing rivers. Dwarka has a subtropical desert/low-latitude arid hot climate. On the basis of 40 years of climatic data, the average annual rainfall is 536 mm spread over a rainy period of 29 days with rainfall limited to the months of June to September; the average maximum temperature is 31°C with a maximum of 42°C and an average minimum temperature is 15°C with a minimum of 5°C and the average annual relative humidity is 72 percent, with a maximum of 80 percent. The Sani basin mainly includes Bhadthari and Gadhki rivers. Sani River is of 60 km long and entire basin area is nearly 854 km². It originates from village Sonardi (Taluka-Khambaliya) and meets to Arabian Sea near Gandhavi village of Kalyanpur taluka. The SWAT model is a conceptual, physically based long-term continuous watershed scale simulation model that operates on a daily time step. The model is capable of simulating a high level of spatial detail by allowing the division of a watershed into a large number of subwatersheds. In SWAT, a watershed is divided into multiple subwatersheds, which are then further subdivided into Hydrologic Response Units (HRUs) that consist of homogeneous landuse, management, and soil characteristics.

Flow generation, sediment yield, and non-point-source loadings from each HRU in a subwatershed are summed, and the resulting loads are routed through channels, ponds, and/or reservoirs to the watershed outlet. Key components of SWAT include hydrology, plant growth, erosion, nutrient transport and transformation, pesticide transport and management practices. Previous applications of SWAT for flow and/or pollutant loadings have compared favorably with measured data for a variety of watershed scales.

Surface Runoff

Surface runoff was predicted in the SWAT for the daily rainfall by using SCS curve number equation as below:

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

Where,

Q_{surf} = accumulated surface runoff or rainfall excess (mm)

R_{day} = rainfall depth for the day (mm)

I_a = initial abstraction which includes surface storage, interception and infiltration prior to surface runoff (mm)

S = retention parameter (mm).

The retention parameter varied spatially due to changes in soils, land use, management and slope and temporally due to changes in soil water content. Retention parameter was calculated by equation as below where CN is the curve number of the area (Neitsch *et al.*, 2005):

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

The model calculated the peak runoff rate with the modified rational method. It was based on assumption that if a rainfall of intensity i begin at time $t=0$ and continues indefinitely, the rate of runoff was increase until the time of concentration, $t = t_{conc}$, when the entire sub-basin is contributing to flow at outlet.

Sensitivity Analysis

After a thorough preprocessing of the required input for SWAT model, flow simulation was 5 performed for an eight years of recording periods starting from 1992 through 1999.

