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Rainfall-Runoff Modeling of a River Basin using SWAT Model

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Abstract— **The present study was undertaken with an aim to test the performance of SWAT Hydrological model on Sher River at Belkheri in Narsimhpur District of Madhya Pradesh, India. For model application, the watershed area was divided into 11 sub-watersheds. The watershed comprises mainly of 6 land use (with more than 65% agriculture area coverage), slope mostly ranges from 0-10 (more than 80%). Available hydrological data (i.e. from 1995-2008) was split into two groups for calibrating and validating parameter of the model (1995 and 1996) was taken as warm up periods). The model was calibrated at Belkheri gauging site both on daily and monthly basis time scale. The model was auto-calibrated and validated using SWAT-CUP SUFI-2 software.. Nash and Sutcliffe Efficiency (NSE) was taken as the main objective function during calibration and validation. The average daily calibration and validation showed good model response with NSE of 0.724 and 0.765 respectively. Also the monthly calibration and validation showed good model fit with NSE of 0.87 and 0.88 respectively. The study was also carried out to perform the sensitivity analysis of different parameters responsible for streamflow generation. Based on the analysis, Overland flow Manning's n (OV_N), Average slope length (SLSUBBSN), Groundwater delay (GW_DELAY.gw), SCS runoff curve number (CN2.mgt), Threshold water depth in shallow aquifer required for return to reach occur (GWQMN.gw), Groundwater "revap" coefficient (GW_REVAP.gw) and Available water capacity of the soil layer (SOL_AWC.sol) were found to be the most sensitive parameters. Overall, the performance of the SWAT model in simulating streamflow at Belkheri gauging site can be rated as very good and the calibrated model could be used for runoff simulation for this agriculture dominating watershed.**

Keywords— Hydrological Model; calibration and validation; SWAT-CUP SUFI-2; sensitive parameters

I. INTRODUCTION

India is one of the most diverse countries in terms of culture and tradition, environment and landscape with various kinds of terrain and climate conditions. The snow cover in the Himalayas and the rainfall received mostly during monsoon season are the main important sources of water in the country. Rainfall in different regions varies considerably both in terms of intensity and distribution. Years of scarcity are followed by periods of excessive floods. Likewise in Madhya Pradesh, during years 2005 and 2006 most of the districts were affected by floods and the year after that 39 out of 50 districts were declared as drought affected (National Institute of Disaster Management, Madhya Pradesh). In order to face the natural calamities like floods and droughts and to meet the growing needs of the society, it is necessary to develop the water resources for assured irrigation and drinking water supply.

There is an urgent need to study the Rainfall-Runoff behavior of the area so as to understand the Hydrological phenomena with regards to their changes in the period of time and how to make an impact on those changes. Also, catchment modeling is required for estimating different hydrological quantities for effective and safe water structure designs or use in forecasting. Hydrological modeling is an important and effective tool for research hydrologists as well as the practicing engineers involved in the planning and development of integrated approach for management of water resources (Schultz, G.A., 1993). Soil and Water Assessment Tool (SWAT) is a watershed model which is used to evaluate stream flow, transportation of sediment and nutrients. SWAT, developed by Agricultural Research Services of USDA, has gained popularity in the recent past world wide as well as in Indian conditions, witnessing continued refinement and is being used in the present study to quantify basin runoff. It has been applied to different basins of India for simulating runoff and sediment yield as well as those cases where most part of the river originates from the intense storm during rainy season, and the results have been found to be reasonably satisfactory (Mishra et al. 2007; Jain et al. 2014; Manaswi et al. 2014; Panhalkar S S 2014; Diwakar et al. 2014). SWAT is a hydrological model functioning on a time step of daily or monthly. In addition, it was used for evaluating the impact of climate change and anthropogenic factors on stream flow, agricultural chemical and sediment yields in large river basins (Arnold et al., 1998).

The main aim and objectives of the study is to understand the Rainfall-Runoff behavior of the Belkheri Basin using SWAT model and to find out the most sensitive parameters which are critically responsible for the hydrologic response with pre-defined conditions. The model simulation is performed using the gridded meteorological data from NASA MERRA of 0.5º X 0.5º resolution, Land use Land Cover Grid derived using Supervised classification of LandSat 7 images, soil Grid from NBSS & LUP and the model run for the period of 14 years (1995-2008). The first two initial years (1995-1996) of simulation was taken as warm up period. SWAT-Calibration and Uncertainty Programs Sequential Uncertainty Fitting (SUFI2) was used for calibration and validation of the model. Calibration was carried out for the period of six years (1997-2002) where a set of parameters commonly responsible for basin

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Hydrologic response in Indian conditions were used for model adjustment. Validation was also carried out for the period of six years (2003-2008) in order to verify the response of the basin using the calibrated fitted values. The model performance and evaluation however was analyzed using the statistical parameters such as correlation Coefficient, Nash Sutcliffe Efficiency and Root Mean Square Error Standard Deviation Ratio (RSR).

II. STUDY AREA

A. Belkheri Basin

The Sher River rises in the Southern Satpura range in the Durg. district of Madhya Pradesh. The basin area up to the confluence point of Sher with the Narmada is about 2900 km^2. However the Central Water Commission has established a gauging site upstream of the confluence covering about 1344.18 km^2 of Sher watershed.

The study area, Belkheri basin lies in the districts of Narsimhpur, Chindwara and Seoni in Madhya Pradesh having a longitude ranges from 79°8'20.4" E to 79°42'0" E and latitude ranges from 22°27'0" N to 22°54'0" N. The river Sher is fairly big tributary located left of river Narmada. About 40 km upstream of the confluence of river SHER with river Narmada, the Narsimhpur-Jabalpur road crosses the river Sher. At this point the Belkheri gauging site maintained by the Central Water Commission is located in Belkheri village which is situated at the distance of 16 km. from Narsimhpur on state highway No.26. The geographic feature of the site is having longitude of 79°20'24" E and latitude of 22°54'54" N.

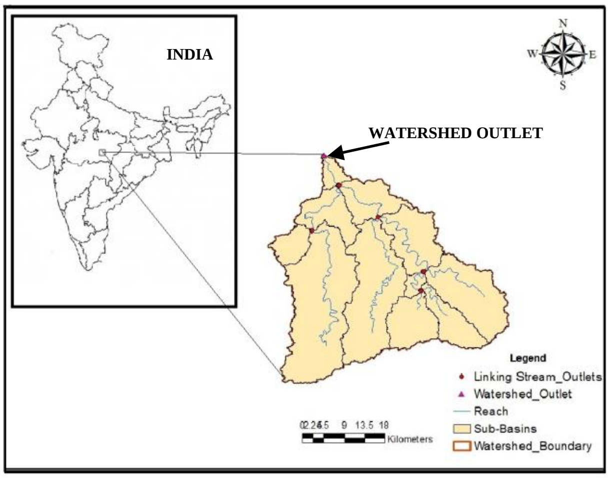

Fig. 1 -Location Map of the study area

B. Climate

Four main seasons are Monsoon starting from mid-June to September, winter from November to February, summer season from March to mid-June. May is the hottest and driest month of the year. The southwest monsoon starts from middle of June and lasts till end of September. October to mid- November is considered as the post monsoon or retreating monsoon.

