User Input In Designing And Developing Computer Aided Farm Decision-support Systems

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Decision-support systems (DSS) are becoming an integral part of computer use in agricultural production. Farmers' reluctance to accept DDS can be attributed to several factors including its complexity, unfamiliar terminology, differences in users' background and the narrow scope of recommendations. Based on newly introduced software capabilities, WINGLY, a soybean crop management decision-support system is being expanded and improved upon to select user-friendly features of a new interface system, Graphical User Interface for Crop Simulators (GUICS). In an effort to determine future user's needs, field surveys were conducted to assess user's satisfaction in seven states in the southern United States which are soybean production areas. We found a variety of requests from farmers for changes in the new interface that depended on farm size, the importance of soybean production in the overall mixed farm operations and management strategies. The survey results are allowing us to phase out certain development features and to introduce and select new user-friendly features for the new interface system. The farmers using the model claimed increase in water use efficiency of up to 400% and seed yield increase up to 14-29%. An analysis of survey responses for future users of the new software and new computer-aided farm decision-support systems will be summarized.

INTRODUCTION

Decision-support systems (DSS) have become an integral part of computer use in agriculture. Such systems are ideally suited for solving complex, unstructured decision problems where the decision maker's judgment, personal preferences and beliefs are important (Bennett, 1992). A variety of decision support systems developed to-date include simulation models, expert systems, data bases and their combinations.

In the early stages, DSS development was both driven and limited mainly by the available knowledge and by tools for packaging the knowledge. Based on our observations, it appears that consumers' acceptance is an important factor that may decide the fate of a DSS. The reluctance of farmers to accept DSS has been attributed to their complexity (McGregor and Thornton, 1990), their unfamiliar terminology (Barrett, 1992), differences in the users' backgrounds (Ladewig, 1990; Barrett, 1992), and the narrow scope of recommendations (Rajotte and Bowser, 1989). Customer satisfaction should be an essential system requirement in developing a DSS.

The WINGLY DSS was developed to warn soybean farmers when water deficiency was occurring, and to estimate the probable effect of various irrigation scenarios on soybean yields. The DSS included a mechanistic soybean crop simulator, GLYCIM (Acock and Trent, 1991), and knowledge-based rules for the timing of irrigation. GLYCIM is a mechanistic model that consists of a collection of modules. Each module describes a set of related processes. The model uses an hourly time step which involves downscaling of daily radiation integral, maximum and minimum temperatures, and precipitation to hourly values. Photosynthesis, carbon partitioning, growth, phenology, and loss of tissues are simulated in detail for each organ. Carbon partitioning between shoot and root is a result of a trade between the roots growing to supply water and nutrients, and the shoots growing to supply carbon and assimilates to the plant. A two-dimensional representation of the soil is implemented, and the movement of water, nitrate and oxygen is simulated in the vertical soil cross-section along with soil processes affecting flow with root growth and proliferation. In spite of its complexity, GLYCIM is quite robust. The expert rule to trigger irrigation has been developed during field trials of GLYCIM on farms in the Mississippi Valley during 1991-1993. Irrigation is recommended if soil water is the main limiting factor of crop growth for more than six hours on three consecutive days.

The use of WINGLY was, in essence, an on-farm trial project. It was not a formal, complex research-designed experiment, since such experiments are known to have a number of problems including logistical support, analytical needs, and farmer participation (Lightfoot and Barker, 1988). The farmers were allowed to experiment with WINGLY, and we established as our main research goal the collection of complete validation data sets for the model. There was permanent technical support for WINGLY, and seven users had on site help available on a regular basis. Irrigation schedules were monitored closely.

- asked whether the user would prefer to retain the old DSS or request a new one

In order to research future needs, we requested information on

- output variables that were needed but not available to date,
- the need for mapping tools for input and output,
- the need for resources to be accessed through the Internet.

OBSERVATIONS, RESULTS AND DISCUSSION

All growers responded positively to the survey. Their ages varied from 45 to 75. Their farm size operations varied from medium to large for Mississippi valley farms. Three of the users produced cotton as the main crop, and soybeans were less important. All farm operations were family farms. WINGLY was properly installed and fully functional in the home computers of all the users. The average interval between runs of DSS was three days for two growers, and a week for another two. Three growers ran DSS only once or twice a season, relying on the results of runs conducted by the DSS support group. The frequency of the DSS runs correlated with the computer literacy of the growers and their use of other software packages.

