Hydrological Modelling with SWAT

Qianwen He, Nov. 2020
Course structure

Lecture 1
• Hydrological modelling and the SWAT model

Lecture 2
• Model performance evaluation and calibration

Assignment
• A model set-up and analysis for a study catchment
• Evaluation: Poster 70% + Presentation 30%
• Timeline
  Before 18th Dec to submit a protocol
  In January to submit poster and to present
Aim of the course

• Understand the concept of hydrological modelling and the SWAT model

• Understand the calibration and the statistical evaluation of the model performance

• Apply the SWAT by setting-up a model for a study catchment, evaluate the model’s reliability and perform scenario analysis.
1. Hydrological modelling
2. SWAT model - The theory
3. SWAT model application - A case study
4. Overview of input data and data sources
5. Set-up a SWAT model demonstration
6. QSWAT installation
Part 1 – Hydrological modelling

- Hydrological process
- Hydrological modelling
- GIS with hydrological modelling
Part 1
The hydrological cycle

- Where does the water on the earth come from?
- How is the water moving around?
- How is the water back to the atmosphere?
What moves together with the water?
Part 1

Watershed – the spatial unit of hydrology

Definition

• An area of land in which all of the incoming precipitation drains to the same place as a result of its topography.
  
  o All water falling on the surface flows downhill.
  o Wherever rainfalls, it will end up in the same place

• Basin/Catchment

(https://www.conservationsolutioncenter.org/solution-center/watersheds/our-watershed-program)
**Part 1**

**Watershed – Water balance equation**

\[ P - Q - E = \Delta S \]

- The flux transferring or storing in the hydrological cycle
  - Flux: a rate of flow of some quantity

<table>
<thead>
<tr>
<th>P</th>
<th>Q</th>
<th>E</th>
<th>∆S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>Runoff</td>
<td>Evapotranspiration</td>
<td>Storage change</td>
</tr>
<tr>
<td>Rainfall</td>
<td>Surface runoff</td>
<td>Plants</td>
<td>Soil moisture</td>
</tr>
<tr>
<td>Snowfall</td>
<td>Lateral flow</td>
<td>Open waterbody</td>
<td>Plant interception</td>
</tr>
<tr>
<td>Hail,...</td>
<td>Groundwater flow</td>
<td>Soil surface</td>
<td>Groundwater</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Waterbody</td>
<td></td>
</tr>
</tbody>
</table>

**Unit:** e.g. mm/day  
**Time span:** subdaily, daily, monthly, annually
Part 1
Content

• Hydrological modelling
  o Model components
  o Model category
Hydrological modelling

(Defined by Singh and Chow, 1988)

To use symbolic expression in logical terms of an idealised, relatively simple situation sharing the structural properties of the original system.

Equations to describe the system

- An approximation of the actual complex system

Aim:

- A better understanding of the hydrologic phenomena operating in a catchment and of how changes in the catchment may affect these phenomena.
- The generation of hydrological data for facility design or for use in forecasting
Hydrological modelling – Model components

Part 1

Hydrological system

Input variable

Precipitation $I(t)$

System boundary

Watershed surface

Output variable

Streamflow $Q(t)$

(chow et al, 1988)
Part 1

Hydrological modelling – Model components

- **A variable**
  A characteristic of a system which maybe measured, and might vary with time

- **A hydrological system**
  A set of physical, chemical, and/or biological processes acting upon input variables, to convert them into an output variable (Dooge, 1973)

- **A parameter**
  A quantity to characterise the system

(chow et al, 1988)
Part 1
Hydrological modelling – Model components

- measured or simulated, but independ from the hydrologic system
- Simulated and relied on the input and the hydrological system

(chow et al, 1988)

- How can the model to describe it properly?
Part 1
Hydrological modelling – Model category

By assumptions:

Theoretical

- A logical structure similar to the real-world system
- Mass, energy, momentum conservation
- e.g. diffusive wave equation for overland flow

Empirical

- Mathematical description between two or more parameters
- No need to have physical significance
- e.g. SCS curve number assumption
  \[ I_a \approx 0.2S \]

Represent different levels of approximation of reality.

