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Runoff Modeling Using SWAT Hydrological Model for Ghataprabha Basin

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***Abstract*— The ultimate challenge being faced by modern world is proper management of water which is one of the scarce natural resources. Growing population, modern urbanization and meeting their demands is one of the greatest challenges for hydrologists. Developments in agricultural practices also add up to the increasing demand of the water. With these considerations, hydrological models plays a vital role in assessment of water functioning at the watershed scale. In this present study, Ghataprabha basin is selected for the estimation of surface runoff using GIS based approach, SWAT (Soil and Water Assessment Tool). The main objective of the study is to predict long-term simulation on the Ghataprabha basin. The model was calibrated for the period 1991-1994 and validated for the period 1995-98.Good results were achieved both in the case of calibration and validation of the model.**

Keywords*- Hydrological model, Runoff, SWAT model, Ghataprabha sub-basin.*

I INTRODUCTION

The proper management of water resources is the need of time in the era of demanding urbanization and growing population of India. In spite of enormous number of rain gauge stations and recording stations in India, the limited infrastructural and data management affects many water resource planning. Estimation of river runoff is an important activity in the study of hydrology. The real-time operations and offline design and planning aids in proper estimation. Analytical methods and simple conceptual models are also required for short term and long term forecasting of the stream flow to optimize the hydrology system. To achieve these high degree of accuracy in estimation of runoff, various hydrological modelling techniques have been developed by various hydrologists. Among these, Soil and Water Assessment Tool (SWAT) model most recently opted model for simulating runoff, sediment yield and water quality of watersheds. (M P Tripathy, R K Panda, N S Raghuvanshi, 20013; Van Liew and Garbrecht, 2003). J G Arnold, R Srinivasan, R S Muttiah, J R Williams (1998) mentioned about simulation of large basins by incorporating GIS into various hydrological models. Neitsch S. L. et al. (2011) and J G Arnold et al. (2012) stated that SWAT model was developed by the USDA Agricultural Research Service (ARS), to assess the impact of land use practices on chemical yield, water quality and sediment yield over long period of time of time in large basins.

II STUDY AREA

A.GHATAPRABHA BASIN

Krishna river is the second largest river in India, which originates from the Mahadev range of the western ghats near Mahabaleswar at the height of about 1337 m above MSL about 64 km from the Arabian sea. After traversing a distance of about 1400 km, the river meets the Bay of Bengal in the Andhra Pradesh. The principle tributaries of the river are Ghataprabha, Malaprabha, Bhima, Tungabhadra, Musi, Palleru and Muneru. The basin is divided into 12 sub basin. Ghataprabha is one of the sub basins of river Krishna. Ghataprabha is one of the southern tributaries of the Krishna in its upper reaches. The catchment of the sub basin lies approximately between northern latitudes 15^0 45’ and 16^0 25’ and eastern longitude 74^0 00’ and 75^0 55’ (as shown in fig.1).The river Ghataprabha originates from the region of Western Ghats in Maharashtra at 884 m altitude, flows for 60 km eastwards through the districts of Sindhudurg and Kolhapur in Maharashtra, then enters Karnataka. In Karnataka, the river flows for 216 km through Belgaum district past Bagalkot. After a run of 283 km the river joins the Krishna on the right bank at Kudalsangam at an elevation of 500 m, about 16 km from Almatti.

Figure 1 Location map of the study area

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B.CLIMATE AND TEMPERATURE

The climate of the sub basin is marked by a hot summer and a mild winter. The monsoon sets early in June and continues to the end of October. The winter is form November to mid-February and the summer is from mid-February to end of May. April is generally the hottest December is generally the coldest month with the mean daily maximum and minimum temperatures being 29.3^0 C and 13.9^0 C respectively.

C.RAINFALL PATTERN

The sub basin experiences only the southwest monsoon and the period is from 1^{st} June to 31^{st} October is the lowest. The relative humidity is high during the south west monsoon and low during the non-monsoon period. In summer the weather is dry and the humidity is low.

D.LAND USE/ LAND COVER

Land Use is elaborative depiction of how the population of the region utilizes the land in their socio-economic activity. The land use/land cover for the basin under study is given in the table 1 below.

