



Application note

# Extension and enhancement of national agricultural pesticide risk analysis (NAPRA) WWW decision support system to include nutrients

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## Abstract

The nutrient component of the groundwater loading effects of agricultural management systems (GLEAMS) model was incorporated into the original national agricultural pesticide risk analysis (NAPRA) WWW system to create a nutrient loss decision support system to evaluate the effects of agricultural management systems on surface and subsurface nutrient water quality. The NAPRA WWW system (<http://pasture.ecn.purdue.edu/~napra>) was extended to the entire US by adding soil data and weather generator models with supporting input data for the continental US. Thus, the NAPRA WWW system can be run for any location in the US. The nutrient enabled NAPRA WWW system can be accessed from any location with a web browser, and it provides an easy to use interface for model users by simplifying model input preparations. The NAPRA WWW system can be used to identify appropriate nutrient application rates to meet water quality specifications such as total maximum daily loads, and to identify critical watersheds or areas from nutrient management perspectives.

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## 1. Introduction

Many hydrologic and water quality models have been developed and tested to assist with nonpoint source (NPS) pollution reduction efforts (Young et al., 1987; Engel and Lee, 1998; Lim and Engel, 1998). However, these models have limits in preparing their model inputs that are often large and sometimes nearly impossible to prepare for potential users. Therefore, many hydrologic and water quality models, such as areal non point source watershed environment response simulation (ANSWERS) (Rewerts and Engel, 1991), agricultural non point source (AGNPS) (Engel et al., 1993), and soil and water assessment tool (SWAT) (Srinivasan and Arnold, 1994), have been integrated with geographic information system (GIS) tools to assist in preparing model inputs and visualizing model outputs in the form of maps, because the nature of agricultural NPS pollution is essentially spatial. These GIS integrated models have the advantages of ease and efficiency of storing, retrieving and formatting the many types of spatial and tabular data required for hydrologic/water quality modeling (Stallings et al., 1992).

A spatial decision support system (SDSS) is a computer system where GIS and decision support technologies are applied to help decision makers with problems having a spatial dimension (Walsh, 1992). The SDSS can be used to help decision makers develop plans to reduce or mitigate NPS pollution. The SDSS utilizes GIS capabilities to store large amounts of spatial data and other environmental information related to water resources planning and management for use in a decision-making process. However, even decision support systems integrated with GIS tools require expertise to operate, so these systems have been largely limited to use by scientific researchers, and many decision support tools have been unsatisfactory or too complicated for novice users (Mohtar et al., 2000). Thus, it is desirable to deliver sophisticated decision support tools with common interfaces and at no or low cost through the WWW.

To provide wide-spread access to a complex hydrologic/water quality model and to help people understand its results in graphical, tabular and map formats, the nutrient enabled national agricultural pesticide risk analysis (NAPRA) WWW SDSS tool was developed and enhanced. The NAPRA WWW system can be efficiently used to simulate the effects of agricultural management systems on NPS pollutants in surface water and shallow groundwater (Engel and Lee, 1998). This paper introduces the framework of the nutrient enabled NAPRA WWW SDSS and describes how the WWW-based NAPRA system can be effectively and easily used through the WWW.

## 2. Overview of the NAPRA WWW system

The nutrient enabled NAPRA WWW system can be accessed at <http://pasture.ecn.purdue.edu/~napra/>. The main input interface, shown in Fig. 1, can be divided into four major categories: (1) field input; (2) management input; (3) pesticide input; and (4) nutrient input. Crop rotations and multiple pesticide and nutrient

NAPRA - Microsoft Internet Explorer provided by Purdue University

File Edit View Favorites Tools Help

Address http://danpatch.ecn.purdue.edu/~napra/SingleField/mainFrame.html

**NUTRIENT ENABLED NAPRA WWW DECISION SUPPORT SYSTEM**

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[OPTIONS] Crop list size:  Full List  Short List Change will take effect only after reload current page

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**Field Input** -- Choose either STATSGO or NASIS soil data --> NASIS data is only available for Indiana

Scenario Name:  (no space in scenario name!)

