Vol. 47, No. 2, pp 126-133, 2019
Indian Journal of Soil Conservation
Online URL : http://indianjournals.com/ijor.aspx?target=ijor:ijsc&type=home

Rainfall – runoff modelling using SWAT for Ong river basin

Souranshu Prasad Sahoo[1,*], Anupam Kumar Nema[1] and Prabhash Kumar Mishra[2]

[1]*Department of Farm Engineering, Institute of Agricultural Sciences, BHU, Varanasi, Uttar Pradesh;* [2]*Water Resources Systems Division, National Institute of Hydrology, Roorkee, Uttarakhand.*

**Corresponding author:*
E-mail: souranshu.sahoo@bhu.ac.in (Souranshu Prasad Sahoo)

ARTICLE INFO

Article history:
Received : November, 2018
Revised : August, 2019
Accepted : August, 2019

Key words:
SWAT
SWAT-CUP
Rainfall-runoff modeling
Sensitivity analysis
Uncertainty analysis

ABSTRACT

The Ong basin, covering major portions of western Odisha in India, has been repeatedly facing threats of hydro-meteorological calamities such as floods, droughts and cyclones in the recent times. In order to understand the different hydrological processes occurring in Ong basin, which covers about 5,128 km^2area with a very diverse hydrological variability, hydrological analysis of the basin has been carried out utilizing Soil and Water Assessment Tool (SWAT). Digital Elevation Model (DEM), soil map, land use (LU) / land cover (LC) map, climatic data, streamflow data etc. have been used. A total of 52 hydrologic response units (HRUs) were created in the 11 sub-basins by applying 5% threshold value of both land use and slope and 10% in soil classes. The calibration process was carried out using SWAT-Calibration and Uncertainty Procedures (SWAT-CUP) tool with SUFI-2 algorithm. Observed monthly stream-flow data at Salebhata (only existing G&D site) of the Ong basin for a period of 16 years (1983 to 1998) were given as input through auto calibration tool which gives Nash-Sutcliffe Efficiency (NSE) of 0.81, R^2 value 0.856, PBIAS of 16.55%, RSR value of 0.43. The validation was also carried out by using the monthly stream-flow data of 13 years (1999 to 2011) which gives NSE of 0.85, R^2 value 0.859, PBIAS of 10.07%, RSR value of 0.39 indicating a decent model performance. Sensitivity analysis was also performed using LH-OAT technique, and out of 10 calibrated parameters 3 parameters *viz.,* effective hydraulic conductivity in main channel alluvium, initial SCS runoff curve number II, and available water capacity factor were found to be highly sensitive. A close observation of these sensitive parameters revealed that the flow characteristics of this area were affected by both surface water and groundwater flow properties. In uncertainty analysis, the P-factor was 0.36 and R-factor was 0.27 for calibration and validation, so calibration and validation can be considered satisfactory for this study.

1. INTRODUCTION

Water, the basic need of survival and essential for life, is at most threatened position today. Availability of water in the world is an emerging issue for sustainable development. In view of the large-scale water scarcity likely to be prevalent in future, watershed approach of water resources management is need of the hour. Watershed is defined technically as a natural integrator of all hydrologic processes within its boundaries, and therefore, a well-accepted unit for scientific management of soil and water. In India, watershed is considered as the ideal unit for micro-level planning. For a development programme, to conserve water by developing watershed, water balance study is very essential because in water resources projects planning, development and operation depends on water availability in terms of both quantity and quality.

The water balance in a watershed states that in a specified period of time, all water entering a basin must be consumed or stored, or it must flow out as surface or subsurface water. Water balance is necessary to appreciate the role of various management strategies in minimizing the losses and maximizing the utilization of water, which is the most limiting factor of crop production in watershed areas. With the interaction of precipitation, land use (LU) / land cover (LC) and soil type, runoff is produced as the end product of the watershed. Hence hydrological modelling of runoff is done to estimate runoff, sediment yield, soil erosion for the sustainable development (Jain *et al.,* 2010). Several hydrological models have been developed and applied in the simulation in several basins and varied purposes, such as SWAT (Green and Van Griensven, 2008), SMAP (Saraiva *et al.,* 2011), LASH (Beskow *et al.,* 2011), and AGNPS (Yuan *et al.,* 2011). Among the hydrological models, the conceptually distributed one should be emphasized that simulates various processes that make up hydrological cycle based on empirical functions and input parameters in spatialized form, which is possible through model and Geographic Information System (GIS) integration. However, hydrological models do not accurately represent water movement in a natural system which is why they should be calibrated with observed data (Andrade *et al.,* 2013).

The current modeling philosophy requires that models are transparently described; and that calibration, validation, sensitivity and uncertainty analysis are routinely performed as part of modeling work. As calibration is "conditional" (*i.e.,* conditioned on the model structure, model inputs, analyst's assumptions, calibration algorithm, calibration data, etc.) and not uniquely determined, uncertainty analysis is essential to evaluate the strength of a calibrated model. The SWAT model (Arnold *et al.,* 1998) has demonstrated its strengths in the aspects specified above. It is an open source code with a large and growing number of model applications in various studies ranging from catchment to continental scales.

