A GRAPHICAL TOOL FOR WATER QUALITY CONSERVATION PLANNING

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Abstract

To address agricultural water quality problems farmers must select and implement management systems that reduce the loads of pollutants leaving agricultural fields. The information available to farmers describing the potential effects of management is usually a limiting factor, as the information is qualitative, not customized for the farmer's conditions, and often focused only on erosion. This paper describes an approach to supporting decision makers facing water quality problems by agricultural pollutants and illustrates the approach for an area in northeastern Iowa, in the corn belt of the United States. Observed data from an intensively monitored research site near Nashua, Iowa with 36 one-acre tile-drained plots were used to parameterize the Root Zone Water Quality Model. Management system effects were simulated on crop yields, water and nitrogen budgets, and pesticide losses. These results were put into a database and an internet interface built to analyze the results. The interface presents a series of graphics to the conservationist and farmer showing how alternative management systems affect the agricultural system to reduce the quantity of agricultural pollutants leaving agricultural fields.

Additional Keywords: simulation model, database, water quality, decision support

Introduction

Conservation efforts frequently focus on conserving soil as the initial step in improving the sustainability of agriculture and minimizing negative environmental effects. Water quality is a recognized and growing problem in the Midwestern United States, especially nitrogen, because of failure to meet drinking water standards, ecosystem effects on streams, rivers and lakes, as well as hypoxia in the Gulf of Mexico. To improve water quality farmers need to understand how management practices can reduce the quantities of nutrients leaving fields and have economic incentives or the will to reduce agricultural pollution. Conservationists can help farmers understand the effects of management, but the relationships are complicated and it is difficult to quantify management effects for localized conditions. While conservationists have experience running the Universal Soil Loss Equation, and its successor, the Revised Universal Soil Loss Equation, quantifying the effects of management on other resource issues can require a very involved simulation effort that is beyond the scope of the effort available from conservation planners. This paper describes an approach to simplifying the process of providing good information to producers by having a modelling specialist perform the simulations for the most common resource problems, putting the results in a database, and then allowing the Conservationist to "tell the story" of conservation through a graphical presentation of the information in the database.

Materials and Methods

The Root Zone Water Quality Model (Ahuja *et al*., 2000) was used to simulate the effects of management systems on an experimental site in Nashua, Iowa. A MySQL (2004) database was created and populated with the observed data from Nashua and a preliminary set of simulation results. Queries of the database were written using standard SQL commands to process the raw data into the appropriate format for the graphical presentation. Graphs were then created using the JFreeChart (2004) library of graphics routines in the Java language. As the simulation model, database and graphical tools are all available at no cost, this same approach could be used in other locations, although observed data, as well as simulation and programming skills, are required.

Field sites

The Nashua Research Center is located in north-eastern Iowa and is managed by Iowa State University. The experimental site consists of 36 one-acre plots that are tile drained and monitored for water quality. Three phases of experiments were conducted during the periods 1979-1993, 1993-1998, and 1998 to the present. The crops studied are either continuous corn or a corn-soybean rotation, with different tillage and nutrient management systems. Detailed observations allow modellers to verify a simulation model's ability to simulate many components of the agricultural system, although this dataset suffers from the problems common to large empirical datasets, such as changes in experimental design, missing observations, uncertainty about carryover effects and possible measurement error.

Analysis

Although the approach presented here greatly reduces the time requirements for the Conservationist, the approach has limitations. To populate the database a modelling specialist must define soil and slope groups and sets of management systems that are representative of conditions commonly encountered. Special cases require an additional modelling effort customized to the particular conditions of each case. Another limitation is the complexity inherent in agricultural systems. By combining crop rotations, tillage systems, nutrient and pest management systems, as well as structural conservation practices such as terraces and grassed waterways, there is a combinatorial explosion in the number of systems that can be simulated. Allowing the conservationist flexibility in customizing the presentation for individual soil and slope groups can reduce part of the complexity, but there is an inherent trade-off between the realism of agricultural systems and the ability to show results in a simple, intuitive way. The interface currently consists of predefined graphs that explore simulation results for the hydrology, erosion, nutrient, pesticide and crop production components, either by comparing groups of management systems, individual systems in detail, or simulated versus observed data. If desired, additional statistical information about the simulated versus observed comparison could be useful, but at this stage, only graphs are provided.

