Procedure of hydrological modeling in a semi-arid river basin with SWAT

By:
Ammar Rafiei

outline

- Objective
- Introduction
- Study area
- Preparation of data sets
- Model parameterization
- Uncertainty analysis
- Sensitivity analysis
- results

Objectives:

1- Building and calibrating a hydrological model in a semi arid river basin of Iran

2- Quantifying the water resources availability in the study area

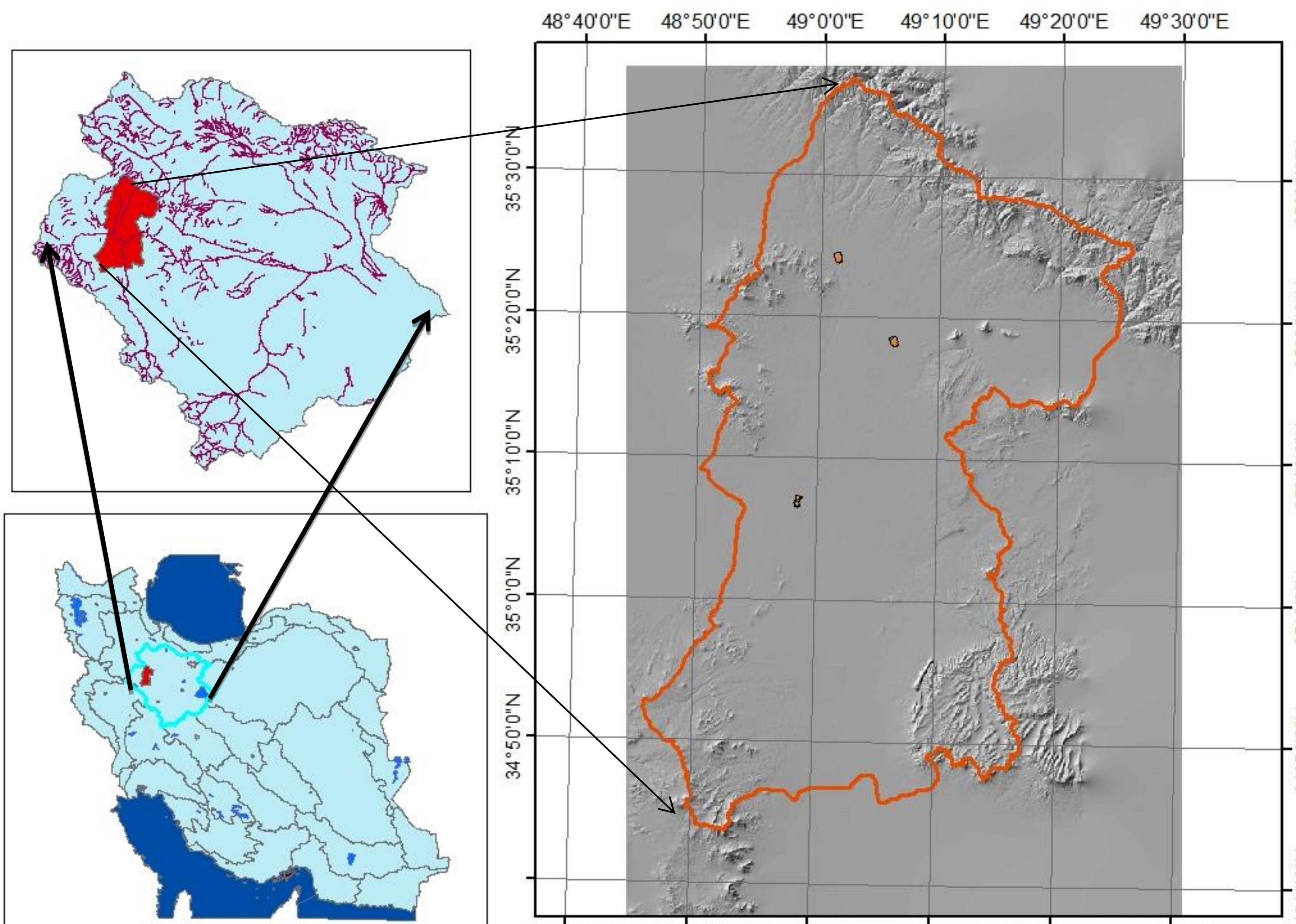
Introduction

- Water scarcity in arid and semi arid area has negative impact on planning and management of this regions.

  - Low precipitation , low water availability
  - weakness of management

- Groundwater usage
- More than 90 % of water are using for agriculture with WUE less than 35 %

Study area

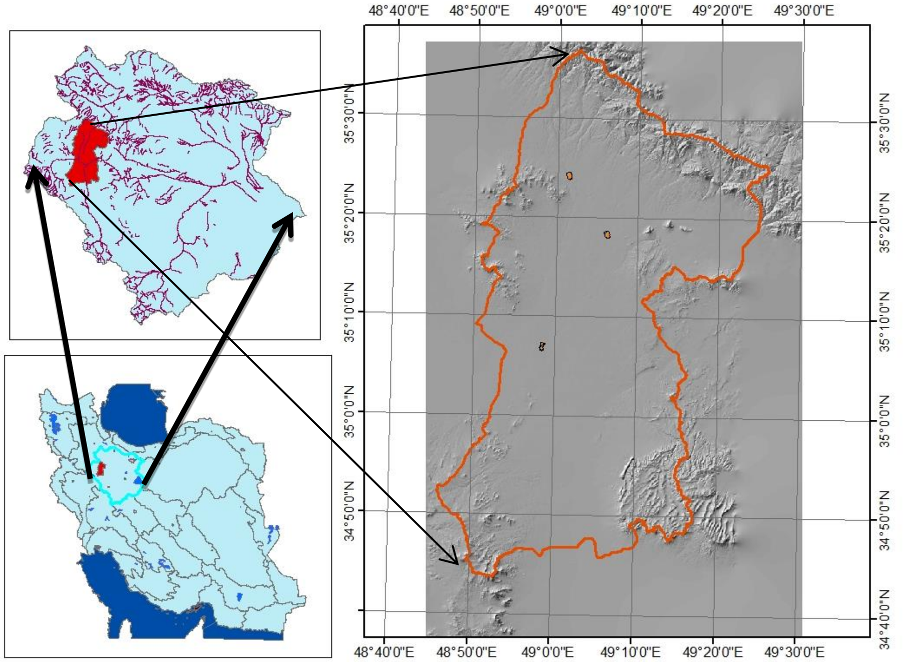

48°40'0"E
48°50'0"E
49°0'0"E
49°10'0"E
49°20'0"E
49°30'0"E
35°30'0"N
35°20'0"N
35°10'0"N
35°0'0"N
34°50'0"N
34°40'0"N

Razan-Ghavand watershed

- Watershed Area: 3100 Km^2
- Max altitude 2842 m
- Min altitude: 1577 m

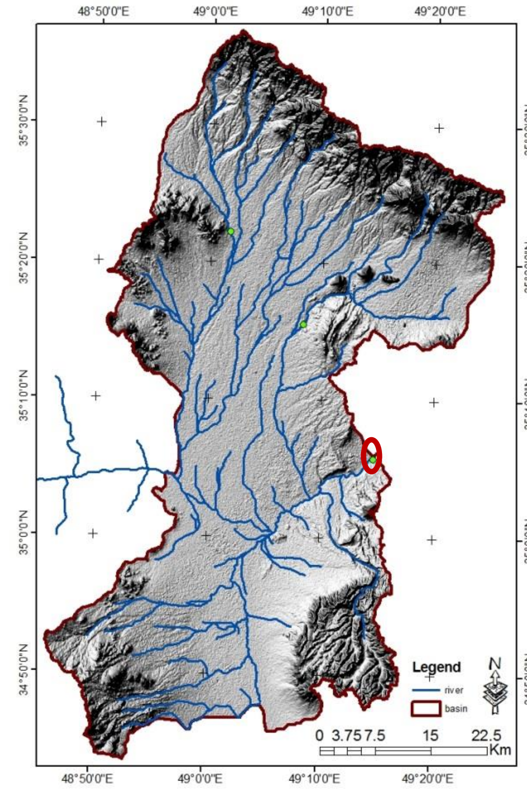
- Climate: semi arid
- Mean annual rainfall: 290 mm
- Mean annual temperature: 11°C

- Aquifer area: 1750 Km^2
- Mean water level: 30 m



Study area: Razan-Ghavand

- Major river: Gharehchay river with mean annual discharge at the outlet: 6.68 m^3s^{-1}



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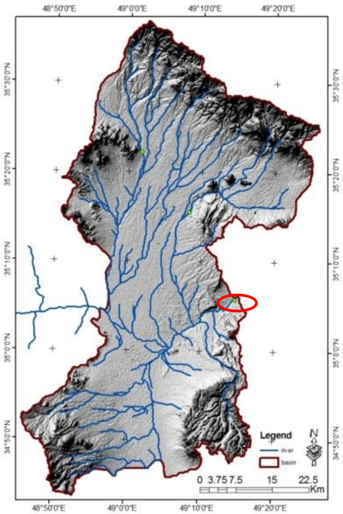