- Objective; complexity of the problem; degree of accuracy required
Part 1

Hydrological modelling – Model category

By spatial delineation:

Lumped

Semi-distributed

Distributed

Homogeneous spatially

Homogeneous partially

Homogeneous in the grid
Part 1
Hydrological modelling – Model category

By scale:

Spatial scale

Micro | Meso | Macro

Local | Hill slope | Small catchment | Large catchment | Continental

Time scale

Short term | Medium term | Long term

Event | seasonal

(Adapted from: Bronster, A.; Coupled models for the hydrological cycle, 2005)
Part 1

Content

- ArcGIS with hydrological model
  - Geo-data processing
    DEM, landuse, spatial distribution of climate data
  - QGIS/ArcGIS as a Geographical user interface (GUI)
    GUI: It allows the use of icons or other visual indicators to interact with electronic devices, rather than using only text via the command line.
Part 1
ArcGIS with hydrological model

- DEM analysis – Hydrology
  - Slope
  - Flow direction
  - Watershed Delineation
Part 1
ArcGIS with hydrological model

- Land use

- Soil type
Part 2 – Approaches used by SWAT

- SWAT introduction
- Approaches to simulate the hydrological processes
- SWAT application: a case study
Part 2

SWAT model introduction

SWAT – Soil and Water Assessment Tool, is a river basin, or watershed scale model developed by Dr. Jeff Arnold for the USDA Agricultural Research Service.

SWAT was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time.

8 components: climate, hydrology, nutrients/pesticides, erosion, land use/plant, management practices, channel processes, water bodies.
Part 2

SWAT model features

- **Physically based**
  - specific information about the catchment
  - Suitable for large catchments/basins, even continents

- **Semi-distributed**
  - HRU: hydrologic response unit (overlay of specific landuse, soil and slope)
  - Not lumped, not fully-distributed
  - Computationally efficient

- **Long term impacts**
  - Long-term effect (10~30 years)
  - Temporal scale: daily/monthly/annually
  - Not suitable for single event storm simulation

- **Readily available datasets**
Part 2
Hydrology component

- Water balance
- Surface runoff
- Infiltration
- Evapotranspiration
- Soil water
- Groundwater
- Channel process

Soil and water assessment tool theoretical report, 2009
Part 2

Water balance

\[ SW_t = SW_0 + \sum_{i=1}^{t} (R_{\text{day}} - Q_{\text{surf}} - E_a - w_{\text{seep}} - Q_{gw}) \]

- \( SW_t \) – final soil water content
- \( SW_0 \) – initial soil water content
- \( R_{\text{day}} \) – precipitation
- \( Q_{\text{surf}} \) – surface runoff
- \( E_a \) – evapotranspiration
- \( w_{\text{seep}} \) – the amount of percolation flow exiting the soil profile bottom
- \( Q_{gw} \) – groundwater flow enters the channel (return flow)
- Unit – mm H₂O
- \( t \) – is the time span to apply the equation
Part 2
Surface runoff

Method: SCS curve number

\[
Q_{surf} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)}
\]

\[
S = 25.4\left(\frac{1000}{CN} - 10\right)
\]

\[
I_a \approx 0.2S
\]

- \(I_a\) is the initial abstraction and \(S\) is the potential storage
- CN is the curve number (CN\(^\uparrow\) potential of runoff\(^\uparrow\)), a function of the soil’s permeability, landuse and antecedent soil water condition.
- Empirical equation, CN is subjective
Part 2

Hydrological analysis – Rainfall and runoff

\[
\begin{aligned}
I_a & \approx 0.2 \, S \\
S & = \frac{25400}{CN} - 254
\end{aligned}
\]

\[Q_{surf} = \frac{(P - 0.2S)^2}{(P + 0.8S)}\]

\(CN\) is the curve number \((0 \sim 100)\)

- Soil infiltration rate
  (soil hydrologic groups: A, B, C, D; by U.S. NRCS)
- Land use
- Antecedent soil moisture condition
  (dry, average moisture, wet)
- Slope