Results and Discussion

When considering adopting a management system to improve water quality, farmers are very concerned about the issue of foregone income. Consequently, the model must simulate crop yields well. Figure 1 shows simulated versus observed crop yields for corn and soybeans on one plot over a twelve-year period. The corn yields show more scatter than the soybean yields, with some underprediction, but the simulated long term average yields for a corn soybean rotation should be close enough to the observed for decision making purposes. A budgeting tool known as “EconDocs”, currently under development by the USDA Natural Resources Conservation Service will be used to compare budgets for particular management systems.

Figures 2 and 3 show the observed versus simulated tile flow and nitrogen concentration for Plot 10 in 1993. Simulated tile flow shows a reasonably close fit with observed data, as does the plot of concentrations, indicating the model is doing a good job simulating the very complicated nitrogen dynamics. Graphics such as Figures 2 and 3 show that controlling N loadings will depend on both controlling tile flow and N concentrations.

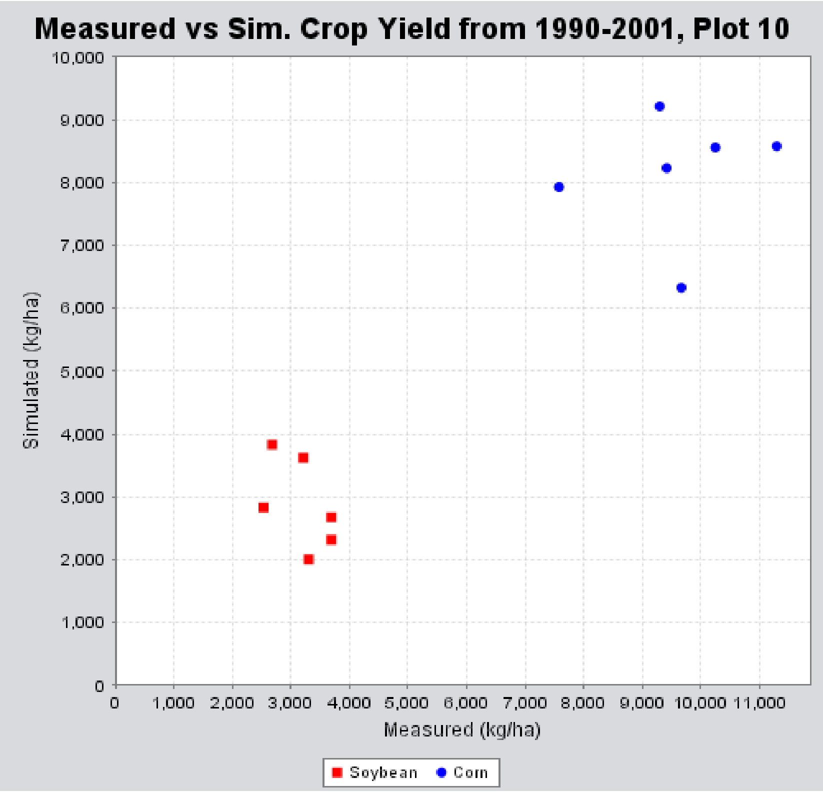

Figure 1. Crop yields are an issue of importance to producers.

