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Model calibration and uncertainty analysis for discharge in the Kunwari River Basin, India using sequential uncertainty fitting

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Introduction

- Kunwari River basin is one of the important river basins for agricultural dominant activities in Central India.
- Due to the impacts of anthropogenic activities and climate change Kunwari river basin facing water scarcity.
- Hence it is essential to manage water resources in the region.
- SWAT model is applied to estimate runoff in the Kunwari River River basin because, extensively applied to issues ranging from hydrology, climate change, and BMP evaluation at various spatial and temporal scales in over several countries. There are over 1000 peer-reviewed journal articles published on SWAT applications.

- To reduce the uncertainties posed by the variation of model parameters, sensitivity analysis and calibration processes have become necessary.
- For calibration and uncertainty analysis the Sequential Uncertainty Fitting (SUFI) Program Version 2 has been used.
- Abbaspour *et al*. (2007) developed SUFI as a tool for sensitivity analysis, multi-site calibration and uncertainty analysis.
- Yang *et al*. (2008) found that SUFI-2 needs the smallest number of model runs to achieve a good calibration and prediction uncertainty results.
- SUFI-2 is the more frequently used and calibration and uncertainty analysis (Abbaspour *et al*. 2007, Schuola et.al. 2008).
- SUFI-2 is linked to SWAT in the SWAT-CUP software (Abbaspour 2007) through an interface.

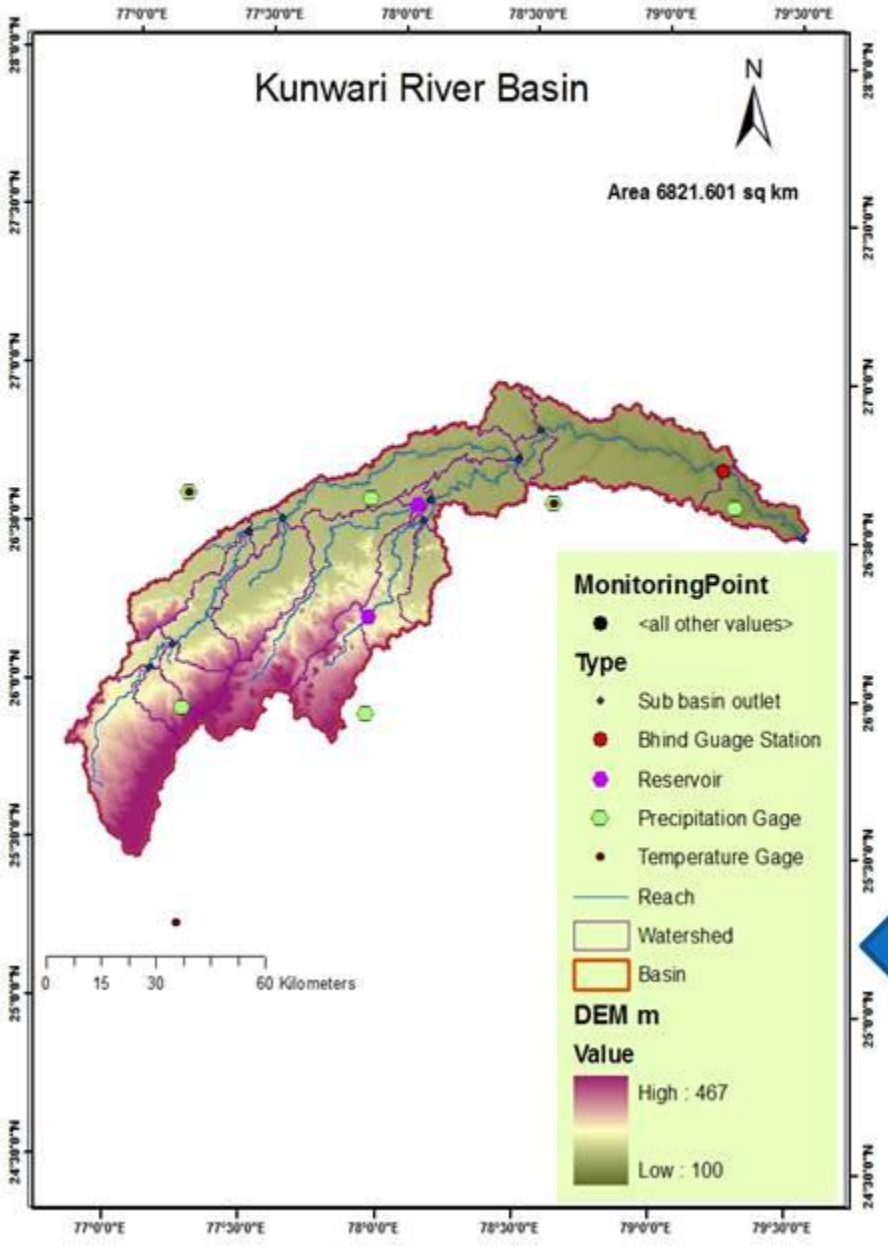
OBJECTIVE

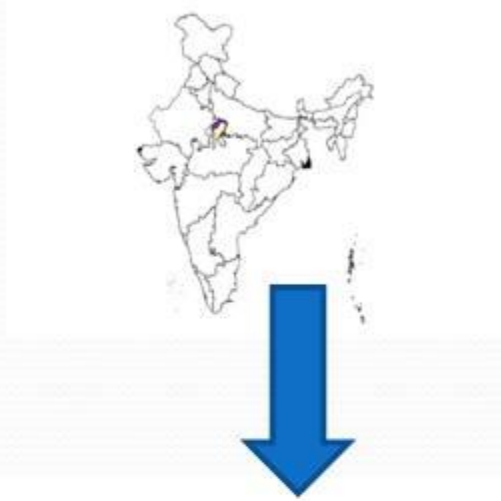
To calibrate and validate the SWAT model for hydrology in Kunwari River Basin using observed data by SUFI-2 Algorithm