In view of the importance of quantifying the water balance components for better planning of water resources, hydrological modelling approach utilizing SWAT has been carried out for the Ong river, a tributary to the Mahanadi, Odisha. The Ong basin has been considered because of several reasons. The study area experiences tropical wet and dry climate. The study area also witnessed decreased stream flow simulated during winter months (December-February) and high water demand during summer (May-June). Sometimes, increased flow during monsoon could lead to more flooding and water logging in rainy season, and the rest months of the year are generally dry because it does not receive any precipitation from north-east monsoon, which is the main reason of drought occurrences in this region. So, with several uncertainties of water availability in future, the overall objectives envisaged in the study are to assess the different water balance components of the Ong river basin situated in Western Odisha.

2. MATERIALS AND METHODS

Study Area

Ong basin comprising of Ong river, a tributary of Mahanadi River, situated in the western part of Odisha and some part of eastern Chhattisgarh, India was selected for the study. It covers an area of 5,128 km^2 and lies between 20^{0}40'14.5"N to 21^{0}28' 35.8"N latitude and 82^{0}33'27.5" E to 83^{0}34'05.3"E longitude. The Ong river emerges from Gandhamardan Range in Nuapada district, Odisha and merges to Mahanadi River 11 km upstream of Sonepur city. The river emerges at an elevation of 457 m and runs 204 km before it meets Mahanadi. Ong basin covers parts of Nuapada, Bargarh, Bolangir, Sonepur districts of Odisha and parts of Mahasamund district of Chhattisgarh. The population of Ong basin was around 12.4 lakh (as per the 2011 census), of which the rural population was around 9.2 lakh and urban population was around 3.2 lakh. Major occupation and livelihood in this region is farming and agriculture labour. More than 60% of the population depends on agriculture, directly and indirectly, in this region. Location map of Ong river basin is shown in Fig. 1.

The study area experiences tropical wet and dry climate. The wet season (June–September) is much shorter

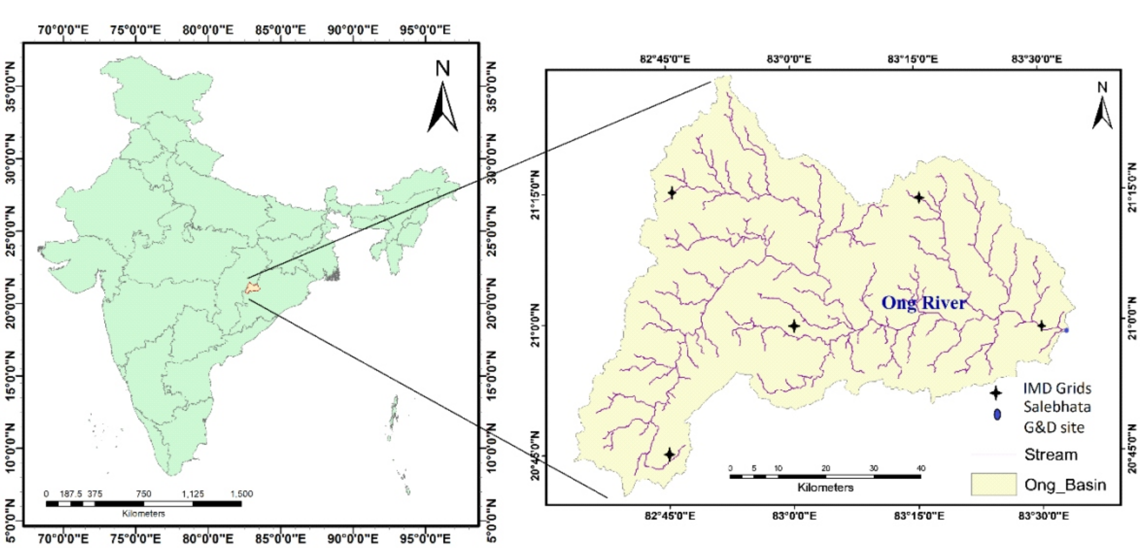

Fig. 1. Location map of Ong river basin

and receives low precipitation from the south-west monsoon. Sometimes, increased flow during monsoon leads to flood and water log situation in rainy season, and the rest of the months of the year are generally dry because it does not receive any precipitation from north-east monsoon, which is the main reason of frequent droughts in this region. The average maximum temperature of around 39˚C is observed in the month of May, whereas the average minimum temperature of around 13˚C is occurs during the month of December. The average annual rainfall is around 1150 mm in the basin, which mainly occurs due to south-west monsoon that spans from June to September, leaving the non-monsoon months almost dry. There is a single G&D site at Salebhata few kilometers up from the confluence at Mahanadi. The soils in the Ong basin can be broadly classified into clayey and loamy soil. Major part of the LU in Ong basin is covered by agriculture, pasture land and forest area. The major crops grown in the area are rice, wheat, maize, gram, linseed, cotton, sugarcane and groundnut.

