Simulation of Discharge using SWAT model over Barman Watershed of Narmada Basin

H L Tiwari[1] **andAnkit Balvanshi**[2]

[1]Maulana Azad National Institute of Technology Bhopal, Bhopal –462051

[2]National Institute of Technology Goa, – 403401

Abstract

A calibration of the soil and water assessment tool (SWAT) was conducted for the Barman ghat catchment area in the Narmada river basin. The purpose of this calibration was to accurately replicate the runoff. The model was executed using QSWAT, which serves as an interface between QGIS and SWAT. The model was simulated for a period of 14 years, from 2001 to 2014. The calibration period spanned from 2001 to 2009, while the validation phase included the years 2010 to 2014. The calibration, validation, and sensitivity analysis were performed using the sequential uncertainty fitting (SUFI-2) technique in conjunction with the SWAT-CUP interface. Two model efficiency metrics were used, namely the coefficient of determination (R2) and the Nash-Sutcliffe efficiency (NSE) index. For sensitivity analysis, nine model parameters were included, with CN2 being identified as the most sensitive. The calibration findings indicate an R2 value of 0.94 and an NSE index of 0.84. For the validation period, the values are 0.86 and 0.78. The findings of this investigation indicate that the model's performance during both calibration and validation is satisfactory.

Keywords:SWAT,DEM,SUFI-2,calibration,validation,SWAT-CUP,QGIS

1.Introduction

The four important phases of hydrological process are precipitation, runoff, evapotranspirationand groundwater. Water is major and important natural resource and generally it is very complexto manage so that this purpose of water management is not an easy task. A watershed is ahydrologic element which generates water as final product by interface of rainfall and landsurface (Jain et al. 2010). As clean water resources of water are increasingly used by agricultureand industrial usage, water conservation has turn out to be extra important. It has become extracritical in places where rainwater is very low and irregular. Estimation of direct runoff for un-gauged watershed is difficult and time taking (Jain et al. 2010). The conventional models forestimating runoff need significant hydrological and climatic data. The watershed hydrologicmodels have been popular for various reasons and therefore have in various forms. Hydrologicalmodels are also providing valuable information for studying the probable impacts of changes inland use or climate. Hydrologic models are conceptual, simplified representation of a part of thehydrologyand water cycle.

The amount of water, generally expressed in

Corresponding Author(Email:hltiwari@rediffmail.com)

mm or inches, that precipitated in liquid form in aparticular area and time interval called rainfall. Rainfall is often including the precipitation that isin solid form such as hail, snow and sleets. Rainfall is the chief constituent of the hydrologiccycle and is the main source of runoff (Beven, 2001b). Rainfall is basically required to fulfill anumber of demands including industries, agriculture, ecology, hydropower and environment.Runoff can be defined as the part of the water phase that circulates over ground as surface waterinstead of being immersed into groundwater or evaporating. According to the U.S. Geological Survey (USGS), runoff is the part of the rainfall, irrigation water, snow melt that flows in unrestrained surface streams, drains, rivers, or sewers.

SWAT is a model used to simulate the quality and quantity of surface and ground water and anticipatethe ecological effect of landutilization, land management practices, and environmental changes for a small watershed to river basin scale. SWAT is broadly utilized as a part of evaluating soil erosion prevention and control, non-point source contamination control and provincial management in watersheds (Arnold et al. 2013). SWAT is a river basin scale modelcreated to measure the effect of land management practices in substantial, complex watersheds.SWAT is an open source programming empowered model effectively upheld by the USD Aagrarian research service at black-land research and extension center in temple,TEXAS(USA).

2. Study area

The Barman ghat catchment of Narmada basin is situated in kareili town of Narsingpur district. It falls between the 23°01'58" North latitude and 79°01'14"East longitude. The overall catchment area of barman ghat is 26453 km2. Barman ghat located near to Rajmarg national highway. Barman is the holy place, Barman has two main ghats, one is the Barman ghat and other is Retghat. The intersection of the Narmada and Warahi rivers at Barman is a holy place and a big fair is held here in January.

