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Hydrological Modeling of Upper Tapi River Sub-Basin, India using QSWAT Model and SUFI2 Algorithm

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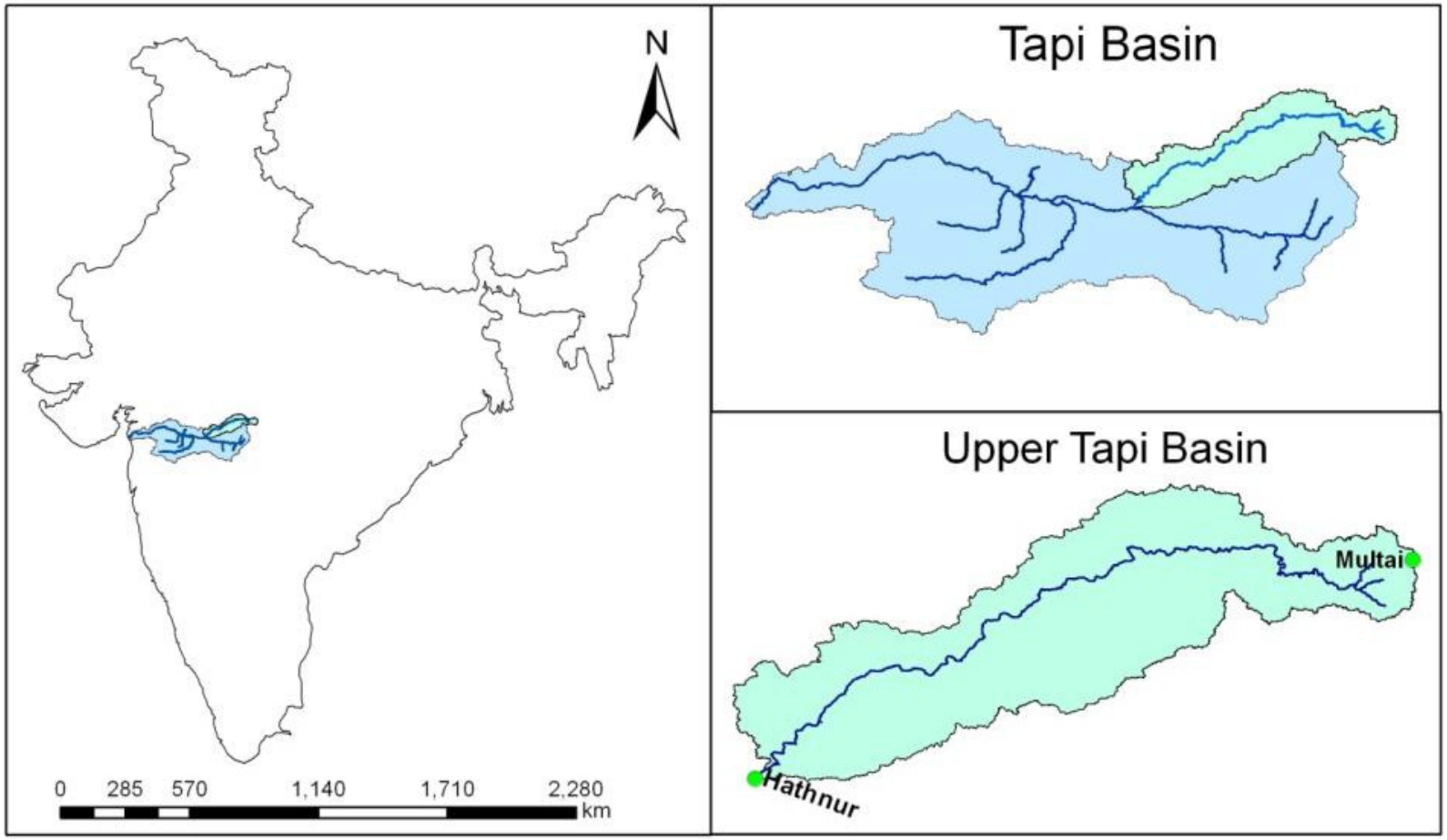
Introduction

- Study of stream flow variation and hydrological responses is important for sustainable utilization of water resources and local ecological preservation in any catchment area.

- For that purpose hydrological modelling is carried out to conceptualize and investigate the relationships among climate, human activities, and water resources.

- Different types of hydrological models are available like MIKE SHE, WEPP, HEC-RAS, TOPMODEL, VIC, SWAT etc.

