SWAT Based Rainfall – Runoff Modeling of Upper Godavari Basin, India

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Abstract: The present study aims to verify a distributed parameter SWAT model based on calibration and validation of monthly surface runoff from the study area of Upper Godavari basin, India. To verify this SWAT model, satellite data, geographic information system (GIS) data and SWAT coupled with Arc GIS 10.2 software were used. The main objective of this study is to develop the correlation between model performance based on calibration and observed discharge from the watershed. For model evaluation digital elevation model (DEM), Land use/Land cover, Soil maps, meteorological data tables etc., has been procured. From DEM, watershed was delineated and HRU's (Hydrologic Response Units) were generated. In SWAT simulation, the output parameters of the swat model for Upper Godavari basin such as monthly precipitation and surface runoff were estimated as 252.1 mm and 89.29 mm respectively and the average curve number for this study area were calculated as 82.33. Calibration of the SWAT model can be done by the software called soil and water assessment tool—calibration and uncertainty procedures (SWAT-CUP), which is used for the auto-calibration of SWAT simulated outputs.

Keywords: Rainfall; Runoff; GIS; SWAT; Calibration; Validation; SWAT-CUP.

1. INTRODUCTION

Water availability is one of the major issues due to the accelerating population growth, water pollution and drastic changes in climate. These things need attention from the present generation across the whole world to attain sustainability (Swain, Verma, & Verma, 2018). For the estimation of water availability, understanding of the water balance of the basin is very necessary. Major hydrological processes related to water resources development and management works are estimated based on water balance equation. This water balance is mainly influenced by physical characteristics of the watershed such as morphology, land use, and soil. Since the hydrologic processes are very complex, their proper comprehension is essential, and for this, watershed models are widely used (Venkatesh et al. 2017). Among semi-distributed hydrological models, SWAT model was originally developed for prediction of discharge from

ungauged basins (Arnold et al. 1998). The water balance Eq. (1), which governs the hydrological components of SWAT model (Neitsch et al. 2005), is as follows

$$SW_t = SW_0 + \sum_{i=1}^{t}(R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}) \quad (1)$$

where: SW_t is the final soil water content (mm); SW_0 is the initial soil water content on day i (mm); R_{day} is the amount of precipitation on day i (mm); Q_{surf} is the amount of surface runoff on day i (mm); E_a is the amount of evapotranspiration (ET) on day i (mm); W_{seep} is the amount of water entering the vadose zone from the soil profile on day i (mm); Q_{gw} is the amount of return flow on day i (mm). In the present study, hydrological modeling procedure was carried out using SWAT model to quantify water balance and to estimate the surface runoff of the Upper Godavari sub basin. The aim and objective of present study are:

- Delineate the watershed, flow direction, flow accumulation, and stream network for Upper Godavari sub basin.
- To understand the rainfall runoff behavior of the Upper Godavari basin using SWAT model and to find out the most sensitive parameters which are critically responsible for the hydrologic response with pre- defined conditions.
- Establishing the spatial correlation between the observed gauge discharge data and SWAT model output data.

2. METHODOLOGY

2.1 Study Area

The area selected for present study is Upper Godavari basin in Maharashtra state, India, which is sub basin of Godavari River basin, situated between East longitudes of 73^0 28'00" to $75^0$29'00" and North latitudes of $19^0$02'00" to $20^0$27'00". The catchment area of Upper Godavari sub basin is 21,933.33 km^2 and this entire area lies in the state of Maharashtra. The minimum and maximum elevations of the study area are 430 m and 1596 m respectively.

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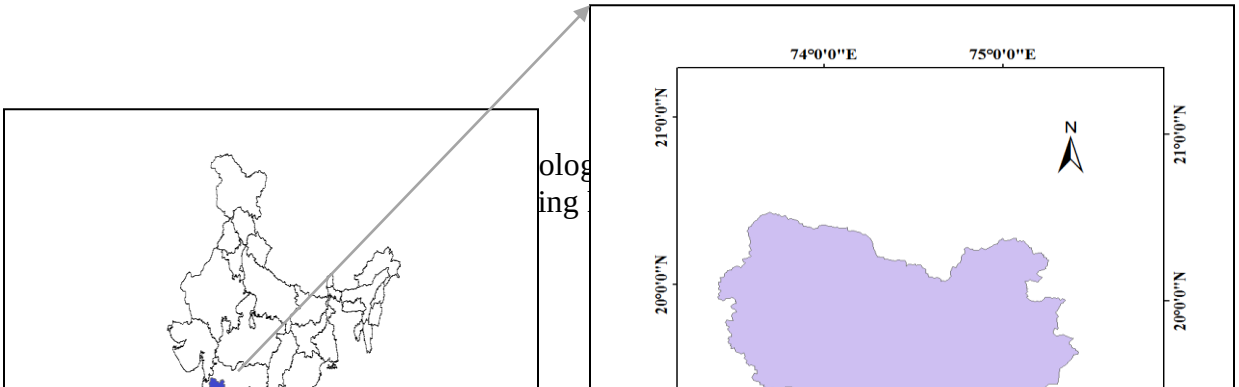


