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Streamflow and sensitivity modeling Using SWAT for an Ib watershed of, India

Leelambar Singh

Research Scholar

(leeli.singh@gmail.com)
https://orcid.org/0000-0002-0734-4004

Department of Civil Engineering

National Institute of Technology, Tiruchirappalli, Tamilnadu, India

Content

Introduction(Why this study?)

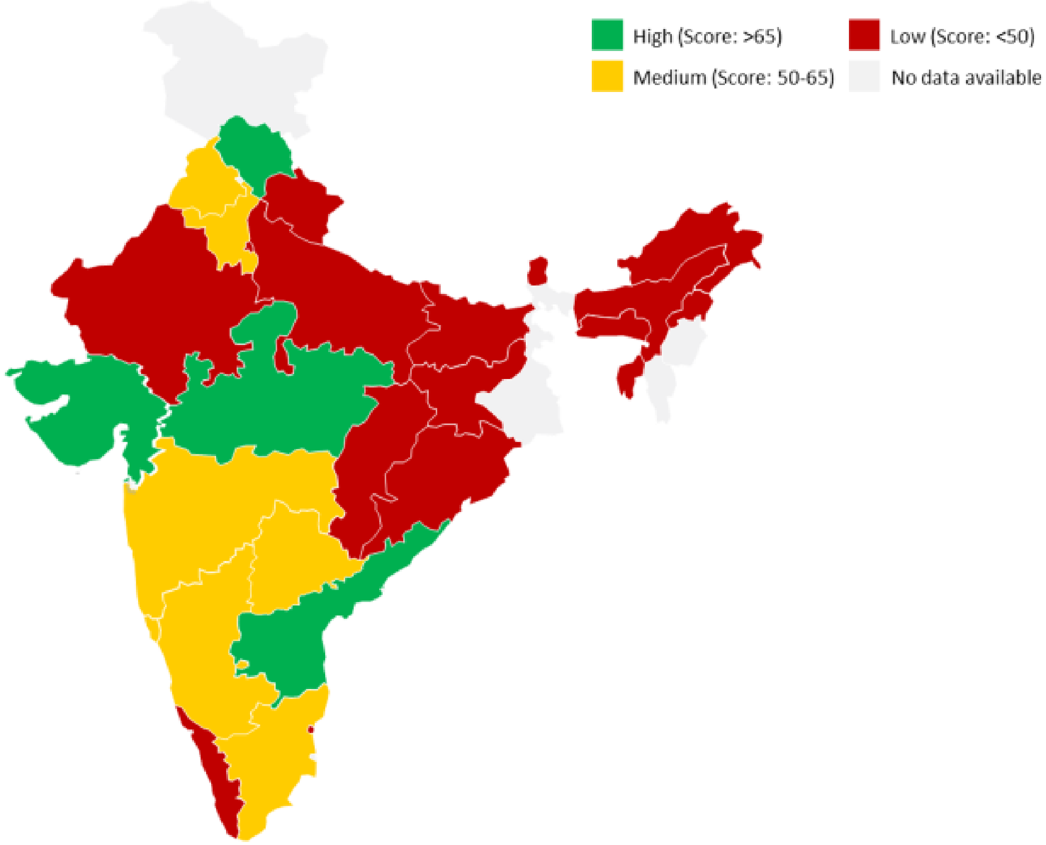
- For water resource management in the watershed, it is necessary to make reliable predictions on the pattern of discharge including scale and frequency during the period of runoff, sediment and water yield.

- Hydrological models build based on the dominant hydrological processes are necessary to accomplish the various tasks in the planning and operation of the integrated water resources management projects

- Hydrological model is employed to draw consistent predictions on the stream discharge of such watersheds. Results of hydrological models sensitively convey various factor including spatial assessment of hydrological cycle and parameter estimation scheme.

Introduction(Why this study?)

High, medium, and low-performing states on water resource management



Source: NITI Aayog Report 2019

Assessment on almost half of the index scores is directly linked to water management in agriculture

A collaborative (and grassroots-based) approach to watershed development and management is necessary for ensuring long-term benefits.

Cont..

- Traditional precipitation observations from rain gauges suffer from several limitations, including Gauge adjustment, sparse gauge networks, data gaps, reporting time delays, and limited access to available data
- In many areas the ground-based observations are usually sparse or unevenly distributed, due to economic or terrain limitations. For example, in several developing countries the ground-based rainfall observation networks have always been relatively sparse.

  - Spatial rainfall distribution can be improved with the inclusion of ancillary data such as radar, satellite and topography data.
  - Tropical Rainfall Measuring Mission
  - A Joint Mission Between The US and Japan (Global coverage 50° S-50°N)

- The Climate Prediction Center (CPC) is a US federal agency that is one of the National Centers for Environmental Prediction, which are a part of the NOAA. It is providing analysis climate data.

SWAT Hydrological Model

Soil and Water Assessment Tools (Arnold et al. 1998)

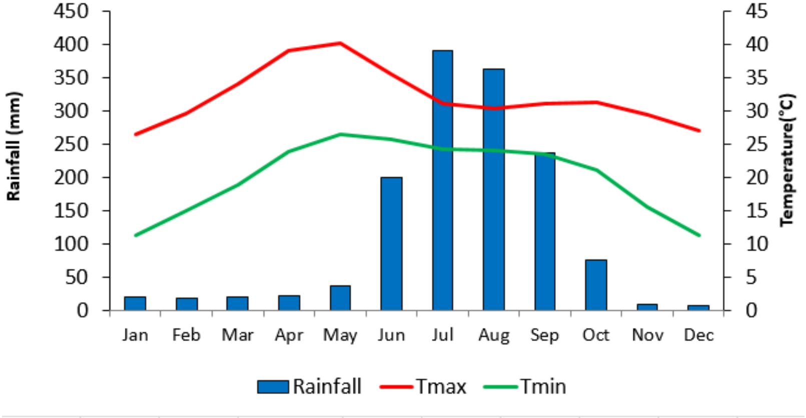
- ***SWAT is continuous, long-term, and distributed-parameter model designed to predict the impact of land management practices on the hydrology and sediment and contaminate transport in agriculture watersheds.***
- ***SWAT subdivide a watershed into sub-basin connected by a stream network, and further delineates HRUs(Hydrologic Response Unit) consisting of unique combination of land cover and soils within each sub-basin.***
- ***The hydrological cycle as simulated by SWAT is based on the water balance equation:***

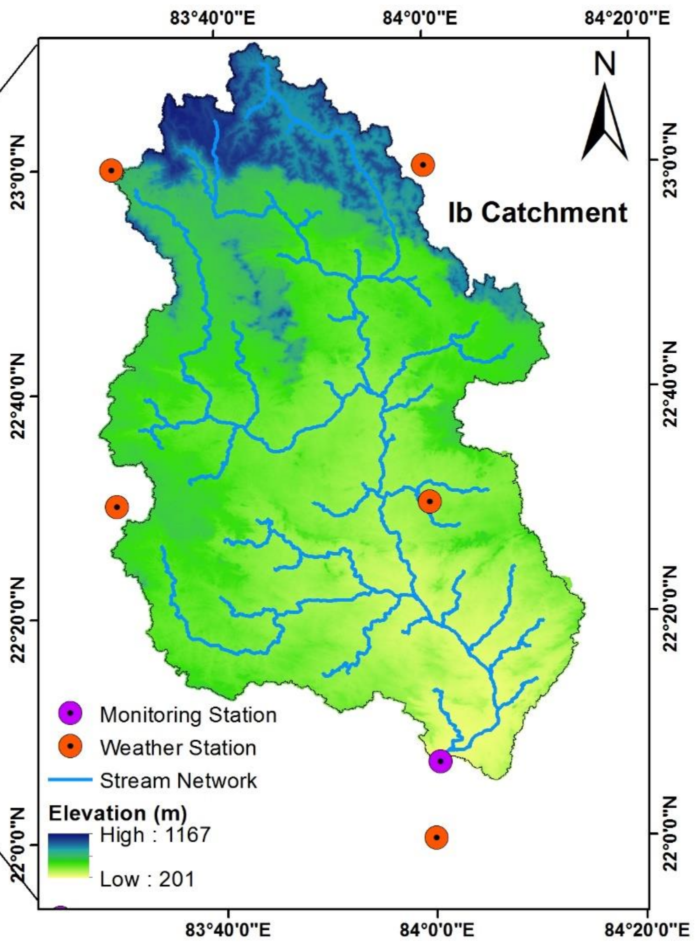
$$SW_t = SW_0 + \sum_{i=1}^{t} (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw})$$