Study area map

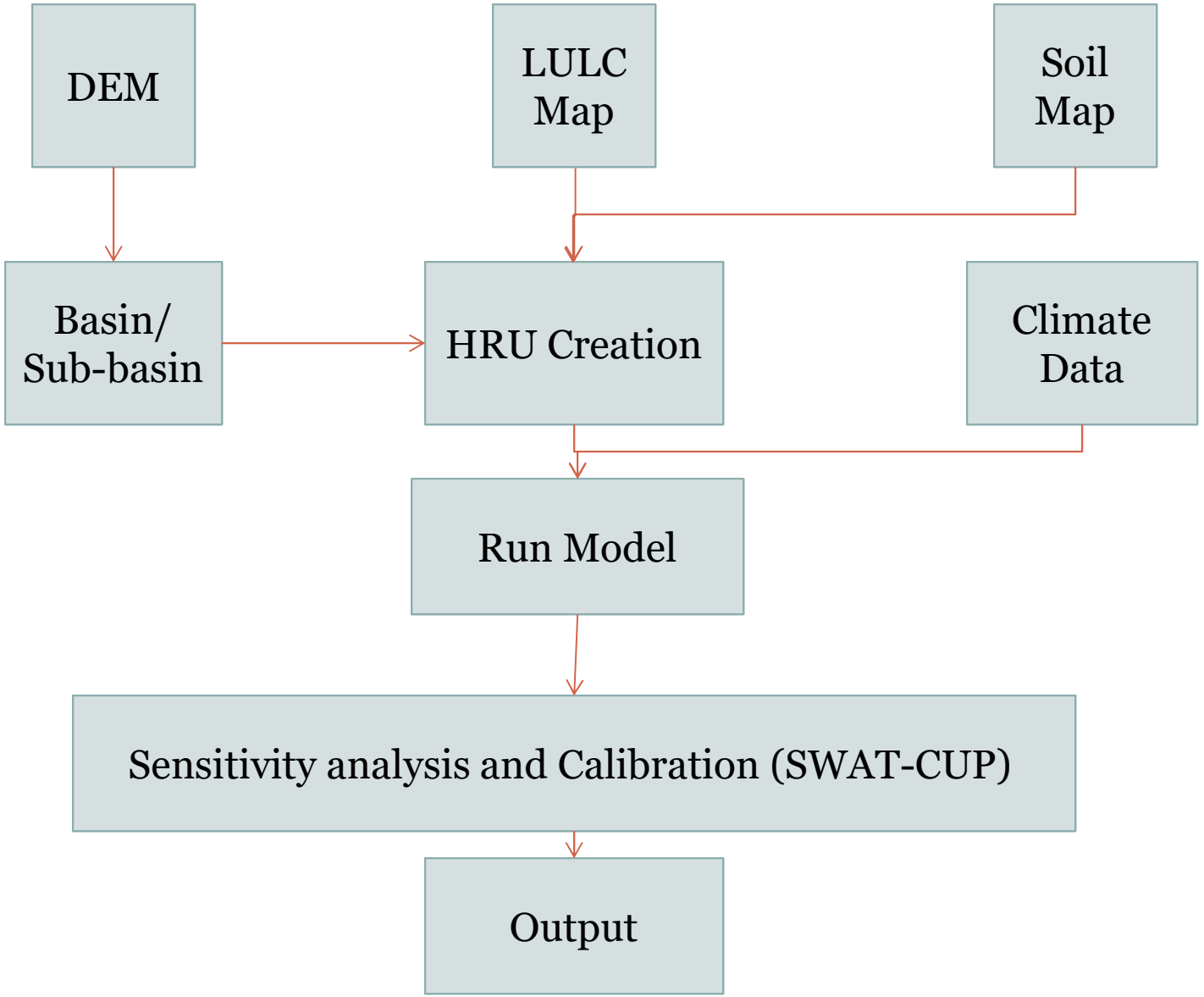


Upper Tapi Basin Area = 10,595 km² ; Elevation : Min 216m, Max 1174m
Average annual Rainfall of Upper Tapi Basin = 950mm
River length (from Multai to Hathnur) = 350km

Input data

Data Type	Resolution	Source
Digital Elevation Model (DEM)	90m	Shuttle Radar Topography Mission (SRTM) http://www2.ipl.nasa.gov/srtm/
Soil	5km	FAO-UNESCO global soil map http:/www.fao.org/nr/land/soils/digital-soil-map-of-the-world/
Landuse	500m 30m	Global Irrigated Area Mapping (GIAM) http://waterdata.iwmi.org/Applications/GIAM2000/ LANDSAT-8 https://earthexplorer.usgs.gov/
Climate	0.5^0 x 0.5^0 0.35^0 x 0.35^0	Indian Meteorological Department (IMD) http://www.imdpune.gov.in Climate Forecast System Reanalysis (CFSR) https://globalweather.tamu.edu/
Discharge	Observed	India WRIS portal http:/www.india-wris.nrsc.gov.in

Working of SWAT Model



Sensitivity Analysis

- Sensitivity analysis is the process of determining the significance of one or a combination of parameters with respect to the objective function. (Abbaspour et al., 2014)

- Two Methods are available

1. Global Sensitivity analysis
2. One at a time

Calibration

- Calibration is the process of adjusting model inputs with observation to get the best simulation result

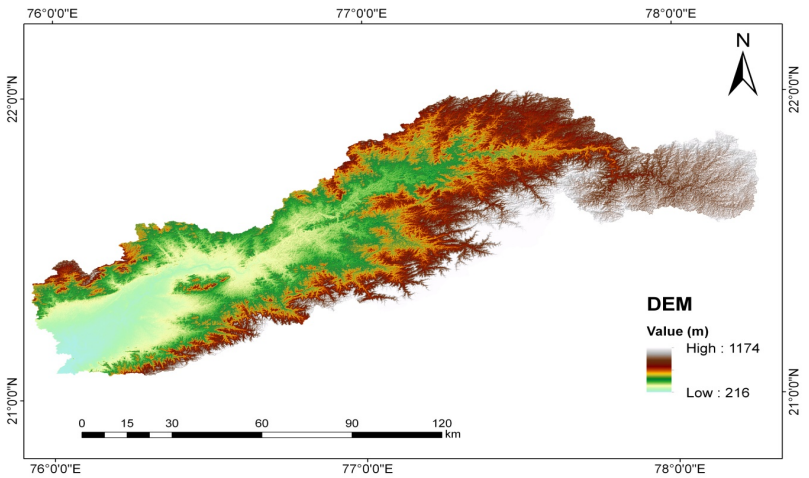
- It can be done either manually or by using auto calibration technique

