APPLICATION OF SWAT MODEL FOR GENERATING SURFACE RUNOFF AND ESTIMATION OF WATER AVAILABILITY FOR BALEHONNURU CATCHMENT AREA FOR BADHRA RIVER BASIN

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Abstract - *Runoff is a very important component of hydrological cycle. In the present work, authors have used the tool "The soil and water assessment tool-SWAT" for simulation of rainfall runoff and estimation of water availability in Balehonnur catchment of 800sqkm. Various parameters digital elevation models, land use land cover, soil data and temporal data for temperature and precipitation was used as input for the model to predict the runoff at catchment outlet. The calibration and validation was carried out manually. The performance of model is evaluated using statistical methods. The R^2 and NSE values for period used for calibration are 0.878 and 0.78 and for the validation period are 0.869 and 0.75 respectively. The water availability estimated using GCM data over-estimates the runoff values when compared with observed values. Hence the values obtained by GCM are to be suitably reduced by multiplying factor to estimate water availability. The authors have made an attempt to estimate water availability for future period from 2021 to 2050 using RCP4.5 and RCP8.5 scenario data*

Key Words: Hydrologic model, SWAT , regression coefficient, Nash Sutcliffe efficiency, calibration , validation, RCP4.5, RCP8.5, Bias correction, flow duration curve, dependability percentage

1. INTRODUCTION

Water is a fundamental requirement in the life of human beings. History revels that most of the civilization started very close to rivers banks due to proximity of water satisfying their demands for various purposes. The estimation of spatial-temporal availability of water in a region is an essential part of the water resources planning. Models are being used in several regions of the world for water resources planning and development. The SWAT is one such model used most frequently for this purpose.
Bhadra River is one of the major stream of Tungabhadra, which originates in the Western Ghats of Karnataka. The Bhadra basin is a principle water source for irrigation and domestic supply to Shimogga, Davanagere and Bellary districts. It has been reported in the recent past that, the project which are on this river is not getting expected amount of water and due to which the committed demands are not met. In addition to this, the Inter-Governmental Panel on Climate Change (IPCC), has forecasted that, the peninsular India will be facing erratic rainfall pattern (IPCC, 2014). This may even worsen the situation of water availability in future. However, evaluation of consequences of changes in climate is very much necessary to develop water resources management plans. Keeping this in mind, a comprehensive scientific study is aimed to estimate the effects of climatic variations related to water availability in the selected area.

1.1 STUDY AREA AND DATA USED

Badra river basin is a branch of the river Tungabhadra. Badra River originates near to Samse in the Aroni mountain range of Kudremukh in Karnataka State, India. Badra River initially flows east, changes its way to north and joins Tunga at Kudli in Shimoga District and named as Tungabhadra. Tungabhadra River, then flows through Karnataka and also in certain part of Andhra Pradesh and joins River Krishna (Annual report of 2011-2012, Tungabhadra board). The study area, Balehonnur watershed lies in the Badra sub basin of Tungabadra River basin. The Balehonnur watershed of Badra basin lies between longitude 75˚20'00̋ E and latitude 13˚ 06' 00̋ N as shown in Figure 3.1. The study area has a geographical area of 800 sq.km.

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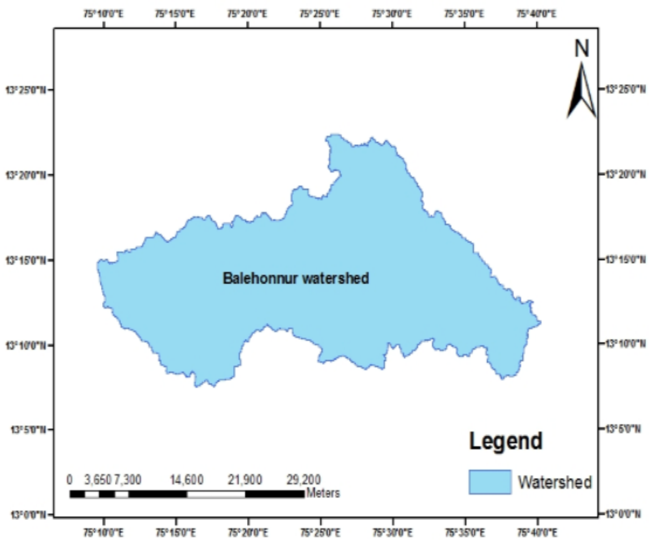