Select State:   Landuse/Practice:

STATSGO:  Soil Symbol:  Component:

NASIS:   Soil Symbol:

Slope Length (ft):  Hydrologic Condition:

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**Crop Management Inputs**

Crop 1:  Tillage:  Effective Rooting Depth (in):

Planting Date:   Maturity Date:   Harvest Date:

**Crop 1 Pesticide Inputs**  User Pesticide database  NAPRA Pesticide database

Trade Name	Common Name	% of soil surface covered by residue and vegetation	Application Method	Application Date	Application Rate (lb/ac) Active Ingredient
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text" value="0: Surface Application"/>	<input type="text" value="Jan"/> <input type="text" value="1"/>	<input type="text"/>
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text" value="0: Surface Application"/>	<input type="text" value="Jan"/> <input type="text" value="1"/>	<input type="text"/>

**Crop 1 Nutrient Inputs**

Application Date	Nutrient Type <small>Animal Waste Composition Manure Production</small>	App. Rate UNIT: <input type="text"/>	Application Method
<input type="text" value="Jan"/> <input type="text" value="1"/>	<input type="text" value="FERTILIZER"/>	<input type="text"/>	<input type="text" value="0: Surface application"/>
<input type="text" value="Jan"/> <input type="text" value="1"/>	<input type="text" value="FERTILIZER"/>	<input type="text"/>	<input type="text" value="0: Surface application"/>
<input type="text" value="Jan"/> <input type="text" value="1"/>	<input type="text" value="FERTILIZER"/>	<input type="text"/>	<input type="text" value="0: Surface application"/>
<input type="text" value="Jan"/> <input type="text" value="1"/>	<input type="text" value="FERTILIZER"/>	<input type="text"/>	<input type="text" value="0: Surface application"/>
<input type="text" value="Jan"/> <input type="text" value="1"/>	<input type="text" value="FERTILIZER"/>	<input type="text"/>	<input type="text" value="0: Surface application"/>

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**Output Options** -- Pesticide Toxicity Information:

Toxicity Types:  \* Toxicity times:

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**NAPRA Annual/Daily Version Option** -- Annual Average is a Default:

Annual Average Version  
 Daily Pesticide Mass/Conc. Version  
 Daily Nutrients Mass/Conc. Version

Index = 0 Internet

Fig. 1. The NAPRA WWW main input interface (only a portion of the input interface is shown due to space limitations).

applications for each crop can be simulated. The NAPRA WWW system uses groundwater loading effects of agricultural management systems (GLEAMS) (Knisel and Davis, 1999) as a core model to simulate hydrology, erosion, pesticide and nutrient losses. The pre-processor in the NAPRA WWW system constructs the GLEAMS input files from the user provided crop management, pesticide, and nutrient data in the input interface, by querying databases and by running weather generator models (Fig. 2). The GLEAMS hydrologic/water quality model within the NAPRA WWW system requires numerous soil properties, crop management information for the area of interest, long-term daily temperature and precipitation data, tillage practice data, pesticide properties and nutrient properties. The GLEAMS model is run with these input files, and then a post-processor generates the hydrology, pesticide, and nutrient loss probability of exceedance and historical curves.

The NAPRA WWW system can also be run for county or watershed areas to visualize the spatial variations of pesticide and nutrient losses in surface and shallow groundwater. The NAPRA predicted output obtained from the runs for county/