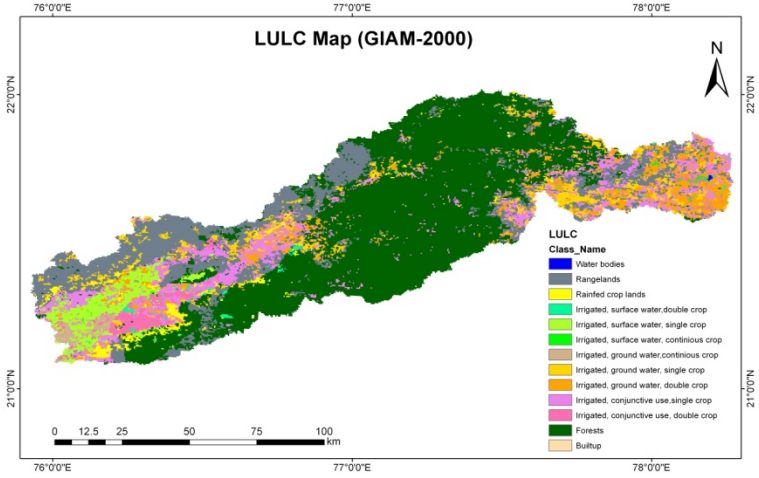
- SWAT-CUP (Calibration and Uncertainty Program) having 5 different methods to do auto calibration

1. SUFI2 (Sequential Uncertainty Fitting)
2. PSO (Particle Swarm Optimization)
3. GLUE (Generalized Likelihood Uncertainty Estimation)
4. ParaSol (Parameter Solution)
5. MCMC (Markov Chain Monte Carlo)

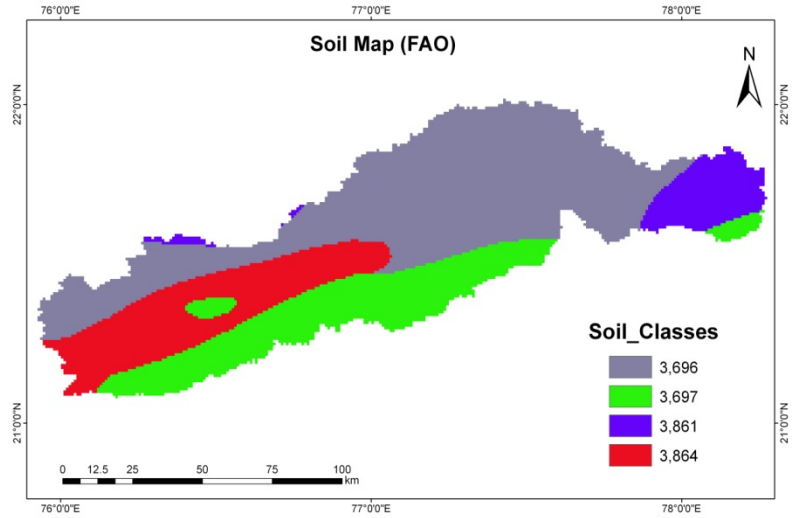
Model performance criteria for flow simulation

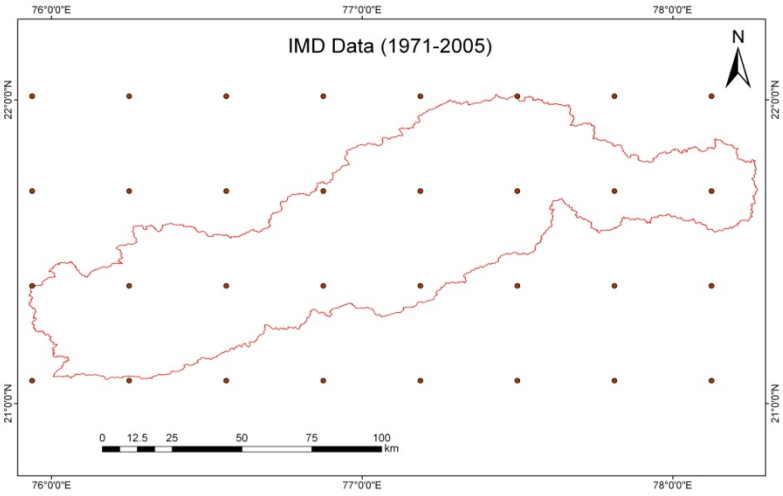
Statistical Indices	Very Good	Good	Satisfactory
R^2	$R^2 > 0.7$	$0.60 < R^2 \leq 0.70$	$0.50 < R^2 \leq 0.60$
NSE	$0.8 < NSE \leq 1.0$	$0.7 < NSE \leq 0.8$	$0.5 < NSE \leq 0.7$