Materials and methods

Study area

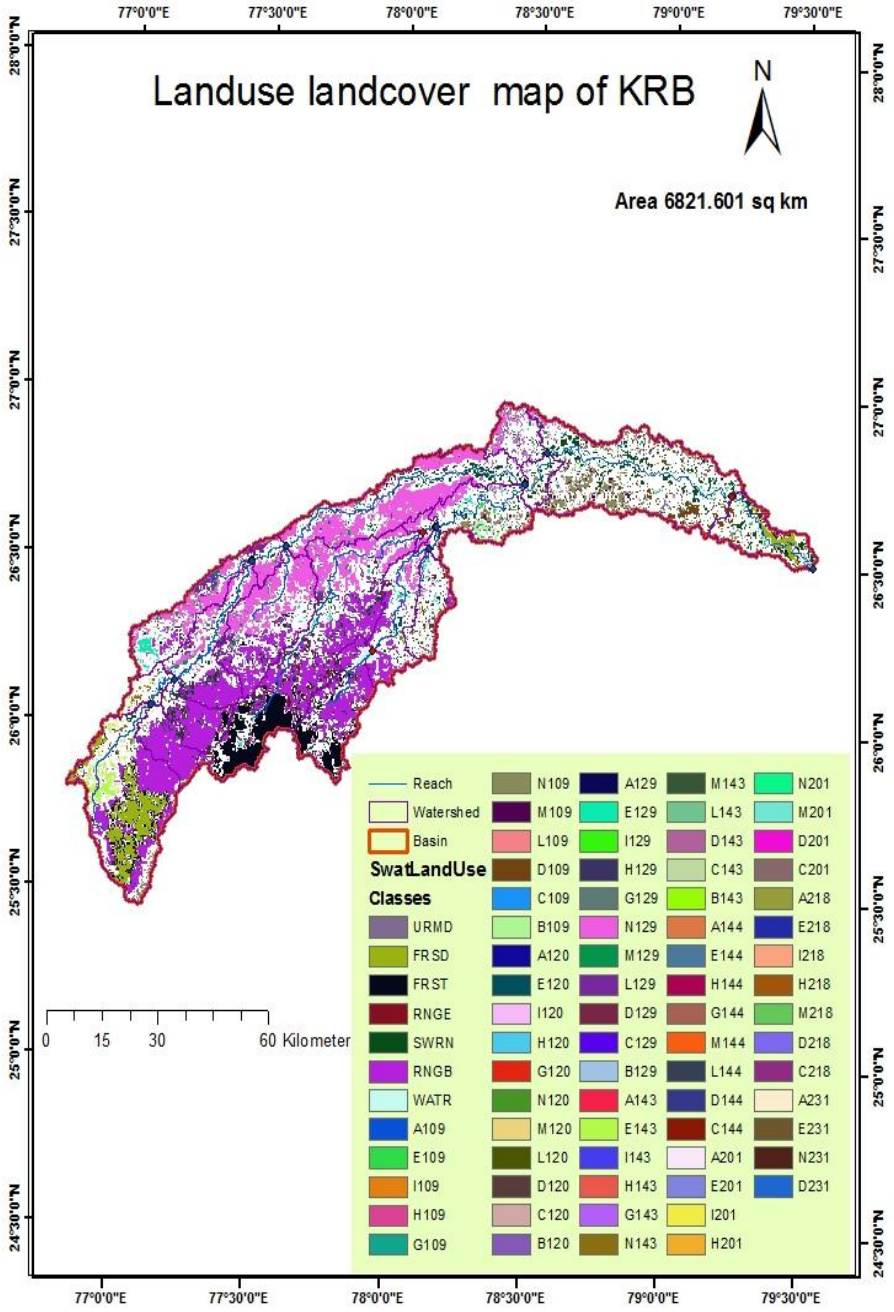
Location map, DEM, Basin, Streams, Ppt., Temp. and Bhind gauge stations





- The study area, Upper Sind river basin is located between latitudes 25^0 38’ 18” N to 26^0 18’ 58” N and longitudes 77^0 10’ 40”E to 79^0 11’ 45”E.
- The altitude varies from 100 m in southwest and 467 m northeast with a mean of 283.5 m and standard deviation of 25.28 m.
- The main channel of the river drains a total land area of about 6,821.601 km^2 and Pachauli gauging station is located at drain point.
- The climate is semi arid to humid with annual rainfall varying from 800 - 1100 mm. The mean annual temperature and evapotranspiration are 21^0C and 482 mm respectively.
- The dominant land use in the region is agriculture and the main food crops include wheat, soyabean, gram, millet, beans and the cash crops consist of mustard, rice, sunflower, and horticultural crops.
- The land cover is predominantly savannah, which consist of grassland interspersed with shrubs and trees.
- No. of Sub basins 20, HRU’s 271 with threshold of 10 10 10 % Lu Soil slope

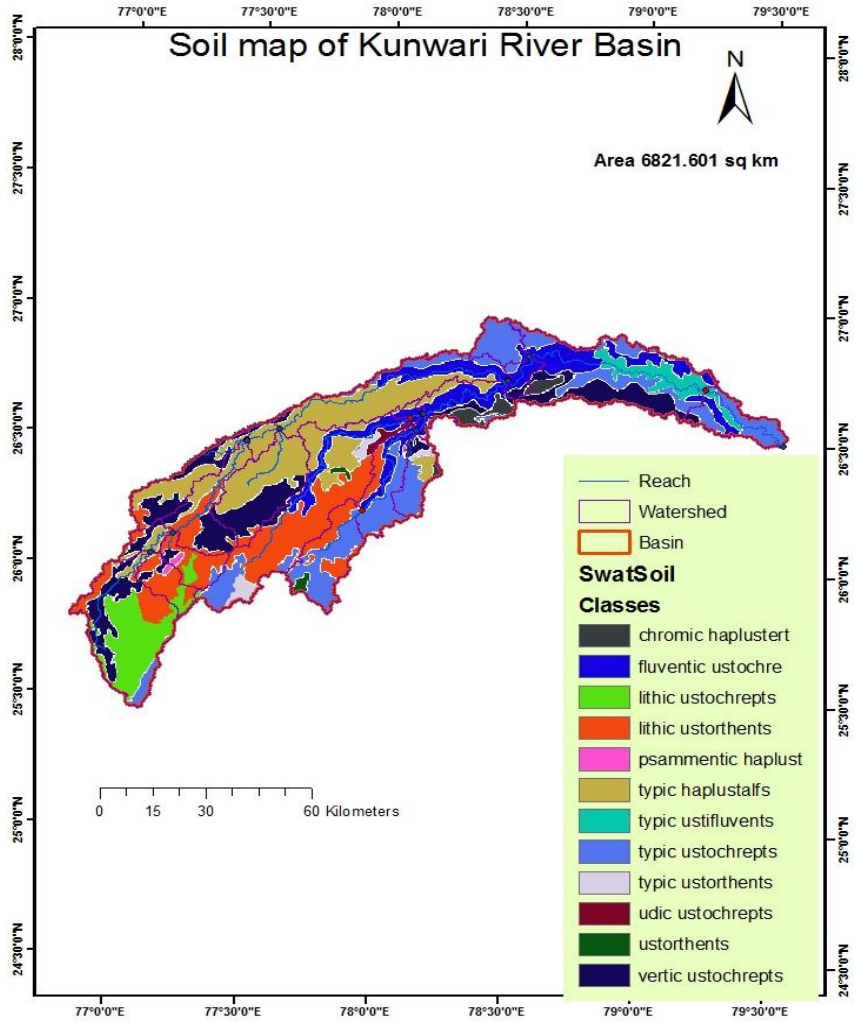
Landuse and land cover map of Kunwari River Basin

