Estimation of water balance components of Patapur Micro Watershed in the Tungabhadra River Basin using QSWAT Model in QGIS environment

ABSTRACT

Aims: Estimation of water balance components of a micro watershed by employing efficient calibrated and validated SWAT model helps to understand each components of water balance and are important to plan agricultural water management, climate change impact assessment, flow forecasting, water quality assessment etc. This water balance study minimizes possibility of drought and mismanagement, and hence will lead to a proper utilization of accessible water resource.

Place and Duration of study: In the present study, QSWAT hydrological model was calibrated and validated using measured runoff data from the outlet of the micro watershed and then put to use for long term simulations in Patapur micro watershed, Raichur District, Karnataka using weather, land use and land cover, soil and digital elevation model for the period of 37 years (1980-2016).

Methodology: The QSWAT model was set up using the input data of Patapur micro watershed and was accurately calibrated and validated using the measured runoff data. The calibrated was used for long term simulation from 1980-2016 and then water balance components of the micro watershed was estimated.

Results: The results revealed that the QSWAT model performed better in simulating the runoff and other water balance components. The daily calibration statistics results for behavioral parameters in SWAT-CUP for stream flow discharge during the period 2012-2014 are R^2, NS, PBIAS and RSR values between measured and simulated by model was found to be 0.88, 0.87, -21.30 and 0.36, respectively indicating the model performance for daily calibration was very good in terms of both R^2 and NS value as their value being >0.75 as per the performance ratings of hydrological model. And also, in terms of PBIAS and RSR value the model performance was found to be satisfactory respectively. The negative PBIAS value showed that the model had slightly over predicted the discharge and goodness of fit.

1. INTRODUCTION

Soil and water are vital natural resources for human survival. Growing world population and increasing standard of living are placing tremendous pressure on these resources. Because the soil and water resources being finite, their optimal management without adverse environmental consequences are necessary to assure sustained development. There is growing realization throughout the world that no longer one could afford to misuse these resources. Furthermore, these resources have to be managed using an integrated watershed approach.

Water resource development is the basic and crucial infrastructure for a nation’s sustainable development. To utilize water in a sustainable manner, it is necessary to understand the quantity and quality in space and time through studies and researches major hydrological processes can be quantified with the help of water balance equations. The component of water balance of a watershed is influenced by climate, and the geographical characteristics of the watershed such as topography, land use and soil. Consideration of the relationship between these physical parameters and hydrological components is very essential for any water resource development related work (A.A. Shawul et al., 2013).Since the hydrologic processes are very complex, their proper comprehension is essential and therefore, watershed based hydrological models are widely used.

The semi-arid region including Raichur District of Karnataka state where the micro watershed is located is characterized by uneven and erratic distribution of rainfall. The year to year fluctuations in rainfall as well as the fluctuations within the monsoon season governs the crop growth its development and yield potential. Even in monsoon months also crops are subjected to moisture stress due to occasional dry spells. The rainfall distribution is erratic making the crop vulnerable to abiotic stress beyond management level even during monsoon. The rainfall pattern including intensity and distribution largely decides the crop planning and agronomic practices. Hence, the scientific study on the quantum, intensity and distribution of rainfall would help enable the farming community to adjust or modify the cropping programs as well as the relevant cultural operations (Shanwad *et al.,* 2015).

Soil and Water Assessment Tool (SWAT) is an efficient watershed model which is used to evaluate stream flow, transportation of sediment and nutrients. Further it has been widely used since 1993 for issues related to watershed and hydrology (Arnold *et al.*, 1998). SWAT is a hydrological model functioning on a time step of daily or monthly periods. In addition, it has been all along used for evaluating the impact of climate change and anthropogenic factors on stream flow, chemical and sediment yields in stream network extending to scale of larger river basins (Arnold *et al.*, 1998). QSWAT has been developed for the watershed modeling with hydrological features, organization manipulation and storage of the related spatial and temporal data with an interface in QGIS.

Therefore, to test the capability of the model in determining the effect of temporal variability of the micro watershed on water balance, QSWAT with QGIS interface was selected to predict the historical water quantity data in the micro watershed from 1980 to 2016. The time series data on climate and runoff yield was measured at the gauging site (out let) of the micro watershed and were used to calibrate and validate the QSWAT model and to assess its applicability in simulating runoff yield from the micro watershed and to estimate water balance components of the micro watershed. The water balancing components helps in water budgeting, gives brief idea about watershed characteristics, this further can be used to predict the availability of water and so can help in water resource management (Akshata M. et. al., 2020).

2.0 MATERIALS AND METHODS

2.1 Description of the study micro watershed

The present study was carried out in the Patapur micro watershed (WS-Code: 4D3A4B1e) covers a total geographical area of 488.75 ha, which is part of the Tungabhadra sub basin and falls within the North-Eastern dry zone (Zone-2 of Region-1) of Karnataka and lies between 16˚ 07' 35.9" N latitude and 76^0 51′ 33.3" E longitudes to 16˚ 08′ 22.3" N latitude and 76˚ 53′ 27.7" E longitudes with an average elevation of 460 m above mean sea level (MSL) altitude in the Raichur District, Karnataka, India. Elevation in the watershed ranges from 432 m to 546 m with an elevation difference of 114 m from head to toe of the watershed. It consists of granite, composite gneisses and basalt rock. The mean maximum temperature varies from 30.3˚C in December to 40.6˚C in May while the minimum temperature ranges from 15.7˚C in December to 25.3˚C in May. Most of the annual rainfall is received during the south-west monsoon in the study area. The location map of the micro watershed is shown in Fig.1

