International Conference on
Soil and Water Assessment Tool 2018
(SWAT-2018)

Evaluation of Daily TMPA Rainfall for Rainfall-Runoff Modelling Using SWAT in Indravati River Basin, India

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Date: 12th Jan 2018

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Introduction

- Water is one of the most important natural resources which support the life of living organisms
- Due to an increase in population, there is a more demand for water from various sectors
- Hydrological modeling is the standard approach to estimate surface runoff
- Rainfall is the major driven force in hydrological modelling
- Recently remote sensing rainfall data application is increasing in water related studies
- Tropical Rainfall Measuring Mission (TRMM) rainfall data is having a great interest among the research community due to the origin of data from multi satellites
  - merging of TRMM rainfall with in-situ rain gauge measurements has extended their application
  - **Huffman and Bolvin, (2013)** developed an advanced version of TRMM 3B42 version7 namely TRMM MultiSatellite Precipitation Analysis (TMPA)

Introduction contd.,

- **Prakash et al., (2015)** carried out validation of TMPA rainfall data with observed gauge rainfall data at different time scales over the selected regions in India
- Along with rainfall data, selection of rainfall-runoff model also very important
- SWAT is a widely used semi distributed hydrological model which is an open source model
- Being SWAT as a semi distributed model, the constraint in data availability can also be reduced **(Arnold et al., 1998; Arnold et al., 2012)**
- SWAT model is applied at different geographical locations of the earth for quantifying daily surface runoff

Objective

- To evaluate the daily TMPA rainfall for rainfall-runoff modelling using SWAT model in Indravati river basin, a sub-basin of Godavari river, India

Methodology

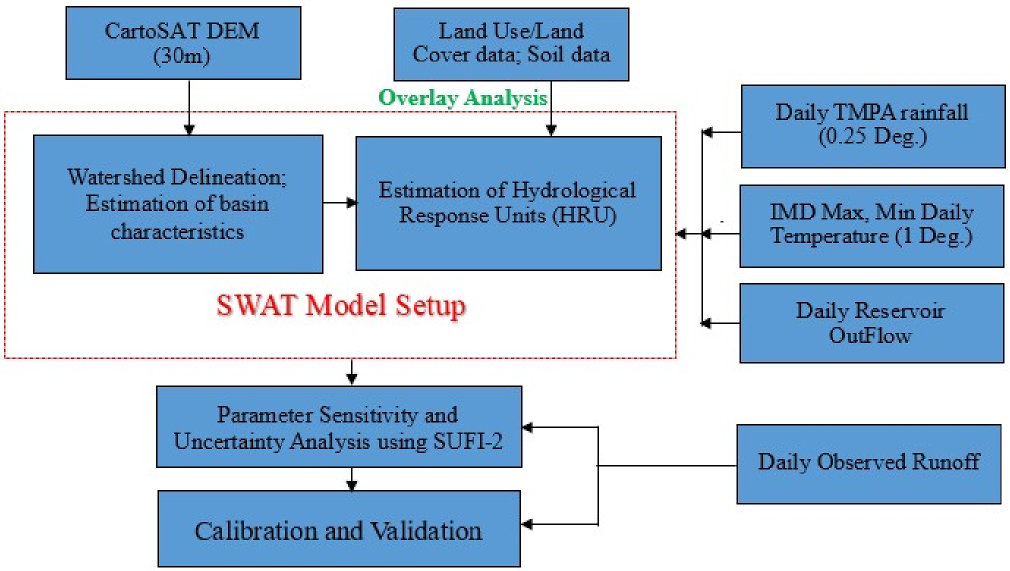

Figure 1. Flow chart of the methodology

Study Area

- The study area Indrāvati river basin is a sub basin of the Godavari river, India
- The Indrāvati basin covers a geographical area of 38,963.78 km^2

