

# Impact Assessment of Climate Change on Hydrological Parameters: Evaluation of Water Balance Components of a River Basin



Raju Narwade and S. K. Ukarande

**Abstract** In recent years, climate change has become a big concern over the world. Global warming and climate change have made the problem terrible. It has attracted the attention of researchers all over the world. Due to climate change, unusual changes are happening in the atmosphere, so accurate modeling will help us address the issue by modeling in terms of parameter finding, assessment, and estimation. Hydrological models are extensively used for different water projects to understand catchment water balance, prediction of streamline flow, rainfall, runoff, flood forecasting, and other water resource management projects. Two watersheds of the Manjra River basin, the tributary of the Godavari River basin, namely MNJR012 and MNJR013, were selected. The Soil and Water Assessment Tool (SWAT) hydrological model is used for impact assessment on those watersheds. Remote sensing data like digital elevation model (DEM), soil map, land use/land cover (LULC), and weather data are used. The simulated and observed data were then compared, and regression analysis was performed which gave values of  $R^2$  0.933 and 0.971 for Watersheds MNJR012 and MNJR013, respectively, which is closer to 1; hence, the simulated values obtained are validated. It has been observed that simulated data and observed data were in very close agreement with each other, which validated the results.

**Keywords** Climate change · Hydrological parameter · Soil Water Assessment Tool (SWAT) · River basin · Watershed delineation

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## 1 Introduction

Water is the fundamental element for the sustenance of life. Due to the increase in population, majority of the river basins are considered as overstressed. Water on the earth is available in several forms in the environment, such as surface bodies like a lake, moisture in the air, snow, and groundwater. These water bodies are interconnected through the hydrological cycle. The hydrological cycle starts when water evaporates from surface water bodies due to solar insolation. When these vapors get condensed, they form clouds and precipitate to fall on earth.

Out of this, only 22% of water seep underground, and only less than half reach the actual groundwater reservoir; the remaining water gets received by oceans, evaporation, and surface water bodies like rivers and lakes. The major components of the hydrological cycle are precipitation, i.e., rainfall, snowfall, hail, sleet, fog, and other components like runoff, evapotranspiration, percolation, etc. These components of the hydrological cycle play a vital role in water resource management and water budgeting projects. Climate change highly affects water resources by altering several water balance components; land use/land cover affects the water quality of streams and water bodies due to pollutants and soil erosion. Water shortage is a main reason of the degradation of the eco-environment in most river basins, and also it is a serious problem for society. To manage effective water resources, attention should be given on the proper distribution of water resources. Based on different scales models, the water balance components have been evaluated during the past few years. To overcome the issue of water shortage, the appropriate water resource management and water budgeting are compulsory.

After the Ganga River basin, the Godavari River is the second largest in India. This basin comes under six different states: Maharashtra, Madhya Pradesh, Orissa, Chhattisgarh, Telangana, and Andhra Pradesh. The water flows in the Godavari basin are shared among these states. The majority of the population in the state depends upon agriculture. In recent years, farmers have been forced to depend upon groundwater for these agricultural needs due to the dwindling nature of rainfall and surface water flows—the overexploitation of groundwater results in depletion of the shallow aquifer. For sustainable water resource management and agricultural development, it is necessary to understand available water resources, their characteristics, and their variation over time [2].

Every year in Maharashtra state, the Marathwada region faces water scarcity problems due to the depletion of water levels. In such cases, proper water budgeting is necessary for further water management and distribution. Two watersheds of the Manjra River MNJR012 and MNJR013 are selected. The Manjra River is a tributary river of the Godavari River and flows through the Marathwada region. Also, it is a major source of water in the Marathwada and surrounding region. Hence, the smaller watersheds of the Manjra River basin are selected to study the characteristics of watersheds and components in detail.

## 2 Data Used and Methodology

### 2.1 Methodology

The SWAT, a hydrological model, is used. In this model, watersheds in Manjra River basin are divided into sub-watersheds, which are further subdivided into (HRUs) Hydrologic Response Units. The HRU includes attributes of land use/land cover, slope, and soil [20]. The HRUs are generally used to simplify the simulation because all land use and soil areas unite into a single response unit. The ArcSWAT requires spatially distributed data which are DEM, soil map and land-use/land-cover data, shape file, grid data, and also weather data and streamflow data are required as input for calibration and future prediction in SWAT. Flowchart of methodology is shown in Fig. 1.