(Tim Davie, Fundamentals of Hydrology, 2002)
<table>
<thead>
<tr>
<th>Cover type and hydrologic condition</th>
<th>Average percent impervious area</th>
<th>Curve numbers for hydrologic soil group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td><strong>Fully developed urban areas (vegetation established)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open space (lawns, parks, golf courses, cemeteries, etc.)$^{3/2}$:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor condition (grass cover &lt; 50%)</td>
<td>68</td>
<td>79</td>
</tr>
<tr>
<td>Fair condition (grass cover 50% to 75%)</td>
<td>49</td>
<td>69</td>
</tr>
<tr>
<td>Good condition (grass cover &gt; 75%)</td>
<td>39</td>
<td>61</td>
</tr>
<tr>
<td>Impervious areas:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>98</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>Streets and roads:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Paved parking lots, roofs, driveways, etc. (excluding right-of-way)</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>Paved; curbs and storm sewers (excluding right-of-way)</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>Paved; open ditches (including right-of-way)</td>
<td>83</td>
<td>89</td>
</tr>
<tr>
<td>Gravel (including right-of-way)</td>
<td>76</td>
<td>85</td>
</tr>
<tr>
<td>Dirt (including right-of-way)</td>
<td>72</td>
<td>82</td>
</tr>
<tr>
<td>Western desert urban areas:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural desert landscaping (permeable areas only)</td>
<td>63</td>
<td>77</td>
</tr>
<tr>
<td>Artificial desert landscaping (impervious weed barrier, desert shrub with 1- to 2-inch sand or gravel mulch and basin borders)</td>
<td>96</td>
<td>96</td>
</tr>
<tr>
<td><strong>Urban districts:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial and business</td>
<td>85</td>
<td>89</td>
</tr>
<tr>
<td>Industrial</td>
<td>72</td>
<td>81</td>
</tr>
<tr>
<td>Residential districts by average lot size:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1/8 acre or less (town houses)</td>
<td>65</td>
<td>77</td>
</tr>
<tr>
<td>1/4 acre</td>
<td>38</td>
<td>61</td>
</tr>
<tr>
<td>1/3 acre</td>
<td>30</td>
<td>57</td>
</tr>
<tr>
<td>1/2 acre</td>
<td>25</td>
<td>54</td>
</tr>
<tr>
<td>1 acre</td>
<td>20</td>
<td>51</td>
</tr>
<tr>
<td>2 acres</td>
<td>12</td>
<td>46</td>
</tr>
<tr>
<td><strong>Developing urban areas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newly graded areas (permeable areas only, no vegetation)</td>
<td>77</td>
<td>86</td>
</tr>
<tr>
<td>Idle lands (CN’s are determined using cover types similar to those in table 2-2c).</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Part 2
Evapotranspiration

- **Potential Evapotranspiration:**
  - Penmen-Monteith
  - Hargreaves equation

- **Actual Evapotranspiration:**

- **Evaporation**
  - Canopy interception
  - Soil (depth, biomass, residue)

- **Transpiration**
  - Leaf Area Index (LAI)
  - Potential E

---

Penmann-Monteith equation:

\[
PET = \frac{0.408\Delta (R_n - G) + \gamma \frac{900}{T + 273} u_2 \delta_e}{\Delta + \gamma (1 + 0.34u_2)}
\]

- \(PET\) – potential evapotranspiration
- \(R_n\) – net radiation at the crop surface
- \(G\) – soil heat flux density
- \(\gamma\) – psychometric constant
- \(u_2\) – wind speed at 2m height
- \(\delta_e\) – saturation vapour pressure deficit
- \(T\) – mean daily air temperature at 2m height

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Solar radiation
Relative humidity
Canopy storage

Infiltration rate

- Green & Ampt infiltration method
- Assumptions
  - Soil profile homogenous
  - Antecedent moisture is uniformly distributed in the profile
  - Soil above the wetting front is completely saturated
  - There is a sharp break in moisture content at the wetting front

\[
f_{\text{inf,t}} = K_e \cdot \left(1 + \frac{\Psi_{\text{wf}} \cdot \Delta \theta_v}{F_{\text{inf,t}}}\right)
\]

Soil properties:
- Saturated hydraulic conductivity
- Bulk density
- Porosity
- Clay and sand content

Figure 2:1-2: Comparison of moisture content distribution modeled by Green & Ampt and a typical observed distribution.

https://soilmoisture.wordpress.com/2016/08/16/soil-water-status-saturation-field-capacity-and-wilting-point/
Part 2
Soil water

- Majority of the soil water is uptaken by plants
- Saturation, field capacity (FC), wilting point (WP), plant available water capacity (AWC)

\[ FC = WP + AWC; \]

