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
Razan-Ghavand watershed

- Watershed Area: 3100 Km²
- Max altitude 2842 m
- Min altitude: 1577 m

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

- Aquifer area: 1750 Km²
- Mean water level: 30 m
Study area: Razan-Ghavand

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

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Land use map

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

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Soil map

• Soil layers up to 5 layers

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• DEM
• Landuse
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• 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
No of rain gage stations: 21
No of Synoptic stations: 4
No. of hydrometric stations = 3

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

**Omarabad**

![Omarabad discharge graph with NS: -0.76, PBIAS:0.12, RMSE:14.20]

**Zehtaran**

![Zehtaran discharge graph with NS: -15.9, PBIAS:2.9, RMSE:1.5]
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

<table>
<thead>
<tr>
<th>Stations</th>
<th>Sub basins</th>
<th>Area (km$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 (Sirab khomigan)</td>
<td>1,2,3,4,5,6,12,13,14</td>
<td>255</td>
</tr>
<tr>
<td>41 (Zehtaran)</td>
<td>23,26, 27,28,29,32, 33, 34, 37,38,41</td>
<td>420</td>
</tr>
<tr>
<td>71 (Omarabad)</td>
<td>All subbasin</td>
<td>3100</td>
</tr>
</tbody>
</table>
Sensitivity analysis

• Global sensitivity
• One at a time method
Sensitivity analysis

- Global sensitivity
- One at a time method

<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>t-Stat</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>r__CN2.mgt________23,26,27,28,29,32,33,34,37,38,39,41</code></td>
<td>-34.67</td>
<td>0.00</td>
</tr>
<tr>
<td><code>r__CN2.mgt________1,2,3,4,5,6,12,13,14</code></td>
<td>-15.06</td>
<td>0.00</td>
</tr>
<tr>
<td><code>v__SMFMN.bsn</code></td>
<td>-11.31</td>
<td>0.00</td>
</tr>
<tr>
<td><code>v__ALPHA_BNK.rte________1,2,3,4,5,6,12,13,14</code></td>
<td>-9.39</td>
<td>0.00</td>
</tr>
<tr>
<td><code>v__ALPHA_BNK.rte________23,26,27,28,29,32,33,34,37,38,41</code></td>
<td>-9.27</td>
<td>0.00</td>
</tr>
<tr>
<td><code>r__SOL_AWC().sol________23,26,27,28,29,32,33,34,37,38,41</code></td>
<td>7.33</td>
<td>0.00</td>
</tr>
<tr>
<td><code>v__SMFMX.bsn</code></td>
<td>-4.93</td>
<td>0.00</td>
</tr>
<tr>
<td><code>v__TIMP.bsn</code></td>
<td>-4.89</td>
<td>0.00</td>
</tr>
<tr>
<td><code>v__GWQMNX.gw________23,26,27,28,29,32,33,34,37,38,41</code></td>
<td>2.02</td>
<td>0.04</td>
</tr>
<tr>
<td><code>V__GW_DELAY.gw________1,2,3,4,5,6,12,13,14</code></td>
<td>2.34</td>
<td>0.02</td>
</tr>
<tr>
<td><code>v__CH_K2.rte________23,26,27,28,29,32,33,34,37,38,41</code></td>
<td>2.47</td>
<td>0.01</td>
</tr>
<tr>
<td><code>r__SOL_AWC().sol________1,2,3,4,5,6,12,13,14</code></td>
<td>1.97</td>
<td>0.05</td>
</tr>
<tr>
<td><code>v__GW_REVPAP.gw________23,26,27,28,29,32,33,34,37,38,41</code></td>
<td>1.78</td>
<td>0.07</td>
</tr>
<tr>
<td><code>V__GW_DELAY.gw________7-11,15-22,24,25,30,31,35,36,39,40,42-138</code></td>
<td>1.64</td>
<td>0.10</td>
</tr>
</tbody>
</table>
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**
- P-factor = 0.51
- R-factor = 1.26
- \( R^2 = 0.48 \)
- NS = 0.35

**Validation**
- P-factor = 0.44
- R-factor = 0.36
- \( R^2 = 0.91 \)
- NS = 0.72
CROP calibration

Calibration winter wheat

Irrigated:
\[ p\text{-factor}= 0.67 \]
\[ r\text{-factor}= 0.70 \]
\[ \text{MSE} = 1.08 \text{ t/ha} \]

Rainfed:
\[ p\text{-factor}= 0.83 \]
\[ r\text{-factor}= 0.77 \]
\[ \text{MSE} = 0.07 \text{ t/ha} \]

Validation winter wheat

Irrigated:
\[ p\text{-factor}= 0.92 \]
\[ r\text{-factor}= 1.25 \]
\[ \text{MSE} = 0.19 \text{ t/ha} \]

Rainfed:
\[ p\text{-factor}= 0.70 \]
\[ r\text{-factor}= 0.54 \]
\[ \text{MSE} = 0.25 \text{ t/ha} \]
- Average (2003-2008) monthly 95PPU ranges of:
  a: actual evapotranspiration
  b: soil water content
  c: percolation
  d: surface runoff
Water components spatial distribution

**Precipitation**

**ET**

**Percolation**
Surface runoff

Soil water
Conclusion

• Low data availability, especially amount of water use, is one of the main problems 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 the model.