GOSSYM/COMAX--THE QUIXOTIC QUEST

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Abstract

GOSSYM/COMAX, the cotton crop simulation model and Cotton MAnagement eXpert system, is an excellent example of a successful technology transfer of collaborative research work from USDA-ARS-CSRU, Clemson University and Mississippi State University. It was hailed as an innovative approach to cotton crop production when it was first introduced in mid-1980s. Its success lies in its state-of-the-art effective utilization of the latest research on the growth and development of cotton, weather stations and personal computers. Extension agents were encouraged to demonstrate and use the system to help their constituents in the management of their cotton crop. Despite GOSSYM/COMAX limitations, it has gained popularity not only in the US cotton belt but also in countries like France and China. The system is continuously being improved--with the addition of an insect model (rbWHIMS), AGBOOK and now as part of a precision agriculture project that will provide links to GPS and GIS. The number of users--researchers, consultants and producers-- reached its peak in the early 1990s. However, in spite of all the efforts put into the system to make it more user-friendly and accommodating to users' suggested improvements, it is slowly losing its ground as a management tool. Primary sources of dicontent and apathy in the use of GOSSYM/COMAX were related to the amount of data and time required to run the system, the cost of hardware and software, and the lack of technical support.

Introduction

US agriculture is among the most productive in the world. This high level of productivity, achieved through heavy use of chemicals for fertilizers and pest control, irrigation water and modern varieties, has also caused the loss of rural communities, degradation of the resource base, increased reliance on purchased inputs and increased regulations (Bezdicek and DePhelps, 1994). "Biotechnology and infotechnology may cause even greater changes than those produced by the combined mechanical and chemical innovations of the twentieth century" (Stauber, 1994). With reduced rural population and increased concerns about food safety and the environment, a new concept for agriculture is emerging.

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Crop models have been developed to serve as educational, research and management tools. Each crop model varies in degree of sophistication and reflects the current understanding of crop growth and development. There are crop models for cotton, wheat, soybean, rice, peanut, corn, potato, etc. Some are appropriate more for strategic planning while others like GOSSYM and GLYCIM, cotton and soybean crop models respectively, are suited for tactical purposes.

Crop Model: GOSSYM/COMAX

GOSSYM/COMAX, the cotton simulation model and *CO*tton *MA*nagement eXpert system, is a result of continuing research efforts since the early 1970's by a multi-disciplinary team at Mississippi State University, Clemson University and the USDA-ARS Crop Simulation Research Unit (CSRU). Because GOSSYM is a process-level, material-balance computer model, it requires constants and rate coefficients that are obtained under closely controlled environmental conditions, called the Soil Plant Atmosphere Research (SPAR) units (Phene, et. al., 1978, McKinion, 1986). GOSSYM simulates the basic biological and physical processes involved in the growth, development and yield of cotton over a wide range of soils and climates (Baker, et.al., 1983, Baker and Landivar, 1991, Boone, et.al., 1995). It uses the farmer's cultural practices (i.e., planting density, row spacing, variety, preplant fertilizer applications, date of crop emergence, in-season fertilizer, irrigation and plant growth regulators applications), soil physical characteristics (i.e., bulk density, hydraulic properties and initial fertility and moisture status), and daily weather data (i.e., maximum and minimum temperature, total solar radiation, rainfall and wind) obtained from a weather station accessed by the user's computer via a modem. It provides a status report on simulated plant height; number of fruiting nodes and vegetative nodes; number of squares, green bolls, open bolls and abscised fruits; and carbohydrate, nitrogen and water stresses as often as daily. A summary table at the end of a full-season run presents the date of maturity, plant height, LAI, yield and the number of nodes, squares, green bolls and open bolls at each designated developmental event.

COMAX, added in 1984, is designed to improve the efficiency in using the GOSSYM simulation and to automate the use of the GOSSYM model for making management recommendations for the cotton crop. To make management recommendations, COMAX uses a set of rules based on the expert knowledge of the GOSSYM model builders on the use and interpretation of model results. It provides three types of analysis of field profiles: advisors, scenarios and risk analyses. The advisors use a set of if-then rules to formulate different strategies for fertilizing and irrigating. It then uses GOSSYM simulation runs to evaluate the impacts of certain cotton management decisions. After a series of optimization runs, specific recommendations on irrigation or fertilization are generated.

Strategies for nitrogen analysis include stress relief and risk analysis while for irrigation, three are included--long-term, short-term and water conservation. To increase the flexibility of the system over the wide variety of cultural practices encountered across the Cotton Belt, COMAX uses local expertise supplied by users to adapt the rules to different cultural conditions.

