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RAINFALL RUNOFF MODELLING OF UPPER TUNGA BASIN WITH THE INTEGRATION OF ARC-GIS AND SWAT

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Abstract— Runoff is a very important component of hydrological cycle. An effective management of land and water can only be achieved through complete understanding of their characteristics. This study involves hydrological modelling of Tunga sub –watershed by using Soil and Water Assessment Tool (SWAT) model, which is integrated with Arc-GIS software. SWAT requires various input data such as land cover/land use data, weather data etc. the model authentication will be verified by calibrating and validating with the field-measured discharged data of watershed. The various parameters like Elevation Model (DEM), slope derived from DEM, Land use /land cover (LU/LC) soil data and temporal data for temperature and precipitation was used as input for the model to predict runoff at the catchment. The output was used to estimate the flow and its variation over the basin. SWAT stimulation is done for daily, monthly, and yearly basis to find out runoff for corresponding runoff. The performance of the model will be checked by parameters like R^2 and NSE coefficients for both calibration and validation. The outcome of this study will show the effectiveness of the model for simulating the flows in a particular watershed.

KEYWORDS— Arc-GIS, Watershed, SWAT, Digital Elevation model (DEM), LU/LC.

I. INTRODUCTION

Water is one of the vital invaluable resources which is existing since the inception of mother earth. All plants and animals must have water to survive, if there was no water there would be no life on earth. The endless circulation of water from the atmosphere to the earth and its return to the atmosphere through condensation, precipitation, evaporation and transpiration is called a watershed. Even though the earth is surrounded by 71% of water, the freshwater accounts for very less, i.e., 2.5% and only less than 1% of it is very easily accessible. Surface water is one of the major sources of water in developing country like India. Due to the emergence of new industries, population growth, urbanisation, etc., the usage of water has been in a high scale resulting water shortage for the upcoming generations. This calls for the effective management of the surface water immediately.

Estimation of surface runoff is tedious and time consuming even though all the data are sufficiently present. This appeal for an easier way of estimating runoff without much effort. Many research scholars, scientists have developed various watershed models in the past which resulted in overcoming the difficulty faced in estimating runoff. The combination of GIS and watershed model such as SWAT proves to be the ideal way for estimating surface runoff in many situations.

In the present study an attempt has been made to model the upper Tunga basin to predict the surface runoff values at the outlet of the watershed using distributed hydrological model SWAT which was developed by the United States Department of Agriculture (USDA). The main objectives of the study are listed as below:

1. To set up a hydrological model using ARC-SWAT for discharge calculations.
2. Calibration of the SWAT model with the observed data.
3. Validation of the SWAT model to check its reliability in estimating discharges.

II. STUDY AREA

The study area chosen for this study is upper Tunga watershed. The Tunga river is the tributary of Krishna river which takes its birth on Western Ghats of Karnataka on a hill known as Varaha Parvatha at a place called Gangamoola. The river flows through the cities of Chikmagalur and Shivamogga districts and it joins the Bhadra River at a place called kudli, a small town which is situated in Shivamogga to form Tungabhadra. The river has an overall length of 147 km from its origin. Later on it joins the Krishna River and flows through Andhra Pradesh before reaching the Bay of Bengal. The Tunga River is famous for its sweetness and a da is built across this river which is situated at Shivamogga known as Gajanur dam.

In the present case. the upper Tunga is delineated from the starting point of Tunga river i.e., Gangamoola till the Gajanur dam to determine the rainfall – runoff characteristics using SWAT model with the help of Arc-GIS.