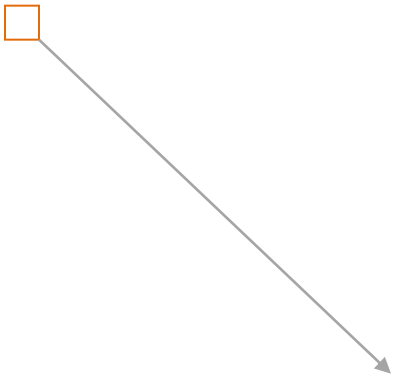


Fig.1. Location map of Upper Godavari basin

2.2 Data Sets

2.2.1 Hydrological and Metrological data

In this study, daily CFSR (Climate Forecast System Reanalysis) downscaled precipitation, wind, relative humidity, temperature and solar radiation data in SWAT file format were used. Monthly stream flow data were obtained for various gauging stations from the Command Area Development Authority (CADA), Aurangabad, India.

2.2.2 Elevation Data

A digital elevation model (DEM) generated from the Shuttle Radar Topography Mission (SRTM) of 30-m resolution was used in this study and it is downloaded from Earth Explorer.

2.2.3 Soil Map

In this study, Soil thematic Maps were collected from National Remote Sensing Centre (NRSC), Nagpur, India. For the reclassification of soil map, User soil database was referred from National

Bureau of Soil Survey and Land Use Planning (NBSS&LUP) - Indian Council of Agricultural Research Nagpur, Publication 79.

2.2.4 Land Use/ Land Cover Map

For preparation of land use/ land cover map, the MODIS Land Cover- Product MCD12Q1 tiles were downloaded from earth explorer. Data are distributed by the USGS at 500m resolution in standard MODIS grid tiles of Type1.

2.2.5 Methodology

Before running the SWAT model, various inputs such as DEM, LU/LC Map, Soil map and weather generation data need to be prepared. For preparation of DEM of Upper Godavari basin, Shuttle Radar Topography Mission (SRTM) tiles of 30-m resolution was downloaded from Earth Explorer, then added this file to Arc GIS 10.2 and done the mosaicking. Reprojected this mosaic file to WGS_UTM_ZONE44 and clipped by creating boundary shapefile of the watershed. For preparation of Land use/ Land cover map, MODIS Land Cover- Product MCD12Q1 tiles were downloaded from earth explorer. To extract the Upper Godavari sub basin, georeferencing had been done to Upper Godavari basin map by creating a shapefile of watershed boundary having the same projection system. Soil map of this study was prepared by collecting thematic maps from NRSC, Nagpur. In Upper Godavari sub basin, around 32 soil types are present. For each soil type, an individual shapefile was created and then merged these shapefiles based on Mapping units which are mentioned in (NBSS&LUP) - Indian Council of Agricultural Research Nagpur, Publication 79. After preparation of input datasets, various steps are followed to run the SWAT model: (1) Watershed Delineation, (2) Hydrological Response Unit (HRU) analysis, (3) Write input tables, (4) SWAT simulation and (5) Calibration using SWAT-CUP. In the first step, initially the SWAT setup was interfaced with ArcGIS and then DEM is added as input file. After adding the DEM file, SWAT model uses the contours and watershed slope to determine the flow direction and flow accumulation. Once the flow direction and flow accumulation established, the model then generates stream network in each individual reach of the sub basin, all of which drains into a major reach. Each reach has a node or outlet. which is delineated based on the location of that outlet and the stream network.

