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Linking Intensive Monitoring Sites to Conservation Planning

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ABSTRACT

A number of developments are converging which may substantially improve the scientific basis available for farmers to make natural resource decisions. The Management System Evaluation Areas (MSEA) have been collecting data, primarily on the effects of management on groundwater, since the early 1990s. A new effort to collect data on a broader range of resource problems is being undertaken at Agricultural Systems for Environmental Quality (ASEQ) sites. Simulation models capable of extrapolating observed data to other areas have been under development for decades. Strides are being made in computer hardware, graphical user interfaces and the databases needed to run simulation models. Multi-objective Decision Support Systems have advanced rapidly in recent years, allowing more systematic consideration of the effects of management on many resources at the farm level during the conservation planning process. Information from the conservation planning process can also be applied to improve research by highlighting the issues important for decision making, particularly the resource problems and management system alternatives that should be observed and simulated. An example showing how observed data, simulation models and Decision Support Systems can improve conservation planning in the deep loess region of western Iowa is presented.

INTRODUCTION

Farmers must integrate information from many sources when selecting management systems. Typically economic issues are very important and farmers will have many years of experience with changes in input costs and output prices. In contrast, information describing the sustainability of management systems and their potential effects on surface and groundwater, animal habitat, and other offsite issues is often difficult to find and incorporate into decision making.

Farmers have an economic incentive to consider sustainability, although the natural resource components of sustainability are often not readily understood. They and their neighbors are often the ones most affected by undesirable environmental effects from agriculture, particularly as it affects groundwater. Those farmers who recognize sustainability and environmental impacts to themselves and their neighbors will often voluntarily adopt management systems to address resource concerns. For other farmers incentives may be required to influence their decision making. In either case, the provision of information relating the effect of alternative management systems on the resources of particular concern could lead to the voluntary adoption of socially preferred management systems.

A basic constraint is the cost of collecting information. Although it would be desirable to perform repeated experiments for all of the alternatives that a farmer is considering, the cost of collecting that information is generally prohibitive. Consequently, expert opinion or findings from similar sites are typically used. As information technology improves, more and better information from these sources could be provided to farmers for management purposes, even though it is likely to be based on more assumptions than a scientist would like to make.

For decades the basis of research and extension has been an attempt to furnish farmers with the state of the art knowledge for decision making, and to improve that understanding over time for future decision making. This paper presents an approach to explicitly link research and decision making through information technology. Databases from intensively monitored sites will be extended using simulation models to quantify the effects of alternative management systems for a number of objectives, including farm income, sustainability and offsite water quality effects. Decision Support System (DSS) technology is proposed to help farmers understand the effects of management and to select management systems as part of a conservation plan. Information from the conservation planning process would then be used to improve the field experiments, models, and Decision Support Systems to improve future decision making.

Intensive Monitoring Sites

Detections of pesticides and nitrate-nitrogen in surface and ground water in the United States prompted concern about the impact of farming practices on water quality. Hallberg (1989) suggested that movement of herbicides and nitrate into groundwater wells would depend upon the intensity of the farming practices and the hydrologic and geologic conditions. Burkart et al. (1999) evaluated vulnerability of shallow groundwater and used GIS tools coupled with hydrologic, geologic, and agronomic factors to determine where sites would be at risk to farming practices. Onstad et al. (1991) described the MSEA research program that was developed with the goal of assessing the impact of farming practices on water quality in the Midwest. The Midwest was selected because of the intensive use of

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herbicides and fertilizer.

Projects were developed in 10 locations throughout the Midwest. These covered a range of tillage systems, crop rotations, fertilizer, and herbicide practices as described by Ward et al. (1994). Studies conducted across these locations collected soil, surface water, ground water, and rainfall samples for the presence of atrazine, alachlor, metolachlor, metribuzin, and nitrate-nitrogen. Concentrations of these agrichemicals were coupled with measurements of meteorological parameters, agronomic practices (time of application, method of application, rate of application, crop cultural practices), and crop growth and yield. These parameters form the basic data set for all of the MSEA locations and data have been collected from 1991 through 1998 at all of the original sites.