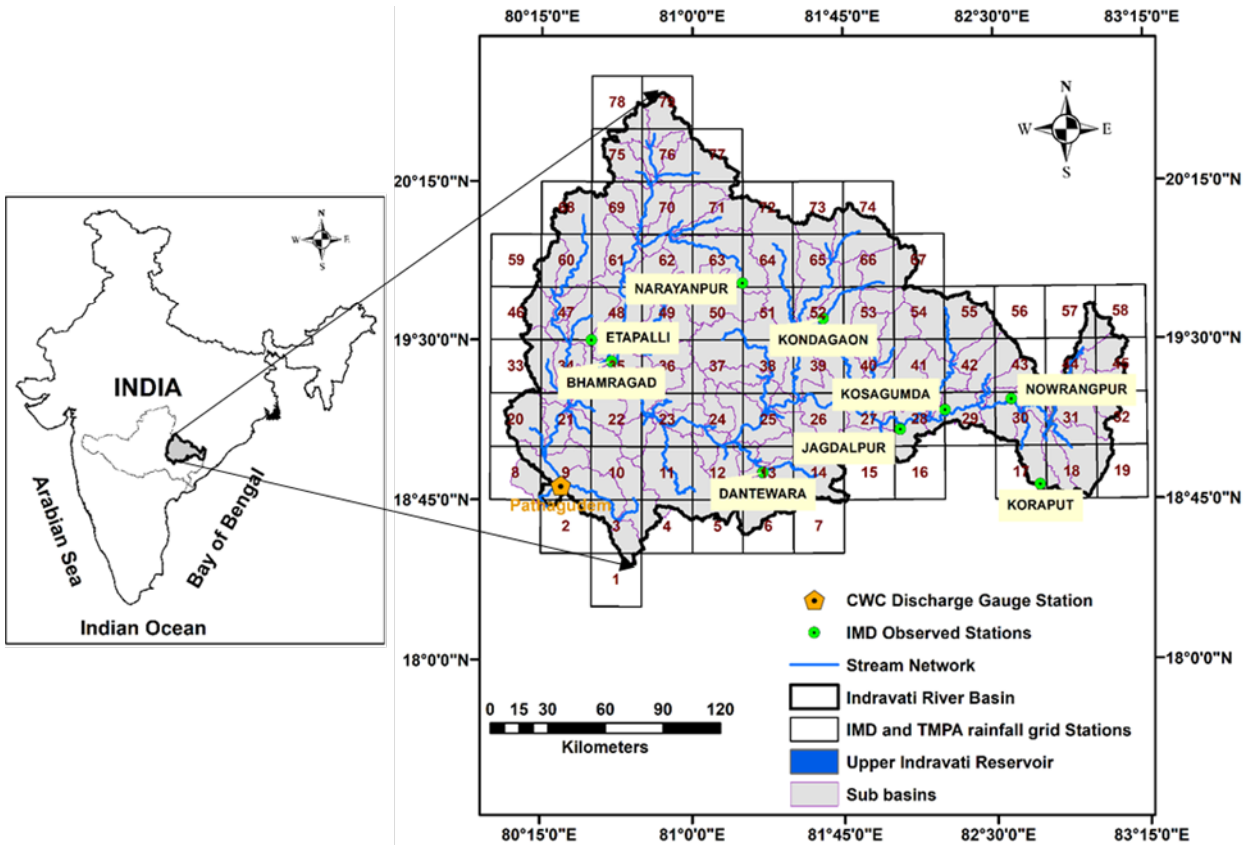

Figure 2. Location map of Indravati river basin with TMPA grid stations

Discharge

- The discharge data available from 2001 to 2013 at catchment outlet located in Pathagudem, Maharashtra

