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Developing Appropriate Technology for Small-scale Farming Populations

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Abstract. GLYCIM/GUICS, a contemporary crop stimulation model, has been used to increase efficiency of crop management, yield prediction, increase profits, and manage resources on large–scale soybean farms. In an effort to develop and test efficient soybean models for small farmers in the mid south, USDA-ARS assigned a cooperative agreement with Florida Agricultural and Mechanical University, an 1890 Land Grant Institution. Approximately 90% of the world's farming populations are small farmers. This research effort will generate national and international agricultural research interest, especially as community collaborators and development agencies seek out hands-on participatory approaches. This research will provide knowledge as to how large-scale farm computer crop model technology may be modified to benefit small-scale farming populations. It will examine access to information and communication technology for underserved populations.

Keywords: Computer plant simulations, Decision support systems, Community informatics, Small farms, Pilot study.

1. Introduction

The development and application of new technologies applicable to small-scale farming enterprises is a continuing need to maintain the sustainability of these farms. In addition to developing relevant technologies, challenges must be overcome to transfer these technologies to farmers (Ballantyne, 1987; Leagans, 1979). The small farmer faces similar problems as those of larger agricultural enterprises. These problems include uncertainties in markets and weather, the need for pre-plant decisions on variety selection and row spacing, allocation of resources including fertilizer and equipment to maximize crop growth and yield and timely harvest. Smaller farmers may have more limited choices, however, due to limited resources and/or land area. Farm operations may also present more risk since the smaller size of the operation may not buffer the grower against failure due to disease, insects, weather or markets.

Tools that allow a farmer to better evaluate risk would be a useful component in the small-farm operation. One such tool would be a computer. Computer use has been growing among the farming population. Myers (2001) reported that Maryland, farmers were third in Internet access and fourth in on-farm computer use in the US. Maryland farmers used their computers for several integrated purposes including, "record-keeping assistance, purchasing equipment, supplies and farm inputs, commodity marketing and trading, collecting information before making local purchases; and precision agriculture. Precision agriculture technology allowed farmers to analyze a field for the plant and environmental factors that affect individual area yield and control of inputs". Potential benefits of precision agriculture include higher yields, lower production costs, less pollution through poor use of chemicals, better information for management decisions and better farm records essential for business planning. Hough, Ascough, and Frasier (2001) surveyed computer use among US Great Plain producers to analyze characteristics of adopters and non-adopters. Their research suggested that though, "education,

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age/experience, and other farm characteristics were important, future research and education could focus on when and where computers are most needed, and therefore when adoption is most appropriate".

As personal computers have become more widely available, there has been an effort among agricultural researchers to provide computer-based tools to help manage and synthesize information. One of these tools is a computer simulation model of crop growth and development. Researchers develop equations that predict how plants respond to light and temperature, and soil properties and code them into a computer language. The computer mimics the plant growth processes as they respond to light and soil properties. The main reason for using computer simulation models on farms is to increase profit and manage resources, although learning more about how crops respond to environmental factors, and help in complying with governmental regulations are also important. Furthermore, the ability to compare the probable outcomes of different decisions can help a producer make a more informed choice and reduce risk in the face of future uncertainties.

2. Decision support systems

Computer programs to help growers manage data and carry out calculations have been called Decision Support Systems (DSS). Such systems are ideally suited for helping to solve complex, unstructured decision problems. Crop simulation models are increasingly available as part of Decision support systems (DSS) for use in personal computers (PC). For example DSSAT, COMAX, and AGVISER are comprehensive crop management packages developed in the US, Netherlands and UK respectively. GOSSYM (Baker et al., 1983; Landivar et al., 1989) was one of the first simulation model based DSS for cotton crops in the USA. GOSSYM was combined with an expert system called GOSSYM-COMAX where rule based reasoning was used to interpret simulation results (McKinion and Lemmon, 1985). A computer network based crop management for wheat and other summer crops in Australia is SIRAGCROP (Anbumozhi et al., 2003).