The output variables of most interest were identified as (1) irrigation timing, (2) yield, and (3) maturity date. The irrigation timing appeared to be accurate for all seven cases to within 1-2 days, this was considered to be satisfactory. The predicted yield was within 3 bu/ac in five cases, which was considered satisfactory, and deviated from actual yield by more than 10 bu/ac in the other two cases which was considered unsatisfactory. The maturity date was within four days in six cases, which was considered satisfactory, and deviated more than 10 days in one case which was considered unsatisfactory. The cultivar parameters were not available for one case. Although GYCIM presents data on more than 20 characteristics of the developing crop and its environment, only one grower expressed interest in studying this further.

The preferred output was a single figure for each of the following: the next irrigation date, projected yield, and maturity date. A short summary of the main parameters of crop development was the second choice, time-dependent plant variables and stress indexes were the third choice, and the full model output was the least desired. The farmers who used WINGLY consistently suggested that graphs would be more useful if allowed to compare several scenarios.

The quality of presentation of results in WINGLY was viewed as satisfactory. Fonts and browsing capabilities in the text files were mentioned as being worthy of further attention. The difficulties in operating WINGLY were mentioned mostly by users who seldom used the DSS themselves. Those who used the system themselves frequently mentioned disadvantages in length of time needed to download new weather data, difficulties in comparing the results of different scenarios, and an insufficient number of error messages and warnings. The major concern of all the users was that the initial gathering of information appeared difficult. The main features of the new DSS included the automatic varying of scenarios, the tabular and the graphic output to compare several scenarios, the memos and icons for scenario and data recognition, wizards to assemble scenarios, the accessibility of data for browsing and editing, toolbars to perform the most frequent operations, and the capability of supporting several crop models simultaneously. Two of the growers who were familiar with Windows 95 were able to go through the process of obtaining advice from the DSS immediately after our demonstration. Wizards appeared to help significantly.

The major difficulties in operating GUICS arose because we had not been consistent in implementing Windows shortcut conventions and in including error messages in the wizards. Two users found icons confusing. Guidelines on naming data sets and scenarios and on writing memos were requested. None of the users noted any advantage in combining various scenarios into projects for the on-farm use. Two of the users pointed out the need for preventing data loss from editing. One of the users indicated that garbage accumulation and collection may become issues as data manipulation and deletion becomes easier. An automated update of weather files and tools to generate several predicted weather files were requested. The ability to use several crop models operating under the same DSS interface was accepted. None of the users objected to the replacement of the WINGLY DSS by GUICS provided there was a converter to transform WINGLY data files to GUICS data files.

New variables that the users were interested in adding were mostly related to weed control. An advisory system on weed control seemed to be an essential component lacking. Users mentioned the percent of canopy cover and early warning of predicted stresses as useful information. These data are produced by GLYCIM but are not an output to the DSS. Two users expressed an interest in seed protein content. Economic information was also indicated as an interesting addition, although users were not enthusiastic about bookkeeping with a DSS.

Discussion of the need for mapping tools revealed a variety of interests mostly related to the familiarity of the users with precision farming technology . All users agreed that it would be convenient to use a mapping unit as the kernel of a project relating soil, weather, management, and cultivar data. There was a concern that no services are available to provide the digitized maps and to gather the initial information for the mapping units. Two users indicated that the soil mapping units could be the kernel units whereas one user indicated that a field might be the more appropriate unit. Three users had yield monitors and indicated that the DSS should have the capability of analyzing yield maps. One user pointed out that the accumulation of data eventually may be desirable for a database that would support complex queries. None of the users were aware of Internet resources that could assist them in running the DSS, although all of them expressed interest in information on such resources.

The 1991-96 experimentation period with WINGLY yielded positive results. Up to 400% increase in water use efficiency, and up to 14-29% increase in yields were reported by the participants. This experience led to the accumulation of validation data sets for more than 80 trials that have shown a necessity to introduce cultivar-specific parameters (Reddy et al., 1995), that improved the plant phenology module (Acock et al., 1997).

Annual meetings of farmers and WINGLY developers were held to ensure that improvements in WINGLY performance would be relevant to the users' needs. Although the decision support capabilities of WINGLY were continually enhanced, we found a need to change the user interface of WINGLY to meet the end users' requirements. We were able to outline the system requirements for the new interface, but tried to obtain more specific comments from the end users before the interface was finalized. Therefore, we undertook a survey of the users by giving them hands-on experience with a prototype of the new DSS interface. The objective of this paper is to report the design and the results of this survey.