C. Rainfall Pattern

The normal annual rainfall of the basin is 1217.6mm. Belkheri basin received maximum rainfall during south west monsoon period i.e. June to September. About 90.84 % of the annual rainfall received during monsoon season. Only 9.15 % of the annual rainfall takes place between October to May period. Rainfall is the main important source for natural recharge to ground water regime and is mainly available during the south west monsoon period only.

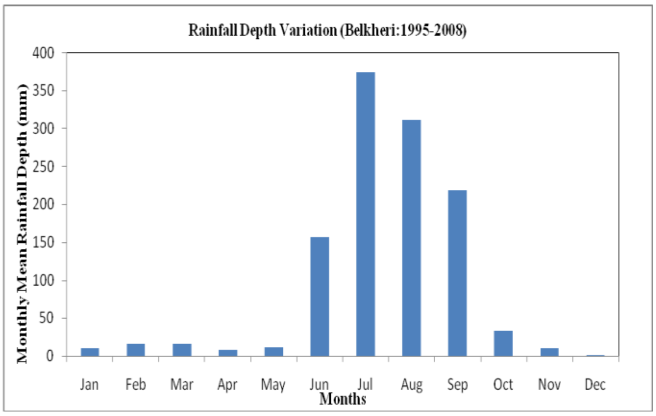

Fig. 2 -Monthly mean rainfall depth (1995-2008)

D. Temperature

The normal maximum temperature received during the month of May is 42.50°C and minimum during the month of January is 8.20°C. The normal daily mean monthly maximum temperature is 31.01°C and daily mean minimum temperature is 20.37°C.

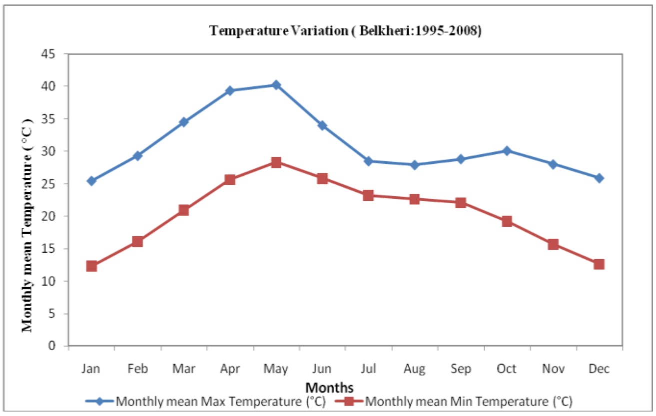

Fig. 3 -Monthly mean temperature (1995-2008)

E. Land Use/ Land Cover

The Land Use data was prepared using the LANDSAT image downloaded from the USGS Archive, http://glovis.usgs.gov/. The downloaded file contains 7 bands and these are layer stacked using ERDAS imagine 2015 into one imagery. This image is then projected into proper projection same as the DEM having the same datum using ArcGIS. The image was classified (supervised Classification) using ERDAS imagine 2015 by identifying different signatures that were present in the Belkheri watershed and converted into grid format in ArcGIS to make it compatible for ArcSWAT. Major classes classified include water, forest, barren land, agriculture land-generic, range land and agriculture Land-row. The Land Use map of Belkheri basin is shown in Figure 4 and the area under various land use type is shown in Table 1.

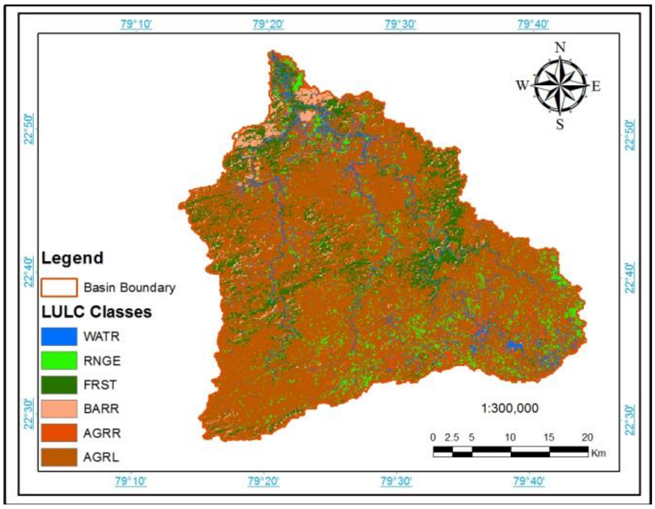

Fig. 4 - Basin LULC Classes

Table 1: Belkheri Basin LULC classes

SWAT Code	Description of Land Use	Area (km^2)	% Watershed Area
BARR	Barren Land	49.92	3.71
RNGE	Range-Grasses	87.27	6.49
FRST	Forest-Mixed	154.48	11.4
AGRR	Agriculture Land-Row Crop	96.19	7.15
WATR	Water	56.40	4.19
AGRL	Agricultural Land-Generic	899.90	66.92
	Total	1344.19	100

F. Soils

The soil map with spatial resolution of 1:50,000 were obtained from the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP). Soil data of Belkheri basin has been divided into twelve different soil groups. The soils are usually clayey to loamy in texture with calcareous concretions invariably present. They are sticky and in summers, due to shrinkage, develop deep cracks . The soils predominantly consist of montmorillonite and beidellite type of clay minerals. Soil map of Belkheri watershed is shown in Figure 5.

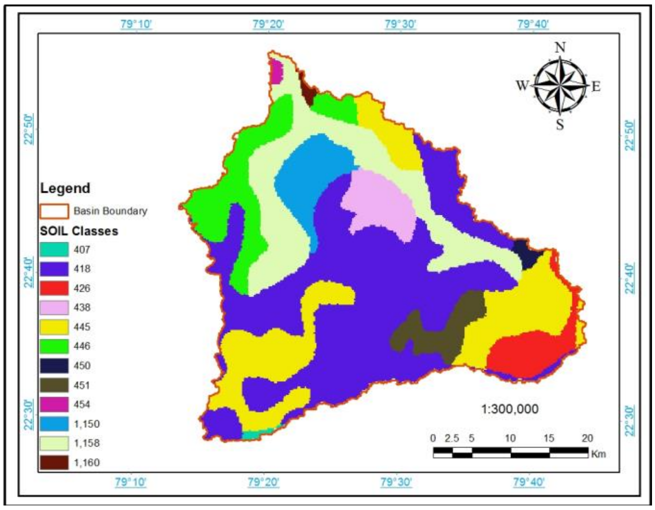

Fig. 5 - Basin Soil Classes

III. METHODOLOGY

SWAT model is a comprehensive, conceptual, continuous time, distributed river basin and deterministic model that require a large number of input parameters varying widely in space and time while transforming input into output. Mainly SWAT satisfies the following criteria: 1) It can be used for conducting Hydrological assessment studies that predicts the effect of land management practices on the water and sediment quantity and quality in large complex watersheds. 2) It can be used as a potential tool for runoff, sediment, nutrients and pesticides predictions both from rural and urban land uses. 3) It can be used as a media to study the impacts on water quality especially the long-term non-point source pollution on the basis of different land management practices. 4) It is a freely available model. Its advantage is that it can run for a very long time period of 150 to 300 years impact. 5) It is a useful tool in areas like water resource planning, management and decision-making policies. Some of the governing processes and equations are discussed below.

