Simulación hidrológica realista utilizando el modelo SWAT en una cuenca andina del Perú

Realistic hydrological simulation using SWAT model in an Andean basin of Peru (submitted to Journal of Hydrology)

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7th HYBAM scientific meeting
Soil and Water Assessment Tool (SWAT)

Inputs
- Weather
- Soil
- Land use
- DEM

Outputs
- Water
- Sediments
- Nutrients

Inputs
- Subbasin
- HRU

Defined by unique combination of:
- Soil
- Crop
- Slope

Evapotranspiration
- Infiltration/plant uptake/soil moisture redistribution

Precipitation
- Surface (Qsurf) runoff

Root Zone
- Revap. From Shallow Aquifer

Vadose Zone
- Percolation to shallow aquifer

Shallow Aquifer
- Return flow (Qgws) from shallow aquifer

Deep Aquifer
- Recharge to deep aquifer

Confining Layer

BF = BF/WYLD

Fig. hydrological processes that are simulated by SWAT
Limitations of automatic calibration

- Automatic calibration techniques do not necessarily guarantee that the model can characterize with physical sense the hydrological processes due to the equifinality presence in SWAT parameters (Shen et al. 2012; Ficklin and Barnhart 2014).

- No automatic calibration algorithm can replace the analyst's knowledge regarding hydrological basins and calibration problems (Abbaspour et al. 2015).
Objective

The aim of this study is to demonstrate objectively how to calibrate the SWAT model so that it is capable of characterizing the hydrological processes in study case for Vilcanota river basin

Emphasizing:
The **objective identification of the most sensitive parameters** and analysis of the influence of these parameters on the quantification of relevant hydrological processes (surface runoff, lateral flow from the soil profile and return flow from the shallow and deep aquifer).
Study area

Surface: 9613 km²

Altitudes ranging from 2124 to 6309

Precipitation: 800 mm/year (>80 %; October – March)

Daily discharges: 30 m³/s (dry season) to 1100 m³/s (rainy season)

Average daily discharge: 133 m³/s

Figure: Location of the study area and hydrometeorological stations network
## Data

Table: Data type, resolution and data source

<table>
<thead>
<tr>
<th>Type of data</th>
<th>Resolution</th>
<th>Source</th>
<th>Link</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrometeorological data</td>
<td>Daily</td>
<td>SENAMHI and EGEMSA</td>
<td><a href="http://www.senamhi.gob.pe/">http://www.senamhi.gob.pe/</a></td>
</tr>
<tr>
<td>DEM</td>
<td>90 m</td>
<td>CGIAR-CSI</td>
<td><a href="http://srtm.csi.cgiar.org/">http://srtm.csi.cgiar.org/</a></td>
</tr>
</tbody>
</table>
Methodology

Multi-objective sensitivity analysis. Where is analyzed the parameter influence on:

- Model performance
- SWAT_BFI

Similar to observed BFI (0.77) in the neighboring Andean Kosñypata basin (Clark et al. 2014)
Initial simulation of the model

NSE: 0.26
PBIAS %: -17.1

CN2: Curve number
SOL_BD: wet bulk density
SOL_AWC: available water capacity
GWQMN: water depth threshold needed in shallow aquifer for that return flow occurs.
RCHRG_DP: recharge fraction into the deep aquifer.
SWAT parameters sensitivity analysis

- **Initial values**
  - BFI

- **CN2**
- **SOL_BD**
- **SOL_AWC**

- **a) Qsurf [mm]**
- **b) Qlat [mm]**
- **c) Qgw [mm]**
- **d) SWAT_BFI**
- **e) NSE**
- **f) PBIAS [%]**

- **CN2**: Curve number
- **SOL_BD**: wet bulk density
- **SOL_AWC**: available water capacity

- **Equifinality of CN2 parameter**
  - CN2 calibration is no necessary since ↑SOL_BD improves SWAT_BFI, NSE, PBIAS
  - SOL_AWC ↓ improves PBIAS

- **BFI ref. 0.78**
SWAT parameters sensitivity analysis

- ↓SURLAG improves NSE
- ↓GWQMN improves PBIAS

<table>
<thead>
<tr>
<th>Order</th>
<th>Parameter</th>
<th>Range</th>
<th>Adjusted value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SURLAG$^v$</td>
<td>[0.2, 0.5]</td>
<td>0.20</td>
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<tr>
<td>2</td>
<td>SOL_BD$^r$</td>
<td>[0.2, 0.5]</td>
<td>0.34</td>
</tr>
<tr>
<td>3</td>
<td>SOL_AWC$^r$</td>
<td>[-0.5, -0.2]</td>
<td>-0.33</td>
</tr>
<tr>
<td>4</td>
<td>GWQMN$^v$</td>
<td>[600, 700]</td>
<td>681.30</td>
</tr>
<tr>
<td>5</td>
<td>RCHRG_DP$^v$</td>
<td>[0.3, 0.5]</td>
<td>0.36</td>
</tr>
</tbody>
</table>

"$^v$": replaced
"$^r$": relative change
observed versus simulated hydrograph

Daily simulation

NSE: 0.73, PBIAS %: 0.8
P-factor: 0.57, R-factor: 0.33

NSE: 0.79, PBIAS %: -2.2
P-factor: 0.63, R-factor: 0.34

Monthly simulation

NSE: 0.95, PBIAS %: 0.8
P-factor: 0.74, R-factor: 0.3

NSE: 0.95, PBIAS %: -2.4
P-factor: 0.8, R-factor: 0.29

Precipitation [mm]
Average annual water balance of VRB

Green water:
419mm (51% of Pp)

Pp: 814mm

Qsurf: 82mm
(21% of WYLD)

Qgws: 97mm

Qgwd: 54mm

BF: 313mm
(79% of WYLD)

Finding:
SWAT is capable characterizing the baseflow and surface runoff contribution since:

BFI_SWAT ≈ BFI_REF
0.79
0.78
Water potential (Qsurf + Qbf)
Conclusions

Based on multi-objective parameter sensitivity analysis, in general SWAT was able to reproduce both daily and monthly observed discharges with a low degree of uncertainty given by the statistics (R-factor < 0.35 for P-factor > 0.5) and very good performances (according to Nash-Sutcliffe NSE > 0.75 and percentage of bias PBIAS < 10%) both in calibration and validation stage.

It was verified that SWAT was capable to characterize very well the surface runoff and baseflow contribution in VRB.