Fig. 1 study area

3. Material and methods

SWAT is a physically based dispersed parameter model which has been created to estimate runoff, soil disintegration, residue and sediment transport from farming watersheds under various management practices (chaubey et al. 1999). The SWAT works in interface with ArcGIS with an extension of ArcSWAT a graphical user interface for SWAT apparatus. The hydrological cycle as estimated by SWAT depends on the water balance equation (Subhadip et al. 2017).

$$SW_t = SW_o + \sum_{i=1}^{10} (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw})$$

Where, SWt is the final soil water content (mm H2O), SWo is the initial soil water content (mm H2O),t is time in days, Rday is amount of precipitation on day i (mm H2O), Qsurf is the amount of surface runoff on day i (mm H2O), Ea is the amount of evapotranspiration on day i (mm H2O), wseep is the amount of percolation and bypass exiting the soil profile bottom on day i (mm H2O), Qgw is the amount of return flow on day i (mm H2O).

In SWAT, the watershed is partitioned into many sub-watersheds or sub-basins for modeling purposes. HRUs refer to aggregated land regions within the sub basin that consist of distinct combinations of land cover, soil, and management. The SWAT model utilizes a daily and monthly time interval to analyze each hydrologic unit, using the water balance equation as described by Shivhare et al. (2014). The hydrologic cycle simulated by SWAT is derived from the water balance equation. In order to conduct a terrain analysis and identify stream reaches and sub-basins, it is essential to use a GIS application that has enough storage space and the ability to show maps. Next, we want a component that can generate all the necessary data files forSWAT. This process involves a combination of extracting information from input data maps and analysis, as well as making human edits.

Therefore, we have chosen to use QSWAT (Version 2012), an open-source software that combines the interface of SWAT with QGIS (version 2.6.1), for our project. The data required for SWAT may be broadly categorized into two types: geographical data and temporal data. The required spatial data inputs include Digital Elevation Model (DEM), Soil map, and Landuse map. Conversely, temporal data comprises Wind, Temperature (both lowest and maximum), Precipitation, sun radiation, and Relative humidity.

The research region's topography is characterized by a Digital Elevation Model (DEM), which represents the elevation of each point inside a specified area at a certain spatial resolution. The DEM was obtained from the USGS Earth Explorer, which stands for the United States Geological Survey. The Digital Elevation Model (DEM) was used to demarcate the watershed and analyze the drainage characteristics of the land surface topography. The DEM was used to determine topographic parameters, including terrain slope, channel slope, and reach length.

The Supervised sorting approach has been used to deduce and differentiate the primary existing land use program in the basin. Creating a Landuse look up table is crucial for SWAT code preparation. This involves combining multiple variables in a manner that ensures the fields have comparable hydrological responses to the greatest extent feasible.

The soil map is derived from the raster global soil map of the Harmonized global Soil Database (HWSD). The SWAT model necessitates distinct soil textural and physical-chemical characteristics, including soil texture, accessible water content, hydraulic conductivity, bulk density, and organic carbon content, for various soil layers.

SWAT requires daily measurements of Precipitation, maximum and lowest Temperature, Solar radiation, Relative humidity, and Wind speed for the purpose of simulating diverse physical phenomena. The rainfall data and temperature data have been acquired from the appropriate sources: http://swat.tamu.edu. The whole model description and operation may be found in the publication by Neitsch et al. (2009).