SWAT Model

Arc-SWAT, which is embodied in Arc-GIS, is a graphical user interface for SWAT model (Arnold *et al.,* 1998). It is a river basin or watershed scale model developed by United States Department of Agriculture - Agriculture Research Services (USDA-ARS) and Agriculture Experiment Station in Temple, Texas (USA). The model can be applied in various watersheds and water quality modelling for current and project management condition, impact assessment of global climate, simulation of land management practices, sediment contamination, poultry waste analization, evaluation of pesticide registration (Winchell *et al.,* 2010). The actual aim of developing this model is to predict the impact of land management practices on water, sediment and agriculture chemical yields in large complex watershed with varying soil, land use and management conditions over a long period of time (Shivhare *et al.,* 2014). SWAT is a deterministic continuous daily time-step model which is used to evaluate land-management practices in large un-gauged rural basins. According to Shivhare *et al.* (2014), it is a hydrodynamic, physical based, continuous time model long term simulation for complex and large basins which originated from an agricultural model.

Model processes include calculations of water balance that is the driving force behind everything that happens in a basin for accurately predicting the runoff, sediment or nutrient movement. Land phase and routing phase are the components of the model processing. Land phase controls the amount of runoff and sediment which flows to the main channel of the basin, so that the control measures can be applied to conserve both soil and water. The routing phase controls the movement of runoff, sediments through the channel network of the basin to the outlet. Flow is routed through the channel using the variable storage routing method or the Muskingum method. In the variable storage routing method, storage routing is based on the continuity equation for a given reach segment.

SWAT uses hourly and daily time steps to calculate surface runoff. The Green and Ampt equation is used for hourly, and an empirical SCS curve number (CN) method is used for the daily computation. For this estimation of runoff, the basin is delineated into sub-basins which are then further subdivided into hydrologic response units (HRUs). Here, SCS curve number method was adopted for the estimation of surface runoff.

SWAT requires daily values of precipitation, maximum and minimum temperatures, solar-radiation, relative humidity and wind speed as input. They can be given to the model as a user defined measured time series or can be generated within SWAT from a monthly data and its statistics summarized over a number of years.

SWAT-CUP

Automated model calibration requires that the uncertain model parameters are systematically changed, then 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. To perform calibration and uncertainty analysis for SWAT, the software package SWAT-CUP has been developed (Abbaspour *et al.,* 2007).

In SUFI-2, parameter uncertainty accounts for all sources of uncertainties, such as uncertainty in driving variables (e.g. rainfall), conceptual model, parameters, and measured data. The degree to which all uncertainties are accounted for is quantified by a measure referred to as the P-factor, which is the percentage of measured data bracketed by the 95% prediction uncertainty (95 PPU). Another measure quantifying the strength of a calibration / uncertainty analysis is the R-factor, which is the average thickness of the 95 PPU band divided by the standard deviation of the measured data. SUFI-2, hence, seeks to bracket most of the measured data with the smallest possible uncertainty band.

Database Creation

DEM provides a terrain model to facilitate drainage network analysis, watershed demarcation, erosion mapping, contour generation and quantitative analysis like volume-area calculation. Cartosat DEM with spatial resolution 24 m downloaded from NRSC Bhuvan website has been used in the present study. LU/LC map was prepared using remote sensing data of LISS-III downloaded from NRSC Bhuvan website. The supervised classification method was used for preparation of the LU/LC map. The study area was classified into six classes *viz.,* 1) Settlement,

2) Sparse forest, 3) Water body, 4) Dense forest, 5) Agriculture land, and 6) Pasture land in WGS_1984_UTM_Zone_44N projection. For the study, soil data were obtained from the Food and Agriculture Organization (FAO) of the United Nations. Daily observed data for precipitation (mm), minimum temperature (°C) and maximum temperature (°C), wind speed (m s^{-1}), solar radiation (Mj m^{-2}) and relative humidity (fraction) were collected from meteorological observatory of Nuapada, Bargarh, Bolangir, Sonepur, Mahasamund district headquarters. Five weather stations were chosen based on the availability of 32-year datasets, from 1980 to 2011. Daily runoff data from 1980-2011 were collected from Water Resources Information System (India-WRIS), Central Water Commission, Government of India for the surface flow gauging station Salebhata, Odisha, which is the outlet of Ong river basin. Runoff data from 1983 to 1998 were used for calibration, and from 1999 to 2011were used for validation purpose.

Model Input

The elevation of the DEM varies from 56 m to 943 m from above mean sea level. This shows that the topography of the study area is moderately undulating. The DEM of study area is shown in Fig. 2. After LU/LC classification, it was found that agriculture area was dominating with a coverage of 2 lakh ha of the total basin area followed by pasture land / barren land, which covers 1.2 lakh ha area. The LU/LC distribution for the Ong river basin is presented in Table 1. LU map for the Ong basin is shown in Fig. 3.

