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Stream flow Estimation Using Swat Model over Seonath River Basin

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ABSTRACT

Water availability is one of the major issues that needs attention from the present generation across the whole world to attain sustainability. Spatial variation of water resources and further climatic changes are main reasons for extremes like droughts and floods. This urges for the quantification and forecasting of availability of the basic need of life. At the river basin level, stream flow is considered as the most crucial parameter to assess water availability, which can be estimated by simulation or modelling approaches. This article presents about the hydrological modeling using a semi-distributed model namely SWAT (Soil and Water Assessment Tool), applied to Seonath river basin, Chhattisgarh, India. The CFSR (Climate Forecasting System Reanalysis) meteorological data for the period of 1979-2014 (35 years) is used and the runoff is generated, which is calibrated using the observed flow at the basin outlet. The results reveal the observed flow and modeled flow to be very poorly correlated. The major causes of such mismatch are identified and possible improvement options are discussed.

I INTRODUCTION

Seonath basin is the largest sub-basin of Mahanadi river basin and it covers a significant portion of the state Chhattisgarh, India. The various problems related to the basin are not being given much attention. Like most parts of India, majority of population in Chhattisgarh is also directly dependent on agriculture for fulfilling their basic amenities. Although Mahanadi basin is highly vulnerable to flooding, the impacts of flood are never so thought provoking for Chhattisgarh. But the rainfall anomalies leading erratic stream flow may be a cause of headache, when the entire world is facing problems due to water scarcity. According to the report of the National Commission for Integrated Water Resources Development, Government of India, various countries have been classified for water scarcity on basis of per capita Annual Water Resource (AWR). The countries with per capita AWR less than 1000 cubic meters are regarded to be in water stressed conditions. The number of countries in water stressed condition in 1990 was 20, which is expected to be detrimental to cause two-third of world population to face water stressed condition by 2050 (Gosain et al., 2006). Furthermore, according to IPCC (2007) reports, the global surface warming has occurred at a rate of 0.56-0.92 0C during the period 1906-2005 and impact of climate change may become severe to cause reduction in the freshwater availability. They have also predicted the decrease in annual average runo_ and availability of water up to 30% by middle of the 21st century. Also, the impact of climate changes will be severe for developing countries like India (Swain, 2014; Swain et al., 2015).

At the river basin level, stream flow is considered to be the measure for estimating the water availability. For estimation of stream flow, various models have been developed. In the last two decades, the hydrological models are extensively used to assess the water availability and prediction of extremes. SWAT (Soil and Water Assessment Tool) is one such model, which incorporates on Digital Elevation Model, land use map, soil map and meteorological parameters to generate runoff at basin scale. The model uses two basic equations for estimating runoff i.e., SCS-CN (Soil Conservation Services- Curve Number) method and Green Ampt- Mein Larsen equations (Arnold et al., 1998; Abbaspur et al., 2009; Setegn et al., 2010; Bekele and Knapp, 2010).

II STUDY AREA AND DATA USED

The study area is Seonath basin, having an area of 30560 square kilometers. The entire basin is within Chhattisgarh state. This basin is situated between 20° 16' N to 22° 41' N Latitude and 80° 25' E to 82° 35' E Longitude. The predominant soil of watershed is sandy clay loam. Sandy loam, loam and clay are also found in the watershed. Seonath basin has a tropical wet and dry climate, temperatures remain moderate throughout the year, except from March to June, which can be extremely hot (Galkate et al., 2015). The area under Seonath basin is mainly fertile plains.

The meteorological data (rainfall, maximum and minimum temperature, wind speed, solar radiation and relative humidity) are collected for 24 stations, as shown in Fig. 1. These data were downloaded from CFSR (Climate Forecasting System Reanalysis) database simulated by National Centers for Environmental Prediction (NCEP) and Texas A

& M University, United States. Digital Elevation Model (DEM) is downloaded from ASTER website (30m Resolution) which was used in watershed delineation. Soil map is collected from Chhattisgarh Council of Science and Technology (CCOST), Raipur (C.G.) which was used in HRU Analysis. Land use/land cover map is downloaded from BHUVAN (LISS III), National Remote Sensing Centre (NRSC). Topographical sheets (for creating shape files) were collected from Survey of India.

