The Role of Decision Support Systems in Sustainable Management of Water Resources

Bernie Engel
Purdue University
Agricultural & Biological Engineering
Overview of Talk

• Introduction

• Water resources decision support system applications
  – NAPRA – biofeedstock production analysis
  – Long-Term Hydrologic Impact Assessment
  – Pollutant load analysis
  – Optimization of management practice selection

• Future opportunities
The water footprint of a product
This is a **global average** and **aggregate** number. Policy decisions should be taken on the basis of:

1. Actual water footprint of certain coffee at the precise production location.
2. Ratio green/blue/grey water footprint.
3. Local impacts of the water footprint based on local vulnerability and scarcity.

[Hoekstra & Chapagain, 2008]
Hoekstra & Chapagain, 2008
Water footprint per capita

[Hoekstra & Chapagain, 2008]
Projected Water Scarcity in 2025

- Physical water scarcity
- Economic water scarcity
- Little or no water scarcity
- Not estimated

Note: □ indicates countries that will import more than 10% of their cereal consumption in 2025.


http://iwmi.org
Water Quality
Decision Support Systems

- Computer-based information system that supports decision-making activities
- Use a number of computing technologies such as:
  - Models
  - GIS
  - Databases
  - Other information technology
Biofeedstock Impact Assessment Approach

NAPRA pre-process

- Climatic data (CLIGEN)
- Soil Data (SSURGO)
- Management
- Residue Removal C-Factors

GLEAMS Model

Post-process

- Perl: Extraction of water quality metrics
- Graphs (Matlab™)
- Spatial Display (ArcMap 9.3™)
- Statistical Analysis (SAS/STAT Software™)

NAPRAWeb Model: https://engineering.purdue.edu/napra/
Groundwater Loading Effects of Agricultural Management Systems (GLEAMS)

About GLEAMS:
• Serves as the engine for the NAPRA model.
• Developed by USDA
• Nutrient and pesticide algorithms are used by Soil & Water Assessment Tool (SWAT) model.
# Erosion: No-till

The chart below presents erosion losses (t ha⁻¹) for different types of soils and rates of corn stover removal. The soils are categorized as Blount Silt Loam, Hoytville Clay, and Oshtemo Sand.

**Rate of Corn Stover Removal**
- **r0**: no residue removal
- **r38**: removal rate at 38%
- **r52**: removal rate at 52.5%
- **r70**: removal rate at 70%

### Blount Silt Loam
- r0: 0.88a
- r38: 3.47a
- r52: 3.61a
- r70: 3.24c

### Hoytville Clay
- r0: 2.18b
- r38: 2.70bc
- r52: 3.24c
- r70: 5.80c

### Oshtemo Sand
- r0: 0.04a
- r38: 0.06b
- r52: 0.08b
- r70: 0.13c

Presented at the 2010 ASABE Meeting, Paper number 1000007
Figure 1. Statewide annual estimates in atrazine concentration to the edge-of-field based on long-term (60-years) using an Aatrex™ application rate of 2 lb a.i/ac based on manufacturer’s label rate.
Watershed Identification and Characterization
EPA HUC

NHD Water layer

Pour Point
## Watershed Summary and Tools

[*NOTE: All links open in new window. Please turn off your Web browser's popup blocker to use the modeling tools in the toolbox.*]

Apparent outlet point coordinate (NAD83 UTM Zone 17, meter): X = 269250.517, Y = 4604235.406, HUC Number = 4100009

<table>
<thead>
<tr>
<th>Land use</th>
<th>Soil group</th>
<th>Area (acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture A</td>
<td>9.8</td>
<td>99.8</td>
</tr>
<tr>
<td>Agriculture B</td>
<td>27.1</td>
<td>271.1</td>
</tr>
<tr>
<td>Agriculture C</td>
<td>14.3</td>
<td>143.3</td>
</tr>
<tr>
<td>Agriculture D</td>
<td>17.3</td>
<td>173.3</td>
</tr>
<tr>
<td>ED Residential A</td>
<td>6.6</td>
<td>66.6</td>
</tr>
<tr>
<td>ED Residential B</td>
<td>7.1</td>
<td>71.1</td>
</tr>
<tr>
<td>ED Residential C</td>
<td>0.9</td>
<td>9.9</td>
</tr>
<tr>
<td>ED Residential D</td>
<td>20</td>
<td>200.0</td>
</tr>
<tr>
<td>L.D Residential A</td>
<td>12</td>
<td>120.0</td>
</tr>
<tr>
<td>L.D Residential B</td>
<td>16.8</td>
<td>168.0</td>
</tr>
<tr>
<td>L.D Residential C</td>
<td>54.8</td>
<td>548.0</td>
</tr>
<tr>
<td>Cropland A</td>
<td>4.4</td>
<td>44.4</td>
</tr>
<tr>
<td>Cropland B</td>
<td>54.3</td>
<td>543.0</td>
</tr>
<tr>
<td>Cropland C</td>
<td>1.2</td>
<td>12.0</td>
</tr>
<tr>
<td>Cropland D</td>
<td>107.9</td>
<td>1079.0</td>
</tr>
<tr>
<td>Forest A</td>
<td>164.5</td>
<td>1645.0</td>
</tr>
<tr>
<td>Forest B</td>
<td>39</td>
<td>390.0</td>
</tr>
<tr>
<td>Forest C</td>
<td>4.1</td>
<td>41.0</td>
</tr>
<tr>
<td>Forest D</td>
<td>274.1</td>
<td>2741.0</td>
</tr>
<tr>
<td>Total Area</td>
<td>1103.3</td>
<td>11033.0</td>
</tr>
</tbody>
</table>