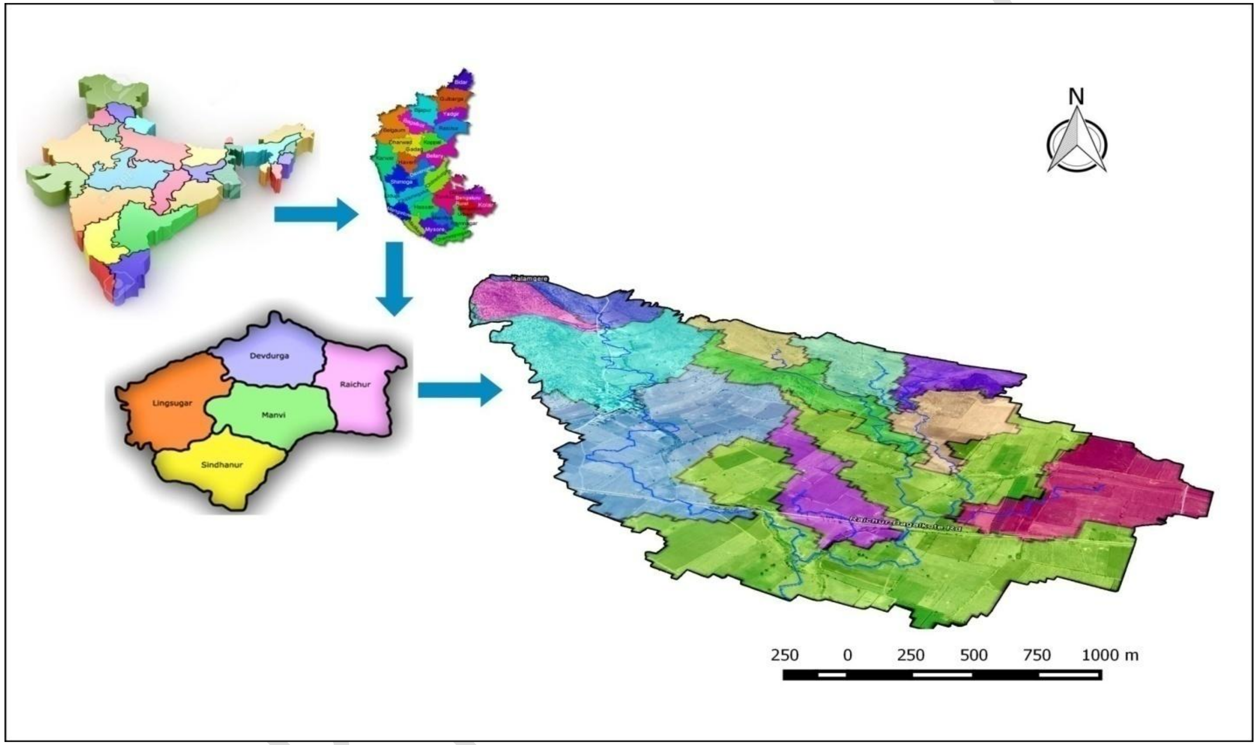

Fig. 1.Location map of Patapur microwatershed in the Raichur district of Karanataka

2.2 SWAT MODEL INPUT DATA PREPARATION AND ORGANIZATION

The different attributes of soil such as number of layers, structure, texture, hydrologic soil group, permeability, soil rooting depth, maximum depth of soil layer, bulk density, soil available water content, soil hydraulic conductivity, soil albedo and soil erodibility factors were collected and prepared in map format. The digital soil raster map with their mapping units were linked with soil ID as shown in lookup table (Table 1) and reclassified. The spatial distribution of various soil mapping units and soil textural distribution along with their nomenclature is shown in the Fig. 2 and Fig 3.

Table 1 Soil lookup tables used in QSWAT

Sl. |No.	SOIL_ID	SNAM
1	110	PTR5mB2g0R0
2	115	PTR5mB2
3	120	PTR3mB2
4	125	PTR5mB2g1R0
5	130	PTR4mB2
6	135	PTR5mC2
7	140	PTR1cD3g2R2
8	145	PTR3cC3
9	150	PTR1hE3g2R1
10	155	PTR5hC2
11	160	PTR2hD3g2R2
12	165	PTR1hE3g2R2
13	170	PTR1hF4g2R2
14	175	PTR3hC2
15	180	PTR3hD3
16	185	PTR1hG3g2R2
17	190	PTR4hB2
18	195	PTR6hB2g2S1
19	200	PTR5cHAB1
20	205	PTR6cC2
21	210	PTR5cD3
22	215	PTR1cF3R4
23	220	PTR3cD3
24	225	PTR3cD3g0S0
25	230	PTR3cD3g2R2

26	235	PTR5hD3
27	240	PTR3cD3g2S1
28	245	PTR4cD3
29	250	PTR2cD3
30	125	PTR5mB2g1R0
31	130	PTR4mB2
32	135	PTR5mC2
33	140	PTR1cD3g2R2
34	145	PTR3cC3
35	150	PTR1hE3g2R1