SW_t = Final soil water content (mm)
SW_0 = Initial soil water content on day i (mm)
R_{day} = Amount of precipitation on day i (mm)
Q_{surf} = Amount of surface runoff on day i (mm)
E_a = Amount of evapotranspiration on day i (mm)
W_{seep} = Amount of water entering the vadose zone from the soil profile on day i (mm)
Q_{gw} = Amount of return flow on day i (mm)

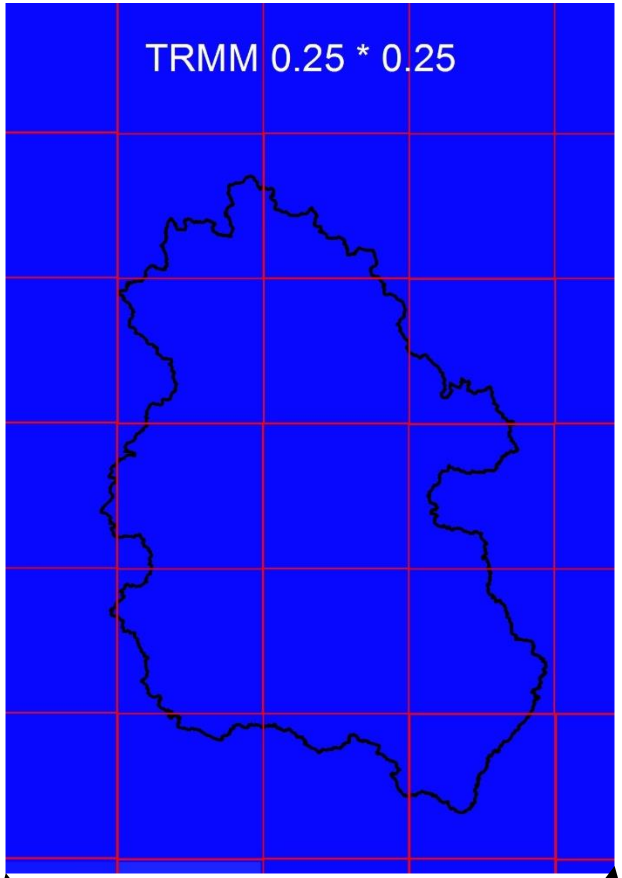
Study Area

- ***Location:*** ***Ib river catchment***
- ***Catchment Area:*** ***5893.15 sqkm***
- ***River Origin:*** ***Hills near Pandrapet***
- ***Annual Rainfall:*** ***800-1200 mm***
- ***Temperature variatio 6.66-46.11°C***





> ***The Ib River is a small river in Chhattisgarh and Odisha and finally meeting at Hirakurd dam.***

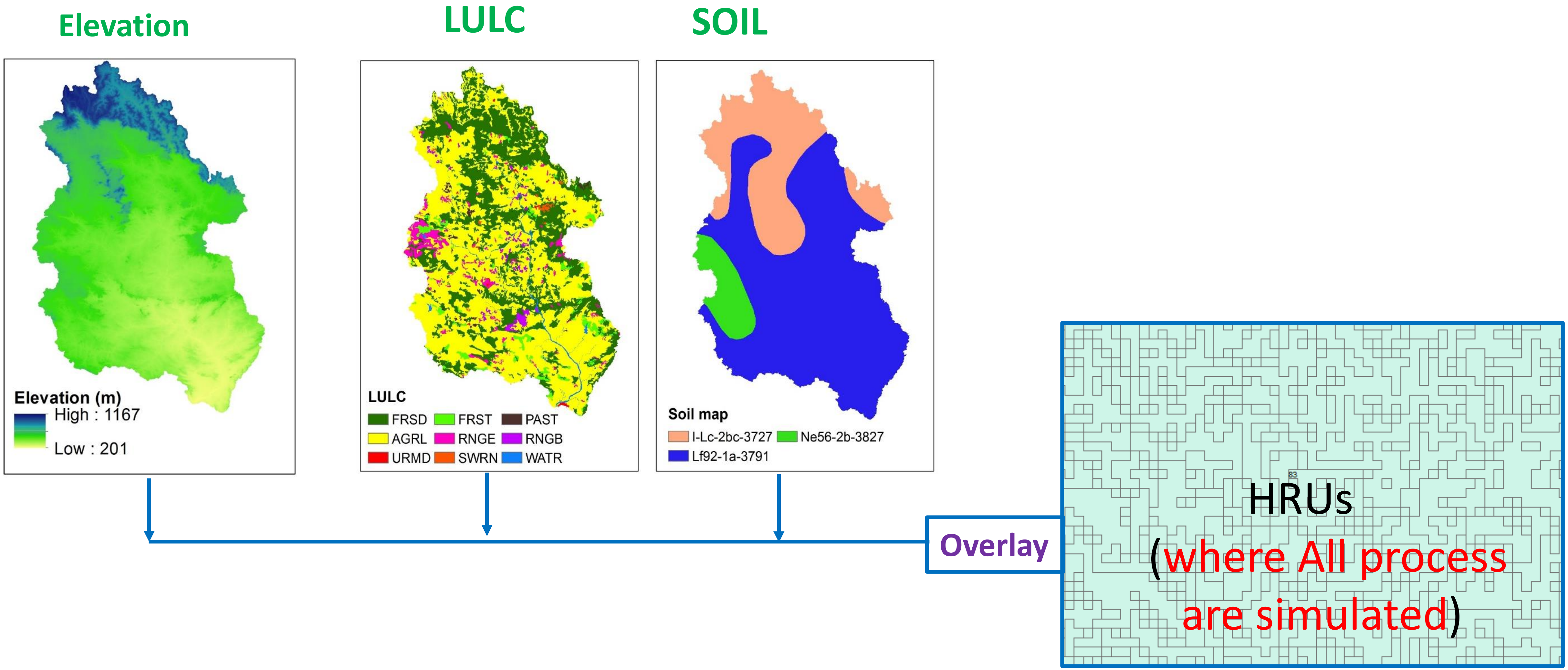


GRIDED TRMM RAINFALL

Data Used

Data Type	***Source***	***Scale/period***	***Description***
Topography	*United States Geological Survey*	*30m*	*Digital elevation model*
Soil	*FAO Digital Soil Map of the World (DSMW)*	*1/50000*	*Soil classification and physical properties*
Landuse	*Earth explorer*	*30m*	*2005 landuse classification from the Landsat satellite image*
Weather Data	*Tropical Rainfall Measuring Mission https://trmm.gsfc.nasa.gov/*	*1998-2011*	*Daily Precipitation, daily Maximum and daily minimum temperature*
Discharge data	*Central Water Commission, India*	*1993-2011*	*Monthly stream flow(cumec) at outlet*