These sites range in scale from plot experiments to watershed scale with multiple production fields. The development of the Agricultural Systems for Environmental Quality (ASEQ) program in 1996 focused on orienting the MSEA program to application of the research findings into evaluation of best management practices that would improve environmental quality. There are five sites that have been added to the original MSEA sites for the ASEQ program. These data bases serve as a rich resource for the development of DSS in support of producers needs to have information that relates production goals to environmental quality.

Simulation Models

Simulation models are useful simplifications of reality. When using models to understand the effects of management on water quality, models should represent the major physical processes that determine the effects on the objectives of interest. The objectives will usually include the crop yield and a related estimate of income, as well as indicators of the sustainability and offsite effects of management systems. Ideally, pollutants will be modeled at downstream points where negative effects are observed.

Those physical processes that do not significantly affect objectives are usually ignored. The water balance is a key determinant of crop production and the movement of pollutants. Hatfield et al. (1999) showed that in the Midwest the water balance of the Walnut Creek watershed was primarily divided between crop water use and subsurface drainage. Nitrate loss through the subsurface drains is the primary loss from this watershed and is driven by the yearly water balance. If groundwater contamination is the major concern, root zone processes and issues affecting the movement of pollutants below the root zone (like macropores) are modeled. If surface water contamination is the key concern, then the processes controlling runoff and the transport and deposition of sediment and associated contaminants must be emphasized. If net returns, groundwater and surface water are all considered important, then the modeling effort will have to do well at simulating all aspects of the water balance. Realistically, a suite of models will be needed to keep the modeling effort feasible and at the same time address different objectives and management alternatives over wide areas. Model interfaces can greatly facilitate large scale modeling efforts.

Just as simulation models are simplifications of complex natural systems, so, very often, the data used to parameterize those models are approximations of what physically exists in a given field. Many parameters can be estimated from soil texture, but often a particular texture implies a range of parameter values from which the user selects a single value. Also, most current models assume soils in particular are much more homogeneous than is actually the case across the landscape and over time. Nevertheless, simulation models are the only practical way to apply our collective understanding of how natural systems function and are influenced by management. As shortcomings appear in databases and models both can be improved.

Decision Support Systems

Decision Support Systems (DSSs) are computer programs designed to structure information to help a decision maker select one course of action from several alternatives. Many DSSs have been developed in recent years to address natural resource management issues (El Swaify and Yakowitz, 1998). There are many different approaches, but typically a DSS will provide a mechanism to document how the effects of the alternatives have been estimated and a method to rank alternatives by integrating the effects of the alternatives on a number of objectives.

A DSS should be designed for a particular application, for example to make strategic, long term decisions such as which crop rotation and tillage system to use. Operational decisions, such as when to perform a particular operation could also be supported in another DSS. Scale can also be an issue, as the decision makers and/or alternatives can change at the field, farm and watershed scales. One point often emphasized in the literature is that a DSS does not “make” a decision, but “supports” a human decision maker, usually by highlighting the tradeoffs inherent among the available choices.

There is a natural link between DSS technology and the approach to encouraging the adoption of conservation management systems used by the Natural Resources Conservation Service known as “Conservation Planning.” In conservation planning a trained conservationist works with farmers to help them understand the long term effects of management on natural resources, which are often not apparent. That understanding is then used by the farmer and conservationist to develop a plan that addresses the whole farm to best achieve the farmer’s objectives subject to the available resources of the farm. The goal is a conservation plan that a farmer both understands and implements.

Example: A Field Trial of Decision Support System

The landscape of Iowa is dominated by agriculture. Approximately 31 million of the state's 36 million-acre area is in farms, with 21 million acres in row crop production. Agriculture in Iowa has profound impacts on the state's economy, environment, quality of life, and contributions (both positive and negative) to the rest of the country. These impacts are varied, complex, and interrelated.