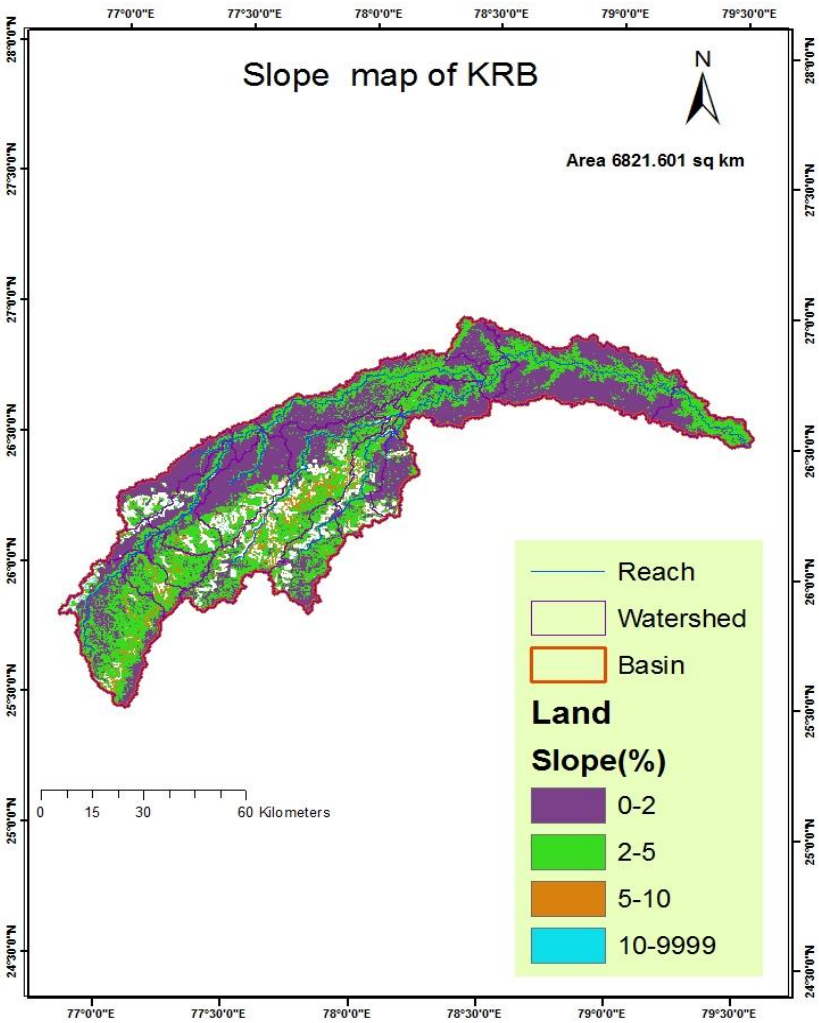


Detailed classification of LULC in KRB

S. No.	SWAT Class	Description	Area ha	% Area	Sub class	Prefix	
1	URMD	Urban	2366.01	0.35	AGRL	A	Rainfed/Dryland Agriculture
2	FRSD	Forest- Decidious	29703.51	4.35	DTCU	B	Double/Triple Crop Conjunctive
3	FRST	Forest-Mixed	36066.06	5.29	DTGW	C	Double/Triple Crop Ground water
4	RNGE	Grassland/Rangeland	25058.97	3.67	DTSI	D	Double/Triple Crop Surface Irri
5	SWRN	Barren land	71850.24	10.53	FALL	E	Current fallow
6	RNGB	Wasteland/ Brushland	156420.72	22.93	KHCU	G	Kharif Crop Conjunctive Use
7	WATR	Water	2827.71	0.41	KHGW	H	Kharif Crop Ground water
8	AGRL		357998.43	52.47	KHSI	I	Kharif Crop Surface Irrigation
					RBCU	L	Rabi Crop Conjunctive Use
					RBGW	M	Rabi Crop Ground water
					RBSI	N	Rabi Crop Surface Irrigation
						Suffix	
						109	Bhind
						120	Gwalior
						129	Morena
						143	Sheopur
						144	Shivpuri
						201	Auraiya
						218	Etawah
Ex.						231	Jalaun
Value	Landuse						
109	A109	The pixel in the landuse having a value of 109 belongs to A (Rainfed/Dryland Agriculture) in District (109) Bhind					
231	N231	The pixel in the landuse having a value of 231 belongs to N (Rabi Crop Surface Irrigation) in District (231) Jalaun					