Raster input of SWAT Model



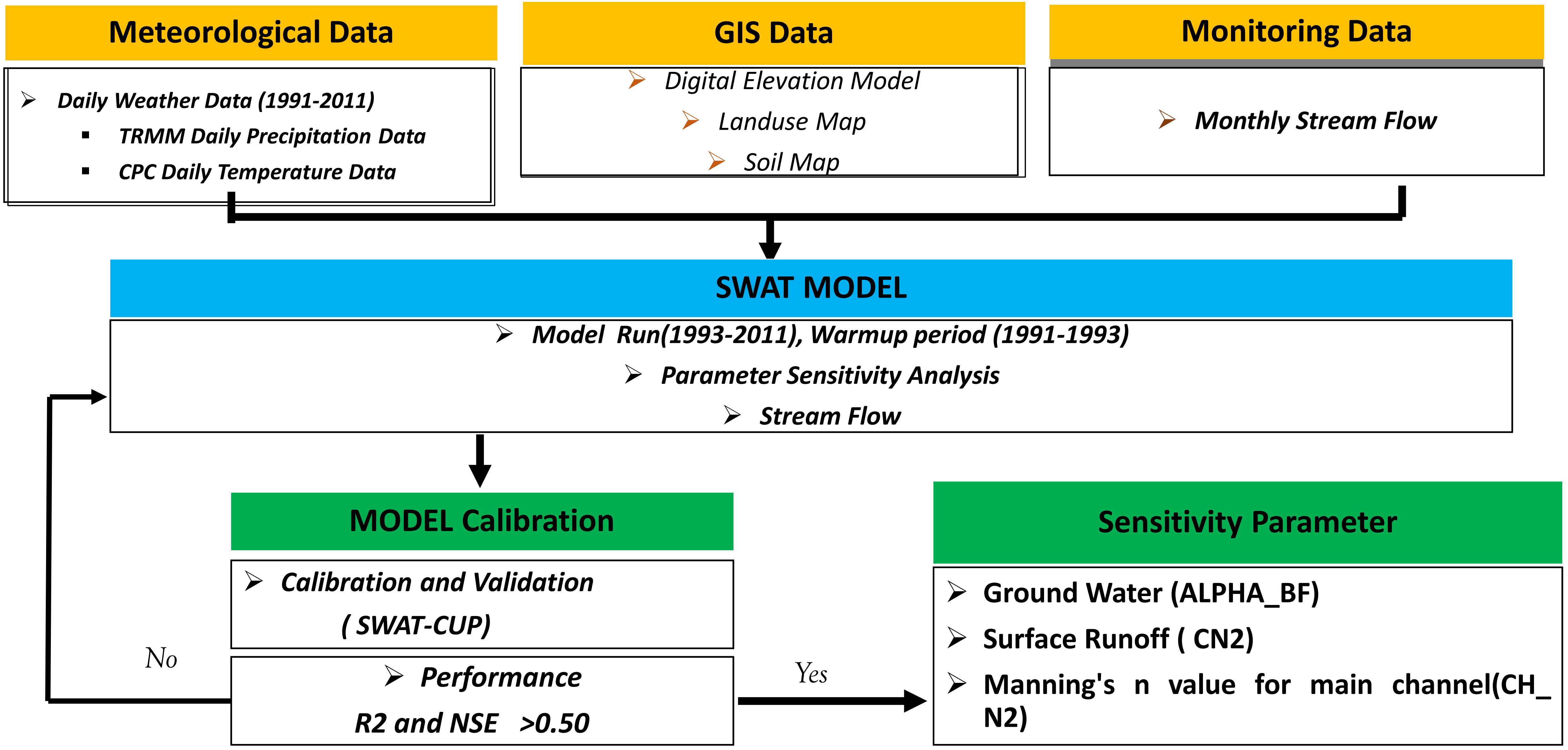
Methods adopted for hydrology

- ***Runoff (SCS curve number)***

  The curve number method was developed by the USDA Natural Resources Conservation Service, which was formerly called the Soil Conservation Service or SCS Curve number
  It is a most common method adopt to predict the runoff

- ***Evapotranspiration (Penman-Monteith)***
  (Monteith, 1965)
  - ***Penman-Monteith method is recommended as the sole ETo method for determining reference evapotranspiration***
  - ***Penman combined the energy balance with the mass transfer method and derived an equation to compute the evaporation from an open water surface from standard climatological records of sunshine, temperature, humidity and wind speed***