A. Surface Runoff

Surface runoff is predicted for the daily rainfall by using SCS curve number method (USDA-SCS, 1972). In SCS method, surface runoff occurs when the rainfall (in mm) for the day (R_{day}) is greater than the initial abstraction (i.e. losses like evapotranspiration, depression storage, infiltration, etc.). SCS curve number method is an empirical conceptual method developed for computation of surface runoff under varying soil types and land uses.

$$Q_{surf} = \frac{[R_{day} - 0.2S]^2}{(R_{day} + 0.8S)} \quad (1)$$

Where, Q_{surf} is the collected runoff (mm of H2O), R_{day} is the precipitation depth for the day (mm of H2O), S is the retention parameter (mm of H2O). I_a is the initial abstraction loss (mm of H2O). The retention parameter S is calculated using the following equation

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

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Where CN is the curve number for the day and it is computed using the following equation 3.

$$CN = \frac{25400}{(S + 254)} \quad (3)$$

B. Evapotranspiration

Evapotranspiration is one of the most important components in the hydrologic cycle. Various methods such as Penman-Monteith method, Priestley-Taylor method and Hargreaves method are included in SWAT depending upon the availability of inputs. In the present study, Penman-Monteith method (requires radiation, temperature of air, relative humidity and wind speed) was used. Penman-Monteith equation accounts component that are responsible for energy needed to sustain evaporation aerodynamic and surface resistance terms and the strength to take out the water vapor. It is represented by the following equation 4.

$$\lambda E = \frac{\Delta \,.\, (H_{net} - G) + \rho_{air} \,.\, c_p \,.\, [e_z^o - e_z]/r_a}{\Delta + \gamma \,.\, \left(1 + {}^{r_c}/_{r_a}\right)} \quad (4)$$

Where λE is the latent heat flux density (MJ m^{-2} d^{-1}), H_{net} is the net radiation (MJ m^{-2} d^{-1}), Δ is the slope of the saturation vapor pressure-temperature curve, E is the depth evaporation rate (mm d^{-1}), G is the heat flux to the ground (MJ m^{-2} d^{-1}), c_p is the specific heat at constant pressure (MJ m^{-2} $^oC^{-1}$), ρ_{air} is the density of air (kg m^{-3}), r_c is the canopy resistance of plants (s m^{-1}), r_a is the aerodynamic resistance (s m^{-1}), e^o is the vapor pressure of air at saturation at height z (kPa), e_z is the water vapor pressure of air (kPa), and γ is the psychometric constant (kPa $^oC^{-1}$).

C. Channel Routing

Variable Storage and Muskingum Routing method are the two types of Channel routing method in SWAT. In the present study, Variable Storage Routing method was used. For a given segment of reach, the storage routing is based on the following continuity equation 5.

$$V_{in} - V_{out} = \Delta V_{stored} \quad (5)$$

Where V_{in} is the inflow volume (m^3), V_{out} is the outflow volume (m^3) and ΔV_{stored} is the change in storage volume during the time step (m^3).

The outflow rate at the end of time step is given by the following equation 6 which represents the Variable Storage routing method.

$$q_{out,2} = SC \,.\left(q_{in,ave} + \frac{V_{stored,1}}{\Delta t}\right) \quad (6)$$

Where $q_{out,2}$ is the outflow rate at the end of the time step (m^3 s^{-1}), $q_{in,ave}$ is the average rate of inflow during the time step (m^3 s^{-1}), $V_{stored,1}$ is the storage volume at the beginning of the time step (m^3), Δt is the length of time step (s) and SC is the storage coefficient which is defined by equation 7.

$$SC = \frac{2 \,.\, \Delta t}{2 \,.\, TT + \Delta t} \quad (7)$$

Where TT is the travel time (s) and it is defined by equation 8 given below.

$$TT = \frac{V_{stored,1}}{q_{out,1}} = \frac{V_{stored,2}}{q_{out,2}} \quad (8)$$

IV. DATA SETS AND MODEL SETUP

Hydrological modeling of the river basin requires certain types of data before simulation: spatial and non-spatial data. SWAT model requires spatial data like DEM, LULC MAP, SOIL MAP and METEOROLOGICAL DATA. The DEM of the study area was downloaded from http://srtm.csi.cgiar.org/, where elevation data at 90 m resolution acquired through shutter radar topographic mission (SRTM) is available for the globe. To get the DEM of the study area, the original DEM (Figure 6) is projected into an appropriate projection system like Asia North Lambert Conformal Conic having a datum of D_WGS_1984 and clip by mask. LAND USE LAND COVER MAP was prepared from LANDSAT images (GLOVIS Archive) using the Supervised classification having cell size of 30 m. SOIL MAP with spatial resolution of 1:50,000 was obtained from NBSS&LUP (Figure 5).