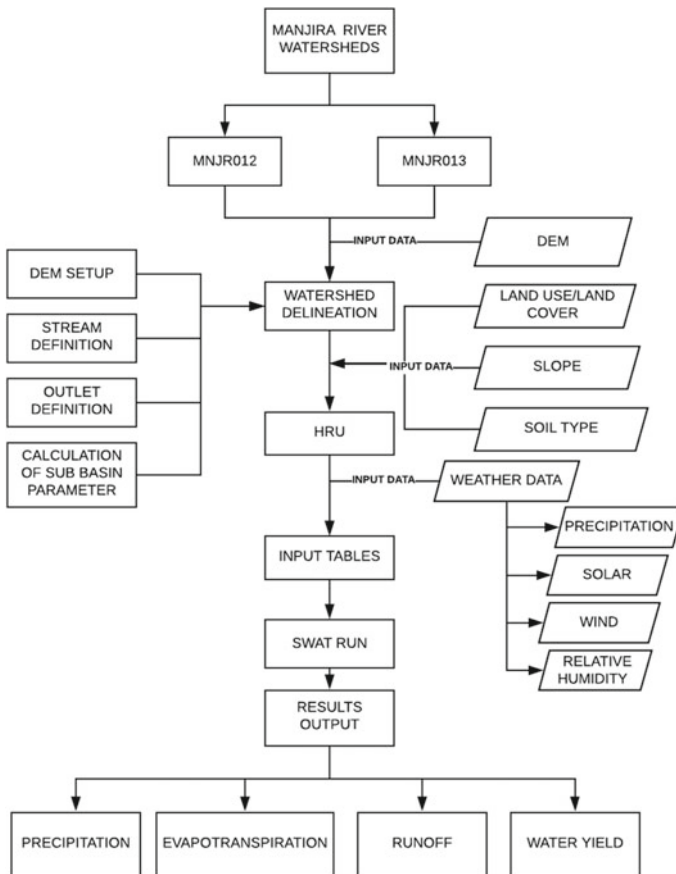
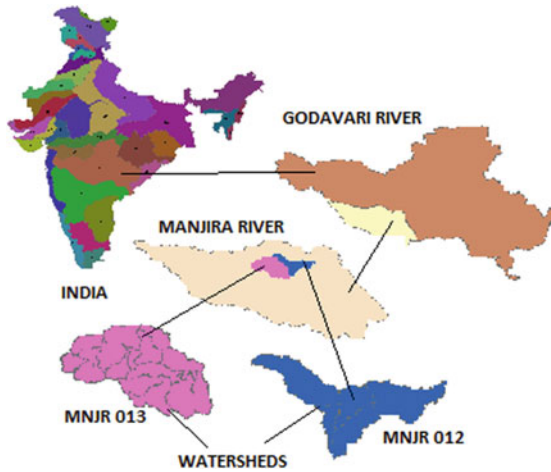


Fig. 1 Flowchart of methodology

**Fig. 2** Study area  
(Watersheds MNJR012 and  
MNJR013)



## Study Area and Data Collection

### 2.1.1 The Manjira River Basin

The Manjira River is a tributary of the second largest river of India, which is the Godavari. It flows through Maharashtra, Telangana, and Karnataka states. The river is 724 km long which starts from the Beed district and ends in Telangana state. This basin has a catchment area of about 30,844 km<sup>2</sup>. Lendi, Terna, Tawarja, Gharni, Manyad, and Teru are the six tributaries of the Manjira River. Singur dam and Nizam Sagar are two major projects in the Manjira River and play a vital role in fulfilling the water requirement of the surrounding region in Maharashtra and Telangana states.

The Manjira River consists of a total of 28 watersheds, among them two watersheds selected. The Central Ground Water Board has given codes to these watersheds. The study area consists of two watersheds having codes MNJR012 and MNJR013 in the Manjira River basin as shown in Fig. 2. Watershed MNJR012 has an area of 756 km<sup>2</sup> and comes under the Lendi River stream. It covers some areas of Andhra Pradesh and some areas of the Maharashtra district. Watershed MNJR013 has an area of about 1249 km<sup>2</sup> and comes under the Terna stream, and it covers some part of Karnataka and Maharashtra states.