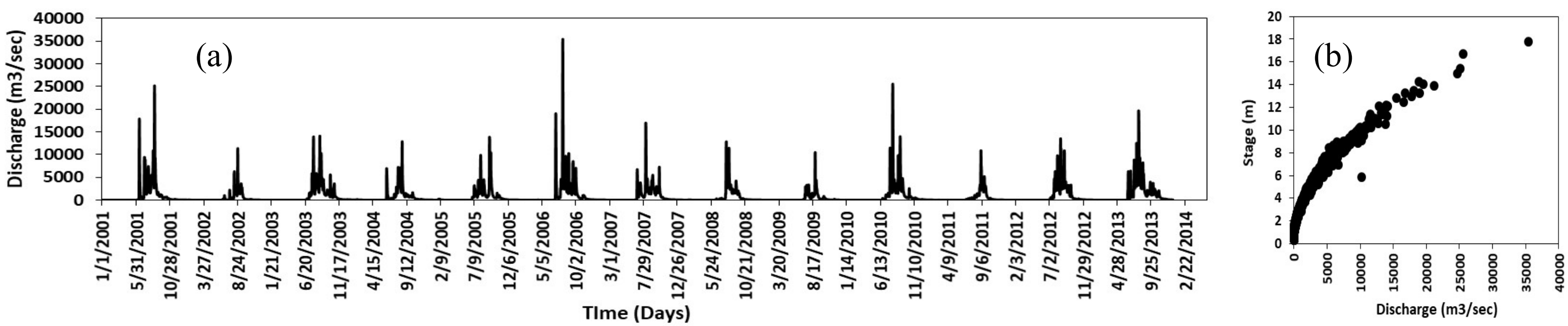

Figure 3. (a) Time series plot of the observed discharge, (b) Stage discharge relationship at Pathagudem (out let of Indravati river basin)

Data used Contd.,

➢ Land Use / Land Cover (LU/LC) data

- Indravati river basin is having forest area as a dominant LU/LC and irrigated or agriculture land as a second dominant LU/LC

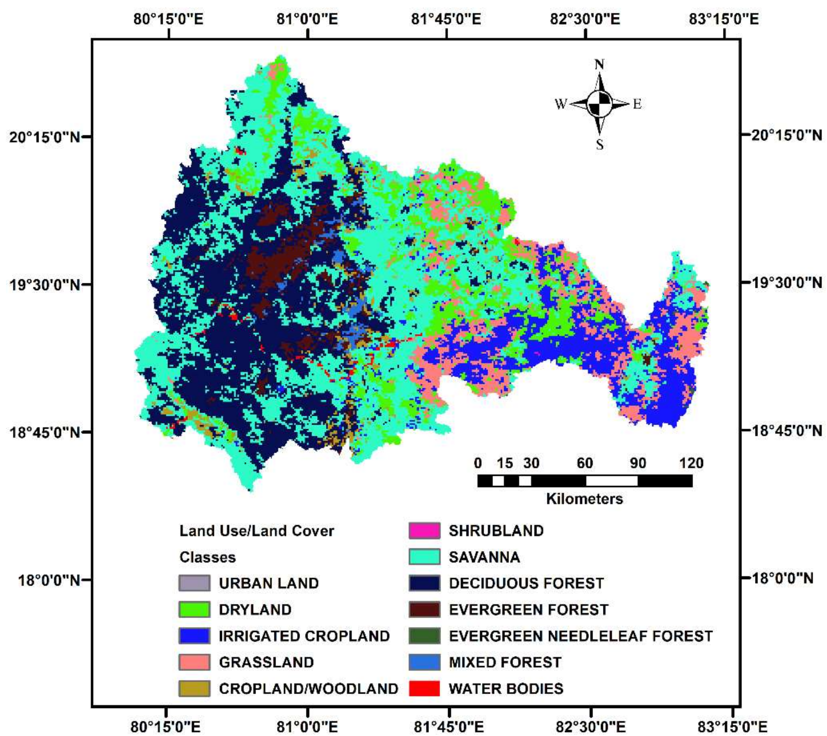

Figure 4. Land Use / Land Cover Map of Indrāvati basin

- Soil data
  - Indravati river basin includes clay loam soil as a dominant soil
  - There exist eight different types of soil classes within the river catchment area
  - Those are sandy clay loam, clay loam, clay, sandy loam, silt, and silt loam are the major soil groups in this basin