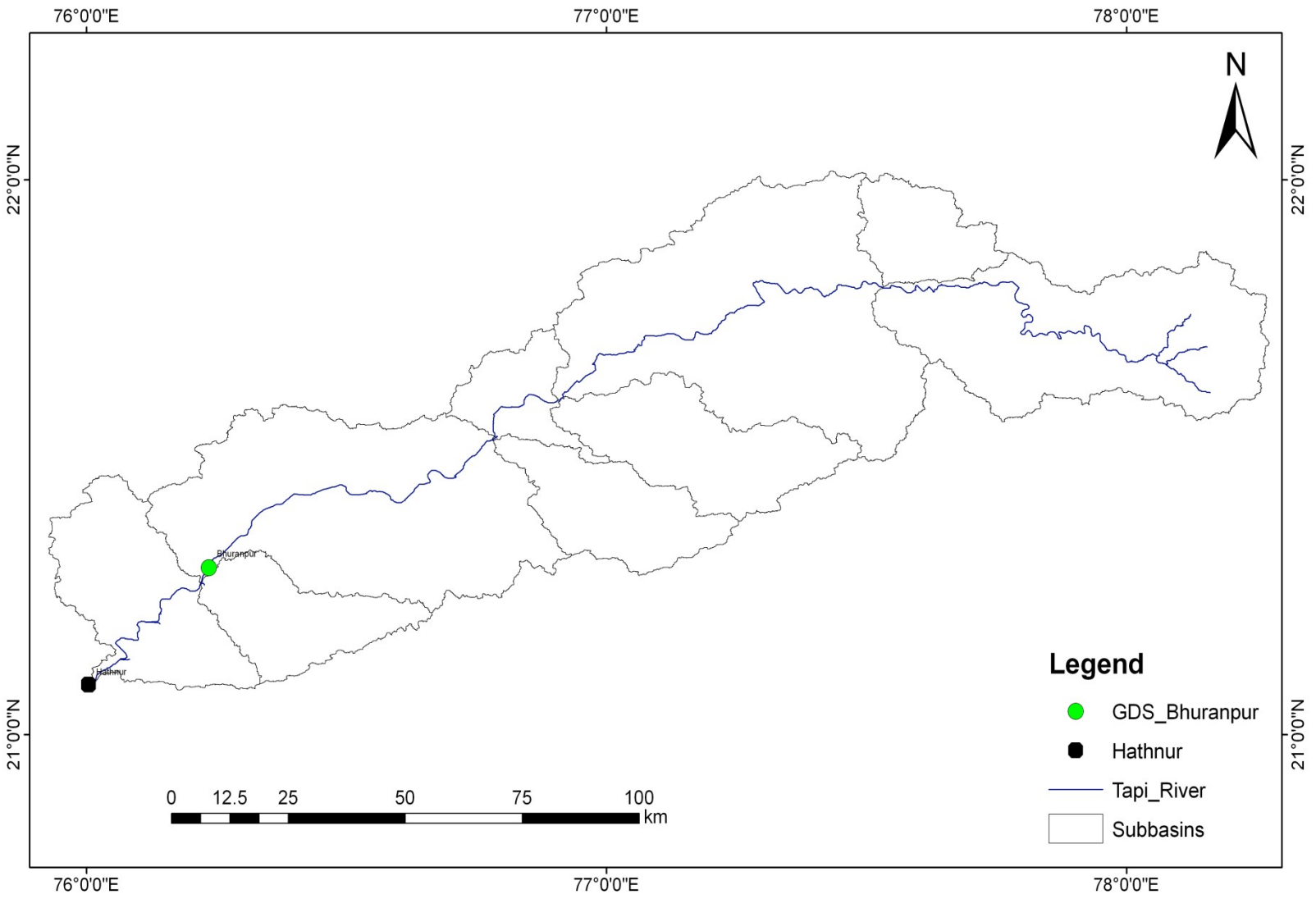

76°0'0"E
77°0'0"E
78°0'0"E
22°0'0"N
21°0'0"N
N
DEM
Value (m)
High : 1174
Low : 216
0 15 30 60 90 120
km


LULC Map (GIAM-2000)
76°0'0"E
77°0'0"E
78°0'0"E
22°0'0"N
21°0'0"N
N
LULC
Class_Name
Water bodies
Rangelands
Rainfed crop lands
Irrigated, surface water,double crop
Irrigated, surface water, single crop
Irrigated, surface water, continious crop
Irrigated, ground water,continious crop
Irrigated, ground water, single crop
Irrigated, ground water, double crop
Irrigated, conjunctive use,single crop
Irrigated, conjunctive use, double crop
Forests
Builtup
0 12.5 25 50 75 100
km