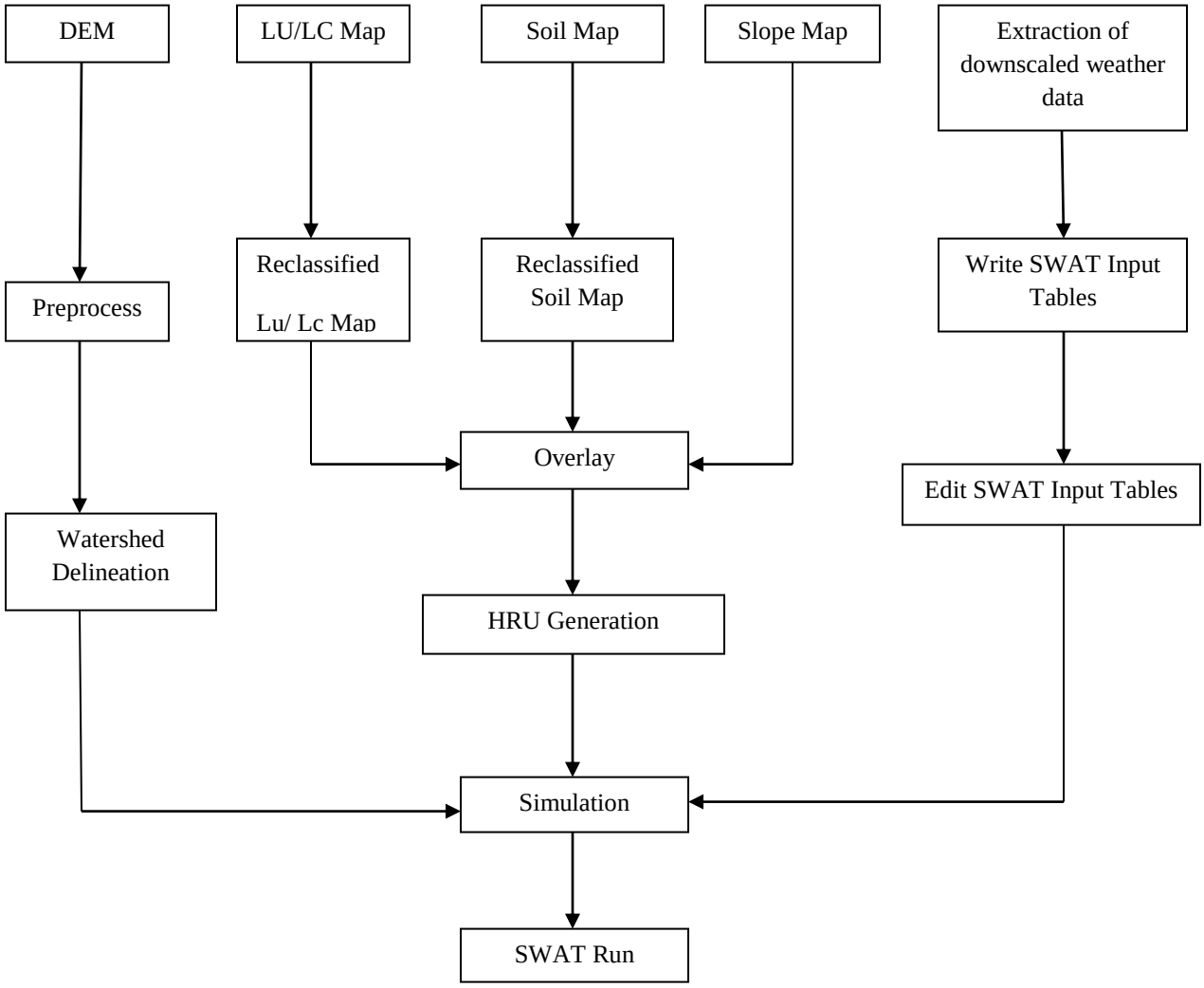


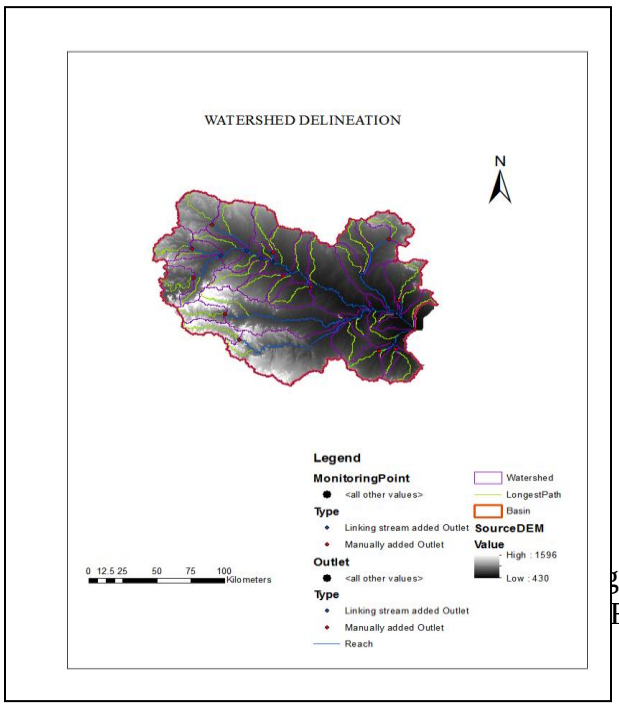
Fig. 2. Methodology Flow chart

After that, choose the watershed outlet to delineate the watershed. Final step in the delineation of watershed was calculation of basin parameters such as geomorphic parameters and relative stream reach. In the second step, Hydrological response units were analyzed based on homogeneous units, which were given as input to the model such as reclassified land use/ land cover and soil maps. For reclassification of land use/land cover, look up table in .txt format was prepared and for reclassification of soil, SWAT user soil database was prepared. Final step in

HRU analysis was overlay of Land use/ Land cover, Soil and Slope maps. Once overlay completed, HRU reports were established. The third step is, writing the input tables. In this step, weather generator data and all other input meteorological data are written in specified tabular format, to run the SWAT simulation. After writing the input tables in the fourth step, simulation period was provided and stream flow data printed as monthly and skewed normal Rainfall distribution selected to complete SWAT model simulation.