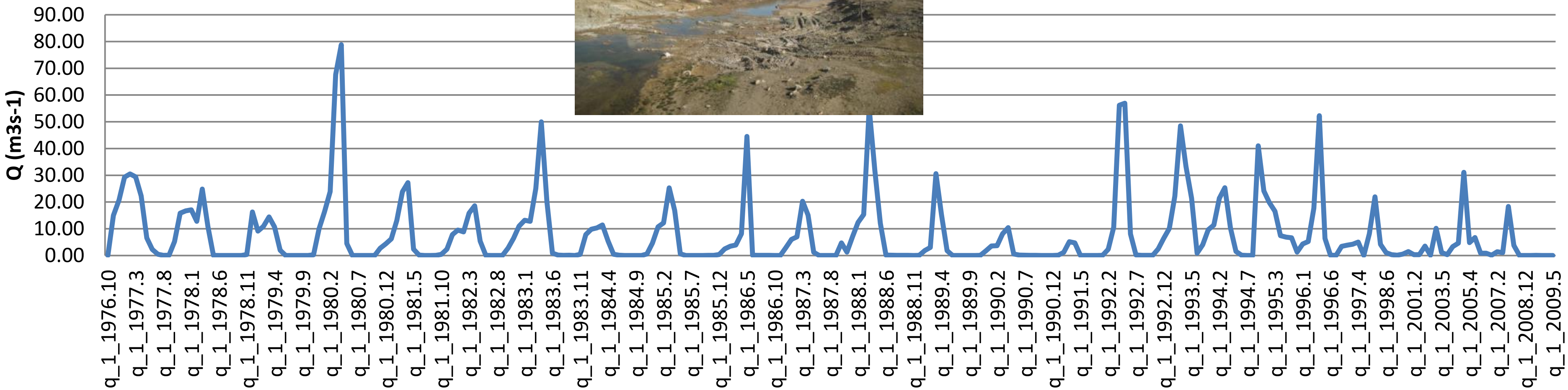

Study area: Razan-Ghavand

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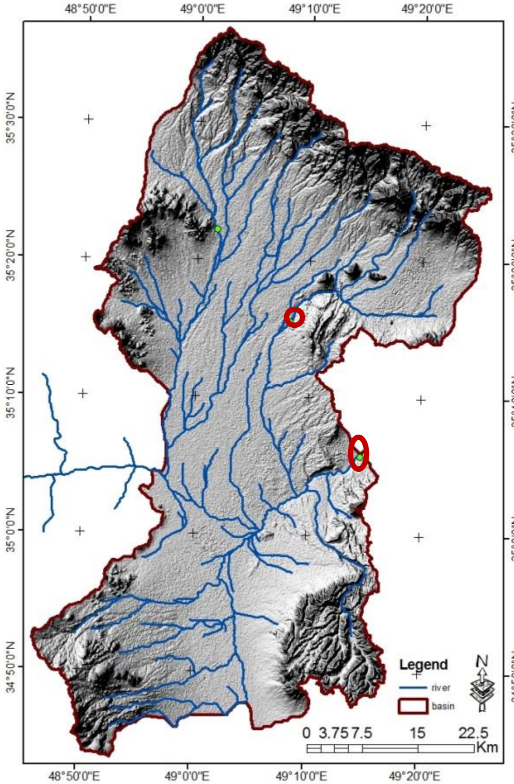
- Zehtaran river with mean annual discharge at the outlet: 0.66 m^3s^{-1}



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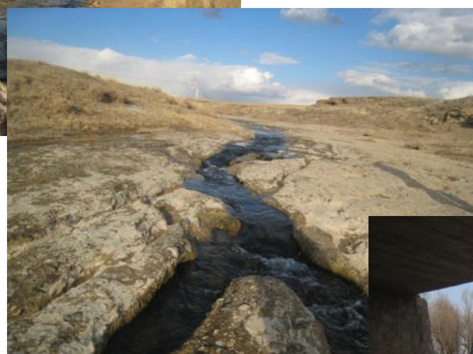

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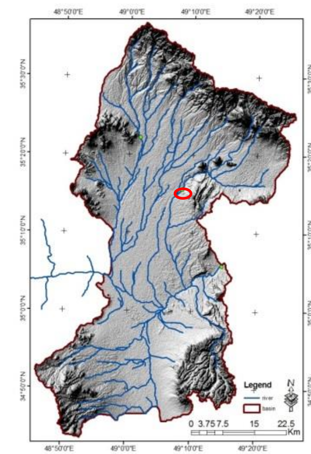

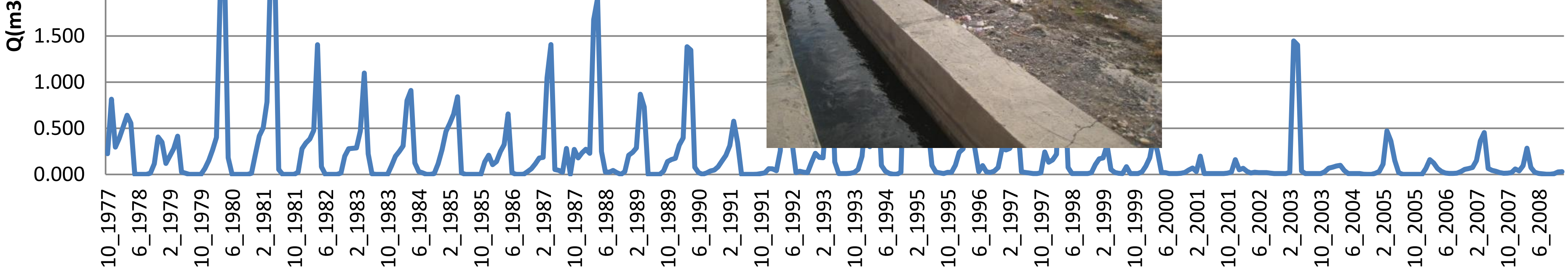

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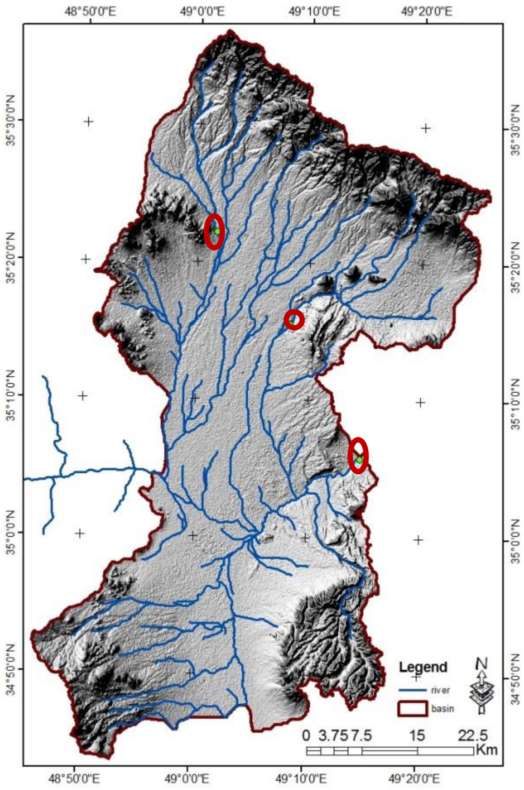
- Sirab-khomigan river with mean annual discharge at the outlet: 0.33 m^3s^{-1}



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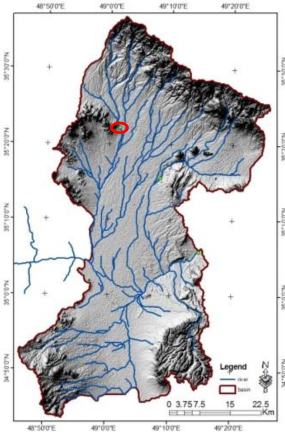