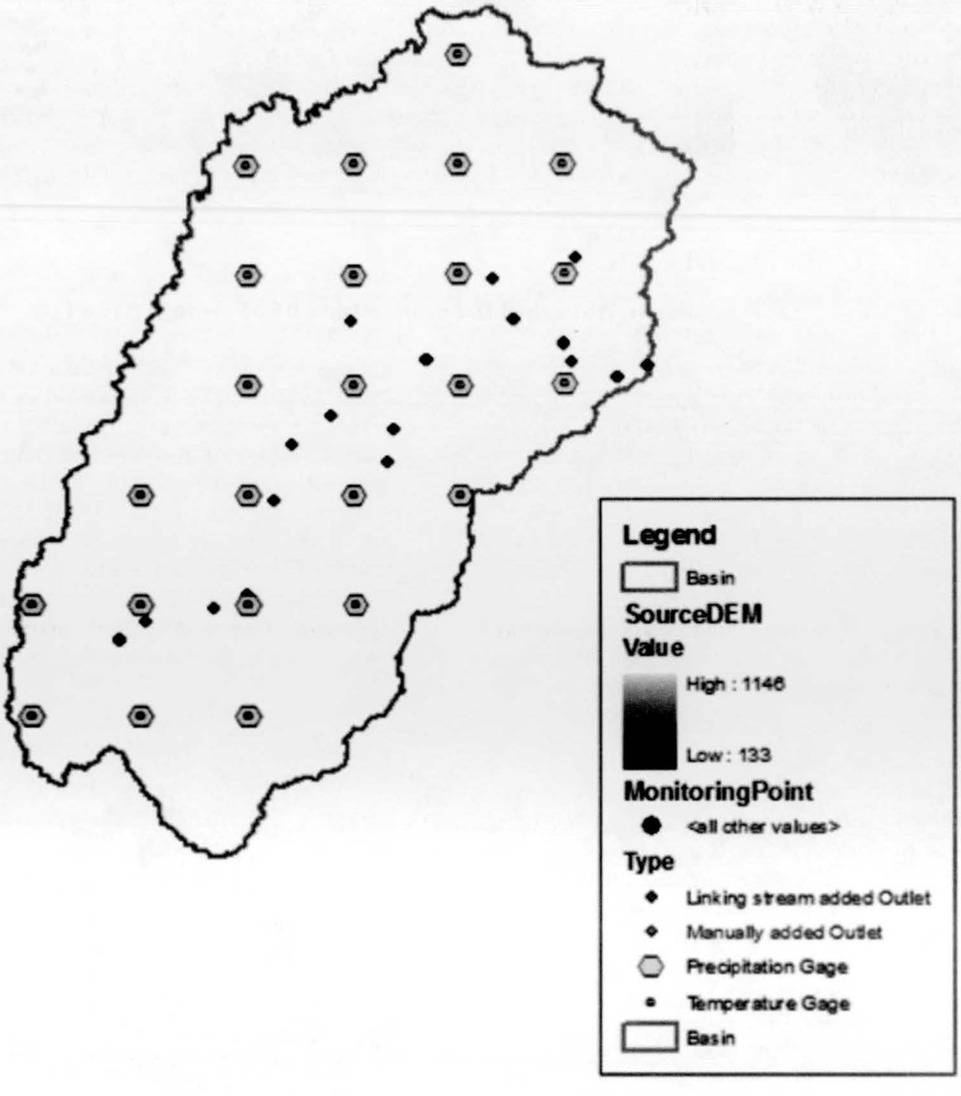

Fig. 1. Location of CFSR stations in Seonath basin

III METHODOLOGY

The various steps of running SWAT model are as follows: 1. Automatic Watershed Delineation, 2. HRU (Hydrological Response Unit) Analysis, 3. Write Input Tables, and, 4. SWAT Simulation. 5. Calibration using SWAT-CUP.