### 2.1.2 Data Collection

For any hydrologic model, the data required are rainfall, discharge data, DEM, LULC, type of soil. Daily rainfall data can be obtained from Indian Meteorological Department (IMD), Pune. Metrological datasets can also be obtained from India Water

Portal (IWP), Ministry of Earth Science (data.gov.in), Central Water Commission (CWC) processing system (nasa.pps.eosdis.nasa.gov), etc. Free satellite images and GIS data can be downloaded from various websites available based on the type of data, such as IndiaRemotSensing.com <http://glovis.usgs.gov>, [www.divagis.org/gData](http://www.divagis.org/gData), [www.gadm.org/cou-ntry](http://www.gadm.org/cou-ntry), [www.mappinghack-s.com](http://www.mappinghack-s.com).

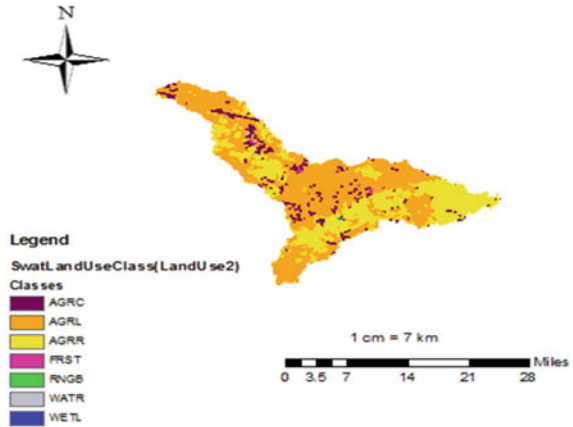
## ***2.2 Selection of Input Parameters***

- Digital Elevation Model: Shuttle Radar Topography Mission project is led by the National Geospatial-Intelligence Agency (NGA) and NASA. (SRTM 90) meter (3 arc-second) resolution.
- Soil Map: National Bureau of Soil Survey and Land Use Planning (NBSSLUP), Nagpur
- LULC Map: Indian Space Research Organisation (ISRO), International Geosphere Biosphere Program (IGBP) was used.

## ***2.3 SWAT Hydrological Model Overview***

This is a river basin-scale hydrological model which is designed to simulate the hydrological process, nutrient cycle, and sediment transport throughout the watershed. The area ranges from 00,015 to 491,700 km<sup>2</sup>. The SWAT modeling is initialized by some input data like soil map, land-use/land-cover data, weather data, elevation data, sub-basin routing, etc. The smallest unit in the SWAT model is the HRU unit, i.e., Hydrological Response Unit, which is used to simulate runoff, erosion, nutrient cycle, infiltration, etc. These units are defined by soil data and land-use data. The simulation also requires meteorological data as input data, which includes rainfall data, temperature, wind, humidity, and solar data, which is provided by ArcSWAT 2012. The simulation gets routed through the internal network. For the selected study area, land use, soil map, and slope data were obtained from the Indian dataset. The development of the entire database required for the model is the initial step for model setup. ArcSWAT 2012 delineates sub-watersheds by using DEM. All the parameters for the selected catchment area were calculated for each basin. SWAT allows importing land use and soil map in the model. The land use gives brief specifications about the land-use layers, and the soil map reclassifies the type of soil into the hydrological soil group based on infiltration rate. A threshold percentage of 10% was adopted to eliminate minor land use, soil, slope. The model requires daily data of precipitation and temperature. This model allows loading weather stations into the project and assigning the weather data to sub-watersheds. Using this data, SWAT model prepares input tables for SWT run, which furthers produces simulated values of water balance components.

**Fig. 3** LULC map of MNJR012



## 2.4 Thematic Maps

The thematic map of LULC, Soil and digital elevation model were prepared as follows.