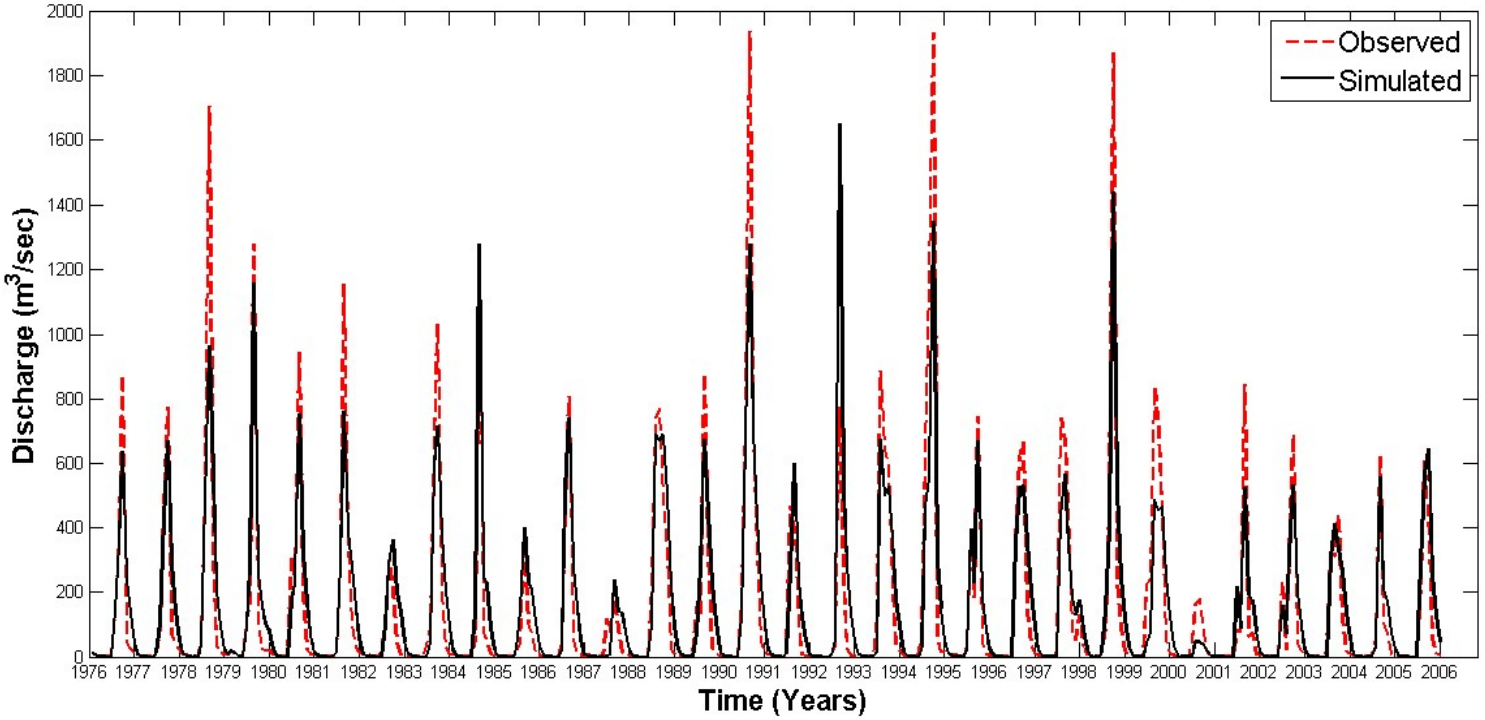
Data Set 1


Soil Map (FAO)
76°0'0"E
77°0'0"E
78°0'0"E
22°0'0"N
21°0'0"N
N
Soil_Classes
3,696
3,697
3,861
3,864
0 12.5 25 50 75 100
km

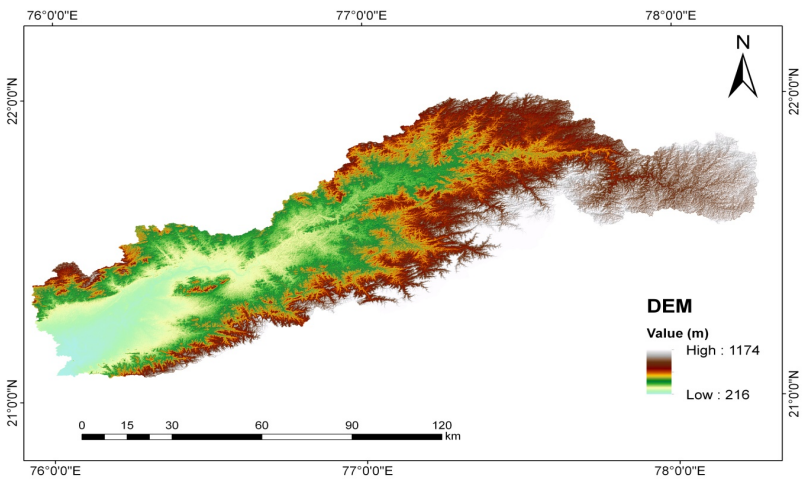

IMD Data (1971-2005)
76°0'0"E
77°0'0"E
78°0'0"E
22°0'0"N
21°0'0"N
N
0 12.5 25 50 75 100
km

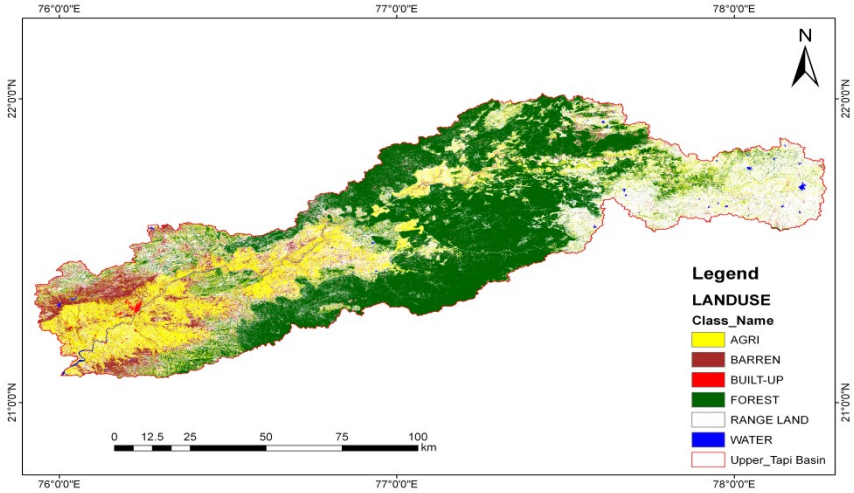

76°0'0"E
77°0'0"E
78°0'0"E
22°0'0"N
21°0'0"N
N
Bhuranpur
Hathnur
0 12.5 25 50 75 100
km
Legend
GDS_Bhuranpur
Hathnur
Tapi_River
Subbasins