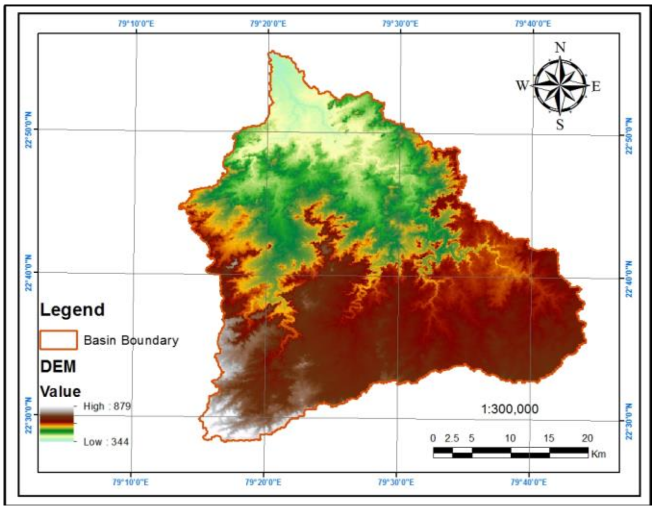

Fig. 6 - Basin DEM

Other than the spatial datasets requirement, extensive non-spatial datasets are required as well for better simulation. Daily gridded Meteorological data such as temperature, precipitation, wind speed, relative humidity, solar radiation were obtained from the Reanalysis climate model, MERRA (NASA Prediction of Worldwide Energy Resource (POWER)) of the resolution of 0.5º X 0.5º. The discharge data in the present study was measured originally at the site in Belkheri, Narsimhpur District of Madhya Pradesh maintained by the Central Water Commission. The daily data was obtained from Water Resource Information System of India (WRIS) for the period of 14 years (1995 to 2008). Using the DEM, ArcSWAT automatically delineates a basin with proper stream definition threshold value and identification of outlet point. The delineated watershed was also subdivided into eleven sub-basins. The delineated area of study was found to be 1345.266 km^2. Land use, soil and slope reclassification for a basin is performed using commands from the HRU analysis, which is menu on the ArcSWAT Toolbar. The land use maps were fed into the model using HRU analysis toolbar and then the lookup tables for land use maps were provided to the model. Similarly the soil maps and the respective lookup tables were also provided to the model. After characterization of the land use and soil maps in the basin, multiple slope class can be selected. The number of the slope classes can be entered as per the user's convenience. In this study five slope classes are used; they are 0-10%, 10-20%, 20-30%, 30-40% and 40-99.99% respectively. Then the Hydrological response units (HRU) will be created by the model. The multiple HRU option can be chosen which will create multiple HRU within each sub-basin. The threshold percentage of the land, soil and slope factors for the creation of the HRU is given as 5%, 10% and 5% respectively. Hence, the whole watershed was divided into 192 HRU's.

In the present study, SWAT2012/Arc 2012.10.18 interface was used to meet the objective of the study. SWAT-CUP is a public domain computer program for calibration, validation and uncertainty analysis of SWAT model. SWAT-CUP SUFI-2 program has been used for model calibration and validation, and sensitivity analysis. Automated model calibration requires that the uncertain model parameters are systematically changed, the model is run, and the required outputs (corresponding to measured data) are extracted from the model output files. The main function of an interface is to provide a link between the input/output of a calibration program and the model. Auto-calibration and validation was performed by trial and error method and it requires less number of model runs to achieve the best possible simulations nearer to the actual values. Workflow diagram of methodology adopted in the present study is given in Fig. 7.

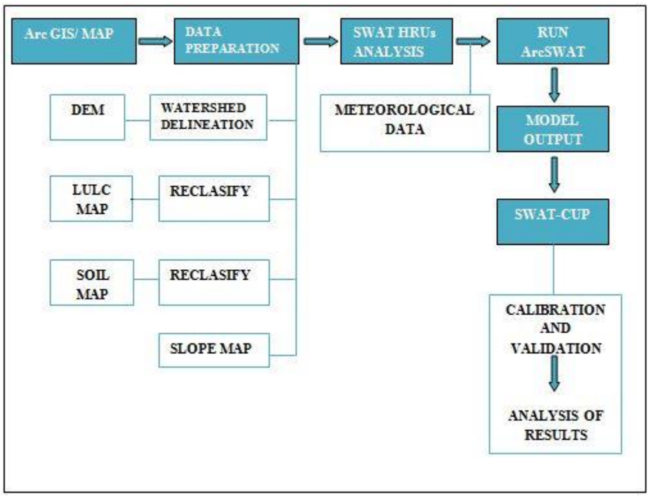

Fig. 7- Workflow Diagram of SWAT simulation

V. ANALYSIS AND DISCUSSION OF RESULTS

SWAT-CUP is a public domain computer program for calibration, validation and uncertainty analysis of SWAT model. The program links SUFI2, PSO, GLUE, ParaSol, and MCMC procedures to SWAT. In the present study, Auto calibration and validation was performed through SUFI2 algorithm of SWAT CUP software by loading the input from SWAT Model text input file. SWAT-CUP SUFI2 is a program used for calibration and validation in this study which has been also carried out in other hydrological studies (Setegn et al. 2008; Patil et al. 2014). SUFI-2 required the minimum number of simulations to obtain better results (Jurgen Schuol et al. 2007). SUFI-2 can also be applied for multi-site and multivariable analysis. In the present study, analysis has been carried out at daily and monthly time steps. Observed data for initial 2 years (1995-1996) has been used as warm up period in the model and data from 1997 to 2002 has been used for calibration of parameters of the model and the performance of the calibrated model has been validated using independent data set from 2003 to 2008. SUFI-2 is based on iterative process which will narrow the parameter value after each iteration process. Each iteration process was set up to 500 simulations. During each iteration, all the statistical coefficients can be calculated at each time and after the number of time the iteration was set, the best simulation can be shown in the output results that will be the best statistical coefficient result. Parameter uncertainty in SUFI-2 accounts for all sources of uncertainties such as driving variables (e.g. rainfall), conceptual model, parameters and measured data (Abbaspour et al. 2004). P-factor and d factor have been used to evaluate the strength of calibration and uncertainty measures in addition to Coefficient of correlation (R2), Nash–Sutcliff Efficiency (NSE) and RMSE standard deviation ratio (RSR) (Abbaspour et al. 2007). For ideal condition, the P-factor should tend towards 1 and have a d-factor close to 0. When acceptable values of P-factor and d-factor are reached, then the parameter uncertainties are in the desired parameter ranges. RMSE is one of the commonly used error index statistics. RSR could be calculated using Equation 9.

$$\boldsymbol{RSR} = \frac{\sqrt{\sum_{i=1}^{n}(O_i^{obs} - P_i^{sim})^2}}{\sqrt{\sum_{i=1}^{n}(O_i^{obs} - P_i^{mean})^2}} \tag{9}$$

Where O^{obs} is the observed data during evaluation period, P^{mean} is the simulated mean data, P^{sim} is the simulated data.

The second evaluation criterion adopted was Nash Sutcliffe coefficient of Efficiency (NSE), (Nash and Sutcliffe, 1970). The NSE was used as main objective function. NSE could be computed using the equation 10.

$$NSE = 1.0 - \frac{\sum_{i=1}^{n}(O_i^{obs} - P_i^{sim})^2}{\sum_{i=1}^{n}(O_i^{obs} - O_i^{mean})^2} \tag{10}$$

The performance rating of RSR and NSE is given in the following Table 2.

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Table 2: Statistical Parameter Performance Rating

Performance Rating	RSR	NSE
Very good	0< RSR <0.5	0.75< NSE <1
Good	0.5< RSR ≤ 0.6	0.65< NSE ≤0.75
Satisfactory	0.6< RSR ≤ 0.7	0.5 < NSE ≤ 0.65
Unsatisfactory	RSR > 0.7	NSE< 0.5

A. *SWAT model calibration and validation*

The main objective of the calibration of the model is to minimize the difference between the observed and the simulated daily, monthly and cumulative annual stream flow and to match the predicted values with the observed values with a reasonable goodness of fit. The calibration of the parameters of the model has been performed using observed data for the period (1997-2002) by adjusting the most sensitive parameters such Manning's n for overland flow (OV_N.hru), average slope length (SLSUBBSN.hru), groundwater delay factor (GW_DELAY.gw), SCS runoff curve number (CN2.mgt), threshold water depth in shallow aquifer required for return to reach occur (GWQMN.gw), groundwater "revap" coefficient (GW_REVAP.gw) and available water capacity of the soil layer (SOL_AWC.sol). Likewise, these model parameters were found to be very sensitive in Hydrological modeling carried out by Abraham et al. (2007), Kushwaha et al. (2013).