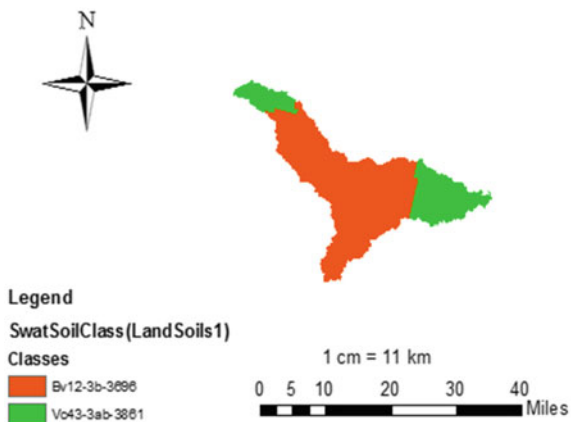
## 2.5 Land Use/Land Cover (LULC)

Land-use documents are used to show how people are using land, whereas land-cover documents specify the physical land type such as open water, forest, bare land. The distribution of land in Watersheds MNJR012 and MNJR013 and land-use/land-cover map of the Manjra River basin are shown in Figs. 3 and 5, respectively. The figures show land-use classes such as Water (WATR), Rangeland Brush (RNGB), Agricultural Land-Generic (AGRL), Agricultural Land-Row Crops (AGRR), Agricultural Land-Close Grown (AGRC), and Forest (FRST).

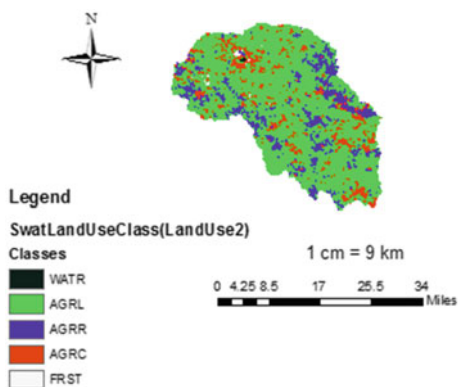
## 2.6 Soil Map

The soil map of Watersheds MNJR012 and MNJR013 of the Manjra River basin are shown in Figs. 4 and 6, respectively. In Watersheds MNJR012 and MNJR013, clay loam and clay soils are shown in Table 1.

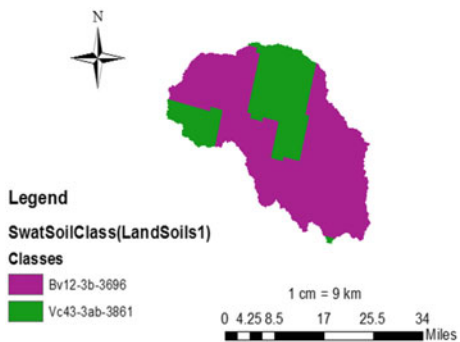
**Fig. 4** Soil map of MNJR012



**Fig. 5** LULC map of MNJR12



**Fig. 6** Soil map of MNJR013



**Table 1** Soil classification

Class	Type
Bv12-3b-3696	Clay loam
Vc43-3ab-3861	Clay
Vo43-3ab-3861	Clay

### 2.7 Digital Elevation Model Map

Figures 7 and 8 show the DEM of Watersheds MNJR012 and MNJR013 in the Manjra River. The data required for DEM are collected from hydrosheds.

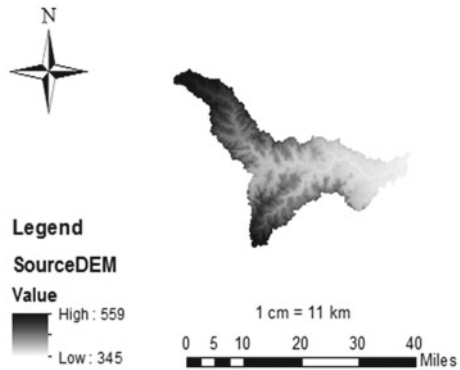
## 3 Results and Discussions

The four different water balancing components of watersheds are generated using the SWAT model and GIS. The water balancing components rainfall, runoff, evapotranspiration, and groundwater recharge are evaluated. The SWAT model also gave the land-use/land-cover distribution in the study area. It has also prepared land use/land cover and soil maps.

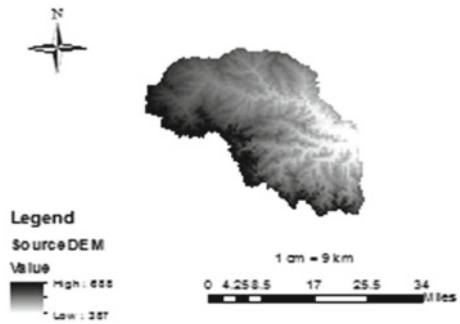
For each watershed, a separate SWAT simulation was used.