Pre Calibration Results

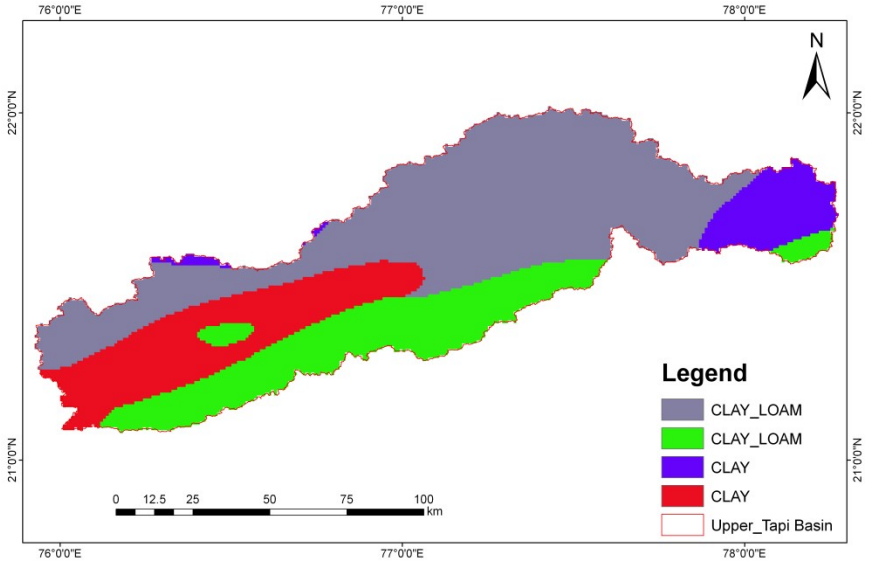


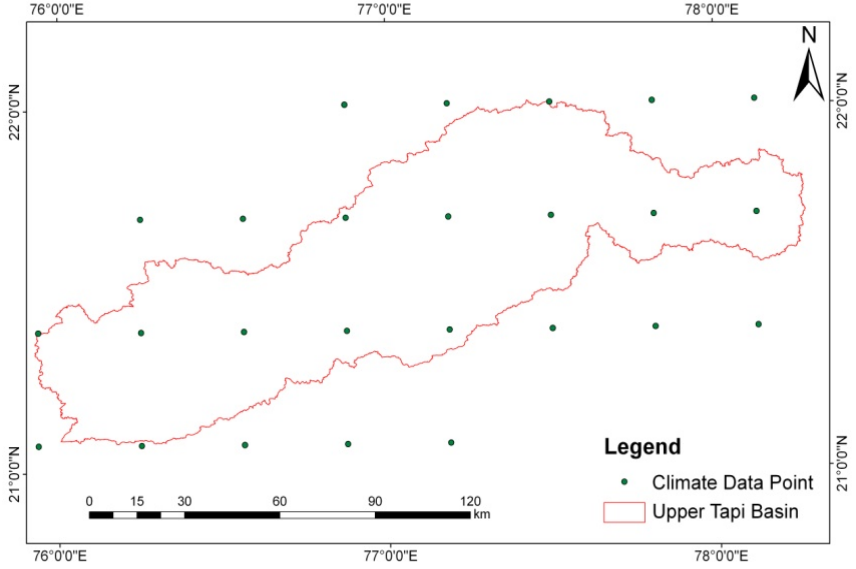
R^2	0.84	$R^2 > 0.7$
NSE	0.84	NSE > 0.5
PBIAS	0.3%	PBIAS < ±25%


76°0'0"E
77°0'0"E
78°0'0"E
22°0'0"N
21°0'0"N
N
DEM
Value (m)
High : 1174
Low : 216
0 15 30 60 90 120
km

