Rainfall Runoff Modeling Using SWAT Model for Chaliyr Basin Kerala, India

Rohtash[1], Dr. L. N. Thakural[2], Dr. M.K.Choudhary[3], Dipti Tiwari[4]

[1, 4] M.Tech Scholar , Water Resource Dept., MANIT Bhopal, M.P., India

[2]Scientist –C, NIH Roorkee, India

[3]Associate Professor, Civil Engineering Dept., MANIT Bhopal, M.P., India

Abstract: ***Rainfall-Runoff modeling is a mathematical representation describing the relation between rainfall and runoff to the catchment area. The rainfall runoff process is a multifaceted process as it is influenced by a number of direct and indirect factors such as precipitation distribution, evaporation, transpiration, abstraction, and topography and soil types. Moreover, detection and quantification of spatial-temporal trends and changing patterns of rainfall and hydrological modelling is essential for water resources planning, management, flood forecasting and in many other applications. There are numerous rainfall-runoff models available according to varying nature, complexity and purpose of study area. One of these hydrological model, SWAT is widely used to evaluate different parameters of the water resources namely rainfall-runoff modelling, sedimentation, eco-hydrological behavior of the watershed SWAT model has been setup to simulate rainfall-runoff for the Chaliyar river basin at Kuniyil with a catchment area of 2013.4 km².The basin was discretized into 15 sub-basin using an automated delineation routine with an input spatial data of DEM, land use/land cover, soil and slope of the Chaliyar basin. There were 103 Hydrologic Response Unit (HRUs) generated for the entire river basin. In the present study, rainfall trend analysis conducted at four different stations experienced a statistically insignificant increasing and decreasing trends for the period of 1991 to 2011. The model efficiency (R^2) value obtained was 0.69, which is considered reasonably satisfactory for estimating a basin runoff. After getting good efficacy of SWAT-run, SWAT-CUP was used to calibrate and validated the model. The SWAT model has been calibrated using daily data of 4 years (2003-2007) and validated for 4 years (2008-2011) considering 2 years of data (2001-2002) for warm up period. The model yielded satisfactory and reliable results with coefficient of determination and Nash-Sutcliffe Efficiency 0.77% & 0.75 % for calibration and 0.77% and 0.73% respectively for validation period.***

Keywords: Rainfall-runoff modeling, SWAT, SWAT-CUP, ArcGIS, Erdas

1. Introduction

The total water contained of hydrological cycle in various form remains more or less constant. The growing population and increasing standards of living are the main cause of decreasing per capita availability of fresh water over India. Hence it is necessary to achieve optimum utilization of available water resources. Further, the spatial and temporal uneven distribution of utilizable water resource makes the situation more complex. As the climate change effects on both quantity and quality of water resources, it results increasing demand for better management planning options for the optimization of available resources. Hydrological modeling is simplified description of hydrological cycle to imitate the natural system. mathematical representation describing the relation between rainfall and runoff to the catchment area. More precisely, it produces the surface discharge of hydrograph as a reply to a rainfall as an input. In other words, Hydrological modeling is representation of normal processes that control primarily the energy and water balances of a watershed. The main purpose of using hydrological modeling is to provide with information for planning and management of water resources in a sustained manner i.e. the hydrologic response of watershed to rainfall, find out the catchment yield, and runoff data are of very importantfor hydrological analysis for the purpose of water resources planning, flood forecasting, pollution control and numerous other applications. Hydrological models are classified into types: (a) Stochastic models and (b) Process-based models. Stochastic models are based on mathematical and statistical concepts to relate a particular input (e.g. rainfall) to the model output (e.g. runoff) and also tries to compute the errors in model outcomes. The stochastic hydrological models can be used for transfer functions, artificial neural networks, and others. Process-Based Models represents the physical processes (surface runoff, subsurface flow, evapotranspiration) observed in the real world. Some of the process based hydrologic models are: SWAT (Soil and Water Assessment Tool), Variable infiltration Capacity (VIC), MIKESHE model (Jingjie *et al.*, 2009)[1].The rainfall-runoff process or hydrological modeling is a intricate activity as it is influenced by a number of implicit and explicit factors such as precipitation distribution, evaporation, transpiration, abstraction, watershed topography and soil type. Hydrologic models especially simple rainfall-runoff models are widely used in understanding and quantifying the impacts of land use land cover changes and to provide information that can be used in land-use decision making. Many hydrologic models are available; varying in nature, complexity and purpose(Sidle, 2006)[2]. Various models have been developed to solve the rainfall-runoff relationship in engineering research and practices. The widely known rainfall-runoff models identified are the Rational method (Meteorological, 2012)[3], Soil Conservation Services (SCS) Curve Number method (Mishra *et al.*, 2004)[4], and Green-Amptmethod (Jiao *et al.*, 2015)[5]. In present study, an appropriate hydrological model, the SWAT model has been identified & rainfall runoff modeling has been carried out for Chaliyar river basin in Kerala state.

