Impact of Tile Drainage on Hydrology and Sediment Losses in an Agricultural Watershed using SWATDRAIN

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Outline

- Introduction
- Objectives
- SWATDRAIN
- Impact of tile drainage on watershed hydrology and sediment loads
- Conclusions
Why SWATDRAIN?

- **SWAT**
  - Surface flow
  - Subsurface flow
  - Water table depth

- **Modified SWAT**
  - Hooghoudt and Kirkham approaches
    - Volume drained and WTD relationship

- **DRAINMOD**
  - Subsurface flow
  - Water table management practices
  - Water table depth

- Inclusion of DRAINMOD into SWAT
Model Development Objectives

- Main goal:
  - Develop SWATDRAIN to simulate surface and subsurface hydrology of agricultural tile-drained watersheds

- Specific objectives:
  - SWATDRAIN – incorporate DRAINMOD into SWAT
  - Evaluate SWATDRAIN model on a fully tile-drained agricultural Watershed
  - Use the SWATDRAIN model to assess impacts of water management systems on watershed hydrology
  - Evaluate SWATDRAIN model for a partially tile-drained agricultural watershed and assess the impact of tile drainage on watershed hydrology and sediment loading
Overall Modeling Approach

DRAINMOD was fully incorporated into SWAT model
Preparing inputs for SWATDRAIN

- Weather data
  - Precipitation
  - Max temperature
  - Min Temperature
- Crop
  - Landuse map
- Soil
  - Soil map
- Subsurface drainage system design
  - Depth, spacing, drainage coefficient...

A full set of SWATDRAIN input files for each HRU in the watershed is generated.

Update variables in SWAT using the computed values from DRAINMOD
## Different Approaches for Tile Drainage and WTD

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Tile drainage</th>
<th>Water table depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>SWATDRAIN</td>
<td>ITDRN=2, DRAINMOD approach of tile drainage determination incorporated</td>
<td>IWTDN=2, DRAINMOD approach of WTD determination incorporated</td>
</tr>
<tr>
<td>SWAT (Original)</td>
<td>ITDRN=0, original tile drainage equation</td>
<td>IWTDN=0, the soil profile above the confining layer is allowed to fill with water up to field capacity</td>
</tr>
<tr>
<td>SWAT (Modified)</td>
<td>ITDRN=1, incorporates Kirkham and Hooghoudt tile drainage equations</td>
<td>IWTDN=1, drainage volume converted into WTD using a variable water table factor</td>
</tr>
</tbody>
</table>
Model Evaluation
Canagagique Creek West Watershed
(Partially Tile-Drained)
Canagagigue Creek Watershed

- Canagagigue Creek
- Area: 18 km²
- Topography: flat-to-undulating
- Land use: agriculture
- Soil: loam or clay loam
- Tile drainage systems (Laterals: 20 m apart and 1 m deep)
Streamflow

<table>
<thead>
<tr>
<th>Index</th>
<th>Daily Calibration</th>
<th>Daily Validation</th>
<th>Monthly Calibration</th>
<th>Monthly Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>R²</td>
<td>0.74</td>
<td>0.62</td>
<td>0.93</td>
<td>0.75</td>
</tr>
<tr>
<td>PBIAS</td>
<td>1.60</td>
<td>17.90</td>
<td>1.60</td>
<td>17.90</td>
</tr>
<tr>
<td>NSE</td>
<td>0.72</td>
<td><strong>0.63</strong></td>
<td>0.92</td>
<td><strong>0.73</strong></td>
</tr>
</tbody>
</table>
Annual and Average Seasonal Sediment Loads

**Annual Sediment Loads-Calibration**

- **Sediment Load (t/ha)**
- **1975** 1.0 0.5 1.5 1.0 1.5 1.0
- **1976** 1.0 0.5 1.5 1.0 1.5 1.0
- **1977** 1.0 0.5 1.5 1.0 1.5 1.0
- **1978** 1.0 0.5 1.5 1.0 1.5 1.0
- **1979** 1.0 0.5 1.5 1.0 1.5 1.0
- **Ave** 1.0 0.5 1.5 1.0 1.5 1.0

**Annual Sediment Loads-Validation**

- **Sediment Load (t/ha)**
- **1980** 1.0 0.5 1.5 1.0 1.5 1.0
- **1981** 1.0 0.5 1.5 1.0 1.5 1.0
- **1982** 1.0 0.5 1.5 1.0 1.5 1.0
- **1983** 1.0 0.5 1.5 1.0 1.5 1.0
- **1984** 1.0 0.5 1.5 1.0 1.5 1.0
- **Ave** 1.0 0.5 1.5 1.0 1.5 1.0

**Seasonal Sediment Loads-Calibration**

- **Sediment Load (t/ha)**
- **Spring** 0.5 0.5 1.0 1.0 1.0
- **Summer** 0.5 0.5 1.0 1.0 1.0
- **Fall** 0.5 0.5 1.0 1.0 1.0
- **Winter** 0.5 0.5 1.0 1.0 1.0
- **Annual** 1.0 1.0 1.5 1.5 1.5

**Seasonal Sediment Loads-Validation**

- **Sediment Load (t/ha)**
- **Spring** 0.5 0.5 1.0 1.0 1.0
- **Summer** 0.5 0.5 1.0 1.0 1.0
- **Fall** 0.5 0.5 1.0 1.0 1.0
- **Winter** 0.5 0.5 1.0 1.0 1.0
- **Annual** 1.0 1.0 1.5 1.5 1.5

- **Obs. Sediment Load (t/ha)**
- **Sim. Sediment Load (t/ha)**
Average Monthly Sediment Loads

<table>
<thead>
<tr>
<th>Index</th>
<th>Calibration</th>
<th>Validation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$R^2$</td>
<td>0.84</td>
<td>0.78</td>
</tr>
<tr>
<td>PBIAS</td>
<td>-13.75</td>
<td>2.74</td>
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<tr>
<td>NSE</td>
<td>0.80</td>
<td>0.68</td>
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Impact of Tile Drainage on Water Balance and sediment Loads
Different Tile Drainage Scenarios

- Existing condition (65% of the watershed under tile drainage);
- Entire watershed is tile-drained; and
- No tile drains installed in the watershed
Water Balance – Average Annual Precipitation

- **Existing Condition**: Average Annual
  - Percolation (%): 2.7
  - Streamflow (%): 47.7
  - ET (%): 45.8
  - Error (%): 3.8

- **100% tile-drained**: Average annual
  - Percolation (%): 4.3
  - Streamflow (%): 51.5
  - ET (%): 43.1
  - Error (%): 0.12

- **No Tile drainage**: Average Annual
  - Percolation (%): 4.9
  - Streamflow (%): 42.6
  - ET (%): 48.3
  - Error (%): 4.33
Water Balance – Dry Year and Wet Year

In the dry year, precipitation was 144.0 mm (~15%) lower than the average.

In the wet year, precipitation was 92.3 mm (~10%) higher than average.
Annual and Seasonal Sediment Loads

Annual Sediment Loads

Seasonal Sediment Loads

Legend:
- Sim. Sediment Load 100% tile drained (t/ha)
- Sim. Sediment Load -Existing Condition (t/ha)
- Sim. Sediment Load -NoDrain (t/ha)
Conclusions

- A new model, called SWATDRAIN, has been developed by fully incorporating DRAINMOD into SWAT in order to improve its capability to predict subsurface hydrology of agricultural tile drained watersheds. The model works well for both fully drained and partially drained watersheds.

- The model appears to predict well the impact of tile drainage on hydrology and sediment loads in tile-drained watersheds.
Thank You!