Fig-1 :Balehonnur watershed of Badra basin

1.2 DATA

Digital elevation model (DEM) is primary a input of SWAT. The DEM information with 32m resolution was downloaded from Bhuvan, Geo-portal developed by ISRO, Government of India in 2009. The meteorological data i.e. daily rainfall data of 30 years starting from 1985 till 2015 was collected from Statistical Department, Government of Karnataka Bengaluru. Daily observed flow data for the Balehonnuru Station was collected from Water Resource development organization Bengaluru. Land use and Land cover map has been prepared by using Arc GIS 9.3. Soil is classified into categories. The slope map is derived from DEM data and the soil map is downloaded from FAO (Food and Agricultural Organization, USA). The IMD data on temperature for the period 1995 to 2015 has been used for the simulation of rainfall and runoff.

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2. METHODOLOGY

SWAT model is a semi-dispersed watershed scale persistent time display with day by day time step. SWAT model involves many components such as hydrology, meteorological conditions, soil temperature, crop growth, nutrients, pesticides, sediment yield, and agricultural management practices. Basically the hydrological components of SWAT model is based on the water balance equation

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

Where,
SW_i = Soil water content at time t;
SW_o = Initial soil water content;
t=Time in days
R_{day}= Amount of precipitation on day i,
Q_{surf}= Amount of surface runoff on day i,
E_o= Amount of evapotranspiration on day i,
W_{seep}= water percolation to the bottom of the soil profile on day i
Q_{gw}= amount of water returning to the groundwater on day i

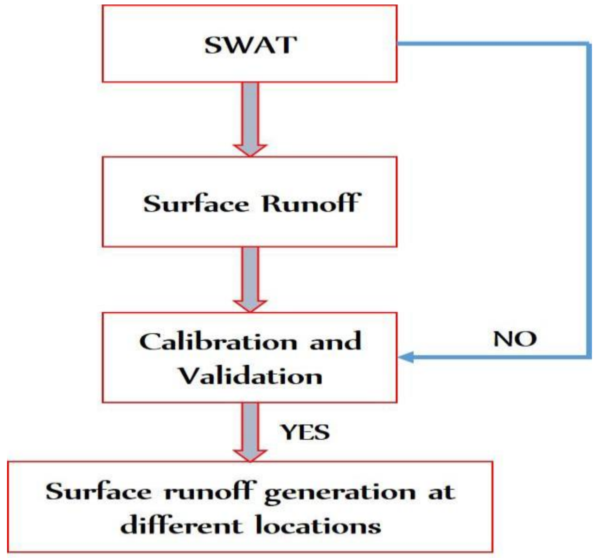

Fig -2: Work Flow of surface runoff generation

2.1 ASSESSOR's CLIMATE CHANGE CHANGE IMPACT

It is necessary to know about climate change for future period, and also to determine its impact on water resources availability.. In the present work, using model parameters on GCM outputs of RCP4.5 and RCP 8.5, precipitation and temperature data through Arc GIS were extracted. After extracting data bias correction was done using linear scale method. The Figure 2 shown below gives the workflow pattern for the estimation of water availability in future period.

