VIRTUAL WATERSHED: A SPATIAL DECISION SUPPORT SYSTEM FOR AN AGRICULTURAL WATERSHED

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Introduction

Watershed management takes place on a landscape controlled by private landowners. Their decisions will, in large part, reflect economic criteria like profit maximization.

To maintain or enhance ecological integrity, as well as avoid conflict with the land users, watershed management plans should reflect the economic uses to which the privately held land can be put.
Virtual Watershed

- *Virtual Watershed* is a prototype web-based agricultural watershed planning tool based on the Big Creek watershed in Southern Illinois.
- Aimed at helping to explore and gain insight into tradeoffs among:
  - agricultural and environmental policies,
  - landowner decision-making processes,
  - and environmental and economic outcomes.
Big Creek watershed issues

- Identified by ISWS as primary source of sediment in the Lower Cache River (Demissie et al., 1992).
- More than 70% of sediment inflows into the Lower Cache based on 1985-1988 data (Demissie et al., 2001)
- Significant amount of nutrient pollution (NPS)
Integrated System

• The tool combines several important systems-related models
  – multi-objective optimization model (evolutionary algorithms)
  – agent-based model, and
  – environmental/hydrologic simulation model
Conceptual Framework

Decision Environment

- Prices/Policy instruments/ Available technology

Land managers/Agents

- Land use, input, and management decisions at field/farm level 1 to N
- Hydrologic and biophysical characteristics

- Land use pattern and distribution at Watershed level

Economic output

Ecosystem service output

Societal Goal? (Tradeoff)

Modify

Decision maker/Stakeholder

Scientists, Policy makers, Interest groups, Public

Evaluate
Translation from Concept to Model

Four essential modeling requirements:

Representing the socio-economic driving forces or the decision environment? Using scenario analysis and formulating scenarios expressed by relevant parameters

Representing farmers/farm operators response to specific decision environment? Using Agent based model

Simulating the economic and environmental outcomes? Using Environmental/Hydrologic simulation model.

Evaluating performance of each outcome? Using a tradeoff curve or Production Possibility Frontier (PPF)
Integrated modeling Framework

PPF generator (Optimization) model

Biophysical parameters

SWAT  NSGA-II

Policy scenario formulation

Scenario parameters

Farmers as Agents

Land use

Farm input and Biophysical parameters

Agent based model

Hydrologic & Environmental model

Env/Eco outcome

NSGA-II : Non-dominated Sorting Genetic Algorithm II (Deb, 2002)
Production Possibility Frontier (PPF)

• The Production Possibility Frontier is a graph that shows all the combinations of goods (or services) that can be produced at maximum efficiency given a set of inputs (resources, labor, etc.)

• **PPF for Virtual Watershed** constructed based on:
  
  – Two competing alternatives
    
    • Production of Agricultural commodities (indicated by *Crop production index*) and
    
    • Production of Ecosystem services (indicated by *Hydrologic water quality index*)
Hydrologic Simulation Model (SWAT)

- Crop yields
- Nitrogen
- Phosphorus
- Sediment yield
- Peak flow

Multiobjective Optimization Model (Genetic Algorithm)

- Crop type
- Tillage practice
- 3 year rotation

PPF for Bigcreek watershed

Crop production index

Water quality index

PPF Generator Model for optimal land uses
Two dimensional PPF where each point represents a discrete land use pattern with considerably different levels of economic and ecological performance.
Agent Based Model

Endogenous
• Labor & machinery

Exogenous variables
(Scenario parameters)
• Crop prices
• Policies
• Biophysical parameters

Environmental Model

• Crop management
• Field operations
• Biophysical parameters

Output

Land use

Input

Legend
- Hay: Pasture
- Corn
- Soy
- CRP

Legend
- Hay: Pasture
- Corn
- Soy
- CRP

• Crop yields
• Nitrogen
• Phosphorus
• Sediment yield
• Peak flow
• Production Index
• Water quality index
The management problem involves user determination of how policy (e.g., public subsidization and regulation) and price structures can be altered to provide incentives so that to move the landscape closer to the PPF through the improvement space.
Virtual Watershed Web Application Demo

- Virtual Watershed can be accessed at http://vws.erp.siu.edu:90/vws/
- Users define scenarios and submit through the scenario entry form
- Policy scenarios are represented by parameters like crop prices, CRP rental rates and level of soil loss
- Simulation results are then displayed in various views as maps, graphs, and tables.
**VWS Implementation Architecture:**