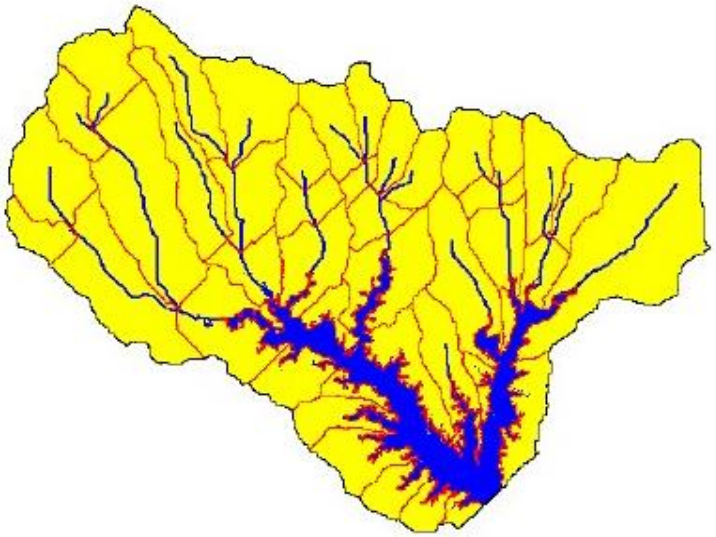
Soil map and Slope map of KRB

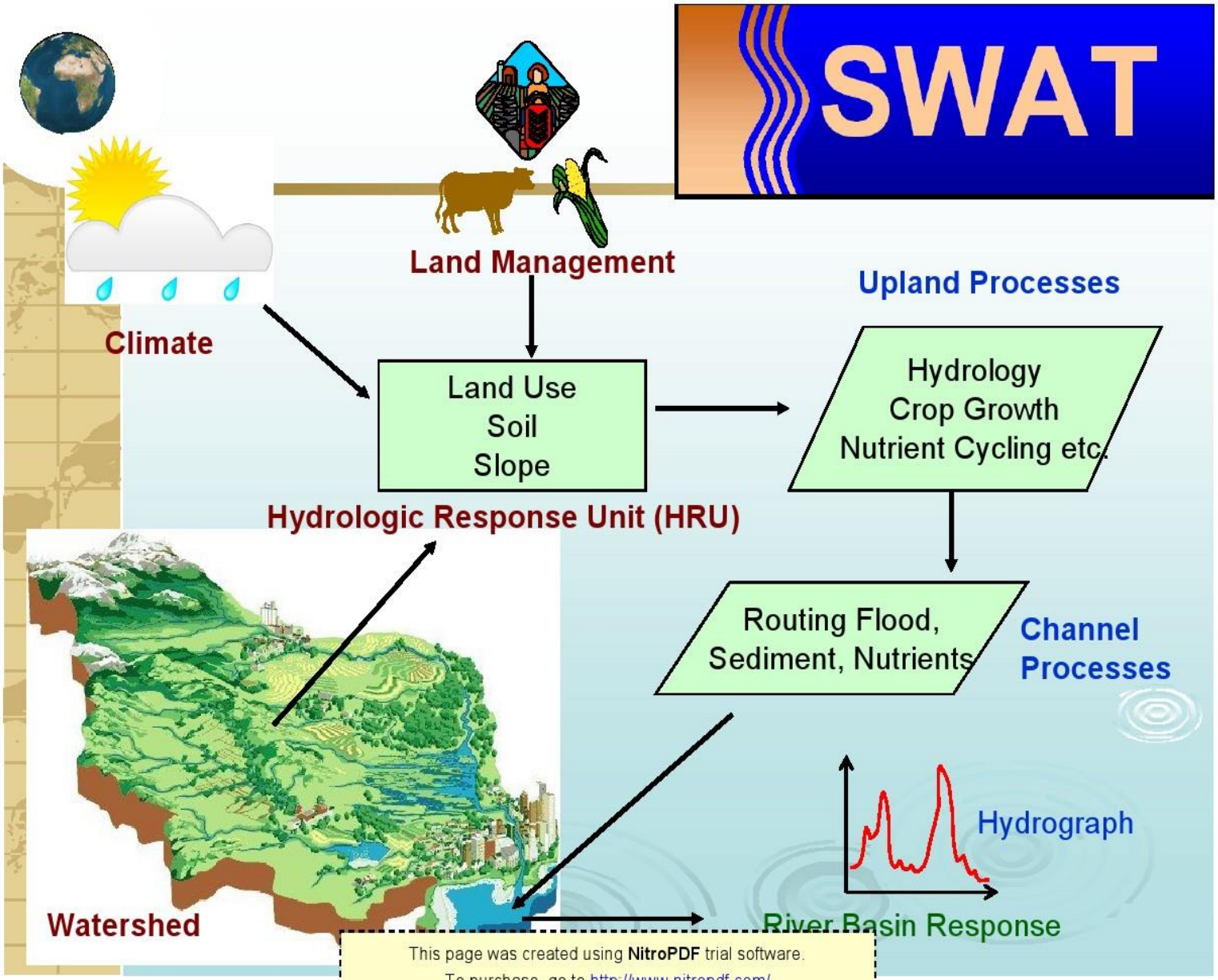




SWAT Hydrological Model

- Physically based
- Continuous Time
  - Daily Time Step
- Distributed Parameter
  - River basin divided into number of Sub-basins
- Hydrologic Response Units (HRU's)




SWAT
Land Management
Climate
Upland Processes
Land Use
Soil
Slope
Hydrology
Crop Growth
Nutrient Cycling etc.
Hydrologic Response Unit (HRU)
Routing Flood,
Sediment, Nutrients
Channel
Processes
Hydrograph
Watershed
River Basin Response
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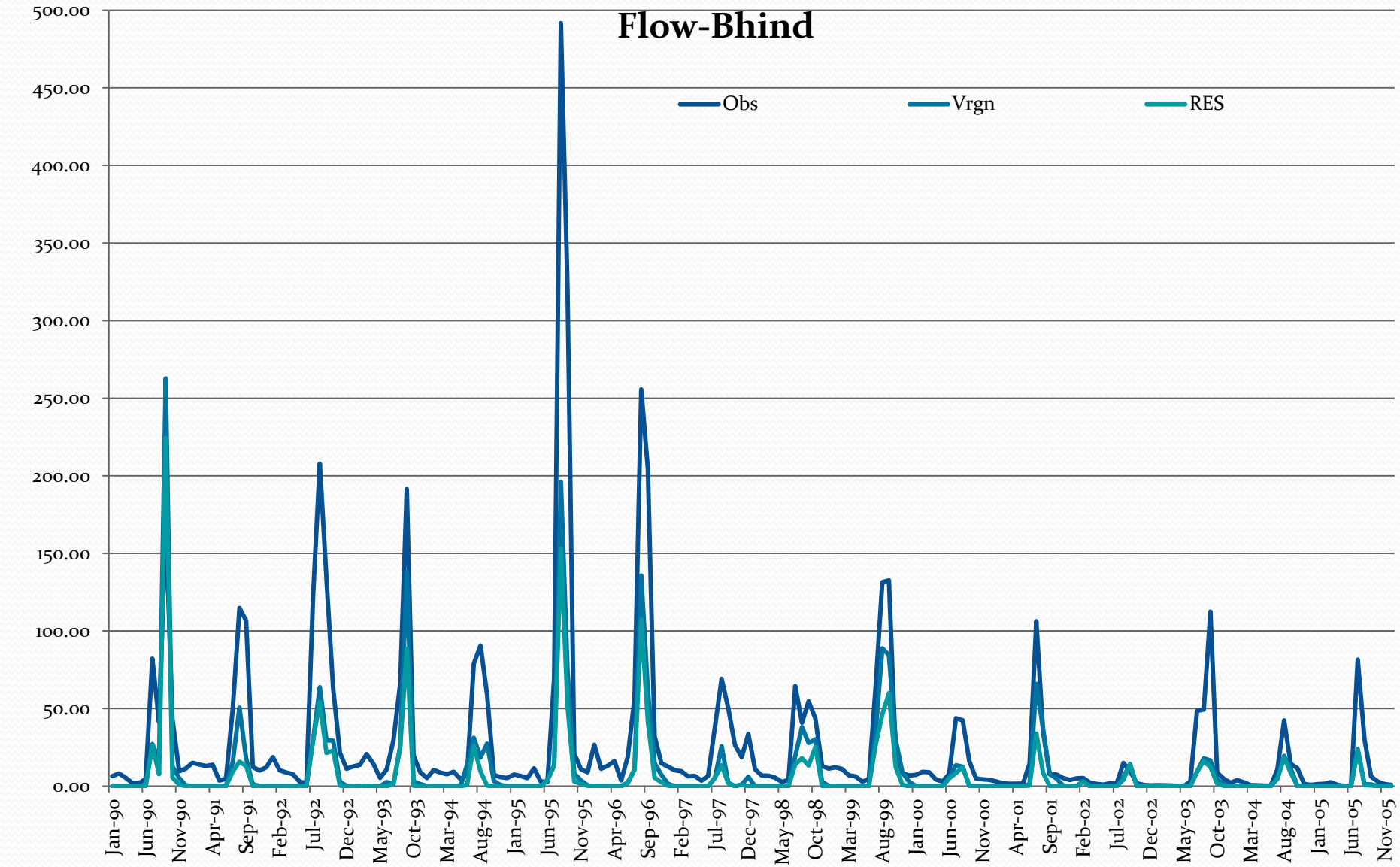
Methodology

- SWAT model was calibrated for monthly simulated stream flows by comparing the observed stream flows on the Bhind gauge station, located in the KRB.
- The model was simulated for a period of 16 years (1987 - 2005) by considering the first three years as warm up and next 10 years (1990 – 2000) for calibration and the last 6 years (2000 – 2005) used for validation.
- The model sensitivity, calibration and uncertainty analysis were carried by using SWAT-CUP (calibration and uncertainty programs) interface.
- *p-factor* and *r-factor* (Abbaspour et al. 2007) was used to evaluate the strength of calibration and uncertainty measures in addition to Coefficient of correlation (R^2) and Nash–Sutcliff Efficiency (NS).