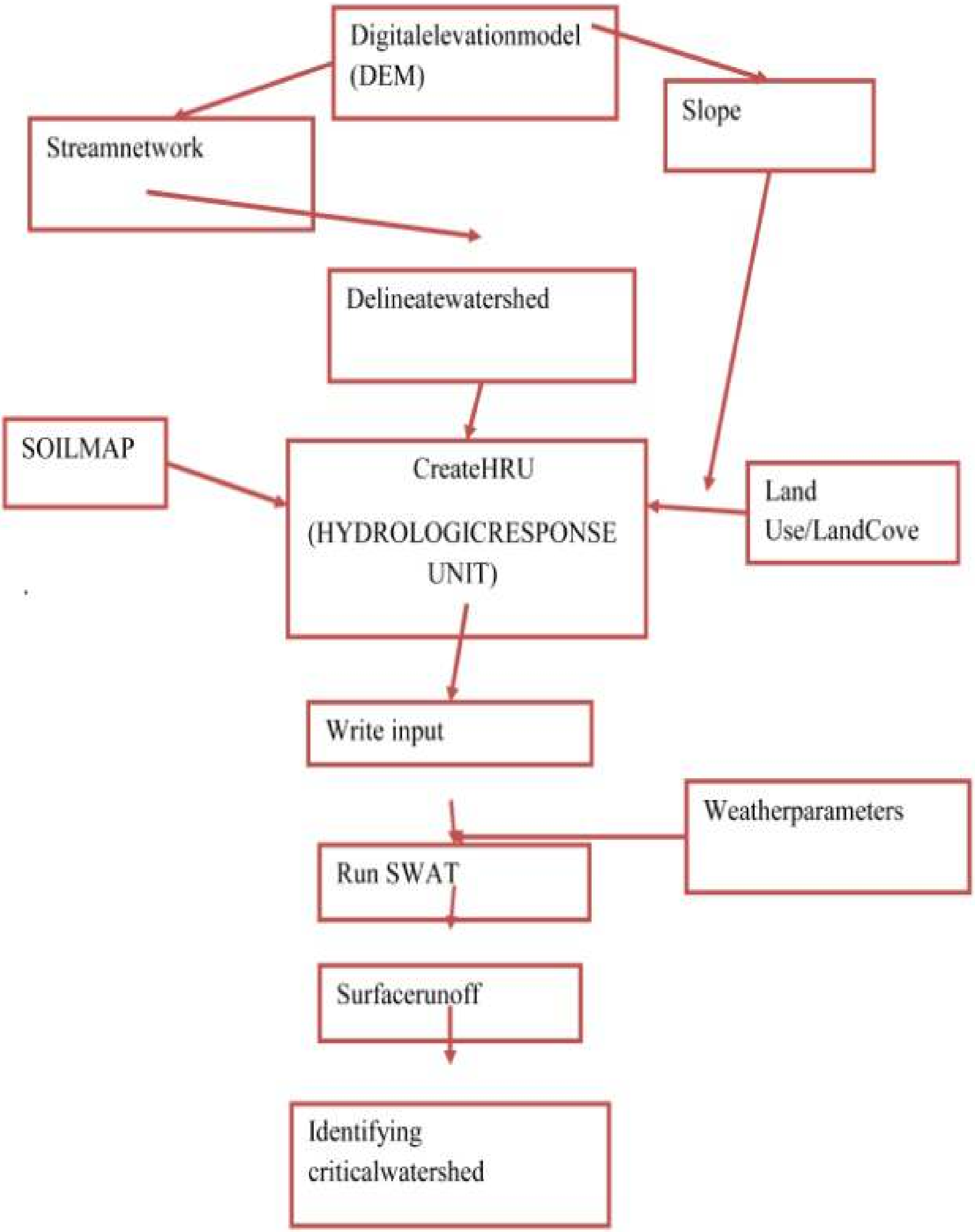
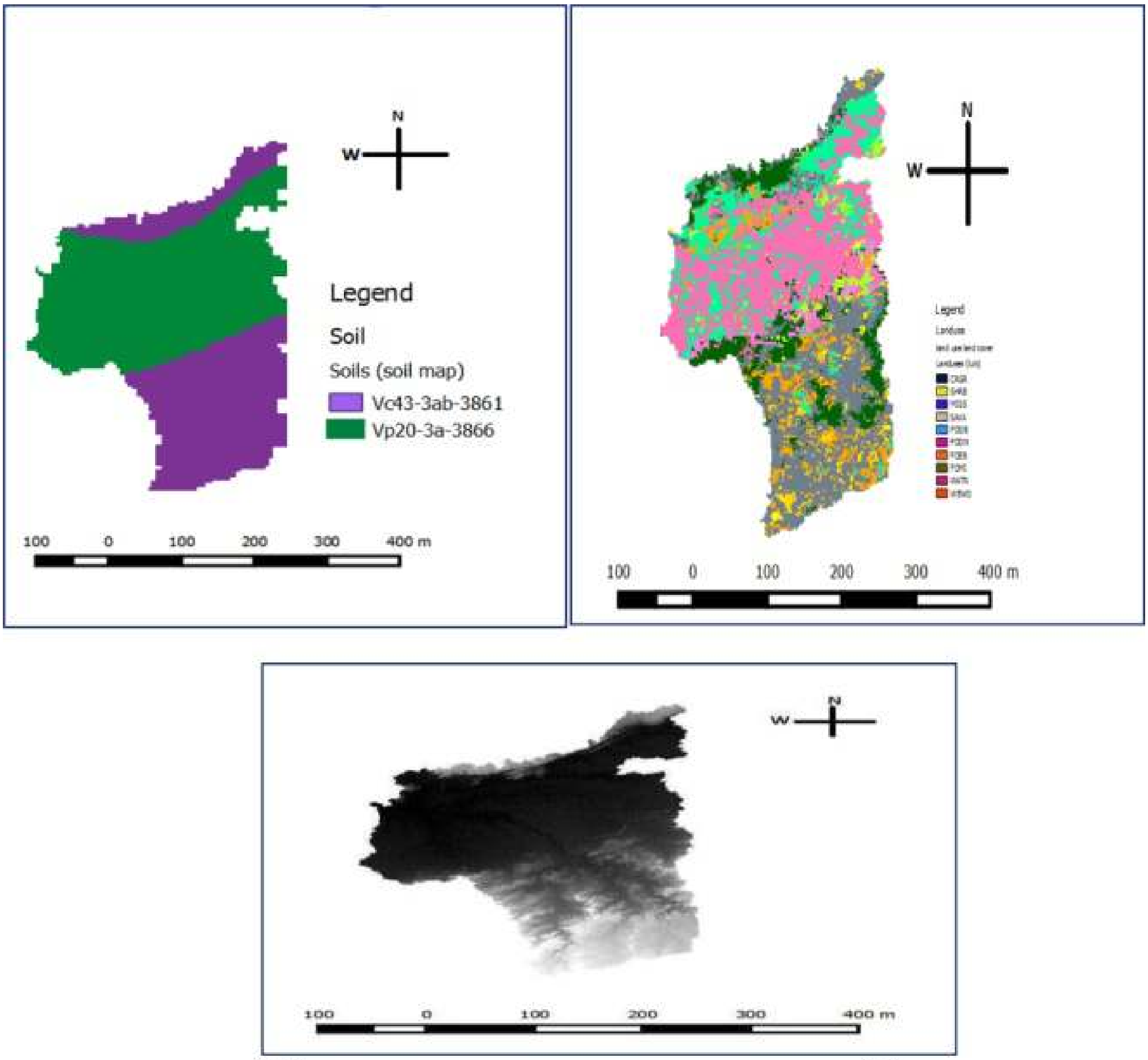