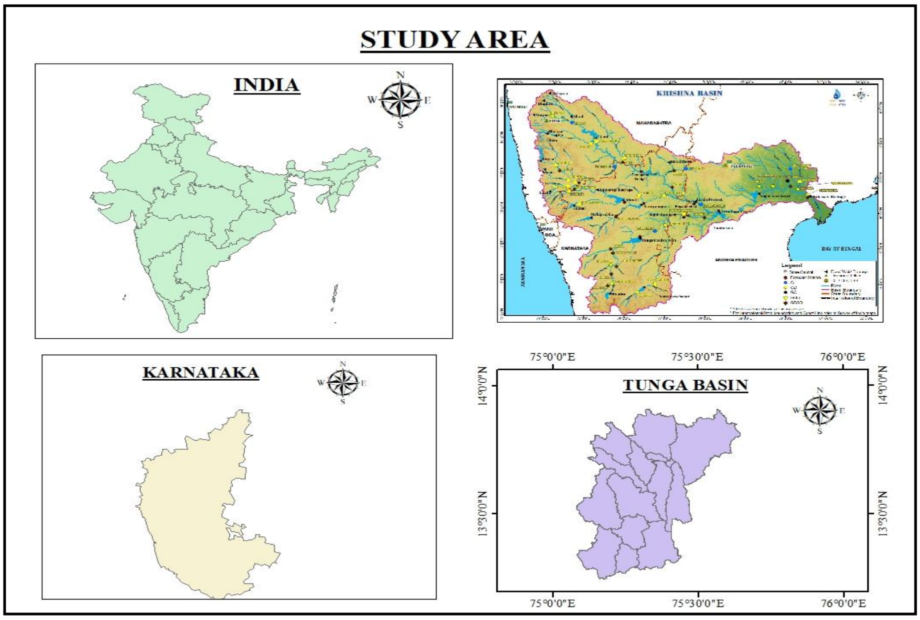

Fig. 1 Location of the Selected Study Area

III. METHODOLOGY

This paper aims in estimating the surface runoff values of the selected basin using the hydrological semi-distributed SWAT model in the Arc-GIS interface which requires various input data in arriving the final results. The Surface Runoff in SWAT model is estimated by SCS curve number (SCS 1972) method. The SWAT model discharge results may be of daily, monthly and yearly basis depending on the data provided by the user. The various steps involved in estimating the surface runoff is depicted in the below flow chart.

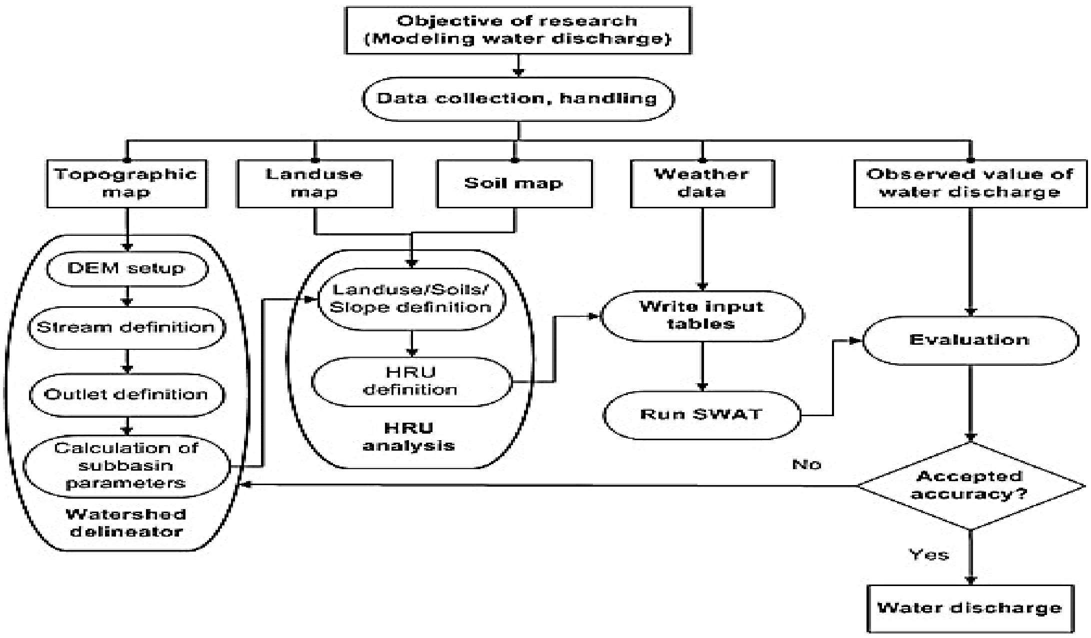

Fig. 1: Work flow process for SWAT (Source: Loi, 2012)

The SCS curve number used in estimating runoff is given by-

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

Where,

Q_{surf} = accumulated runoff or rainfall excess (mm of H20),

R_{day} = rainfall depth for the day (mm of H20),

I_a = initial abstractions which includes surface storage, interception and infiltration

S = retention parameter (mm of H20).

The retention parameter is defined as,

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

Where,

CN = Curve number for the day,

I_a = commonly approximated as 0.2*S.

Source: SWAT Theoretical Documentation, 2011.