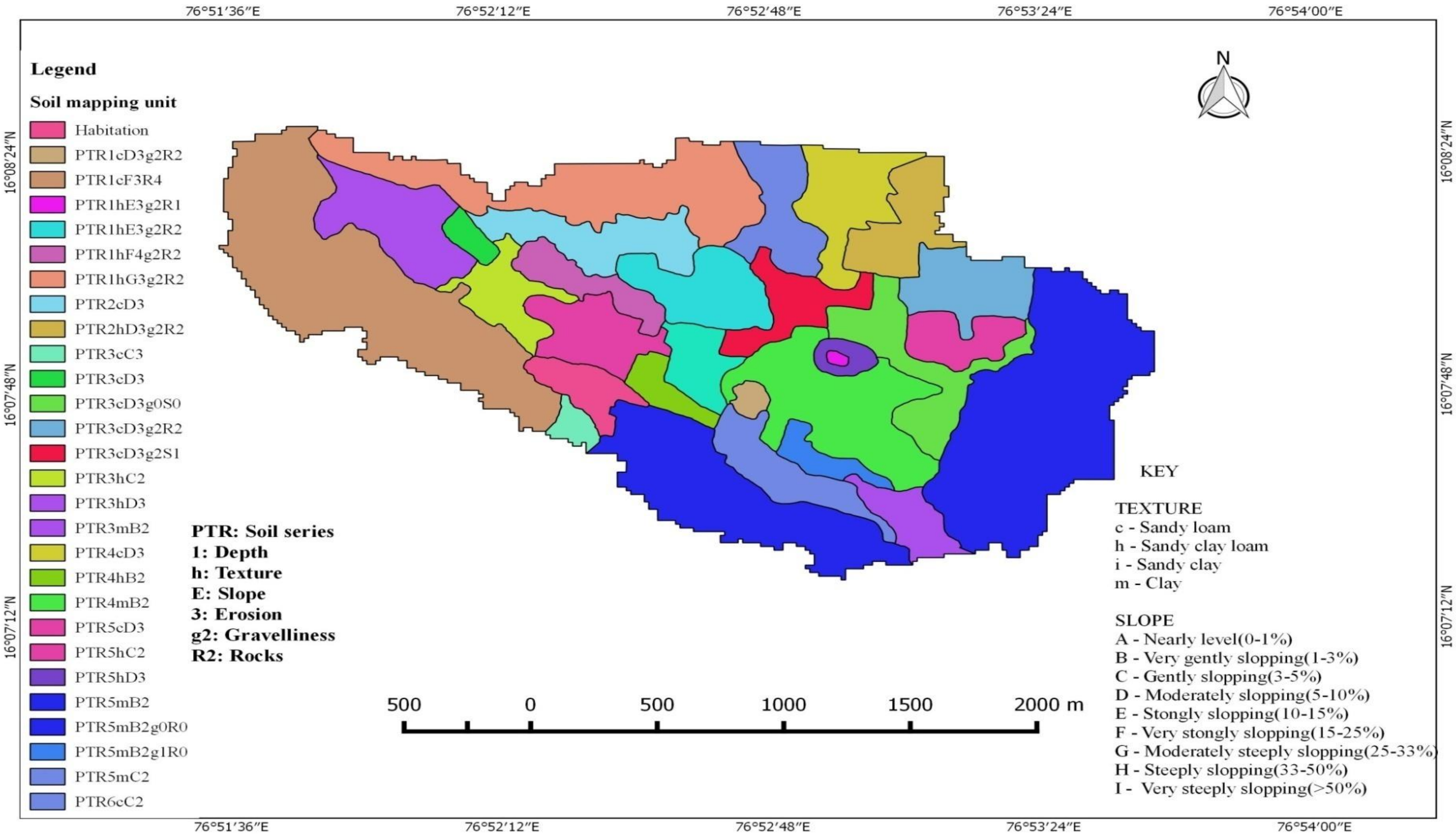

Fig. 2. Delineation of soils into mapping units of Patapur watershed

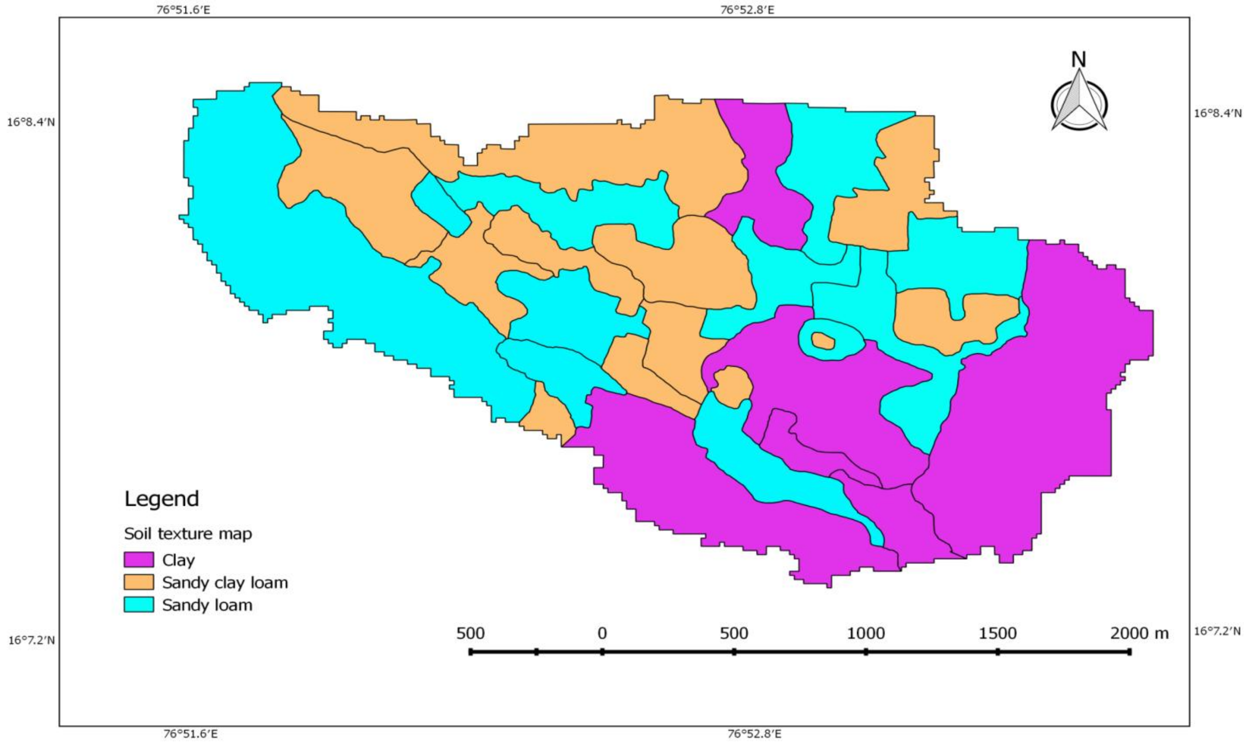

Fig. 3. Distribution of soil texture of Patapur micro-watershed

The digital elevation model (DEM) was extracted from the global US Geological Survey’s (USGS) in the format of SRTM (Shuttle Radar Topography Mission) with a spatial resolution of 30 m × 30 m and re-sampled to 15 m × 15 m for ease in data acquisition. The re-sampled DEM was projected to WGS1984 UTM Zone 43 N (EPSG: 32643) using the raster projections in QGIS before it was imported to QSWAT. The generated DEM is depicted in Fig.4

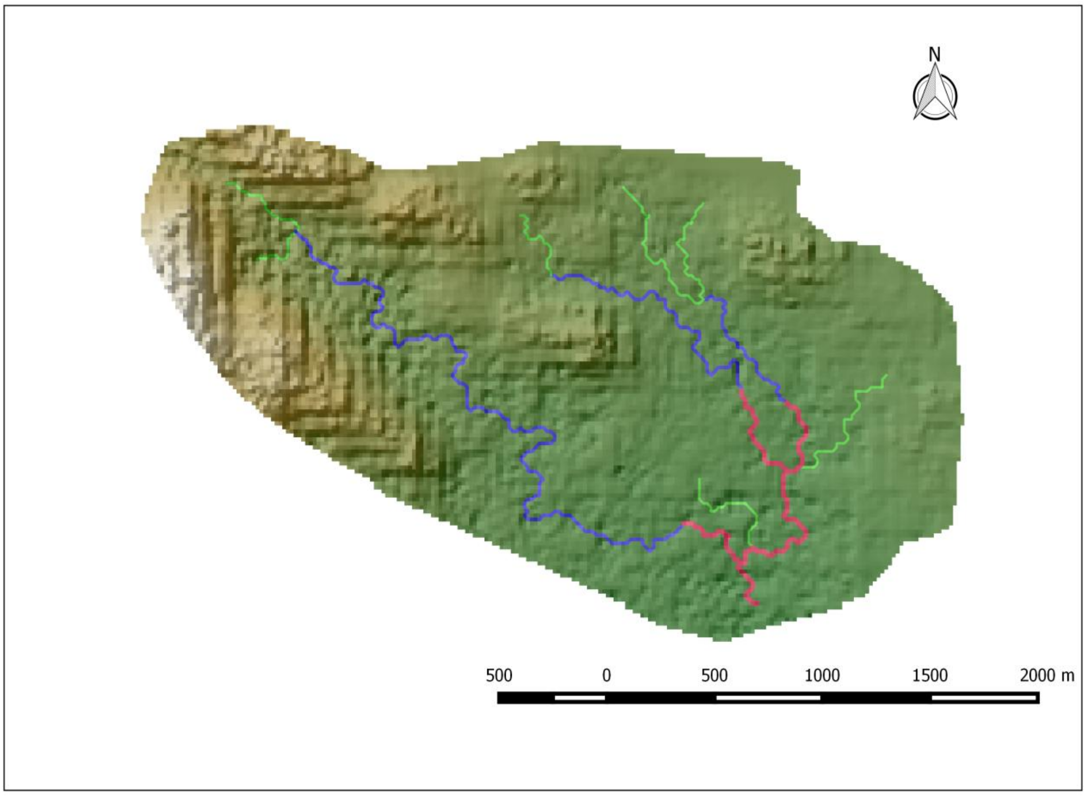

Fig. 4. DEM map of Patapur micro-watershed

The micro watershed field parcels were digitized representing the land use and land cover of each parcel/field. The shape file along with attribute table was also prepared in data base format with respect to the above mentioned land use land cover data and is shown in Fig 5 and Table 2.

