Performance Evaluation of SWAT with a Conceptual Rainfall-Runoff Model GR4J for a Catchment in Upper Godavari River Basin

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- Introduction to Water Resources Management
- Brief Overview of eWater's Source
- Study Objectives
- Overview of Models Used
- Study Area and Datasets
- Methodology
- Results and Discussion
- Conclusion

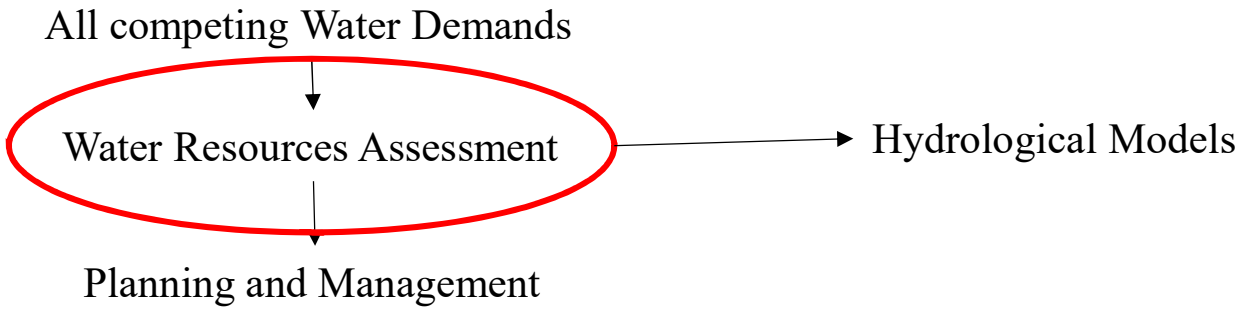
Introduction

Water Resources Management

- ✓ Planning
- ✓ Developing
- ✓ Distributing
- ✓ Managing the optimum use

} Water Resources

Goal: Sharing in equitable basis amongst the stakeholders



- Model Complexity
- Data Requirement
- Structural Parameters

Distributed/Semi Distributed Models	Conceptual Models	Black Box Models
Complex	Over Simplified Hydrological Cycle	Based on Input and Output
High	Low	Low
Physically Based	Conceptually Based , Depends Upon Model Structure	Neither Physically nor, Conceptually Based

- **Distributed models** although **most ideal**, they are **not suitable** for **data scarce areas**.
- **Conceptual models** are gaining popularity due to their **simple structure** and **less data requirement.**
- These models have **very few parameters** which also helps in **faster model setup** and **calibration**.
- Conceptual models have been applied at various parts of world and proved to be very good water resources management tools. However studies in Indian catchments are scanty.

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eWater's Source

- *eWater's Source ,developed by CRC , Australia ,*provides a modelling framework for conceptual models.
- The framework provides flexibility in **choosing models** , **objective function for calibration** and **calibration method**.
- The **GIS tools** in framework is helpful of delineating catchments and dividing them into many sub-catchments.
- Out of the 11 models provided in the Source's Modelling Platform, **GR4J** is selected as they are the ***simplest*** and have ***wide application area.***

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Study Objectives

- **Calibration**, **validation** and **determination of parameters** of the models.
- Comparison of rainfall runoff models **GR4J** and **SWAT** for a medium sized catchment in Upper Godavari River Basin.
- Discussing the **limitations** and **scope** of the models.