Precipitation ( $P$ )–Runoff ( $Q$ )–Evapotranspiration ( $ET$ )–Base flow

**Fig. 7** DEM of Watershed MNJR012



**Fig. 8** DEM of Watershed MNJR013





$$\pm \Delta TWS - (\text{other components}) = 0 \dots \dots \dots (\text{Water Balancing Equation}) \tag{1}$$

$\Delta TWS$  is change in terrestrial water storage and other components which include groundwater storage (shallow and deep) and soil moisture.

### 3.1 Watershed MNJR012

Figure 9 gives water balancing components in the MNJ012. All parameters indicate the average values.

Precipitation (P) = 979.2 mm, Total runoff (Q) = 420.17 mm, Groundwater recharge = 7.71 mm and Evapotranspiration (ET) = 515.1 mm. So, from (Eq. 1);

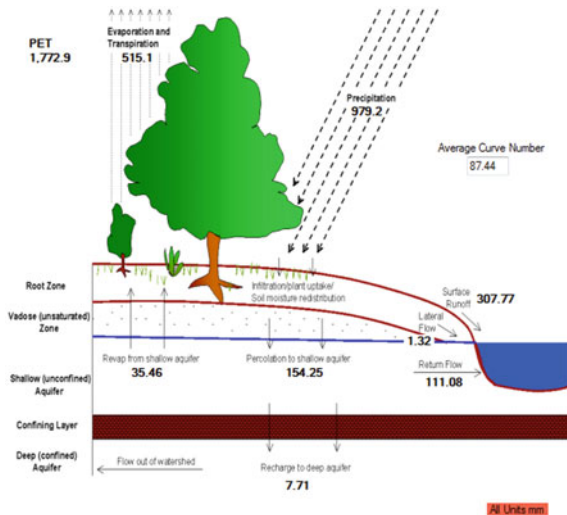
$$979.2 - 420.17 - 515.1 - 7.71 = 36.1$$

Therefore,  $979.2 - 420.17 - 515.1 - 7.71 - 36.1 = 0$ .

As the summation of water balance components is equal to zero, this means the incoming and outgoing of water in Watershed MNJR013 are equal. Table 2 shows the value of incoming and outgoing of water in Watershed MNJR012 region, which are equal, which justifies the water balance equation.

Using the SWAT simulation, monthly basin values of important parameters for Watershed MNJR012 of the Manjra River were derived which are shown in Table 3. It includes precipitation values, runoff, water yield, evapotranspiration of selected watershed. These components are shown in Figs. 10, 11, 12, and 13 in the graphical form.

**Fig. 9** Water balance components of Manjra Watershed MNJR012



**Table 2** Water balance components of Watershed MNJR012

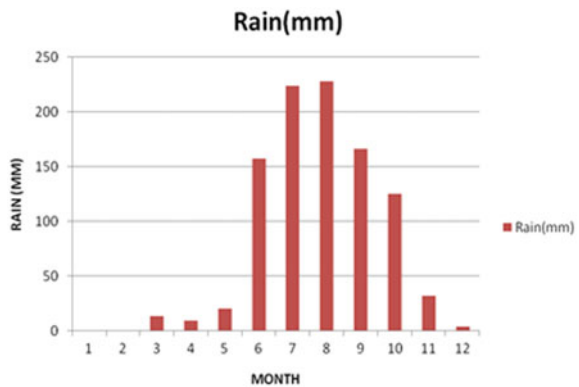
Components	Incoming (mm)	Outgoing (mm)
P	<b>979.2</b>	
ET	–	515.1
Q	–	420.17
$\Delta$ TWS	–	36.1
Groundwater recharge	–	7.71
<b>Total</b>	<b>979.2</b>	<b>979.2</b>

Bold values in the columns indicate the total precipitation i.e. total water entering in the watershed in the form of precipitation and total water leaving in the form of runoff, groundwater recharge, evapotranspiration and other components

