Effects of landuse, soil and weather in the development of Northern Lake Erie Basin

Prasad Daggupati
Balew Mechonnen & Rituraj Sukhla
Ramesh Rudra -- Asim Biswas -- Pradeep Goel -- Shiv Prasher
Introduction

• The Great Lakes bordering US and Canada, holding one-fifth of all the freshwater on earth, are an unparalleled treasure for Canada
  • Provides water to 10 million Canadians

• In the last decade, the health of the Great Lakes has come under serious threat
  • increased levels of harmful pollutants and rising levels of phosphorus
Introduction

- The phosphorus-induced algae bloom levels in Lake Erie (one of the Great Lakes) were 50 times above the World Health Organization limit for safe bodily contact in 2011.
- The summer of 2015 produced the largest algae bloom in Lake Erie in 100 years.
- Province of Ontario and United States signed the Lake Erie Collaborative Agreement committing to a 40% reduction in phosphorus entering Lake Erie by 2025
Introduction

- Models in combination of monitoring can be used make better management decisions to solve emerging phosphorus and water quality issues
- Watersheds (e.g. WLEB) contributes to Lake Erie from USA side was modeled using SWAT and is being used for various decision making
- In Ontario, Thames River basin and Grand River basin which are major contributors to Lake Erie are simulated individually with different models
- In addition several small scale watersheds are simulated in greater details
  - GLASSI priority subwatersheds
- There is a need to simulate entire contributing basin to the Lake Erie from Ontarian side to understand the spatio-temporal differences
  - Use the model to make better management decisions
Introduction

• The accuracy of a model output is greatly dependent upon the quality of the input data including their spatial and temporal resolution
• Inputs typically used in models are digital elevation models (DEMs), landuse and land management, soils and precipitation
• Input data available from different sources and in different resolution
  • **Global** – coarse resolution –Less HRUs – faster simulation time
    • E.g. FAO soils, GLCC landuse
  • **Local** – finer resolution – higher HRU’s – Lower simulation time
    • E.g. SLC soils, SOLARIS landuse
• Need to critically analyze the data sources and resolution needed for large scale modeling in Ontario
  • In USA, several studies performed input data analysis and have provided recommendation
Objectives

**Overall goal** is to evaluate the impacts of various data inputs on watershed hydrological processes and streamflow in Northern Lake Erie Basin

**Objectives** are
- Prepare various inputs from different sources in SWAT format
- Develop SWAT model for Northern Lake Erie Basin in Ontario that contributes to Lake Erie
- Investigate the impacts of landuse, soil and weather
Study Area

Northern lake Erie Basin
Inputs

- DEM
- 10m DEM
Landuse

• **SOLARIS (Southern Ontario Land Resource Information System)**
  - provides a comprehensive, standardized
    - Landscape level inventory of natural, rural and urban lands
  - SOLARIS V2 used
  - 1:50,000 scale
  - Resolution: 30m

Agriculture: 76.14%

<table>
<thead>
<tr>
<th>Landuse</th>
<th>SWAT</th>
<th>Area [ha]</th>
<th>%Wat.Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barren</td>
<td>BARR</td>
<td>5430</td>
<td>0.25</td>
</tr>
<tr>
<td>Range-Grasses</td>
<td>RNGE</td>
<td>14204</td>
<td>0.65</td>
</tr>
<tr>
<td>Forest-Mixed</td>
<td>FRST</td>
<td>36810</td>
<td>1.69</td>
</tr>
<tr>
<td>Forest-Deciduous</td>
<td>FRSD</td>
<td>119221</td>
<td>5.48</td>
</tr>
<tr>
<td>Range-Brush</td>
<td>RNGB</td>
<td>163039</td>
<td>7.5</td>
</tr>
<tr>
<td>Water</td>
<td>WATR</td>
<td>14931</td>
<td>0.69</td>
</tr>
<tr>
<td>Agricultural Land-Row Crops</td>
<td>AGRR</td>
<td>1290220</td>
<td>59.32</td>
</tr>
<tr>
<td>Transportation</td>
<td>UTRN</td>
<td>71886</td>
<td>3.31</td>
</tr>
<tr>
<td>Residential-Med/Low</td>
<td>URML</td>
<td>26209</td>
<td>1.2</td>
</tr>
<tr>
<td>Residential-High Density</td>
<td>URHD</td>
<td>67142</td>
<td>3.09</td>
</tr>
<tr>
<td>Agricultural Land-Generic</td>
<td>AGRL</td>
<td>365937</td>
<td>16.82</td>
</tr>
</tbody>
</table>
Landuse