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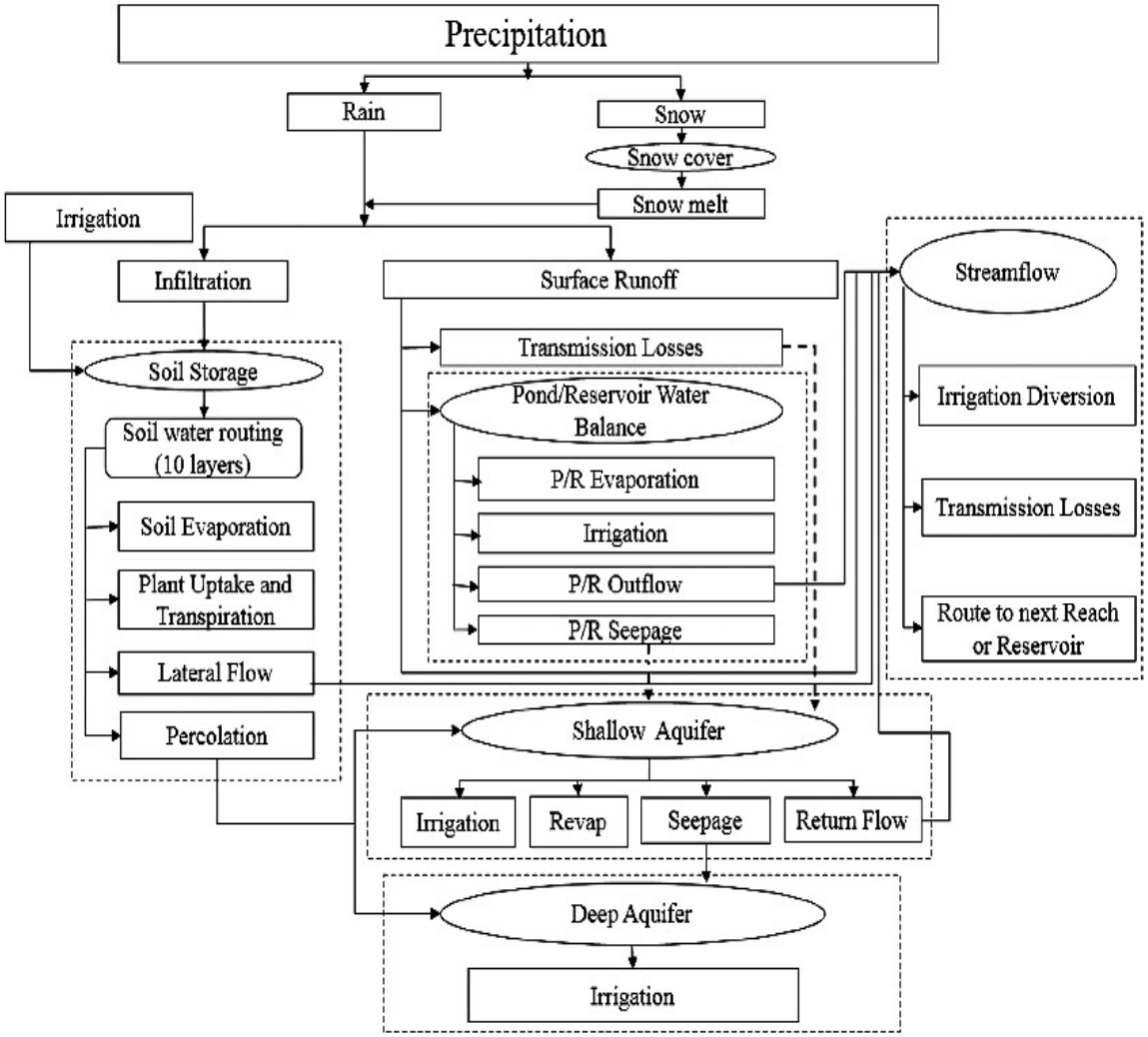
SWAT

- Stands for Soil and Water Assessment Tool.
- It is physically based, semi distributed model.
- It works on daily time steps.
- It divides the catchment into a number of Sub-basins and then into Hydrological response units with respect to Land use , Slope and Soil data.
- Being a distributed model, the data requirement of this model consists of various meteorological and non-meteorological inputs.