As per the FAO soil database, three distinct soil classes have been found in the study area, *viz.,* clay-loam, sandy-loam and clay. The soil map is shown in Fig. 4.The SWAT generated drainage map considering Salebhata as the outlet is shown in Fig. 5.

SWAT Model Setup

In SWAT model, a basin is divided into a number of

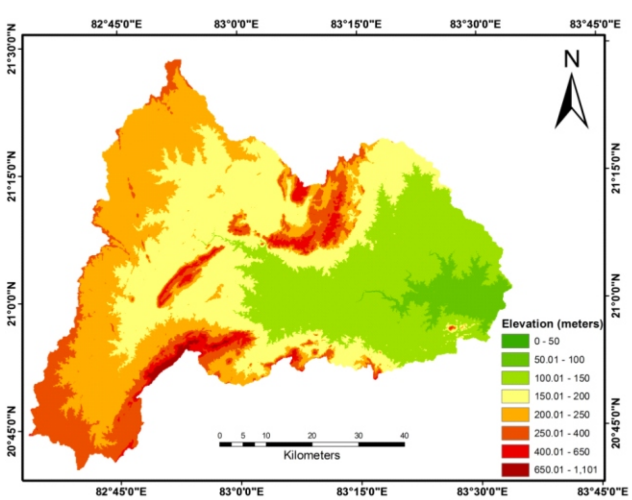

Fig. 2. DEM of the Ong basin

Table: 1
Land use distribution in Ong basin

Land use classes	Area (ha)	Percentage Area (%)
Settlement (URBN)	10693.41	2.32
Sparse Forest (RNGB)	62119.07	13.47
Water Body (WATR)	5906.63	1.28
Dense Forest (FRST)	61912.01	13.43
Agriculture Land (AGRL)	200104.66	43.40
Pasture Land (PAST)	120347.31	26.10

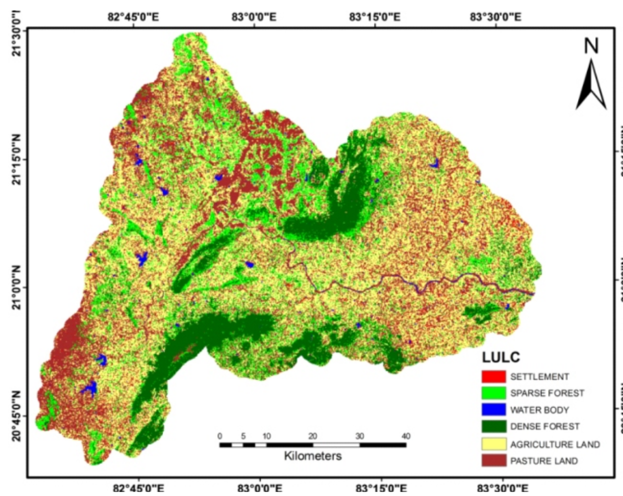

Fig. 3. Land use map of the Ong basin

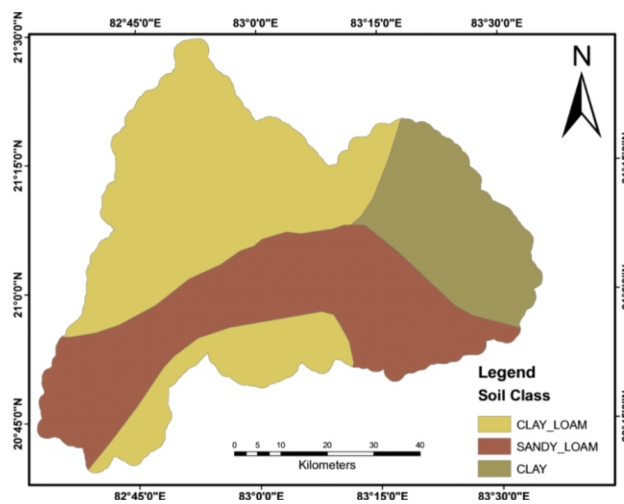

Fig. 4. Soil map of the Ong basin

sub-basins. Each sub-basin contains at least one HRU, a tributary channel and a main channel or reach. Sub-basin possess a geographical position and are spatially inter-connected; flow from one sub-basin enters another. The sub-basins are partitioned into HRUs, which are lumped land areas that are comprised of unique land cover and soil combinations. The partition of sub-basin into HRUs increases accuracy and gives a much better physical description of the water balance (Geza and McCray, 2008). Contrary to flow among sub-basin, there is no interaction between the HRUs. Runoff is predicted separately for each HRU.

