DEVELOPING A GIS-BASED INTEGRATED MODELLING INTERFACE
FOR WATERSHED EVALUATION OF BMPS (WEBS)

WANHONG YANG, UNIVERSITY OF GUELPH

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Canadian Water Network

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WHY DID WE DEVELOP THE WEBS GIS TOOL?

With growing concerns about the adverse environmental effects of agriculture on watersheds, governments have established various conservation programs that provide financial incentives to farmers to implement beneficial management practices (BMPs) that mitigate nutrient runoff and other impacts. However, the benefit to water quantity and quality from the adoption of agricultural BMPs may vary based on the farm's location within the watershed. Information is needed about the costs and environmental impact of BMPs in order to prioritize and assess the benefits of implementation[1].

In recent years, scientists have been examining information on economic costs, water quantity/quality benefits, and cost effectiveness of agricultural BMPs at a watershed scale using farm economic, watershed hydrologic and integrated economic-hydrologic modelling[2, 3]. While these models improve our knowledge on spatial variations and tradeoffs of BMP costs and benefits, they are also complex and not user-friendly for conservation practitioners to examine various scenarios of agricultural BMP adoption[4]. This CWN project further develops the WEBs open source geographic information system (GIS) tool to make BMP modelling systems accessible to agricultural conservation practitioners.

The project builds on two previous projects: "*Hydrologic and Integrated Modelling of South Tobacco Creek Watershed in Southern Manitoba*" funded through AAFC's Watershed Evaluation of BMPs (WEBs) program[5] from 2005 to 2013, and "*Modelling for Evaluating the Economic and Environmental Effects of Multiple BMPs in Gully Creek Watershed in Southwestern Ontario*" funded through OMAFRA's Watershed Based BMP Evaluation (WBBE) program[6] from 2011 to 2013.

HOW DOES THE WEBS GIS MODELLING TOOL WORK?

The GIS interface has two modules to serve BMP assessment needs. In the first module, the users can construct "what if" scenarios simulating the impact of one BMP or multiple BMPs at one or multiple locations (Figure 1). The users can then examine economic costs, water quantity/quality benefits, and cost effectiveness ratios of BMP scenarios using maps, charts, and tables (Figure 2).

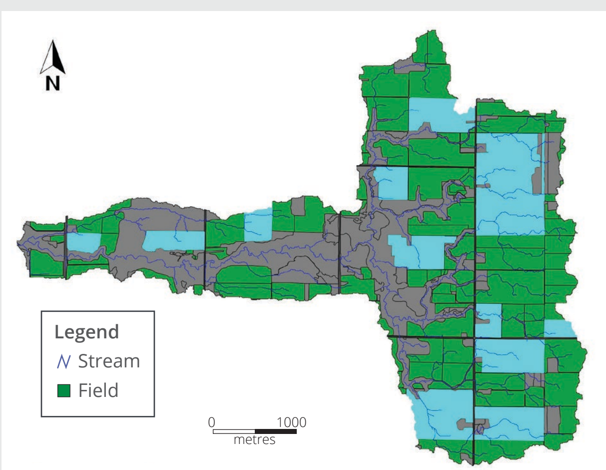

Figure 1. User defined "what if" scenario for multiple locations of conservation tillage BMP.

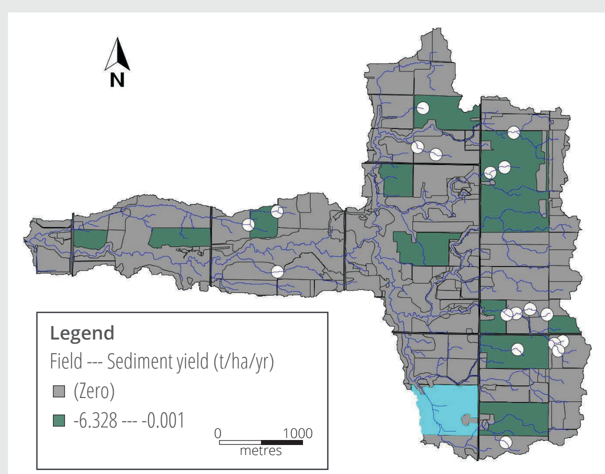

Figure 2. Display of farm economic, watershed hydrologic and integrated modelling results for the conservation tillage BMP scenario

In the second module, conservation extension staff or farmers can use the tool to evaluate various combinations of BMPs within a farm or a watershed, in order to identify BMP policy/management scenarios based on environmental targets — for example, 10 to 20% sediment reductions from base loadings at the watershed outlet. The interface will generate an optimal set of BMPs with locations and types within the watershed to achieve the environmental targets with minimized BMP costs (Figure 3).