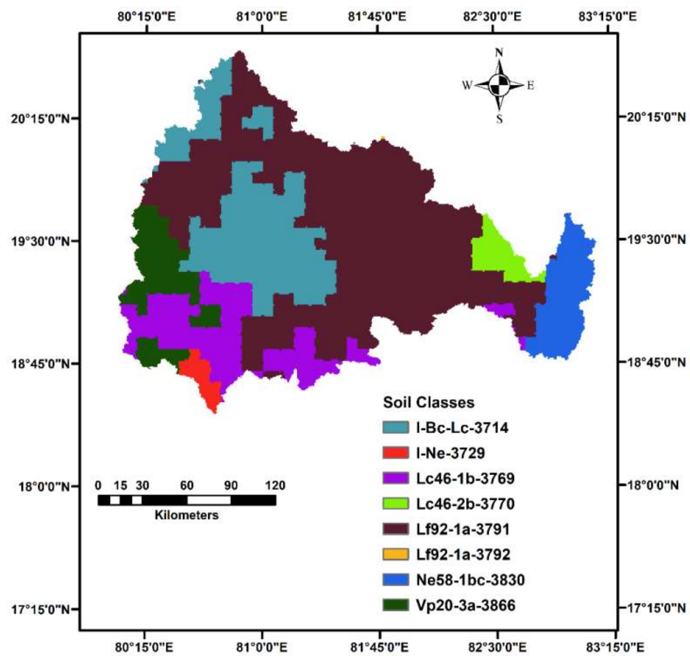

Figure 5. Soil map of Indrāvati basin
(source: webarchive.iiasa.ac.at/Research/LUC/External-World-soil-database)

Data used Contd.,

➢Digital Elevation Model (DEM)

- The Indravati rises on the western slopes of Eastern Ghats
- The highest elevation is 1325 m

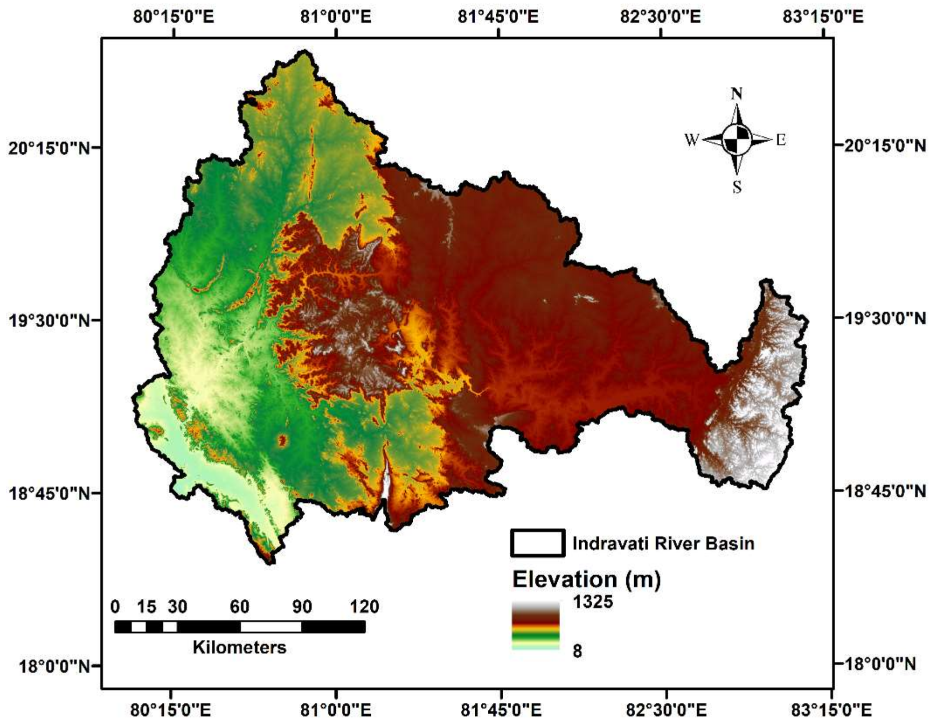

Figure 6. Digital elevation map of Indrāvati basin (Source: bhuvan.nrsc.gov.in)