Table 1 Land Use Details

Net Area Sown	63.7%
Forest	12.6%
Current Fallows	8.7%
Non Agricultural Use	4.0%
Barren Land	3.9%
Cultivable waste	2.7%
Permanent Pasture and Other Grazing Land	2.3%
Other Fallows	1.8%
Land Under Miscellaneous crops and trees	0.3%

E.SOILS AND CROPPING PATTERN

Coarse shallow black soils are occupying areas in north and north-west parts of the districts of Belgaum and Kolhapur in the sub basin .these soils are shallow at depths less than 23 cm. These are well drained and have moderate permeability. The crops grown under rain fed conditions are jowar, bajra, millet and pulses. However, the yields of the crops are poor owing to shallow rooting depths and scanty rainfall. Medium black soils usually occur in the Deccan trap, schist, lime-stone and shale regions of the Karnataka state, occupying areas in parts of Belgaum, Hukkeri ,Bailhongal, Mudhol and Bailagitaluks. The medium black soils are also found to some extent on the peninsular gneiss areas. Deep black soils occur on very gently sloping to nearly level or flat topography in the low lands of Deccan trap and limestone region. Mixed red and black soils usually occur on gently undulating plain or complex geological material comprising gneisses, Dharwar schistose and sedimentary rock formation and occupy areas in the basin. Lateritic soils are found on undulating, rolling plain to gently sloping topography of the peninsular gneisses region occupy areas in parts of Kolhapur. The Soil classification is shown in table 2.

Table 2 Distribution of Soil group in Ghataprabha basin.

Soil groups	Area in sq. km	Area in %
1.Coarse shallow Black Soil	402.32	40
2.Medium Deep Soil	301.74	30
3.Coarse Shallow Soil	301.74	30
Total	1005.8	100

III METHODOLOGY

A. SWAT Model

SWAT is abbreviation for SOIL AND WATER ASSESSMENT TOOL developed by United States Department of Agriculture-Agriculture Research Services (USDA-ARS) in Texas. SWAT is physically based, continuous time model for long term simulation and prediction of hydrological components, sediment and nutrient movement of large catchments. The hydrological components simulated by SWAT is based on water balance equation:

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

Where,

SW_t = soil humidity (mm H_2O),

SW_o = base humidity of the soil (mm H_2O),

t = time (days),

R_{day} = volume of rainfall (mm H_2O),

Q_{surf} = surface runoff (mm H_2O),

w_{seep} = value of water seepage from soil into deeper layers (mm H_2O),

E_a = evapotranspiration (mm H_2O) and

Q_{gw} = underground runoff (mm H_2O).

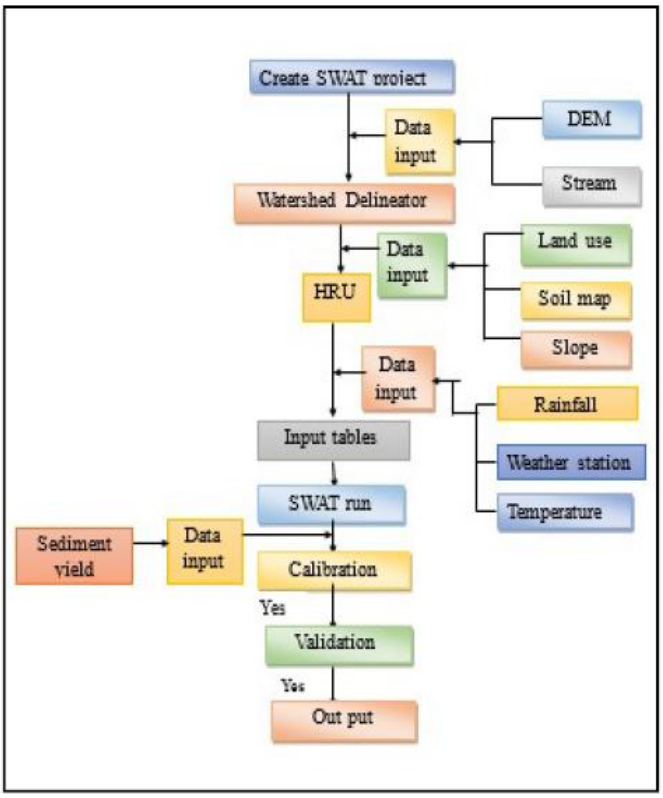

Figure 2. Flowchart for SWAT methodology.

To calculate surface runoff, SWAT model uses hourly and daily time step data. The Green & Ampt method is used for hourly simulation and an empirical SCS-CN is used to compute daily runoff. In SWAT, a watershed is delineated to sub basins, which further sub divided areas of homogeneous similarity between land use, soil type and slope, known as Hydrological Response Units (HRUs). Model setup and execution of model is done as shown in flowchart (fig.2).