2. Study Area

Chaliyar river basin in Kerala, India, situated between 11^0 30'N and 11^0 10'N latitudes and 75^0 50'E and 76^0 30'E longitudes falls in Survey of India (SOI) topo sheets 58A and 49M. Chaliyar River forms the fourth largest river in Kerala, originating from the Elambalarihills, Nilgiri district of Tamil Nadu, at an elevation of about 2066m above mean sea level (MSL). The river is in nature that flows along the northern boundary of Malappuram district through Nilambur, Mambad, Edavanna, Areakode and Feroke&finally joins the Lakshadweep Sea south of Kozhikode near Beypore after flowing over a distance of about 169 kms named "Beypore" River.

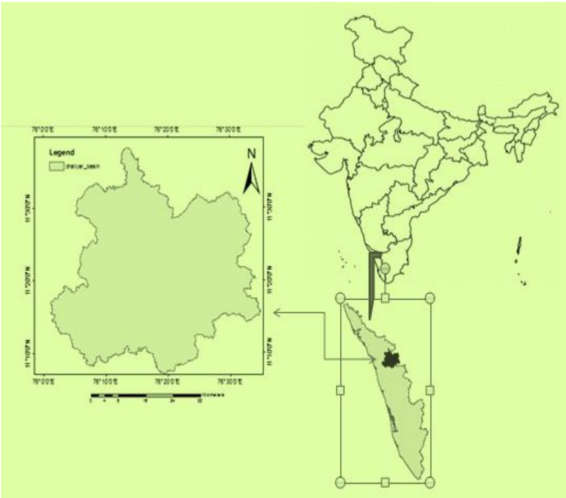

Figure (i): Chaliyar Riverbasin, Kerala, India

2.1 Climate

Kerala lies closer to the equator compared to other Indian states, Yet Kerala is bestowed with a pleasant and equable climate throughout the year generally March and April are the hottest and December and January are the coolest. The maximum temperature ranges from 22ºC to 32.9ºC and the minimum temperature ranges from 22ºC to 25.8ºC. The average annual maximum temperature is 30.9ºC and minimum is 23.7ºC. The temperature starts rising from January reaching the peak in April. It decreases during the monsoon months. On an average about 3000 mm of rainfall occurs annually in the basin. The principal rainy seasons are the southwest (June-September) and northeast (October-November) monsoons in India. The pre-monsoon months (March-May) are characterized by major thunderstorm activity and the winter months (December-February) by minimal cloudiness and rainfall (Tachikawa *et al.*, 1995)[6]. *Sahyadri*(Western Ghats) has a significant influence on the intensity and distribution of rainfall over Peninsular India. As a mountain barrier, the *Sahyadrin* polarizes precipitation along its crest. As moist airflow during the southwest monsoon ascends, the windward slope receives copious rainfall (Kokkonen *et al.*, 2003)[7]. Thus, the *Sahyadri*forms the watershed for a large number of rivers. These rivers have high run off and sediment load during the monsoon months. Southwestern India experiences a tropical climate with seasonally reversing wind patterns and large variations in precipitation. Along the west coast of India, the southwest (SW) monsoonal winds of oceanic origin are established by mid-May. During the SW monsoon, winds blow from southwest during May-September, but change to a north easterly direction during the northeast (NE) monsoon. These winds continue to grow strong until June, when there is a sudden burst or strengthening of the southwest winds. The winds are the strongest during July and August, but become weak in September, ahead of the NE monsoon, which lasts through October and November. The wind speed is generally 15-20 km/hr during the SW monsoon, but lower (10-12 km/hr) during the NE monsoon. Temperature in the region ranges between 23° and 37°C(Abdulla, Lettenmaier and Liang, 1999)[8]. Whereas the winter monsoon (October-January) accounts for about 50-60 cm rainfall. Temperature in the region ranges between 23° and 37°C. Rivers in mountainous terrains commonly carry higher sediment loads and yields than do upland rivers, whose loads and yields in turn, are higher than those of lowland rivers. A better relationship was documented between the annual variability of rainfall and sediment transport. The positive relationship among rainfall, run-off and sediment discharge suggests that precipitation and run-off exert a first order control on the sediment discharge of Kerala Rivers (Cheikha and Gueddari, 2008)[9]. Tectonic uplift/subsidence alters the fluvial regime with resultant changes in rates of sediment erosion and deposition.