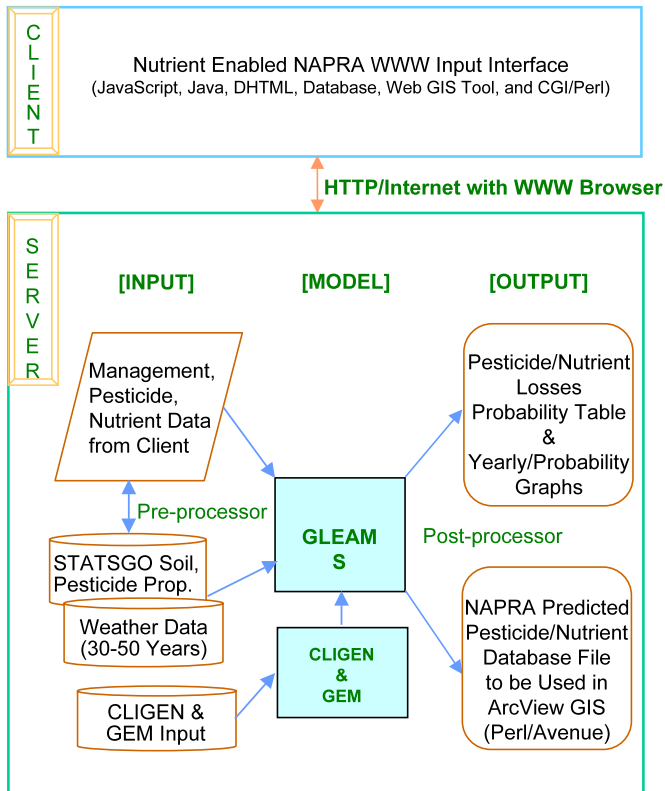


Fig. 2. Overview of the nutrient enabled NAPRA WWW decision support system.

watershed areas can be used to prioritize areas by identifying critical watersheds or areas within watersheds from a nutrient loss perspective.

### 3. Extension and enhancement of the NAPRA WWW system

The original NAPRA WWW system (Engel and Manguerra, 1998) was able to simulate the effects of different agricultural management on hydrology, erosion, and pesticides, but not nutrients. However, many limitations existed in the original NAPRA WWW system. Thus, there were necessities to extend and enhance the original NAPRA WWW system. The nutrient enabled NAPRA system was developed for these reasons. Table 1 shows how the nutrient enabled NAPRA WWW system has been extended and enhanced, compared with the original NAPRA WWW system.

The original NAPRA WWW system could not simulate nutrient losses. Thus, the nutrient component of GLEAMS was added to the NAPRA WWW system by modifying and extending existing NAPRA code. Also, the original NAPRA WWW system could simulate only continuous crops with one pesticide application,

Table 1  
Extensions and enhancements to the NAPRA WWW system

Extension/enhancement	Original NAPRA WWW	Extended enhanced NAPRA WWW
Nutrient simulation	Not enabled	Enabled
Crop rotation	Not enabled	Crop rotations
Multiple pesticide applications	Not enabled	Two pesticides per crop
NASIS soil data	Not provided	All of Indiana
State-wide STATSGO soil	Only Indiana	48 Continental US states
Graphical interface using GIS	Not enabled	Web GIS interface
State-wide weather data	Only Indiana	CLIGEN and GEM models are employed nationwide
Pesticide database	Most widely used pesticides	Search using ‘trade name’ or ‘common name’ for extended group of pesticides
Pesticide active ingredient	Not provided	Linked CDMS database and active ingredient calculator
USLE C value	User needed to estimate	Linked USLE C values with representative tillage
Pesticide human/fish toxicity	Not provided	Plots on pesticide loss graphs
Plotting output graphs	GNUPLOT: required approximately 1.5 min to generate graphs	Java: much faster (few seconds to create graphs)
Output in English/metric unit	Not provided	Provide English/metric units
Model input/output/miscellaneous files	Not provided	Provide model input/output/miscellaneous files for further analysis

although crop rotations and multiple pesticide applications are common. Thus, crop rotations and multiple pesticide application options were added to the nutrient enabled NAPRA WWW system. The original NAPRA WWW contained only Indiana state soil geographic database (STATSGO) soil data. The national soil information system (NASIS, 2001, <http://nasis.nrcs.usda.gov/>) soil data for Indiana were added to the NAPRA database to permit more site-specific NAPRA runs. The STATSGO soil data for the continental US was added to the original NAPRA database to extend NAPRA nationwide.

In the original NAPRA WWW system, model users had to select the area of interest from pull down menus in the input interface. In some instances, it is more convenient to choose the area of interest from a map, rather than a pull down menu. Thus, the nationwide STATSGO soil data is provided through a customized GIS MAPSERVER WWW interface (Mapserver, 2001: <http://mapserver.gis.umn.edu/>), so the user can select the spatial location of interest from the map directly. The Java applet that comes with the MAPSERVER software was modified to include basic GIS functions. The soil parameters required by NAPRA for the selected Map Unit ID are obtained from STATSGO. Relevant soil parameters such as porosity, field capacity, wilting point, organic matter content, and soil erodibility are extracted from a relational database to build the NAPRA WWW input files.