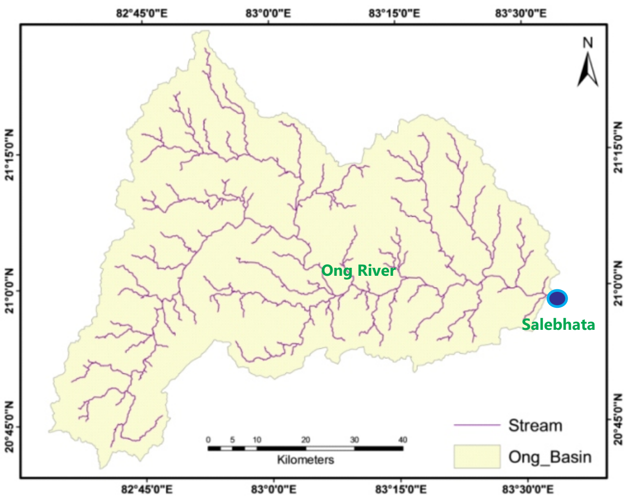

Fig. 5. Drainage map of the Ong basin

Watershed delineation is the first step for development of SWAT model. For delineation of Ong basin, DEM was provided, and digitized stream was burnt in the automatic watershed delineation tab. To define the watershed boundary, the main outlet was selected and after that watershed delineation was processed, which resulted into a number of sub-basins of Ong basin. After the delineation of watershed, HRUs analysis is the next step to form identical areas of similar land-use type and soils located at different locations within a sub-basin. For defining the HRUs, basically three inputs - LU/LC map, soil map and slope classification were required. Previously, prepared land use and soil layers were added to the map and were reclassified as per the user defined classes. Information about slope was obtained from the initial DEM layer. Four slope classes were defined for the reclassification purpose. After providing the three inputs separately, they were combined using the overlay option in Arc SWAT tool to generate HRUs for the study site. The HRUs' thresholds were defined individually for three different input classes *i.e.* 5% for land use, 10% for soil and 5% for slope. Weather data were provided as inputs to the model in the write input tables command in SWAT. WGEN USER was selected as the custom weather database. Six weather parameters, namely, precipitation, minimum and maximum temperature, solar radiation, wind speed and relative humidity of five weather stations were provided as input on daily basis.

During the process of simulation by SWAT, a total of 52 HRUs were created in the 11 sub-basins by applying 5% threshold value of both land use and slope and 10% for soil classes. The SWAT generated sub-basin map of the Ong basin is shown in Fig. 6.

Model Calibration

Calibration is an important step in developing any hydrologic model as it provides representation of accurate and realistic physical processes occurring inside the basin.

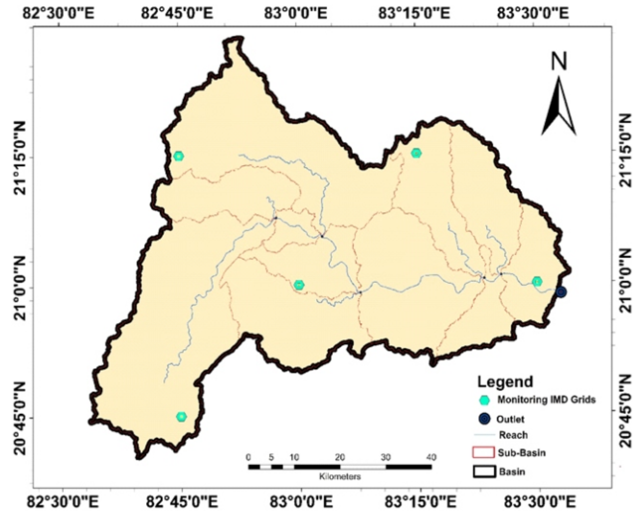

Fig. 6. Sub-basin map of the Ong basin

A set of parameters that are more influencing on runoff process were set for performing the calibration process like management parameters, groundwater parameters, soil parameters, main channel parameters etc. and were given as inputs in SWAT-CUP for the calibration. These calibrated parameters set aims at minimizing the difference between simulated and observed stream flows. In this study, a calibration period of sixteen years was considered, from 1983-1998 excluding three years of warm up period *i.e.* 1980 to 1982. In total, 10 parameters *i.e.* management parameters like curve number (CN2), groundwater parameters like base flow alpha factor (ALPHA _BF), groundwater delay time (GW_DELAY), threshold depth of water in the shallow aquifer for "revap" or occurrence of percolation to deep aquifer (REVAPMN), groundwater "revap" coefficient (GW_REVAP) and deep aquifer percolation fraction (RCHRG_DP), soil parameters like available water capacity (SOL_AWC) and saturated hydraulic conductivity (SOL_K), main channel parameters like effective hydraulic conductivity in main channel alluvial (CH_K(2), and HRU general parameters like soil evaporation compensation factor (ESCO) were used for performing the calibration process. Observed runoff data of outlet station located at Salebhata were used as inputs.

SWAT Model Performance Evaluation

The monthly time-series (1983 to 1998) plots of measured and simulated data were evaluated by using four statistical indicators like Nash-Sutcliffe Efficiency (NSE), root mean square and standard deviation ratio (RSR), percent bias (PBIAS), coefficient of determination (R^2).