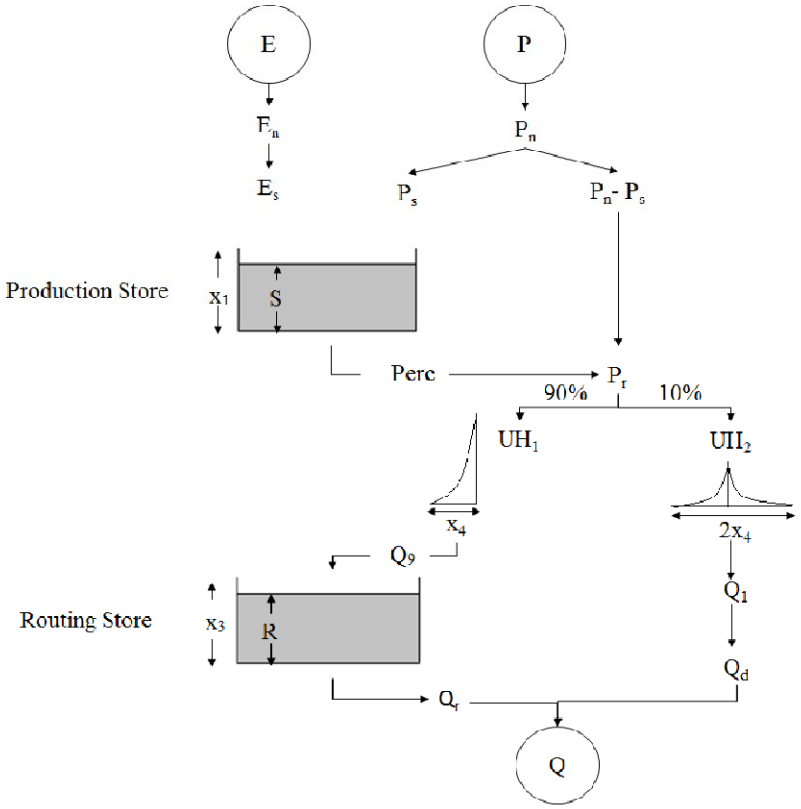


Source: Neitsch et al. 2009

GR4J

- Stands for **Ge´nie Rural a` 4 parame`tres Journalier**.
- It belongs to the family of soil moisture accounting models.
- It is a **continuous lumped conceptual model** which operates in **daily step**.
- The parameters used in this model are independent and represent the components of conceptual hydrological model.
- Using Source platform a catchment can b e divided into many sub catchments manually which are also called functional units and parameters can be calibrated for each unit separately.
- The data used for this model are **rainfall** (P) and **potential evapotranspiration** (E).

GR4J - Model Structure



Source: Perrin et al,2003

Parameters	Description of Parameters	Units	Range	Significance
x_1	Maximum capacity of the production store	mm	1-1500	Represents Soil store from which losses occur
x_2	Water exchange coefficient	mm		Quantifies Baseflow contribution
x_3	Maximum capacity of the routing store	mm	1-500	Represents Soil store which contributes to stream flow
x_4	Time Parameter for unit hydrographs	day	0.5-4	Controls peak flow occurrence

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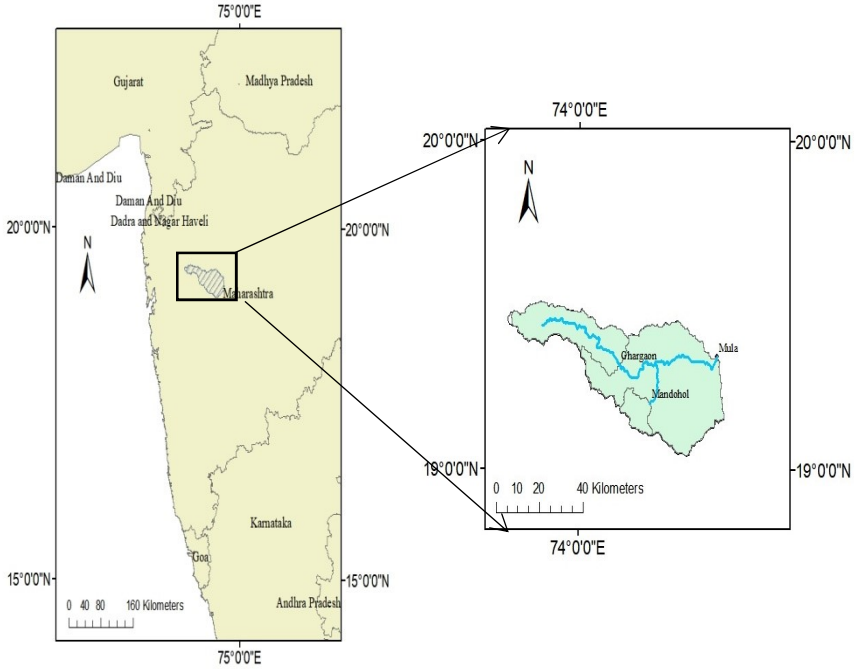
STUDY AREA



- Catchment Location: Ahmednagar district, Maharashtra
- It is delineated with respect to the Mula dam which is the 2nd largest dam after Paithan dam in Upper Godavari Region.
- Catchment Area: 2300 km^2
- Primary land-use pattern are barren and agricultural lands.
- Soil type: Loam
- Water Resource Usage: Mainly for Irrigation and Drinking

Data Requirement for SWAT

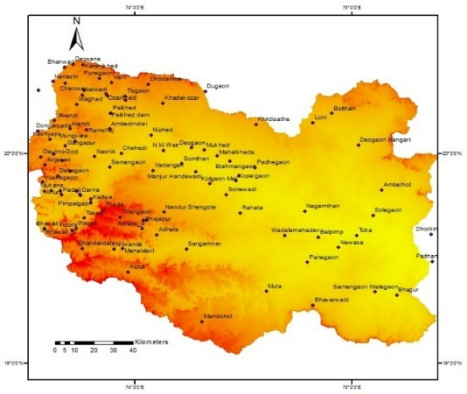
DATA TYPE	SOURCE	SCALE/ PERIODS	DATA DESCRIPTION
DEM	SRTM digital elevation data produced by USGS	30m x 30m	Terrain properties.
SOIL	FAO (Food and Agricultural Organization)	1/5000000	Soil classification and physical properties
LAND USE	NRSC, ISRO Hyderabad	28m*28m /2004	Land use classification(19 classes)
CLIMATE	Indian Meteorological Department (IMD)	0.25 degree / 2000-2011	Minimum and Maximum temperature, wind speed, relative humidity, solar radiation
DISCHARGE	WALMI,Aurangabad	2000-2011	Daily discharge data at selected station
PRECIPITATION	WALMI,Aurangabad	2000-2011	Daily Rainfall for 102 Rain-gauges in Upper Godavari River Basin

Data Requirement of GR4J

•Digital Elevation Model from **USGS's Shuttle Radar Topography Mission** is used for delineation of the catchment area.