3. GLYCIM/GUICS – Decision support system

Soybeans are a particularly important crop for small enterprise farmers. Soybean (Glycine max) a leguminous plant is one of the world's primary providers of protein and oil. In 2000, approximately 56% of the world oilseed production was due to soybeans. Other oilseeds sharing world production figures included 23% due to rapeseed and cottonseed; and 20% due to peanut, sunflower seed, copra, and palm kernel. It has low nitrogen requirements and can provide fodder as well as grain.

A DSS called GLYCIM/GUICS (Timlin et al., 2003) that simulates soybean growth and yield may be a promising tool for small farmers. The soybean simulation model, GLYCIM, has highly mechanistic, dynamic representations of plant growth, development and yield, soil and weather processes. The mechanism involved in the physical and physiological processes in soybean and its environment are mathematically described in GLYCIM. These processes include light interception, carbon and nitrogen fixation, organ initiation, growth and abscission, and flows of water, nutrients, heat, and oxygen in the soil (Acock et al., 1985; Acock and Trent, 1991).

GLYCIM has been designed to simulate the growth of any cultivar on any soil and at any location and time of year. Simulations are initiated at the cotyledonary stage with appropriate data on the number, size, and weight of organs on the plant. Plant growth in size and phenological stage are predicted by the model. During simulation, GLYCIM provides predicted values for most of the physiological variables. It also simulates nitrogen contents of various organs on the plant and water and nitrogen status of the soil. The model provides the dry weights of all plant parts and final seed yield.

The environmental inputs necessary to run GLYCIM are solar radiation, maximum and minimum air temperature, rainfall, and wind speed. The model also uses wet and dry bulb temperature if available and has the capability to use either hourly or daily data. GLYCIM also needs information on the physical and hydraulic properties of the soil, maturity group of the cultivar, latitude of the field, date of emergence, row spacing, plant population within a row, row orientation, irrigation amount, method and date, and CO2 concentration in the atmosphere.

Since the 1991 growing season, GLYCIM has been used by farmers for crop management and input optimization in the Mississippi Valley region of the U.S (Timlin et al., 2003). The model is being used for selecting cultivar, row spacing, plant population and planting date prior to planting, and for post-planting decisions such as irrigation scheduling, insect control, harvest timing, and forecasting of final yield (Reddy et al., 1995). The model helps farmers to optimize inputs and maximize profits. As GLYCIM was used on-farm, an interface was developed for it and this interface has evolved over time.

4. On-farm experiences with GLYCIM/GUICS

Large-scale farmers have used GLYCIM for pre-plant (strategic) planning decisions, for example the selection of cultivar/soil type combination, planting date, row spacing and post-plant (tactical) decisions/irrigation scheduling, harvest timing and yield prediction. One farmer found that the interface allowed him to make yield and growing season comparisons among varieties and soils and began using the model to make pre-plant decisions (Remy, 1994). Another farmer has said he doesn't plant a field that he hasn't tested with model runs before hand (Remy, 1994). He runs scenarios and compares estimated yields and harvest dates to test for soil, cultivar, and row spacing interactions. The farmer uses different weather records from his farm, and irrigation schedules to get the best-simulated production.

According to the cooperating large-scale farmers, the use of the GLYCIM/GUICS for crop management decision-making, and input optimization has increased profits and resulted in more efficient water use by the farmers (Remy, 1994). In a survey by Mississippi State University, the soybean farmers using GLYCIM/GUICS attributed an increase in soybean yields of up to 29% and irrigation use efficiency of up to 400% to the use of GLYCIM (Remy, 1994). Many of the soils in the Mississippi Valley are shrinking and swelling clays. Large cracks form as these soils dry. Traditionally, farmers would not irrigate until they began to observe cracks, although the soybean plants were already beginning to be stressed. The model alerts the farmers to irrigate earlier than their traditional practice. Farmers reported that before using GLYCIM to schedule irrigation they started watering too late and quit too early (Manning, 1996). By irrigating earlier, water stress to the soybeans is alleviated and less water is lost to deep drainage through the cracks. The soil also wets up faster and takes less time to irrigate; this increases irrigation efficiency. One farmer reported that irrigation time on a cracking clay soil went from 4-5 days to 30 hours by irrigating earlier as recommended by GLYCIM/GUICS. Another farmer, after noticing how much yield loss the model was predicting due to moisture stress, purchased an additional irrigation system realizing that it would pay for itself through increased yield.