- \( WP \) – proportional to bulk density and clay content
- \( AWC \) – crop individual parameter

Percolation assumptions: when the water content > FC, percolation starts

**Storage routing methodology**

- \( W_{perc,ly} = SW_{ly,excess} \left( 1 - \exp \left(-\frac{\Delta t}{TT_{perc}}\right) \right) \)
- \( TT_{perc} = \frac{SAT - FC}{K_{sat}} \)
Part 2
Groundwater

- **Water balance**
  \[ aq_{sh,i} = aq_{sh,i-1} + w_{rchr,g,sh} - Q_{gw} - w_{revap} - w_{pump,sh} \]

- **Recharge:** \( w_{rchr,g,sh} \)
  - Function of water existing at the bottom of the soil profile and drainage time
  - Partition between shallow and deep aquifer

---

Table 2:4-1: SWAT input variables used in shallow aquifer calculations.

<table>
<thead>
<tr>
<th>Variable name</th>
<th>Definition</th>
<th>File Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>GW_DELAY</td>
<td>( \delta_{gw} ): Delay time for aquifer recharge (days)</td>
<td>.gw</td>
</tr>
<tr>
<td>GWQMN</td>
<td>( aq_{infr,g} ): Threshold water level in shallow aquifer for base flow (mm H2O)</td>
<td>.gw</td>
</tr>
<tr>
<td>ALPHA_BF</td>
<td>( \alpha_{gw} ): Baseflow recession constant</td>
<td>.gw</td>
</tr>
<tr>
<td>REVAPMN</td>
<td>( aq_{infr,rev} ): Threshold water level in shallow aquifer for revap (mm H2O)</td>
<td>.gw</td>
</tr>
<tr>
<td>GW_REVP</td>
<td>( \beta_{rev} ): Revap coefficient</td>
<td>.gw</td>
</tr>
<tr>
<td>RCHRG_DP</td>
<td>( \beta_{deep} ): Aquifer percolation coefficient</td>
<td>.gw</td>
</tr>
<tr>
<td>GW_SPYLD</td>
<td>( \mu ): Specific yield of the shallow aquifer (m/m)</td>
<td>.gw</td>
</tr>
</tbody>
</table>
Assumption
- Channel: trapezoid, side slope: 0.5

Steady state
- Flow rate and velocity: Manning’s equation
  - Water depth, Width of channel, length of the channel, n
- Flow storage routing: kinetic wave model
  - \( V_{stored} = Prism\ storage + Wedge\ storage \)

Balance:
- Transmission loss
- Evaporation
- Diversion
- Bank storage

\[
q_{ch} = \frac{A_{ch} \cdot R_{ch}^{2/3} \cdot s l p_{ch}^{1/2}}{n}
\]

\[
v_{c} = \frac{R_{ch}^{2/3} \cdot s l p_{ch}^{1/2}}{n}
\]

Figure 7:1-3: Prism and wedge storages in a reach segment (After Chow et al., 1988)
<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Climate</strong></td>
<td>Meteological data</td>
</tr>
<tr>
<td></td>
<td>Historical meteorological data</td>
</tr>
<tr>
<td></td>
<td>Simulation period, as driving force</td>
</tr>
<tr>
<td></td>
<td>Weather generator, to generate missing data</td>
</tr>
<tr>
<td><strong>Nutrient/Pesticide</strong></td>
<td>Nitrogen</td>
</tr>
<tr>
<td></td>
<td>Phosphorous</td>
</tr>
<tr>
<td></td>
<td>Pesticide</td>
</tr>
<tr>
<td></td>
<td>Plant uptake, in-soil process, erosion, in-stream process</td>
</tr>
<tr>
<td><strong>Erosion</strong></td>
<td>Over land, instream, water body sediment</td>
</tr>
<tr>
<td></td>
<td>MUSLE approach</td>
</tr>
<tr>
<td><strong>Water bodies</strong></td>
<td>Reservoir</td>
</tr>
<tr>
<td></td>
<td>Pond/wetland</td>
</tr>
<tr>
<td></td>
<td>Water balance</td>
</tr>
<tr>
<td><strong>Land use/Plant growth</strong></td>
<td>Growth cycle of plants based on heat unit theory</td>
</tr>
<tr>
<td><strong>Management strategies</strong></td>
<td>Plant growth cycle, time of fertilizer/pesticide, removal of plant biomass</td>
</tr>
</tbody>
</table>
Part 2
Nitrogen module in SWAT