Research Methodology

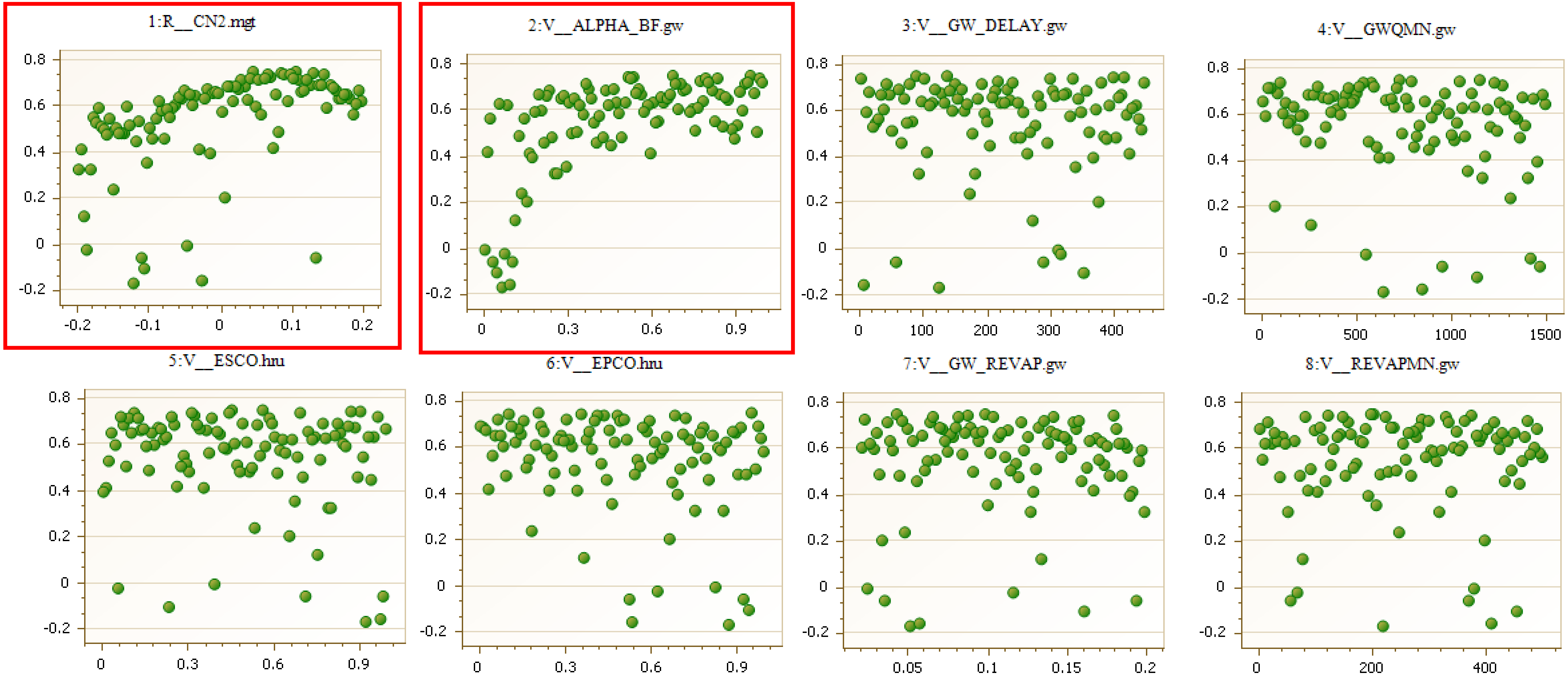


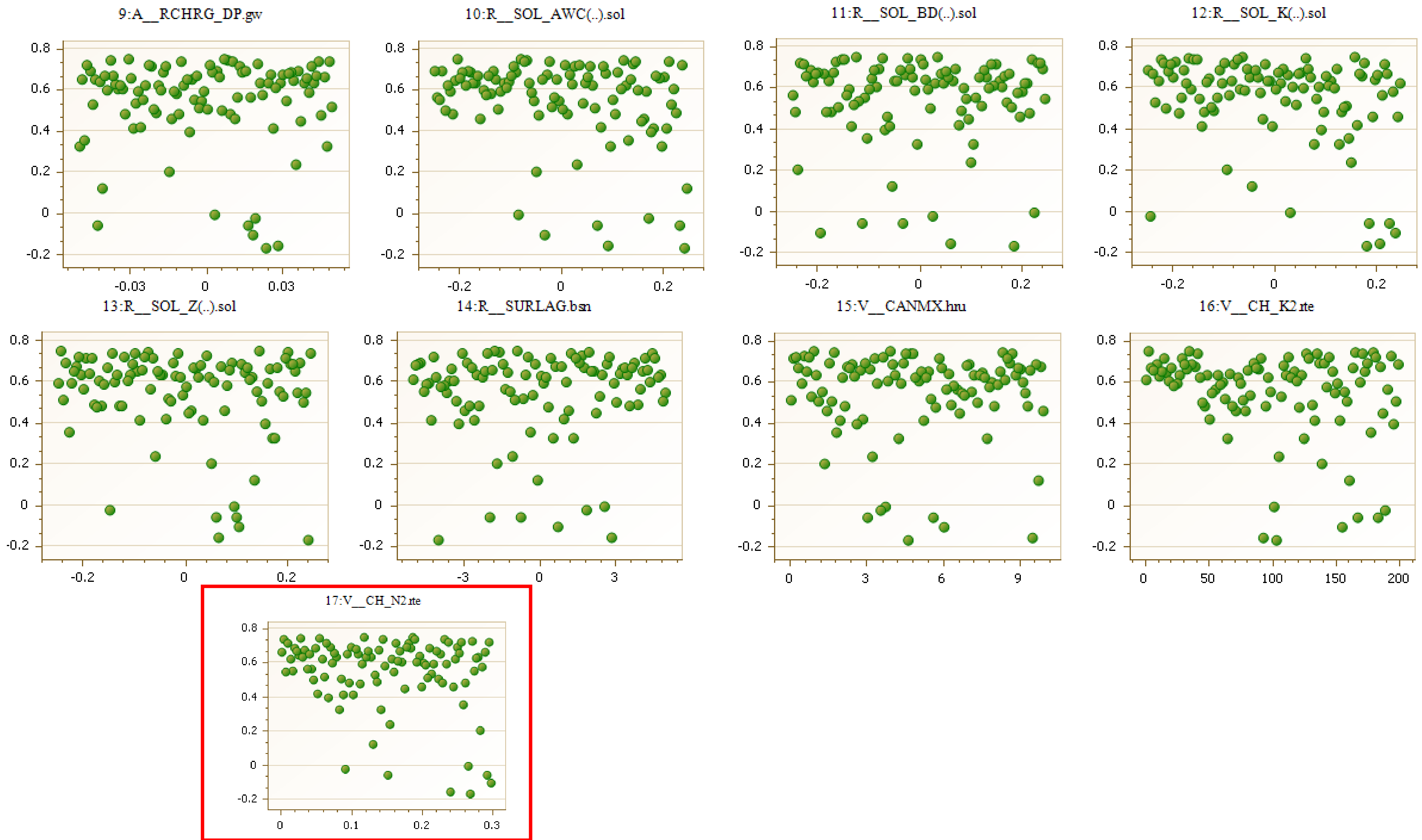
SWAT Calibrated Parameter

Parameter	Description	Lower limit	Upper limit	Optimal Value
r__CN2	Initial SCS runoff curve number for moisture condition II	-0.2	0.2	0.106
v__ALPHA_BF	Baseflow alpha factor Baseflow recession constant	0	1	0.675
v__GW_DELAY	Groundwater delay time (days)	0	450	87.750
v__GWQMN	Threshold depth of water in the shallow aquifer required for return flow to occur (mm)	0	1500	1147.50
v__ESCO	Soil evaporation compensation factor	0	1	0.4550
v__EPCO	Plant uptake compensation factor	0	1	0.95
v__GW_REVAP	Groundwater “revap” coefficient	0.02	0.2	0.0425
v__REVAPMN	Threshold depth of water in shallow aquifer for “revap” to occur (mm)	0	1000	197.50
a__RCHRG_DP	Deep aquifer percolation fraction	-0.05	0.05	0.0075
r__SOL_AWC()	Available water capacity of soil layer (mm H2O/mm soil)	-0.25	0.25	-0.0775
r__SOL_BD()	Moist bulk density (g/cm3)	-0.25	0.25	-0.1225
r__SOL_K()	Saturated hydraulic conductivity	-0.25	0.25	0.1575
r__SOL_Z()	Depth from soil surface to bottom of layer	-0.25	0.25	-0.2425
r__SURLAG	Surface runoff lag time	-5	5	-1.75
v__CANMX	Maximum canopy storage	0	10	3.95
v__CH_K2	Effective hydraulic conductivity in main channel alluvium (mm/h)	0	200	35.00

SWAT hydrological parameters sensitivity analysis

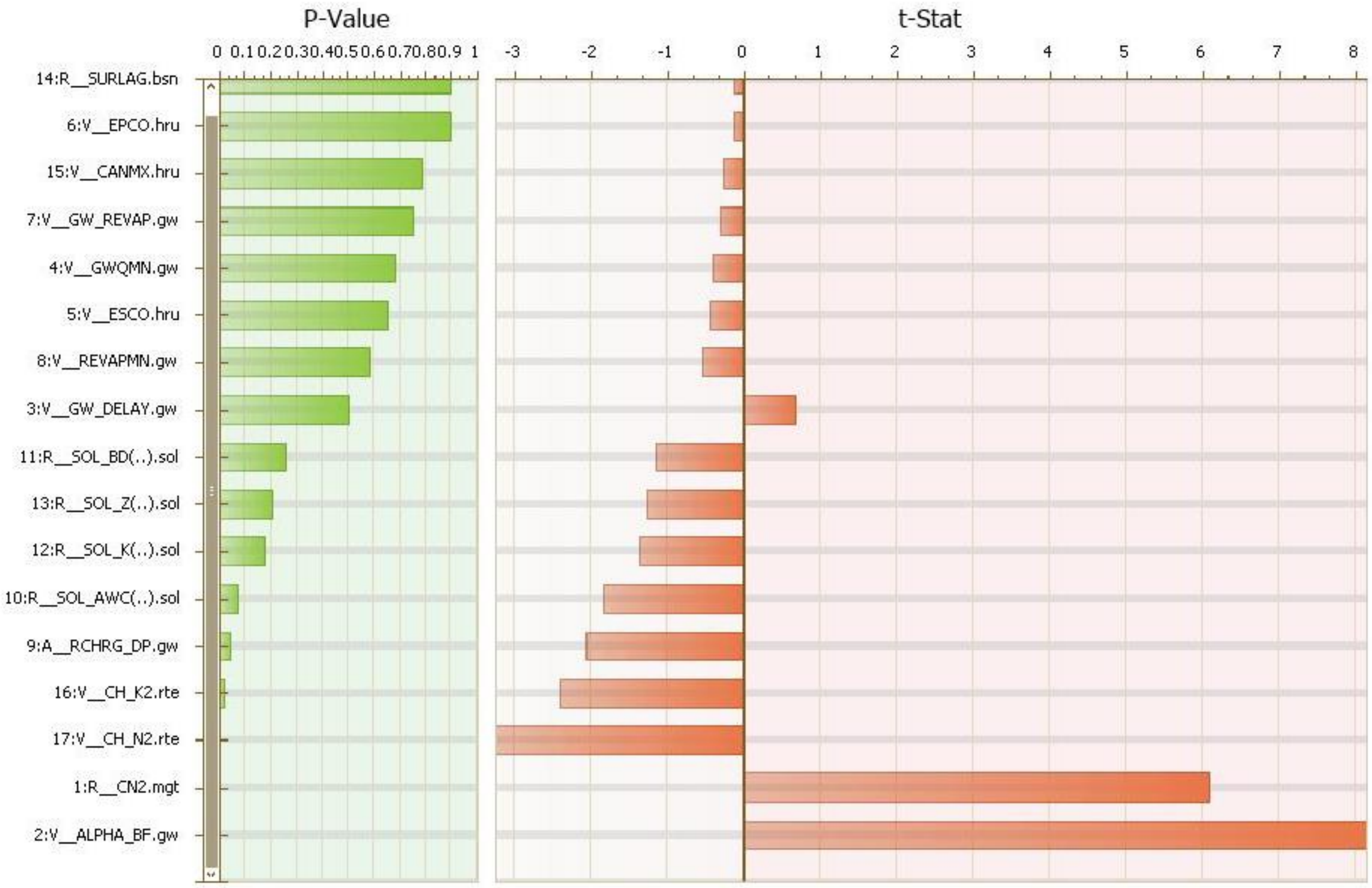
✓ ***A sensitivity analysis was conducted on the SWAT model parameters before the calibration.***