The comparison of model simulated values with the observed values determines how well a model could simulate hydrological behavior of the study area (Haan et al. 1982). The auto calibration and validation through SUFI2 algorithm of SWAT CUP software was used to simulate the daily and monthly flow data. The SUFI2 algorithm of SWAT CUP software gives results on visual comparison and statistical criteria such as Nash-Sutcliffe Efficiency (NSE), coefficient of determination (R^2) and RMSE-observations standard deviation ratio (RSR).

Visual comparison provides information about overall qualitative visual match such as matching of peaks, trends of recession and general agreement in hydrograph characteristics. On the other hand, statistical evaluation criterions evaluate model fit in terms of quantitative numbers which help in quantification the degree of agreement between observed and computed variables as well as comparison between two different durations such as calibration and validation periods.

Visual plots showing observed and model computed runoff are shown in Figures 8 and 9 for daily calibration and validation periods respectively. As can be seen from these figures that few high peaks are underestimated and in many events deviation could be clearly seen between observed flow and simulated flow. This could be the reason that soils have high hydraulic conductivity and available water holding capacity which absorbs considerable amount of rainfall when it falls during monsoon months and later releases slightly higher amount of water from their storages to appear as base flow. In the following figure 8, the dark blue circle represents the model simulated flow to be very much underestimated as compared to observed flow in spite of rainfall event happening. This may be the cause of post monsoon Land use land cover (Agriculture land covers about 65 % of total area) behavior in which there is high infiltration and less soil water content. Brown circle shows that when there is continuous high rainfall the model predicts high runoff and it is seen to be gradually receding. This indicates the basin characteristic like slope (80 % area coverage for slopes ranging 0 to 10 %) may play an important part in obtaining such kind of hydrological response. Similarly, green circle shows that high runoff computation with high rainfall events. This may be the cause of rainfall data accuracy since it was computed using a coarse resolution gridded meteorological data which instead can be improved if observed station data sets are available. Plots showing observed and model computed monthly runoff have been prepared which are shown in Figure 10 and Figure 11 for calibration and validation periods respectively. As can be seen from plots of monthly runoff values, the visual fit between observed and corresponding computed values is better compared to daily simulated runoff values since averaging of the values compromised all the basin parameters responsible for hydrological response.