•The Meteorological inputs required are : **Precipitation Data** and **Potential Evapotranspiration Data**

- PET data is collected from **2 stations Inside the Mula catchment**.
- Representative precipitation for the catchment is calculated using **Theissen Polygon Method** for available rain gauges in **Upper Godavari River Basin**.



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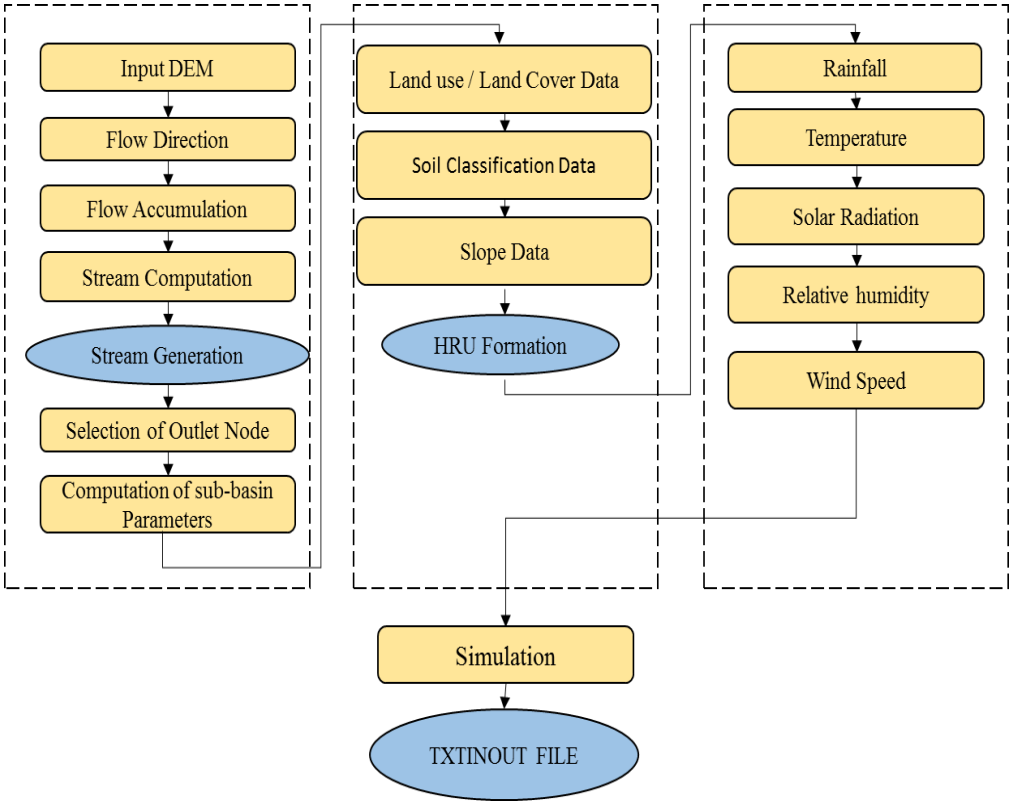
Calibration and Validation