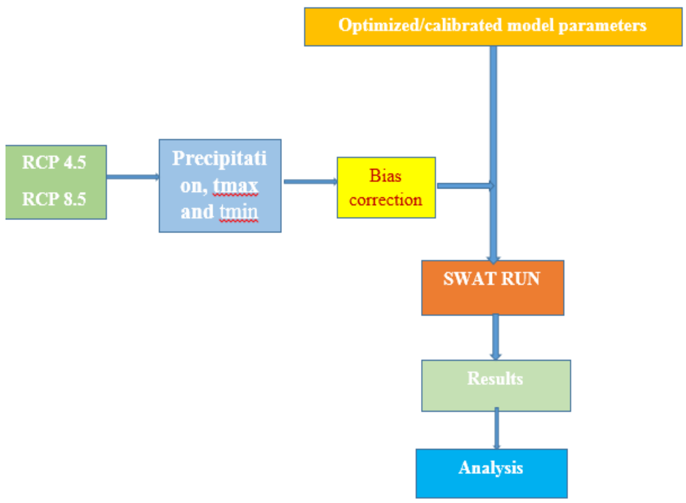

Fig -3: Work Flow of SWAT

3. SWAT MODEL SETUP AND EXECUTION:

The delineation of Bhadra basin is accomplished by uploading UTM projected DEM shown in Figure 4.

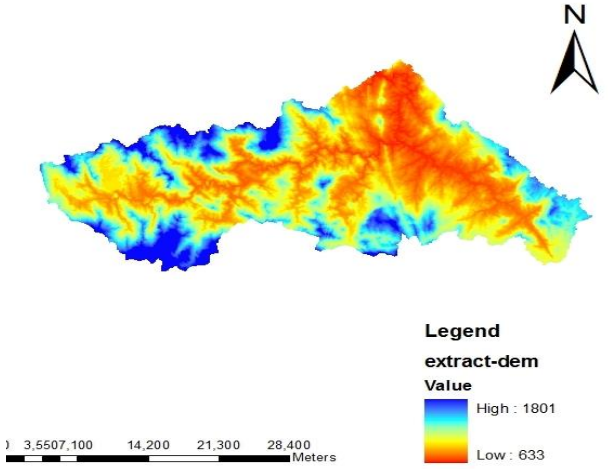

Fig-4: Digital elevation model for the study area.

Land use and Land cover map (Figure 5) has been prepared by using Arc GIS 9.3. The LULC changes are important elements of the global environmental change processes. Satellite remote sensing-based classification is the statistical technique most commonly used. The satellite image IRS P6 LISS III data of 2005–2006 periods were utilized and classified into 4 classes.

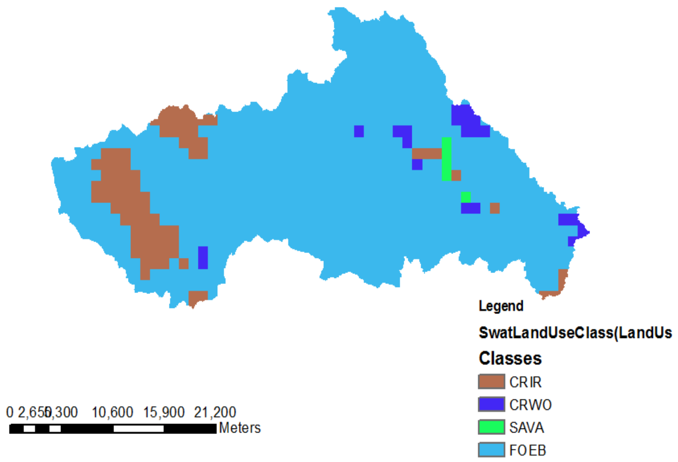

Fig-5: land use land cover map

Soil is classified into categories (Figure 6) in order to understand relationships between different soils and to determine the usefulness of a soil for a particular use. Soil absorbs rainwater and releases it later, thus regulating floods and drought