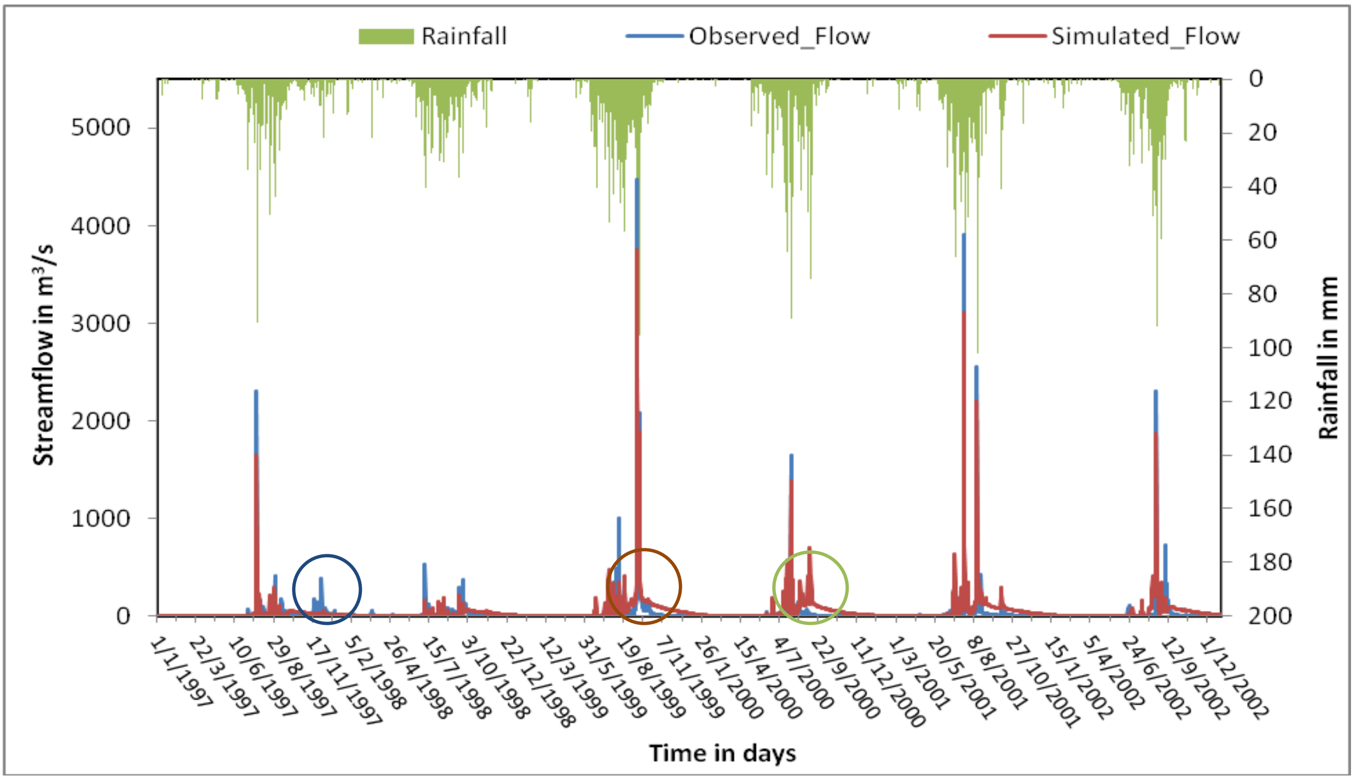

Fig. 8 – Daily calibration from 1997 to 2002

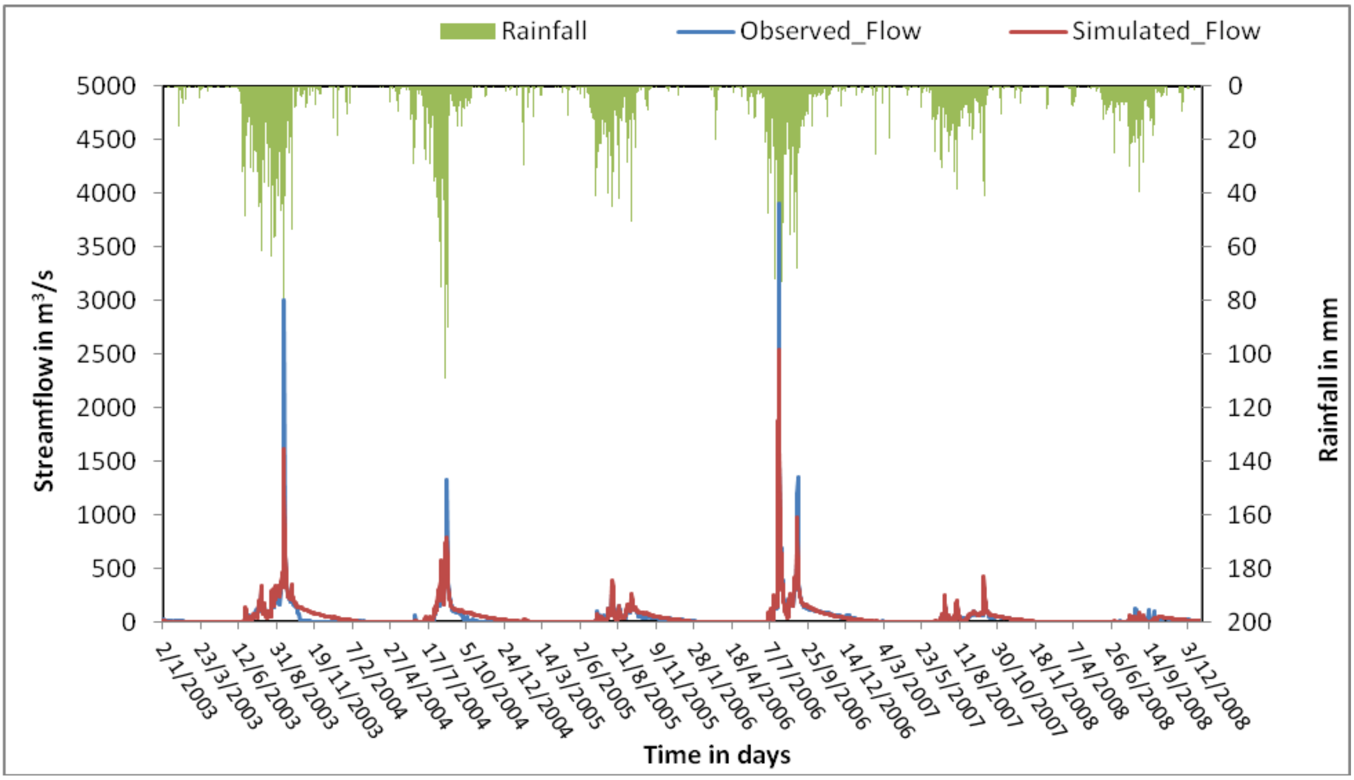

Fig. 9 – Daily Validation from 2003 to 2008

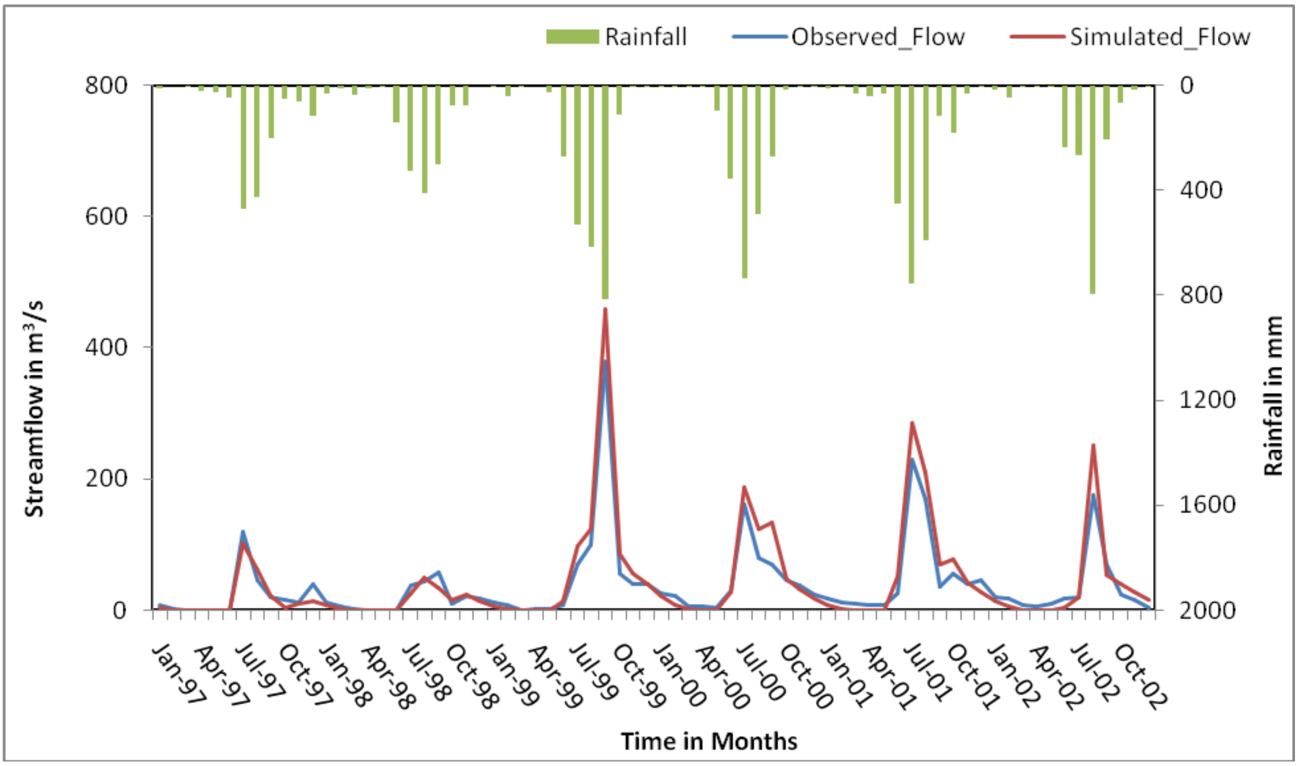

Fig. 10 – Monthly calibration from 1997 to 2002

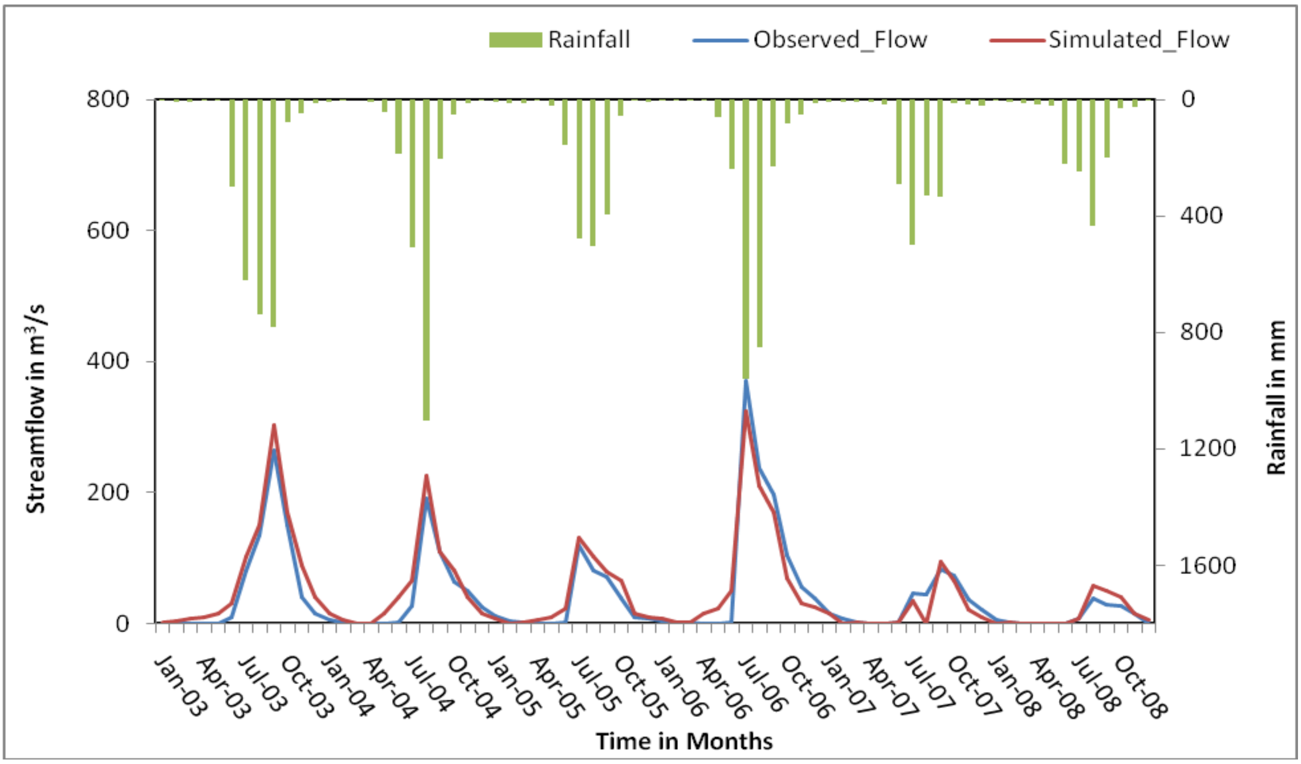

Fig. 11 – Monthly validation from 2003 to 2008

Results obtained for statistical evaluation criteria used for checking model performance are presented in Tables 3 and 4 for daily and monthly periods respectively. As can be seen from these tables the performance of the model could be rated as very good based on performance evaluation criteria mentioned in Table 2.

Table 3: Daily calibration and validation statistical model results

Statistical Parameter	R^2	NSE	RSR
Calibration (1997-2002)	0.724	0.744	0.513
Validation (2003-2008)	0.765	0.78	0.471

Table 4: Monthly calibration and validation statistical model results

Statistical Parameter	R^2	NSE	RSR
Calibration (1997-2002)	0.96	0.87	0.35
Validation (2003-2008)	0.95	0.88	0.34

The total annual observed flow and simulated flow was computed in terms of volume (m^3), so that annual percent error for daily calibration and validation could be defined. In the present study the standard percent value was taken as 25% which can be seen in Figure 12. The percent error for each calibration and validation year was computed. As seen from figure 12 the error bar for the year 2000 and 2001 does not fall within the specified standard range (i.e. 25 %). This may be due to lack of accuracy of the data sets specially the rainfall data in particular where there is direct response with increase of runoff with high rainfall as discussed previously. Figure 13 shows the error bar for validation period and it is found that it is a better result compared to calibration period. As shown in the figure only in the year 2004 that it is not within the specified error range. Therefore, the average percent error for daily calibration and validation were found to be 