Conservationists who provide planning assistance to farmers need to be able to explain the varied and complex impacts of potential agricultural management systems to support more informed decision-making. There is a well-defined process for conservation planning (NRCS, 1996). The first phase, collection and analysis, consists of four steps: identify problems and opportunities, determine objectives, inventory resources, and analyze resource data. The second phase, decision support, consists of three steps: formulating alternatives, evaluating alternatives, and making decisions. Once a plan is developed, the last two steps are implementation and evaluation.

Data from monitoring sites can complement many of the steps in conservation planning. Monitored data could help define regional problems and opportunities, as well as helping to clarify the farmer's objectives. An inventory of resource problems on a particular farm can be done by going through a checklist of potential resource problems known as SWAPA+H, for soils, water, air, plants, animals, and humans. Under each resource there are a number of specific potential problems, each with a quality criterion to determine if, indeed, there is a problem. Data from intensely monitored sites can be used, over time, to make these criteria less qualitative.

Once the resource problems have been identified for a particular farm in the inventory and analysis steps of the planning process, how can a management plan be formulated to treat them? The Conservation Practice Physical Effects (CPPE) tables in the NRCS Field Office Technical Guide are helpful tools in describing the expected impacts of management on a wide range of resource concerns. See Table 1 for an example from the Iowa Field Office Technical Guide (1991).

Table 1. An example of the description of the effect of No-till on sheet and rill erosion from Section V of the NRCS National Field Office Technical Guide.

Conservation Practice Physical Effects			
Resource: A. Soil			
			(a) Sheet and Rill
Practice	Type of Practice	Other Explanations	The movement of soil from water forces, requiring treatment when the soil loss tolerance level is exceeded.
Conservation Tillage	No Till	Provides protective cover and reduces runoff.	Significant decrease [in the sheet and rill problem] because of increase in surface residue cover.

Thus, if sheet and rill erosion has been identified as a problem, by exceeding the soil loss tolerance level, "T", for example, then one option is changing the tillage practice to No till, which is expected to lead to a significant decrease in sheet and rill erosion. The CPPE tables are not automated, and do not support the rapid formulation and evaluation of alternative management systems, consisting of groups of management practices, on multiple resource problems and economic indicators.

The volume of conservation planning assistance needed in Iowa, and across the Midwest, as well as the complexity of agricultural management system impacts, points to the need for automated conservation planning support tools. Any such tool could be called a decision support system, because it would help with the decision support phase of the conservation planning process, specifically the steps of formulating alternatives, evaluating alternatives, and making a decision. Such tools are needed if comprehensive conservation planning assistance is to be provided to significant numbers of farmers in Iowa and other heavily agricultural states.

A Water Quality DSS (WQDSS) was field tested in the Harrison County, Iowa, Natural Resources Conservation Service Field Office in 1998. This particular DSS consisted of a modified version of the GLEAMS simulation model, the CARE economic accounting tool, a model interface, and a multi-objective decision component as described in Yakowitz et al. (1993). The goal of the trial was not to assess this particular DSS for national application, as it requires a Unix operating system. Rather, the primary goal was to determine if a multi-objective DSS could improve conservation planning and to evaluate the response of soil conservationists and farmers to DSS technology.

The WQDSS appeared to provide a good working framework for selecting management systems that incorporate water quality concerns at the field scale. A strength of this framework is the conceptual simplicity of its decision making process. Five soil/slope groups were defined for the steeply sloped, deep loess (wind blown silt) area of Harrison County. A total of 66 management systems were defined for the five soil/slope groups and the effects of those management systems on a number of water quality criteria were simulated based on data in Heilman (1995), which in turn was based on monitored data from the Deep Loess Research Station near Treynor, Iowa.

A table was created for each soil/slope group with columns for a typical management system and several alternatives. Rows of resource concerns (including economic returns) were used to compare the alternatives. The example assumes that an inventory identified the following SWAPA+H resource problems: soil - soil deposition offsite (sediment yield), water - pesticide in surface water (atrazine in runoff) and nitrate N in groundwater (nitrate in percolation), and human – income (net returns). To address the sediment problem, conservation tillage, such as mulch till or no till, is one obvious practice. Similarly, to address the atrazine problem, an alternative herbicide could be used.