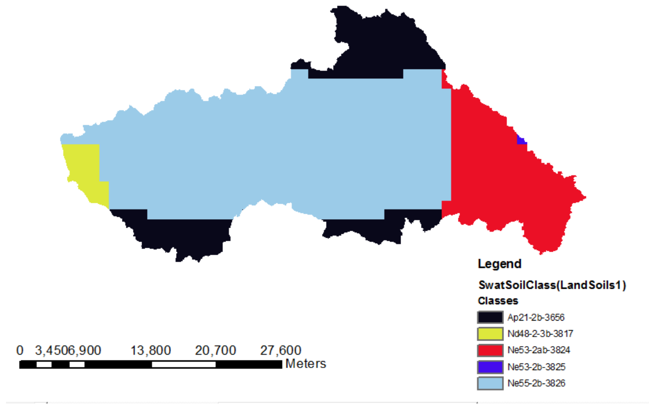

Fig -6:Map of soil classification

The slope map is derived from DEM data and The Soil map is downloaded from FAO (Food and Agricultural Organization, USA) department. The data are clipped using Arc GIS 9.3.The SRTM model has been utilized to generate the slope map of the watershed. Low slope (0–5 %) indicates presence of low rate runoff flow whereas high slope ([20 %) shows presence of high surface water flow The slope has been grouped into 4 classes: a) 0 - 5 %, b) 5 –10 %, and c) 10 – 15 % d)>15% (Figure 7).

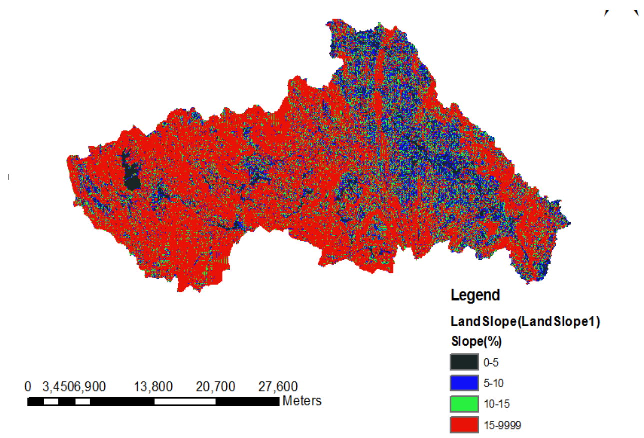

Fig-7: Slope map

Daily observed flow data (for the period 1995-2015) for the Balehonnuru Station located within the study area was collected from Water Resource development organization Bengaluru. Daily observed flow data was averaged into the monthly discharge values. These observed discharge data was used for the calibration and validation of the model. The variation of annual rainfall with the year for the period 1995-2015 is shown in Figure 8.

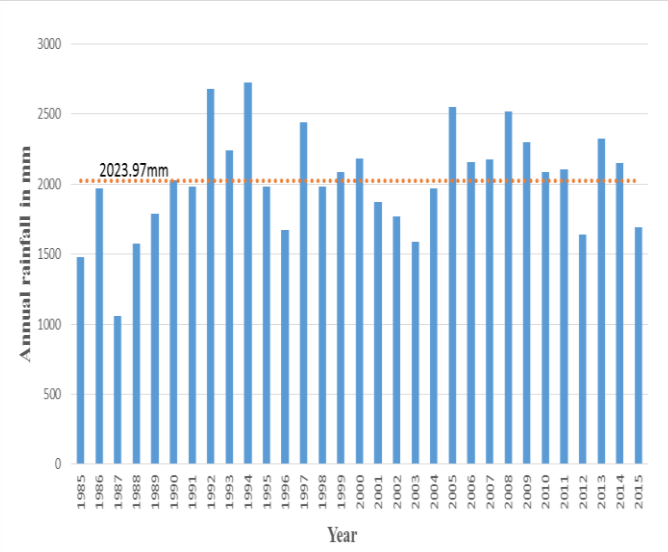

Fig-8: Variation in annual rainfall

4. RESULTS AND DISCUSSION

In the present work, the authors have used the "SWAT model" to generate surface runoff for Balehonnur catchment and also attempted to predict water availability. Calibration of the model is done for the period of 1995 to 2010 and validation is done for the period of 2011 to 2015. Before calibration of the model the values of simulated discharge were not matching with observed discharge values. The objective functions chosen for calibration purpose were R^2 and NSE. For the first trial, the values of R^2 and NSE were 0.567 and 0.50. The model was simulated for different scenarios by changing the various parameters (Table 1). Finally after calibration the values of R^2 and NSE were 0.878 and 0.8 is obtained. The Figure 9 shows the variations of discharge values after calibration and validation.