30.68% and 20.38% respectively. This showed to be a good model. Therefore, SWAT can be an important tool for integrated basin management with respect to water flow and its availability where the significant factor lies with the basin dominated with Agriculture fields. This will bring the potential for irrigation and better agriculture management practices and directly and indirectly helps in improving the socio-economic life of the people.

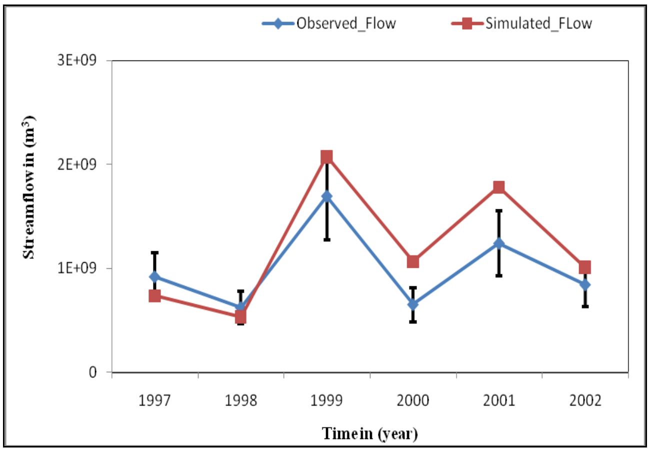

Fig. 12 – Error Bar plot between observed and simulated flows for daily calibration period

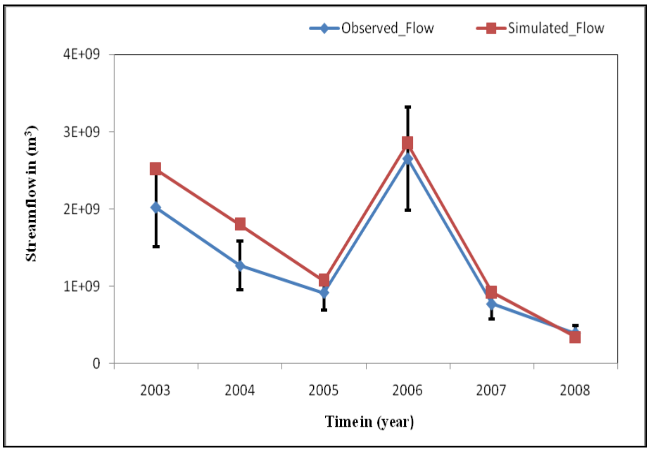

Fig. 13 – Error Bar plot between observed and simulated flows for daily validation period

B. Sensitivity Analysis

A set of parameters were used for the sensitivity analysis in process to determine the major parameters controlling the Hydrological process for streamflow computation represented by SWAT model. These parameters were identified and selected by referring from relevant studies carried (Cao et al. 2006; Khan et al. 2014; Kushwaha et al. 2013; Jain et al. 2014; Manaswi et al. 2014; Singh et al. 2013) and SWAT technical documentation (Neitsch et al. 2002). Parameter sensitivity has been performed by SWAT CUP SUFI-2 software using Global sensitivity analysis. The parameters used in the study area were OV_N.hru, SLSUBBSN.hru, GW_DELAY.gw, CN2.mgt, GWQMN.gw, GW_REVAP.gw, SOL_AWC.sol, EPCO.hru, REVAPMN.gw, ALPHA_BF.gw, SURLAG.bsn, CH_N2.rte and ESCO.hru. Results of sensitivity analysis for most sensitive parameters of the model are listed in Table 5. The results for sensitivity analysis shows that Manning's n for overland flow (OV_N.hru), Average slope length (SLSUBBSN.hru), Groundwater delay (GW_DELAY.gw), SCS runoff curve number (CN2.mgt), Threshold water depth in shallow aquifer required for return to reach occur (GWQMN.gw), Groundwater "revap" coefficient (GW_REVAP.gw) and Available water capacity of the soil layer (SOL_AWC.sol) are the most sensitive parameters of the model.