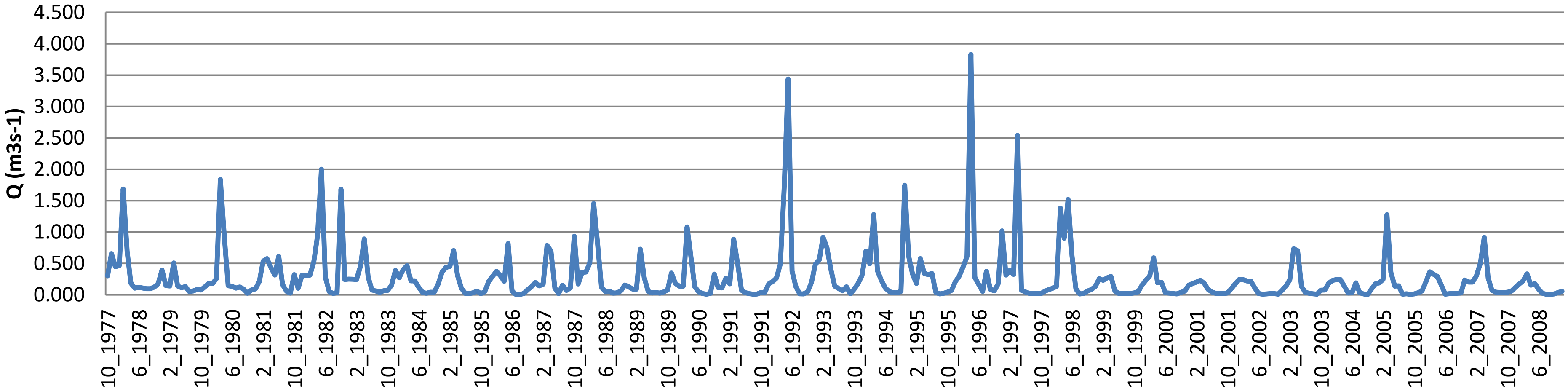

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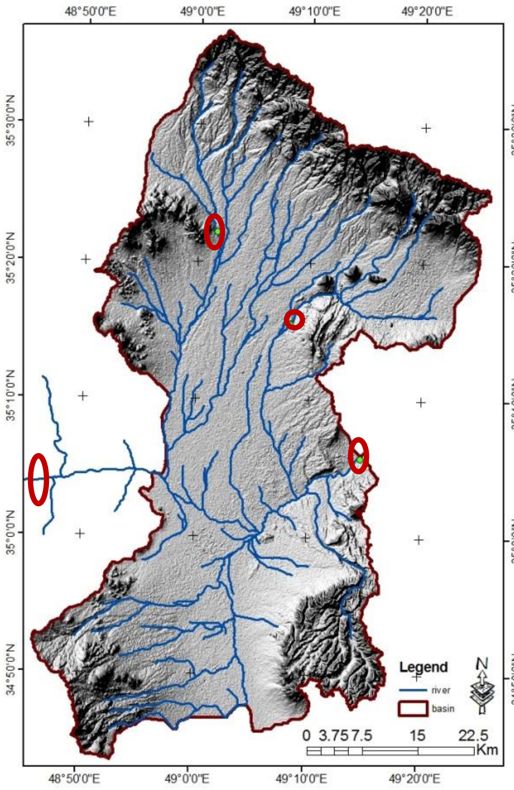
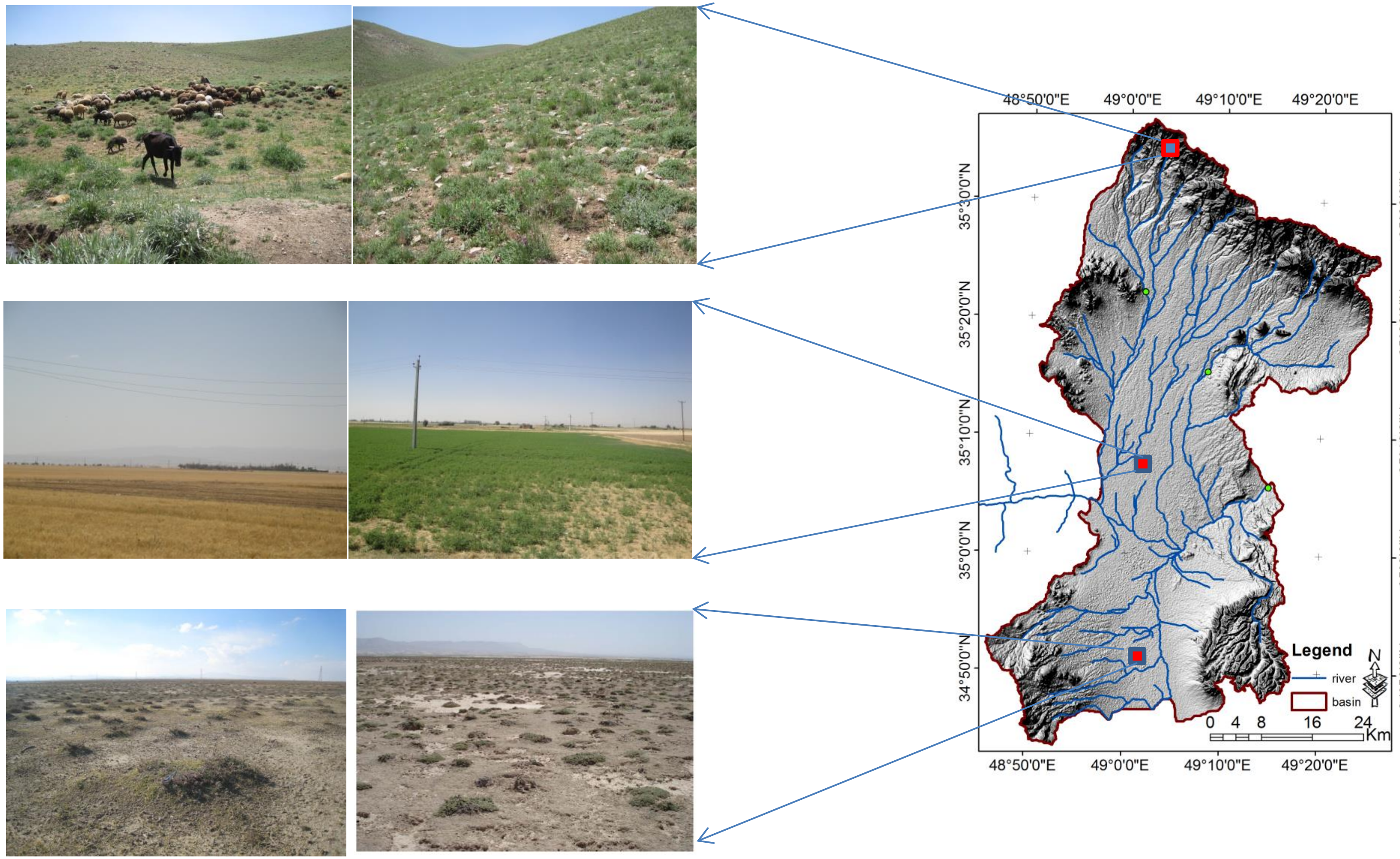
- Major river: Gharehchay river with mean annual discharge at the outlet: 6.68 m^3s^{-1}
- Zehtaran river with mean annual discharge at the outlet: 0.66 m^3s^{-1}
- Sirab-khomigan river with mean annual discharge at the outlet: 0.33 m^3s^{-1}
- Koshabad river station, outside the watershed, with mean annual discharge at the outlet: 2.25 m^3s^{-1}



Land types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49°20'0"E
35°30'0"N
35°20'0"N
35°10'0"N
35°0'0"N
34°50'0"N
Legend
river
basin
N
0 4 8 16 24
Km

Material and method

SWAT input/output

Input:

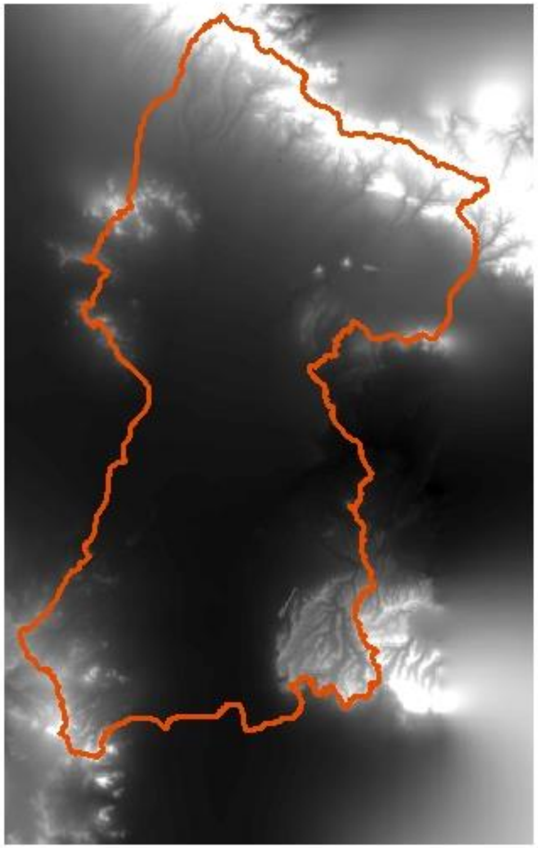
- DEM
- Landuse
- Soil
- Climate data
  - Daily precipitation
  - Daily temperature
- Agriculture management & practice data

Output:

- Hydrological component
  - Groundwater recharge
  - Soil moisture
  - Actual evapotranspiration
- Other Components:
  - Crop yield
  - Water quality
  - Sediment

Digital elevation model

Resolution : 25 m
Source: topographical map 1:25000



Input:

- **DEM**
- Landuse
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Output:

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- Groundwater recharge
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Other Components:
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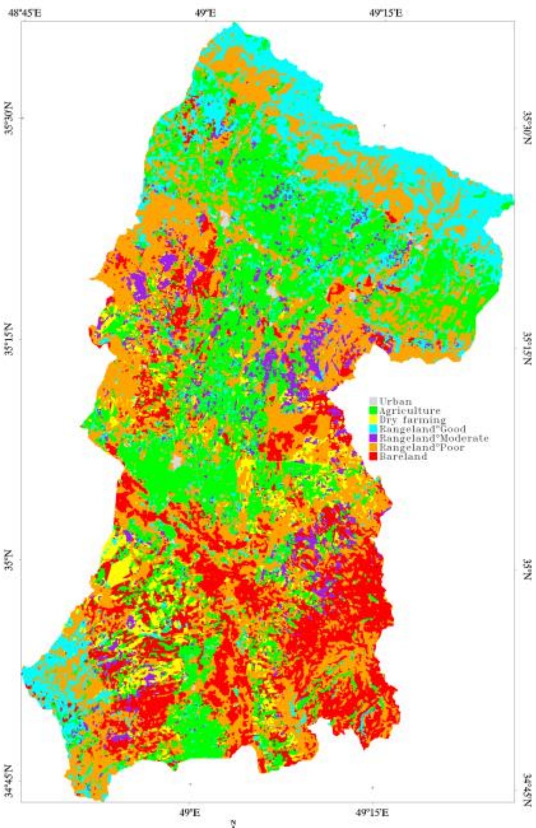
- Sediment

Land use map

- **Landsat 2009**
- **Supervised classification**
- **Overall Accuracy = 71.4317%**
- **Kappa Coefficient = 0.6604**



Input:

- DEM
- **Landuse**
- Soil
- Climate data
  - Daily precipitation
  - Daily temperature
- Agriculture management & practice data

Output:

Hydrological component

Groundwater recharge

Soil moisture

Actual evapotranspiration

Other Components:

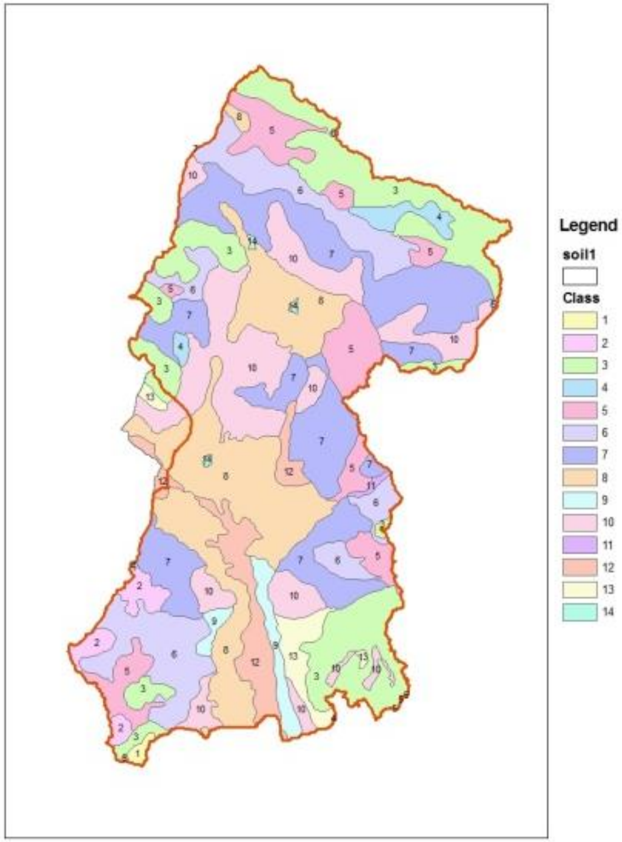
Crop yield

Water quality

Sediment

Soil map

- **Soil layers up to 5 layers**



Input:

- DEM
- Landuse
- **Soil**
- Climate data
  - Daily precipitation
  - Daily temperature
- Agriculture management & practice data

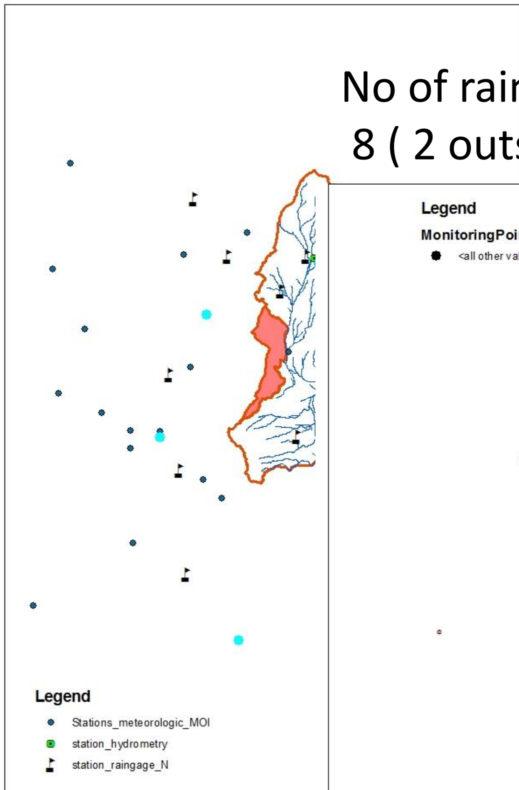
Output:

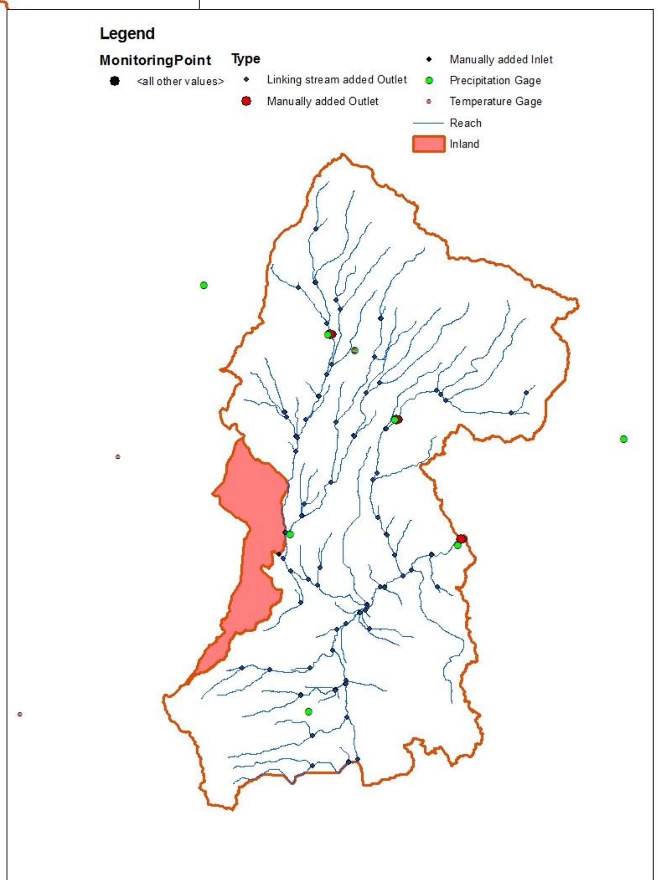
Hydrological component
- Groundwater recharge
- Soil moisture
- Actual evapotranspiration

Other Components:
- Crop yield
- Water quality
- Sediment

Climate data

No of rain gage selected:
8 (2 outside + 6 inside)





No of rain gage stations:
No of Synoptic stations=
No. of hydrometric stati

Input:

- DEM
- Landuse
- Soil
- **Climate data**
  - Daily precipitation
  - Daily temperature
- Agriculture management & practice data

Output:

Hydrological component
- Groundwater recharge
- Soil moisture
- Actual evapotranspiration

Other Components:
- Crop yield
- Water quality
- Sediment

Agriculture management & practice

- Agricultural schedule both for rainfed and irrigated lands

Input:

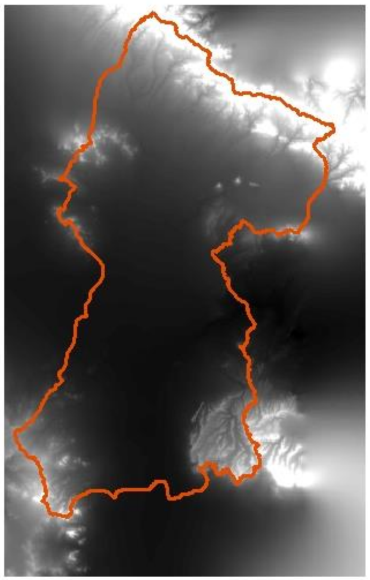
- DEM
- Landuse
- **Soil**
- Climate data
  - Daily precipitation
  - Daily temperature
- **Agriculture management & practice data**

Output:

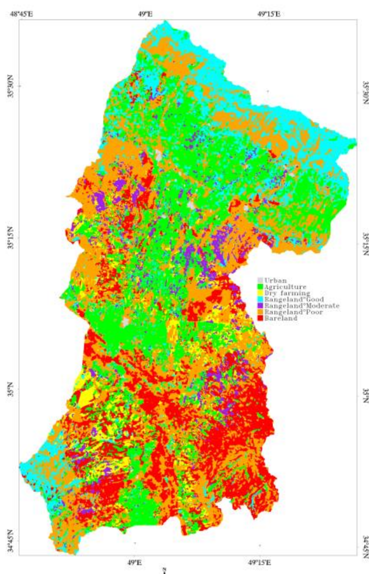
Hydrological component
  Groundwater recharge
  Soil moisture
  Actual evapotranspiration
Other Components:
  Crop yield
  Water quality
  Sediment

Model setup

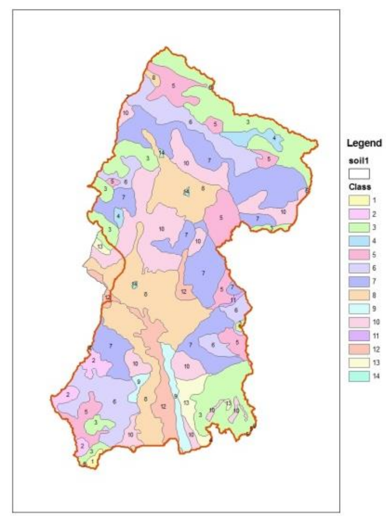
DEM
15 × 15 m



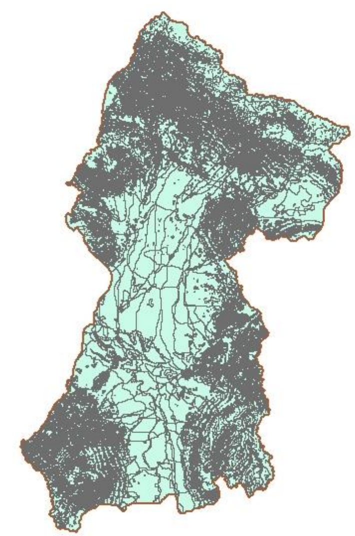
Landsat Derived 2009
30 × 30 m



Soil Map 1:250000



HRU



No of sub basin with inlet: 138,
No. of HRU with HRU: 831

Model set up

- Model was set up with inlet with non dominate HRU,

- Type of crop : winter wheat
- Auto-irrigation and fertilization operation options were used to simulate crop growth.

- evapotranspiration method : Hargreaves method
- curve number (CN) was adjusted based on the slop

Uncertainty analysis

- SUFI-2 was used to calibration and validation, uncertainty and sensitivity analysis,

  Duration of calibration: 2003-2008
  Duration of validation: 1998-2002
  Warm up duration: 2 years

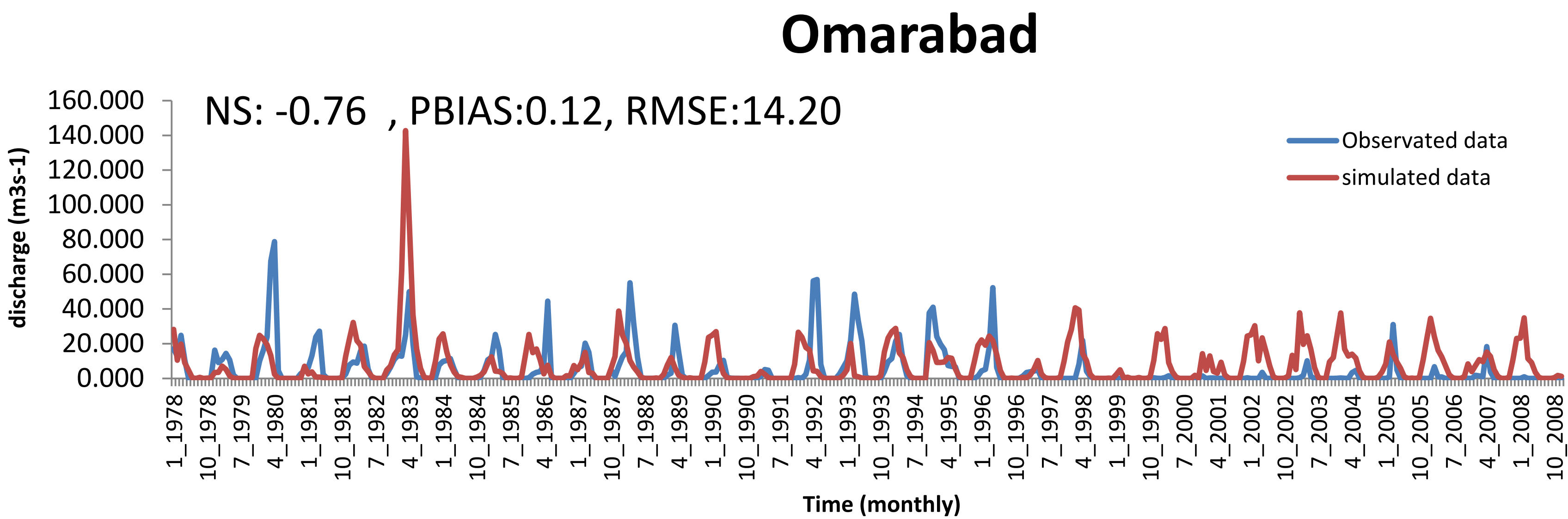
  - 28 Parameters was used for optimization