Fig.2 Runoff modeling methodology



(A) **(B)**

(c)

Fig.3 (A) Soil map (B) Landuse map (C) DEM of study area

4.Methodology

Watershed delineation is a standout amongst the most usually performed exercises in hydrologic and climatic analysis. Digital elevation models (DEM) give great territory portrayal from which the watersheds can be inferred naturally utilizing GIS techniques. The basins Watershed Delineation techniques permit you characterize numerous hydrologically associated sub- watersheds inside a given catchment region. This is valuable in watershed modeling and to define watershed characteristics. These techniques permit you with adaptability in altering shapes and characteristics of delineated watersheds and outlets, and in creating stream networks.

The SWAT tool works by dividing whole stream network into small homogeneous zones called hydrological response unit (HRUs). A HRU has a specific mix of soil, land use and slope. The HRU in QSWAT are made with the assistance of land use land cover map and soil map layers and related query tables. For modeling, a watershed is subdivided into various homogenous small basins (hydrologic reaction units or HRUs) having different soil, land use and slope properties.

The model requires the use of daily or monthly data pertaining to precipitation and temperature. SWAT enables the user to import weather station locations into the ongoing project and allocate weather data to the sub-watersheds. The data used in this analysis consists of daily rainfall measurements from four raingauge sites and daily maximum and lowest temperature measurements for the years 2001 to 2014. To load weather data, use the 'Write Input Tables' option located on the QSWAT toolbar. Prior to executing SWAT, it is necessary to establish the starting values for the watershed input. The values are automatically determined based on the watershed demarcation and the categorization of land use, soil, and slope, either from specific data or from predetermined defaults. Following this procedure, the model was executed to replicate the phenomenon of surface runoff.