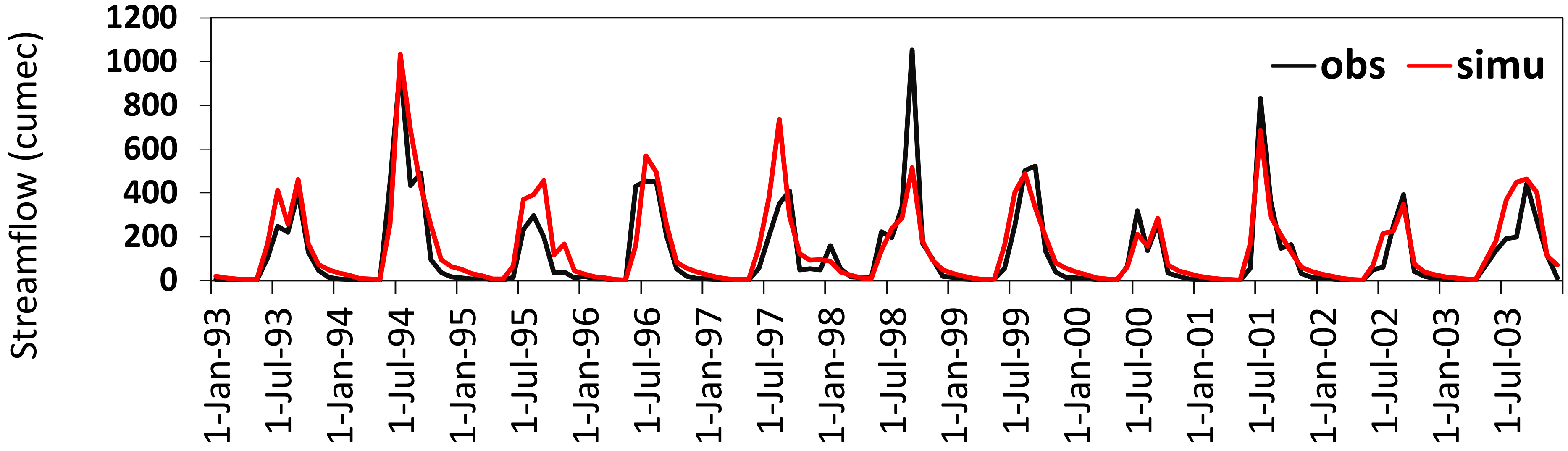

9:A__RCHRG_DP.gw
10:R__SOL_AWC(..).sol
11:R__SOL_BD(..).sol
12:R__SOL_K(..).sol
13:R__SOL_Z(..).sol
14:R__SURLAG.bsn
15:V__CANMX.hru
16:V__CH_K2.rte
17:V__CH_N2.rte
0.8
0.6
0.4
0.2
0
-0.2
-0.03
0
0.03
-0.2
0
0.2
-3
0
3
0
3
6
9
0
50
100
150
200
0
0.1
0.2
0.3

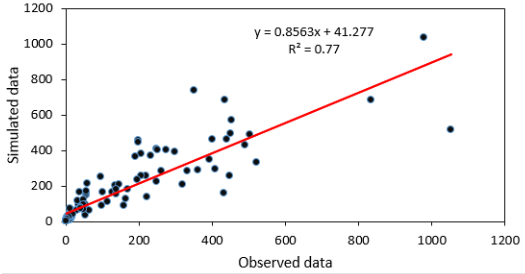
Sensitivity Analysis

Parameter	t-Stat	P-Value	Rank
SURLAG.bsn	-0.13	0.90	17
EPCO.hru	-0.13	0.89	16
CANMX.hru	-0.27	0.78	15
GW_REVAP.gw	-0.31	0.75	14
GWQMN.gw	-0.41	0.68	13
ESCO.hru	-0.45	0.65	12
REVAPMN.gw	-0.55	0.58	11
GW_DELAY.gw	0.67	0.50	10
SOL_BD.sol	-1.15	0.26	9
SOL_Z.sol	-1.27	0.21	8
SOL_K.sol	-1.37	0.17	7
SOL_AWC.sol	-1.84	0.07	6
RCHRG_DP.gw	-2.07	0.04	5
CH_K2.rte	-2.41	0.02	4
CH_N2.rte	-3.25	0.00	3
CN2.mgt	6.08	0.00	2
ALPHA_BF.gw	8.15	0.00	1