Since the PIX, PREP and defoliation advisors are under development, the scenario options can be used as GOSSYM information managers. The PIX and Crop Termination Scenario options run the GOSSYM simulator for several weather scenarios with a set of user-specified inputs and provide a summary output comparing the selected scenarios (AGBIT, 1995).

rbWHIMS, developed in 1991, is a rule-based expert system designed to assist farm managers, consultants, or extension personnel in making decisions on cotton arthropod pests in the Midsouth. It models dynamic pest associations through the season by partitioning the season into nine distinct plant growth stages. These stages are determined by crop phenological events that have significant effects on pest population dynamics and management. Pest management is very data intensive and demands high quality information acquired with minimal use of resources. Therefore, the system has been designed to utilize the latest methods in sampling and statistical research, including line-intercept and quadrat sampling methods. The 1995 version has a Windows™ based graphical user interface and makes management recommendations on 13 arthropod pest species (D.C. Akins, 1996, personal communication).

Today, GOSSYM is the only cotton crop model used routinely in commercial crop production. It is used as a decision aid for fertilizer application, irrigation, crop growth regulator applications, crop growth terminator applications, planting and harvesting. The GOSSYM model has been validated against numerous comprehensive data sets. The validation tests consist of checking model prediction against actual phenological events such as time of first square, time of first bloom, and time of first open boll. More detailed tests compare model predictions of plant height, number of main stem nodes, leaf area index, stem weight, leaf weight and fruit weight over time to weekly field plot measurements of the same parameters. GOSSYM has been validated across multiple varieties, regions, climates and soils (yield data comparison for several variety classes across the US is shown in Table 1). The GOSSYM/COMAX system now has detailed soil physical property information on over 350 cotton soils.

Despite the constant updates of GOSSYM-COMAX, it is still far from perfect. Factors unaccounted for by the model can influence the growth of the crop. These include herbicide injury, nematodes, plant pathogens, insect pests, deficits of mineral nutrients other than nitrogen, and weather events, (e.g., high winds which cause lodging and hail damage). Consequently, periodic plant mapping data and visual field observations can be used to adjust the simulation results and still use the model effectively when non- modeled issues corrupt the simulation.

Field Adoption History

GOSSYM/COMAX system was first pilot tested in the field in 1984--one in South Carolina and the other in Mississippi. Two years later, the system was released for use in other fields. The research team at CSRU shouldered the additional tasks of training, field monitoring and attending to the users' problems and concerns on the system's performance. By 1989 the GOSSYM/COMAX Information Unit (GCIU) had been created to serve as the national center to handle the training and other support services needed to facilitate the field adoption of the system across the cotton belt. GCIU was supported by government grants.

GCIU offered training and retraining courses by mid-February of each year at a cost of $350 for the 3-day training, which includes the training and the software. The number of users trained by GCIU peaked in the 1991-1992 period and slowly declined thereafter. By 1994, when GCIU was privatized into AGBIT, more users were lost. The system was offered at a cost of $6000 to consultants and $3000 to producers and free to cooperating research partners.

Initially the cost of the system was blamed for the lost of users. However, the decline in users started in 1992. A recent unreleased survey of former and current users (producers, researchers and consultants) have indicated that most of the users were unhappy and concerned with the amount of data needed to be collected and inputed into the system--soil hydrology and fertility data, insect data, plant data and/or cultural practices data. They were also bothered by the length of time it takes to run the system. They also found the results of the simulation too hard to interpret. Other reasons cited were the frequent hardware upgrade, the cost of the system and the lack of technical support. The users felt that they had nobody to consult with when they ran into problems with the system.

Average users are in their 40's and older and have had at least a college education. The last version used by the producers was the 1989 version while the extension agents used the 1993-1994 versions. Although the majority indicated lack of interest in trying the system again, a few have expressed their interest and satisfaction with the system.

Possible Courses of Action

The technology transfer problem encountered in the GOSSYM/COMAX case had been perceived as early as 1992 by Ladewig and King of Texas A&M University. In their follow-up evaluation of the GOSSYM-COMAX Cotton Program, they reported that an adequate communication and information flow would be critical to the furtherance of the systems adoption and effective use. Their recommendations are as valid now as they were then and merit greater attention to revive GOSSYM/COMAX's sagging credibility amongst its users. These recommendations are:

Creation of a network that will serve as a hub of the GOSSYM/COMAX system and perform four primary functions:

a. model development and enhancement of the system,
b. information coordination and dissemination,
c. interact with expert system professionals, and
d. develop alternative sources for resource development.

Organization of regional teams responsible for:

a. customizing of existing models to meet local conditions,
b. maintenance and technical support to users,
c. training of current and potential users,
d. marketing of GOSSYM/COMAX to new consumers, and
e. development of alternative resource bases.