B. Data Required:

Following are the input dataset required for the model to process the required parameter:

1. Digital Elevation Model (DEM) file (fig.3)
2. Topographic Map (Slope map) (fig.4)
3. Soil Classes
4. LULC map (fig.5)
5. Weather Data

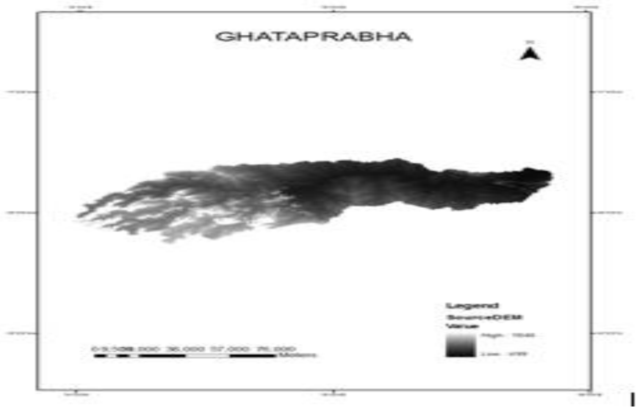

Figure 3. DEM of Ghataprabha sub-basin

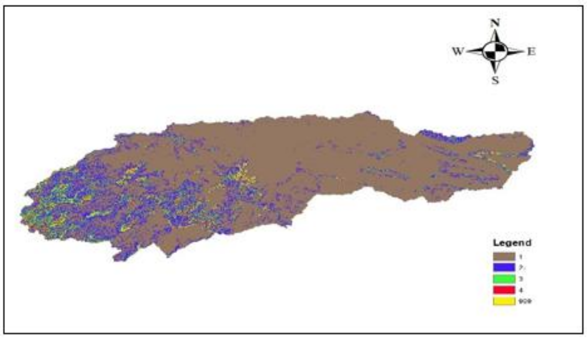

Figure 4 Slope classification of Ghataprabha sub basin.

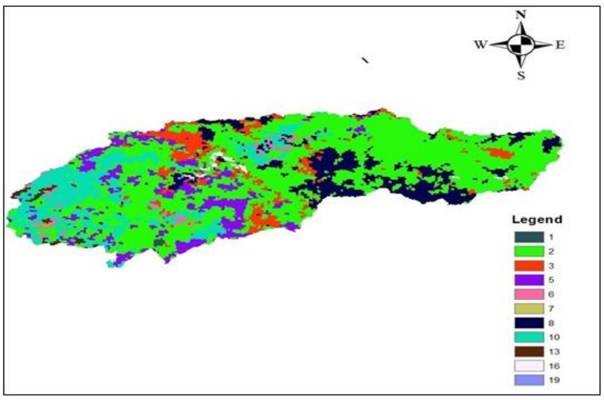

Figure 5 LULC of Ghataprabha sub-basin

IV CALIBRATION AND VALIDATION

The SWAT model was calibrated for discharge for the period 1991-94 and validated for next consecutive years (1995-98). The first step in calibration was calibration for water balance and discharge for mean annual conditions in calibration period (1991-94) followed by monthly and daily calibrations. The calibration process focussed on adjusting model sensitive input parameters determined by sensitive analysis to obtain best fit between simulated and observed data.

The observed and calibrated curves are shown in fig.6.a to fig. 6.d for year 1991-1994 respectively.

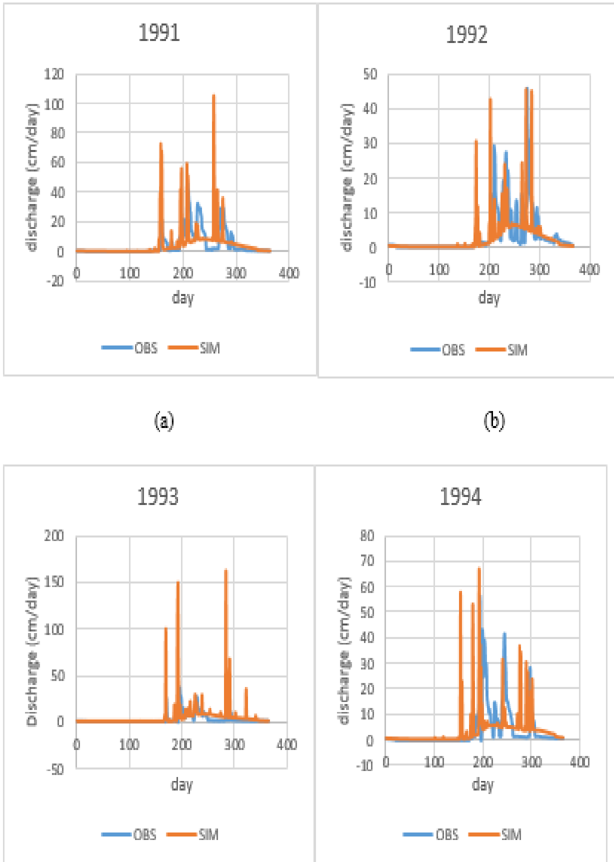

Figure 6 Graphs showing observed and simulated daily discharge for a) 1991; b) 1992; c) 1993; d) 1994

For this model, the calibrated values of the parameters are shown in table 3 below.

Table 3. Calibrated values of SWAT parameters.