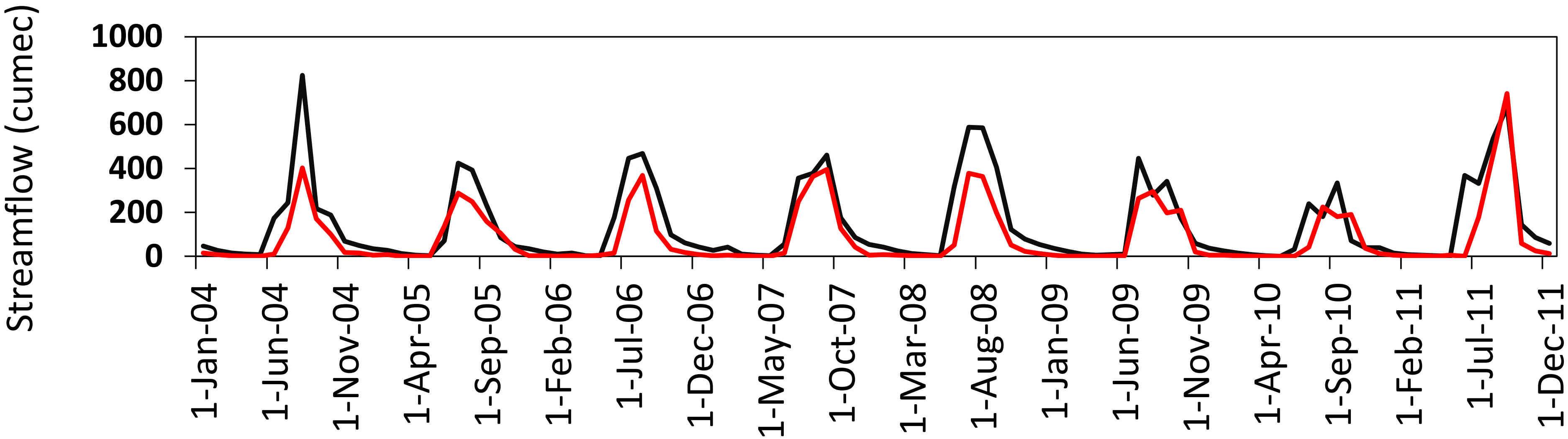
SWAT Calibration and validation

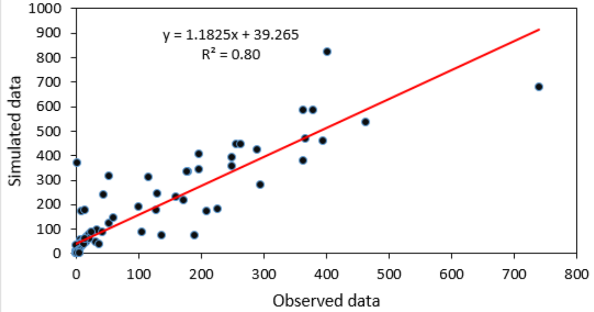




Calibration (1993-2003)

R2 = 0.77(Very good)
NSE = 0.75(Very good)
PBIAS = -19.5

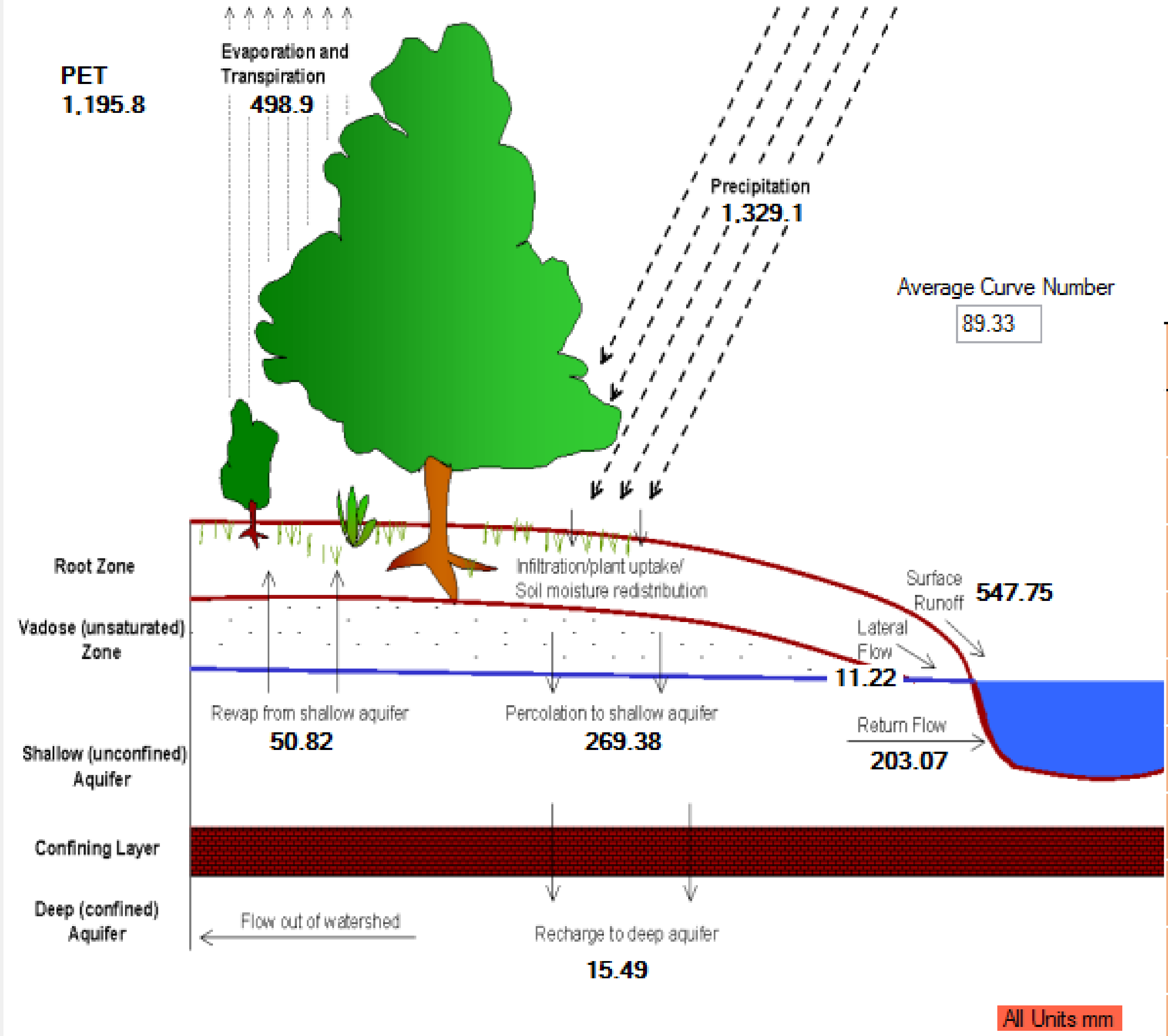




Validation (2004-2011)

R2 = 0.80 (very good)
NSE = 0.62
(Satisfactory)
PBIAS = -23.6

Cont..



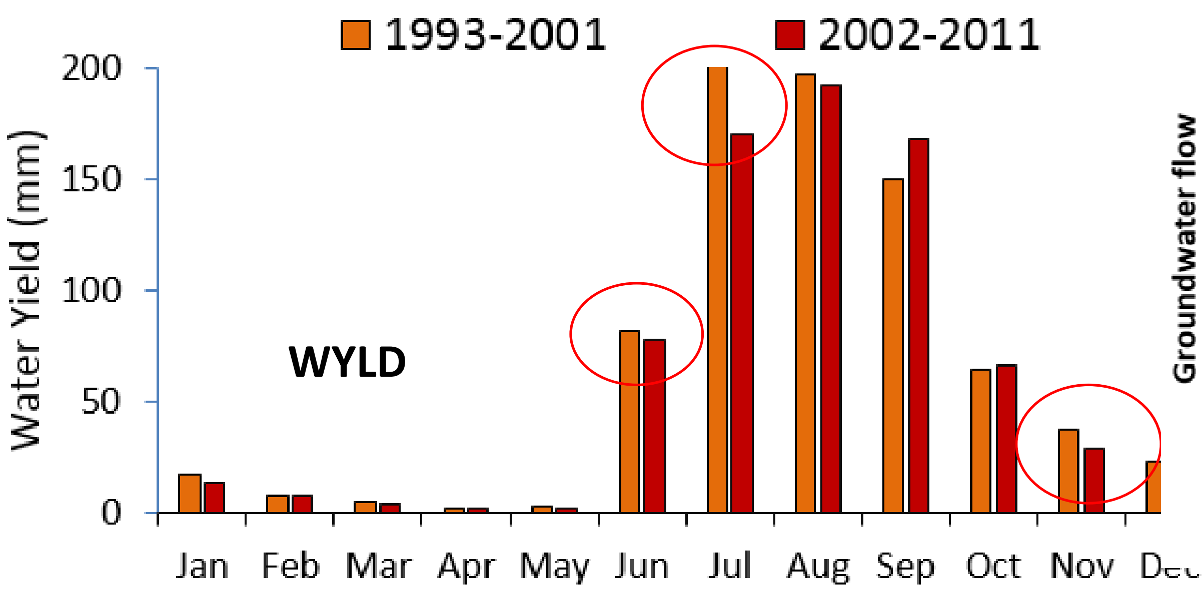
Water balance components	Amount(mm)
Precipitation; Precip	1329.1
Potential evapotranspiration;PET	1195.8
Actual evapotranspiration; ET	498.9
Percolation out of soil	269.38
Ground water flow contribution; GW_Q	203.07
Deep Aquifer Recharge;DA_RCHG	15.49
Surface Runoff; SURF	547.75
Total Water Yield; WYLD	777.39
Lateral Soil flow contribution; LA_Q	11.22