Data used Contd.,

➢Rainfall

- ❖The daily TMPA rainfall with 79 grid station pertaining to Indravati river basin is used.
- ❖The study period of 13 years from 2001 to 2013 is considered

➢Reservoir Outflow

- ❖The reservoir outflow data provided by CWC for upper Indravati reservoir is collected
- ❖This data is available from 1st Jan 2005 to 31st May 2017. The data period from 2005 to 2013

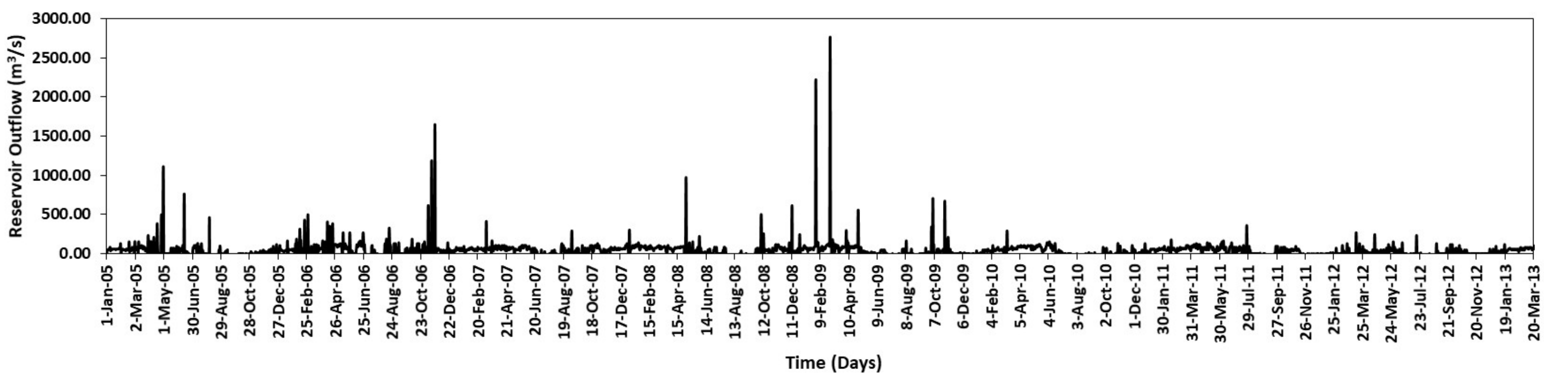

Figure 7. Daily reservoir outflow data at upper Indravati reservoir

Sensitivity analysis of SWAT model parameters

Table 1. Best fitted values of SWAT model parameters for TMPA rainfall

S. No.	Parameter name	Parameter description	Initial value	Parameter range		Best fitted value
				Lower bound	Upper bound	TMPA rainfall
1.	a_CN2.mgt	SCS runoff curve number	70	0	0.2	13.01
2.	v_ALPHA_BF.gw	Base flow alpha factor (days)	0.048	0	0.1	0.075
3.	v_GW_DELAY.gw	Ground water delay (days)	31	20	60	57.692
4.	a_GWQMN.gw	Threshold depth for ground water flow to occur (mm)	1000	100	1000	921.07
5.	a_CH_K2.rte	Effective channel hydraulic conductivity (mm/hr)	0	0	100	84.37