2.2 Physiography

The Chaliyar river basin can be physio graphically divided into four well-defined units viz., highland, midland, low land and coastal plains. Based on the relief pattern and topographic alignment, the basin can be divided into five physiographic sub-units. (i) High ranges with an elevation ranging from 600m to 2600m. This form part of the Wayanad plateau and the high hill ranges with steep slopes of the Western Ghats, (ii) Foot hills of Western Ghat with elevation ranging from 300 to 600 m above MSL comprise rocky mounds and slope areas of the high hills, (iii) Upland regions consisting of the ridges and valleys, isolated hills with altitudes ranging from 100-300 m. At places these units are lateritic, (iv) Mid-land zone with elevation ranging from 10 to 100 m characterized by rolling topography with lateritic ridges, isolated hills and alluvial valleys, and (v) Low-land characterized by coastal stretches and alluvial plains with an elevation of < 10 m

2.3. Hydrometric Stations

In this study area of Chaliyar river basin contains two rainfall gauges namely **Ambalavaya**l and **Nilambur** with as outlet as **Kuniyil**(Id-KB00J3) is selected for the rainfall-runoff model

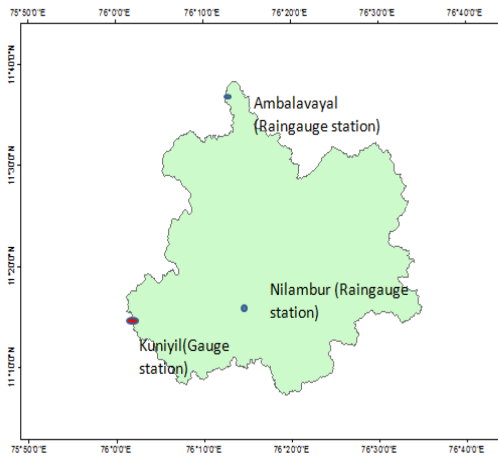

Figure (ii) Hydrometric stations in the study area

3. Data Used

Three Geographic Information System (GIS) data layers were used to parameterize SWAT: a gridded 30 m digital elevation model (DEM), a soil dataset from NBSS and a land use map . All GIS data were downloaded and prepared from deferent sources. SWAT also requires daily climate data, including precipitation, maximum air temperature, minimum air temperature, solar radiation, wind speed, and relative humidity to drive the water balance model.The detail of the all type of data is given below table:

Table (i): Data uses and sources

TYPE OF DATA	LOCATION	PERIOD OF RECORD	SOURCES
Digital Elevation Model	Chaliyar River basin, Kerala		https://earthexplorer.usgs.gov SRTM DEM
Land use/Land Cover	Chaliyar River basin, Kerala	18 Dec 2016	https://earthexplorer.usgs.gov
Soil map			NBSS publ. 48b
Precipitation Data	Chaliyar basin,Kerala 1-Nilambur 2-Ambalayaval	2001-2011	http://www.imd.gov.in
Discharge data	Kerala (Kuniyil Gauge station)	2001-2011	CWC (Central Water Commission)
Max , Min temperature, Relative humidity, Solar Radiation, Wind speed	Chaliyar River basin, Kerala	2001-20011	https;//globalwearther.tamu.edu

4. Software Used

4.1 SWAT Model

SWAT model is a soil water assessment tool. The model was developed by Jeff Arnold for the (USDA) agricultural research service. SWAT is multitasking software developed to assess the impact of land management practice on water, sediments and agricultural yield. SWAT is a physically based model that requires two types of data i.e. spatial data and meteorological data.

(I) Spatial Data
1) DEM (Grid Format)
2) Land Use Map(Grid Format)
3) Soil Map(Grid Format)

(II) Meteorological data
1) Daily Rainfall (mm)
2) Daily Min and Max temperature (^{0}C)
3) Daily Relative Humidity Data(Optional)
4) Daily Wind Speed Data (Optional)
5) Daily Solar Radiation Data (Optional)

All the physical processes like sediment movement &water, crop growth are directly modeled by SWAT using this input data and thus a simulation can be performed. The various hydrological processes simulated by the model are precipitation, infiltration, surface runoff, evapotranspiration, lateral flow and percolation. The model uses a common structure as hydrological model (HYMO) (Ye, Jakeman and Young, 1998)[10] for runoff routing. Specific model that contributed in the advancement of SWAT model were CREAMS (Chemical Runoff & Erosion from Agricultural Management system) (Schellekens *et al.*, 2004)[11] and EPIC (Erosion Productivity Impact Calculator) (Hueso-gonzález *et al.*, 2015)[12].