The first step in estimating the surface runoff is setting up of the SWAT model. The upper Tunga basin is delineated with the DEM data downloaded from the CARTOSAT 3R1 satellite of 32m spatial resolution and is as shown in fig 2. SWAT helps in delineating the basin as per the outlet provided by the user automatically. Here in this study, the outlet is chosen as the discharge point of the Gajanur dam. Soil data was extracted from Harmonised World Soil database from Food and Agricultural Organisation as shown in fig 3. Land use and Land Cover data were taken from the LANDSAT-7 satellite available at the Bhuvan website as shown in fig 4. The necessary slope map was prepared from the DEM data.

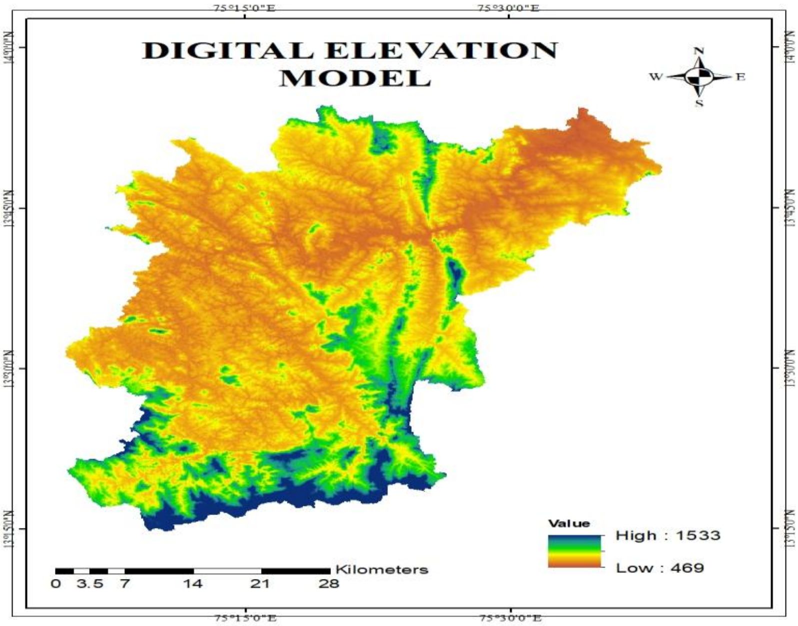

Fig. 2 Digital Elevation Map of Upper Tunga Basin

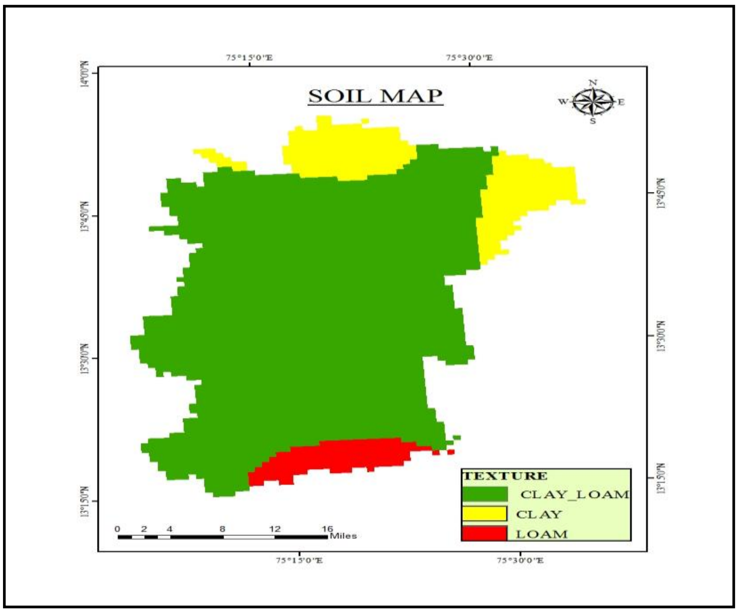

Fig. 3 Soil Map of Upper Tunga Basin

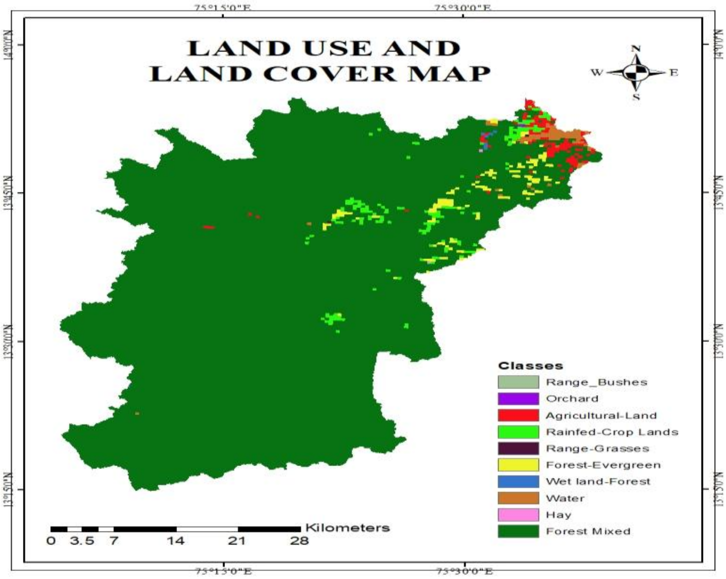

Fig. 4 LU/LC Map of Upper Tunga Basin

The Metrological data required for the SWAT model in estimating surface runoff was collected from the Water Resources Development Organisation (WRDO), Shivamogga for the period 1997-2017. The Yearly average Rainfall data is as shown in fig 5.