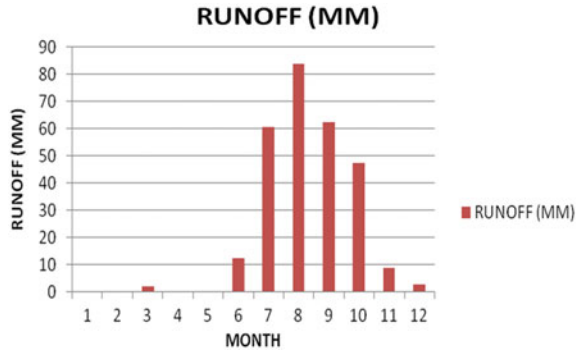
**Table 3** Monthly basin value of Manjra Watershed MNJR01

Month	Rain (mm)	Runoff (mm)	Water yield (mm)	E.T. (mm)
1	0.1	0.11	1.57	11.91
2	0.17	0.1	0.71	7.21
3	12.83	2.13	2.63	41.2
4	9.26	0.18	0.54	52.51
5	20.17	0.3	0.57	20.19
6	157.66	14.98	14.14	60.76
7	224.25	68.54	68.76	71.19
8	228.08	92.12	105.2	74.22
9	165.9	62.2	91.64	69.11
10	125.38	55.45	91.68	54.96
11	31.82	10.69	37.33	32.19
12	3.74	2.36	13.25	19.88

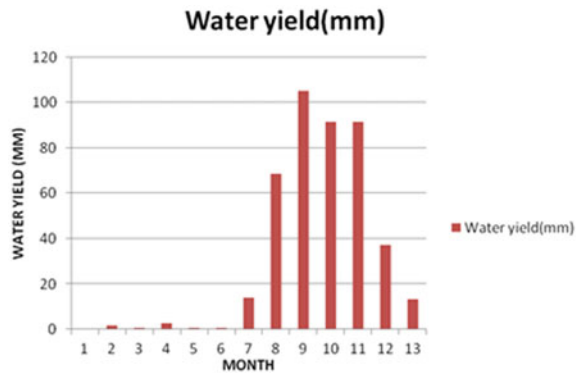
**Fig. 10** Monthly rainfall (average) MNJR012



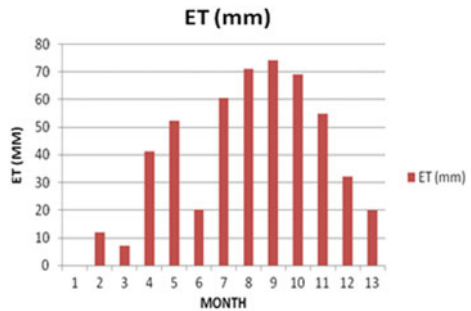
**Fig. 11** Monthly runoff (average) MNJR012



**Fig. 12** Monthly water yield (average) MNJR012



**Fig. 13** Monthly evapotranspiration (average) MNJR012

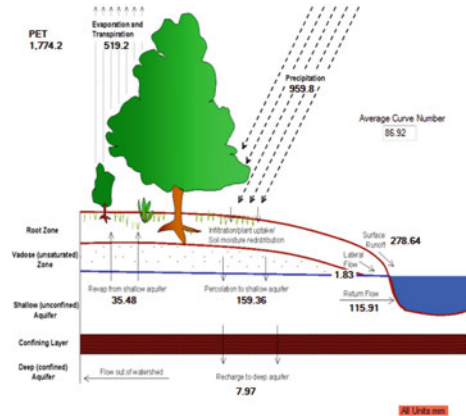


### 3.2 Watershed MNJR013

Figure 14 gives water balancing components in the watershed.

Precipitation (P) average = 959.8 mm, Total runoff (Q) average = 396.38 mm, Groundwater recharge (average) = 7.97 mm, Evapotranspiration (ET) average = 519.2 mm.

**Fig. 14** Water balance components of MNJR012



**Table 4** Water balance components of MNJR01

Water balance component	Incoming (mm)	Outgoing (mm)
P	959.8	
ET	–	519.2
Q	–	396.38
ΔTWS	–	36.25
Groundwater recharge	–	7.97
<b>Total</b>	<b>959.8</b>	<b>959.8</b>

$$959.8 - 396.38 - 519.2 - 7.97 = 36.25 \dots \text{ from Eq. (1);}$$

The value 36.25 mm including other components as mentioned for MNJ012.

$$\text{Therefore, } 959.8 - 396.38 - 519.2 - 7.97 - 36.25 = 0.$$

As the summation of water balance is equal to zero, this means the incoming and outgoing of water in Watershed MNJR013 are equal. Table 4 shows the values of incoming and outgoing of MNJR013 watershed.