SWAT simulation is based on water balanced equation-

$$SW_t = SW_o + \sum_{i=1}^{N}(R_{day} - Q_{surf} - E_a - W_{seep} - Qgw \text{.................. (i)}$$

Where
SW $_t$ = final soil water content in mm of H_2O
SW $_o$ = initial soil water content in mm of H_2O
T = time in days
R $_{day}$ = Amount of precipitation of ith day in mm of H_2O
Q $_{surf}$ = Amount of surface runoff of ith day in mm of H_2O
E$_a$= Amount of evaporation of ith day in mm of H_2O
W $_{seep=}$ Amount of water entering the vadose zone from the soil profile of ith day in mm of H_2O
Q $_{gw}$= Amount of return flow of ith day in mm of H_2O.

For calculating the surface runoff the SCS curve number (CN) is used in the model. There are two equations(Li *et al.*, 2014)[13]. First equation expresses the relation between runoff, rainfall and retention parameters whereas the second equation relates the retention parameters to curve number (CN).

$$Q_{surf} = \frac{(R_{day} - 0.2S)^2}{(R_{day} + 0.8S)} \quad \text{...... (ii)}$$

$$S = 25.4\left[\frac{100}{CN} - 10\right] \quad \text{....... (iii)}$$

Where-
R $_{day}$ = Amount of precipitation of ith day in mm of H_2O
S = Retention parameter

4.2 Calibration by SWAT Cup

SWAT cup means SWAT calibration and uncertainty procedures. It is a software that helps in the calibration, validation and sensitivity analysis of the SWAT model. There are various methods that are available as Sufi2, PSO, Glue, Parasol, and Mcmc. In the process of calibration all the programs like sufi2 and glue etc utilizes the SWAT input file and modifies the given parameters according to the inputs(Devi, Ganasri and Dwarakish, 2015)[14].GLUE was invented partly to allow the non uniqueness of the parameter sets in the estimation of model parameters in over parameterized models. The procedure of GLUE uses some assumption that there is no inverse solution in over parameterized model hence the value of unique set of parameters which optimize goodness of fitting criteria is not possible. The technique is based on the estimation of the weights or the probabilities associated with different parameter set. GLUE can currently support a likelihood measure expressed as the *Nash-Sutcliffe* coefficient.PARASOL method combines the objective function into a global optimization criterion (GOC) and then minimizes this objective function or a GOC using SCE-UA algorithm. This algorithm is a well known algorithm to minimize a single function for up to 16 parameters. The type of objective function used in parasol is limited to the sum of the square of the differences of the measured and simulated values after rankings.

SUFI2 (The Sequential Uncertainty Fitting ver. 2) program is same as GLUE in concept but it utilizes a different methodology to obtain posterior parameters from previous. In SUFI2 the uncertainty of parameters accounts all sources of uncertainty such as uncertainty in driving variables, conceptual model, parameters and measured data etc. The degree of uncertainties in the model is denoted as P factor which is the measured data bracketed by the 95% prediction uncertainty (95PPU). The 95PPU is calculated at the 2.5% and 97.5% levels of the cumulative distribution. Another measure that shows the strength of the calibration is d factor or R factor which is the ratio of the average thickness of 95ppu band and the standard deviation of the measured data. For a good calibration in SUFI2 this parameter should be close to 0. For an ideal situation P *factor* should be 100% and a *d-factor should be near* to zero. When acceptable values of *d-factor* and *p-factor* are reached, then the parameter uncertainties are the desired parameter ranges. Further goodness of fit can be quantified by the R^2 or Nash-Sutcliff (NS) coefficient between the observations and the final best simulation.

- The main advantage of SWAT cup is to combine various calibration and uncertainty analysis in a single platform for SWAT
- It made the calibration procedure simpler for professionals as well as the students. It provides a faster way to perform the calibration
- The learning of this program is also very simple.

5. Methodology and SWAT Inputs

In SWAT model various inputs are required regarding the study area provided by the some government or private agencies that is used to simulate the runoff, sediments etc. In the present study Arc SWAT is used to calculate the net runoff for Chaliyar basin. For calculating the runoff at the gauge station we have to set up the model first and then we have to provide various inputs that runs SWAT. The inputs are generally regarding the topography, land-use/land-cover, soil, climate and rainfall etc.The various input data used in this study are given below

5.1 Digital Elevation Model (DEM)

DEM is a digital model or a 3D representation of a particular area. A DEM provides the details in all x, y and z direction at each latitude and longitude. A DEM can be represented as raster (A grid of square) or as a vector based triangular irregular network (TIN). The TIN is a Digital Elevation Model that is referred as the primary or measured dataset whereas the Raster DEM is the secondary or computed DEM. The DEM can be acquired through various techniques such that photogrammetry, land surveying etc. (Chen, Chen and Xu, 2007)[15]. In the figure given below the DEM of the study area is given which is being provided by the usgsearthexplore site. The DEM is required to project before start editing in Arc SWAT. In this present study, DEM of Chaliyar River basin is downloaded from the USGS explorer website. Thereafter, the DEM has been projected to was WGS 1984_UTMZone_43N co-ordinate system in the arc GIS. The elevation in the Chaliyar river basin range from 4m (minimum) to 2607m (maximum)

5.2 Stream Network

By using the DEM first of all we draw a stream network in the study area that defines the flow direction using spatial analyst tool hence we get a digitalized stream network data set which is superimposed into the DEM to find the flow at each point after defining the flow direction we calculate filling & flow accumulation under Hydrology section of spatial analyst tool.