3. RESULTS AND DISCUSSIONS

After completion of Automatic watershed delineation, Land use/Land cover map which already had 13 classes was Reclassified into 6 classes which is shown in Fig. 3. After reclassification it was found out that the Croplands occupied the maximum area covering 91.86 percentage of the total Land cover followed by pasture lands with a percentage share of 3.74. The soil map has been reclassified into 7 classes based on the Mapping units which is shown in Fig.4 and 5 different slopes were given. After that HRU analysis reports has been established. This reports showed that the model created 376 HRUs and 41 number of subbasins in the watershed. SWAT simulation was done on monthly basis and simulation period of 34 years from January 1980 to December 2013 executed successfully. In SWAT output the average monthly monsoon precipitation and surface runoff were found to be 252.1 mm and 89.29 mm, respectively and average curve number as 82.33. Based on model prediction Curve number is high, i.e., higher the curve number more will be the surface runoff in the basin.



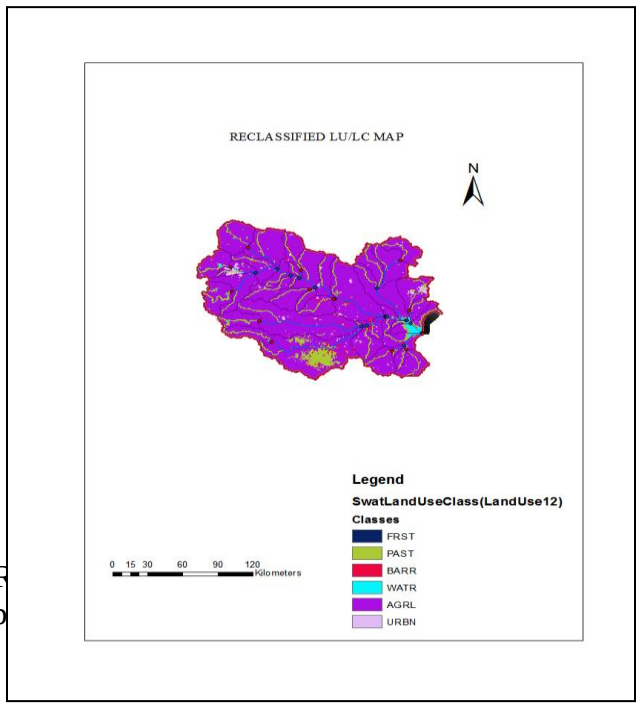
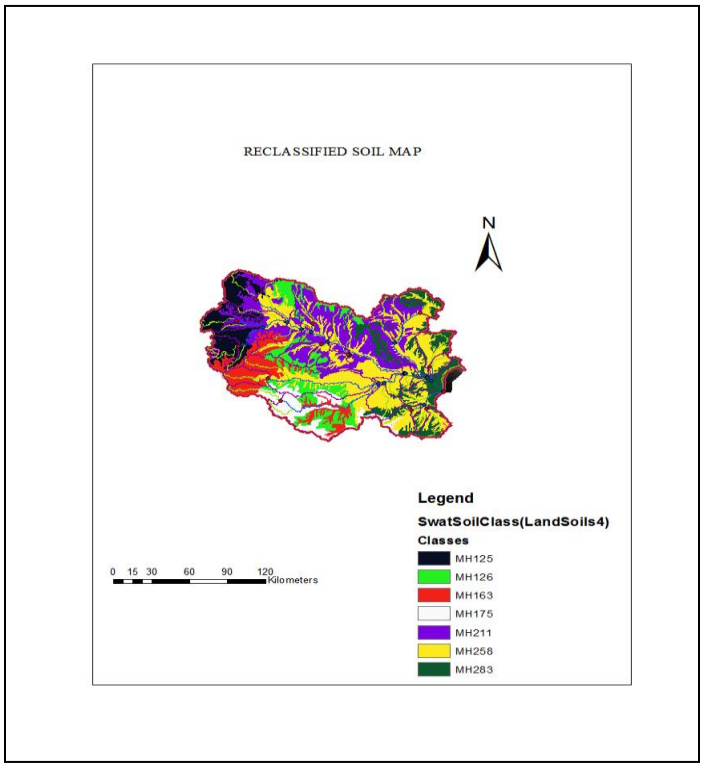