METHODS

The GUICS Interface

The new interface with the tentative name GUICS (Graphical User Interface for Crop Simulators) runs under WINDOWS 95 and WINDOWS NT and can support many crop models simultaneously. The hierarchy of information units in GUICS is based on the fact that one run of any crop simulator makes predictions for a particular combination of weather, soil, crop cultivar, and farm operations. Such a combination is referred to as a scenario. Data on weather, soil, and weed control, etc. are referred to as data sets of a scenario. Several related scenarios may be combined in a group that is called a project. Any scenario belongs to a project. Similar data sets, e.g., weather data, belong to the same data category.

GUICS runs a crop simulator after arranging the input data for one or for several scenarios according to the user's request. GUICS displays the results in graphic, tabular, and text forms. If several scenarios are of interest, the tables and graphs will display results of all scenarios simultaneously to facilitate a comparison of results. Several ways to visualize the results are available. A toolbar is included to simplify viewing results.

Copying, deleting, and editing functions are available at all levels of the 'project-scenario-data set' hierarchy. Several additional functions are specific to a level of the hierarchy. At the scenario level, a user can vary the scenario. For example, it can generate a set of scenarios differing in one data set only. At the data set level, calling a weather station to update weather data set is possible. Each information unit (a project, scenario, data set) has a name, and may have an icon and a memo. A memo is a text description of a unit. Both the icon and the memo are meant to simplify recognizing a unit. The interface has a set of wizards to guide a user through all stages of project development, scenario assembly, viewing results, and editing data sets. On-line help is included and a guided tour will be included in future developments.

GUICS interacts with a crop simulator as with a stand alone code. Scripts need to be written to connect a simulator into GUICS. The scripts describe the structure of input and output data sets specific to a particular simulator. Authors may want to modify the output of their simulators to take advantage of the capabilities of GUICS in viewing results. There are no standard data sets for crop simulators. GUICS allows different simulators to have different data sets for the same data category, for example, different soil files for the same field. GUICS has a fully object-oriented design and implementation. It is open to enhancements and further development, e.g., using maps, displaying animation, using data bases to store data sets, etc.

DESIGN OF THE SURVEY

The objectives of the survey were formulated in terms of a customer satisfaction study (Naumann, 1995) and were threefold: a) to assess the users' satisfaction with WINGLY, b) to predict acceptance of the new interface, and c) to research future needs. This survey of seven users was designed to include all the farmers presently using GLYCIM/WINGLY for soybean crop management at the farm level. As the model becomes used by a larger group, a detailed survey using a larger number of growers may be conducted to make needed adjustments to the new GUICS. We ensured that each question was answered completely, and that all participants contacted, responded (Dillman, 1989). The survey was conducted in the form of a one-to-one interview with hands-on experience of a prototype interface loaded onto a laptop computer.

In order to assess the end users' satisfaction, we specifically requested each participant to

- inform us on how often the DSS was used
- list the output variables available in WINGLY in the order of importance to the user
- estimate any error in WINGLY predictions for the variables that were accepted
- inform us on how accurate the WINGLY predictions were for each variable
- list the types of output available in WINGLY (graphic, single number, summary, full history of the crop development) in order of their usability
- assess the quality of the presentation of results
- assess operational difficulties of the DSS
- assess the safety and security of the data in WINGLY

In order to predict the acceptance of the new interface, GUICS, we

- outlined the features of the new interface
- demonstrated how to obtain advice from the DSS
- asked the user to go through the entire process of obtaining advice from the DSS by oneself, and recorded all the difficulties the user experienced
- asked the user to identify inconveniences, and discussed the usability of the new features with the user

CONCLUSIONS AND RECOMMENDATIONS

Since our earlier experience with WINGLY had been utilized in developing the new GUICS DSS, we were not overwhelmed by the comments of the users and were able to focus their attention on several new features and to let them go through the whole process of seeking advice from the DSS. Still, we found that we had overlooked several essential elements in the setup of the interface, accessibility of data and results, ergonomics, coping with human errors, and facilitating data recognition. The survey proved to be very useful.

The group of users that participated in the survey had previous experience with WINGLY and found it useful. They were willing to learn the new GUICS DSS with its enhanced capabilities, and to upgrade their computers if necessary. Their main concern was the absence of a service for gathering the initial information on soils and cultivars. We can now see that a DSS support service will be needed if this group of users expands rapidly.

Although GUICS should serve its purpose as a decision-aid for soybean crop management, the survey indicated that GIS capabilities will be an essential part of future decision support systems for crop growers. Development of model components for DSS that will be able to utilize information from yield monitoring, grid sampling, and remote sensing seems to be an important future direction for crop modeling research.

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