5.3 Land Use/ Land Cover Map

Erdas Imagine 9.2 software is used for preparing Landuse/land cover map. Land use change has great influence in rainfall-runoff modeling. LULC is very important input to the model as it affects the runoff, evaporation, surface erosion etc.Thelandsat OLI 8 image of 2016 has been downloaded from USGS Earth explorer for Land use/Land cover classification. The Chaliyar river basin is manually classified into fiveclasses. In the study area of more than 50% area is covered with deciduous and evergreen forest. Which are sub categorized as Deciduous, Evergreen and mixed. The study area is dominated by deciduous forest with an area of about 49.52 % and the classification of another class is water. Water estimation is depends upon the scale and resolution of the remote sensing that can be used for various purposes like runoff and precipitation studies. The water bodies of any study area may be categorized as streams, canals, reservoir, lake, bays etc. In the study area .048 % of area is being covered up by the water bodies. Wetland is the area in which water table is at near or above the land surface for a larger area. Barren land is the land having vegetation less than one third of the total area and the soil found in such area is generally dry and sandy. The percentage of the various land use available in the study area is given in the table(ii)and also shown in figure (v).

Table ii: Distribution of land in study area

S.NO.	Category	Percentage of total area	Land class
1	Water	0.048	WATR
2	Forested-Mixed	4.113	FRST
3	Barren	11.303	BARR
4	Forest-Evergreen	35.015	FRSE
5	Forest-Deciduous	49.522	FRSD

5.4 Soil Map

The soil map was prepared from from **National Bureau of Soil Survey and Land Use Planning (NBSS&LUP)maps.** The data used by SWAT can be divided into two groups, physical and chemical characteristic. The physical property of soil shows the movement of water and air through the soil profile and has a measure effect of cycling of water within HRU. Input for chemical characteristics is used to fix an initial level of chemical in soil. The soil input (.sol) file defines the physical properties to all layers. The soil of the Chaliyar river basin is shown in figure(vi) and its distribution is given in table (ii).

Table iii: Types of Soil in Study Area

S.No.	Category	Classification	Percentage of total
1	CL-LS-MD-D	Loam	64.486
2	FL-LS-MD-D	Loam	35.514

5.5 Slope Input Map

Soil mapping is the procedure of delineating natural bodies of soils, and it is basically classifying and grouping the delineated soils into map units, and finding soil properties for deciphering and explaining soil spatial distribution on a map. Slope map shows the rate of change of elevation. Slope also shows the path of drainage and the direction of the flow. In SWAT it is also used to create HRU. In the present study area, mainly three slopes have been taken one is 0-30 which covers 62.9% of the total area & second is 30-55 which covers 24.18% of the total area and third is 55-90 which cover 10.22 The slope of the Chaliyar river basin is shown in figure (vii).