Input Data Used for Modeling

- DEM: **SRTM 90 m x 90 m grid data**
- LULC: **National Remote Sensing Centre data**
- Soil : **NBSSLUP – ICAR data**
- Stream flow: **Central Water Commission, MoWR, GOI**
- Weather: **Indian Meteorological Dept. regridded data**

  Rainfall: **Daily 0.5^0 x 0.5^0** & Temp.: **Daily 1^0 x 1^0**


Flow-Bhind
Obs
Vrgn
RES
500.00
450.00
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
Jan-90
Jun-90
Nov-90
Apr-91
Sep-91
Feb-92
Jul-92
Dec-92
May-93
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Mar-94
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Jan-00
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Nov-00
Apr-01
Sep-01
Feb-02
Jul-02
Dec-02
May-03
Oct-03
Mar-04
Aug-04
Jan-05
Jun-05
Nov-05

Calibration of KRB

The selected parameters were to be adjusted in such a way that they could represent the characteristics of the existing land use and topographic condition of the Kunwari river basin. The final values of parameters were to be obtained by calibration.

Uncertainty Analysis

- In SUFI-2, Uncertainty accounts for all sources of uncertainties

a. Uncertainty in driving variables (ex. Rainfall & Discharge)
b. Conceptual model
c. Parameters
d. Measured data

- Degree of uncertainty quantified by P-factor
- P-factor is % measured data bracketed by 95% prediction uncertainty (95PPU).
- The 95PPU calculated at 2.5% and 97.5% levels of cumulative distribution of an output variable obtained through Latin hypercube sampling, disallowing 5% bad simulations

Results

Sensitivity Analysis

S. No.	Parameter_Name	Fitted_Value	Min_value	Max_value
1	r__CN2.mgt	-0.074847	-0.240952	-0.001262
2	v__ALPHA_BF.gw	0.419283	0.061954	0.971188
3	v__GW_DELAY.gw	436.176666	81.558029	476.016998
4	v__GWQMN.gw	1.33709	-0.007261	1.518677
5	v__GW_REVAP.gw	0.187855	0.155999	0.305557
6	v__REVAPMN.gw	4.879577	1.524443	6.064543
7	v__ESCO.hru	0.981918	0.934109	1.045552
8	v__EPCO.hru	-0.148963	-0.815036	0.137858
9	v__CH_N2.rte	-0.019486	-0.088842	0.088538
10	v__CH_K2.rte	27.839415	18.718681	103.959183
11	v__ALPHA_BNK.rte	-0.592071	-0.721744	0.18506
12	r__SOL_AWC(1).sol	-0.139015	-0.145708	0.145312
13	r__SOL_K(1).sol	0.820435	0.137716	0.987927
14	r__SOL_BD(1).sol	0.583576	0.05434	0.695838
15	r__HRU_SLP.hru	0.166514	0.107905	0.212751
16	r__OV_N.hru	-0.065536	-0.166267	-0.038921
17	r__SLSUBBSN.hru	0.203941	0.132441	0.268115
18	v__SFTMP.bsn	-1.138128	-2.68934	0.876664

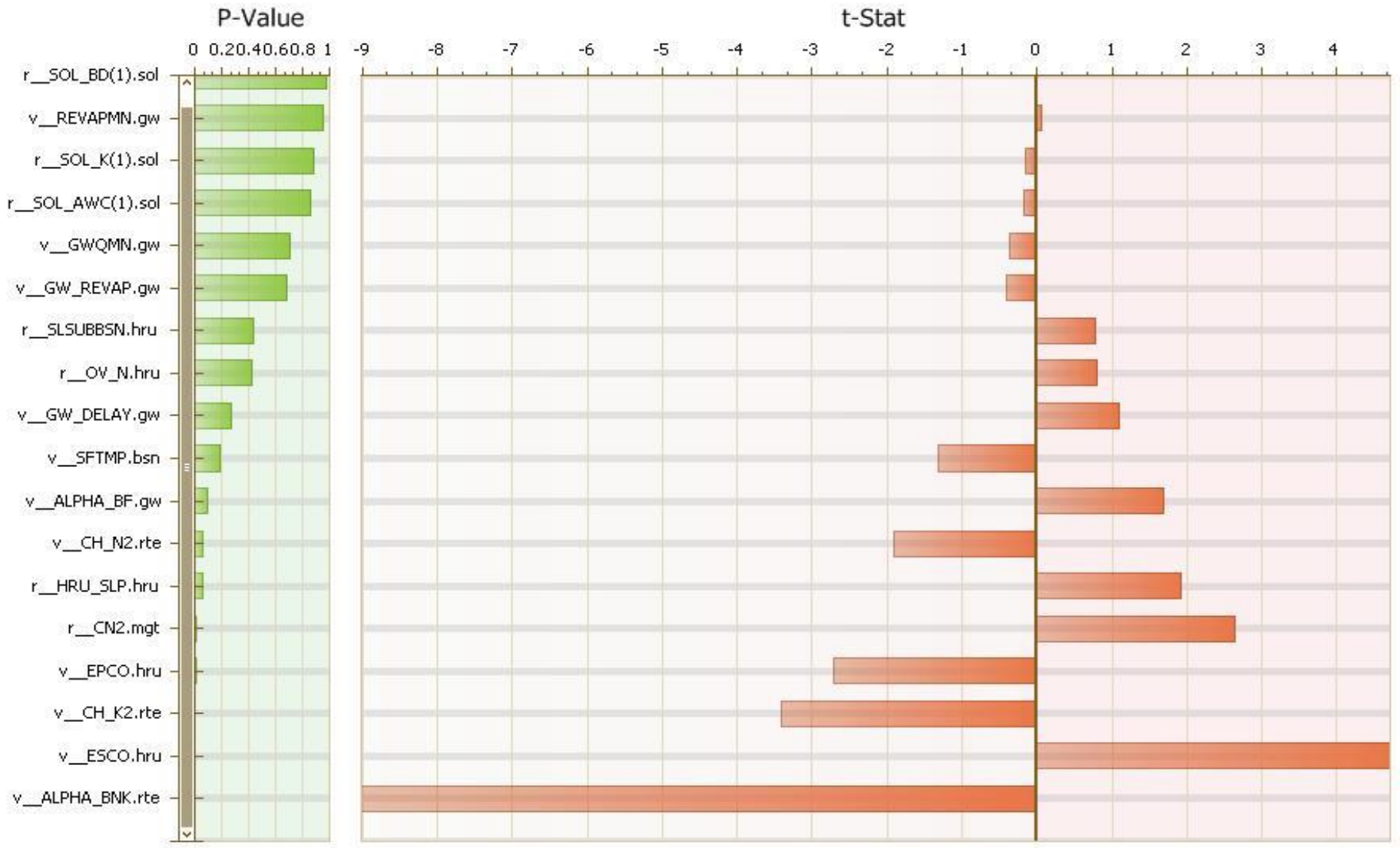
Fitted values with highest sensitivity was used to calibrate and validate the model