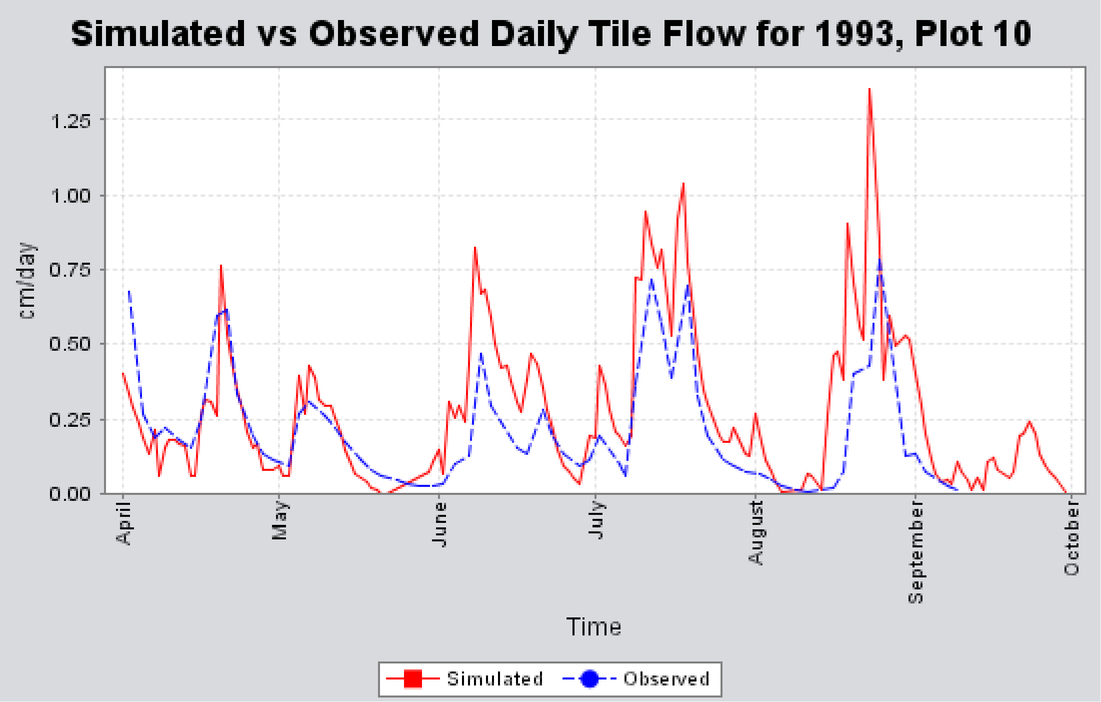

Figure 2. Correctly simulating flow is critical to simulating N movement from tile drains.

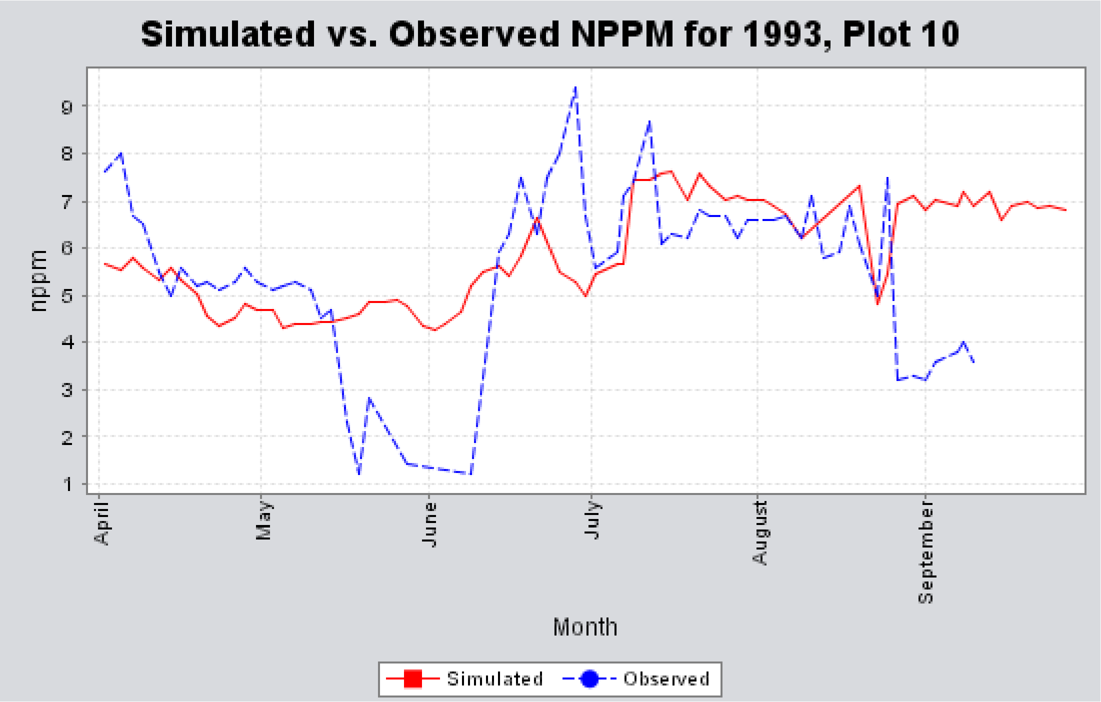

Figure 3. Nitrogen concentration information is also needed to understand nitrogen loading from tile flow.