- Front-end to Back-end interaction
- Back-end inter application communication

**Web Map Service (Mapserver/Geoserver):**
- Config. Files
  - Raster files
  - Vector files
- Web server (Apache)

**Agent Based Model**

**SWAT Model**

**Input**

**Openlayers/Extjs/JQuery/Openfl:**
- AJAX

**Google map service Yahoo map service**

**Python controller**

**RDBMS Postres/PostGIS**

**Back-end 1**

**Back-end 2**

**Front-end**
New Scenario View

Virtual Watershed Application Prototype

Menu
- New Scenario
- PPF Graph View
- Map View
- Table View
- Overview
- About

Details
New Scenario
Create new scenario based on crop prices. Fill out the form and submit, and you can view results in Tabular, Graph, and Map formats. This may take about 5 minutes to run.

Scenario
- Scenario Name:
  - test
- Scenario Description:
  - testing
- Com Price ($/bu):
  - 2.3
- Soybean Price ($/bu):
  - 5.6
- Hay Price ($/ton):
  - 60
- Soil T level compliance:
  - ✓
- If T compliance, what is T value? :
  - 2

CRP Payment
- Checkmark all that apply:
  - Regular CRP rental rate:
  - Hay harvest in CRP
  - Continuation CRP rental rate:
  - Switch grass harvest in CRP
  - Full period in CRP

If regular CRP is checked, what is the rate in $/acre:
  - 68

If continuation of CRP is checked, what is the rate in $/acre:

Available Scenarios
- ID: SCENARIO: ethanol
  - 9774 ethanol: Ethanol loan 438.678.719 0.202881
- ID: SCENARIO: Flood
  - 7366 Flood: Wide spread flood 0.494.027.512 0.435674
- ID: SCENARIO: Flood2
  - 9110 Flood2: testing 232.102.823 0.446889
- ID: SCENARIO: scenario7
  - 9371 scenario7: Testing with ESS 0.427.512 0.476889

Submit  Reset
PPF Graph View 1

This is the graph view of Big Creek watershed. You can view the results of your current scenario run on a PPF graph. Hovering on the graph points will pop up tabular information for that particular point. Clicking on a point will show three year land use distribution.

Hydrologic Water Quality Index (HWI)
3. Hover
4. Click
Virtual Watershed Application Prototype

Map View

This is the map view of Big Break watershed. You can zoom in, zoom out, and click on the map to display info.

Legend:
- Forest
- Urban
- Water
- Corn
- Soybeans
- CRP/Grass
- Alfalfa

Details:

pie chart for gross margin by crop:
- Corn
- Soybean
- CRP
- Alfalfa

Pie chart for soil loss by crop:
- Corn
- Soybean
- CRP
- Alfalfa

Pie chart for carbon sequestered by crop:
- Corn
- Soybean

Pie chart for acre by crop:
- Corn
- Soybean

Available Scenarios:

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>CRP Index</th>
<th>HAI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scenario 1</td>
<td>Flood</td>
<td>436.763719</td>
<td>0.202661</td>
</tr>
<tr>
<td>Scenario 2</td>
<td>Wide spread flood</td>
<td>494.037512</td>
<td>0.436674</td>
</tr>
<tr>
<td>Scenario 3</td>
<td>Testing</td>
<td>232.101823</td>
<td>4.46489</td>
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<tr>
<td>Scenario 4</td>
<td>Average</td>
<td>167.256823</td>
<td>12.3694</td>
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<tr>
<td>Scenario 5</td>
<td>Extreme</td>
<td>1113.65</td>
<td>16.607</td>
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<tr>
<td>Scenario 6</td>
<td>CRP1</td>
<td>1670.23</td>
<td>72.28</td>
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<tr>
<td>Scenario 7</td>
<td>CRP2</td>
<td>1757.58</td>
<td>62.934</td>
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<tr>
<td>Scenario 8</td>
<td>CRP3</td>
<td>1761.8</td>
<td>50.036</td>
</tr>
</tbody>
</table>

http://wss.erp.stuw.edu/wss/prot.php#
Advantages of Web Applications

No special configuration or hardware requirements for the user.
Lower costs.
Centralized data is secure and easy to backup.
Updates can be made quickly and easily.
Information is accessible to a wide audience anywhere in the world.
Everybody has a browser. Familiar interface encourages use.
Web-applications make collaboration easy, as basically everyone is using one “instance” of an application.
Because all activity takes place on your servers you can see how people are using your application.

Source: http://www.pssuk.com/AdvantagesWebApplications.htm