Implications of Different Nutrient Load Estimation Techniques for Testing SWAT: An Example Assessment for the Boone River Watershed in North Central Iowa

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Funded in part by CenUSA Bioenergy (www.cenusa.iastate.edu/), a USDA-NIFA-AFRI-coordinated agricultural project (Project #: 20116800530411-BEI-KLI).
Overview of Presentation

- Description of the Boone River Watershed (BRW) and Des Moines Lobe region
- SWAT model structure including nutrient inputs
- Pollutant load estimation issues / model testing results
- Conclusions
Boone River Watershed

- 2,370 km² in parts of six counties in north central Iowa
- Des Moines Lobe landform region; southern portion of North American Prairie Pothole region
- Generally level topography; heavily tile drained
- Dominated by crop production
5. Our large resources and financial reliability, and our over thirty years of reputation for fair dealing, insure that you will get nothing but the highest class product, and the squarest possible treatment from us.

MASON CITY BRICK AND TILE CO.

Mason City, Iowa.

A bird's-eye view of one of our factories.
Effects of Tile Drainage on Soil Water

Wetland Loss in the Des Moines Lobe Region: 99%

2005 Land Use
Determined from Field-level Survey
<table>
<thead>
<tr>
<th>Type</th>
<th>Total operations</th>
<th>Total head</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swine</td>
<td>109</td>
<td>481,448</td>
</tr>
<tr>
<td>Cattle</td>
<td>13</td>
<td>4,265</td>
</tr>
<tr>
<td>Layers</td>
<td>6</td>
<td>6,962,112</td>
</tr>
</tbody>
</table>

Source: 2005 IDNR CAFO data
Estimated Manure Application Zones (112 kg/ha N rate)

Data generated by C. Wolter, Iowa Dept. of Natural Resources, Des Moines, IA; Software developed by D. James, USDA -ARS, Ames, IA
Nutrient Applications

• N fertilizer rates on corn not receiving livestock manure
  - corn after soybean:
    - spring: 172 kg/ha
    - fall: 183 kg/ha
  - corn after corn: 196 kg/ha

  - P2O5 fertilizer rate for corn: 49 kg/ha

• Manure assumptions less straightforward
  - 80% applied on corn & 20% on soybean
    - N rate: 190 kg/ha
    - P rate: 70 kg/ha
  - 50% of manured corn also fertilized
20% of the N load to the Gulf of Mexico
SWAT Version & Simulation Approach

- SWAT version 2012; Release 615
- Simulation period: 1984 to 2013
- Used ET-based Runoff Curve Number Approach
- Account for tile drainage (original method)
  - depth of 1200 mm (~4 ft)
- Tile drains simulated for cropland <2% slope
  - ~80% of the cropland
  - 2012 USDA-NASS Census: ~70% for six counties
30-Year Streamflow Comparison (1984-2013)

Initialization years: 1982 & 1983

\[
R^2 = 0.95; \text{NSE} = 0.95
\]

\[
R^2 = 0.92; \text{NSE} = 0.92
\]
USGS LOADEST Problems


IMPORTANT NOTE: LOADEST can produce biased load estimates when the selected model is a poor representation of the relationship between load and the explanatory variables. Problems with load bias may be identified through careful analyses of model residuals. LOADEST has therefore been modified since its initial release to include several features that facilitate residual analysis and bias identification. This updated version of the software was placed on the web site on March 27, 2013 .....
# Description of Nitrate Load Estimation Methods

<table>
<thead>
<tr>
<th>Load Estimation Method</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear interpolation</td>
<td>Fill concentration gaps between measured values by a straight line; multiply by streamflow to obtain loads</td>
</tr>
<tr>
<td>Average monthly values</td>
<td>Average monthly streamflow multiplied by a monthly nitrate concentration</td>
</tr>
<tr>
<td>AutoBeale method</td>
<td>Annual load is computed as a function of concentrations and an adjusted flow ratio</td>
</tr>
</tbody>
</table>

### Description of Nitrate Load Estimation Methods

<table>
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</tr>
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<tbody>
<tr>
<td>Cokriging</td>
<td>Correlation of measured NO3-N loads to daily discharge, to improve interpolation</td>
</tr>
<tr>
<td>LOADEST</td>
<td>Seven parameter regression model; uses continuous stream flow to estimate loads</td>
</tr>
<tr>
<td>WRTIDS</td>
<td>Regression method that accounts for discharge, seasonality, long-term trend, and a random component</td>
</tr>
</tbody>
</table>

**Source:** Schilling et al. 2016. Assessment of Nitrate-N Load Estimation Methods to Quantify Load Reduction strategies. JSWC (accepted).
BRW Pollutant Monitoring Data

• Collected near watershed outlet (2000 to 2013)

• Monthly grab samples at best (sometimes periods of multiple months between samples)

• Just calibration was performed for pollutant loss/transport testing
## Estimated Nitrate Loads at Boone Outlet

<table>
<thead>
<tr>
<th>Load Estimation Method</th>
<th>Estimated Daily Average Nitrate Load (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear interpolation</td>
<td>17,848</td>
</tr>
<tr>
<td>Average monthly values</td>
<td>13,626</td>
</tr>
<tr>
<td>AutoBeale method</td>
<td>16,517</td>
</tr>
<tr>
<td>Cokriging</td>
<td>24,652</td>
</tr>
<tr>
<td><strong>LOADEST</strong></td>
<td><strong>40,009</strong></td>
</tr>
<tr>
<td>WRTDS</td>
<td>17,376</td>
</tr>
</tbody>
</table>

*Source: Schilling et al. 2015. Assessment of Nitrate-N Load Estimation Methods to Quantify Load Reduction strategies. JSWC (accepted).*
Estimated Nitrate Loads at Boone Outlet

Year

Nitrate load (million kg)


Data generated by C. Wolter, Iowa Department of Natural Resources, Des Moines, IA
Estimated Total P Loads at Boone Outlet

Data generated by C. Wolter, Iowa Department of Natural Resources, Des Moines, IA
LOADEST Sediment Results were also Excessively Biased

IMPORTANT WARNING:

Load Bias (Bp) Exceeds + or - 25%
THE CALIBRATED MODEL SHOULD NOT BE USED FOR LOAD ESTIMATION
Baseline mean sediment load = 0.6 t/ha

WRTDS-based SWAT Result

LOADEST-based SWAT Result
Simulated vs. “Measured” Nitrate Loads
(Measured Loads Based on LI Method)

\[ R^2 = 0.75, \text{NSE} = 0.72 \]
Simulated vs. “Measured” Total P Loads
(Measured Loads Based on WRTDS Method)

R² = 0.68; NSE = 0.68
Conclusions

- LI and WRTDS provided most accurate nitrate and total P load estimates, respectively
  - SWAT captured most of the estimated load trends

- BRW sediment load estimates have bias problems
  - but sediment loads are relatively low (mean = .6 t/ha)

- LOADEST severely overestimated nitrate loads

- Will investigate comparisons with nitrate sensor data as part of the ongoing research