Model Validation

Model validation was performed, after the model calibration, considering the observed data at Salebhata G&D site. In this process, all the input parameter ranges used for calibration remain unchanged. Evaluation has been performed in a similar way as in model calibration process, *i.e.* visual comparison of hydrographs, statistical index of NSE and with the analysis of residuals. For the present study, a validation period of thirteen years was considered *i.e.* from 1999-2011.Validation process is carried out in SWAT-CUP SUFI-2 by using the fitted value of calibrated parameters to make one complete iteration (using the calibration button) without changing the parameters further.

3. RESULTS AND DISCUSSION

Water Balance of Ong Basin Generated by SWAT

SWAT Check is a screening tool to assist users in the identification of potential model application problems, which also provided component wise water balance of Ong basin as listed in Table 2. SWAT Check was applied and it produced no warnings for several aspects of the model, including common errors related to hydrology, and common simulation errors related to application options.

Table: 2
Water balance of Ong basin

S.No.	Component of hydrological cycle	Quantity
1	Average annual Pprecipitation (mm)	1273.1
2	Evaporation and transpiration (mm)	590.1
3	Surface runoff (mm)	405.04
4	Lateral flow (mm)	9.3
5	Return flow (mm)	249.23
6	Percolation to shallow aquifer (mm)	274.68
7	Revap from shallow aquifer (mm)	11.72
8	Recharge to deep aquifer (mm)	13.73
9	Average curve number	80.8

Model Setup and Sensitivity Analysis

The calibration ranges and fitted values of calibrated parameters are listed in the Table 3.

Initial SCS runoff curve number II (CN2) value in the model calibration was found to be -0.04, which shows the soil has medium permeability, land cover by vegetation is more than 60%, and antecedent soil moisture remains less because of good drainable soil. As lower runoff potential is usually found where more permeable soils exist, this Initial SCS runoff CN2 value indicates surface runoff is less dominant in the Ong basin. Ground water delay (GW_DELAY) value in the model calibration was found to be around 61 days, which shows quick groundwater recharge. This results into lesser surface flow as well as lesser runoff at the outlet. The outcome of the calibration of base flow alpha factor (ALPHA_BF) parameter was found to be 0.69, which indicates study area is dominated by land with a quick response to ground water recharge.

Sensitivity analysis was carried out for the period of calibration with the objective of number of parameters and their properties as input for modelling. Global sensitivity analysis was performed using LH-OAT technique which highlighted the sensitive parameters for the runoff generation process inside Ong river basin as given in Table 4 among 10 parameters, those were considered for the calibration process.

These ranks were obtained according to the objective function: the P-value of calibration between observed and simulated values. It is clearly evident that the stream flow is affected by both groundwater and management parameters of the study area. This reveals that the study area has a very diverse hydrological variability. Effective hydraulic conductivity in main channel alluvium (CH_K2), Initial SCS runoff CN2 and available water capacity of the soil layer (SOL_AWC) had very high sensitivity value showing that the stream flow of this area is mainly governed by main channel, management and soil characteristics.

Uncertainty Analysis

The P-factor and R-factor for calibration were found to be 0.36 and 0.27, respectively. As P-factor is lying between 0-1 and R-factor is close to 0, so calibration can be considered satisfactory for this study. In validation, the value of P-factor was also 0.36 and of R-factor was 0.27.

Table: 3
Calibration range and fitted value of different parameters

Parameter Name	Bound		Auto-calibration result	
	Lower	Upper	Fitting value	Method
Initial SCS runoff curve number II (R__CN2.mgt)	-0.08	-0.02	-0.04	Relative
Base flow alpha factor (V__ALPHA_BF.gw)	0.67	0.76	0.69	Replace
Groundwater delay time (V__GW_DELAY.gw)	60	130	61.19	Replace
Groundwater "revap" coefficient (V__GW_REVAP.gw)	0.20	0.258	0.23	Replace
Soil evaporation compensation factor for basin (R__ESCO.hru)	0.882	0.895	0.892	Relative
Available water capacity factor (R__SOL_AWC.sol)	0.38	0.54	0.44	Relative
Saturated hydraulic conductivity (R__SOL_K().sol)	-1.0	-0.30	-0.87	Relative
Effective hydraulic conductivity in main channel alluvium (R__CH_K2.rte)	166.0	268.0	267.90	Relative
Threshold depth of water in the shallow aquifer for "revap" to occur (mm) (V__REVAPMN.gw)	300.46	690.0	414.60	Replace
Deep aquifer percolation fraction (V__RCHRG_DP.gw)	0.470	0.660	0.505	Replace