6.	v_OV_N.hru	Manning's N	0.01	0.1	7	5.934
7.	v_SURLAG.bsn	Surface runoff lag coefficient (days)	4	0.1	20	17.24
8.	v_ESCO.bsn	Soil evaporation compensation factor	1	0.6	1	0.668
9.	v_EPCO.bsn	Plant uptake compensation factor	1	0.6	1	0.827
10.	v_RCHRG_DP.gw	Deep aquifer percolation fraction	0.05	0.01	0.2	0.129
11.	v_GW_REVAP.gw	Ground water "revap" coefficient	0.02	0.01	0.2	0.135
12.	r_SOL_AWC (...).sol	Available water capacity of the soil layer (mm H_2O/mm sol)	1	0.1	1	0.46
13.	v_SOL_BD (...).sol	Moist bulk density (g/cm3)	2.5	0.1	2	0.84
14.	r_SOL_K (...) .sol	Saturated hydraulic conductivity (mm/hr)	2000	0	0.2	0.133

Daily runoff estimation of SWAT model

➢ The runoff estimations of SWAT model with TMPA daily rainfall

- During the calibration period, R^2 and NSE values are 0.35 and 0.3 respectively
- During the validation period, these values are 0.51 and 0.45 respectively

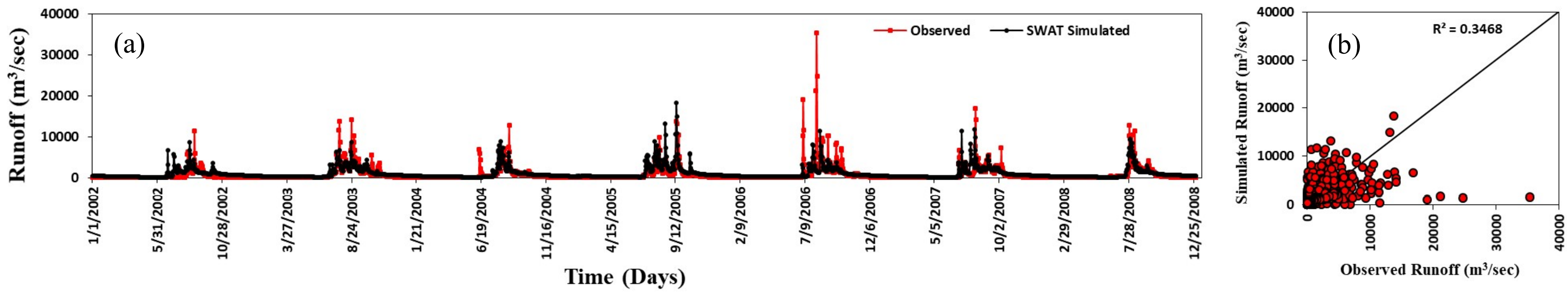

Figure 8. Daily runoff estimated during calibration period using SWAT model with considering reservoir