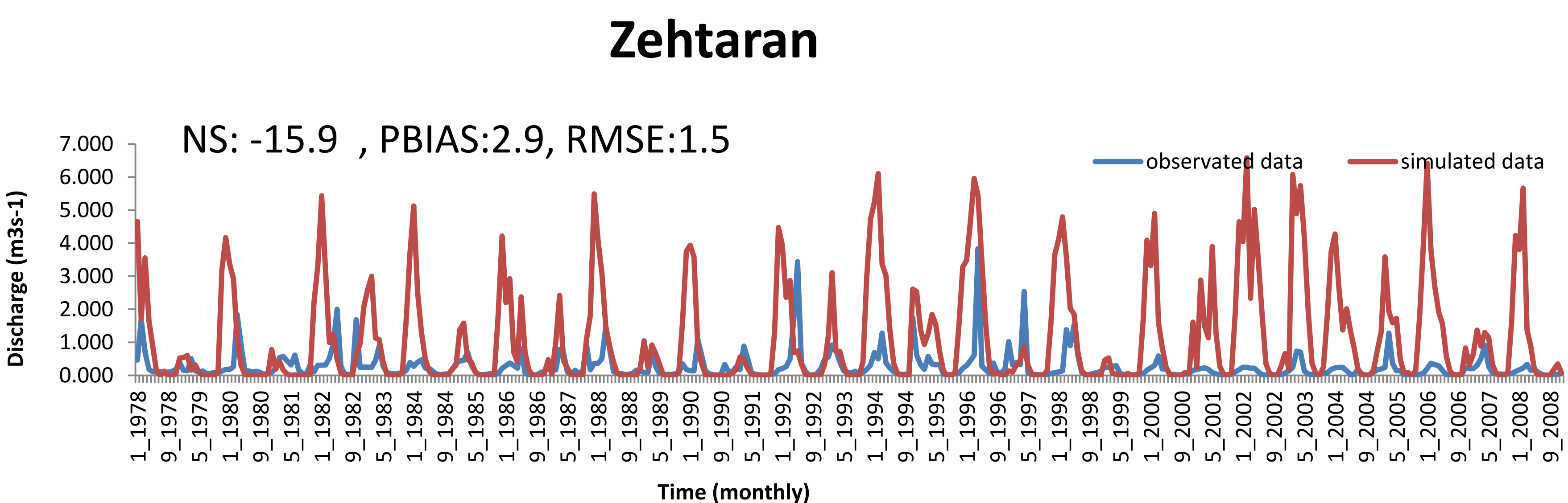
optimization

Parameter	Definition
CN2(.mgt)	SCS runoff curve number for moisture condition II
GW_DELAY(.gw)	Groundwater delay time (days)
ALPHA_BF(.gw)	Baseflow alpha factor (days)
REVAPMN(.gw)	Threshold water in shallow aquifer
GW_REVAP(.gw)	Revap coefficient
RCHRG_DP(.gw)	Aquifer percolation coefficient
GWQMN(.gw)	Threshold water level in shallow aq. for baseflow
SOL_AWC(.sol)	Available water capacity factor
SOL_K(.sol)	Saturated hydraulic conductivity
SOL_BD(.sol)	Soil bulk density
SOL_ALB(.sol)	Moist soil albedo
EPCO(.hru)	plant uptake compensation factor
SLSUBBSN(.hru)	Average slope length (m)
OV_N(.hru)	Manning's n value for overland flow
CH_N2(.rte)	Manning's n value for main channel
CH_K2(.rte)	Effective hydraulic conductivity in main channel alluvium
ALPHA_BNK(.rte)	Base flow alpha factor for bank storage (days)
SFTMP(.bsn)	Snowfall temperature
SMTMP(.bsn)	Snow melt base temperature (ºC)
SMFMX(.bsn)	Melt factor for snow on 21 Jun
SMFMN(.bsn)	Melt factor for snow on 21 Dec
TIMP(.bsn)	Snow pack temperature lag factor
SURLAG(.bsn)	Surface runoff lag coefficient
ESCO(.hru)	Soil evaporation compensation factor
HEAT_UNITS	heat unit
HI_TARG	harvest index
AUTO_WSTRS	Water stress
BIO_TARG	bio target

Results & Discussion

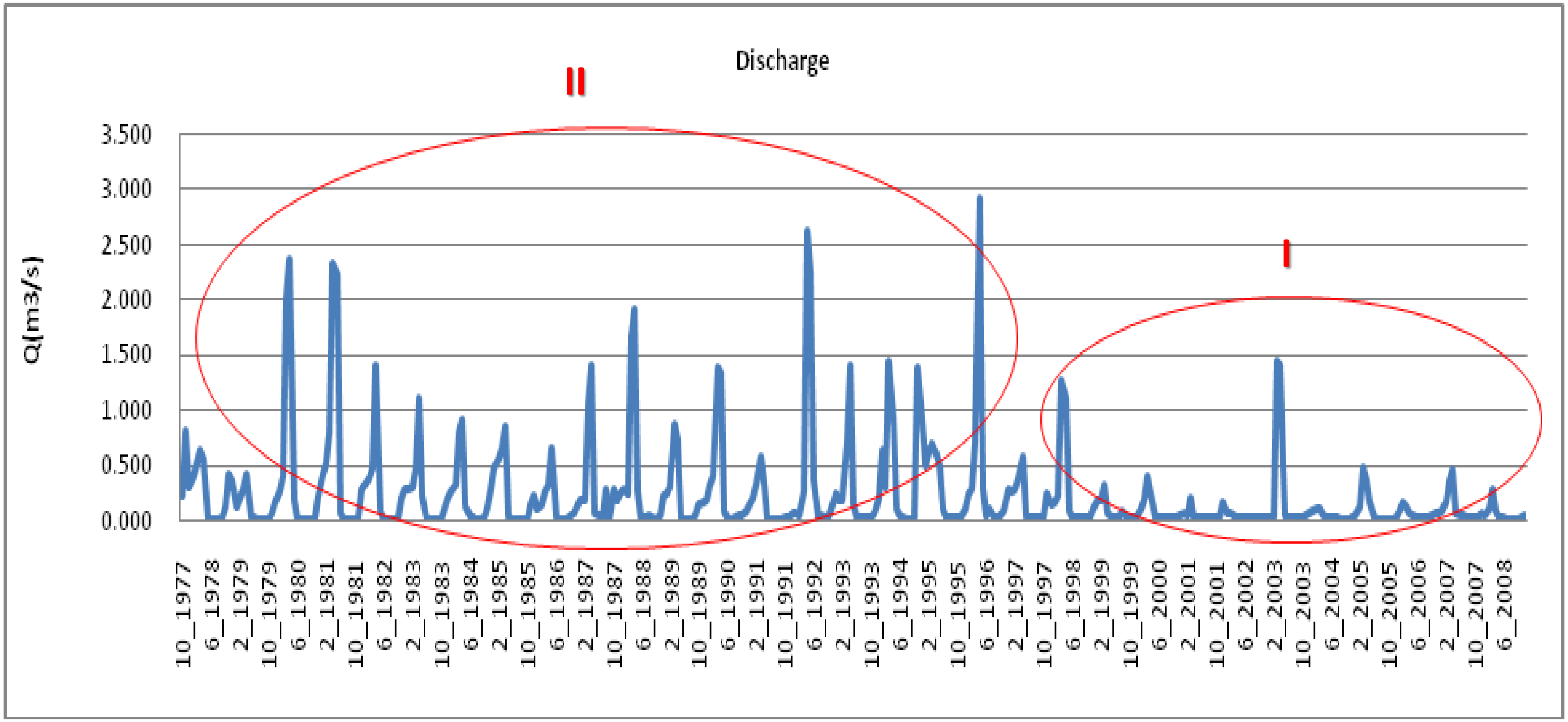
Results of SWAT output





Choose the duration for calibration and validation

- Sirab-khomigan discharge-shows different hydrological condition in I and II periods.



Sub basins affected to flow in each station

Stations	Sub basins	Area(km^2)
14 (Sirab khomigan)	1,2,3,4,5,6,12,13,14	255
41(Zehtaran)	23,26, 27,28,29,32, 33, 34, 37,38,41	420
71(Omarabad)	All subbasin	3100