Table: 4
Sensitivity analysis results of calibrated parameters

Parameter Name	Parameter Name in SWATCUP	P-value	Sensitivity rank
Effective hydraulic conductivity in main channel alluvium	v__CH_K2.rte	0.00	1
Initial SCS runoff curve number II	r__CN2.mgt	0.00	2
Available water capacity factor	r__SOL_AWC(..).sol	0.00	3
Groundwater delay time	v__GW_DELAY.gw	0.03	4
Base flow alpha factor	v__ALPHA_BF.gw	0.10	5
Groundwater "revap" coefficient	v__GW_REVAP.gw	0.21	6
Saturated hydraulic conductivity	r__SOL_K(..).sol	0.34	7
Deep aquifer percolation fraction	v__RCHRG_DP.gw	0.39	8
Threshold depth of water in the shallow aquifer for "revap" to occur (mm).	v__REVAPMN.gw	0.51	9
Soil evaporation compensation factor for basin	v__ESCO.hru	0.52	10

Calibration and Validation

Observed data for the period 1980-1998 (19 years) was considered for the calibration process, whereas a period of thirteen years was considered for validation purpose, from 1999 to 2011. The scatter plot between observed and simulated values of discharge during calibration period and validation period are shown in Fig. 7 and Fig. 8, respectively. The model performance is satisfactory with a high correlation coefficient of 0.858 and 0.859 for model calibration and model validation, respectively. The model performance statistics during calibration and validation on the observed and estimated discharge has been given in Table 5.

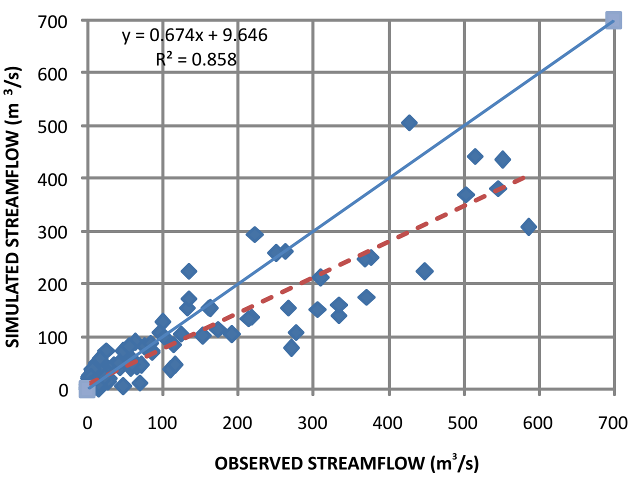

Fig. 7. Scatter plots of monthly observed and simulated stream flow during calibration (1980-1998) for Salebhata station

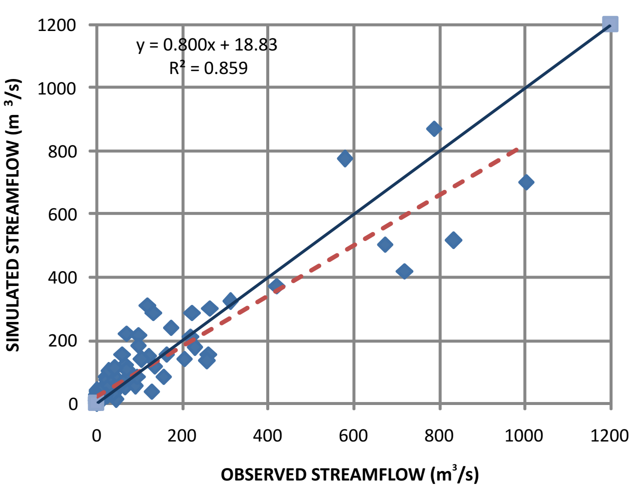

Fig. 8. Scatter plots of monthly observed and simulated stream flow during validation (1999-2011) for Salebhata station

Graphical representation of comparison between monthly observed and simulated stream flow during calibration (1980-1998) and validation (1999-2011) were carried out. Fig. 9 shows the graphical representation of calibration and validation.

As shown in Fig. 9, the simulated stream flow is matching the observed stream flow with some exceptions. Throughout the analysis, the model predicted the stream flow with very good accuracy. But later on, it was observed that during the months of July, and August in the years 2001 and 2009, the model over estimated the monthly flow as there is a sudden increase in the value of stream flow. This is due to the fact that a very high magnitude of one day or two days rainfall occurred in the upstream area of the basin

Table: 5
Calibration and Validation results at Salebhata

	R^2	NSE	PBIAS	RSR
Calibration (1980-1998)	0.858	0.81	16.55	0.43
Validation (1999-2011)	0.859	0.85	-10.07	0.39

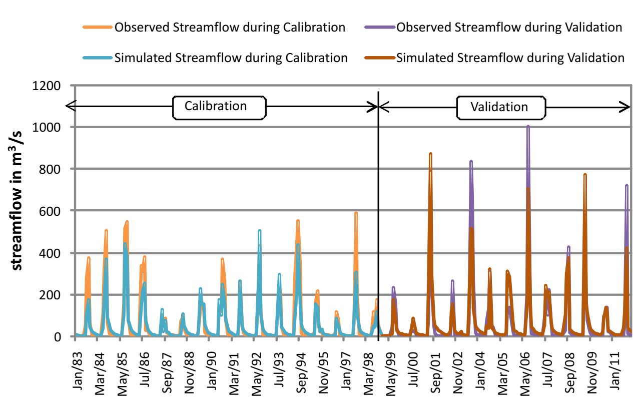

Fig. 9. Comparison between observed and simulated stream flow during calibration (1983-1998) and validation (1999-2011) for Salebhata station

during those periods. In rest of the period, the model estimated the observed stream flow in good accuracy. As the variability of stream flow, and the model's prediction of outflow trend are similar in calibration and validation period, it can be concluded that rainy season is predominant in Ong river basin, particularly in the month of July and August, and some times in the months of September and October. Often, cyclonic storms in the months of October and November result in significant stream flow in the region.