Table -1: Parameters used in Calibration of the Model

No of ranking	Parameter name	Initial value	Final value
1	Recharge_dp	0.5	1
2	CN2	77	38
3	ESCO	5	0.5
4	Soil.AWC	0.11	0.3
5	GW_Reavap	0.002	0.02
6	Sol.K	20	21
7	Alpha_Bf	0.048	0.50
8	REVAPMN	0.8	1
9	EPCO	1	1.3
10	GW_Delay	31	30
11	SURLAG	0.33	0.5

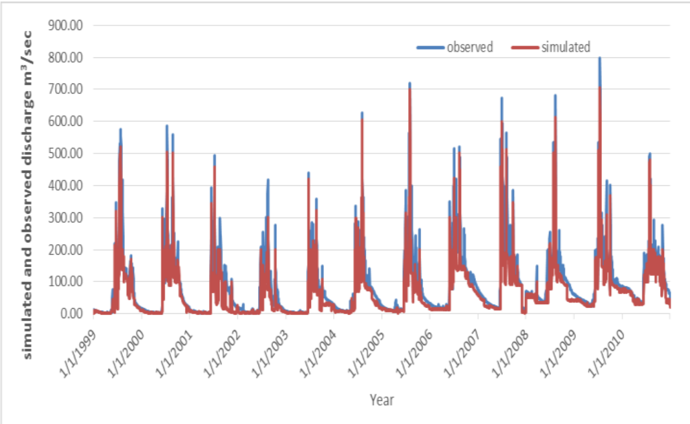

Fig-9: Comparison between observed and simulated discharge values after calibration

The validation of the model is carried out for the period 2011 to 2015. The Figure 10 illustrates the validation procedure

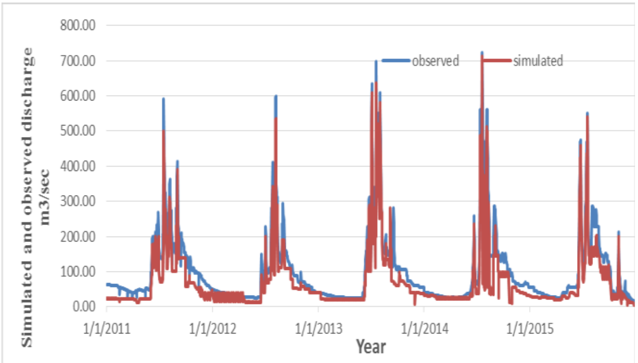

Fig -10: Variation in observed and simulated discharge values on Validation

The coefficient of determination R^2 and NSE were used to assess the model performance. In general, model simulation can be judged as satisfactory if NSE > 0.50 and typical value of R2 greater than 0.5 for stream flows. Based on the result obtained, model is assumed to be valid and further analysis of model output has been made.

The results of objective functions on calibration and validation of the SWAT model for the monthly discharge data at Balehonnuru gauging station is shown in the Table 2.

Table -2: Performance Criteria for the Calibration and Validation Periods

Performance Criteria	SWAT Calibration	SWAT Validation
R2	0.878	0.860
NSE	0.806	0.780

4.1 ESTIMATION OF WATER AVAILABILITY

The bias correction using linear scale method is done to correct the GCM predicted rainfall data as obtained from GCM output provided by the IITM (Indian institute of meteorology) stands at the scale of 0.25°X0.25°grid through observed rainfall data. The correction factors are determined by linear scaling method based on the observed and predicted data.The average rainfall as obtained by RCP 4.5 and RCP 8.5 scenario is shown in Table 3 below.

Grid no	RCP 4.5		RCP 8.5		Observed	
	2021-2050		2021-2050		1985-2015	
	Av. Rain fall	Max rainfall	Av. rainfall	Max rainfall	Av. rainfall	Max rainfall
1	1917.93	446.06	1747.61	319.35	2023.97	175
2	1690.25	278.98	1437.49	209.44	1323.22	264.66
3	3411.51	457.07	3208.90	345.91	2104.36	455.30
4	11491.8	1892.6	11023.0	1251.57	5341.95	366