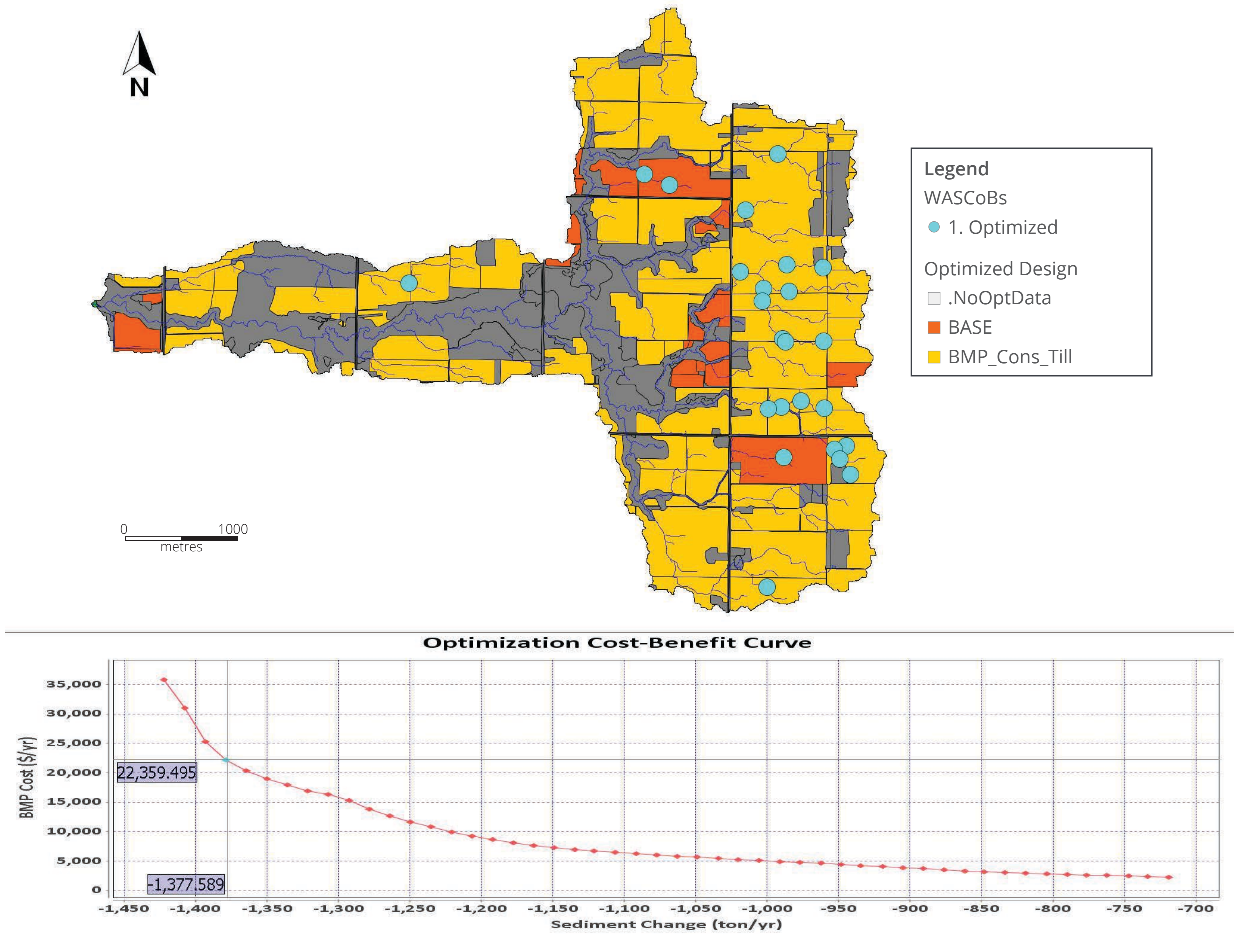

Figure 3. The setup and result display of the policy scenario from 10 to 20% sediment reductions at watershed outlet. The interface shows a map on the optimal set of multiple BMPs in the watershed and a tradeoff curve of BMP costs and sediment abatement benefits for the policy scenario.