4. CONCLUSIONS

During the process of simulation by SWAT a total of 52 HRUs were created in the 11 sub-basins by applying 5% threshold value of both land use and slope and 10% in soil classes. Observed stream-flow data at Salebhata (only existing G&D site) of the Ong basin for a period of 19 years (1980 to 1998) were given as input through auto calibration tool which gave model performance evaluation outcome of NSE of 0.81, R^2 value 0.856, PBIAS of 16.55%, and RSR value of 0.43.The validation was also carried out by using data of 13 years (1999 to 2011) which gave NSE of 0.85, R^2 value 0.859, PBIAS of 10.07%, and RSR value of 0.39, indicating a very good model performance. Sensitivity analysis was also performed using LH-OAT technique, and out of 10 calibrated parameters 3 parameters, *viz.,* effective hydraulic conductivity in main channel alluvium, Initial SCS runoff CN2 and available water capacity factor were found to be highly sensitive. A close observation of these sensitive parameters revealed that the flow characteristics of this area were affected by both surface water and groundwater flow properties. In uncertainty analysis, the P-factor was 0.36 and R-factor was 0.27 for calibration, and same P-factor was 0.36 with 0.27 value of R-factor for validation. As P-factor is lying between 0-1 and R-factor is close to 0, so calibration and validation can be considered satisfactory for this study. This indicated a very good performance of the model at monthly time scale in the data scare region. Therefore, the SWAT model should be used to simulate monthly stream-flow and for identifying hydrological controlling factors / parameters in such an ungauged basin like the Ong basin due to data scarcity and uncertainty.

REFERENCES

Abbaspour, K.C., Yang, J., Maximov, I., Siber, R., Bogner, K., Mieleitner, J. and Srinivasan, R. 2007. Modelling hydrology and water quality in the pre-alpine/alpine Thur watershed using SWAT. *J. Hydrol.,* 333(2): 413-430.

Andrade, M.A., Mello, C.D. and Beskow, S. 2013. Simulaçãohidrológicaemumabaciahidrográficarepresentativa dos Latossolosnaregião Alto Rio Grande, MG. *RevistaBrasileira de EngenhariaAgrícolae Ambiental,* 17(1): 69-76.

Arnold, J.G., Srinivasan, R., Muttiah, R.S. and Williams, J.R. 1998. Large area hydrologic modeling and assessment part I: Model development. *J. Am. Water Resour. Assoc.,* 34(1): 73-89.

Beskow, S., Mello, C.R., Norton, L.D. and Da Silva, A.M. 2011. Performance of a distributed semi-conceptual hydrological model under tropical watershed conditions. *Catena*, 86(3): 160-171.

Geza, M. and McCray, J.E. 2008. Effects of soil data resolution on SWAT model stream flow and water quality predictions. *J. Environ. Manage.,* 88(3): 393-406.

Green, C.H. and Van Griensven, A. 2008. Autocalibration in hydrologic modeling: Using SWAT2005 in small-scale watersheds. *Environ. Model. Softw.,* 23(4): 422-434.

Jain, S.K., Tyagi, J. and Singh, V. 2010. Simulation of runoff and sediment yield for a Himalayan watershed using SWAT model. *J. Water Resour. Protec.,* 2: 267-281.

Saraiva, I., Fernandes, W. and Naghettini, M. 2011. Simulação Hidrológica Mensal em Bacias Hidrográficas sem Monitoramento Fluviométrico. *Ravista Brasileira de Recursos Hídricos,* 16(1): 115-125.

Shivhare, V., Goel, M.K. and Singh, C.K. 2014. Simulation of surface runoff for upper tapi sub catchment area (Burhanpur Watershed) using SWAT. *Int. Arch. Photogram. Remote Sens. Spatial Inform. Sci.*, 40(8): 391-397.

Winchell, M., Srinivasan, R., Luzio, M.D. and Arnold, J.G. 2010. ArcSWAT interface for SWAT 2009, User's Guide.

Yuan, Y., Binger, R.L., Locke, M.A., Theurer, F.D. and Stafford, J. 2011. Assessment of subsurface drainage management practices to reduces nitrogen loadings using Ann AGNPS. *Appl. Eng. Agric.,* 27(3): 335-344.