- Both in-land and in-stream dynamic
  - Transformation + plant uptaken
- Transport processes
  - Nitrate $\rightarrow$ runoff + infiltration
  - Organic N $\rightarrow$ erosion
- Catchment nitrogen input
  - Point sources: effluent from sewers
  - Non-point sources: waste from rural area, fertilizer, feedlots, atmospheric deposition and etc.
Phosphorus and sedimentation module in SWAT

- Plant uptake and erosion
- Low mobility of solution P

Erosion
MUSLE: modified universal soil loss equation

\[ sed = 11.8 \cdot \left( Q_{surf} \cdot q_{peak} \cdot area_{hru} \right)^{0.56} \cdot K_{USLE} \cdot C_{USLE} \cdot P_{USLE} \cdot LS_{USLE} \cdot CFRG \]

- Runoff rate; soil erodibility factor; etc.
Part 2

Plant growth module in SWAT

- Heat Unit approach
  - Heat accumulated if temperature above a threshold
  - Plants specific parameters to identify the respective heat needed to go mature

![Plant growth diagram]

<table>
<thead>
<tr>
<th>Average Biomass (Mg/ha)</th>
<th>21</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Yield (Mg/ha)</td>
<td>6.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>N Removed in Yield</th>
<th>130.56</th>
</tr>
</thead>
<tbody>
<tr>
<td>P Removed in Yield</td>
<td>21.12</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Fertilizer N</th>
<th>201.977</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Fertilizer P</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Plant Uptake N</th>
<th>221.587</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant Uptake P</td>
<td>38.081</td>
</tr>
</tbody>
</table>
Part 2
In-stream module in SWAT

- Load from point and non-point source aggregated at each outlets
- QUALE2 model
  - Algae growth rate
  - Hydrolysis rate
  - Settling
- Computational unit
  - channel (upstream to downstream)

Figure 0.9: In-stream processes modeled by SWAT
Content

Part 3 – A case study

• Catchment overview
• Problem identification
• Model results analysis
Part 3
Case study – Le Sueur River Watershed (LRW)

- South central Minnesota, 2850 km²
- Precipitation: 800mm
- 41% of the stream network is perennial
- T: min -11°C, max 22°C
- Elevation: 223m to 418m
- Land use: 70% corn/soybean, 2 year rotation
- Population: 56100
- Livestock: 1.1 million
Part 3
Problem identification

- An impaired water body, Only occupy 7% of the Minnesota River Basin
- Contribute to Minnesota River
  - Sediment: 53%
  - NO$_3$-N: 20%
  - P: 31%
  - Pesticide

Mitigate the contaminant loads!!!
Part 3
Objectives

• To accurately and efficiently **quantify** sediment, nutrient and pesticide losses from the watershed

• To identify and prioritize **critical sub-watersheds** and to evaluate the relative importance of managing them

• To evaluate the **effectiveness** of alternative best management practices (**BMPs**) at reducing pollutant loads from the Le Sueur River watershed.

Quantify the problem and identify critical location, find solutions and evaluate solutions
Part 3
Le Sueur River Watershed – Discharge simulation

Figure 2-14: Calibration of monthly stream flow

Figure 2-15: Validation of monthly flow in the Beauford sub-watershed
Part 3
Le Sueur River Watershed – Nitrogen simulation

Figure 5-3: Nitrate-Nitrogen calibration in the Beauford Sub-watershed.

Figure 5-4: Average Monthly Nitrogen Loss Validation in the Beauford Sub-watershed.

Calibration
Validation
Part 3
Le Sueur River Watershed – Annual water budget

ET occupies > 70%;
Water yield in the River = Surface Q + Groundwater Q + Lateral Q + Tile Q

Tile flow

https://articles.extension.org/sites/default/files/w/a/a3/Tile_drainage_Ohio.jpg
Part 3
Le Sueur River Watershed – Spatial variation of water yield

The contribution of water in river from each watershed
Part 3
Le Sueur River Watershed – spatial distribution of sediment yield

- To identify critical areas
- 25% of the total area generates 50% of the sediment losses
- Only 9% of the region contributes more than 5 t/a of sediment