SWAT input parameters are process based and should be held inside a reasonable uncertainty. The initial phase in the calibration and validation process in SWAT is the assurance of the most sensitive parameters for a given watershed or sub-watershed. It is important to distinguish key parameters and the parameter accuracy required for calibration.

a) This initial step decides the dominating procedures for the part of interest. Sensitivity of one parameter frequently relies upon the estimation of other related parameters; consequently, the issue with each one in turn examination is that the right estimations of different parameters that are settled are never known. The hindrance of the global sensitivity examination is that it requires a large amount of iterations and simulations.

b) The second part is the calibration procedure. Calibration is a method to better parameterize a model to a given arrangement of usual conditions, so that decrease in uncertainty. Model calibration is performed with suitable care in choosing values for model input parameters (inside their respective limits) by looking at model estimation for a given arrangement of accepted conditions with observe data for similar conditions.

c) The last process is validation for the segment of intrigue (stream flow, residue yields, and so on.). Model validation is the way toward showing that a given site-particular model is equipped for making adequately precise results. Validation includes running a model utilizing parameters that were resolved during the calibration procedure, and comparing the results with observed information not utilized as a part of the calibration process.

5.Results and Discussion

In this study SUFI-2 was used for model calibration and validation. By using SUFI-2, we could perform uncertainly analysis and calibrate the model for more number of parameters. The model was calibrated for runoff using parameters which affect runoff; the model was then validated with the measured discharge available at the watershed outlet. The SUFI-2 algorithm withSWAT-CUP software been used for model calibrations on monthly basis by realizing 250 simulations for the nine most sensitive parameters.

In order to identify the most sensitive parameters initially SWAT-CUP is run with large number of parameters for simulation. Once the sensitive parameters have been identified they can be used for better convergence of simulation during calibration of the model.