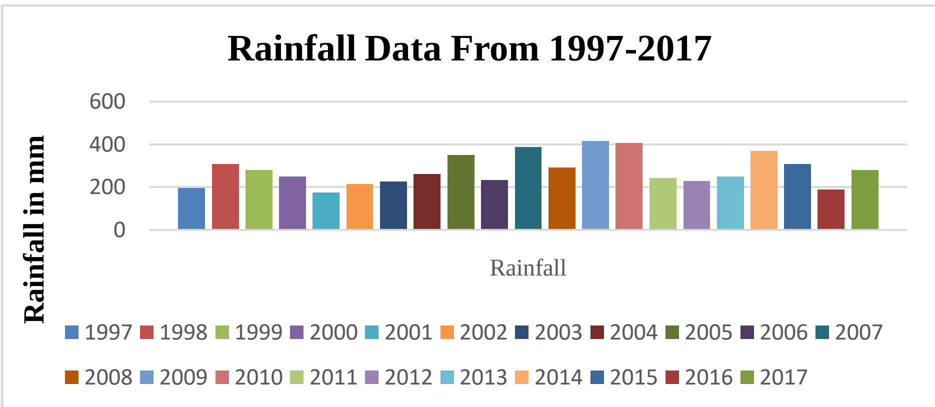

Fig. 5 Yearly average Rainfall data

The runoff data were collected from Gajanur dam gauge station from the year 1997-2017. This discharge data was used to calibrate and validate the model which helps in recreating the same environment which is in existence at the ground in the Arc GIS interface.

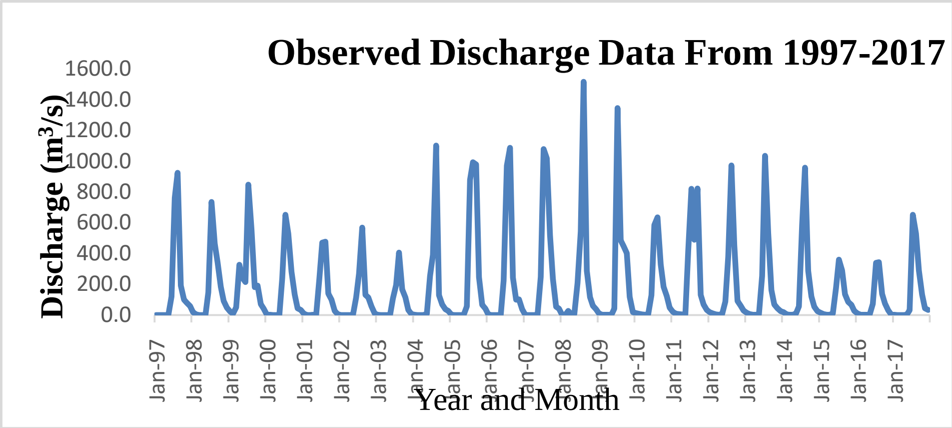

Fig. 6 Average Monthly Discharge data

For defining the basic units of modelling, HRU (Hydrological Response Unit), Land use/ land cover map and soil map were overlaid after the automatic watershed delineation process is done. In the present study, HRUs were defined by taking all land uses, soil type and slope occupying 10% or more of sub-basin area. HRU report was then generated. The Metrological data such as Precipitation, Temperature, Solar radiation, Humidity and Wind speed data obtained from the Water Resources Development Organisation (WRDO), Shivamogga was fed into model as a user defined data for the weather parameters. Weather generator was used to generate and write meteorological parameters files. Then the SWAT was run for the period of 20 years from the year 1997 to 2017 with the warm up period of 02 years.