To extend the original NAPRA WWW nationwide, long-term daily weather data for each county are required. It was somewhat hard to obtain long-term daily precipitation and temperature data for tens of locations within each state in the continental US. Therefore, climate generator (CLIGEN, 2001: <http://horizon.nserl.purdue.edu/Cligen>) and generation of weather elements for multiple applications (Johnson et al., 1996; GEM, 2001; GEM homepage: <http://www.nwrc.ars.usda.gov/models/gem/index.html>) were integrated with NAPRA.

The original NAPRA pesticide database contained properties for a limited group of pesticides. Thus, pesticide property data were obtained from the GLEAMS User's Manual and USDA databases, and incorporated into the NAPRA database. The user can search for the pesticide of interest by selecting either the trade name or common name. Based on the pesticide name the user selects after querying the database, the NAPRA WWW queries obtain the pesticide attributes, such as water solubility, organic carbon partitioning coefficient ( $K_{oc}$ ), half-life, and washoff fraction, from the database to construct the NAPRA pesticide component input parameter file.

The NAPRA WWW system primarily focuses on hydrology, and pesticide and nutrient losses in runoff and to shallow groundwater, rather than with soil erosion. In the original NAPRA WWW system, universal soil loss equation (USLE) cropping management (C) factors were one of the most difficult values for NAPRA users to estimate in the input interface. Thus, representative USLE C factors were computed and associated with 15 representative tillage operations. As a result, the user needs to select only a tillage system description rather than provide USLE C values. USLE C factors are used to estimate the soil erosion in the GLEAMS model.

The new NAPRA WWW output interface was developed as shown in Fig. 3. Java applets were used for graphing purposes, because it took too much time to generate

graphs using GNUPLOT (GNU Plotting Software, 2001: <http://www.gnuplot.info/>) in the original NAPRA WWW (Engel and Manguerra, 1998). The post-processor of the NAPRA WWW system generates the hydrology, pesticide, and nutrient loss probability of exceedance and historical curves. The output interface also provides access to all GLEAMS input and output files generated during the model runs. Four GLEAMS input files and four output files are provided, so model users can download and use these data for further analysis if desired.