Sensitivity analysis

- Global sensitivity
- One at a time method

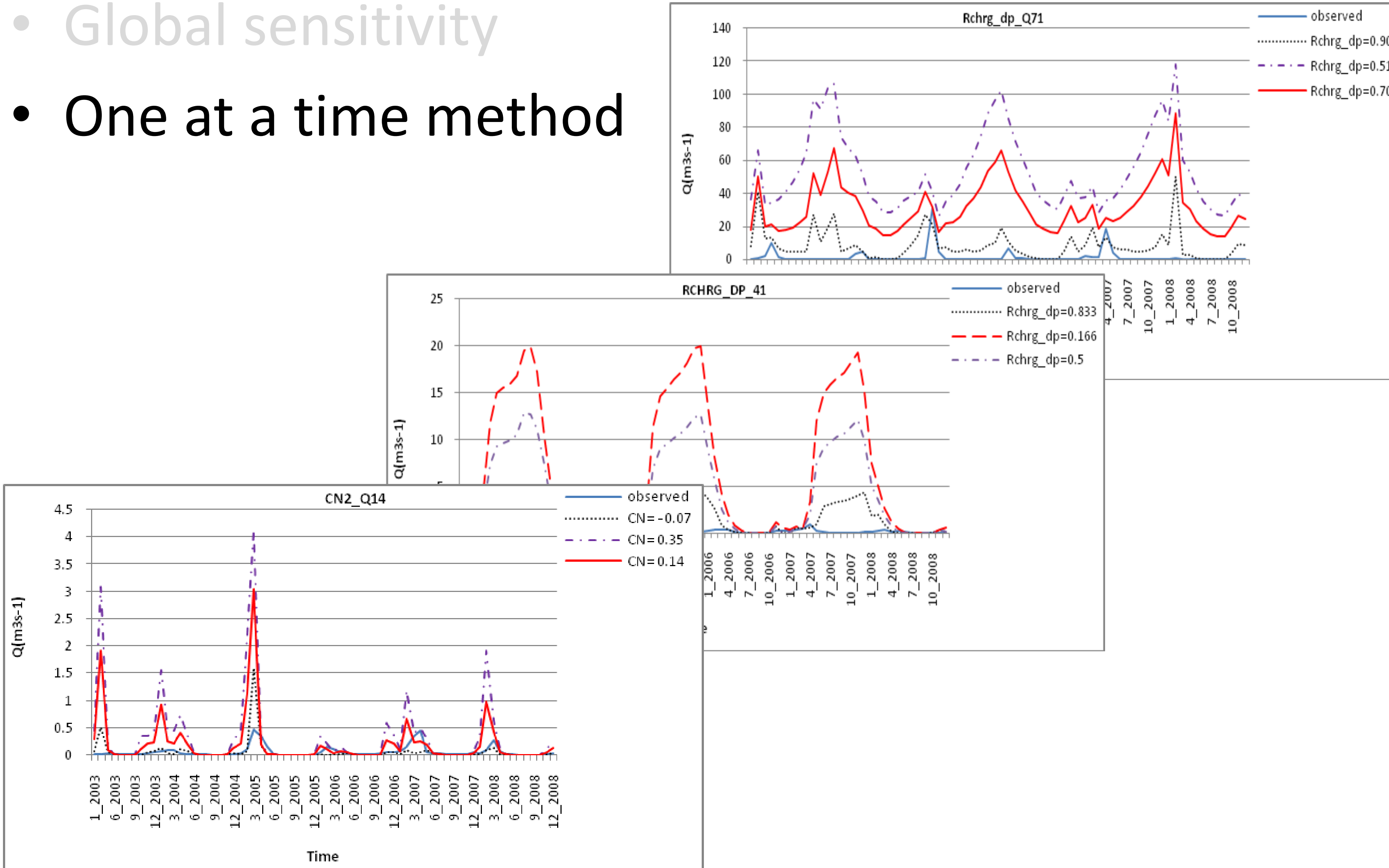
Sensitivity analysis

- Global sensitivity
- One at a time meth

Parameter Name	t-Stat	P-Value
r__CN2.mgt________23,26,27,28,29,32,33,34,37,38,41	-34.67	0.00
r__CN2.mgt________1,2,3,4,5,6,12,13,14	-15.06	0.00
v__SMFMN.bsn	-11.31	0.00
v__ALPHA_BNK.rte________1,2,3,4,5,6,12,13,14	-9.39	0.00
v__ALPHA_BNK.rte________23,26,27,28,29,32,33,34,37,38,41	-9.27	0.00
r__SOL_AWC().sol________23,26,27,28,29,32,33,34,37,38,41	7.33	0.00
v__SMFMX.bsn	-4.93	0.00
v__TIMP.bsn	-4.89	0.00
v__GWQMN.gw________23,26,27,28,29,32,33,34,37,38,41	2.02	0.04
V__GW_DELAY.gw________1,2,3,4,5,6,12,13,14	2.34	0.02
v__CH_K2.rte________23,26,27,28,29,32,33,34,37,38,41	2.47	0.01
r__SOL_AWC().sol________1,2,3,4,5,6,12,13,14	1.97	0.05
v__GW_REVAP.gw________23,26,27,28,29,32,33,34,37,38,41	1.78	0.07
V__GW_DELAY.gw________7-11,15-22,24,25,30,31,35,36,39,40,42-138	1.64	0.10

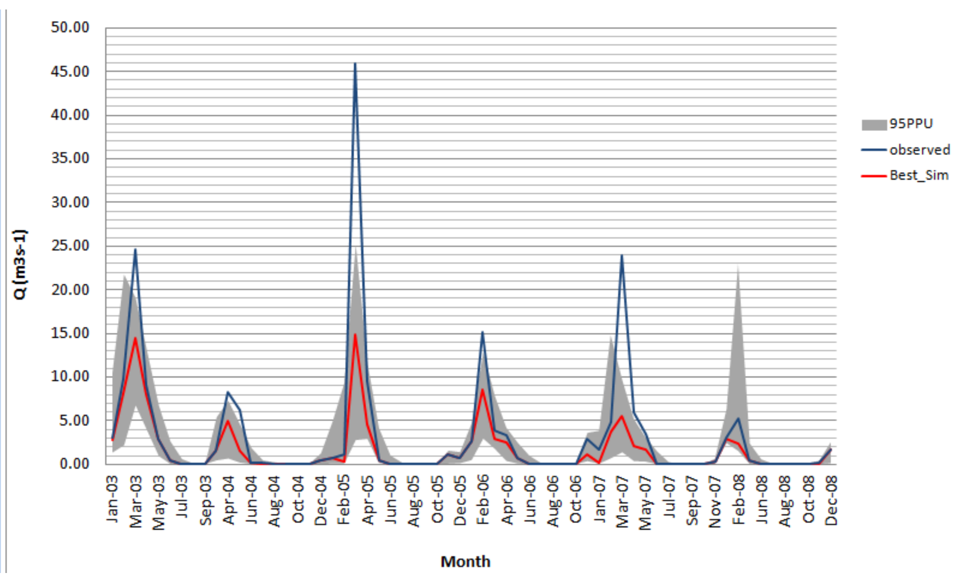
Sensitivity analysis

- Global sensitivity
- One at a time method



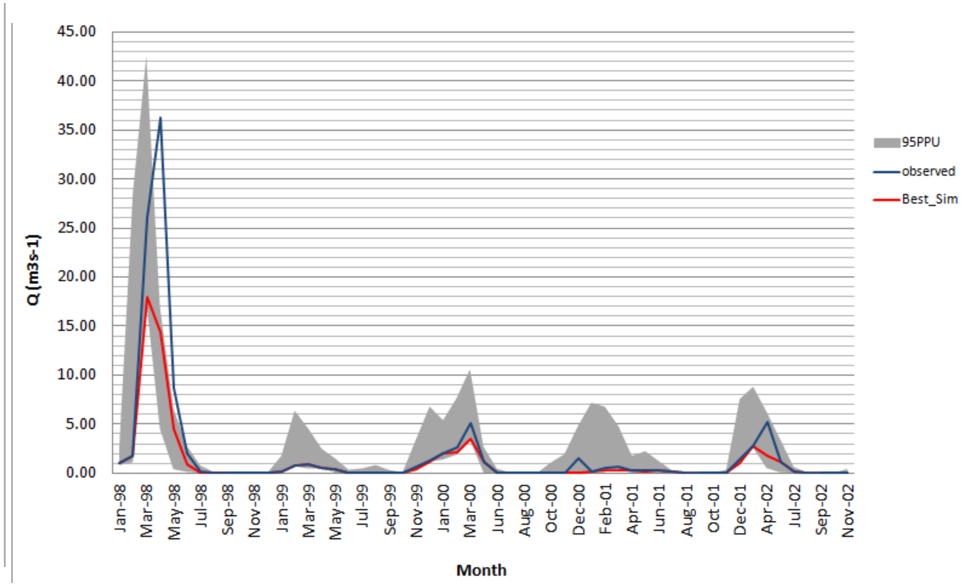
Calibration and validation of outlet No.71

calibration



- P-factor=0.38
- R-factor=0.78
- R2 = 0.57
- NS= 0.56

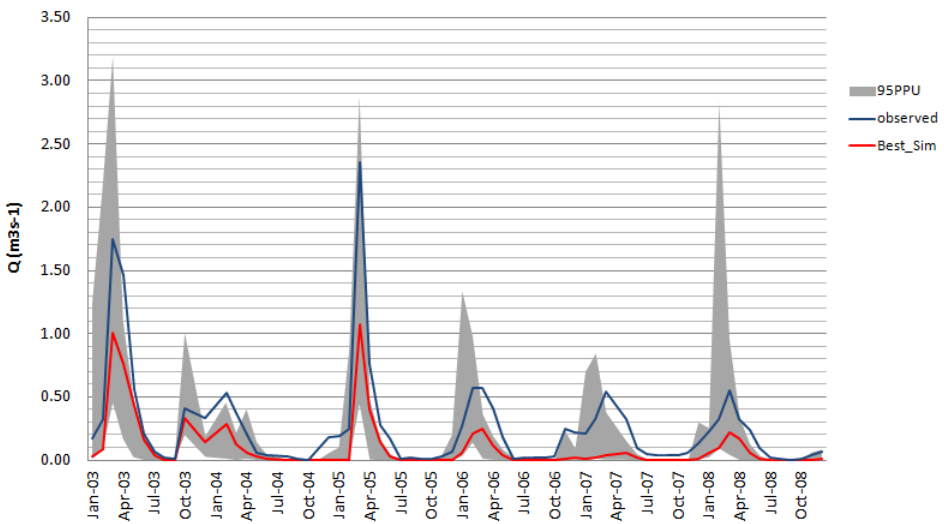
validation



- P-factor= 0.45
- R-factor= 1.02
- R2 = 0.69
- NS= 0.66

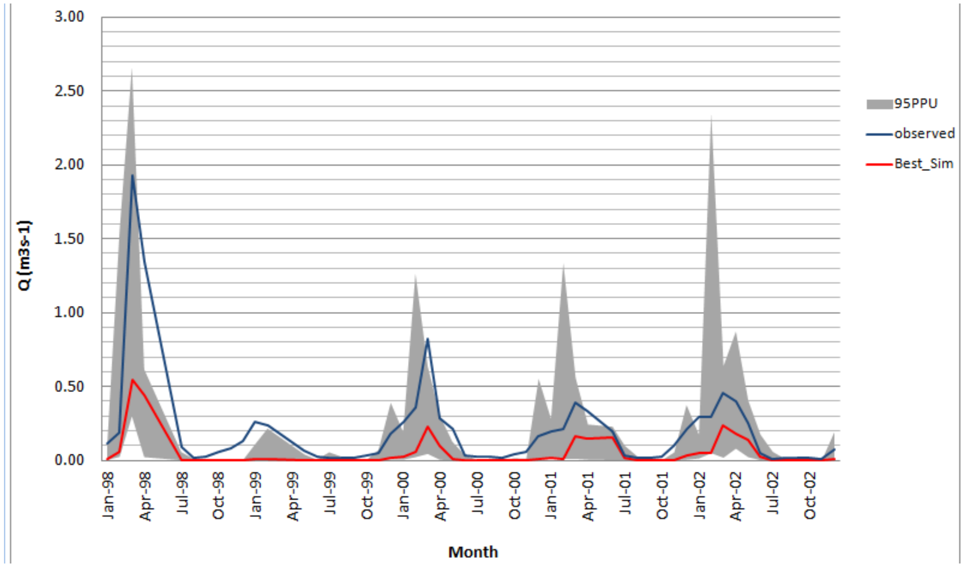
Calibration and validation of outlet No.41