IV. RESULTS AND DISCUSSIONS

The SWAT model was used to generate the monthly discharges for the period 2000 to 2017. But for the calibration purpose the monthly discharge from the period 2010 – 2014 was used. Calibration of the SWAT model can be done manually and automatically. In the present case, manual calibration is done by changing the sensitive parameters which are responsible for the change in surface runoff values. Before calibrating the model the discharge values were under predictive as simulated peaks were lower than the observed peaks. The objective functions chosen for calibration purpose were R^2 and NSE. In general, model simulation can be judged as satisfactory if NSE > 0.50 (Moriasi et. al, 2007) and typical value of R^2 greater than 0.5 for stream flows (Santhi et al., 2001; Van Liew et al., 2003). For the first run, R^2 and NSE were obtained as 0.528 and 0.43 respectively.

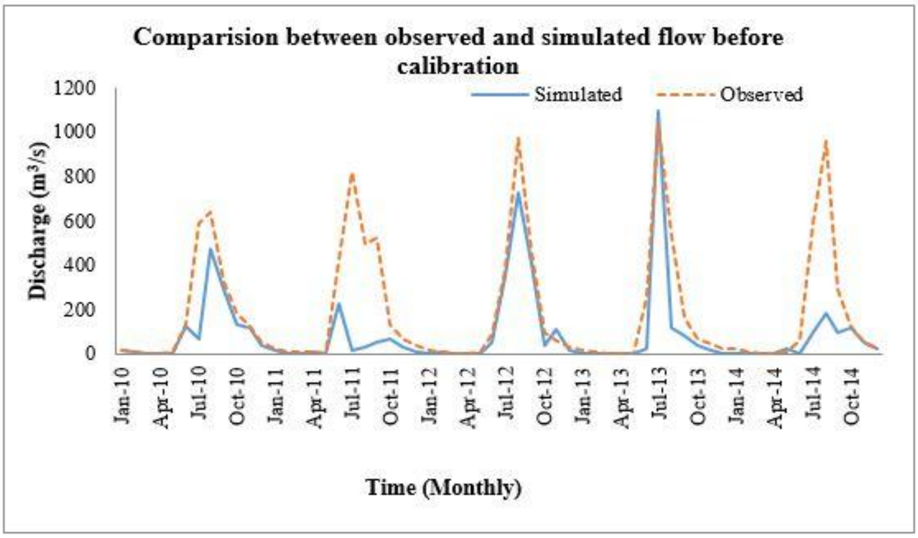

Fig. 7 Comparison of Observed and Simulated Discharge before Calibration

Thereafter the model was simulated for various scenarios by changing the sensitive parameters which are responsible for change in values of surface runoff as shown in Table 1. After a successive number of trials, the objective functions were found to be improved and showed the good results as R^2 = 0.781 and NSE = 0.595. Fig 8 shows the variation of discharge values after calibration.

TABLE I: PARAMETERS USED IN CALIBRATION OF SWAT MODEL

Parameters	Initial Values	Adjusted Value
CN_2	79	83
GW_DELAY	31	60
ALPHA_BF	0.048	0.35
ESCO	0.95	0.8
SURLAG	2	7
SOL_AWC	0.16	0.4