Global Sensitivity

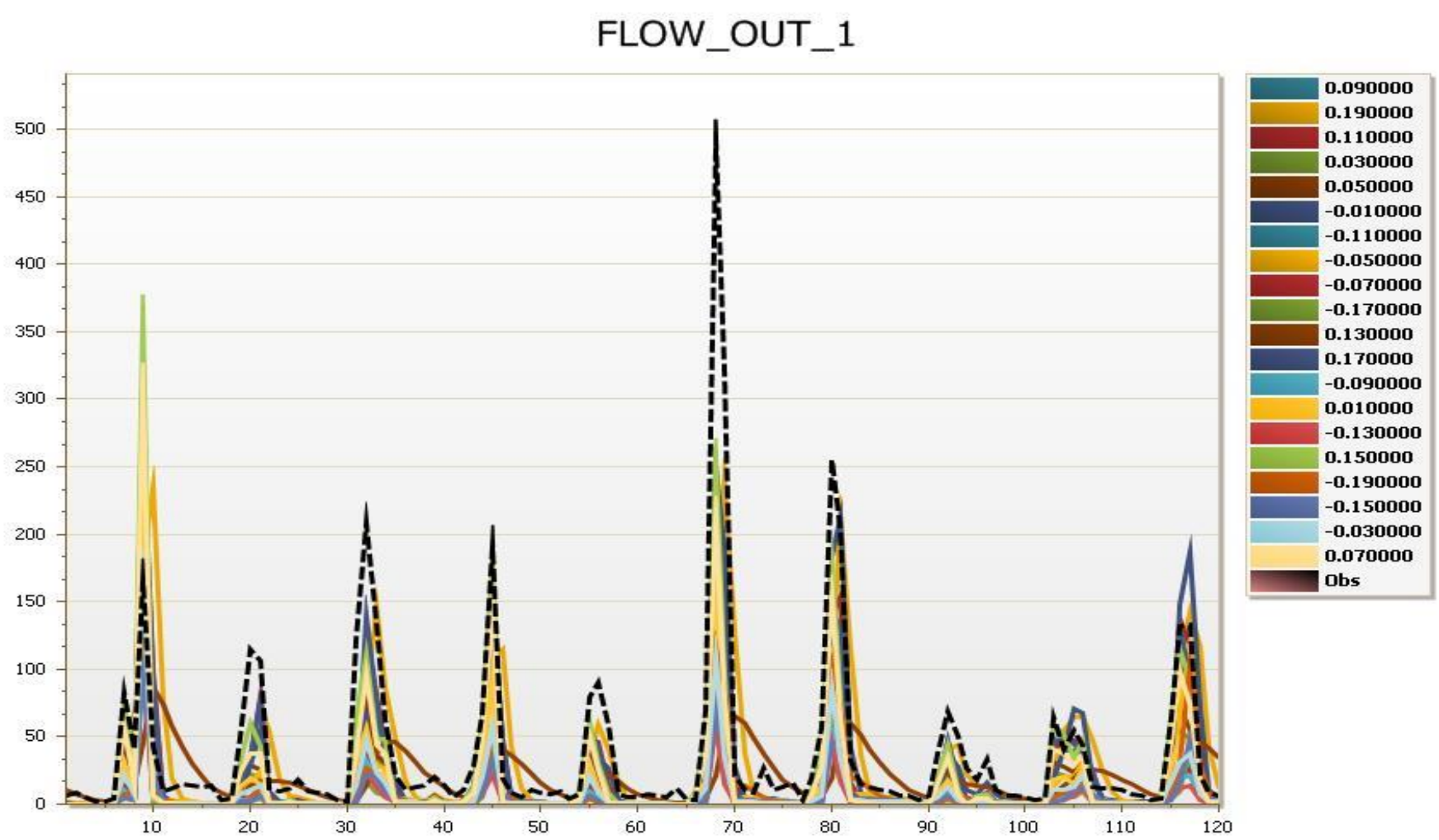
S. No.	Parameter Name	t-Stat	P-Value
1	r__SOL_BD(1).sol	-0.02	0.98
2	v__REVAPMN.gw	0.06	0.95
3	r__SOL_K(1).sol	-0.15	0.88
4	r__SOL_AWC(1).sol	-0.18	0.85
5	v__GWQMN.gw	-0.37	0.71
6	v__GW_REVAP.gw	-0.40	0.69
7	r__SLSUBBSN.hru	0.77	0.44
8	r__OV_N.hru	0.80	0.42
9	v__GW_DELAY.gw	1.10	0.27
10	v__SFTMP.bsn	-1.32	0.19
11	v__ALPHA_BF.gw	1.68	0.09
12	v__CH_N2.rte	-1.91	0.06
13	r__HRU_SLP.hru	1.93	0.05
14	r__CN2.mgt	2.63	0.01
15	v__EPCO.hru	-2.72	0.01
16	v__CH_K2.rte	-3.41	0.00
17	v__ESCO.hru	4.71	0.00
18	v__ALPHA_BNK.rte	-9.01	0.00

t-stat : A measure of sensitivity (larger absolute values are more sensitive)
p-value : Significance of sensitivity (a value close to zero has more significance)