Evaluation of BMPs in impaired watershed using the SWAT model
Part 3
Le Sueur River Watershed – sediment BMPs

Evaluation of BMPs in impaired watershed using the SWAT model
Part 3
Le Sueur River Watershed – sediment BMPs

- Problem identification
- Input data collection and analysis
- Model set-up, calibration and validation
- Model application to management strategies
Content

Part 4 – Overview of input data and data sources

• Input data
• Date sources
Part 4
Input and output data overview

https://www.researchgate.net/figure/259527294_fig2_Fig-2-Overview-of-the-swat-model-model-inputoutput-parameters
### Part 4

#### SWAT model input data overview

<table>
<thead>
<tr>
<th>Category</th>
<th>Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Raster data</strong></td>
<td></td>
</tr>
</tbody>
</table>
| Land use               | 1. [http://due.esrin.esa.int/page_globcover.php](http://due.esrin.esa.int/page_globcover.php)          
| **Time series**        |                                                                                                        |
| Climate data           | 1. [https://www.ncdc.noaa.gov/cdo-web/](https://www.ncdc.noaa.gov/cdo-web/)                             
2. [https://globalweather.tamu.edu/](https://globalweather.tamu.edu/) |
| Streamflow for calibration| 1. [http://www.bafg.de/GRDC/EN/Home/homepage_node.html](http://www.bafg.de/GRDC/EN/Home/homepage_node.html)  
2. [https://waterdata.usgs.gov/nwis/rt](https://waterdata.usgs.gov/nwis/rt) |
1. CGIAR “Consortium for Geospatial Information”
   SRTM (Shuttle Radar Topography Mission), NASA, 2000

<table>
<thead>
<tr>
<th>Product Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Projection</strong></td>
</tr>
<tr>
<td><strong>Horizontal Datum</strong></td>
</tr>
<tr>
<td><strong>Vertical Datum</strong></td>
</tr>
<tr>
<td><strong>Vertical Units</strong></td>
</tr>
<tr>
<td><strong>Spatial Resolution</strong></td>
</tr>
</tbody>
</table>

Robit Watershed: N 11°27′26″ ~ 11°47′49″; E 37°22′55″ ~ 37°30′50″
Part 4

SWAT model input data – DEM

1. Earth Explorer by U.S. Geological Survey

http://earthexplorer.usgs.gov/
Part 4
SWAT model input data – land use

1. GlobalCover ESA – European Space Association
http://due.esrin.esa.int/page_globcover.php
Spatial resolution: 300m, 23 land use classes
Part 4

SWAT model input data – land use

2. GLOBELAND30 – National Geomatics Center of China


2000 or 2010, 10 land use classes
Part 4
SWAT model input data – land use

3. Copernicus Global Land Service –
2015 – 2019, 100m
Part 4

SWAT model input data – soil type

Harmonized World Soil Database


Spatial resolution: 1000m
Part 4

SWAT model input data – climate

1. U.S. National Centers for Environmental Information

https://www.ncdc.noaa.gov/cdo-web/

Land-based stations

<table>
<thead>
<tr>
<th>LOCATION DETAILS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Name</td>
<td>Ethiopia</td>
</tr>
<tr>
<td>ID</td>
<td>FIPS:ET</td>
</tr>
<tr>
<td>Type</td>
<td>Country</td>
</tr>
<tr>
<td>Included Stations</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>(See station list below)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PERIOD OF RECORD</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Start&lt;sup&gt;1&lt;/sup&gt;</td>
<td>1951-01-01</td>
</tr>
<tr>
<td>End&lt;sup&gt;1&lt;/sup&gt;</td>
<td>2017-06-11</td>
</tr>
<tr>
<td>Coverage&lt;sup&gt;2&lt;/sup&gt;</td>
<td>100%</td>
</tr>
</tbody>
</table>
Part 4
SWAT model input data – climate

2. Climate Forecast System Reanalysis
https://globalweather.tamu.edu/
From 1979-01-01 to 2014-07-31, time series of daily data in SWAT file format
Part 4
SWAT model input data – streamflow

1. Global runoff data center

http://www.bafg.de/GRDC/EN/Home/homepage_node.html

9,200 stations in 160 countries
Part 4
SWAT model input data – streamflow

2. U.S. Geological Survey


USGS Current Water Data for the Nation

**Daily Streamflow Conditions**

*Friday, November 25, 2016 11:30ET*

The colored dots on this map depict streamflow conditions as a percentile, which is computed from the period of record for the current day of the year. Only stations with at least 30 years of record are used.