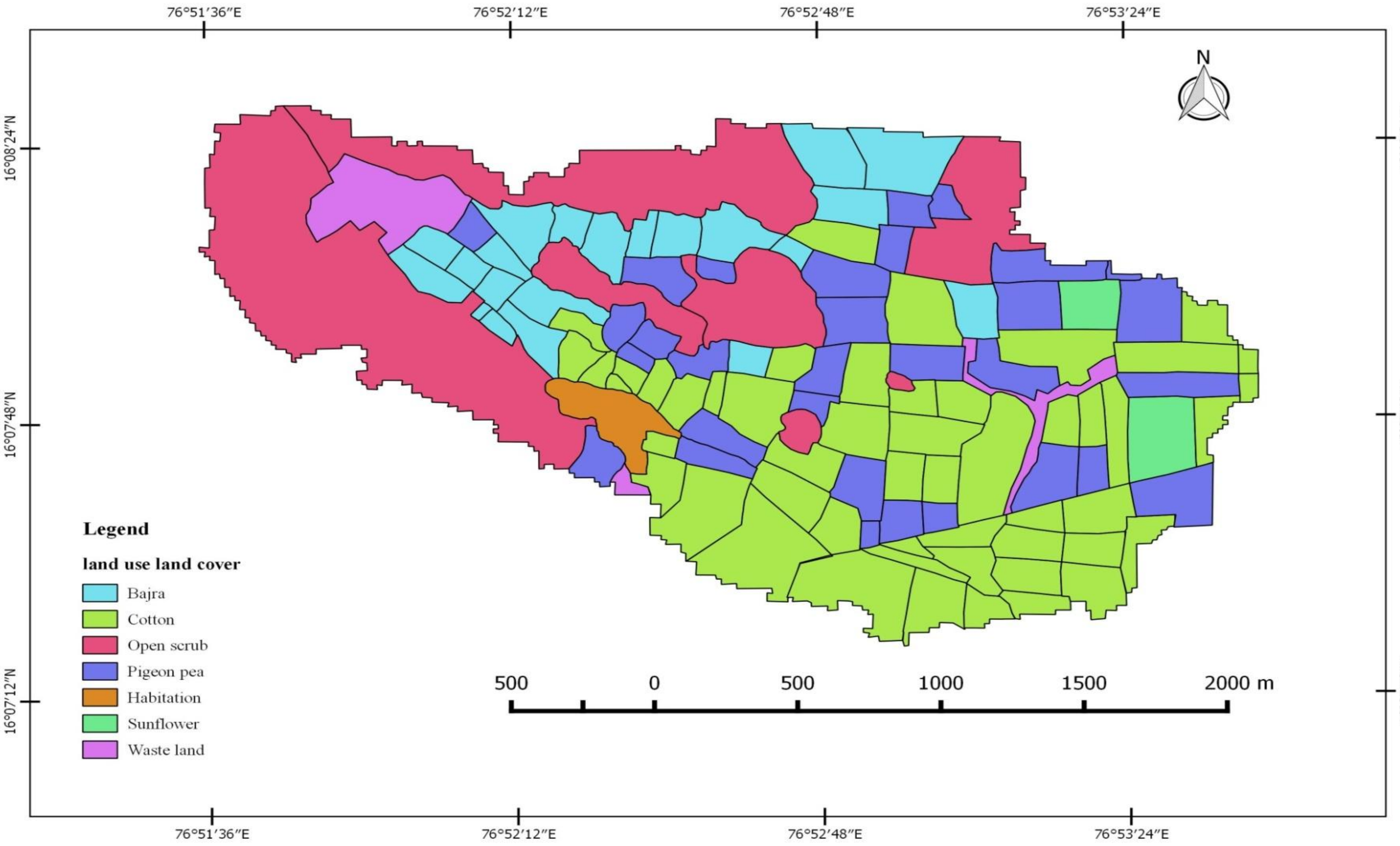

Fig. 5 . Land use map of Patapur micro-watershed during 2015

Table 2 Land use land cover and soil lookup tables used in QSWAT

LANDUSE_ID	SWAT_CODE	Particulars
1	PMIL	Pearl millet (Bajra)
2	COTP	Cotton
3	SETT (HABIT)	Settlement/Habitat
4	SCRB	Scrub land
5	FPEA	Field pea
6	BARR (WASTL)	Barren land/wasteland

2.3 Model Setup

SWAT is a comprehensive physically-based, conceptual, semi-distributed, continuous simulation watershed model, developed by the United States Department of Agriculture-Agriculture Research Service (USDA-ARS) at the Grassland Soil and Water Research Laboratory Temple, Texas (Arnold *et al.*1998; Neitsch *et al.* 2005a) that operates on a daily time step. It originated from the SWRRB model-Simulator for Water Resources in Rural Basin. The model was developed to simulate the long-term impact of land management practices on water, sediment movement, pesticide and nutrient yields for un-gauged agricultural watersheds with varying soils and land cover. The SWAT model divides the watershed into a number of sub-watersheds based on topography and user defined threshold drainage area (minimum area required to begin a stream). Each sub-watershed is further divided into Hydrologic Response Units (HRUs), which are unique combination of soil, land use, and land management. The HRUs is the smallest landscape components of SWAT used for computing the hydrologic process (Arnold *et al.* 1998).

2.3.1 Hydrological components and Processes in SWAT model

SWAT allows a number of different physical processes to be simulated in a watershed (Neitsch *et al.*, 2011). SWAT simulates various hydrological processes. The simulated processes include surface runoff, infiltration, evapotranspiration (ET), lateral flow, percolation to shallow and deep aquifers and channel routing (Arnold *et al.*, 1998). All these hydrological processes are simulated in surface, soil, and intermediate (vadose) zone, shallow and deep aquifers. Among the aforementioned hydrological processes, surface runoff, subsurface or lateral flow and return flow or base flow contributed to stream flow in the main channel. The hydrologic cycle as simulated by SWAT is based on the water balance equation. The simulation of hydrological processes in SWAT model is based on the water balance equation.

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

where, SW_t is the final soil water content (mm), SW_0 is the initial soil water content (mm), t is the time (days), R_{day} is the amount of precipitation on day i (mm), Q_{surf} is the amount of surface runoff on day i (mm), Ea is the amount of evapotranspiration on day i (mm), W_{seep}= the amount of percolation and bypass flow exiting the soil profile bottom on day i (mm) and Q_{gw} is the amount of return flow on day i (mm).

Since the model maintains a continuous water balance, the subdivision of the watershed enables the model to reflect differences in evapotranspiration for various crops and soils. Thus runoff is predicted separately for each sub area and routed to obtain the total runoff for the basin. This increases the accuracy and gives a much better physical description of the water balance.

2.3.2 Surface runoff

SWAT provides two methods for estimating the surface runoff: the SCS curve number procedure (SCS, 1972) and the Green and Ampt infiltration method (Green and Ampt, 1911). The SCS curve number is a function of the soil's permeability, land use and antecedent moisture conditions (SCS, 1972) whereas the Green and Ampt infiltration method calculates infiltration as a function of the wetting front matric potential and effective hydraulic conductivity. SWAT uses the daily and hourly time steps to calculate surface runoff. For daily time steps, SWAT uses an empirical SCS curve number (CN) method and for sub daily time steps SWAT uses the Green and Ampt equation. For present study the SCS curve number was adopted to calculate surface runoff volume using the following equation;

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

where, Q_{surf} is the accumulated runoff or rainfall excess (mm), R_{day} is the rainfall depth for the day (mm), I_a is the initial abstractions which includes surface storage, interception and infiltration prior to runoff (mm), and S is the retention parameter (mm).

The retention parameter varies spatially due to changes in soils, land use, management and slope and temporally due to changes in soil water content. The retention parameter is defined as:

$$S = 25.4\left(\frac{1000}{CN} - 10\right) \quad \text{... (3)}$$

where, CN is the curve number for the day.

The initial abstractions, I_a, is commonly approximated as $0.2S$ and equation 3.26 becomes

$$Q_{surf} = \frac{(R_{day} - 0.2S)^2}{(R_{day} + 0.8S)} \quad \text{... (4)}$$

Runoff will only occur when $R_{day} > I_a$.

where, Q_{surf} is the accumulated runoff or rainfall excess (mm), R_{day} is the rainfall depth for the day (mm), and S is retention parameter (mm). Runoff will occur when $R_{day} > 0.2S$. The retention parameter varies spatially due to changes in soils, land use, management and slope and temporally due to changes in soil water content.