5. Small–scale Farms

The majority of farms in the United States are small farms (Ikerd, 2002). Ikerd indicated that approximately 80% of all U.S. farms are defined as small farms. These are serious farming operations not hobby farms or rural residences. Generally, small farmers have not had an opportunity to participate in education and training designed for large-scale farming populations. Small farmers need an opportunity to make informed decisions in managing their farm enterprises more efficiently.

In an effort to develop and test efficient soybean models for small farmers in the mid-south, USDA-ARS assigned a cooperative agreement with Florida Agricultural & Mechanical University (FAMU), 1890 Land Grant Institution, to test crop simulation models and to develop a participant-oriented small farm validated crop model. Small-scale soybean farmers from the western region of Florida were selected to participate in the pilot project.

6. Conclusions

During the first year of the pilot project (2003) two small-scale soybean farmers were identified and selected to participate in the pilot project. Their small farms were located in the western region of Florida, USA.
The following on-farm data were collected and used for model validation and development of cultivar parameters of the models: soil samples, plant emergence, plant vegetative and reproductive stages, dry matter, and yield. Weather data was collected from the local weather stations.

Research suggested that soybean production may become more profitable for small farmers trained to use the GLYCIM/GUICS computer program. Year one GLYCIM analysis of the data collected provided two scenarios for Farmer A and Farmer B. The parameterization is not complete. Qualitative data collected provided narrative information on farm diversity, years farming, irrigation practices, planting and harvest dates, yield, soybean acreage, approximate income, etc. The participating farmers produced soybeans under rain-fed conditions.

The second year of the pilot study will begin with the 2004 soybean season. Florida A&M University and USDA-ARS will continue to work jointly to test crop simulation models and to develop a participant-oriented small farm validated crop model that will be effectively used by small farmers to enhance their enterprise. On-farm validation data and qualitative farmer data will be collected. The second year will include farmer training, farmer usage of the GLYCIM/GUICS model, and farmer input/feedback, farmer-benefits.

Approximately 90% of the world's farming populations are small farmers. This research effort will generate national and international agricultural research interest; especially as community collaborators and development agencies seek out hands-on participatory approaches. This research will provide knowledge as to how large-scale farm computer crop model technology may be modified to benefit small-scale farming populations.

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Jennifer E. Taylor received her Ph.D. from Virginia Polytechnic Institute and State University. Her research interests include the evaluation of agricultural development in light of sustainable development/Agenda 21 and related global documents. Her focus is in the implementation of effective participatory-capacity building for underserved populations. Jennifer Taylor is the Coordinator of Small Farm Programs and is the Program Leader for Agricultural Technology Education B.S. Degree Program (Agricultural Communications, Natural Resources and Environmental Management, and Leadership and Extension) at Florida Agricultural and Mechanical University.

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Dennis Timlin received his PhD from Cornell University in 1986. By training he is a soil physicist and a biologist which leads to his interest in biophysics. Dennis Timlin's research is directed toward understanding the fundamentals of physical and biological soil processes and their interaction over a range of scales, from the plant to the field. He is interested in how plants and their environment interact and how to quantify that interaction using mathematical relationships and simulation modeling. He is also interested in plant-soil relationships at both the plant and field scale. Another facet of Dennis Timlin's work is the study of spatial relationships among soil and landscape properties such as soil texture and soil surface curvature, and crop growth and yield.

Vangimalla R. Reddy, received his PhD from Mississippi State University. Presently he is the Plant Physiologist/Research Leader, at USDA/ARS Alternate Crops and Systems Laboratory, Beltsville, MD. Vangimalla Reddy's research has focused on photosynthesis, respiration, carbon and nitrogen metabolism and growth analysis of cotton and soybean crops in response to temperature, CO_2-enrichment, drought, and growth regulators. His responsibilities include developing and applying advanced systems theory to the solution of complex problems by the development of computer-aided farm decision-support systems. Results of these studies will be used to develop process level crop simulation models sensitive to the CO_2 concentrations, temperature, water and nutrient levels. Vangimalla Reddy provides team leadership in the development, testing and use of crop simulation models to make predictions about the effects of climate, soil and various management practices on crop yield, plant physiological processes and ground water pollution.