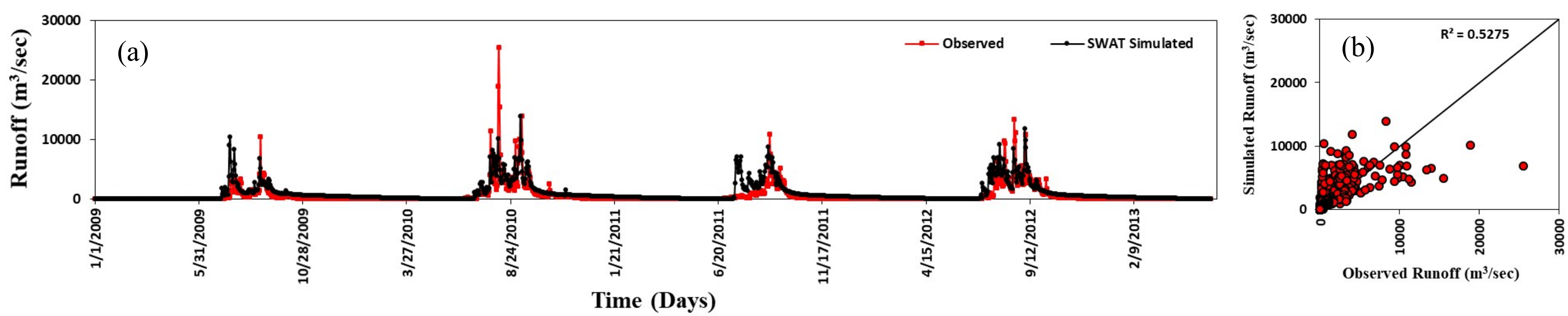

Figure 9. Daily runoff estimated during validation period using SWAT model with considering reservoir

Monthly runoff estimation of SWAT model

- The runoff estimation of SWAT model forced with TMPA monthly rainfall
  - During the calibration period, R^2 and NSE values are 0.35 and 0.3 respectively
  - During the validation period, these values are 0.51 and 0.45 respectively

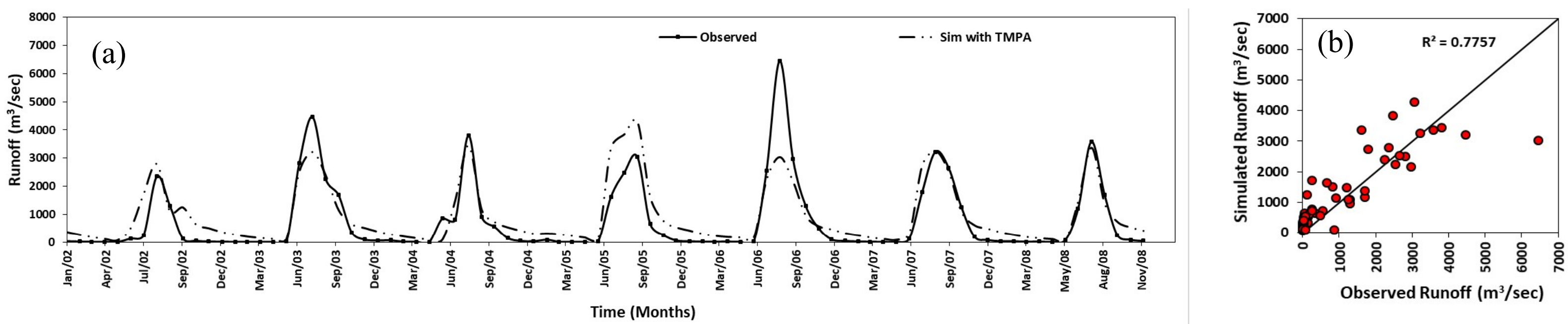

Figure 10. Monthly runoff estimated during calibration period using SWAT model with considering reservoir