Figure 4 integrates the information in Figures 2 and 3 to show the average daily loadings for plot 10 in 1993's growing season. The timing of the simulation peaks is similar to the observed, but the simulation peaks and overall volume of N in tile flow underestimate observed N loadings. Additional plots could be used to examine observed and simulated results over longer time periods, simulated results for conservation management systems, as well as other soil or weather conditions. Graphs are available to show the hydrology and water balance, erosion, nutrient and pesticide movement and crop growth.

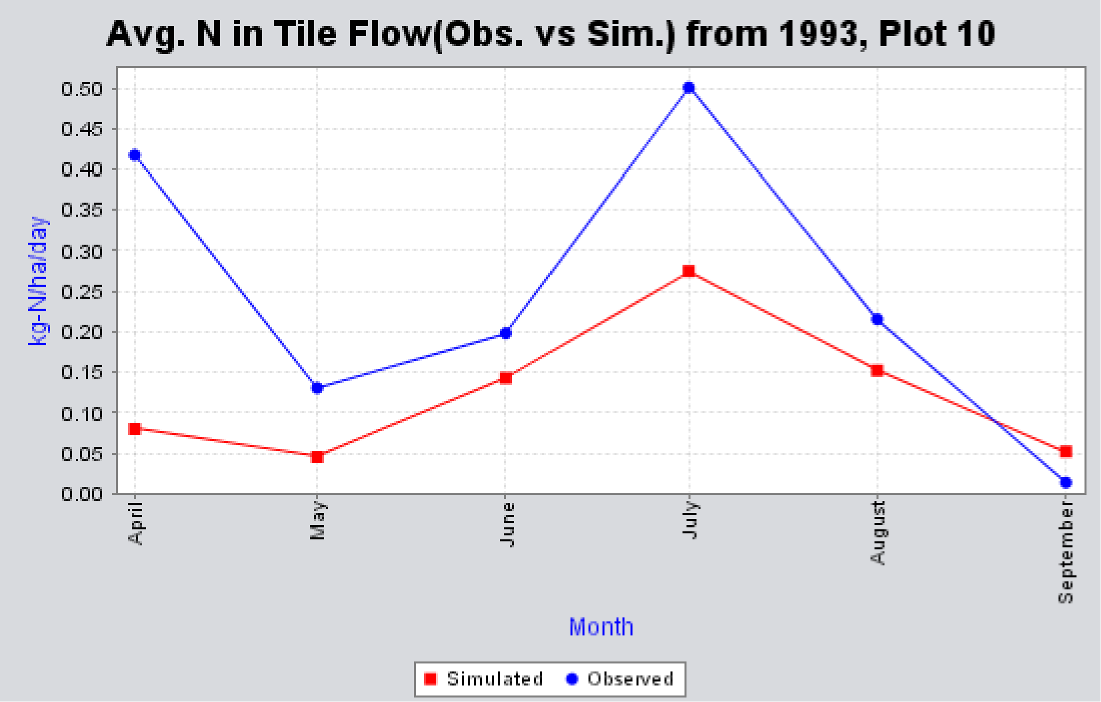

Figure 4. Nitrogen loadings spike in July for plot 10 in 1993.

Conclusions

Space does not permit a systematic description of processes simulated by the RZWQM model for even one management system on a number of pollutants, let alone a complete evaluation of model results versus observed data. Nevertheless, the ability to assess both yields and water quality issues by graphically displaying modeling results from a database is clear. Automated graphical tools are an obvious approach for the assessment of large datasets. Realistically, large datasets are needed to provide conservation information that is quantitative, customized to local conditions and covers effects on a number of natural resources, especially water quality. The advantage of creating a database is that a modeling specialist can invest the time and effort to model management effects on water quality at the field scale. A tool to graphically display the simulation results will help conservationists focus on “telling the story”, or interpreting that information to producers and evaluating the potential for government programs to provide incentives to improve water quality.

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