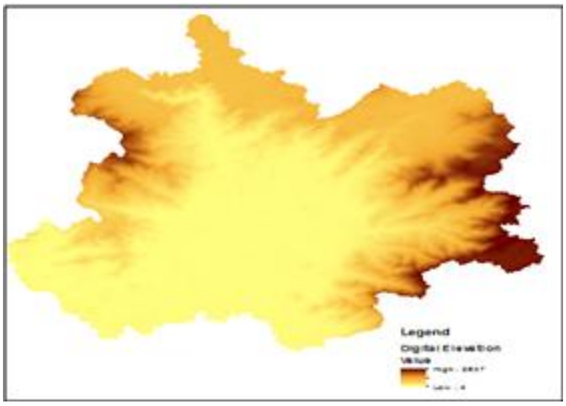

Figure (iii): Dem of Study Area

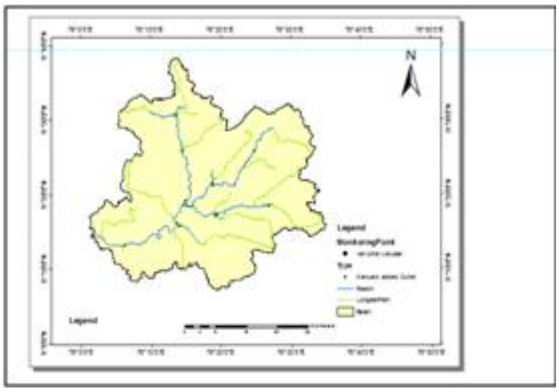

Figure (iv): Stream Network of Study Area

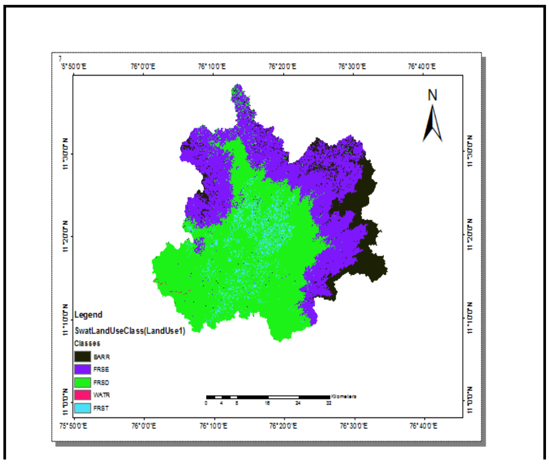

Figure (v): Land-use Map of the Study Area

Figure (vi): Soil Map of the Study Area

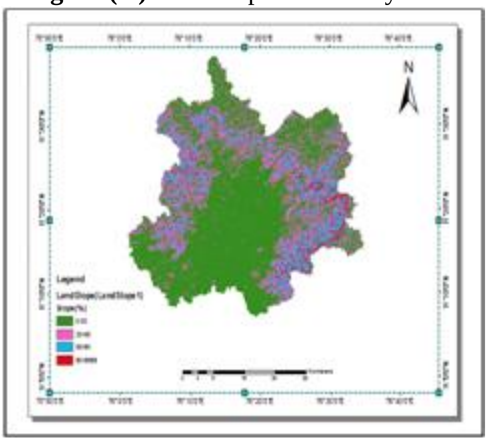

Figure (vii): Slope Map of Study Area

5.6 Meteorological Inputs

The Various types of meteorological data collected at gauge station namely minimum and maximum temperature ranges, precipitation, solar radiation, relative humidity, wind data are firstly converted into txt format then provided to SWAT model as input these data are useful in the simulation of the model that is performed in a certain interval. The data among this parameter, for which data is not available, may be downloaded from website http://globalweather.tamu.edu. The website provides the SWAT input files for the climate data such as minimum and maximum temperature ranges, precipitation, solar radiation, relative humidity, and windfor a period of 11 year (2001 to 2011)

6. Results & Discussion

The various output of SWAT model regarding sensitivity, calibration and validation are discussed below-

6.1 SWAT-RUN

To obtain the output from the model, it should be properly simulated. In this present study model simulation was done for a period of 7 years, starting from 1st January 2001 to 31st December 2007. Two year of warm up period was also considered for better simulation performance. After the SWAT run, simulation outputs were obtained with efficiency that is-

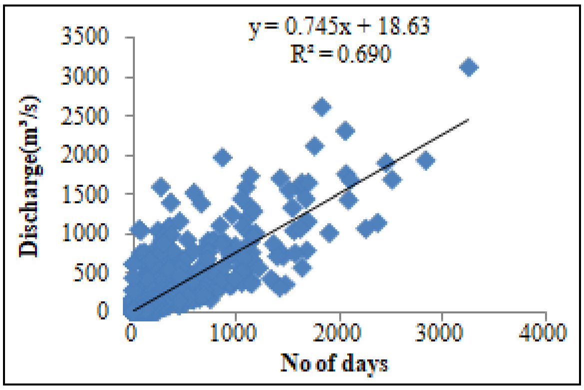

Figure viii: Observation versus simulated flow rate during SWAT-Run

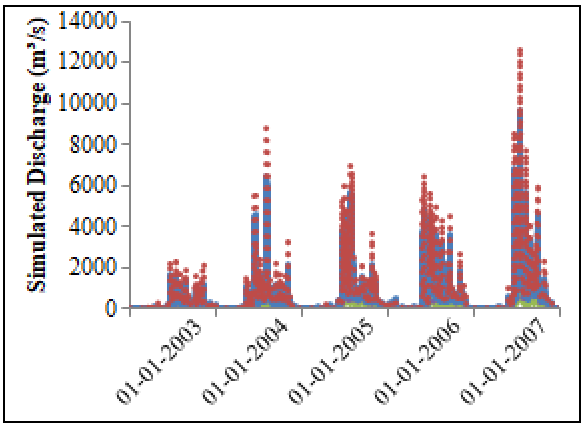

Figure ix: Comparison of observed and simulated runoff Hydrograph during SWAT-RUN

In figure (ix) line shows best fit line of simulated discharge and blue line shows discharge data. After running the model with good accuracy based on the sensitivity analysis, calibration and validation was performed.