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Table 5: Most sensitive Parameters with calibrated values

Parameter Name	Minimum Value	Maximum value	Fitted Value
OV_N.hru	0.01	15.11	0.08
SLSUBBSN.hru	35	120	82
GW_DELAY.gw	9	100	62.77
*CN2.mgt	-0.15	0.2	-0.11
GWQMN.gw	100	1000	404.7
GW_REVAP.gw	0.09	0.2	0.16
SOL_AWC.sol	0	0.7	0.13

*CN2.mgt - Relative method is used for model parameter adjustment

VI. CONCLUSIONS

The Sher River is one of the important tributary of the Upper Narmada basin located in the state of Madhya Pradesh. As per the study conducted it is found that most of its area is covered with agricultural land (more than 65%) and possess mild slope and less forested area. In order to meet the maximum and efficient water requirement for proper agricultural practices and productivity, proper planning for sustainable management of water resources can be carried out using Hydrological model like SWAT. The model was calibrated and validated using the daily observed streamflow at Belkheri gauging site for a period of 12 years. The model was auto-calibrated using SUFI2 from 1997 to 2002. The validation for observed and simulated flow was from 2003 to 2008. The average Nash-Sutcliffe Efficiency (NSE) for daily calibration and validation was 0.724 and 0.765 respectively whereas NSE for monthly calibration and validation was 0.87 and 0.88 respectively. The coefficient of determination (R^2) for daily calibration and validation was 0.744 and 0.78 respectively, and 0.96 and 0.95 respectively for monthly basis. Also the average RSR for daily calibration and validation was 0.513 and 0.471 respectively whereas RSR for monthly calibration and validation was 0.35 and 0.34 respectively. The annual average % Error for daily calibration and validation was 30.68% and 20.38% respectively.

The accuracy and precision of the model can be improved drastically with better and high resolution gridded rainfall data or if available observed meteorological data. Therefore, SWAT can be an important tool for integrated basin management with respect to water flow and its availability where the significant factor lies with the basin dominated with Agriculture fields. This will bring the potential for irrigation and better agriculture management practices and directly and indirectly helps in improving the socio-economic life of the people.

REFERRENCES

[1] Abbaspour K C, Johnson C A, Genuchten M T V. 2004. Estimating Uncertain Flow and Transport Parameters Using a Sequential Uncertainty Fitting Procedure. Vadose Zone Journal, pp 1341-1351.
[2] Abraham L Z, Roehrigi J, Alamirew D A. 2007. Calibration and Validation of Hydrologic Model for Meki Watershed, Ethiopia. University of Kassel-Witzenhausen and University of Göttingen.
[3] Cao W, Bowden B W, Davie T. (2006). Multi-variable and multi-site calibration and validation of SWAT in a large mountainous catchment with high spatial variability. Hydrol Process 20:1057–1073.
[4] Diwakar S K, Kaur S, Patel N. 2014. Hydrologic Assessment in a Middle Narmada Basin, India using SWAT Model. International Journal of Engineering Technology and Computer Research (IJETCR), Volume 2 Issue 6; Page No. 10-25.
[5] Haan C T, Storm D E, Al-Issa T, Prabhu S, Sabbagh G J, Edwards D R. 1998. Effect of parameter distributions on uncertainty analysis of hydrologic models. Trans. ASAE 41(1): 65-70.
[6] Jain M, Sharma S D. 2014. Hydrological Modeling of Vamsadhara River Basin, India using SWAT. International Conference on Emerging Trends in Computer and Image Processing (ICETCIP'2014) Dec. 15-16, Pattaya (Thailand).
[7] Khan A D, Ghoraba S, Arnold J G, Luzio M D. 2014. Hydrological Modeling of Upper Indus Basin and Assessment of Deltaic Ecology. IJMER, ISSN: 2249–6645, Vol. 4, Iss. 1.
[8] Kushwaha, Akansha, Jain M K. 2013. Hydrological Simulation in a Forest Dominated Watershed in Himalayan Region using SWAT Model. J. Water Resources Management, Springer, Vol. 27: 3005 – 3023. (DOI: 10.1007/s11269-013-0329-9).
[9] Manaswi C M, Thawait A K. 2010. Application of Soil and Water Assessment Tool for Runoff Modeling of Karam River Basin in Madhya Pradesh. International Journal of Scientific Engineering and Technology (ISSN: 2277-1581) Volume No.3 Issue No.5, pp : 529-532.
[10] Mishra et al. 2007. Evaluation of the SWAT Model for Assessing Sediment Control Structures in a Small Watershed in India. Transactions of the American Society of Agricultural and Biological Engineers (ASABE) 50(2):469-477.
[11] Nash J E, Sutcliffe J V.1970 River flow forecasting through con-ceptual models, Part I – A discussion of principles, J. Hydrol., 10, 282–290.
[12] Neitsch S L, Arnold J G, Kiniry J R, Srinivasan R, William J R. 2002. Soil and Water Assessment Tool User's Manual Version 2000.
[13] Panhalkar S S. 2014. Hydrological modeling using SWAT model and geoinformatic techniques. The Egyptian Journal of Remote Sensing and Space Sciences (2014) 17, 197.
[14] Patil N S, Raikar R V, Manoj S. 2014. Runoff Modeling for Bhima River using Swat Hydrological Model. International Journal of Engineering Research & Technology (IJERT), ISSN: 2278-0181, Vol. 3 Issue 7.
[15] Schultz G A, 1993. Application of GIS and remote sensing in hydrology. IAHS publication, N.211, pp. 127-140.
[16] Schuol J, Abbaspour K C. 2007. Using monthly weather statistics to generate daily data in a SWAT model application to West Africa. Ecol. Model. 201(3-4): 301-311.
[17] Setegn S G, Srinivasan R and Dargahi B. 2008. Hydrological Modeling in the Lake Tana Basin, Ethiopia Using SWAT Model. The Open Hydrology Journal, 2, 49-62.
[18] Singh V, Bankar N, Salunkhe S S, Bera A K, Sharma J R. 2013. Hydrological stream flow modelling on Tungabhadra catchment: parameterization and uncertainty analysis using SWAT CUP. Current Science: vol. 104, No. 9, pp 1187-1199.
[19] Water Resource Information System (WRIS). (2008).