The model calculates the peak runoff rate with a modified rational method. It is based on assumption that if a rainfall of intensity i begins at time t= 0 and continues indefinitely, the rate of runoff will increase until the time of concentration, $t = t_{conc}$, when the entire sub-basin area is contributing to flow at the outlet. The rational equation is expressed below;

$$q_{peak} = \left(\frac{CiA}{3.6}\right) \quad \text{... (5)}$$

where, q_{peak} is the peak runoff rate in ($m^3.s^{-1}$) C is a runoff coefficient, i is the rainfall intensity ($mm.h^{-1}$) for the watershed's time of concentration, and A is the drainage area (km^2) and 3.6 is the unit conversion factor.

Table 3 Land use land cover and soil lookup tables used in QSWAT

LANDUSE_ID	SWAT_CODE	Particulars
1	PMIL	Pearl millet (Bajra)
2	COTP	Cotton
3	SETT (HABIT)	Settlement/Habitat
4	SCRB	Scrub land
5	FPEA	Field pea
6	BARR (WASTL)	Barren land/wasteland

2.3.3 Meteorological data

In this study, measured meteorological data were used and the weather generator model was set up. The meteorological data used were daily precipitation, minimum and maximum air temperature, solar radiation, wind speed and relative humidity on a daily basis. Daily weather data of Patapur watershed during the period from January 01-01-1980 to 31-12-2016 were obtained from the nearest meteorological station installed by Hatti Gold Mines Company limited, Hatti, Lingsugur Taluk, Raichur, District. The rainfall data during the period from 01-01-2012 to 31-1-2016 were collected from the digital rain gauge installed at the outlet point with the integration of silt monitoring station. The rainfall data for this period was used as input for the SWAT model setup.

2.4. HYDROLOGICAL DATA

The hydrological data pertaining to discharge (m^3/sec) and runoff (mm) was measured at the outlet point of the micro watershed and has been used for calibration and validation.

2.5. SWAT model configuration and setup using QSWAT

2.5.1 Delineation of watershed and sub-watersheds boundaries

The watershed delineation process include five major steps, DEM setup, stream definition, outlet and inlet definition, watershed outlet selection and definition and calculation of sub-basin parameters. For the stream definition the threshold based stream definition option was used to define the minimum size of the sub-basins. The boundary of the watershed and 37 number of sub watersheds were created. As the number of sub watersheds comprising of small area less than 20 ha were merged to neighbouring area and divided into 12 sub watersheds.

2.5.2 Hydrological response units (HRU’s)

The SWAT model overplayed soil, LULC and DEM maps and reclassified. HRU’s distribution was carried out using the multiple HRU’s option and the HRU definition was done using a combination of 20% land use area over sub-basin, 10% soil class over land use area and 20% slope class over soil area. After the land use and soil were imported, reclassified and overlaid with slope class. With these combinations, a total of 12 HRUs were defined.

3.0 RESULTS AND DISCUSSION

3.1 Global sensitivity analysis

Global sensitivity analysis was performed after one iteration by selecting 500 numbers of simulations (Abbaspour, *et al.*, 2013) and is depicted in Table 4.

Table 4. Global sensitivity analysis for stream flow parameters in Patapur micro-watershed

Sl. No.	Parameter Name	Sensitivity rank	t-Stat	p-Value
1	R_CN2.mgt	1	-7.22	0.00
2	R_CH_K2.rte	2	5.32	0.00
3	R_SOL_AWC .sol	3	1.62	0.10
4	V_GW_DELAY.gw	4	-1.19	0.23
5	R_ESCO.hru	5	-1.04	0.29
6	R_SURLAG.bsn	6	-0.96	0.33
7	V_GW_REVAP.gw	7	-0.91	0.36
8	V_REVAPMN.gw	8	-0.90	0.37
9	V_ALPHA_BF.gw	9	0.77	0.44
10	V_GWQMN.gw	1	0.64	0.51

11	R_SOL_K .sol	11	0.48	0.63
12	V_EPCO.hru	12	-0.47	0.64
13	V_HRU_SLP.hru	13	0.02	0.98

Sensitivity analysis for the flow parameters of the SWAT model shows that Curve Number (CN2) is the most sensitive parameter among all other parameters which indicates the changes in LULC. The channel hydraulic conductivity (R_CH_K2.rte) is the second most sensitive parameter followed by Soil available water content (R_SOL_AWC .sol), groundwater delay (GW DELAY) (Table 4). Subsequently, the task involving model calibration was made easier after undertaking the sensitivity analysis.

3.2 MODEL CALIBRATION AND VALIDATION

3.2.1 Daily calibration and performance evaluation

The daily calibration statistics results for behavioral parameters in SWAT-CUP for stream flow discharge during the period 2012-2014 is shown in Table 5. It is observed from the table that, the calibration statistics R^2, NS, PBIAS and RSR values between measured and simulated by model was found to be 0.88, 0.87, -21.30 and 0.36, respectively indicating the model performance for daily calibration was very good in terms of both R^2 and NS value as their value being >0.75 as per the performance ratings of hydrological model. And also, in terms of PBIAS and RSR value the model performance was found to be satisfactory respectively. The negative PBIAS value showed that the model had slightly over predicted the discharge and goodness of fit is shown in Fig.8. Daily stream flow calibration fitted values for Patapur micro-watershed (2012-2014) is shown in Table 5.

Table.5. Model performance statistics results

Sl. No.	**Performance index**	**Calibration (2012-2014)**	**Validation (2015-2016)**
1	**p-factor**	0.07	0.85
2	**r-factor**	0.07	0.05
3	**R^2**	0.88	0.75

4	**NS**	0.87	0.64
5	**PBIAS**	21.30	24.00
6	**RSR**	0.36	0.56

3.2.2 Daily validation performance evaluation

The calibrated model was then run for two years from 2015-2016 to validate the calibrated model. Daily validation statistics results for behavioral parameters in SWAT-CUP for stream flow discharge during the period 2015-2016 is shown in Table 6. The validation statistics also displayed satisfactory model performance, with R^2 , NS, PBIAS and RSR values between measured responses and values predicted by the calibrated model was found to be 0.75, 0.64, -24.00 and 0.56 respectively indicating the model performance for daily validation good in terms of both R^2 and NS values. However, with respect to PBIAS and RSR values the model performance was found to be satisfactory and good respectively. The negative PBIAS value indicated that the model had over predicted the daily average discharge. It was also noted that the model did not perform well during the year 2015-2016 (lower performance and larger uncertainty).

The correlation graphs between observed and simulated data are shown in Fig 6 and Fig 7.

Table 6 Daily stream flow calibration fitted values for Patapur micro-watershed (2012-2014)

Sl. No.	Parameter Name	Fitted value	Min value	Max value
1	R_CN2.mgt	0.06	0.03	0.12
2	R_CH_K2.rte	0.09	0.00	18.93
3	R_SOL_AWC .sol	18.37	14.79	24.59
4	V_GW_DELAY.gw	143.71	85.26	186.91
5	R_ESCO.HRU	1.88	1.36	2.22
6	R_SURLAG.bsn	0.85	0.57	2.34
7	V_GW_REVAP.gw	0.03	0.03	0.03
8	V_REVAPMN.gw	468.07	452.70	586.29
9	V_ALPHA_BF.gw	0.47	0.39	0.53
10	V_GWQMN.gw	887.70	765.00	1673.88
11	R_SOL_K.sol	20.16	5.50	53.57
12	V_EPCO.hru	1.10	0.89	1.32
13	V_HRU_SLP.hru	0.14	0.13	0.18

Note: Goal type=Nash Sutcliff,
No. of Sims=100,
Best_sim_no=39,
Best goal = $8.735510 \times 10^{-001}$
R- Relative means the existing parameter value is multiplied by (1+ a given value)
V-Replace means the existing parameter value is to be replaced by the given value.