Table 2 shows the results of simulating a corn – soybean rotation, with mulch till and no till and the use of two herbicides as the only variations in the management systems. Space prevents consideration of a wider assortment of alternatives here. One way to systematically consider a number of alternatives is to define management systems as combinations of a crop rotation, tillage system, nutrient management system, pesticide management system, and conservation practice (such as terraces or grassed waterways). Quantifying the effects of management on a number of resource problems, for a suite of management systems, using a simulation model is a complex task. Such a simulation effort requires observed data from similar conditions, and a number of assumptions, such as that the climate, topography, soil, and management parameters used and the model representation of the processes are adequate for the decision making task.

Inside the WQDSS, the raw simulation results, from Table 2, and including other resource problems and all 66 management systems, were converted to scores to eliminate units. Thus, creating a table of scores for each soil/slope group that ranged from 0 to 1, where 1 is as desirable as possible. Lastly, an interactive multiple-objective decision making component was used to rank the alternatives, given the relative importance of each of the concerns to a particular decision maker.

Table 2. An example of the quantified estimates of the effects of management on resources by using data from intensive monitoring sites and simulation models.

	Mulch Till Atrazine	Mulch Till Banvel	No Till Atrazine	No Till Banvel
Atrazine in Runoff (g/ha)	4.1	0.0	1.4	0.0
Sediment Yield (Mg/ha)	4.5	4.5	2.7	2.7
Nitrate in Percolation (kg/ha)	5.8	5.8	6.5	6.5
Net Returns ($/ha)	69	58	77	67

The WQDSS successfully incorporated a broad range of natural resource concerns, primarily for water quality, and helped improve understanding of the interrelationships among those resources, by conservationists and farmers. Farmer response to the WQDSS depended in part on the farmer's age, with younger farmers showing much more interest and some older farmers feeling antagonistic. The comfort level of individuals with computer technology also influenced reactions. Farmers wanted to be sure that the simulation results took into account their unique conditions, particularly that net income estimates were realistic. Farmers were enthusiastic about seeing the effects of management on sediment, nutrient and pesticide losses quantified.

In the course of the evaluation, we discovered many different efforts underway to develop components, databases and data collection efforts, simulation models, and decision support systems around country. Unfortunately, there appears to be little overall coordination and the components are generally not designed to interact with each other. A modular approach could allow these components to interact without being re-written. For example, if the multi-objective decision component could accept a table of management systems and resource concerns, many simulation models could be used, each with their own interface as appropriate for local problems.

Future Plans

A cooperative effort between the Agricultural Research Service and the Natural Resources Conservation Service is in the planning stages to pilot-test DSS technology more widely in support of conservation planning. To ensure that the science is sound, this effort will build on data from intensively monitored sites as much as possible. The GLEAMS or EPIC field scale models will be used to assess agricultural contaminants moving toward surface waters and the Root Zone Water Quality Model those issues in locations where groundwater is considered at risk. Computerized multi-objective decision support will also be incorporated into the conservation planning process.

The goal of the cooperative effort is to improve the information available to farmers about the effects of management systems in three ways. First, we will try to automate the provision of quantified information for the common management systems and resource problems at the field scale. Second, we will customize the information to soil-slope groups, although probably not to individual fields. Third, we will make the information as scientifically defensible as possible with a quality review before entering the data in the database.

Recent advances in information technology have the potential to greatly improve the quality of information used to select management systems in agriculture. Observed data, extended with properly calibrated and validated simulation models, can quantify the effects of management on many objectives of interest. Decision Support Systems can put that information into context, to educate farmers and help select management systems as part of a conservation planning process. In many cases farmers may still face economic incentives that favor unsustainable or polluting management systems, but the tradeoffs will be clearer.

A DSS to support farm decision making should also feed back into ongoing research to improve data collection, model refinement and decision support efforts based on farmer response. Linking research and conservation planning through information systems can bring better information to bear on the selection of natural resource management systems, and so help farmers voluntarily improve the management of their natural resources.

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