These recommendations require resources that the current GOSSYM/COMAX distribution and marketing setup cannot provide. The state universities' agricultural research and extension personnel already have tight schedules and cannot accommodate fully the additional task required for the GOSSYM/COMAX system. AGBIT or its current company does not have enough manpower and financial resources to carry out all its objectives.

A possible approach is the creation of cooperatives where users can pool their resources--assisting one another in collection and entering of data and interpreting the simulation results. Some of these cooperatives are found to be successful in other states for other commodities. These require a central station or services of a consultant(s) where members can send in their data, have simulation runs made and summarized results sent back to the users. It will be beneficial if the summaries are in formats useful and easy to understand by the user.

Another alternative is a private consulting firm that uses the Internet for faster turnaround time. A user can send his data and output request through the network and get his results back the same way. There are several of these companies that now offer precision agriculture technologies--geographic information systems (GIS), global positioning systems (GPS), and sattelite imaging techniques. These technologies should improve input efficiency, maximize farm profitability and provide computerized field histories. [Precision, prescription, site-specific crop management--all refer to a management system of production agriculture using diverse technologies i.e., crop simulation models, geographic information systems (GIS), global positioning systems (GPS), intelligent implements (II) and site specific management (SSM) farming techniques, to increase field productivity and protect the environment].

Conclusion

GOSSYM/COMAX/WHIMS simulates cotton growth, development and yield over a wide range of soils and climate. Mechanistic and process-oriented crop models using: a) real-time daily climatic data obtained from a weather station accessed by the user's computer via a modem; b) soil information such as textural classification, bulk density, soil-water retention and initial soil fertility nitrogen status; and c) cultural inputs like timing, amounts and methods of application of water, fertilizer and plant growth regulators can provide relevant information for the day-to-day or weekly management of the crop. The system has proven its usefulness over the years. Yet the number of users has declined and interest in the further field adoption of the system has waned recently. Sources of apathy to the sytem include difficulty in collecting and inputing the data requirements, and interpretation of the simulation results; frequent hardware upgrades; cost of the software; and lack of support. Recommendations offered are establishment of users cooperatives; increased involvement of consultants/consulting firms; and incorporating the system into a precision agriculture type package.

Other Decision Support System Development at CSRU

Farmers and consultants have expressed their interest in seeing GOSSYM/COMAX/WHIMS integrated with GPS and GIS. They have also suggested that better plant mapping methods be explored to facilitate their scouting. Scouting is the observation of production fields during the course of the growing season to check for harmful insects, weeds, nutrients levels and anything else that would cause a decrease in production so as to make recommendations to improve yields (T.W. Oswald, 1996, personal communication). Normally, plant mapping is employed in cotton fields and is quite labor intensive and time consuming.

To improve the efficiency and speed of plant mapping, COTTON TALK, a speech interface for cotton plant mapping, has been developed using the IBM™ Continuous Speech Series (ICSS) speech recognition toolkit. It allows the user to speak directly to the computer while examining and mapping the plant by speech input. It also provides appropriate audio responses to help confirm the user's previous input. This system is intended to be an improvement over the current plant mapping method by eliminating the paper data sheets and subsequent data entry (Liang, et.al., 1996).

CropView is a GIS-based, multi-crop, decision-support system currently in prototype form (R. Olson, 1996, personal communication). It integrates simulation and decision-support technology with a spatially-registered database and a user-friendly graphical user interface. The simulation models will allow short-term (i.e., a week in advance) predictions of agronomic needs at within-field scales. Other modules will take this information and provide control programs for variable-rate field implements, such as fertilizer and pesticide applicators. The system is object-oriented, modular and is implemented in the PC-based ArcView GIS programming system (Earth Sciences Resources Inc., Redfield, CA).

"AgBook™, developed by AGBIT and marketed as part of the GOSSYM/COMAX software, is a computerized record keeping program designed to assist in managing the farming business. It runs under Microsoft Windows and has user friendly screens and menus to help maintain records on every cropping operation including pesticide and fertilizer use, purchases and quantity on hand. Pesticide information includes date, rate and cost of application, chemical name and all data required by State and Federal guidelines concerning Restricted Use Pesticide. It includes Profit Analysis data and graphics that enable users to determine production costs as well as break-even yields and current profit margin (AGBIT, 1995)."

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Table 1. Validation of GOSSYM in terms of yield prediction expressed in terms of average absolute ratio of actual over simulated yield.

Cultivar class	n	Yield ratio*
GC 510	8	0.86
DES 119	16	0.83
EARLY	15	0.82
FULL	8	0.80
MID	36	0.81
ST1	3	0.92
ST2	3	0.87
OVERALL	89	0.83

*ratio of maximum (actual or predicted) over mimimum (actual or predicted) yield.