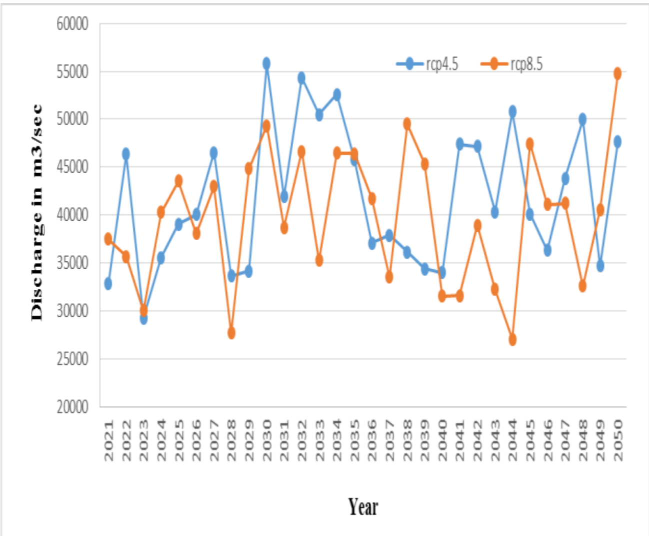

Fig -11: Annual discharge for both RCP4.5 and RCP8.5

The results shown in Table 3 we can observe that the average rainfall for the basin is more in the future period compared to observed period i.e. 1985-2015. It is also observed that the rainfall valued obtained by RCP 4.5 is more than the RCP 8.5 scenario

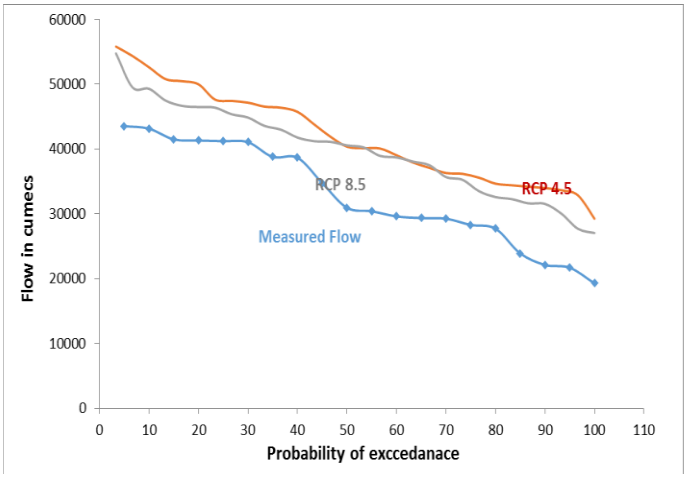

Fig -11: Frequency curve

Corresponding to different dependability.

S.No	Percentage Dependability	Deviation of discharge in comparison with the observed discharge	
		RCP 4.5	RCP 8.5
1	50	0.47	0.50
2	75	0.42	0.37
3	90	0.98	0.86

The dependable yield at 50% dependability is 47% higher in RCP4.5 and 50% higher in RCP8.5 and also it is 42% higher in RCP 4.5 and 37% higher in RCP 8.5 for the 75% trust worthiness rate .and for 90% it is 98% higher in RCP 4.5 and 86% higher in RCP 8.5. So by observing all those we can conclude that the water availability in future days will be more compare to present availability of water. In view of higher expected rainfall in the future period, it is necessary to develop plan to harvest and conserve available water resources with more efficiency.

5. CONCLUSION:

The paper reports the simulation of surface runoff for the Balehonnur catchment falling under Badra river basin using SWAT model. The SWAT model is found to give encouraging results to generate the surface runoff and predict water availability in the catchment. The calibration and validation of the model has been carried out for the period of 1999-2010 and 2011-2015 respectively. Two objective functions were used to test results of SWAT. The R^2 and NSE values was found to be 0.878 & 0.78 and 0.869 & 0.76. The water availability estimated using GCM data over estimates the runoff values when compared with observed values. However, water availability for the future period can be estimated by both the RCP 4.5 and RCP 8.5 scenario. Hence the values obtained by GCM are to be suitably reduced by multiplying factor to estimate water availability.

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