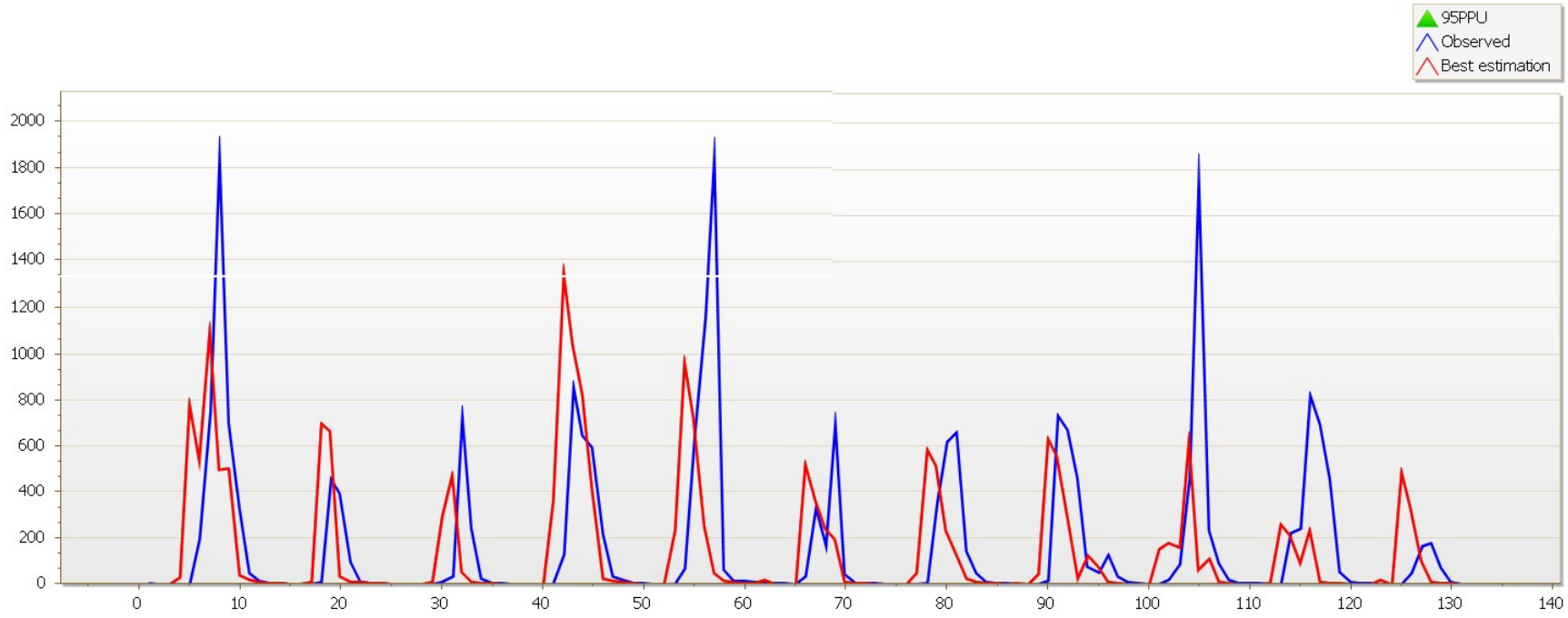

76°0'0"E
77°0'0"E
78°0'0"E
22°0'0"N
21°0'0"N
N
Legend
LANDUSE
Class_Name
AGRI
BARREN
BUILT-UP
FOREST
RANGE LAND
WATER
Upper_Tapi Basin
0 12.5 25 50 75 100
km

Data Set 2


76°0'0"E
77°0'0"E
78°0'0"E
22°0'0"N
21°0'0"N
N
Legend
CLAY_LOAM
CLAY_LOAM
CLAY
CLAY
Upper_Tapi Basin
0 12.5 25 50 75 100
km

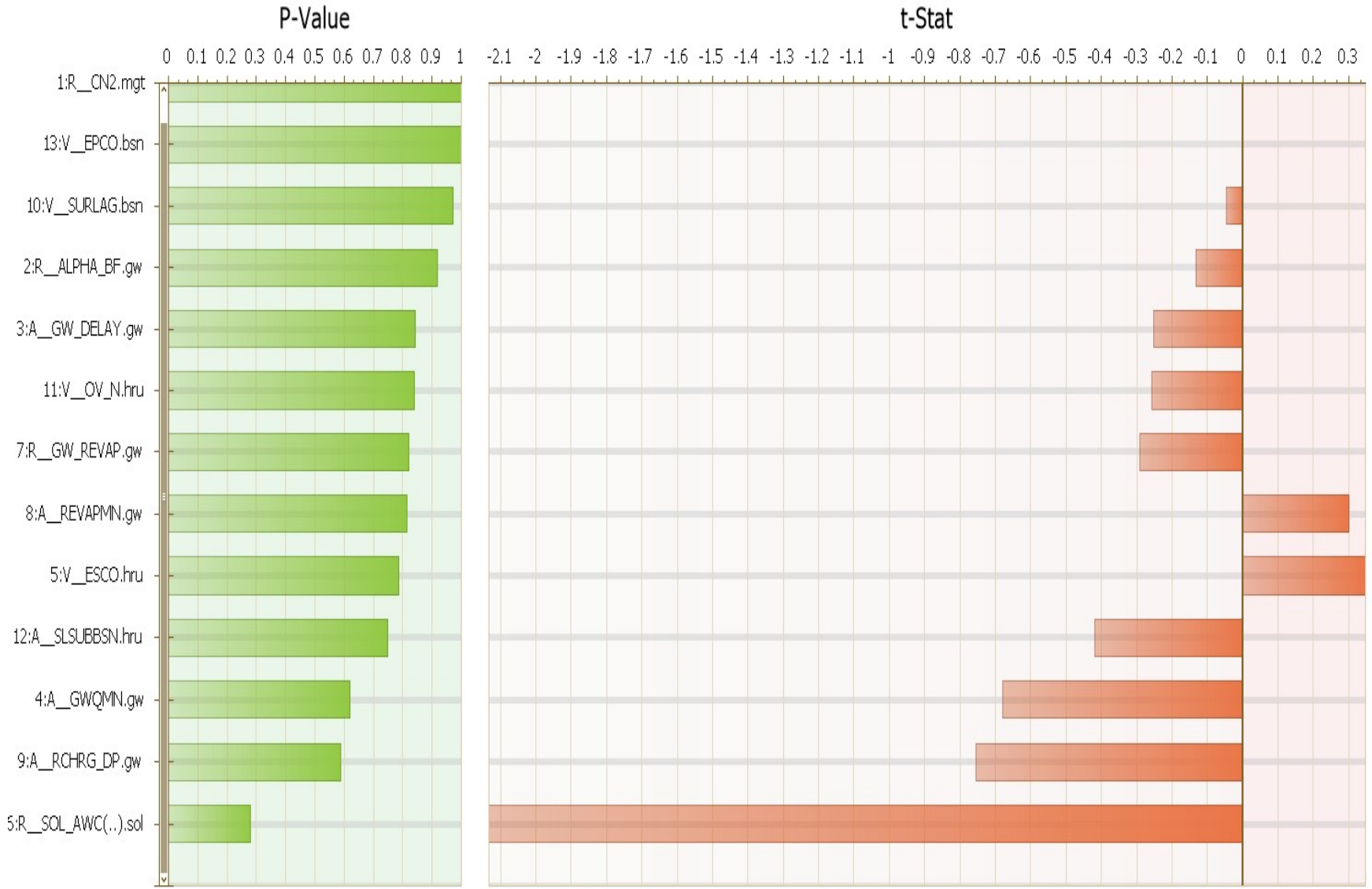

76°0'0"E
77°0'0"E
78°0'0"E
22°0'0"N
21°0'0"N
N
Legend
Climate Data Point
Upper Tapi Basin
0 15 30 60 90 120
km