### Modeling Tools

- [View watershed/Apply BMPs](#): Use this tool to view the watershed, change land use, add agricultural best management practices (BMPs) to farm fields, and apply structural BMPs in the watershed.

- [Get Google Maps](#): Use this tool to view the watershed image on Google maps.

- [Estimate sediment](#): Use this tool to estimate long-term average annual sediment yield (ton/year) from the watershed using the Revised Universal Soil Loss Equation (RUSLE) and the sediment delivery ratio approach.

- [Estimate Imperviousness](#): Use this tool to estimate percent imperviousness in the watershed.

- [Estimate Peak Runoff](#): Use this tool to estimate the peak rate of runoff, depth of runoff (computed using the SCS CN method), computed time of concentration (using the Kripkitch formula), and the corresponding rainfall depth for the watershed.

- [Run LTHIA Model](#): The Long-Term Hydrologic Impact Assessment Model estimates average annual runoff and nonpoint source pollutant levels in the watershed.

- [Run Calibrated LTHIA](#): Use this tool to run Midwest Calibrated LTHIA model.

- [Run SWAT LTHIA](#): Use this tool to run SWAT LTHIA model.

- [Low Impact Development](#): Use this tool to run Low Impact Development LTHIA Spreadsheet Model. Copy the tasks, soil, and land summary into the spreadsheet.

- [Run SEDSPEC Model](#): The Sediment and Erosion Control Planning Design and SPECification Information and Guidance tool allows users to design a channel, culvert, sediment basin, level terraces, runoff diversion, or low water crossing for the watershed.

Download data for the delineated watershed. Metadata:
- Watershed data (boundary, landuse raster etc) from this site (Purdue ABE)
L-THIA
Long-Term Hydrologic Impact Assessment

- Based on the rainfall – land cover – runoff analysis method already used in many communities
- Input: Land Use Pattern(s) + Soils Pattern
- Process: Daily Runoff and Pollutant Loading Calculations (30 years)
- Output: Average Annual Runoff and NPS loads for Specific Land Use Patterns
Land Use Decisions Affect Runoff, Recharge, and Water Quality
Landuse and Soil are automatically entered into spreadsheet.
**L-THIA Basic Model**

**Step Four**

**Runoff and Nonpoint Source Pollutant Results**

Based on the information provided (see Summary of Scenarios), L-THIA estimates the following rates of runoff volume, runoff depth, and nonpoint source pollutants. Results can also be viewed in comparative bar graphs and pie charts by using the pull-down menus located at the top-left of each table.

Go to:
- SCENARIOS
- RUNOFF RESULTS
- NPS POLLUTANTS

**Warning:**
- Do not change volumes of pollution input
- Do not change land use data

### Average Annual Suspended Solids Losses in lbs

<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>100</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>0</td>
<td>50</td>
<td>25</td>
</tr>
<tr>
<td>Lead</td>
<td>0</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Copper</td>
<td>0</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Zinc</td>
<td>0</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Cadmium</td>
<td>0</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Chromium</td>
<td>0</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Nickel</td>
<td>0</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>BOD</td>
<td>0</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>COD</td>
<td>0</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Oil and Grease</td>
<td>0</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Fecal Coliform</td>
<td>0</td>
<td>50</td>
<td>75</td>
</tr>
<tr>
<td>Fecal Strept</td>
<td>0</td>
<td>50</td>
<td>75</td>
</tr>
</tbody>
</table>