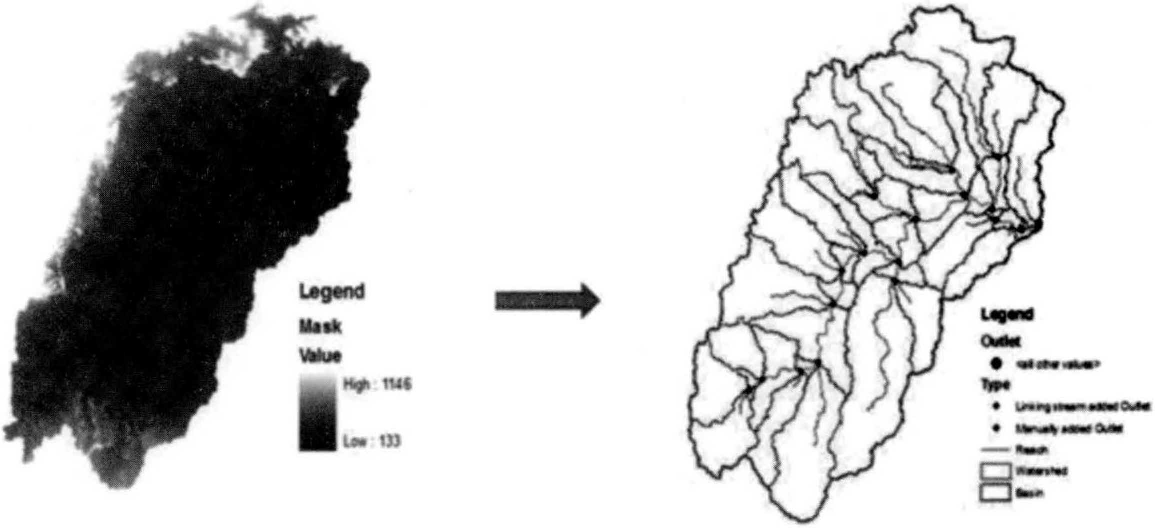

Fig. 2. Automatic Watershed Delineation from DEM through SWAT

First of all, the SWAT project is set up with ArcGIS as an interface. Then automatic watershed delineation is carried out from the DEM provided as input file. Fig. 2 shows the process of delineating the watershed from DEM. The outlet point of the basin is also fixed by SWAT automatically based on DEM. In the second step, analysis of Hydrologic Response Units is carried out through the model. The land use and soil map of the basin is provided as input and based on these; the whole basin is sub-divided into various homogenous units. The HRU is obtained based on the response of soil and land use of different parts of the basin. The reclassification of both the maps is done in this step. Fig. 3 and fig. 4 presents the reclassification of the input land use/ land cover and soil map respectively. Table 1 and table 2 represent the attribute table of the LULC map before and after reclassification respectively. After HRU analysis, comes the writing of input tables. In this step, the weather generator data and all the input meteorological data are written in specified tabular format, for the simulation to run.

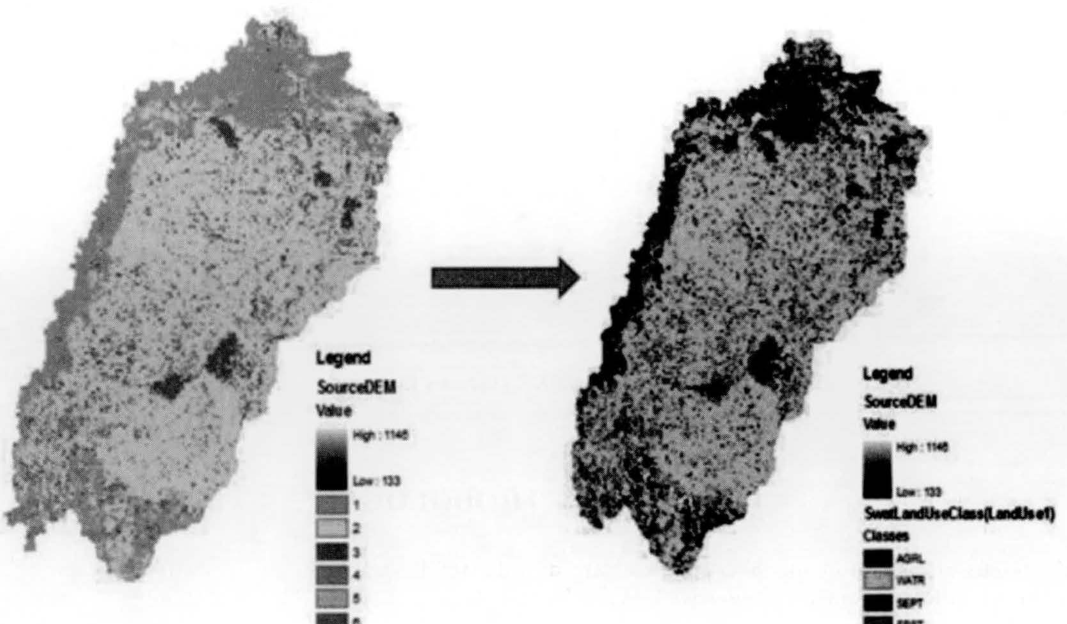

Fig. 3. LULC Map Reclassification in HRU Analysis

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Table 1:
Attribute Table before Reclassification of LULC

Rowid	VALUE*	COUNT	LU_CODE
0	1	8439	Forest
1	2	27232	Agricultural Land
2	3	2277	Build Up
3	4	579	Tree Clad Area
4	5	1139	Water Bodies
5	6	2170	Wastelands

Table 2:
Attribute Table after Reclassification of LULC

Rowid	VALUE*	COUNT	Object ID	LUArea1.Area	LUArea1.LUSWAT
0	1	6677863	0	19.843	AGRL
1	2	22033842	1	65.472	WATR
2	3	1843005	2	5.476	SEPT
3	4	428189	3	1.272	FRST
4	5	917401	4	2.726	URHD
5	6	1753325	5	5.21	WETL