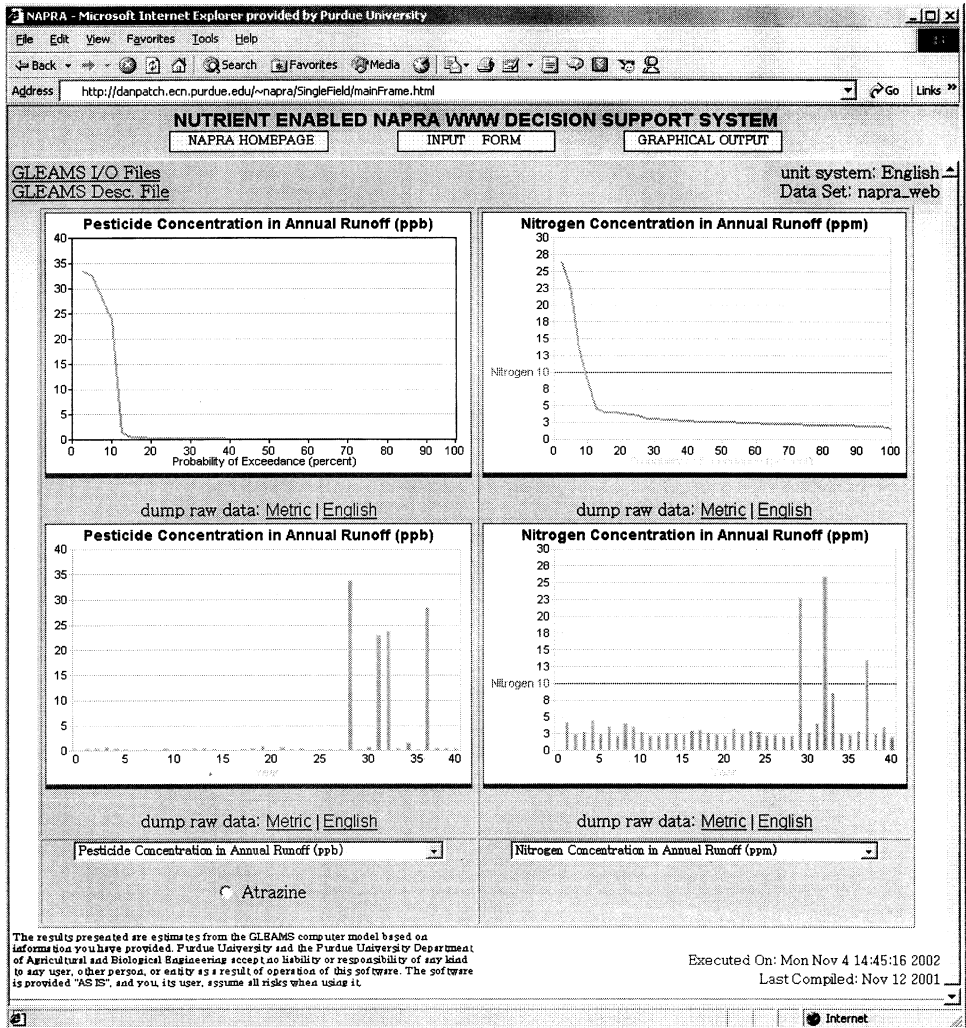


Fig. 3. The output interface of the single field NAPRA WWW system.



Table 2  
User feedback from NAPRA workshops at five locations in Indiana

Please indicate whether the topics listed below were helpful to you	Not Help- ful	←	Helpful	→	Very Helpful
Regulatory overview—when, where, and how have pesticides been used	0	1	9	33	16
Introduction to the NAPRA Tool, GLEAMS model, history, and model development	0	0	8	27	24
Explanation of the NAPRA model—how management changes affect outcomes and BMP’s	0	0	7	27	27
Use of the NAPRA model and discussion of the outputs. Hands-on activities	0	0	2	22	35

*3.1. Advantages of the NAPRA WWW system*

The NAPRA WWW system offers several other advantages in running the GLEAMS hydrologic/water quality model through the WWW versus running it on a desktop computer. First, it can be accessed from any location in the world through a WWW browser. Second, large databases and GIS data are provided on a powerful server that simplifies the model input preparation. Third, all model users access the same version of model, because it is maintained at a single location. Fourth, computationally intensive aspects of the system, when the NAPRA is run for larger areas, are run on a more powerful computer than typically available to most model users. Fifth, the predicted values are presented in tabular and graphical formats, making it easier for users to understand the results quickly.

*3.2. Limitations of the NAPRA WWW system*

Many features have been enhanced in the NAPRA WWW system. However, limitations still exist. All information provided in the NAPRA input interface is assumed to be the same throughout the long-term simulation period. It was assumed that nutrients and pesticides were applied on the same day each year, irrespective of rainfall prior to the pesticide application. Large amounts of nutrients and pesticides may be lost if there is significant rainfall shortly after the application to the field. When the NAPRA system is run for large watersheds or areas, no routing and degradation of pollutants is considered.

**4. NAPRA workshop**

NAPRA workshops were conducted for natural resources and environmental protection personnel at five Indiana locations from 28 February to 12 April 2001. The following are the primary subjects presented in the NAPRA workshops: (1) pesticide regulatory overview; (2) basic concepts of NAPRA/GLEAMS model and history of the model; (3) specific features of NAPRA model; (4) use of management



to reduce NPS pollution; (5) hands-on experience using NAPRA WWW system with case studies using local data sets. More than 98% of workshop participants indicated that the NAPRA workshop was helpful to understand the subjects described above and 43% of participants indicated the workshop was ‘Very Helpful’ (Table 2). Most participants were pleased with the hands-on experience using the NAPRA WWW system, indicating they liked its easy to use interface. Some participants indicated that they could use the NAPRA WWW system for their job immediately due to hands-on experiences. Based on user feedback, the web-based NAPRA WWW tool is an efficient tool for pesticide and nutrient management evaluation.

## 5. Future developments

As described in this paper, a nutrient component was incorporated in the original NAPRA WWW system. If used for livestock waste management purposes, NAPRA users need to estimate appropriate amounts of animal manure application. Software called AMANURE (AMANURE, <http://danpatch.ecn.purdue.edu/~amanure/amanure/frame.html>) was developed (Jones and Sutton, 1999) to provide an estimate of the appropriate agronomic application rates to crop land and to help framers develop manure application plans. Therefore, integrating AMANURE with the NAPRA system would help NAPRA users create appropriate animal manure management plans that consider environmental consequences in addition to agronomic nutrient requirements.

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