calibration



- P-factor= 0.49
- R-factor= 1.76
- R2 = 0.71
- NS= 0.59

validation

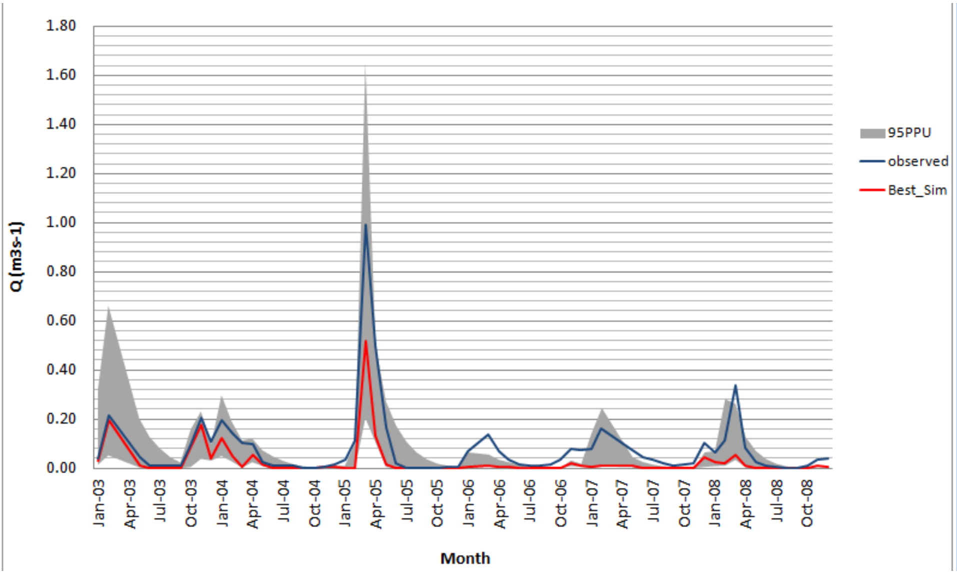


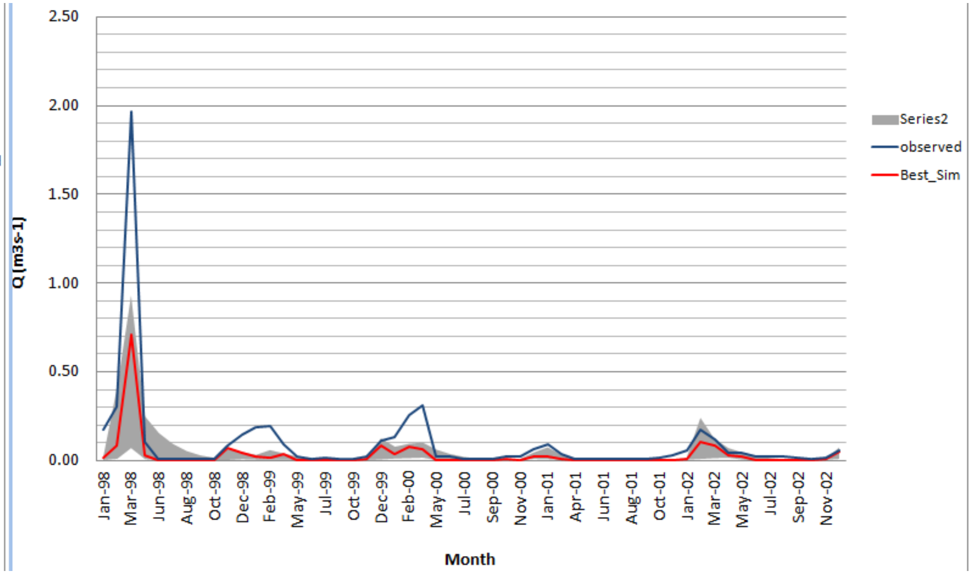
- P-factor= 0.51
- R-factor= 1.33
- R2 = 0.78
- NS= 0.42

Calibration and validation of outlet No.14

calibration

validation





Calibration:

- P-factor= 0.51
- R-factor= 1.26
- R2 = 0.48
- NS= 0.35

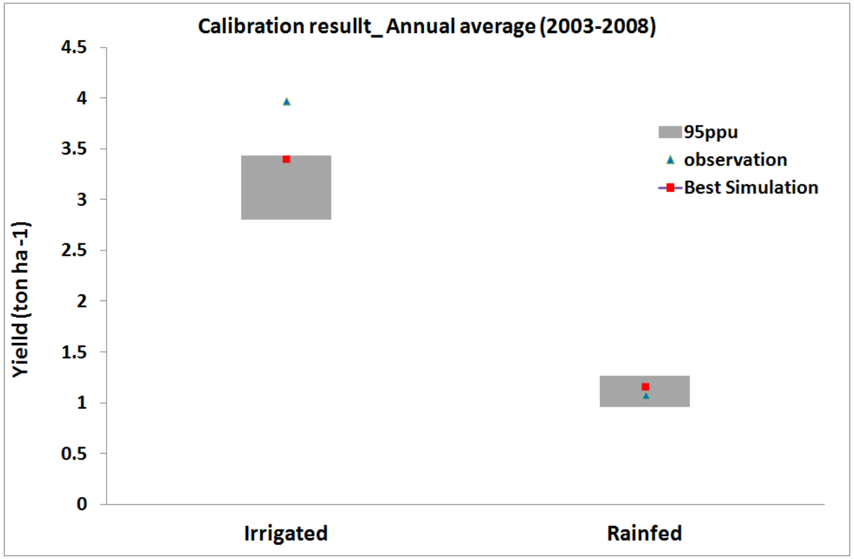
Validation:

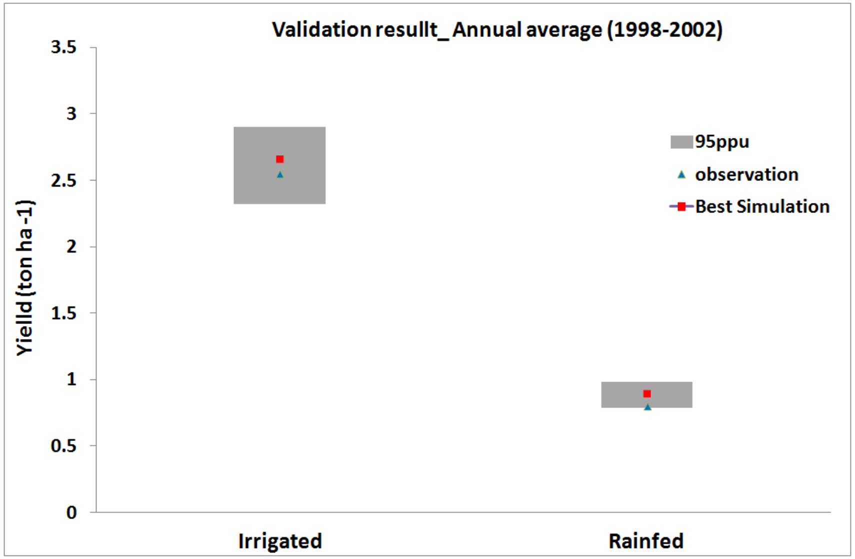
- P-factor= 0.44
- R-factor= 0.36
- R2 = 0.91
- NS= 0.72

CROP calibration

Calibration winter wheat

Validation winter wheat

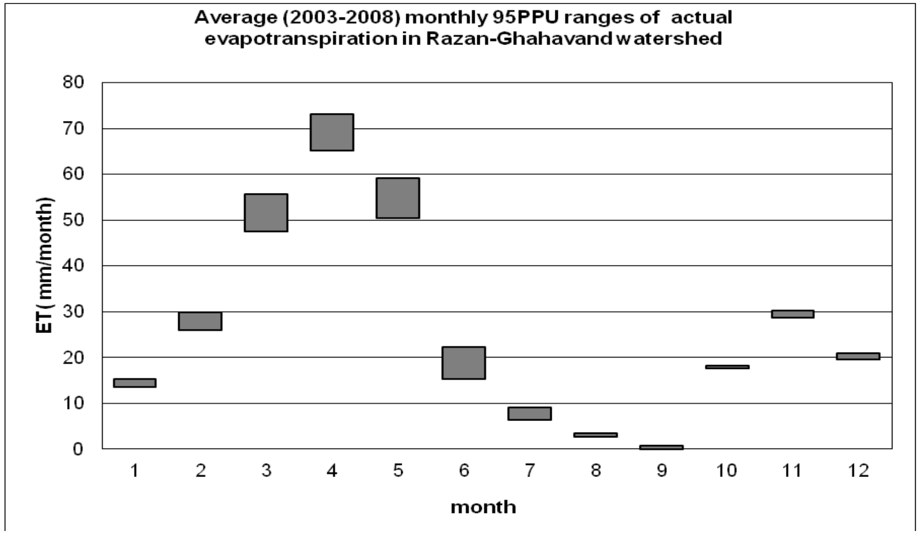


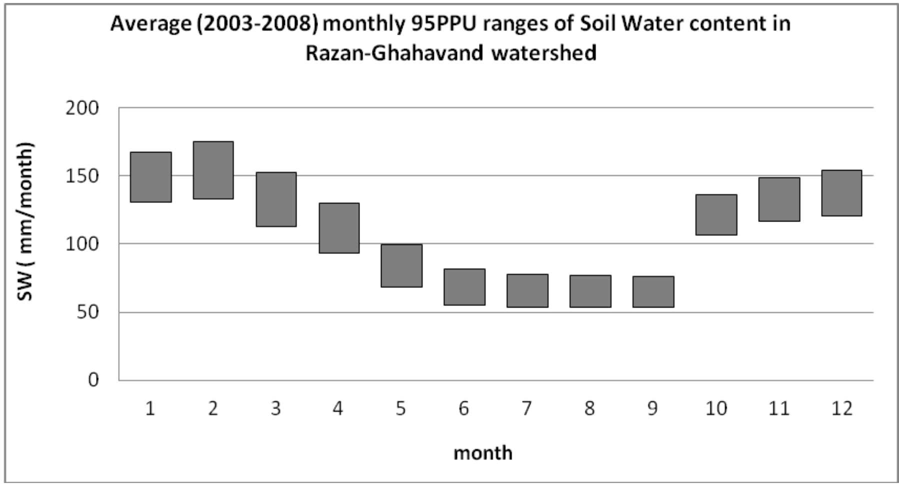


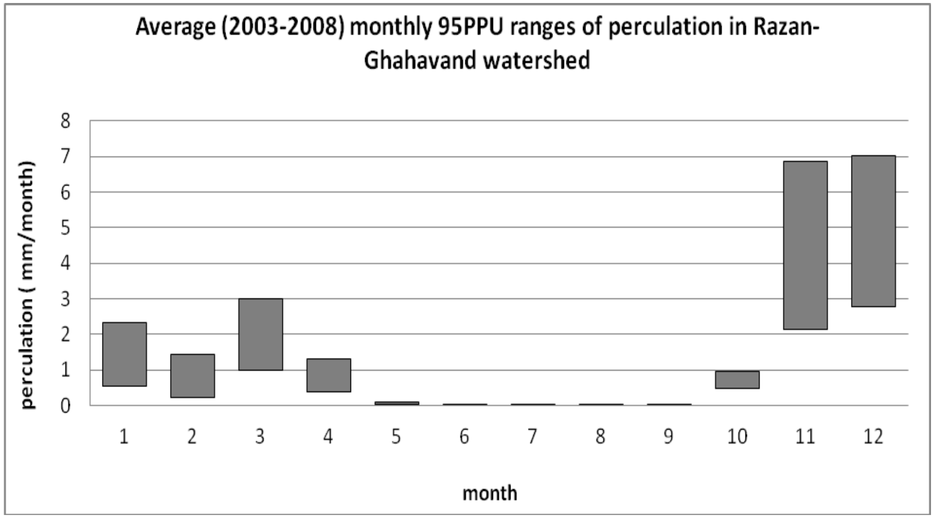
Irrigated: p-factor= 0.67 r-factor= 0.70 MSE = 1.08 t/ha	Rainfed: p-factor= 0.83 r-factor= 0.77 MSE = 0.07 t/ha