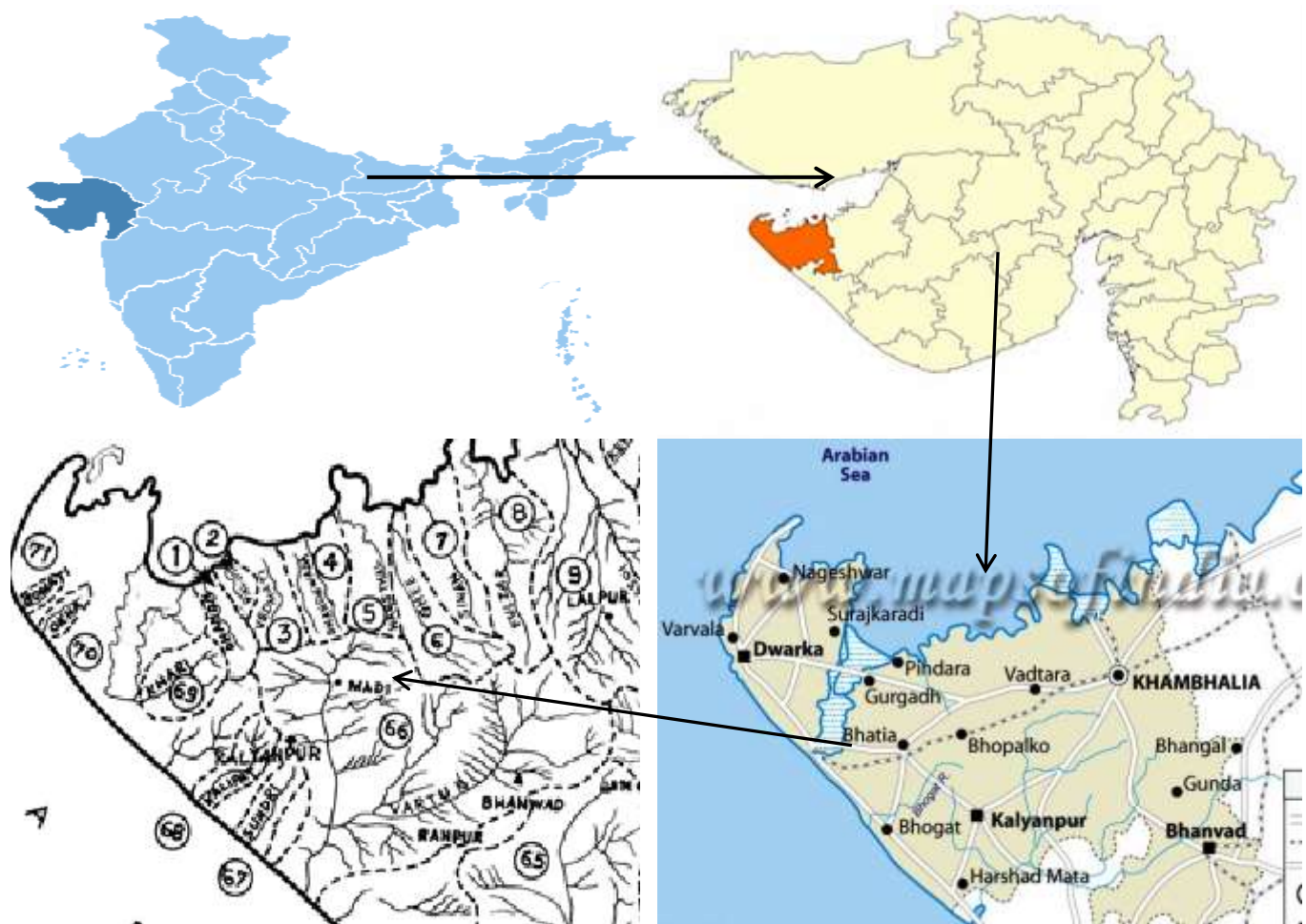


Fig 1. Location map of study area

The first three years of which was used as a warm up period and the simulation was then used for sensitivity analysis of hydrologic parameters and for calibration of the model. The sensitivity analysis was made using a built-in SWAT sensitivity analysis tool that uses the Latin Hypercube One-factor-At-a-Time (LH-OAT) (Van Griensven, 2005).

Calibration

Manual calibration method was applied. First the parameters were manually calibrated for the period of 1990 to 2000 until the model simulation results were acceptable as per the model performance measures. Next, the final parameter values that were manually calibrated were used as the initial values for the autocalibration procedure. The graphical and statistical approaches were used to evaluate the SWAT model performance a number of times until the acceptable values were obtained for surface runoff and baseflow independently.

The flow calibration procedure made by SWAT developers in (Santhi *et al.*, 2001 and Neitsch *et al.*, 2005) was carefully followed. SWAT developers assumed an acceptable calibration for hydrology at $r2 > 0.6$ and $ENS > 0.5$ (Santhi *et al.*, 2001; Moriasi *et al.*, 2007).

Validation

Streamflow data of three years from 2001 to 2005 were used for validation. The three statistical model performance measures used in calibration procedure were also used in validating streamflow.

Model Performance Evaluation Nash-Sutcliffe Efficiency (NSE)

The Nash-Sutcliffe efficiency (NSE) is a normalized statistic that determines the relative magnitude of the residual variance (“noise”) compared to the measured data variance (Nash and Sutcliffe, 1970).

NSE indicated the how well the plot of observed versus simulated data fits the 1:1 line. NSE was computed as shown in Eq.:

$$NSE=1- \frac{(Y_{iobs} - Y_{isim})^2}{(Y_{iobs} - Y_{mean})^2} \dots(3)$$

Where,

Y_{iobs} = ith observation for the constituent being evaluated

Y_{isim} = ith simulated value for the constituent being evaluated

Y_{mean} = mean of observed data for the constituent being evaluated

n = total number of observations.

NSE ranges between $-\infty$ and 1.0, with $NSE=1$ being the optimal value. The values between 0.0 and 1.0 are generally viewed as acceptable levels of performance, whereas values <0.0 indicates that the mean observed value is a better predictor than the simulated value, which indicates unacceptable performance (Moriassi *et al.*, 2007). The performance of the model in simulating hydrologic variables was evaluated with the help of statistical parameter coefficient of determination (R^2) and NSE which indicating the relationship between the observed and simulated values.

Results and Discussion

SWAT model was run for the period 1990-2000 periods and runoff was computed and compared with observed runoff.