Global sensitivity – Graphical view

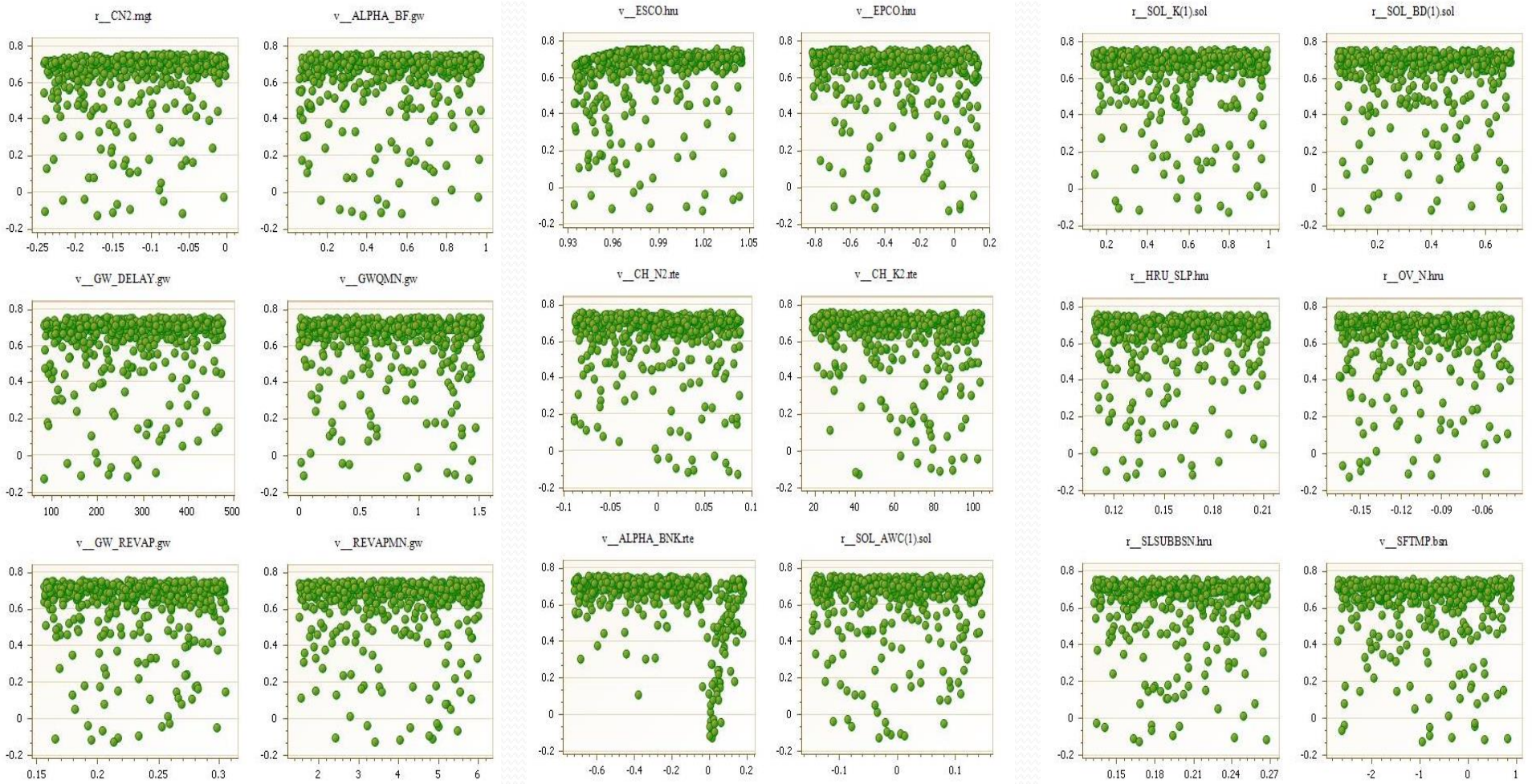


One at a time sensitivity



Dashed line is observed discharge plotted for different values of v__ALPHA_BNK.rte

Dotty Plots



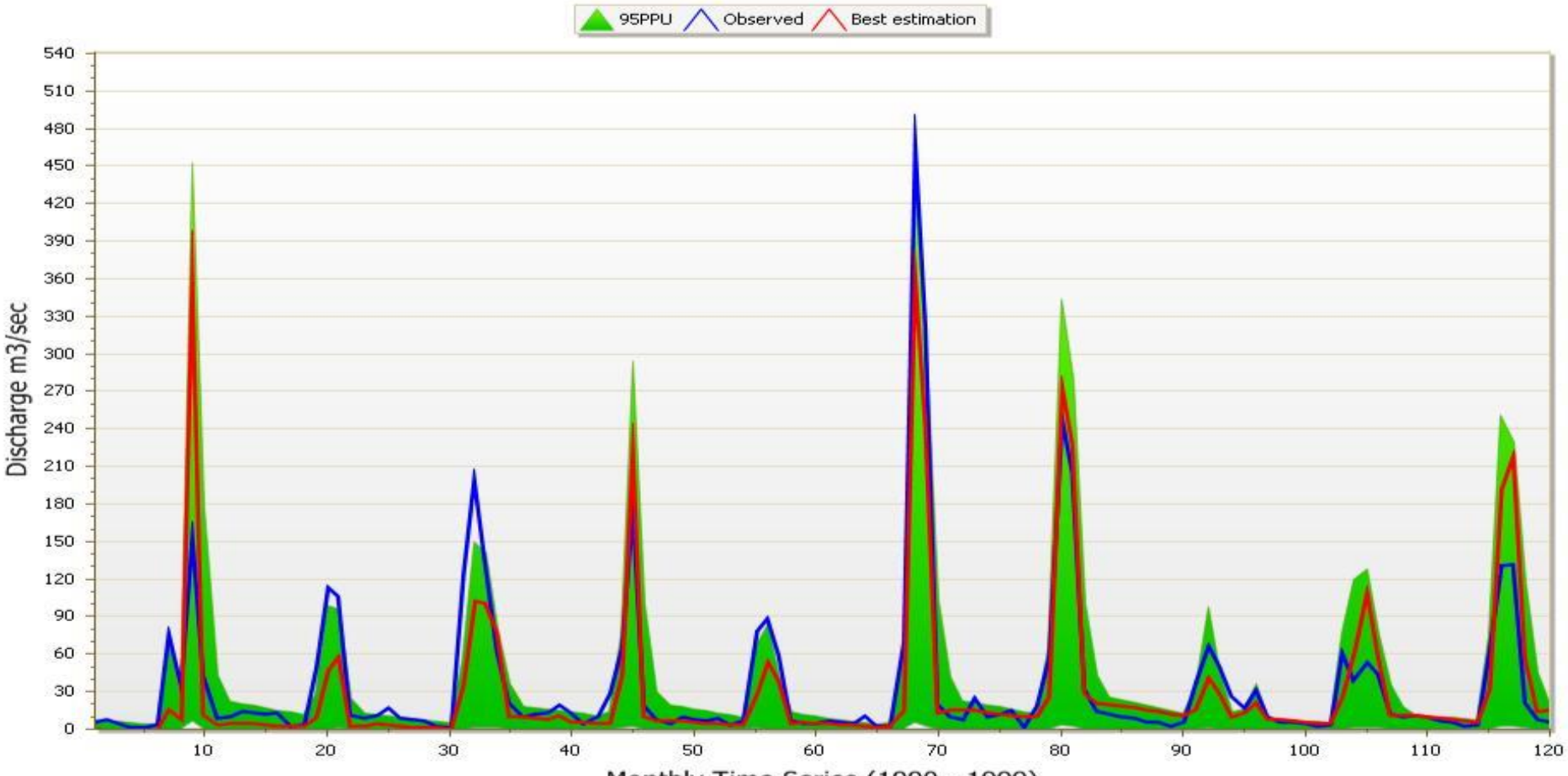
Parameter values versus Objective function