6.1.1 Calibration Results

Once the SWAT model run with good accuracy and sensitive parameters were optimized the model was calibrated for the inflow data of Chaliyar basin for the period of 2003-2007. During the calibration numerous iterations was run to find the most favorable range of parameters until the observed and simulated flows appropriately matches to each other. These optimum values of simulated flow shows the performance and the accuracy of the model. It was seen that the observed and simulated values of the calibrated model matched reasonably well which is being shown in figure (x). The time series plot of the measured daily data simulated during the calibration period is given in figure (xi). Various parameters showing the accuracy of SWAT model are as follows.

- R^2 = 0.77
- NSE = 0.75
- P Factor = 0.21
- R Factor = 0.13

6.1.2 Validation

The validation of the model is done by four year inflow data (2008 to 2011) ofChaliyar basin starting from. The comparison of observed and simulated flow is given in fig.(xii)And the time series plot of the monthly simulated data during the validation period of 2008-2011 is given in fig(xiii). The parameters that shows the accuracy of the model is given as.

- R^2 = 0.765
- NSE = 0.73
- P Factor = 0.13
- R Factor = 0.12

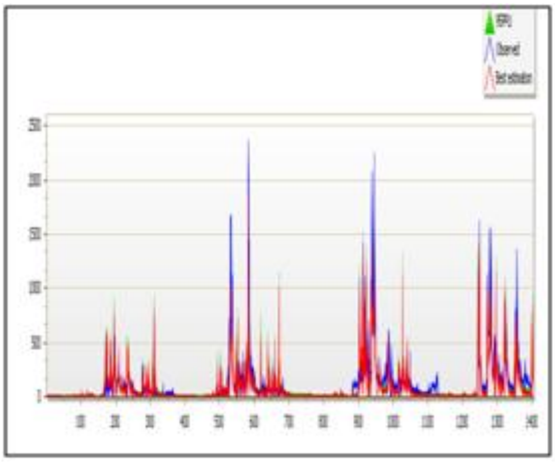

Figure x: Comparison of observed and simulated daily runoff Hydrograph during calibration

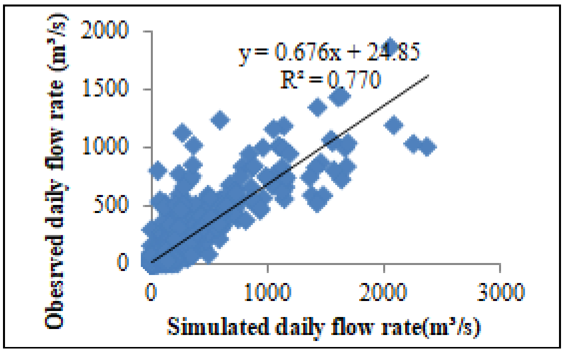

Figure xi: Observation versus simulated flow rate during calibration period

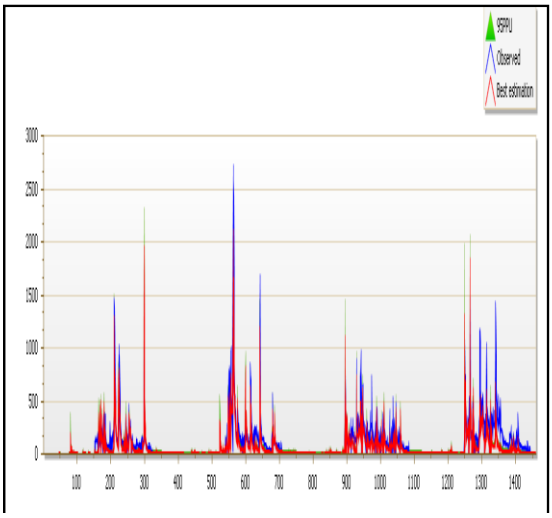

Figure xii: Comparison of observed and simulated daily runoff Hydrograph during Validation