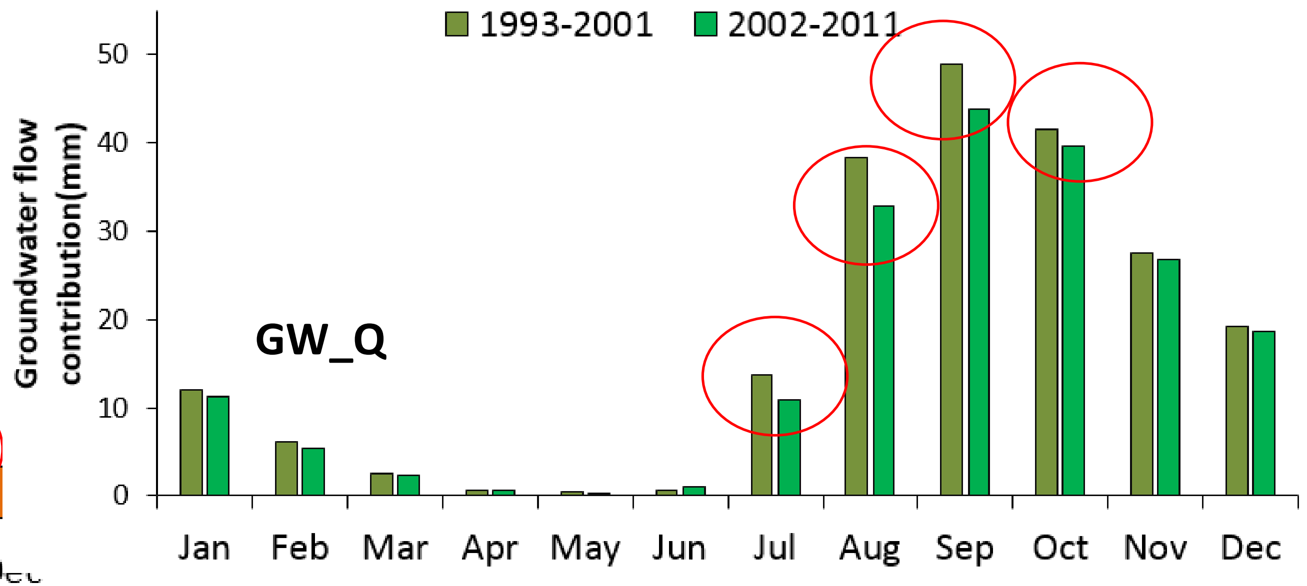
Water balance components

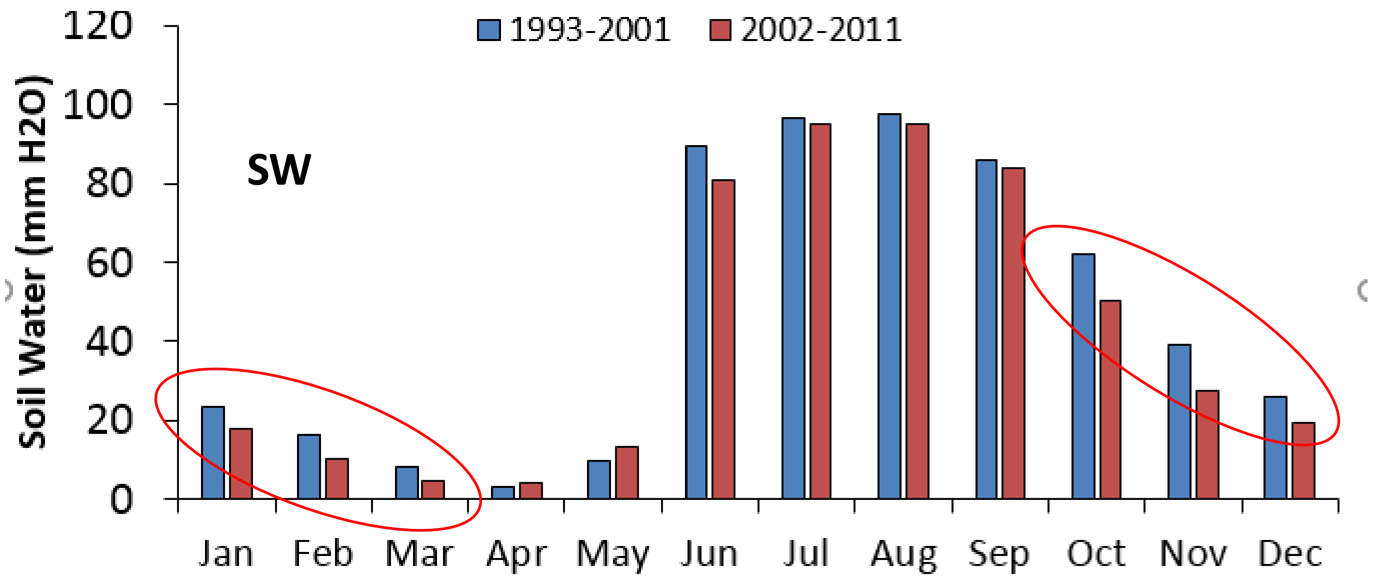
Year	PRECIP(mm)	SURQ(mm)	PERC(mm)	GWQ(mm)	LATEQ(mm)	ET(mm)	WYLD(mm)
1993	1320.15	537.55	10.97	184.3	265.33	496.65	745.82
1994	1894.47	984.11	14.92	314.59	404.01	494.55	1333.32
1995	1393.72	566.84	11.06	195.82	237.9	558.31	791.7
1996	1298.24	586.77	10.52	181.67	245.15	479.36	793.38
1997	1484.21	606.07	12.51	240.18	317.86	494.48	874.83
1998	1393.05	497.33	12.6	214.35	273.82	650.65	741
1999	1340.84	552.85	12.01	224.43	304.48	477.65	805.64
2000	897.06	250.74	8.73	148.74	186.32	459.51	422.71
2001	1302.87	495.49	11.32	211.79	287.2	502.72	733.06
2002	1008.07	341.61	8.47	112.56	158.76	501.47	474.73
2003	1546.92	693.22	12.63	216.43	327.99	490.5	935.11
2004	1376.97	582.86	11.52	242.79	287.73	517.21	855.89
2005	1134.3	443.19	9.19	147.9	193.79	477.25	614.47
2006	1352.8	549.43	11.61	201.86	284.16	518.88	776.52
2007	1314.77	513.06	11.68	222.89	297.99	492.04	763.74
2008	1533.38	696.59	12.91	278.42	347.15	479.88	1007.39
2009	1148.74	438.56	9.89	169.23	222.09	473.13	633.55
2010	950.23	326.79	7.9	106.86	163.26	447.67	452.63
2011	1561.35	744.22	12.72	243.52	343.25	468.16	1014.89
Mean	1329.06	547.7516	11.218	203.07	270.96	498.951	777.388

PRECIP = precipitation; SURQ= surface runoff; GWQ = Ground water contribution to stream flow; ET= evapotranspiration & WYLD= water yield