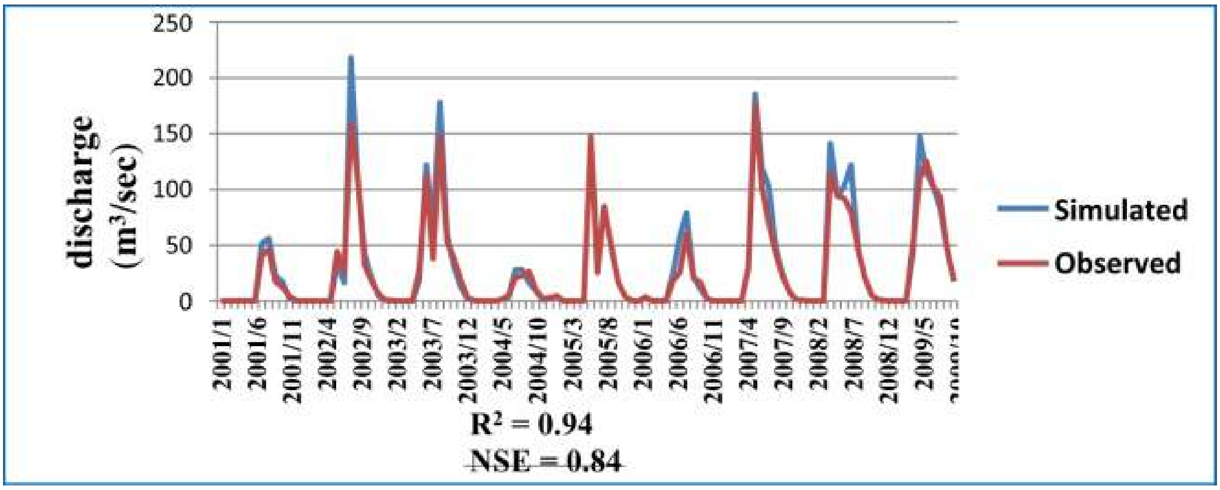


Fig. 4 simulated v/s observed monthly flow for calibration period

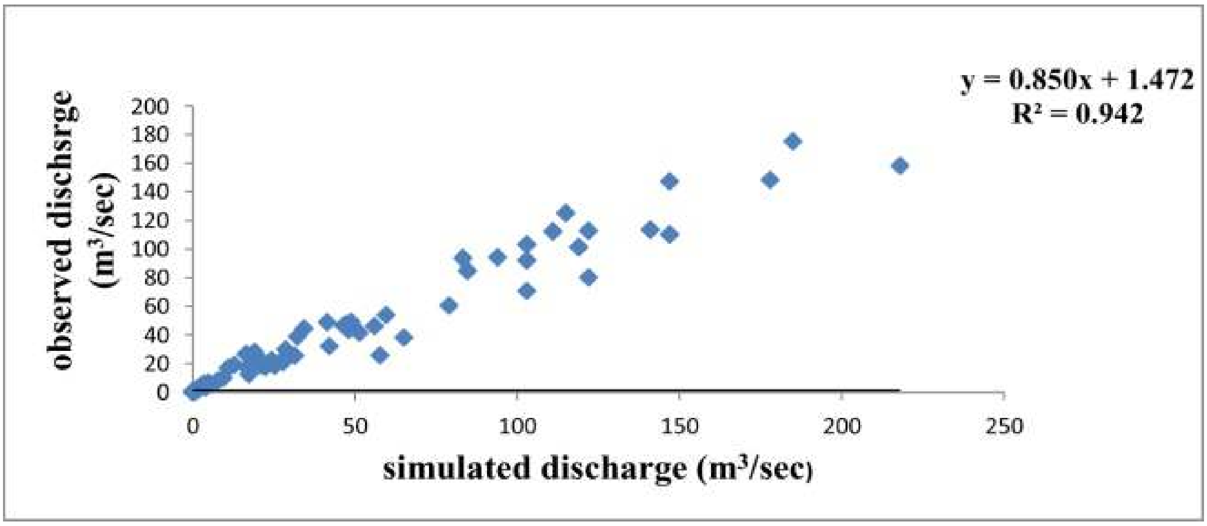


Fig. 5 simulated v/s observed surface runoff during calibration

Based on literature review parameters listed in table 5.1 were identified for sensitivity analysis of runoff that are CN2, SOL_AWC, ALPHA_BF, ESCO.hru, A_RCHRG, GWQMN, EPCO.hru, GW_DELAY, GW_REVAP in which first four are most sensitive. The t-stat value may be positive or negative. The magnitude of t-stat value gives a measure of sensitivity, parameterswith larger absolute values shows more sensitive. P-value range from zero to one. P-value indicates the significance of the sensitivity with parameters having a value close to zero being more significant.

The calibration of SWAT model for runoff was done by using monthly observed runoff data at the outlet of the study watershed (Barman ghat) for the periods of 2001-2009.

The model performance was analyzed on the basis of statistical values of coefficient of determination (R2) and Nash-Sutcliffe (NSE). In the present study R2 and NSE values are determined and to be 0.94 and 0.84. This suggests that the model can be used to predict the monthly flow values. After calibration the model was validated for the surface runoff by applying different set of data from 2010 to 2014 to verify the prediction accuracy of the model. The values of coefficient of determination R2 and NSE for monthly runoff during validation period were 0.86 and 0.78 respectively. Hence the model shows good prediction efficiency.