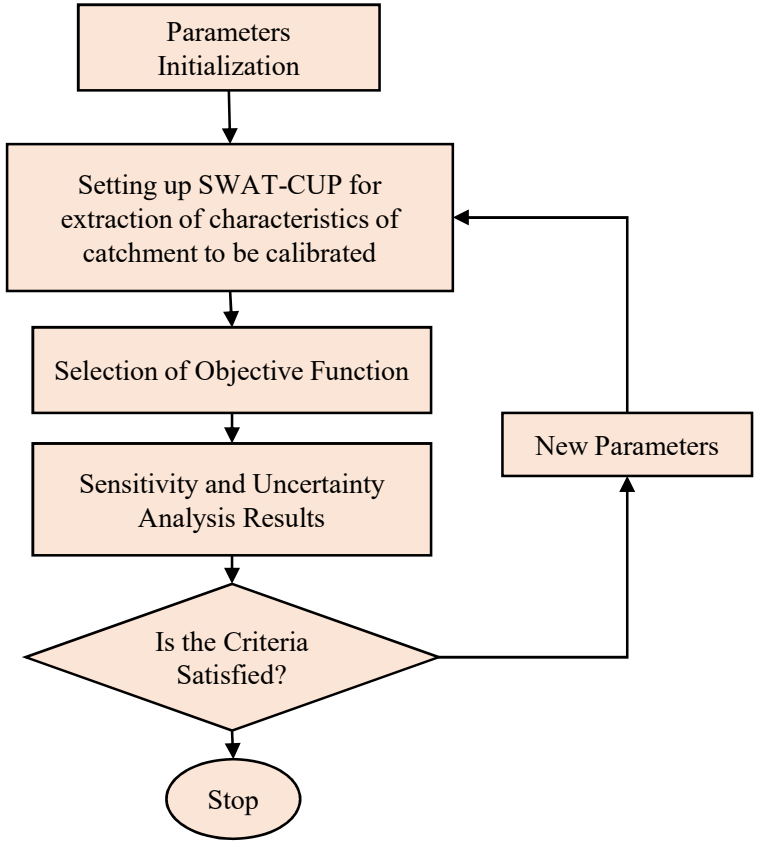
Models	GR4J	SWAT
Calibration Tool	Source's Calibration Wizard.	SWAT -CUP
Calibration Method	Shuffled Complex Evolution then Rosenbrock's Function	SUFI2
Objective Function:	NSE daily and bias penalty	NSE
Number of SCE Complexes	7	--
Number of Parameters used for calibration	**4**	**11**
Number of Iterations	1000	1000 simulations Iterated 4 Times
Performance Evaluation Parameters for Calibration	•NSE •R^2	•NSE •R^2 •PBIAS •P-factor •R-factor
Calibration Period	2000-2007	2000-2007
Validation Period	2008-2011	2008-2011
Scale	Monthly	Monthly