### Average Annual Suspended Solids Losses in lbs

<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural</td>
<td>73.000</td>
<td>236.000</td>
<td>118.000</td>
</tr>
<tr>
<td>Commercial</td>
<td>73.000</td>
<td>236.000</td>
<td>118.000</td>
</tr>
<tr>
<td>Low Density Residential</td>
<td>73.000</td>
<td>236.000</td>
<td>118.000</td>
</tr>
</tbody>
</table>

Also view Annual Variation and Probability of Exceedence.
Preliminary Evaluation of LID for Pendleton, IN
Using L-THIA LID Lot Level

- Reduce street width from 26ft. to 18ft.
- Rain barrels for Residential
- Green Roofs for Commercial
- Bioretention/Raingardens

Reduces Post-developed runoff by **46%**
Extends L-THIA online tool to entire Great Lakes area.
Tool will now allow use of a polygon as an area of analysis. This will improve ability to model zoning and LID BMP areas.
New Results Options
Pollutant Load Analysis
Purdue University is an Equal Opportunity/Equal Access institution.
Enhancement of Web-based LDC Tool – Data Retrievals

User Side
- Map-based User Interface (HTML/CGI)
- Parsing to ‘Water Quality Data Table’

Purdue
- Web Services Request (CGI) with “Organization ID” and “Monitoring Location ID”
- WQ Data Handling (CGI)

WQP
- WQP Web Services

STORET Data Warehouse Location DB
**Objective 3. Enhancement of Web-based LDC Tool – about LDC**

Flow and Load Duration Curves

- Simple, quick, and statistical approach
- Cumulative frequency of historic data over a specified period

* USEPA, 2007. An approach for using load duration curves in the development of TMDLs. *U. S. Environmental Protection Agency*
Objective 3. Enhancement of Web-based LDC Tool – Result

- LOADEST Run
- Flow Duration Curve
- Load Duration Curve
- Time Series Plot
- Concentration Plot
<table>
<thead>
<tr>
<th>Flow Regimes</th>
<th>Target Load (lb)</th>
<th>Current Load (lb)</th>
<th>Required Reduction (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-Flow</td>
<td>197901939.80</td>
<td>240566480.00</td>
<td>19.70</td>
</tr>
<tr>
<td>Moist-Condition</td>
<td>366838786.01</td>
<td>324189650.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Mid-range Flow</td>
<td>152533833.00</td>
<td>111062500.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Dry-Condition</td>
<td>170610360.45</td>
<td>94379500.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Low-Flow</td>
<td>31717363.16</td>
<td>13330200.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Overall</td>
<td>919752322.27</td>
<td>799474578.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

**Target Load in each flow regime**

**Estimated Load by LOADEST in each flow regime**

**Required Reduction Percentage**

**Pollutant Constituent for Load**

(N, P, BOD, or Sediment)
BMP List for each Landuse

The user needs to select an option in each landuse table for interactive results which may be used in models.

The BMP suggestions were tested in STEPL. Required Reduction percentage from LDC was found to be similar to STEPL reductions.
Optimization of Management Practice Selection
SWAT Predicted Pollutant Load (before Conservation Practices)

- **Phosphorus**
  - TP Load (lb/yr):
    - 0 - 17
    - 18 - 75
    - 76 - 160
    - 161 - 320
    - 321 - 711

- **Nitrogen**
  - TN Load (lb/yr):
    - 0 - 170
    - 171 - 550
    - 551 - 1300
    - 1301 - 2020
    - 2021 - 3700

- **Sediment**
  - Sed. Load (lb/yr):
    - 0 - 32
    - 33 - 110
    - 111 - 210
    - 211 - 400
    - 401 - 660
The process - Overview

A. Stakeholders provide:
   • List of conservation practices to include
   • Water quality goals
   • Cost limits (budget)

B. Modelers provide:
   • SWAT model, calibrated and validated for the watershed

C. Optimization tool:
   • Develops thousands of sets of practices
   • Calculates cost
   • Calculates water quality benefits
   • Identifies greatest benefit for each cost

D. Stakeholders:
   • Receive results
   • Provide feedback on how results can help make watershed decisions
   • Suggest changes to inputs
Final solution is a curve with minimum cost, maximum benefits.
Optimization Results (SJRW)

- Pesticides in the raw water reduced by 30%
- Nutrient levels in the raw water reduced by 50%
- Sediment loading reduced by 50%
- Cedar Creek Watershed Management Plan
Mobile Apps
Summary

• Opportunities to use decision support systems to reduce water and environmental impacts of biofeedstock production (and other land use decisions)
• Can reduce negative impacts of land use and management decisions
• Water resources protection and utilization can be optimized