The gray circles indicate other stations that were not ranked in percentiles either because they have fewer than 30 years of record or because they report parameters other than streamflow. Some stations, for example, measure stage only.
Content

Part 5 – Set-up a SWAT model demonstration

- Robit Watershed in Ethiopia as an example
- Model set-up procedure
- Data structure of the model
Part 5
Input data overview – Robit watershed

Digital Elevation Model

Area: 16.75 km²
Part 5
Input and output data overview

https://www.researchgate.net/figure/259527294_fig2_Fig-2-Overview-of-the-swat-model-model-inputoutput-parameters
## Part 5

### Input data overview

Example Data Set: Robit Watershed, Lake Tana Basin  
Path: C:\user’s home directory\.qgis2\python\plugins\Qswat

<table>
<thead>
<tr>
<th>Remark</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Climate input, with measuring sites and time series</td>
<td>ClimateRobit, DEM, Landuse, MainOutlet, Observed, RobitStreams, Soil, MainOutlet.zip, Robit_landuses.csv, Robit_soils.csv, usersoil.xlsx, WGEN_Robit.xlsx</td>
</tr>
<tr>
<td>Location of the outlet</td>
<td>ClimateRobit, DEM, Landuse, MainOutlet, Observed, RobitStreams, Soil, MainOutlet.zip, Robit_landuses.csv, Robit_soils.csv, usersoil.xlsx, WGEN_Robit.xlsx</td>
</tr>
<tr>
<td>Observed discharge at basin outlet (m³/s)</td>
<td>ClimateRobit, DEM, Landuse, MainOutlet, Observed, RobitStreams, Soil, MainOutlet.zip, Robit_landuses.csv, Robit_soils.csv, usersoil.xlsx, WGEN_Robit.xlsx</td>
</tr>
<tr>
<td>Stream .shp</td>
<td>ClimateRobit, DEM, Landuse, MainOutlet, Observed, RobitStreams, Soil, MainOutlet.zip, Robit_landuses.csv, Robit_soils.csv, usersoil.xlsx, WGEN_Robit.xlsx</td>
</tr>
<tr>
<td>Landuse look up table, with corresponding SWAT Landuse Code</td>
<td>ClimateRobit, DEM, Landuse, MainOutlet, Observed, RobitStreams, Soil, MainOutlet.zip, Robit_landuses.csv, Robit_soils.csv, usersoil.xlsx, WGEN_Robit.xlsx</td>
</tr>
<tr>
<td>Soil look up table, with corresponding data to link the usersoil.xlsx</td>
<td>ClimateRobit, DEM, Landuse, MainOutlet, Observed, RobitStreams, Soil, MainOutlet.zip, Robit_landuses.csv, Robit_soils.csv, usersoil.xlsx, WGEN_Robit.xlsx</td>
</tr>
<tr>
<td>Soil database created by the user</td>
<td>ClimateRobit, DEM, Landuse, MainOutlet, Observed, RobitStreams, Soil, MainOutlet.zip, Robit_landuses.csv, Robit_soils.csv, usersoil.xlsx, WGEN_Robit.xlsx</td>
</tr>
<tr>
<td>Weather statistics for weather generator</td>
<td>ClimateRobit, DEM, Landuse, MainOutlet, Observed, RobitStreams, Soil, MainOutlet.zip, Robit_landuses.csv, Robit_soils.csv, usersoil.xlsx, WGEN_Robit.xlsx</td>
</tr>
</tbody>
</table>
Part 5
Input data overview – Robit watershed

Digital Elevation Model

Area: 16.75 km²
Part 5
Input data overview – Robit watershed

Landuse

Cell size: 30m

Soil

Cell size: 90m

Legend

LVx
VRe
Part 5
Input data overview – Robit watershed

Daily weather data: (1990 - 2013)

- Precipitation
- Temperature
- Wind speed
- Solar Radiation
- Relative humidity

PET

Daily precipitation from 1990 to 2013 in mm
Part 5
Input data overview – Robit watershed