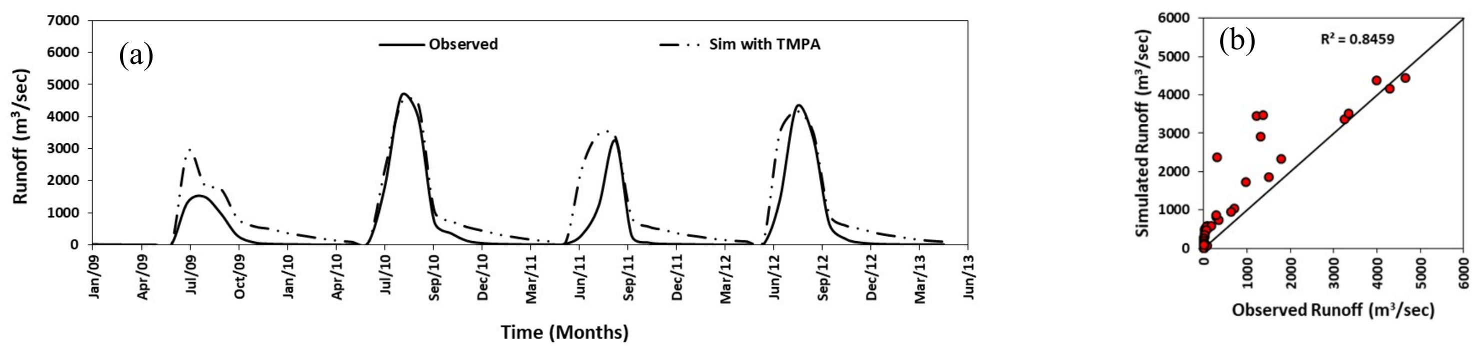

Figure 11. Monthly runoff estimated during validation period using SWAT model with considering reservoir

Results of SWAT model simulations

- The results indicates that, SWAT model estimated runoff more accurately during validation period than calibration period
- This may be due to the under estimation of TMPA maximum rainfall at higher elevations
- The addition of reservoir data improved the accuracy of model estimations in Indravati river basin
- Since, the drainage area under this reservoir is very less compared to basin area, the reservoir effects need to be studied at other basins with consideration of more reservoirs

Table 2. Results of SWAT modelling in Indravati river basin

S.No.	SWAT simulation	Time Step			
		Daily		Monthly	
		R^2	NSE	R^2	NSE
Calibration period 2002 to 2008					
1.	Without Reservoir	0.29	0.26	0.72	0.65
2.	With Reservoir	0.35	0.3	0.78	0.75
Validation period 2009 to 2013					
3.	Without Reservoir	0.51	0.45	0.86	0.76
4.	With Reservoir	0.53	0.42	0.85	0.71

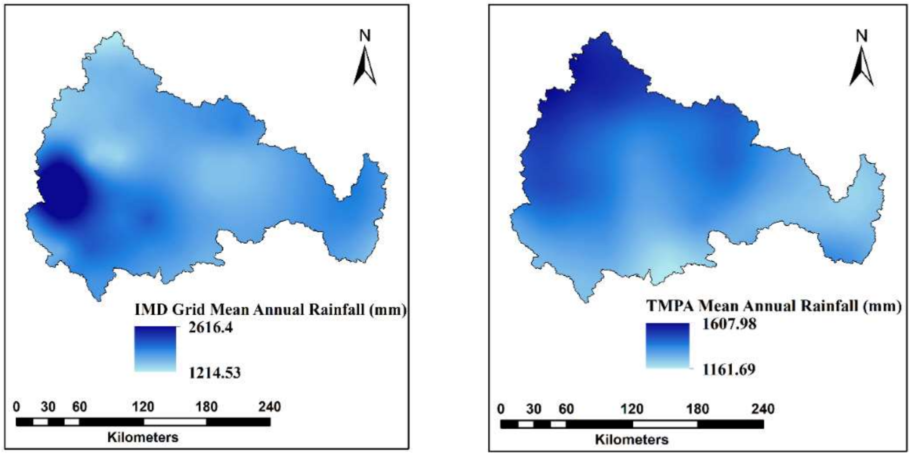

Figure 12. Mean annual rainfall in Indravati river basin. a) IMD gridded and b) TMPA rainfall

Conclusions

- Around 1000 mm difference in TMPA maximum rainfall magnitudes is observed at a higher elevation when compared to observed data
- From the sensitive analysis of SWAT model parameters, ALPHA_BF, GW_REVAP, RCHRG_DP, SOL_K, SOL_BD, ESCO and GW_DELAY are observed to be most sensitive parameters
- Around 5 percent catchment area under upper Indravati reservoir improved the 10 percent of model accuracy for TMPA grid based SWAT model simulations at daily time step
- Overall, TMPA rainfall, an open source data with global coverage is a promising dataset for estimating surface runoff at large river catchments, especially at data scarce regions

Important references

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Thank You