The tool can also identify an optimal set of BMPs to maximize environmental benefits subject to financial constraints (e.g. $25,000 budget). All user-defined “what if” BMP scenarios and policy/management scenarios can be compared to each other or to the base scenarios (such as a conventional scenario without BMPs or historical scenario with existing BMPs). The comparisons allow users to identify BMP scenarios to meet various conservation and economic needs.

CASE STUDY:

The WEBs GIS tool was applied to the 15-km^2 Gully Creek watershed in the shoreline areas of Lake Huron and examined the economic costs, water quantity/quality benefits, and cost effectiveness ratios of four representative BMPs (Figure 4):

1. Conservation tillage

The practice of leaving crop residue on the soil surface (rather than ploughing it under) to reduce water runoff and soil erosion.

2. Nutrient management

The task of matching a specific field's soil, climate, and crop management conditions to an optimal rate, source, timing, and placement of land-applied crop nutrients for optimizing nutrient use efficiency, yields, crop quality, and economic returns, while reducing off-site transport of nutrients to the watershed.

3. Cover crops

A crop grown primarily for the protection and enrichment of the soil.

4. Water and sediment control basins (WASCoB):

A structural method of erosion control that involves constructing an earthen embankment across a natural drainageway to intercept surface runoff and then slowly release it into an underground drainage pipe, this helps prevent gully erosion along the natural drainageway and encourages some setting of sediment and nutrients from the ponded water.

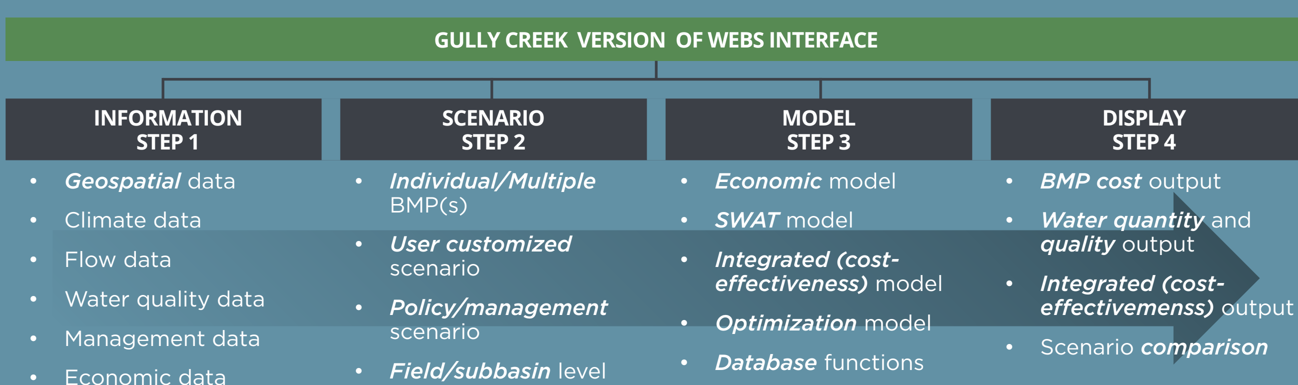

Figure 4. Framework of the Gully Creek version of WEBs GIS tool

THE WEBS GIS TOOL: A STEP-BY-STEP GUIDE

1. INPUT INFORMATION

The first step in using the WEBs GIS tool is to collect information to set up, calibrate and validate the farm economic and watershed hydrologic models, including:

- geospatial data (i.e., DEM, landuse, soil, stream network, watershed and field boundary, location of climate and hydrologic stations)
- climate data
- flow and water quality data
- BMP and agricultural management data
- related agricultural economic data

2. GENERATE SCENARIOS OF BMP ADOPTION

The first module of the scenario component is designed for users to construct "what if" BMP scenarios by defining BMP types and locations from maps or tables. Specified BMPs in the case study watershed (e.g., conservation tillage, nutrient management, cover crop, and water and sediment control basins) are incorporated into the interface for simulating a conventional scenario, as well as historical/existing and future BMP scenarios. Different BMP combinations are defined at field and sub-basin scales.