- **GLCC** (Global Land Cover Characterization)
  - primarily unsupervised classification
    - 10-day NDVI composites
  - Resolution: 1km

<table>
<thead>
<tr>
<th>Landuse</th>
<th>SWAT Code</th>
<th>Area [ha]</th>
<th>%Wat.Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential-Medium Density</td>
<td>URMD</td>
<td>30273.73</td>
<td>1.39</td>
</tr>
<tr>
<td>Agricultural Land-Row Crops</td>
<td>AGRR</td>
<td>2009463</td>
<td>92.39</td>
</tr>
<tr>
<td>GRASSLAND</td>
<td>GRAS</td>
<td>15314.33</td>
<td>0.7</td>
</tr>
<tr>
<td>SHRUBLAND</td>
<td>SHRB</td>
<td>16.5627</td>
<td>0.0</td>
</tr>
<tr>
<td>SAVANNA</td>
<td>SAVA</td>
<td>1649.973</td>
<td>0.08</td>
</tr>
<tr>
<td>DECIDUOUS BROADLEAF FOREST</td>
<td>FODB</td>
<td>79695.97</td>
<td>3.66</td>
</tr>
<tr>
<td>EVERGREEN NEEDLELEAF FOREST</td>
<td>FOEN</td>
<td>8242.396</td>
<td>0.38</td>
</tr>
<tr>
<td>MIXED FOREST</td>
<td>FOMI</td>
<td>22371.95</td>
<td>1.03</td>
</tr>
<tr>
<td>Water</td>
<td>WATR</td>
<td>7421.01</td>
<td>0.34</td>
</tr>
<tr>
<td>WOODED TUNDRA</td>
<td>TUWO</td>
<td>579.6061</td>
<td>0.03</td>
</tr>
</tbody>
</table>
SLC: Soil Landscapes of Canada (SLC) version 3.2
- Contains soil map of Canada together with major characteristics of soil for the whole country.
- Resolution of 1:1 million
- Prepared by Agriculture and Agri-Food Canada.
- Each polygon on the map describes a distinct type of soil and its associated characteristics.

FAO Soil (Global database of soils)
- Joint FAO/Unesco Soil Map
- Resolution 1: 5 million
- MWSWAT has soils database in SWAT format
Inputs

Weather

- **CFSR** (Climate Forecast System Reanalysis): a global, high resolution, coupled atmosphere-ocean-land surface-sea ice system
  - Provides the best estimate of the state of these coupled domains over this period
  - Resolution: 38 sq. km
  - 1979 to 2014

- **GCDC** (Gridded Climate Dataset for Canada):
  - Prepared by Agriculture and Agri-Food Canada (AAFC)
  - Resolution: 10 km gridded
  - The data were interpolated from daily Environment Canada climate station observations using a thin plate smoothing spline surface fitting method implemented by ANUSPLIN V4.3.

