COMPARISON OF WEPP AND SWAT FOR WATERSHED HYDROLOGY AND EROSION PREDICTION

Jan Boll¹, Erin Brooks¹, Zach Easton², Tammo Steenhuis³

¹University of Idaho, Moscow, ID
²Virginia Tech, Blacksburg, VA
³Cornell University, Ithaca, NY

CEAP Synthesis Project Funded by USDA-NIFA, NRCS
Introduction

• Hydrological modeling at hillslope and watershed scale:
  – placement of conservation practices
  – to determine BMP effectiveness
  – for understanding implications of land use change

• Comparison of WEPP and SWAT using modified versions, in the Town Brook watershed in New York state.
WEPP

• Process-based model
• Simulates both infiltration-excess and saturation-excess overland flow
• Improved subsurface lateral flow algorithms
• Direct input of key soil hydraulic properties ($\rho_b$, $K_{sat}$, $\theta_{fc}$, $\theta_{wp}$)
• Simulated streamflow and sediment load consisted of cumulative hillslope output
• Baseflow determined using linear reservoir coefficient in post-processing
• No calibration to improve observed vs simulated results
SWAT-VSA

• Watershed scale model: CN and MUSLE
• Water balance methodology: soil water storage capacity \((n \times \text{soil depth})\) distributed using topographic wetness index
• Baseflow index derived from time series of baseflow separated streamflow
• Calibration on CN to minimize root mean square error between observed and simulated
• Sediment export was calibrated to measured daily sediment yield at watershed outlet (1999-2001 WY)
WEPP vs SWAT-VSA

- WEPP can simulate hillslope scale hydrology, erosion and sediment yield
- SWAT uses Hydrologic Response Units (HRUs), which operate independently of landscape position; no flow between HRUs
- WEPP can be applied to small watersheds
- SWAT includes stream channel algorithms for application to larger watersheds
Town Brook watershed

37 km²
Catskills Mtns, NY

Steep to moderate hillslopes
Soil depth 0.5 m - > 1.0 m
Fragipan restricting layer
SWAT defines HRUs as the coincidence of soil type and landuse

- Hydrological/chemical properties are defined at the HRU

- So runoff/P loss is the same here (lowland pasture)
- As here (upland pasture)
- We know this is not the case
SWAT-VSA defines HRUs as the coincidence of soil topographic index (and soil) and landuse. A weighted average of soil properties nested within an area weighted index class. So runoff/P loss is now not the same here (lowland pasture) and as here (upland pasture).
Results

• Observed vs simulated streamflow (Oct 1, 1998 – Sept 30, 2004)
• Statistical comparison
• Composition of streamflow
• Major water balance components
• Sediment at the Town Brook watershed outlet
• Within hillslope water and net erosion
WEPP: observed & simulated streamflow
SWAT: observed & simulated streamflow
## Agreement: observed vs simulated

<table>
<thead>
<tr>
<th>Time Period</th>
<th>NS Eff</th>
<th>SE (mm)</th>
<th>R²</th>
<th>NS Eff</th>
<th>SE (mm)</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>All Years</strong></td>
<td>0.58</td>
<td>2.05</td>
<td>0.64</td>
<td>0.40</td>
<td>2.09</td>
<td>0.41</td>
</tr>
<tr>
<td>1999</td>
<td>0.43</td>
<td>2.34</td>
<td>0.59</td>
<td>0.45</td>
<td>1.44</td>
<td>0.46</td>
</tr>
<tr>
<td>2000</td>
<td>0.55</td>
<td>1.64</td>
<td>0.59</td>
<td>0.36</td>
<td>1.08</td>
<td>0.38</td>
</tr>
<tr>
<td>2001</td>
<td>0.69</td>
<td>1.69</td>
<td>0.70</td>
<td>0.15</td>
<td>1.73</td>
<td>0.17</td>
</tr>
<tr>
<td>2002</td>
<td>0.28</td>
<td>1.43</td>
<td>0.36</td>
<td>0.20</td>
<td>0.71</td>
<td>0.21</td>
</tr>
<tr>
<td>2003</td>
<td>0.59</td>
<td>1.95</td>
<td>0.60</td>
<td>0.22</td>
<td>2.29</td>
<td>0.29</td>
</tr>
<tr>
<td>2004</td>
<td>0.62</td>
<td>2.83</td>
<td>0.70</td>
<td>0.59</td>
<td>2.74</td>
<td>0.63</td>
</tr>
</tbody>
</table>

NS Eff = Nash-Sutcliffe Efficiency; SE = standard error
WEPP: composition of streamflow
SWAT: composition of streamflow
## Average annual distribution of water balance components simulated

<table>
<thead>
<tr>
<th>Water Balance Component</th>
<th>Percent of annual Precipitation (%)</th>
<th>SWAT-VSA</th>
<th>WEPP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>100%</td>
<td>100%</td>
<td></td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>37%</td>
<td>39%</td>
<td></td>
</tr>
<tr>
<td>Baseflow</td>
<td>14%</td>
<td>12%</td>
<td></td>
</tr>
<tr>
<td>Runoff</td>
<td>21%</td>
<td>13%</td>
<td></td>
</tr>
<tr>
<td>Lateral Flow</td>
<td>28%</td>
<td>35%</td>
<td></td>
</tr>
</tbody>
</table>
# Observed vs simulated sediment at Town Brook watershed outlet

<table>
<thead>
<tr>
<th>Description</th>
<th>Sediment Yield (T/yr)</th>
<th>Sediment Yield (T/ha/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obs. at watershed outlet</td>
<td>1,931</td>
<td>0.5</td>
</tr>
<tr>
<td>SWAT at watershed outlet</td>
<td>15,717</td>
<td>4.3</td>
</tr>
<tr>
<td>WEPP from hillslopes</td>
<td>546</td>
<td>0.1</td>
</tr>
</tbody>
</table>
WEPP: predictions within hillslope
Net-erosion & sediment yield
Conclusions

• Agreement between observed & simulated streamflow comparable
• SWAT (calibrated) simulated a (flashy) hydrograph that agreed better with observations than WEPP (non-calibrated)
• Simulated hydrographs by WEPP can be improved with better representation of transpiration changes in deciduous forests
**Conclusions**

- Sediment yield was over-predicted by SWAT
- Sediment yield predictions from hillslopes suggest that the majority of sediment delivered at the outlet of the stream may be derived from streambanks
- This study shows WEPP can be applied to large watersheds
- SWAT is more appropriate for large scale applications
- WEPP has ability to provide detail water and mass balance evaluation at the hillslope scale