Comparison of Green-Ampt and Curve Number Infiltration Methods in a single-gauged Brazilian watershed

Julio Issao Kuwajima

Toulouse, 2013
The volume and rate of runoff of rain events are of great importance to understand the processes of a watershed.

The infiltration determines the amount of water available for runoff, evaporation, root uptake, and recharge to the groundwater beneath.
Introduction

**Infiltration Capacity**
(depth/time)

**Rainfall Rate**
(depth/time)

*Infiltration capacity tells us how much of the rainfall can be absorbed by the ground without running off.*

*When the rainfall rate is greater than the infiltration capacity, the difference is the runoff.*

©The COMET Program
Runoff in the SWAT

- The runoff can be estimated in SWAT using:
  - SCS Curve Number procedure
  - Green & Ampt infiltration method

- The CN is the most common method adopted to predict runoff and does not consider rainfall intensity and duration, only total rainfall volume.
- The GA method is a time-based model and can simulate impacts of rainfall intensity and duration and infiltration processes.
SCS-CN

* Developed by the USDA in the 1950s
* Has gone through more than 20 years of studies and research.
* Very simple
* Function of the precipitation, soil’s permeability, land use and antecedent water content of the soil.
The SCS CN equation is (SCS, 1972):

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

* \( Q_{Surf} \), Accumulated runoff (mm H\(_2\)O),
* \( S \), Retention parameter (mm H\(_2\)O),
* \( R_{day} \), Rainfall depth for the day (mm H\(_2\)O),
* \( I_a \), Initial abstractions.
$S = 25.4 \left( \frac{100}{CN} - 10 \right)$

- $S$, Retention parameter (mm H$_2$O),
- $CN$, Curve Number for the day
- The CN can be obtained from tables with correlations with soil moisture, land cover and soil types.
Green-Ampt

- Homogenous soil profile
- Uniformly antecedent moisture distributed in the soil profile
- The soil above the wetting front is considered to be completely saturated
The Green-Ampt Mein-Larson infiltration model is described as:

\[ f(t) = K_e \left( 1 + \frac{\psi \Delta \theta}{F(t)} \right) \]

Where:
- \( f(t) \), Infiltration Rate for time \( t \) (mm/hour);
- \( K_e \), Effective hydraulic conductivity;
- \( \psi \), Wetting front matric potential (mm);
- \( \Delta \theta \), Variation of moisture content;
- \( F(t) \), Cumulative infiltration (mm);
Itaqueri Watershed
Itaqueri Watershed

Land and Use (2010)

Soil Classes

Monitoring Points and Subbasins
## Comparison between GA and SCS-CN

<table>
<thead>
<tr>
<th>Factors</th>
<th>Curve Number</th>
<th>Approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>Rainfall Amount</td>
<td>Green &amp; Ampt</td>
</tr>
<tr>
<td>Soil</td>
<td>Antecedent moisture condition (I,II,III)</td>
<td>Rainfall intensities or rainfall distribution</td>
</tr>
<tr>
<td></td>
<td>Hydrologic Soil Group (HSG)</td>
<td></td>
</tr>
<tr>
<td>Soil</td>
<td>Antecedent soil-water storage (volume) by soil layers or soil depth</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soil-water properties by layers or soil depth, i.e., bulk density, saturated conductivity and water entry or bubbling pressure</td>
<td></td>
</tr>
<tr>
<td>Cover</td>
<td>Land Use</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Treatment or Practice</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hydrologic conditions</td>
<td></td>
</tr>
<tr>
<td>Soil</td>
<td>Initial abstraction $I_p$, assumed as 0.2 (S)</td>
<td>Total infiltration prior to surface ponding</td>
</tr>
<tr>
<td>Surface</td>
<td>Included with initial abstraction $I_s$</td>
<td>Estimated soil surface storage as influenced by topography, land use, and tillage</td>
</tr>
<tr>
<td>Interception</td>
<td>Included with initial abstraction $I_s$</td>
<td>Estimated interception storage by ground cover (live and/or mulch)</td>
</tr>
</tbody>
</table>
## Defining The Simulation Periods

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Annual Precipitation (mm)</th>
<th>Average Daily Precipitation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>1763.476</td>
<td>4.831441</td>
</tr>
<tr>
<td>2003</td>
<td>1639.532</td>
<td>4.491868</td>
</tr>
<tr>
<td>2004</td>
<td>2200.182</td>
<td>6.011426</td>
</tr>
<tr>
<td>2005</td>
<td>2257.642</td>
<td>6.185321</td>
</tr>
<tr>
<td>2006</td>
<td>2718.853</td>
<td>7.448912</td>
</tr>
<tr>
<td>2007</td>
<td>2841.218</td>
<td>7.784159</td>
</tr>
<tr>
<td>2008</td>
<td>2722.739</td>
<td>7.439178</td>
</tr>
<tr>
<td>2009</td>
<td>3681.07</td>
<td>10.08512</td>
</tr>
<tr>
<td>2010</td>
<td>3009.951</td>
<td>8.246441</td>
</tr>
</tbody>
</table>
Defining The Simulation Periods

Total Annual Precipitation

- **Total Annual Precipitation**
- **Dry**
- **Average**
- **Wet**

Years:
- 2002
- 2003
- 2004
- 2005
- 2006
- 2007
- 2008
- 2009
- 2010

Precipitation (mm):
- 0
- 500
- 1000
- 1500
- 2000
- 2500
- 3000
- 3500
- 4000
Dry Period Simulation (2002-2004)
Dry Period Simulation (2002-2004)
Dry Period Simulation (2002-2004)

<table>
<thead>
<tr>
<th>Runoff Method</th>
<th>NS</th>
<th>R2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curve Number</td>
<td>-0.231</td>
<td>0.15</td>
</tr>
<tr>
<td>Green-Ampt</td>
<td>-0.229</td>
<td>0.11</td>
</tr>
</tbody>
</table>
Average Period Simulation
Average Period Simulation
## Average Period Simulation

<table>
<thead>
<tr>
<th>Runoff Method</th>
<th>NS</th>
<th>R2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curve Number</td>
<td>-0.445</td>
<td>0.05</td>
</tr>
<tr>
<td>Green-Ampt</td>
<td>-0.518</td>
<td>0.01</td>
</tr>
</tbody>
</table>
Wet Period Simulation
Wet Period Simulation
### Wet Period Simulation

<table>
<thead>
<tr>
<th>Runoff Method</th>
<th>NS</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curve Number</td>
<td>-0.572</td>
<td>0.03</td>
</tr>
<tr>
<td>Green-Ampt</td>
<td>-0.168</td>
<td>0.23</td>
</tr>
</tbody>
</table>
As expected the GA simulations presented an overall better performance compared to de SCS-CN simulations,

- GA can better represent the storm events of a tropical climate.

- For the dry and wet period the GA presented a slightly advantage to the SCS-CN method and for the average period the SCS-CN presented better results but methods failed to represent the rainfall events.

- The main cause for the superior performance of the Green–Ampt method is because it is a physically based infiltration excess, rainfall–runoff model, and is therefore not suitable for regions where the rainfall rate seldom exceeds the saturated conductivity of the soil, which is not the case in Brazil.
Merci !