The second module includes an economic-hydrologic optimization model for prioritizing the cost-effective solutions/scenarios (BMP type and distribution) based on environmental targets or financial constraints.

3. MODEL ECONOMIC AND ENVIRONMENTAL IMPACTS

The modelling component is the engine of the WEBs GIS tool. A suite of computer programs have been developed to automate model parameterization of user-defined BMP scenarios and to run the models to generate outputs on BMP effects. The component includes a farm economic model, a watershed hydrologic model and an integrated economic-hydrologic model to couple both modelling outputs together. Based on the integrated modelling results, the BMP optimization module supports spatial BMP policy/management and decision making.

4. DISPLAY COMPONENT

Once the output data has been generated, the tool displays and analyzes modelling results for specific BMP scenarios in the watershed using maps, charts, and tables. Farm economic, watershed hydrologic, and integrated outputs can be displayed at field or sub-basin scale for the watershed. An on/off site option allows users to view modelling results in each field/sub-basin or at the outlet of the watershed. Users can compare BMP costs, benefits, and cost effectiveness ratios by comparing a defined BMP scenario with a base scenario (such as conventional or historical/existing scenario) or two BMP scenarios.

Comments from WEBs GIS tool users:

It is amazing to see that non-modellers can interact with complex BMP assessment modelling to examine BMP scenarios. A good feature of the interface is to jointly examine both economic costs and water quality benefits, and tradeoffs of agricultural BMPs. The "what if" and "policy/management" scenarios are useful functions for exploring different options of BMP implementation on agricultural landscapes.

WHAT ARE THE BENEFITS FOR USERS OF THE WEBS GIS TOOL?

The development of this tool is one of the first efforts in Canada to make complex modelling operational for watershed evaluation of agricultural BMPs. It has the potential to be transferred to other watersheds, based on three key steps:

- Basic datasets need to be prepared for topography, landuse, land management, soil, climate, water quantity and quality, and BMPs.
- Farm economic, watershed hydrologic and integrated modelling need to be set up, calibrated and validated.
- The open source GIS interface needs to be transferred to the new study site by linking the three modelling components

with the interface and redeveloping the associated databases, and analysis and visualization functions.

The most challenging task for the WEBs GIS tool is the availability of basic datasets. The knowledge developed in this project and previous projects will considerably reduce the resource requirements for transferring the GIS interface for BMP assessment to a new study site.

A series of workshops were held to showcase the WEBs GIS tool to stakeholders and decision makers from government, conservation authorities, non-governmental organizations, farmer associations and universities. Feedback from these workshops was positive and constructive.

In the future, the WEBs GIS tool should be expanded to include more BMPs for use in other watersheds across Canada. Development of an online version of the tool would enable more widespread use. There may also be opportunities to use the tool to communicate to the public about the economic costs, environmental benefits, and cost effectiveness of agricultural BMPs.

TO CONTACT THE RESEARCHER, EMAIL RESEARCHSPOTLIGHT@CWN-RCE.CA.
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REPORT AUTHORED BY WANHONG YANG, UNIVERSITY OF GUELPH

RESEARCH TEAM

WANHONG YANG, University of Guelph
JOHN LINDSAY, University of Guelph
YONGBO LIU, University of Guelph
HUI (SHAWN) SHAO, University of Guelph
ANATOLIY OGINSKYY, University of Guelph
ZHIQIANG YU, University of Guelph
DAVID RADFORD, University of Guelph

PARTNERS

ONTARIO MINISTRY OF AGRICULTURE, FOOD AND RURAL AFFAIRS
AUSABLE BAYFIELD CONSERVATION AUTHORITY
ONTARIO MINISTRY OF THE ENVIRONMENT AND CLIMATE CHANGE
CONSERVATION ONTARIO

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