- **Measured**: climate stations
Methods

- Developed SWAT models with combinations of inputs
  - 10m DEM, SLC soil, SOLARIS landuse – Model 1
  - 10m DEM, SLC soil, GLCC landuse – Model 2
  - 10m DEM, FAO soil, SOLARIS landuse – Model 3
  - 10m DEM, FAO soil, GLCC landuse – Model 4
    - Weather (measured, CFSR, GCDC) inputs added separately in each model

- HRU delineation
  - 0-2, 2-4,4-9999
  - Threshold: 5/5/5 – landuse/soil/slope
  - Model 1: 3831  Model 2: 1470  Model 3: 2961  Model 4: 1159

- Tile Drainage
  - All agricultural lands in 0-2% slope (Daggupati et al., 2015)
    - Ddrain: 1000
    - Gdrain: 48
    - Tdrain:24
    - D_IMP: 2100
    - Daily curve number calculation method: Plant Based ET
    - CNCOEFF = 0.5

- Land management
  - Corn – Soybean rotation based on Heat units
  - Auto fertilization

- No calibration
Methods

Various scenarios developed

Model 1
- **SC1**: SLC soil, SOLARIS landuse, GCDC
- **SC2**: SLC soil, SOLARIS landuse, CFSR
- **SC3**: SLC soil, SOLARIS landuse, Measured

Model 2
- **SC4**: SLC soil, GLCC landuse, GCDC
- **SC5**: SLC soil, GLCC landuse, CFSR
- **SC6**: SLC soil, GLCC landuse, Measured

Model 3
- **SC7**: FAO soil, SOLARIS landuse, GCDC
- **SC8**: FAO soil, SOLARIS landuse, CFSR
- **SC9**: FAO soil, SOLARIS landuse, Measured

Model 4
- **SC10**: FAO soil, GLCC landuse, GCDC
- **SC11**: FAO soil, GLCC landuse, CFSR
- **SC12**: FAO soil, GLCC landuse, Measured
Methods

• Streamflow comparison stations

- Thames at Ingresol
- Thames at Thamesville
- Bear creek at Brigden
- Grand at Brandford
- Grand at Marsville
- Bigcreek at Walsingham
Results

Hydrological budget

- Compare weather (GCDC vs. CFSR vs. Measured)

- Compare landuse (Solaris vs GLCC)
Results

- Compare Soils (SLC vs FAO)

SOLARIS landuse, GCDC weather

GLCC landuse, GCDC weather

- Compare fine resolution vs coarse resolution datasets

SLC soil SOLARIS landuse, GCDC weather VS FAO soil, GLCC landuse, CFSR weather
Results

Streamflow @ Thames at Ingresol

• Compare Weather (GCDC vs. CFSR vs. Measured)

![Graph showing streamflow comparison](image)

- SC1
- SC2
- SC3
- Observed flow

![Bar chart showing NSE values](image)

- NSE for SC1: 0.73
- NSE for SC2: -0.69
- NSE for SC3: 0.70
Results

- Compare Landuse (Solaris vs GLCC)

Similar results were also seen in Sc 7 and SC10 when comparing Solaris and Global landuse for similar FAO and GCDC/CFSR/Measured weather
Results

- Compare Soils (SLC vs FAO)

Similar results were also seen in SC 4 -SC10 when comparing SLC and FAO soils for similar Global landuse and GCDC/CFSR/Measured weather.
Results

Similar results in:
- Thames at Thamesville
- Grand at Brantford
- Grand at Marseville
- Bear creek at Bridgton
  - GCDC and Measured weather are similar
  - CFSR over estimated
  - Landuse (SOLARIS and Global) results looked similar
  - Soils (SLC vs FAO) results varied

- Observed and simulated differ significantly (next slide)
- But the overall trends of weather, landuse, soil are similar
Results

Streamflow @ Bear creek at Bridgton

- Compare Weather (GCDC vs. CFSR vs. Measured)
Not many fields in the watershed have tile drainage. But we represented all agricultural lands in 0 to 2% have tile drainage and therefore the results differ. Spatial representation of intra-watershed processes very important.
Conclusion

• SWAT model developed for Norther Lake Erie basin
  • Contributing basin to the Lake Erie from Canadian side
• Various inputs were analyzed using hydrological budgets and streamflow at various locations
  • Weather
    • GCDC and Measured are similar
    • CFSR over predicted
  • Landuse
    • SOLARIS and GLCC are similar
  • Soils
    • Differences in FAO and SLC
      • SLC performed better
  • Representing intra-watershed processes in the model is important
    • Tile drainage
Thanks