The basin values (monthly) of important parameters for Watershed MNJR013 of Manjra River were derived by SWAT simulation and are as follows: Table 5 gives average monthly values of P, Q, E.T, and water yield for MNJR013 in the Manjra River. Figures 15, 16, 17, and 18 show the graphs of the components.

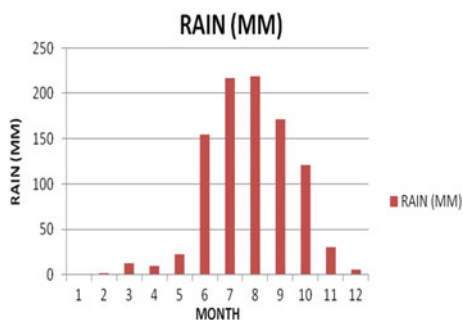
Modeling has given the water balance components of Manjra River watersheds.

So we can get the information about availability of water for all purposes use. This will help in real water resource management and distribution of water for different purposes in that region.

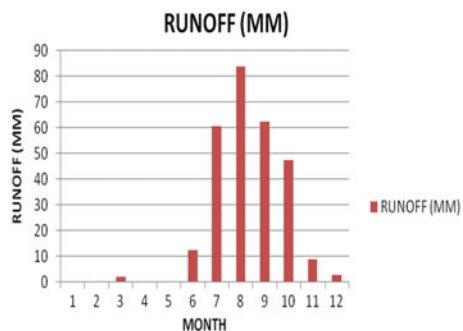
**Table 5** Monthly basin value of Manjra Watershed MNJR013

Month	Rain (mm)	Runoff (mm)	Water yield (mm)	E.T. (mm)
1	0.1	0.16	1.83	12.2
2	0.62	0.22	0.86	7.52
3	12.29	1.84	2.36	40.45
4	9.24	0.17	0.55	52.83
5	21.9	0.29	0.57	21.8
6	154.15	12.25	11.72	61.89
7	216.69	60.67	61.18	71.01
8	218.87	83.74	96.88	73.76
9	170.87	62.31	91.71	69.14
10	120.48	47.4	85.12	56.4
11	29.74	8.88	37.16	32.38
12	5	2.61	14.54	20.04

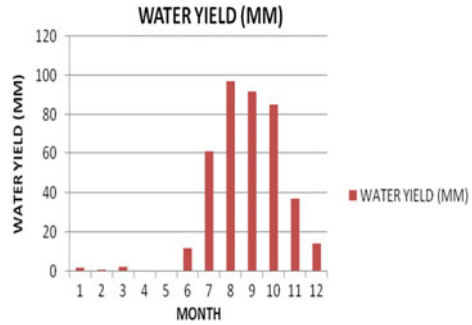
**Fig. 15** Monthly rainfall (P) average MNJR013



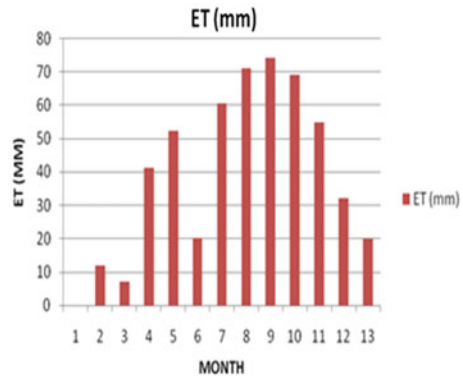
**Fig. 16** Monthly runoff (Q) average MNJR013



**Fig. 17** Average monthly water yield for MNJR013



**Fig. 18** Average monthly evapotranspiration MNJR013



### 3.3 Validation

The different water balancing components of Manjra River watersheds are evaluated by SWAT simulation. The regression analysis was performed to validate these simulated results; these simulated values have been compared with observed values. The coefficient of determination, i.e.,  $R^2$  was found for each watershed. The range of coefficient of determination  $R^2$  is between 0 and 1. It is considered that if the value of  $R^2$  is closer to 1, then the similarity between the two datasets is more.