River network and measured streamflow discharge

- Monthly average discharge in m$^3$/s

Watershed outlet

Monthly average streamflow at Robit Watershed outlet [m$^3$/s]
Part 5

SWAT model procedure

1. Watershed delineation
2. HRU analysis
3. Write Input tables
Part 5
SWAT model data structure

Database

• Reference database: QSWATRef2012.mdb
• Project database: prj1.mdb
Part 5
SWAT model procedure

1. Watershed delineation (DEM)
   o Insert the DEM, outlet, stream network
   o Define the shape of the basin/watershed
   o Delineate the basin in order to obtain the subbasins
Part 5
SWAT model procedure

2. HRU analysis (landuse, soil type, slope)
   - Add land use, soil type data and link the attributes to SWAT database
   - Choose the combination of landuse, soil type and slope range in order to obtain the suitable HRUs
HRU: Hydrological Response Unit

- Computational unit
- combination of land use, soil and slope within one subbasin
- HRUs is spatially defined and has no interactions with each other
Part 5
SWAT model procedure

2. HRU analysis
The number of HRUs (too many?? Too long computational time??)
- **Dominant HRU**: only the largest HRU will be considered
- **HRU threshold**: select the threshold of landuse, soil and slope (e.g. 10%,..)
- ...
Part 5
SWAT model procedure

- DEM $\rightarrow$ Watershed delineation!
- Landuse and soil type, slope $\rightarrow$ HRU analysis
- Climate!
3. Write Input tables (*weather data, management strategy,…*)
   - Weather data as the driving force of the model
   - Other input data are also considered if obtained
     - Point source input at each subbasin if applicable
     - Agricultural operations: fertilization (date, time, quantity)
     - Irrigation, water consumption,…
Part 5
SWAT simulation

- Skip 3~5 years as warm up period

Import output to Database
Part 5
SWAT model project structure

- Scenarios
  - All the saved simulations with input and output data
- Source
  - Store DEM, landuse and soil
- Watershed
  - Store the generated subbasin, HRU information in .txt
Part 5
Model output database
Part 6. QSWAT installation

https://swat.tamu.edu/software/qswat/

QGIS3 + SWAT Editor + QSWAT

- Windows Operation System
- Better to have no other QGIS version installed

QSWAT3 Requirements

- Microsoft Windows (any version, as far as we are aware)
- Text editor and a tool to unzip archived files

**SWAT Editor - requirements include:**
- Microsoft Windows
- Microsoft .Net Framework 3.5
- Adobe Acrobat Reader version 7 or higher

Installation

Install QGIS3 by going to the QGIS download page and selecting under Long term release repository (most stable) the QGIS Standalone Installer Version 3.10 (32 bit or 64 bit: see Release Notes above for which to choose). This gives you an executable file which you run to install QGIS3. Use the default folder C:\Program Files\QGIS 3.10 (or C:\Program Files (x86)\QGIS 3.10) as the installation folder. Note that it is essential that you select QGIS3 rather than the earlier QGIS2, because they use different versions of the Python language, and it is also essential that you select a 32 bit or 64 bit version according to the Release Notes, and the corresponding QSWAT3 or QSWAT3_64. We recommend that you select the long term release version of QGIS (currently 3.10) because that is the one we test QSWAT3 against.

Install SWAT Editor 2012 in its standard place C:\SWAT\SWATEditor.
- Refer to Appendix I of the QSWAT Manual for help updating a database.
- Refer to the SWATEditor_Documentation.pdf in C:\SWAT\SWATEditor\SWATEditorHelp for help getting started.

Other Documents

- Download global datasets
- Preparing global DEM data for QSWAT
Task for next two weeks

• Install QSWAT: QGIS3+SWAT Editor +QSWAT

• Set-up the hydrological model for Robit Watershed (voluntary)
  o Reference: step_by_step_installation_model_set_up.pdf
• Axel Bronstert (2005): Coupled models for the hydrological cycle. Integrating atmosphere, biosphere and pedosphere
• swat.tamu.edu
• SWAT2009 Theoretical Documentation http://swat.tamu.edu/documentation/
• SWAT2009 Input/Output File Documentation http://swat.tamu.edu/documentation/
• Folle, Solomon Muleta (2010). Swat modeling of sediment, nutrients and pesticides in the Le-Sueur River watershed, south-central Minnesota
  https://conservancy.umn.edu/handle/11299/59212