SWAT

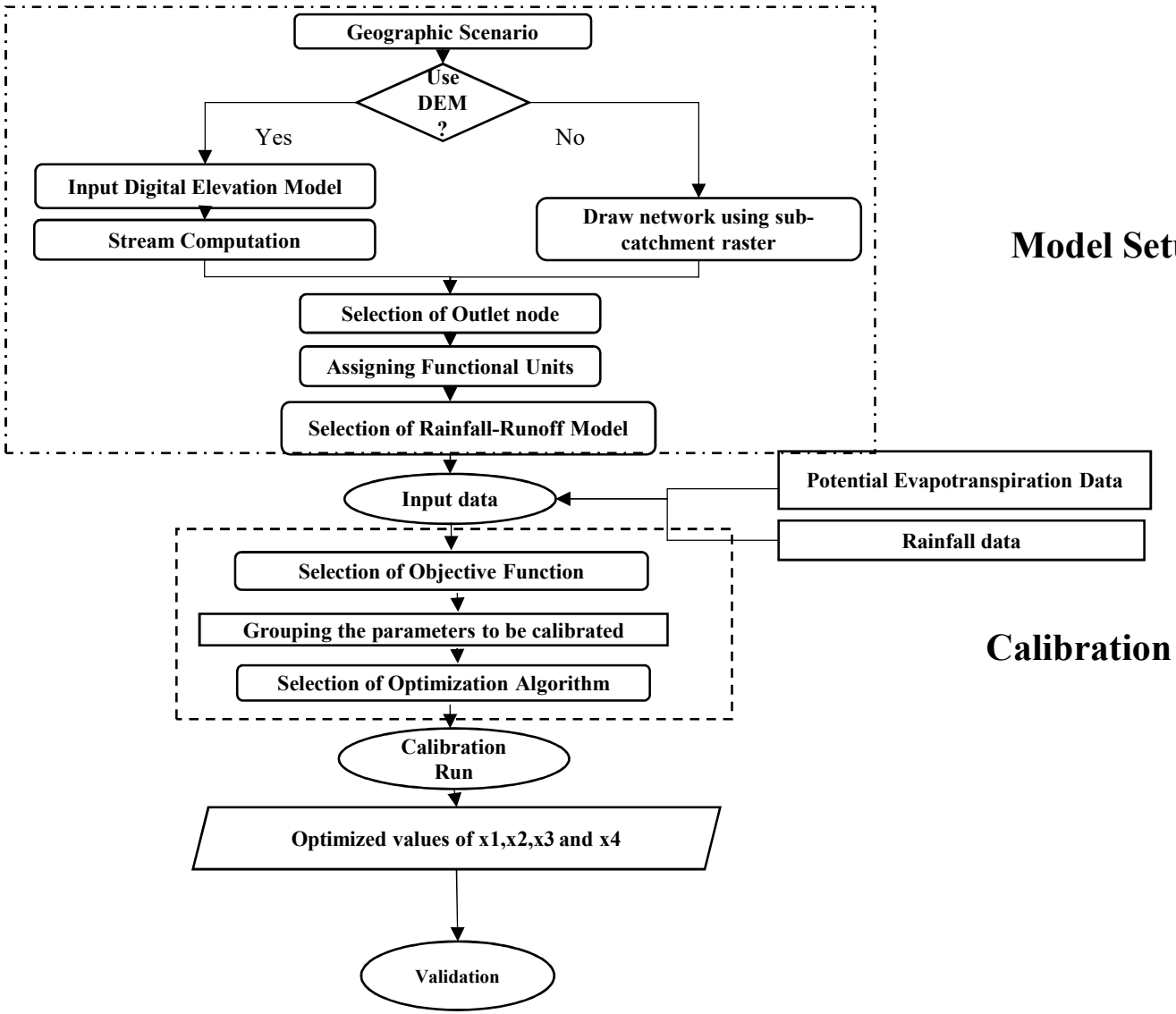
Model Set Up and Simulation



Calibration and Uncertainty Analysis



GR4J


Geographic Scenario
Use DEM ?
Yes
No
Input Digital Elevation Model
Stream Computation
Draw network using sub-catchment raster
Selection of Outlet node
Assigning Functional Units
Selection of Rainfall-Runoff Model
Model Setup
Input data
Potential Evapotranspiration Data
Rainfall data
Selection of Objective Function
Grouping the parameters to be calibrated
Selection of Optimization Algorithm
Calibration Setup
Calibration Run
Optimized values of x1,x2,x3 and x4
Validation