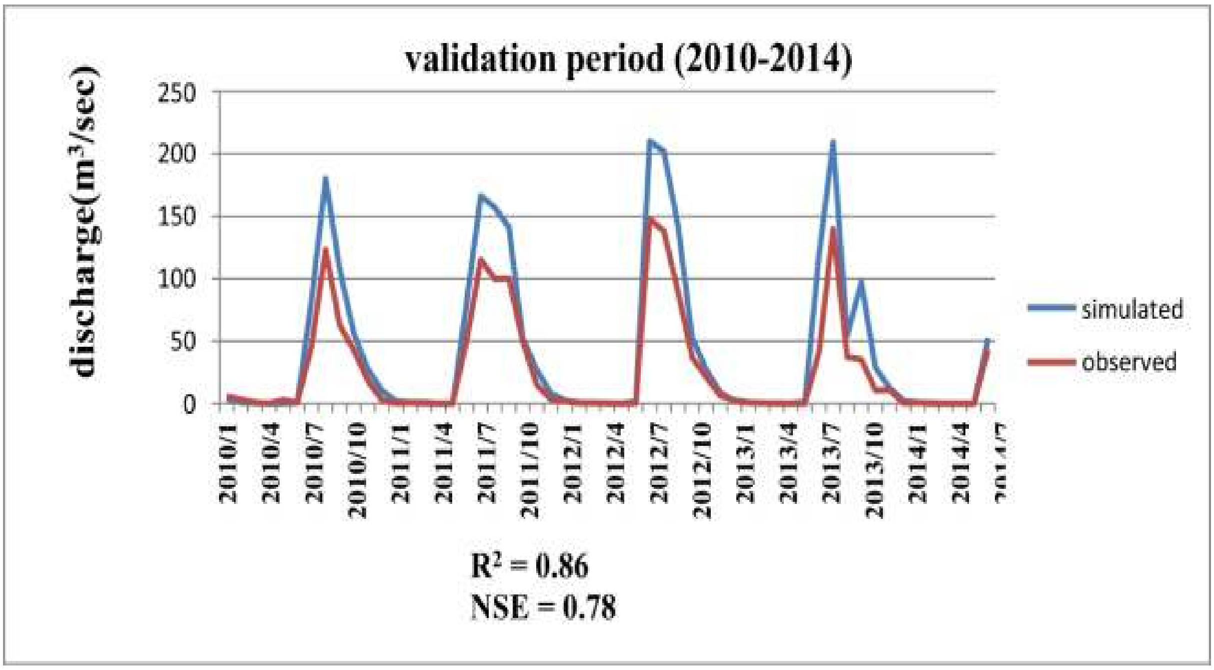


Fig. 6 simulated v/s observe monthly flow for validation period

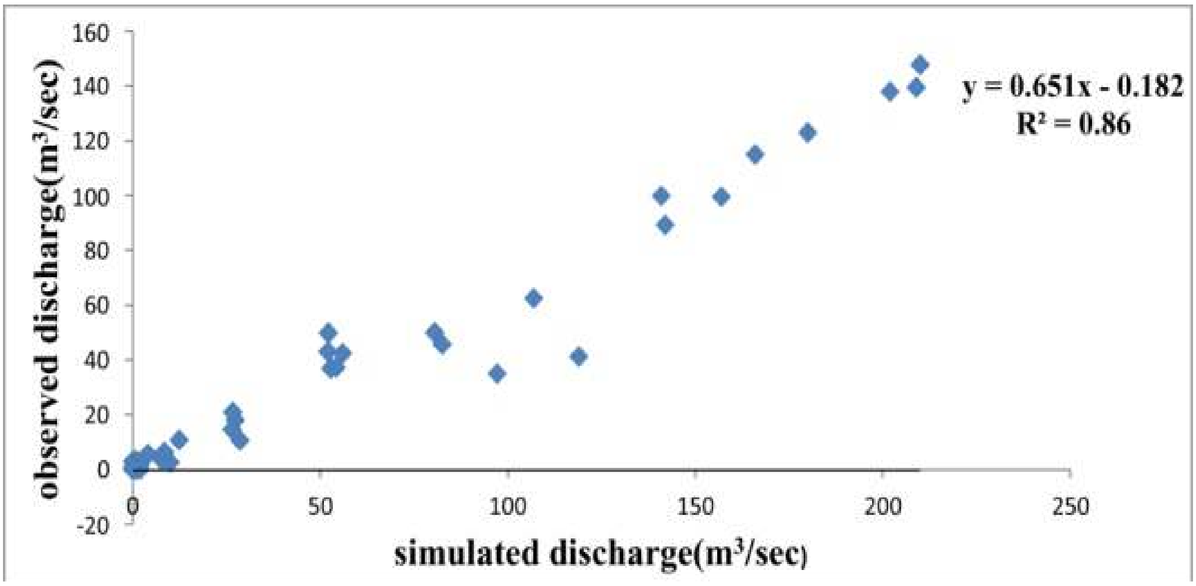


Fig. 7 simulated v/s observed monthly surface runoff during validation

Table 1 Statistical values for calibration and validation period

Statistical parameters	Barman ghat watershed	
	Calibration (2001-2009)	Validation (2010-2014)
	Runoff	Runoff
R^2	0.94	0.86
NSE	0.84	0.78

6. Conclusion

SWAT has proven to be a robust research and investigation tool for many types of hydrological and water quality applications. The goal of this paper was the execution of a calibrated SWAT model in the Barman ghat catchment. The simulation contains the hydrological model of discharge (flow) and sensitivity analysis.

The study area contains an area of 26000 km² which was further subdivided into 23 sub-basins and a total of 23 HRUs. Four discharge gauges are available for calibration and validation of discharge in the Barman ghat catchment. The simulation period was set from the year 2001 to 2014, with a calibration period from 2001 to 2009 (9 years) and a validation period from 2010-2014 (5 years).

The calibrated and validated NSE values for the outlets of Barman ghat on a monthly time step were 0.84 and 0.78 respectively, which can say a very good model performance.

SWAT gives acceptable outcomes and powerful model when adjusted and approved successfully for large range of applications

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