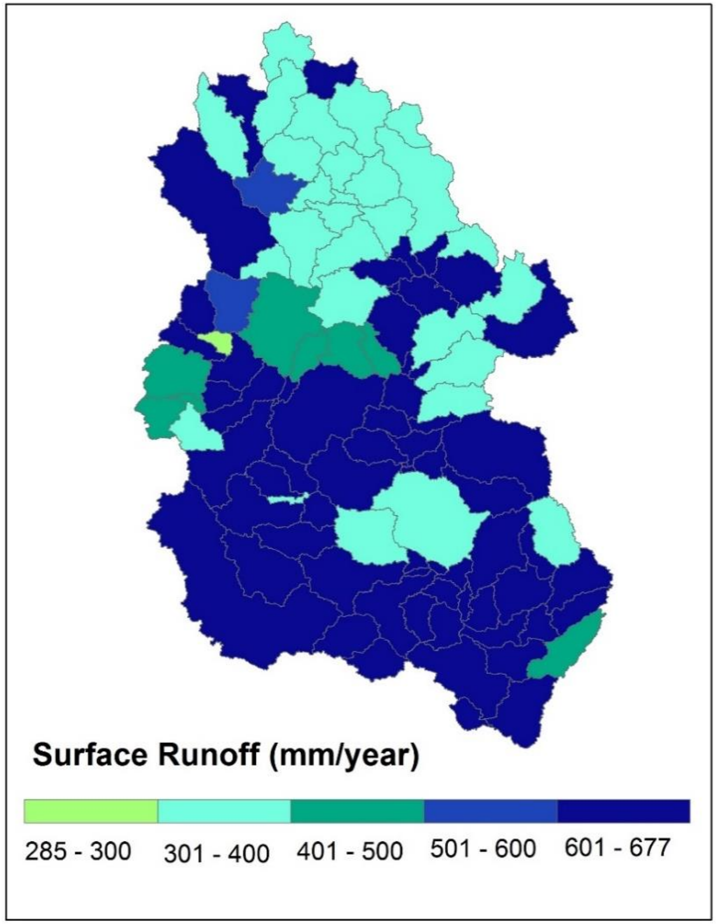
Cont..

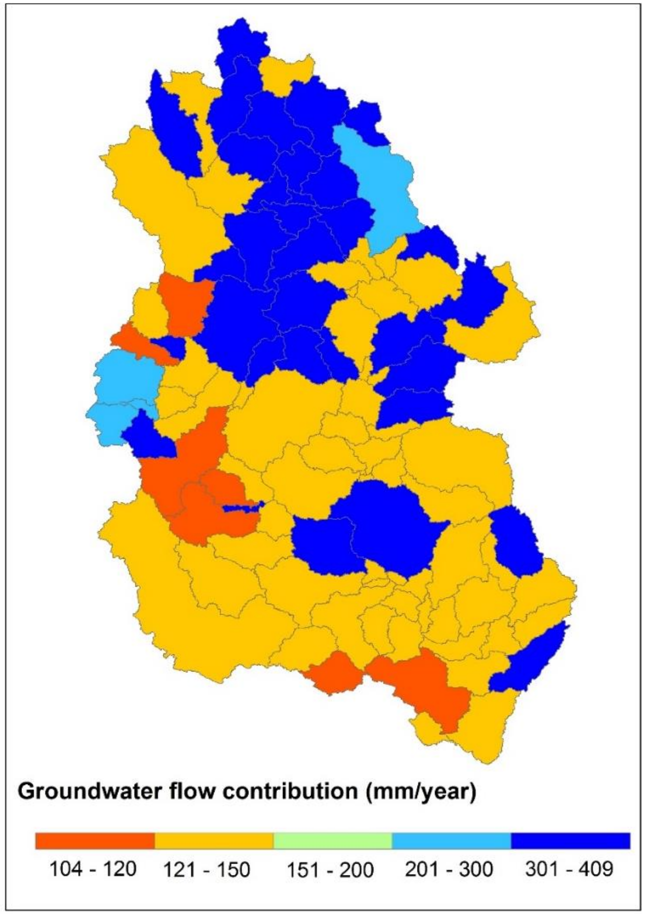

1993-2001
2002-2011
Water Yield (mm)
200
150
100
50
0
WYLD
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

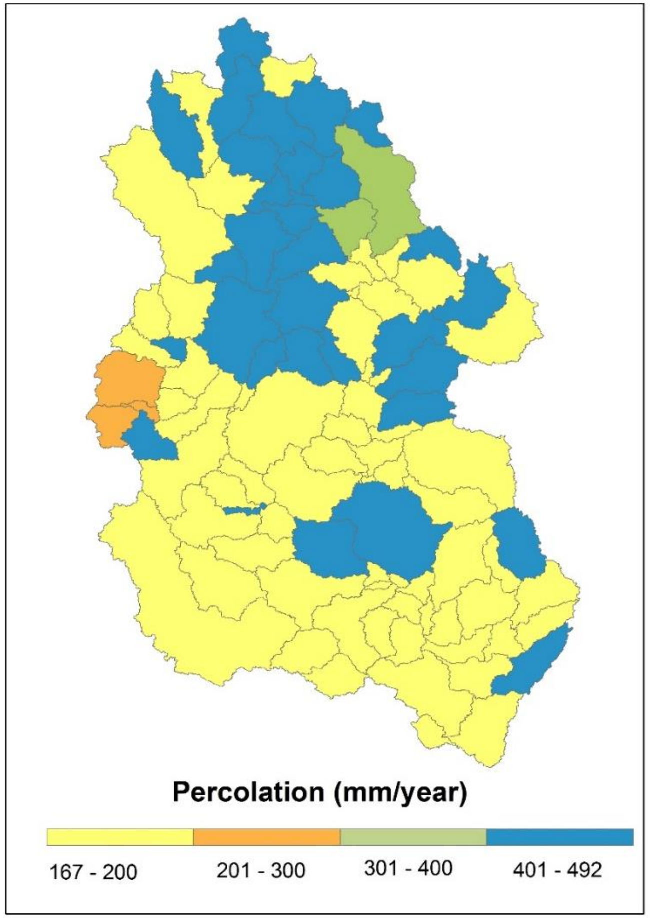

1993-2001
2002-2011
Groundwater flow contribution(mm)
50
40
30
20
10
0
GW_Q
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


1993-2001
2002-2011
Soil Water (mm H2O)
120
100
80
60
40
20
0
SW
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Cont..


Surface Runoff (mm/year)
285 - 300
301 - 400
401 - 500
501 - 600
601 - 677


Groundwater flow contribution (mm/year)
104 - 120
121 - 150
151 - 200
201 - 300
301 - 409


Percolation (mm/year)
167 - 200
201 - 300
301 - 400
401 - 492

Summary and conclusions

In this study, we tried to calibrate the SWAT (Soil and Water Assessment Tool) model parameters for check feasibility of model in Ib river catchment and validate other periods and it showed good results.

- ***The SWAT Hydrology calibration results in Ib catchment***
  - *For the calibration , the parameters SCS_CN(SCS curve number for moisture condition), ALPHA_BF(Baseflow factor and* Manning's n value for main channel *(CH_K2) were the most sensitive and important for the water balance accounting.*
  - *The NSE of calibration and validation was obtained 0.75 an d 0.62*

- ***Water Balance components results in Ib Catchment***
  - *In case of surface runoff much of surface runoff coming from high elevation and northern region less sensitive to runoff.*
  - *Groundwater flow contribution is high in northern region.*
  - *Drought years are more affected (i.e. 2000 and 2010, due to less than average rainfall and also very low percolation).*
  - *Hydrological components are in decreasing trends(Rainfall, percolation and water yield etc).*

Thank You..