S. No.	Parameter_Name	Fitted_Value	Min_value	Max_value
1	R__CN2.mgt	-0.020000	-0.200000	0.200000
2	V__ALPHA_BF.gw	0.450000	0.000000	1.000000
3	V__GW_DELAY.gw	51.000000	30.000000	450.000000
4	V__GWQMN.gw	0.900000	0.000000	2.000000

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Where,

CN2 = Initial SCS-CN for AMC condition II

ALPHA_BF = Base flow alpha factor

GW_DELAY = Groundwater delay (days)

GWQMN = Threshold depth of water in the shallow aquifer for return flow to occur (mm H_2O).

Validation of model is the process of comparing output given by model (i.e. simulated values of runoff) with, for ranging time series without any further changes of the values of the parameters that was calibrated and it is done to confirm that the model performs satisfactorily. For the present study validation is done for the Ghataprabha sub basin for the period 1995-98. The results of the validation process are shown in fig7. It is noticed that there is a considerable match between observed and simulated results.

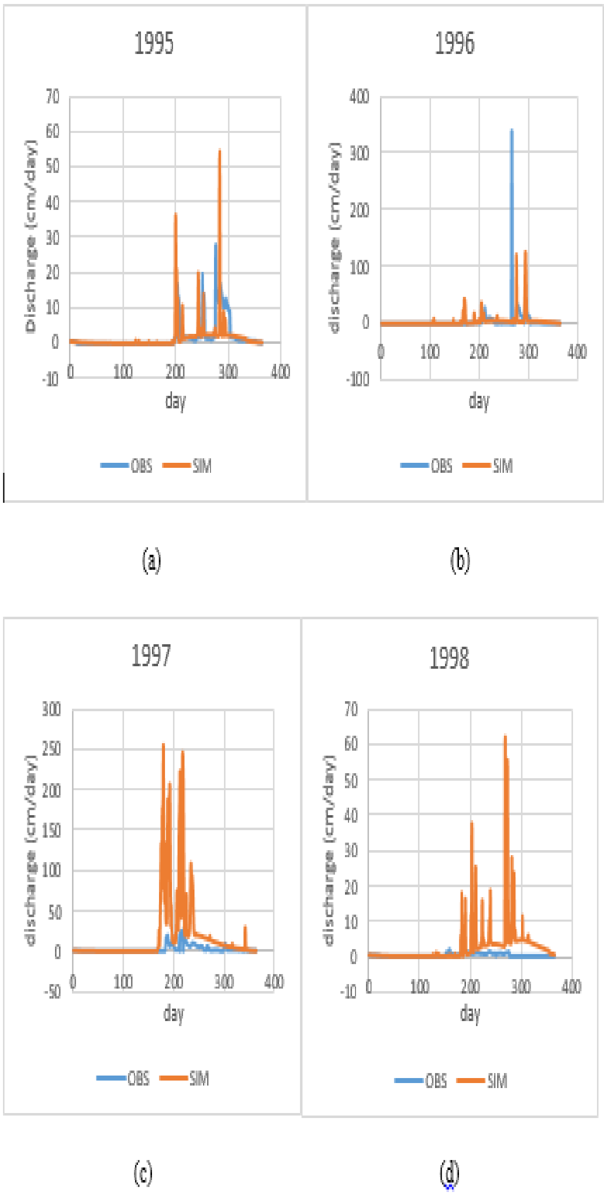

Figure 7. Graphs showing observed and simulated daily discharge for (a) 1995; (b) 1996; (c) 1997; (d) 1998

V RESULTS AND DISCUSSION

On basis of SWAT documentation (Neitschet et al. 2002) and Arnold 2001; Santhi et al. 2001, Van Griensven et al. 2006, the sensitive parameters have been chosen.
The R^2 value obtained is shown in fig 8.

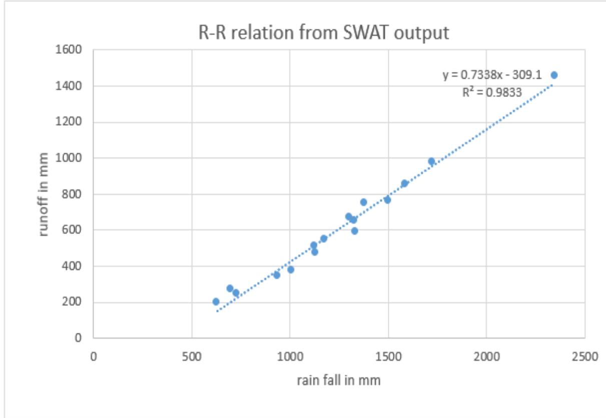

Figure 8. Scattered plot for observed and simulated runoff

VI CONCLUSION

The present study adopted hydrological model SWAT for Runoff computation for the Ghataprabha sub-basin. The model performed well during the calibration and validation period for the Ghataprabha sub-basin.

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