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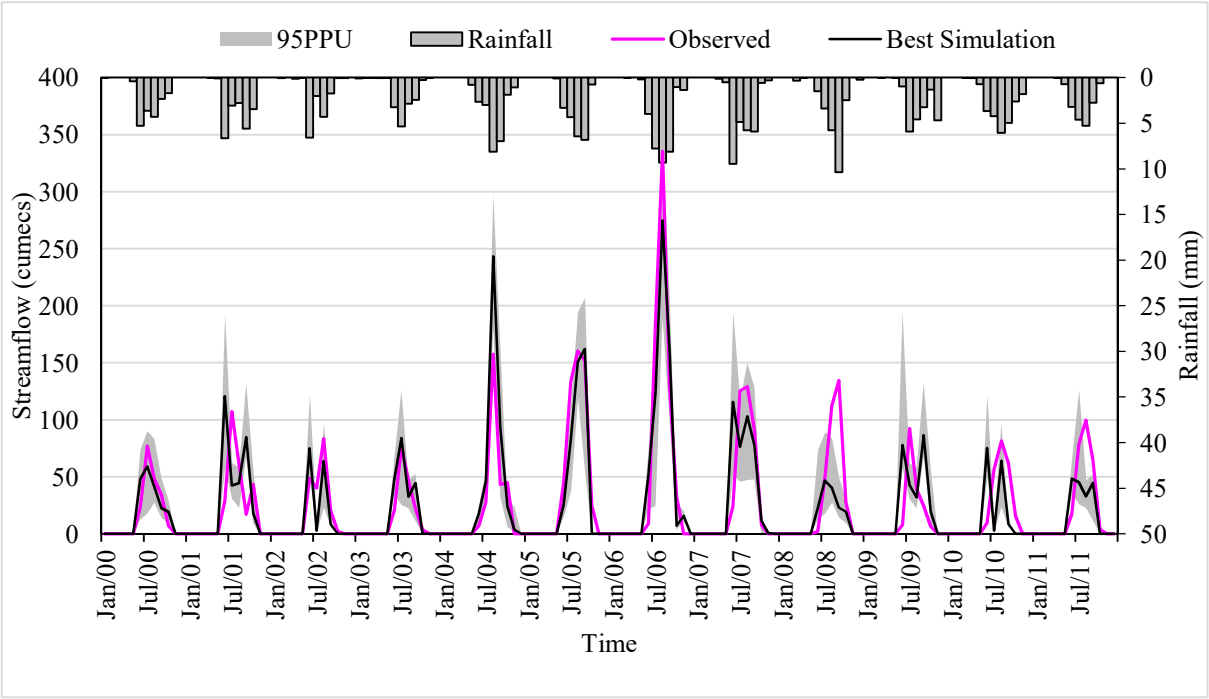
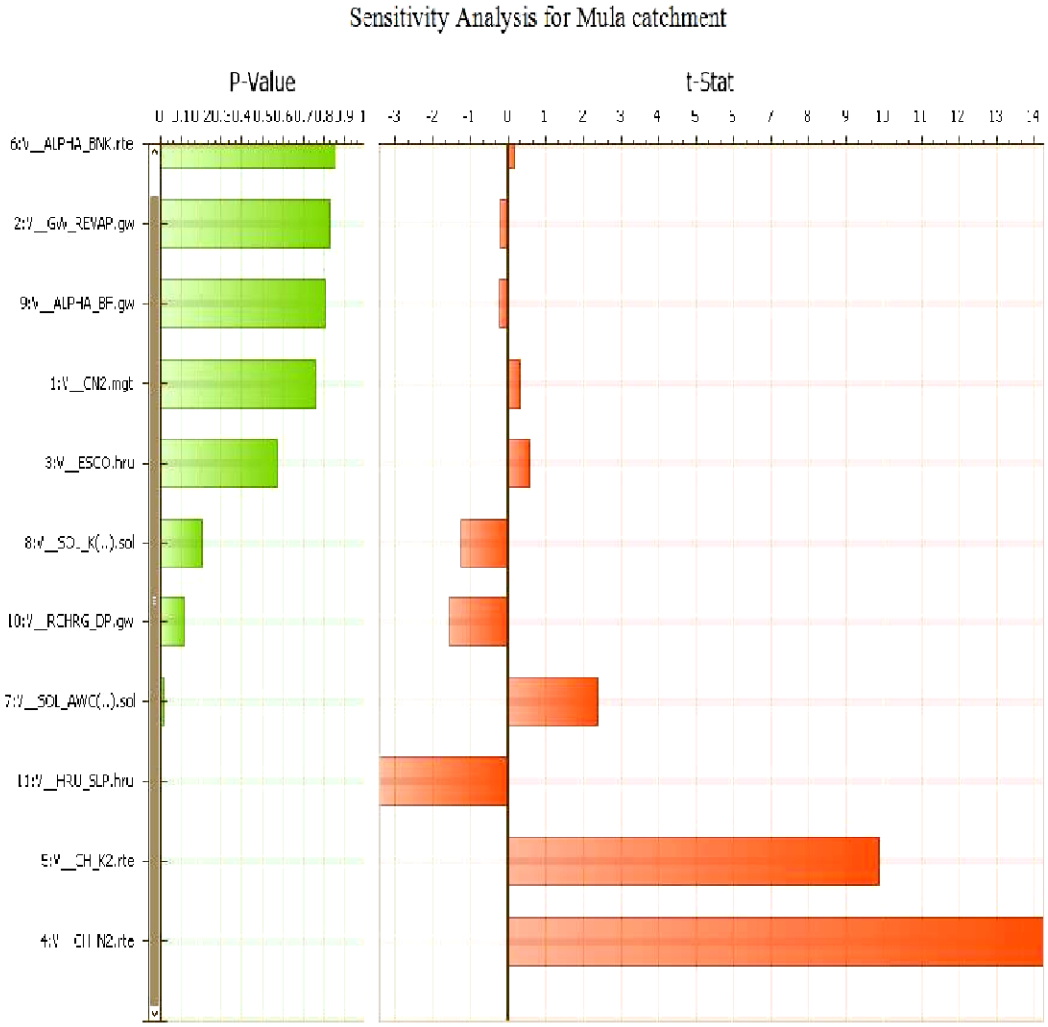
SWAT Model Results