The input parameters like soil available water (SOL_AWC in.sol), soil evaporation compensation factor (ESC in .bsn), deep percolation loss (adjust threshold depth, GWQMN in .gw), groundwater revap coefficient (GW_REVAP in.gw), threshold depth of water in shallow aquifer (REVAPMN in.gw) and curve number (CN in .mgt), slope for over land flow (SLOPE in .hru), Manning's roughness coefficient (OV_N in .sub or .rte) etc. were changed from database by trial and error method such that the SWAT modelled runoff and observed runoff could be matched. After calibrating the SWAT model, it was run for the validation period (2001-2005). The SWAT was run for the observed hydrometeorological data from (1990-2005). The observed data of runoff and water table fluctuations were available only for the period (1990-2005). Therefore, the calibration was done for the period (1990-2000) and validation for the period (2001-2005). The comparison of observed and SWAT runoff are compared graphically in fig 2 for calibration and validation period. The major portion of the scatter plot is well distributed about the regression line indicating the model capability of estimating stream flow. The R^2 and NSE values were found as 0.83 and 0.93 respectively for calibration and 0.80 and 0.79 respectively for validation period (2001-2005) (fig 2). R^2 and NSE values indicated a good correlation between observed and simulated values of seasonal runoff as per (Kulkarni *et al.*, 2014).

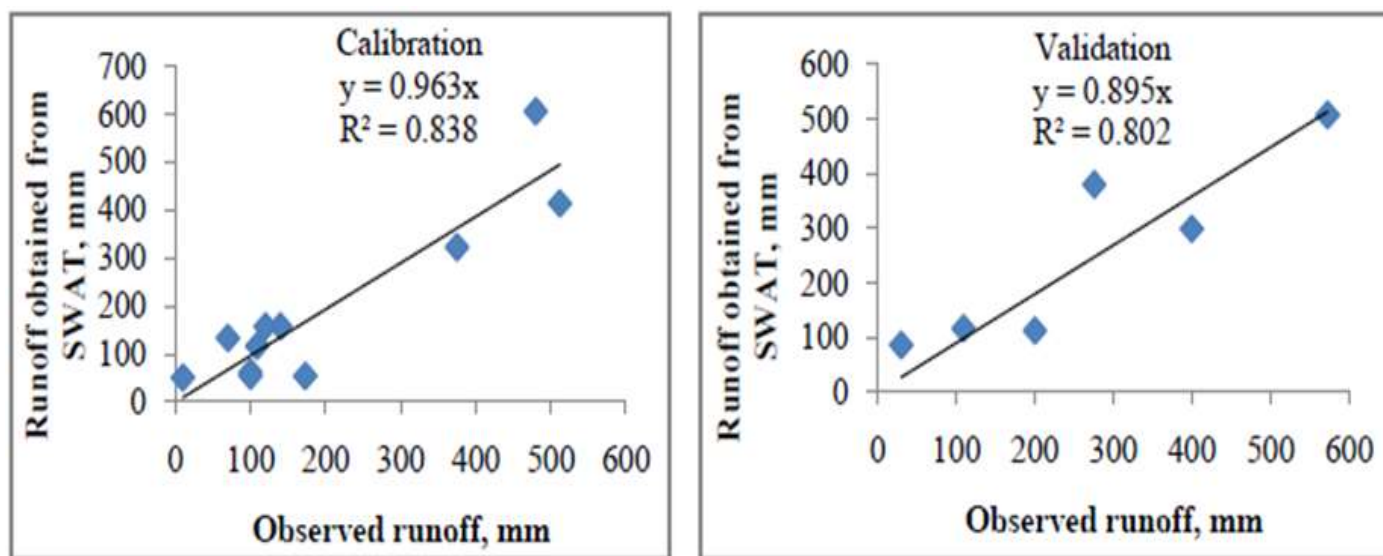


Fig 2. Scatter plot during calibration (1990-2000) and Validation (2001-2005) periods of SWAT model Sani river basin

Conclusion

Understandings on hydrological processes and develop suitable models for a watershed is the most important aspect in water resource development and management programmes. Watershed based hydrologic simulation models are likely to be used for the assessment of the quantity and quality of water. The performance and applicability of SWAT model was successfully evaluated through sensitivity analysis, model calibration and validation. Subsurface flow parameters were found to be more sensitive to the streamflow of the watershed, signifying the watershed is rich in ground water as a result of good recharge capacity.

SWAT model was found to produce a reliable estimate of monthly runoff for Sani watershed which was confirmed by various model efficiency measures. Therefore, the calibrated parameter values can be considered for further hydrologic simulation of the watershed. The model can also be taken as a potential tool for simulation of the hydrology of watershed, which behaves hydro-meteorologically similar with Sani watershed. However, for a more accurate modeling of hydrology, a large effort will be required to improve the quality of available input data. Future studies on Sani watershed modeling should address the issues related to water quality and evaluate best management practices to address different watershed management issues.

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