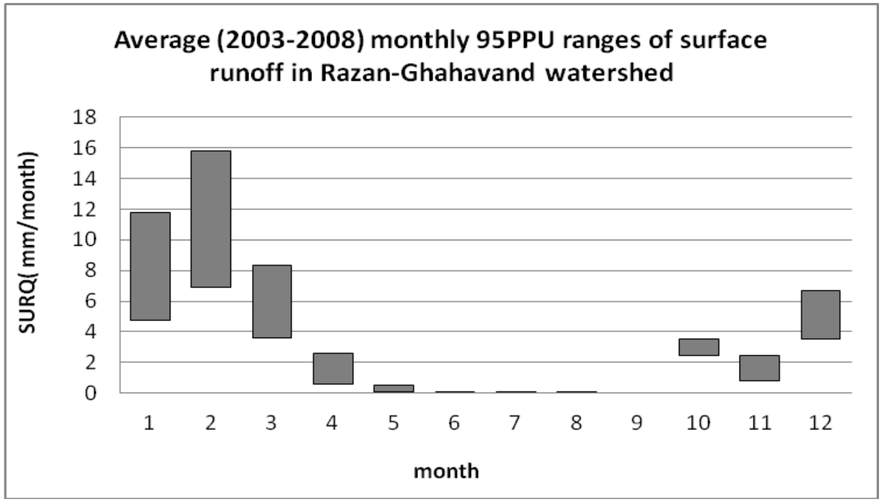
Irrigated: p-factor= 0.92 r-factor= 1.25 MSE = 0.19 t/ha	Rainfed: p-factor= 0.70 r-factor= 0.54 MSE = 0.25 t/ha

-Average (2003-2008) monthly 95PPU ranges of a: actual evapotranspiration b: soil water content c:perculation d:surface runoff



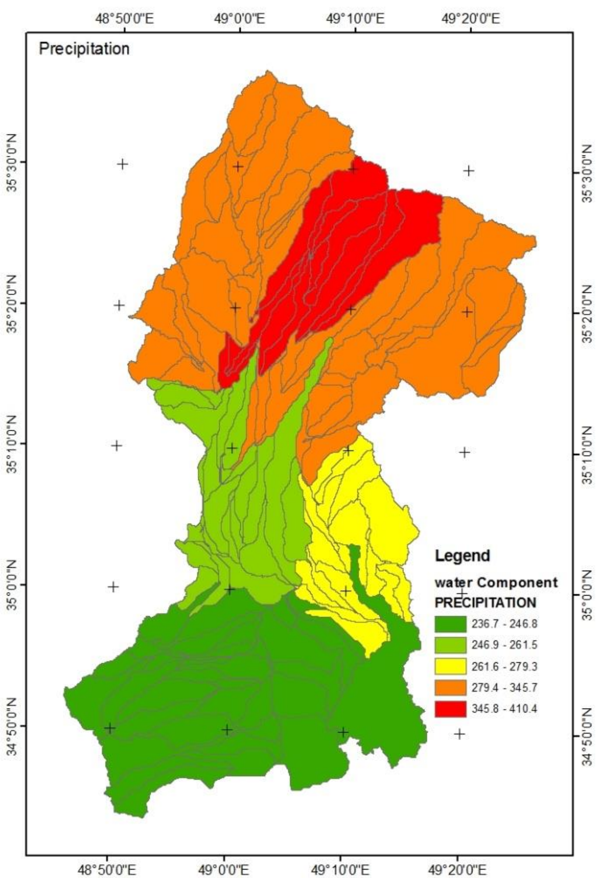






Water components spatial distribution

Precipitation



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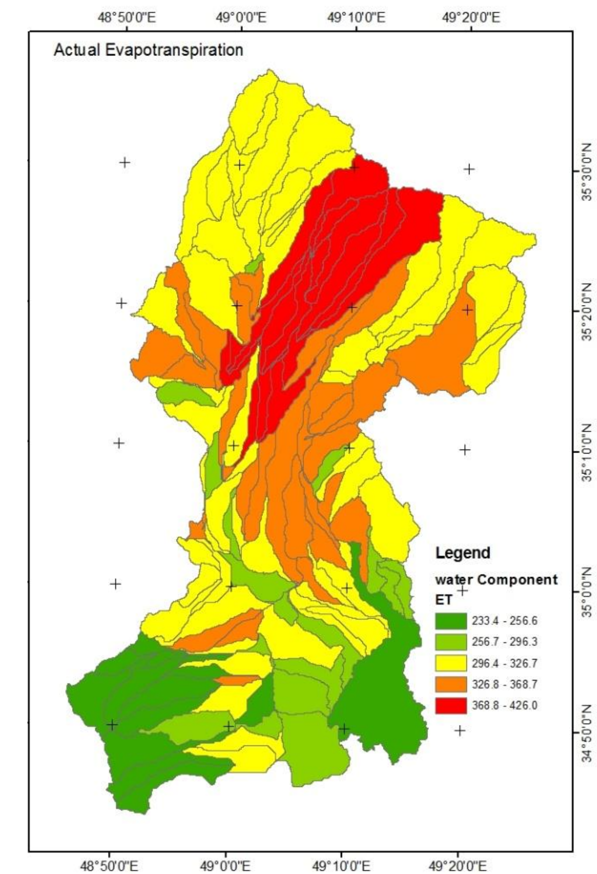
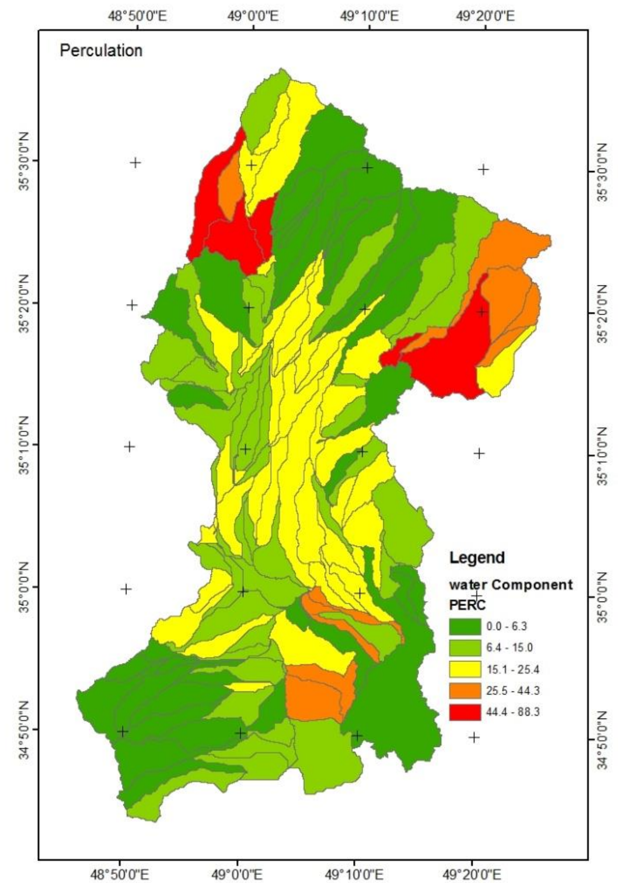
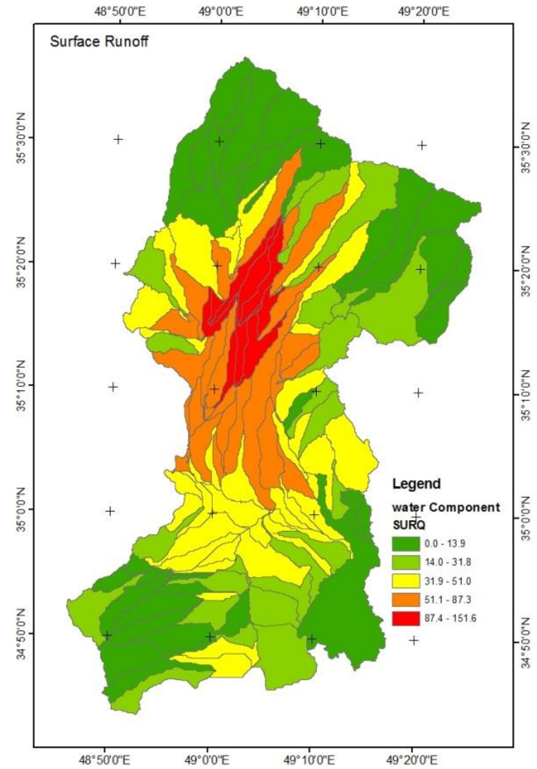


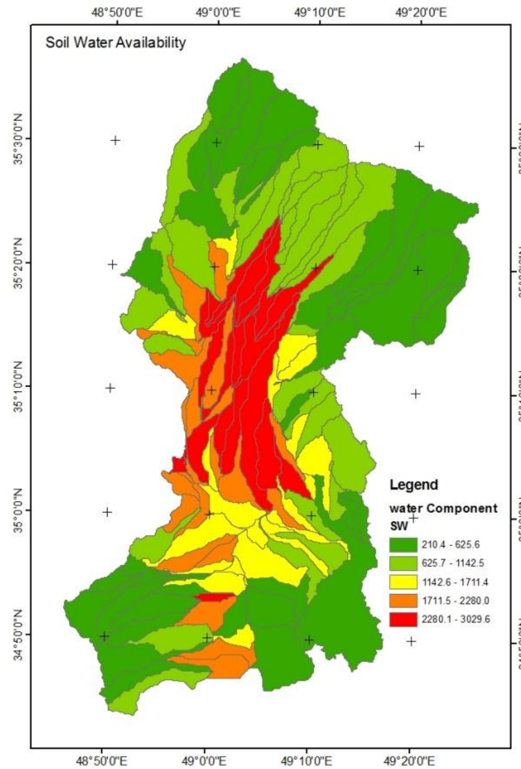
Percolation



Surface runoff



Soil water



Conclusion

- Low data availability , especially amount of water use , is one of the main problem to calibrate the model.
- In semi arid regions because of low river discharge, the calibration process is pretty difficult . hence, the crop calibration can increase the precision of model.