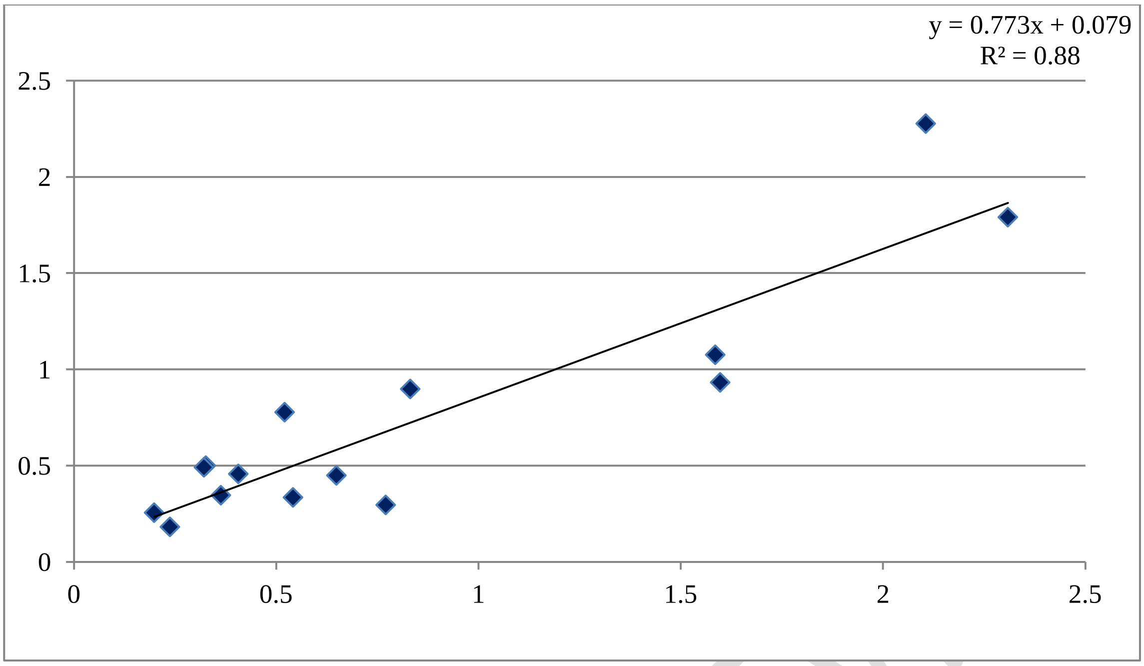

Fig. 6 Comparison between daily simulated and observed stream flow for calibration period (2012-2014)

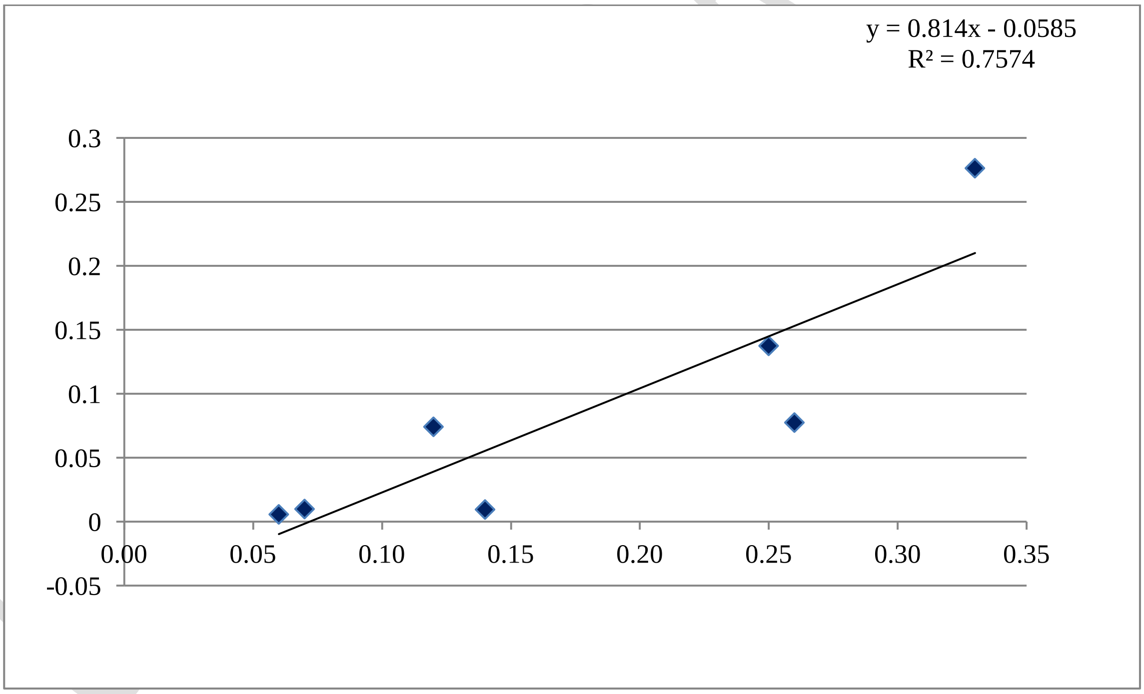

Fig. 7 Comparison between daily simulated and observed flow for validation period (2015-2016)

3.2.3 Water balance of the watershed

Using calibrated QSWAT model long term simulations (1980-2016) were carried out to study the water balance components and water balance ratio of the micro-watershed is shown in and Table 7 and Table 8 and depicted in Fig.8.

The water balance equation is as follows

P-Q-ET-Base flow±±ΔTWS-(Other components)=0 ………………….(6)

Where,

P= Precipitation

Q= Runoff

E= Evapotranspiration

ΔTWS= change in terrestrial water storage and other components consists soil moisture, shallow and deep ground water storage, glacier and soil moisture.

According to the model output the average precipitation	=527.70 mm
Average total runoff (Surface+lateral+return)	= 164.30 mm
Average groundwater storage	= 4.14 mm
Average Evapotranspiration	=322.50 mm

Therefore, from equation (6)

527.70-164.30-322.50-4.14=36.76

The value 36.76 mm includes other components such as interception, shallow and deep ground water storage also soil moisture and snow, glaciers.

Therefore,

527.70-164.30-322.50-4.14-36.76=0

This equation shows water balance is equal to zero which means the incoming water in the micro watershed is equal to the outgoing water.