Pre Calibration Results



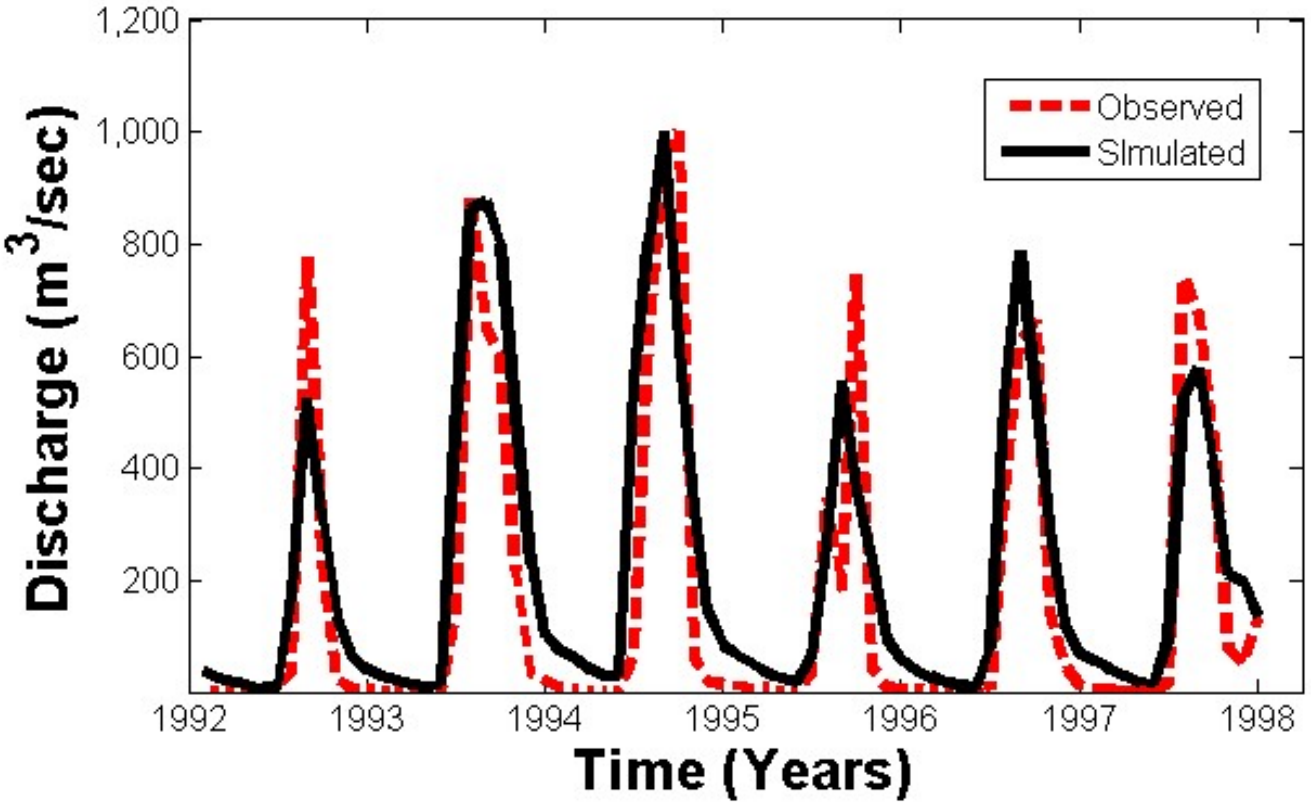
R^2	0.10
NSE	-0.10
PBIAS	14.9%

Global Sensitivity analysis



Final Parameter Values

Parameter_Name	Min_value	Max_value	Fitted_Value
r__CN2.mgt	-0.68	-0.7	-0.698
r__ALPHA_BF.gw	0.11	0.12	0.119
a__GW_DELAY.gw	-30	60	-11.1
v__ESCO.hru	0.6	0.8	0.62
r__SOL_AWC(..).sol	0.5	0.8	0.77
r__GW_REVAP.gw	0.02	0.2	0.146
a__REVAPMN.gw	-750	750	-600
a__RCHRG_DP.gw	0.25	0.26	0.259
v__SURLAG.bsn	2	5	2.3
v__OV_N.hru	0.4	0.8	0.44
a__SLSUBBSN.hru	15	20	17.5
v__EPCO.bsn	0.2	0.6	0.4



R^2	0.64
NSE	0.62
PBIAS	-12.2%

Conclusions

1. Model uncertainty analysis is one of the important research contents of hydrological models

2. Uses of different data sources introduces the uncertainty in the modelling process

3. For different data sources there can be a different set of input parameter with different sensitivity

4. The SWAT model could simulate satisfactorily the stream flow for the study area with the satisfactory values of R^2, NSE and PBIAS.

References

- Abbaspour, K.C., 2014. SWAT-CUP 2012: SWAT Calibration and Uncertainty Programs—A User Manual. Swiss Federal Institute of Aquatic Science and Technology.

- Arnold, J.G., Srinivasan, P., Muttiah, R.S., Williams, J.R., 1998. Large area hydrologic modeling and assessment, Part I: Model development. J. Am. Water Resour. Assoc. 34, 73–89.

- Beven, K., Freer, J., 2001. Equifinality, data assimilation and uncertainty estimation in mechanistic modeling of complex environmental system using the GLUE methodology. J. Hydrol. 249 (1–4), 11–29.

- Moriasi, D.N., Arnold, J.G., Van Liew, M.W., Bingner, R.L., Harmel, R.D., Veith, T.L., 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. Trans. ASABE 50, 885–900.