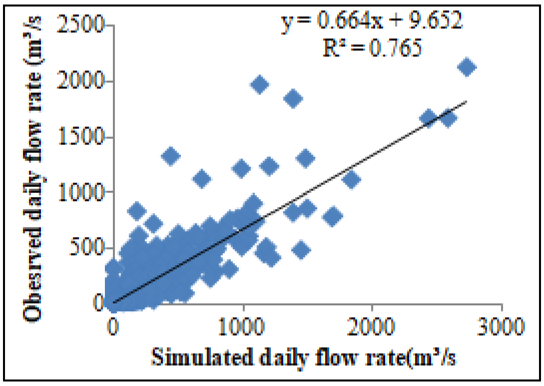

Figure xiii: Observation versus simulated flow rate during calibration period

7. Conclusion

Hydrological modeling is of foremost importance for appropriate planning, designing and decision making activities of water resources. A simple, logistic and systematic modeling of Rainfall-Runoff is an important & challenging issue in recent changing environments to properly manage water resources for socio economic development of the society in the region. Rainfall-Runoff for a basin is an important hydrological study as these results are required in the most hydrological analysis for the purpose of water resources planning, development & management. In the present study, a lumped conceptual model of SWAT model has been used. Rainfall –runoff modeling for Chaliyar river basin, Kerala, India with a basin area of 2013 km².The hydrological model SWAT model has also been successfully applied for modeling hydrological characteristic of the Chaliyar basin. It is a useful tool to use in water management models on large scale modeling with middle and long term simulation periods. The model yielded satisfactory and reliable results with coefficient of determination and Nash-Sutcliffe Efficiency 0.77 &0.75 % respectively for calibration and validation these value are .77 & .73 respectively . The capability of the model was revealed by a good match of simulated data with the observed data and a good overall agreement of the shape of the hydrograph with respect to timing, rate and volume.

Conflict of Interest: All the authors here declare that they have no conflict of interest.

Funding: There is not any funding related to this work.

Ethical approval: This research paper does not contain any experiment that is performed on humans or animals by any of the authors.

References

[1] Jingjie, Y. U. et al. (2009) ‘Slope runoff study in situ using rainfall simulator in mountainous area of North China’, (40371025), pp. 461–470. DOI: 10.1007/s11442-009-0461-x.
[2] Sidle, R. C. (2006) ‘Storm flow generation in forest headwater catchments : a hydro geomorphic approach’, 128, pp. 115–128.
[3] Meteorological, P. (2012) ‘Development and Application of an Atmospheric-Hydrologic- Hydraulic Flood Forecasting Model Driven by TIGGE’, (41105068), pp. 93–102. DOI: 10.1007/s13351-012-0109-0.1.
[4] Mishra, S. K. et al. (2004) ‘Catchment area-based evaluation of the AMC-dependent SCS-CN-based rainfall–runoff models’, 0(July), pp. 1–19. DOI: 10.1002/hyp.5736.
[5] Jiao, P. et al. (2015) ‘Improved SCS-CN Method Based on Storage and Depletion of Antecedent Daily Precipitation’, pp. 4753–4765. DOI: 10.1007/s11269-015-1088-6.
[6] Tachikawa, Y. et al. (1995) ‘of Hydraulic Engineering, Estimation of River Discharge using Xinanjiang Model’, 39, pp. 91–96.
[7] Kokkonen, T. S. et al. (2003) ‘Predicting daily flows in ungauged catchments : model regionalization from catchment descriptors at the Coweeta Hydrologic Laboratory, North Carolina’, 2238(October 2002), pp. 2219–2238. DOI: 10.1002/hyp.1329.
[8] Abdulla, F. A., Lettenmaier, D. P. and Liang, X. (1999) ‘Estimation of the ARNO model baseflow parameters using daily streamflow data’, 222, pp. 37–54.
[9] Cheikha, L. Ben and Gueddari, M. (2008) ‘L ’’, 19(3), pp. 155–162
[10] Ye, W., Jakeman, A. J. and Young, P. C. (1998) ‘Identification of improved rainfall-runoff models for an ephemeral low-yielding Australian catchment’, 13, pp. 59–74.
[11] Schellekens, J. et al. (2004) ‘Stormflow generation in a small rainforest catchment in the Luquillo Experimental Forest, Puerto Rico’, 530(January 2001), pp. 505–530. DOI: 10.1002/hyp.1335.
[12] Hueso-gonzález, P. et al. (2015) ‘Geomorphology Overland flow generation mechanisms affected by topsoil treatment : Application to soil conservation’, Geomorphology. Elsevier B.V., 228, pp. 796–804. DOI: 10.1016/j.geomorph.2014.10.033.
[13] Li, Z. et al. (2014) ‘Comparative Study on the Performance of SWAT and Xin ’ anjiang Models in Xunhe Basin SWAT

模型和新安江模型在汉江旬河流域的应用比较研究’, (August), pp. 307–314.

[14] Devi, G. K., Ganasri, B. P. and Dwarakish, G. S. (2015) ‘A Review on Hydrological Models’, 4(Icwrcoe), pp. 1001–1007. DOI: 10.1016/j.aqpro.2015.02.126.

[15] Chen, X., Chen, Y. D. and Xu, C. (2007) ‘A distributed monthly hydrological model for integrating spatial variations of basin topography and rainfall’, 252(April 2006), pp. 242–252. DOI: 10.1002/hyp.