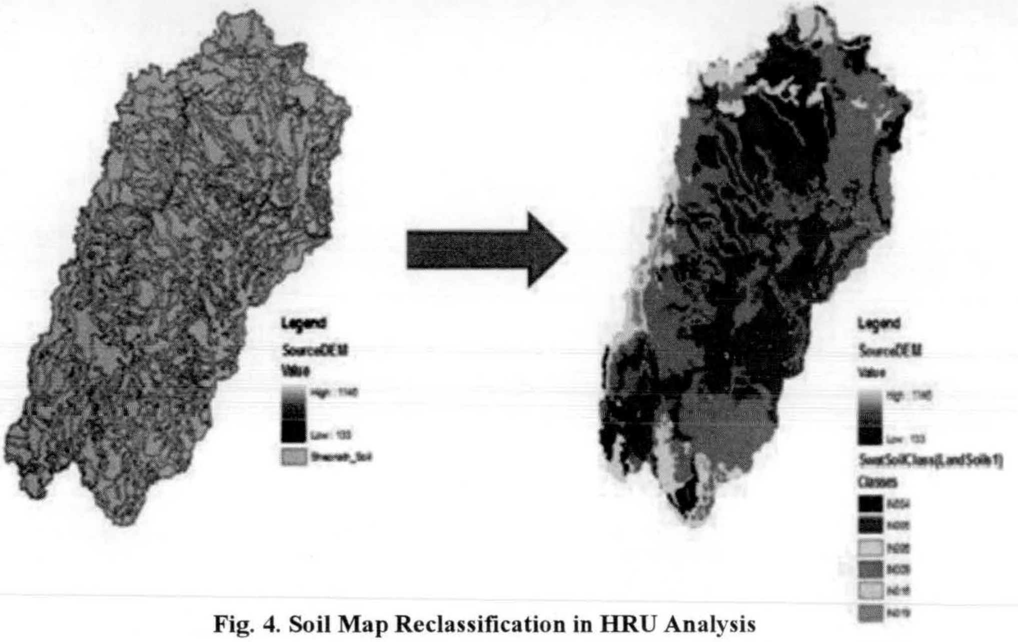

Fig. 4. Soil Map Reclassification in HRU Analysis

In the next step, the model is run for the required period i.e. from January 1979 to July 2014. The simulation is carried for the duration whose required data are already provided as input for SWAT simulation. We have to provide the starting and ending date of the stream flow that we require as output. The stream flow data can be generated as hourly, daily, monthly or annually output. Here, it has been printed for daily output, where the rainfall distribution is chosen as Skewed normal distribution. At the end of this step, when the execution is successfully completed, the output file of stream flow at basin outlet for the required duration will be generated, which needs to be checked with that of actual observed runoff at the outlet so as to calibrate the model.

The Calibration of the SWAT model is made by a software SWAT-CUP (Soil and Water Assessment Tool- Calibration and Uncertainty Procedures), which is used for the auto-calibration SWAT simulated outputs. The software uses various types of tools out of which Glue, Sufi2 and ParaSol are widely used. For the auto-calibration of the SWAT model for Seonath basin, Sufi2 is used here. The number of simulations carried was 50 and out of them, the closest values to that of observed data is considered.

IV RESULTS AND DISCUSSION

Out of the 24 sub-basins, the runoff is generated at sub-basin numbered 15. The actual observed value of runoff at the outlet and number of simulations required has to be provided as input for SWAT-CUP and it was given 50 for this case. More the number of simulations, more accurate is the calibration. At the end of the simulation, the model gives the 43rd simulation as the best simulation, which is most close to the observed values. But the results are having a clear mismatch with respect to that of observed data. The Nash-Sutcliffe efficiency and the coefficient of determination are found to be 0.07 and 0.31 respectively, which denotes that the model does not produce satisfactory results for the basin.

There are some prominent reasons for such a disagreement between the observed and the model generated stream flow. First of all, the meteorological data used are collected from CFSR and the observed runoff data is collected from Water Resources Department, Chhattisgarh. As there was no meteorological data available for temperature, wind speed etc. from WRD, the CFSR data were used for analysis. This might have accounted for the mismatch. Secondly, the observed data is collected at Jondhra outlet, whose location is not congruent to that of the outlet denoted by SWAT after automatic watershed delineation. Although they are close, since their exact locations are different, addition or loss to the stream flow may occur in the distance between these two points, which may definitely affect the final output. Thirdly, the default values of HRU thresholds have been used in the model, which may contradict to the original case. Moreover, there might also be errors in stream flow data during collection due to lack of updated instruments and human errors.

V CONCLUSION

The problems of water availability have raised itself as a crucial issue, which is addressed by assessing the runoff over Seonath river basin, Chhattisgarh, India. SWAT model was applied to the basin for a period of 35 years to check if the model can be used for future application. With a number of assumptions and using default values, the model was run and the stream flow generated by the model clearly showed disagreement with that of observed runoff values. The Nash-Sutcliffe efficiency and coefficient of determination were less than 0.5, for the best matched simulation. The various causes of the mismatch are also found, which needs to be focused upon to check the applicability of the model for further use over the basin.

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