(a) **Watershed MNJR012:**

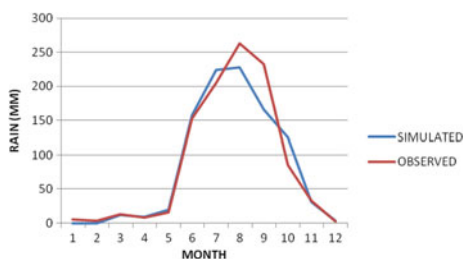
To validate the simulated results, regression analysis was carried out between simulated and observed precipitation values. The observed precipitation data were derived from global weather data. Table 6 shows simulated and observed rainfall values for Watershed MNJR012.

Figure 19 shows a graphical representation of the simulated and observed precipitation values of the Manjra Watershed MNJR012. The regression analysis gave value of  $R^2$  as 0.933, which is closer to 1; hence, the simulated values obtained from SWAT simulation are validated. Table 7 shows a summary of regression analysis for rainfall values of Watersheds MNJR012 and MNJ013 of the Manjra River.

**Table 6** Monthly observed and simulated values of rainfall MNJR012

Rainfall (mm)		
Month	Simulated values	Observed values
Jan	0.11	5.57
Feb	0.18	3.36
Mar	12.82	13.16
Apr	9.27	8.4
May	20.17	16.06
June	157.67	152.56
July	224.25	204.39
Aug	228.08	262.66
Sept	165.9	232.72
Oct	125.38	84.61
Nov	31.82	33.07
Dec	3.74	2.42

**Fig. 19** Graphical representation of simulated and observed rainfall MNJR012



**Table 7** Regression analysis for MNJR012 and MNJ013 watersheds

Sr. No.	Summary (MNJ012)	Summary (MNJ013)
<i>Regression statistics</i>		
R (multiple)	0.966083663	0.971735413
R (square)	0.933317643	0.944269713
R square (adjusted)	0.926649407	0.938696684
Standard error	24.79042288	21.74800299
Observations	12	12

(b) **Watershed MNJR013:**

For validation of the simulated result, regression analysis was carried out for simulated and observed precipitation values. The observed precipitation data were derived from global weather data. Table 8 shows simulated and observed rainfall data for Watershed MNJR013.

**Table 8** Monthly simulated and observed values of rainfall for MNJR013

Rainfall (mm)		
Month	Simulated values	Observed values
Jan	0.1	5.33
Feb	0.62	3.07
Mar	12.29	13.08
Apr	9.24	7.94
May	21.9	18.54
June	154.15	161.98
July	216.69	209.62
Aug	218.87	275.82
Sept	170.87	242.7
Oct	120.48	91.74
Nov	29.74	38.5
Dec	5	2.77

**Fig. 20** Graphical representation of simulated and observed rainfall data for MNJR013 watershed

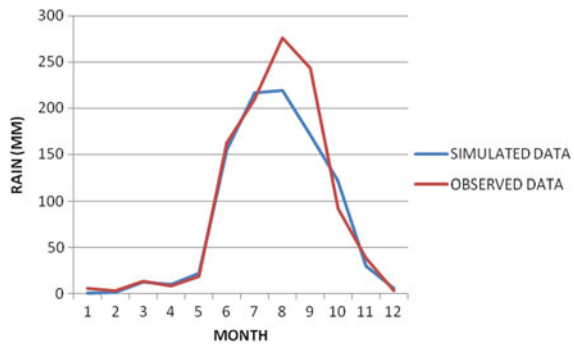


Figure 20 shows a graph between the simulated and observed precipitation values of the Manjra River Watershed MNJR013. The regression analysis gave the value of  $R^2$  as 0.971, which is closer to 1; hence, the simulated values obtained from SWAT simulation are validated. Table 7 shows the summary of regression analysis for rainfall values of Watershed MNJR013 of the Manjra River.

## 4 Conclusions

In this study, the water balance components for the Manjra River Watersheds MNJR012 and MNJR013 were evaluated through SWAT simulation, which are precipitation, runoff, water yield, and evapotranspiration. Also, land use/land cover and soil classification were obtained. The necessary thematic maps and databases



were prepared. To validate the obtained data, simulated data were compared with observed data, and regression analysis was performed, which gave values of  $R^2$  0.933 and 0.971 for Watersheds MNJR012 and MNJR013, respectively, which is closer to 1; hence, the simulated values obtained are validated. This study can be further used for different effective water resource management projects.

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