Table 7 Water balance components of watershed

Sl. No.	Water balance component	Incoming (mm)	Outgoing (mm)
1	Precipitation	-	-
2	ET	-	322.53
3	Runoff (Surface+lateral+return)	-	164.30
4	Surface runoff		114.91
4	Other components	-	36.76
5	Groundwater storage	-	4.14
	Total	**527.70**	**527.70**

Table 8 Average annual Water balance ratio for Patapur micro-watershed

Sl. No.	**Water balance ratio**	**Water balance ratios**
1	Precipitation	**527.70**
2	Stream flow/precipitation	0.31
3	Base flow/Total flow	0.30
4	Surface runoff/total flow	0.700
5	Percolation/precipitation	0.16
6	Deep recharge/precipitation	0.01
7	ET/precipitation	0.61

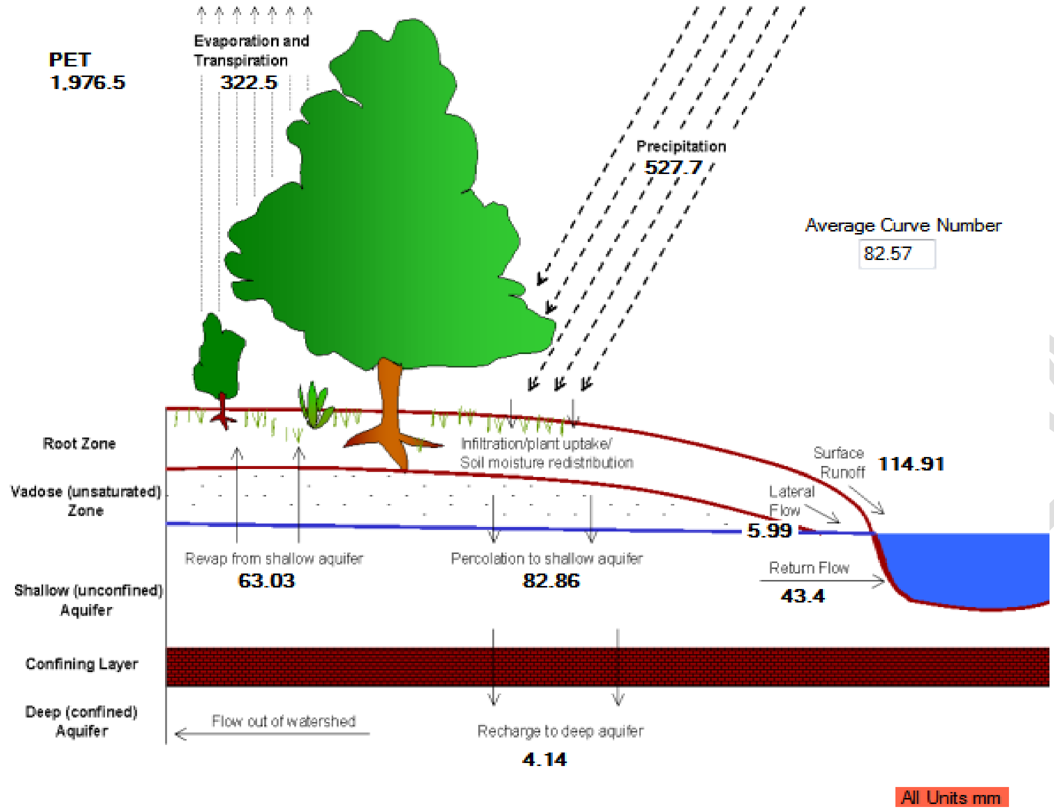

Fig. 8 Schematic representation of hydrologic components by SWAT output

It clearly shows that, the water yield that is draining out of the watershed includes surface runoff, lateral flow and groundwater contribution to stream flow minus the transmission losses (water lost as deep percolation and evapo-transpiration) which amounts to 168.40 mm. The annual water balance components for the watershed indicated that out of 527.70 mm of annual precipitation, 322.50 mm and 114.91 mm was lost by evapo-transpiration and surface runoff, respectively. The water balance also revealed that 82.86 mm was contributed to groundwater by percolating into shallow aquifer which was followed by 43.40 mm of base flow but the ground water recharge and storage is very meager that accounts to only 4.14 mm that is the matter of concern over the micro watershed. This clearly shows that on yearly basis, the runoff contribution was quite more consequently the watershed suffers almost 68 days with water stress hence; the surface runoff leading to outlet needs to be reduced and harvested for enhancing the available soil moisture coupled with groundwater recharge by adopting conservation measures and recharge structures at appropriate sites.

3.2.4 Temporal distribution of water balance components

The calibrated value of SWAT model parameters has been edited in the SWAT model, and model was run for simulating historical data sets of water balance componenets from 1980 to 2016 and the temporal variations of the water balance components were studied. The water balance components are shown in Table 9.The surface runoff (SURFQ) was varying from 16.29 mm to 369.44 mm, the highest value was observed in 1998 and lowest in 1999. The variation of surface runoff was due to rainfall variation.The overall surface runoff was less in the micro watershed, with mean value of 114.92 mm. In 1999, 1997, 1984 and 1985, which were driught years, the contribution to the water budget by surface runoff, groundwater discharge, latral flow, water yield and percolation were decreased significantly. The contribution to the water budget by surface flow, groundwater discharge and lateral flow, water yield and percolation were reached highest value in 1998 that was a highest rainfall year. The groundwater contribution to stream (GWQ) was moderate and it was moderate, and it was found maximum and minimum with 7.21 mm (1999) and 112.68 mm (1998), whereas 1998 was the highest rainfall year.

The maximum and minimum lateral flow was observed in 1999 (2.64 mm0 and 1998 (12.240mm) whereas 1998 was the highest rainfall year. The maximum and minimum percolation (PERCO) was observed in 1998 (220.470mm) and 1999 (19.520 mm), whereas 1998 was highest rainfall year. The maximum and minimum evapotranspiration (ET) was observed in 2016 (495.830 mm) and 1985 (198.15 mm). Concerning adequate precipitation and completely developed canopy of vegetation, as well high downward radiation fluxes. The maximum and minimum water yield (WYLD) was observed in 1998 (502.61 mm) and 1997 (55.49 mm) whereas 1998 was the highest rainfall year. Overall 1998 was highest potential year for all water balance components whereas 1999 was a very critical year due to less concentration of all water balance components in the watershed. Water yield was increasing with increasing rainfall. Water yield variation is completely depending on runoff, groundwater and lateral flow. Therefore, it was following same pattern.

The simulation model indicates that 58.77 to 64.54% by rainfall was lost by evapotranspiration and very less amount lost through the lateral flow. Groundwater flow and percolation were contributing 3.68 to 10.13% and 9.95 to 19.82 % respectively, from total rainfall.During the highest rainfall year, about 33.22, 10.13% and 1.10% of the rainfall was transformed into surface runoff, groundwater flow and lateral flow respectively. During lowest rainfall year, about 8.31%, 3.68% and 1.35% of the rainfall was transformed into surface runoff, groundwater flow and lateral flow respectively. Results reveal that maximum surface runoff was generating during highest rainfall year than dry year. Inter-annual variations of all components of water cycle is strongly linked to the rainfall variability (Leelamber Singh and Subbarayan. S 2020).The time series graph of various simulated components has been shown to understand the dynamics of parameters behviour over the years Fig 9. All components are temporally varying with respect to rainfall variation and all were showing high concentration at high rainfall year (1998). Lowest concentration has been found in lowest rainfall year (1999). This graph represents the dynamics of components behviour changing with respect to rainfall and time.