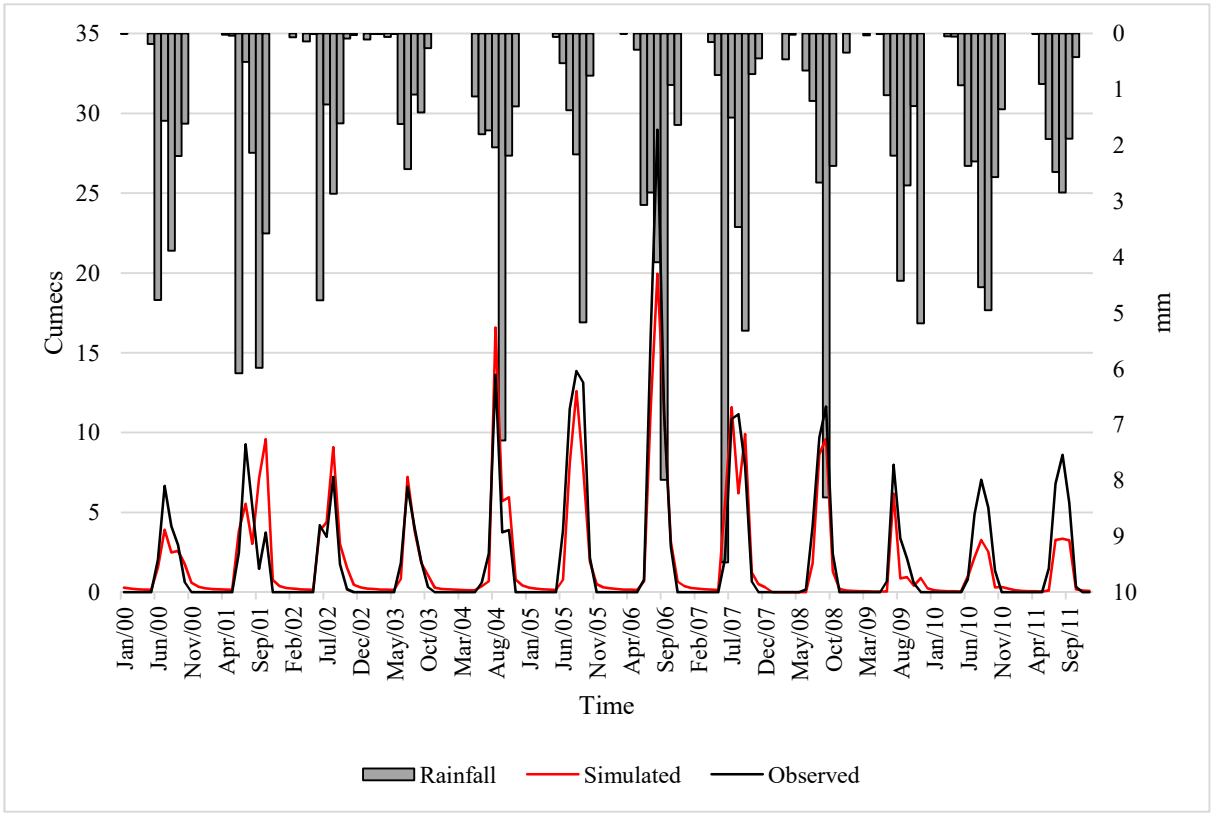


	Calibration	Validation
NSE	0.78	0.65
R^2	0.78	0.67
PBIAS	-1.7	25.6
p-factor	0.77	0.59
r-factor	0.49	0.55



Parameter_Name	Fitted_Value
V__CN2.mgt	34.54417
V__GW_REVAP.gw	0.073399
V__ESCO.hru	0.871966
V__CH_N2.rte	0.045024
V__CH_K2.rte	64.824745
V__ALPHA_BNK.rte	0.103641
V__SOL_AWC(..).sol	0.93245
V__SOL_K(..).sol	1166.42627
V__ALPHA_BF.gw	0.044351
V__RCHRG_DP.gw	0.566686
V__HRU_SLP.hru	0.177506
V__REVAPMN.gw	189.188705

GR4J Model Results



Calibrated Parameters

x1	x2	x3	x4
127.76	2.46	59.69	2.82

	Calibration	Validation
NS	0.82	0.57
R^2	0.84	0.61

Comparison

	GR4J	SWAT
Type	Conceptual model	Semi-Distributed model
Parameters	4	More than 20 parameters to calibrate using streamflow
Structure	Simple structure	Complex structure
Data Requirement	Requires only two input variables, PET and Rainfall	Requires meteorological properties such as wind speed, relative humidity, Temperature, etc. and physical watershed properties such as LULC, soil along with rainfall as input.
Time requirement	Low	High
Suitability	Suitable for data scarce regions	Not suitable for data scarce regions
Calibration	Deterministic calibration	Stochastic calibration
Output	Streamflow	It can generate other hydrologic processes along with stream flow
Catchment characteristics	Does not consider physical properties of the watershed for modeling	Considers physical properties of the watershed for modeling e.g., LULC, Soil
Scale of catchment	Provides best results in small catchments	Provides best results in small as well as large catchments

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Conclusions

- GR4J has 4 independent parameters, SWAT has many interdependent physically based parameters.
- The parameters of GR4J give a vague idea about catchment characteristics , where as that of SWAT being physically based helps us understand various hydrological processes in the catchment concerned.
- The **calibration process** for **GR4J** is **faster** than **SWAT** due to it **lower complexity**.
- The **performance** of both **GR4J and SWAT** are similar in terms of NSE and R^2.
- **Conceptual models** such as **GR4J** can be used as effective water resource modelling tools in **data scarce areas** for short term analysis and prediction.
- Due to unreliability of parameters , GR4J can't be used for long term prediction and analysis. In such cases, distributed model such as SWAT can be used.

ACKNOWLEDGEMENT

We are thankful to **Water And Land Management Institute (WALMI), Aurangabad** and **eWater, Australia** for providing necessary data for this study.

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Any Questions /Suggestions?

Thank You