Fig.3. Watershed delineation map and Reclassified landuse landcover map of upper godavari basin



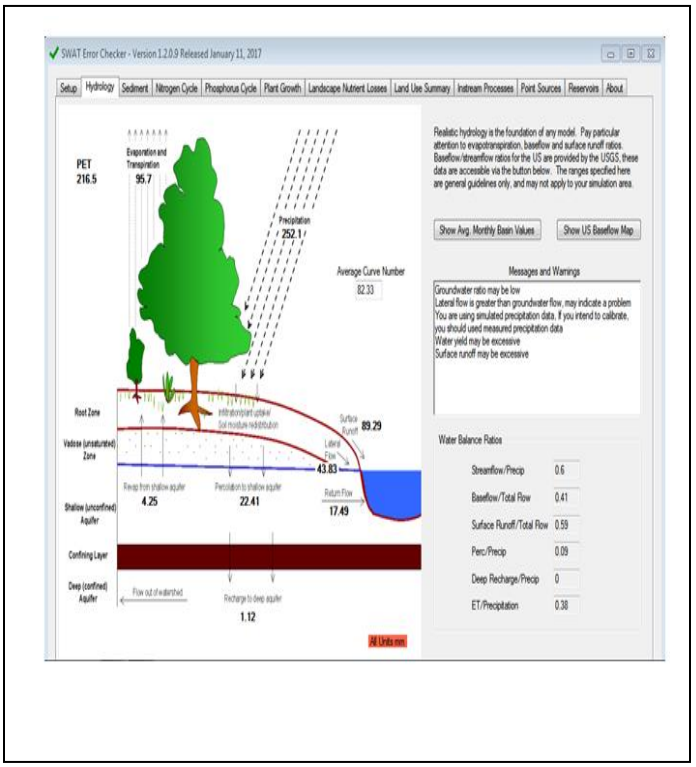


Fig.4. Reclassified soil map of Upper Godavari Basin

Fig.5. SWAT Model Output

Table1 Reclassification of LULC

Value	Land use	LU- SWAT CODE	Area %
2	Mixed Forest	FRST	0.02

7	Pastures	PAST	3.74
8	Barren Land	BARR	1.67
11	Water bodies	WATR	0.87
12	Crop Lands	AGRL	91.86
13	Residential Area	URBN	1.84

Table2 Reclassification of Soil

Value	Soil type	Soil- SWAT CODE	Area %
125	clayey	MH125	9.80
126	Clayey loam	MH126	10.55
163	clayey	MH163	9.87
175	Gravely sandy loam	MH175	7.05
211	Clay & sandy clay	MH211	20.62
258	clayey	MH258	29.50
283	Clay loam	MH283	12.62

4. CONCLUSIONS

SWAT model produced good results for the study area during the monsoon period. The monthly value obtained for precipitation and runoff during the monsoon period are 252.1mm and 89.29 mm respectively. So, 35.4% of precipitation gets converted into surface runoff in the Upper Godavari sub basin during January 1980 to December 2013. Model predicted good results because of less percentage area of forest cover and more percentage area of croplands and also due to the presence of black cotton soil in the Upper Godavari basin. Calibration and Validation of the model can be performed further.

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