Table 9. Water balance components of Patapur micro watershed

Year	**Rainfall (mm)**	**Runoff (mm)**	**Groundwater flow (mm)**	**Lateral flow (mm)**	**Percolation flow (mm)**	**ET (mm)**	**Water yield (mm)**
1980	519.50	130.71	75.02	5.520	84.030	297.030	214.230
1981	631.70	132.97	11.75	7.630	121.460	356.560	257.740
1982	383.00	47.78	52.09	4.640	53.150	288.290	107.930
1983	405.00	59.90	65.46	4.960	67.070	269.120	133.600
1984	293.00	30.41	39.05	3.540	38.080	234.050	75.440
1985	307.00	64.65	34.14	3.410	40.440	198.150	104.160
1986	414.50	61.46	47.76	4.990	68.250	270.410	117.030
1987	704.90	157.22	69.41	8.160	122.490	401.220	240.590
1988	642.00	145.3	70.79	8.090	130.360	356.400	230.610
1989	564.00	112.84	44.78	6.620	93.970	350.950	169.090
1990	695.00	140.32	68.76	8.130	118.190	437.610	223.070
1991	506.00	114.97	40.9	6.000	81.290	310.510	166.570
1992	707.90	213.51	42.9	6.970	98.560	361.820	267.190
1993	507.00	144.44	46.06	5.980	80.480	281.430	200.970
1994	338.00	67.11	23.25	4.280	61.470	209.050	97.930
1995	565.30	73.2	40.15	6.290	77.840	406.590	123.530
1996	369.70	84.55	25.03	4.460	63.860	220.960	117.500
1997	273.70	37.5	12.46	3.200	35.800	212.520	55.490
1998	1112.40	369.44	112.68	12.240	220.470	457.900	502.610
1999	196.00	16.29	7.21	2.640	19.520	208.610	30.030
2000	622.20	145.03	40.22	6.780	100.270	348.760	195.950
2001	513.50	125.27	34.26	6.040	91.970	282.620	170.060
2002	435.00	43.04	27.02	5.310	67.110	339.080	79.430
2003	360.00	43.35	14.88	4.100	46.870	262.680	64.970
2004	437.00	50.9	23.56	4.870	52.710	335.980	82.020
2005	782.00	269.35	40.89	7.800	102.730	382.050	322.130

2006	396.00	47.96	16.58	4.570	43.150	313.850	72.150
2007	537.00	140.79	28	5.750	76.230	314.230	178.150
2008	463.00	95.92	24.94	5.420	74.750	284.170	130.070
2009	**917.00**	**367.77**	**62.32**	**8.450**	**137.470**	**368.900**	**443.980**
2010	467.70	80.12	22.17	5.160	56.610	356.520	111.770
2011	379.00	38.54	17.08	4.450	51.510	288.980	62.660
2012	520.00	108.24	36.83	6.250	86.760	311.210	155.000
2013	706.30	125.81	52.15	8.030	104.010	458.240	191.020
2014	589.50	129.43	46.3	6.970	104.200	348.340	188.070
2015	420.20	60.12	20.79	4.690	56.000	313.170	88.920
2016	843.80	175.88	68.01	9.400	139.310	495.830	259.070
Mean	**527.70**	**114.92**	**40.69**	**5.990**	**82.910**	**322.530**	**168.398**

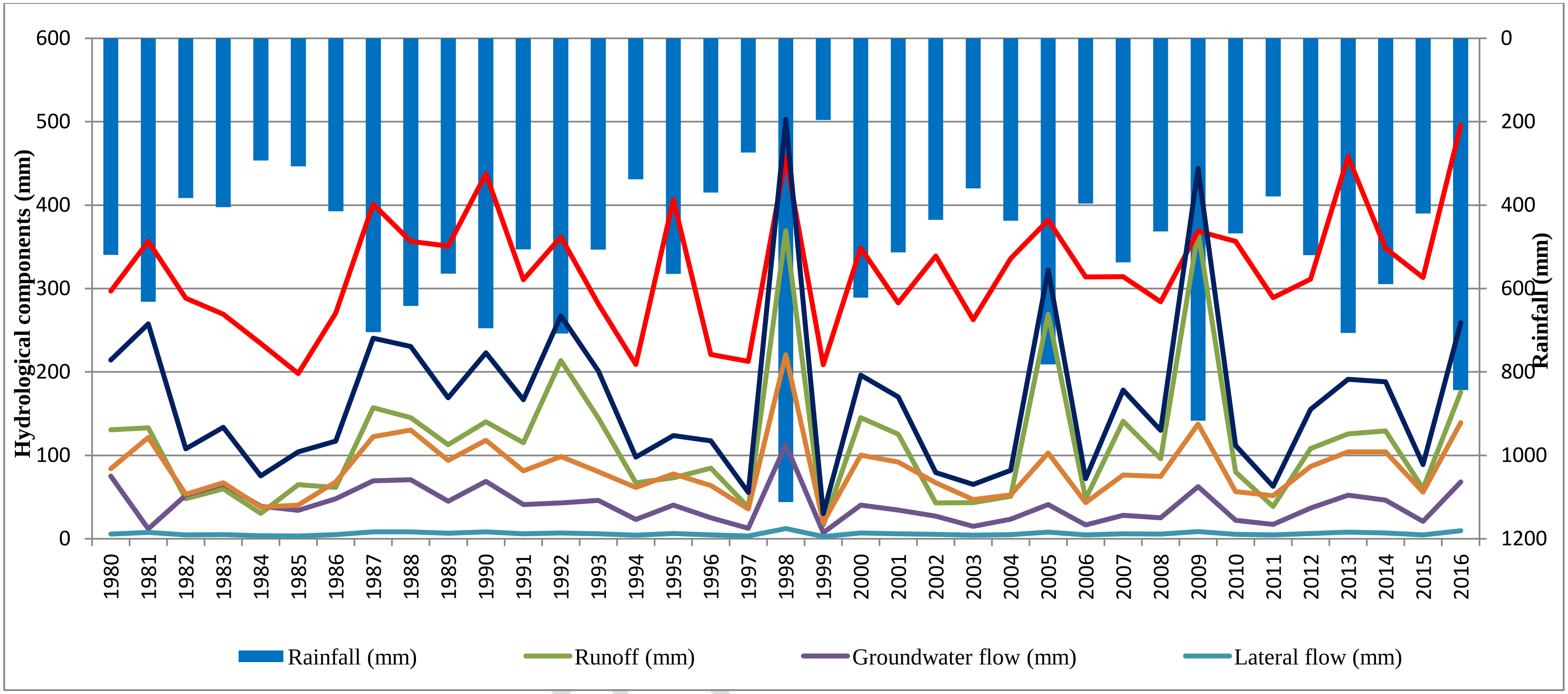

Fig.9 Time series of various simulated components

4. CONCLUSION

The water cycle operates on a time and space scales. Since precipitation is the central component of hydrological water balance, accurate and timely knowledge of micro watershed scale precipitation is essential for improving the ability to manage freshwater resources and for predicting high-impact weather events. As a result, the future of water availability depends on the understanding of the spatial and temporal variation and interaction of hydrologic components hence, could be instrumental to assisting water planners in the formulation of strategies for water conservation. Water regime of the particular region is well understood by estimation of resources. Water balance is finest way of find out accessibility of water in different parameters of hydrological cycle and variations in between these parameters. The open-source geospatial techniques were utilized to create different thematic maps of study area influence land use, soil, drainage, and slope used as input for QSWAT model. QSWAT model proves as a powerful tool in simulating the hydrology at micro watershed scale. This provides long-term simulated results of each parameter. The evaluated parameters can be used for many other purposes of study such as agricultural water management, climate change impact assessment, flow forecasting, water quality assessment etc. This water balance study minimizes possibility of drought and mismanagement, and hence will lead to a proper utilization of accessible water resource.

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