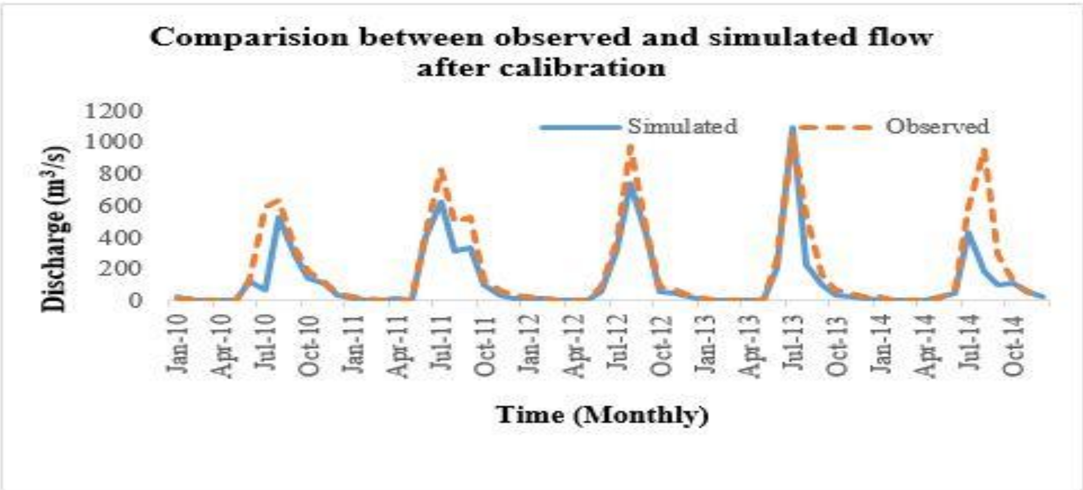

Fig. 8 Comparison of Observed and Simulated Discharge after Calibration

Validation of the model was checked for the period 2015 – 2017. The model was simulated and compared with the observed data for the same period for the variation between observed and simulated discharge data. The results were found to be satisfactory as the R^2 and NSE values were 0.829 and 0.573 respectively and the variation is as shown in the fig 9.

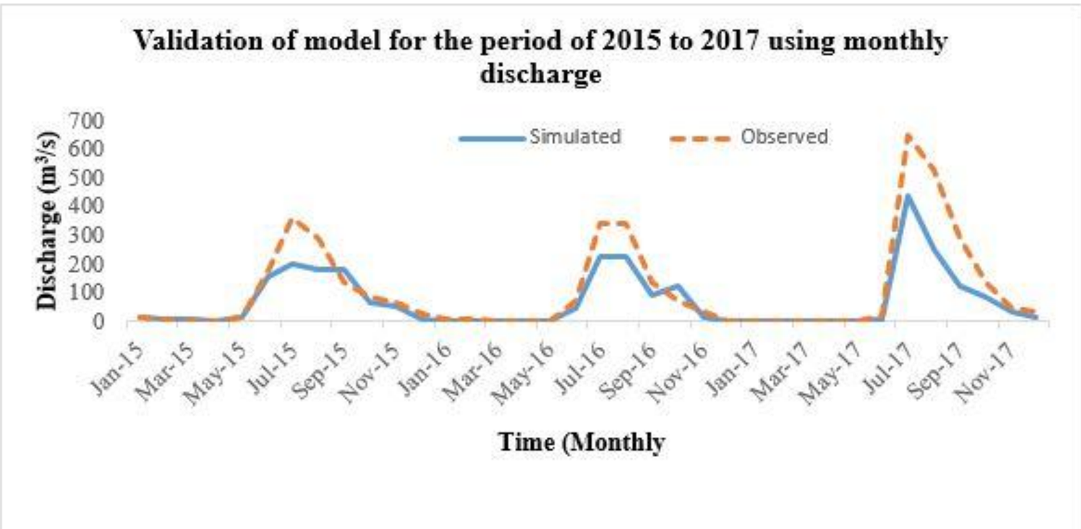

Fig. 9 Comparison of Observed and Simulated Discharge on Validation

V. CONCLUSIONS AND SCOPE FOR FUTURE STUDIES

The present work shows the way to estimate the Surface runoff generation at a selected point using SWAT model in an Arc-GIS interface. The usage of model aids in estimating surface runoff very precisely along with the accuracy saving lots of time. It proves to be one of the emerging tool in estimating surface runoff provided necessary data are available. In the present case, two objective functions were tested to evaluate the simulated results from SWAT model. The R^2 and NSE values were found to be 0.781 and 0.595 during calibration and 0.829 and 0.573 on validation respectively.

The study reveals that, SWAT model can be applied on any watersheds to generate the surface runoff values provided, calibration and validation of the model for the selected watershed is done with the observed data and the values are within the acceptable limits.

Scope for future studies

1. The greater accuracy can be achieved with the use of finer resolution data
2. Calibration and Validation can be better done for daily discharge data.
3. Using the simulated discharge data at the outlet, it is proposed to estimate the design flood discharges by doing flood frequency analysis.
4. It is proposed to do study on mitigating the flood along the downstream river course to reduce likely damage.

VI. AKNOWLEDGMENT

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