Shows distribution of sampling points and idea of sensitivity

Calibration

Calibration_Bhind

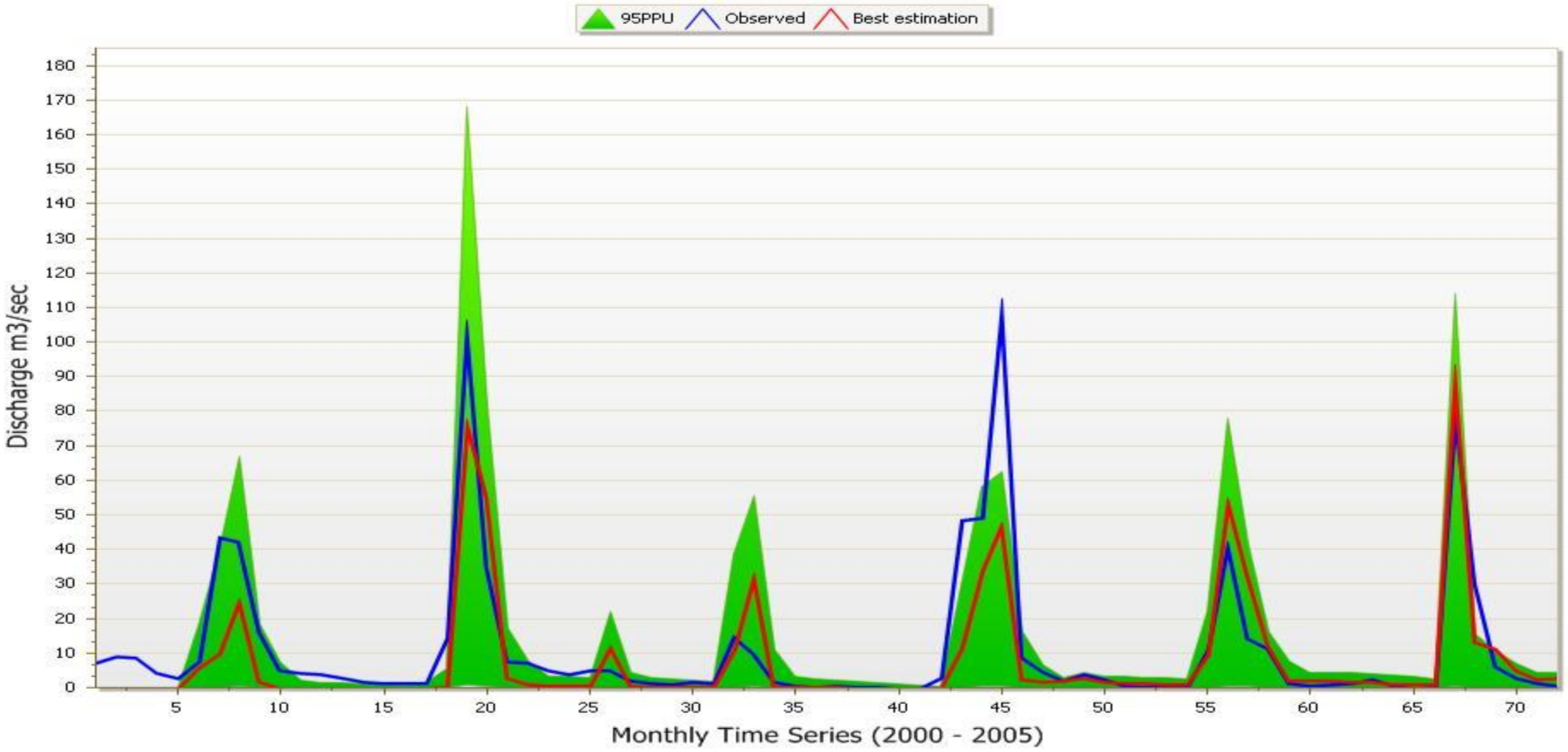
Variable	p-factor	r-factor	R2	NS	br2	MSE	SSQR
FLOW_OUT_1	0.82	0.76	0.77	0.74	0.6890	1205.1620	333.8251



Validation

Validation_Bhind

Variable	p-factor	r-factor	R2	NS	br2	MSE	SSQR
FLOW_OUT_1	0.71	0.72	0.71	0.69	0.4884	151.7658	40.3805

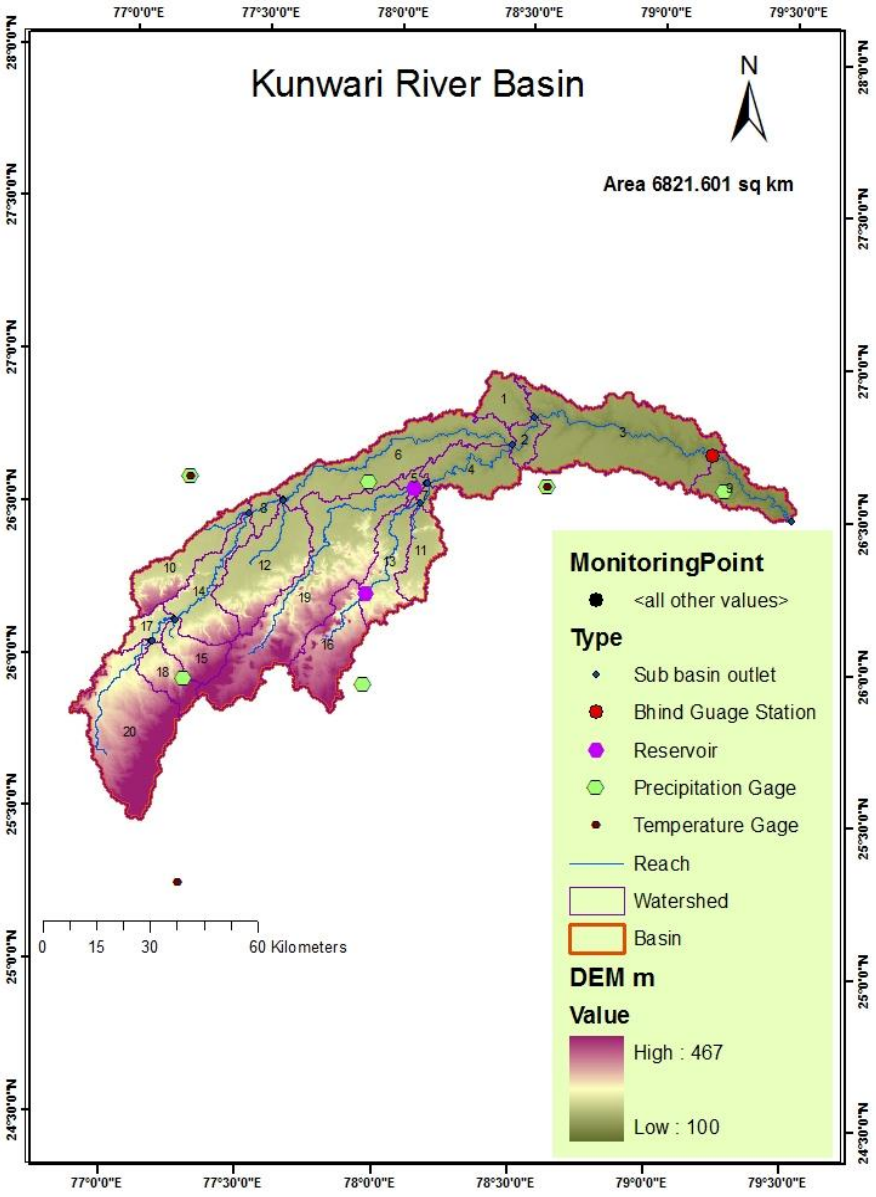


Conclusions

- The SWAT model was applied to simulate hydrologic regimes in the Kunwari River Basin in the central part of India.
- The sensitivity analysis, model calibration and uncertainty analysis were performed using SUFI-2 algorithm integrated with SWAT.
- The SWAT model was calibrated and validated using observed discharge data.
- The SWAT model performed well during the calibration and validation periods for the Kunwari River Basin. Results of calibration and uncertainty analysis were satisfactory.
- The outcome of this study can be extended to evaluate the impacts of climate change on water resources of Kunwari River Basin.

Thank you for your attention!

Sub basins 20
Threshold area 15000 ha
HRU's 271



p-factor

% observed data bracketed by the 95PPU (1)

d-factor

The ratio of the average distance between the 95PPU band by the standard deviation of the measured data (0)