DETERMINE THE BEST CROP MANAGEMENT OPTION ON CANADIAN PRAIRIES WITH A COMPUTERIZED DECISION SUPPORT SYSTEM.

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INTRODUCTION

Agricultural systems are very complex. To achieve the goal of increased efficiency in managing scarce agricultural resources, agricultural managers need a tool to assist them in analyzing and choosing the most promising and the least risky one from among various management options. They will make these decisions based on consideration of the profitability of crop production system and its long-term impacts on soil and water qurlity. During the past decade, a team of scientists from several international research institutes has collaborated with the common goal of producing such a tool.

A computerized decision support system that enables the user to determine the best management option on a variety of issues related to crop management is now available. Recent advances in computer technology, coupled with enhancements in modeling techniques and our improved knowledge on the physical and physiological processes involved in crop production, has made this possible. The system can substantially improve the quality, number, and timeliness of decisions made by an agricultural manager. It takes only a few minutes to generate information for facilitating a proper decision that would otherwise have required a lifetime of analysis by an agronomist. Decisions can be made, not only on how to obtain profitable crop production, but also to deal with such issues as climate change, regional adaption of new crops or cultivars, environmental degradation, and agricultural sustainability.

The core of this decision support system arc crop growth simulation models. The system relies heavily on these models to predict the performance of crops grown in a wide range of environments. Among the challengers involved in the development of the decision support system, the construction and validation of the crop models are the most difficult because plant and soil systems are very complex, with numerous interacting factors influencing the results. Because crop models were built based on our understanding of natural processes, and using this understanding to describe agricultural systems performance through systems analysis, the development and validation of crop models can improve our understanding of the underlying processes, pinpoint inadequacies in our understanding, and hence, provide the basis for initiation of agricultural research.

DECISlON SUPPORT SYSTEM FOR AGROTECHNOLOGY TRANSFER

In 1982, the International Benchmark Sites Network for Agrotechnology Transfer (IBSNAT) project was initiated by the U.S. Agency for International Development (USAID). The main objective of this project was to develop computerized simulation technology to generate information for addressing a wide range of agricultural, environmental, and economic problems (Uehara and Tsuji 1993). To achieve its goal, IBSNAT chose to use physiologically based crop growth simulation models and adopted the system analysis approach. In principle, the technique employed is to represent the biological system as a simulation model, modify it in various ways to represent management options, and mn it with various sequences of weather data. By optimizing the outcomes in terms of the economic benefit within the constraints of soil and environmental qualities, the best management strategy can be determined from various management options (Figure 1).

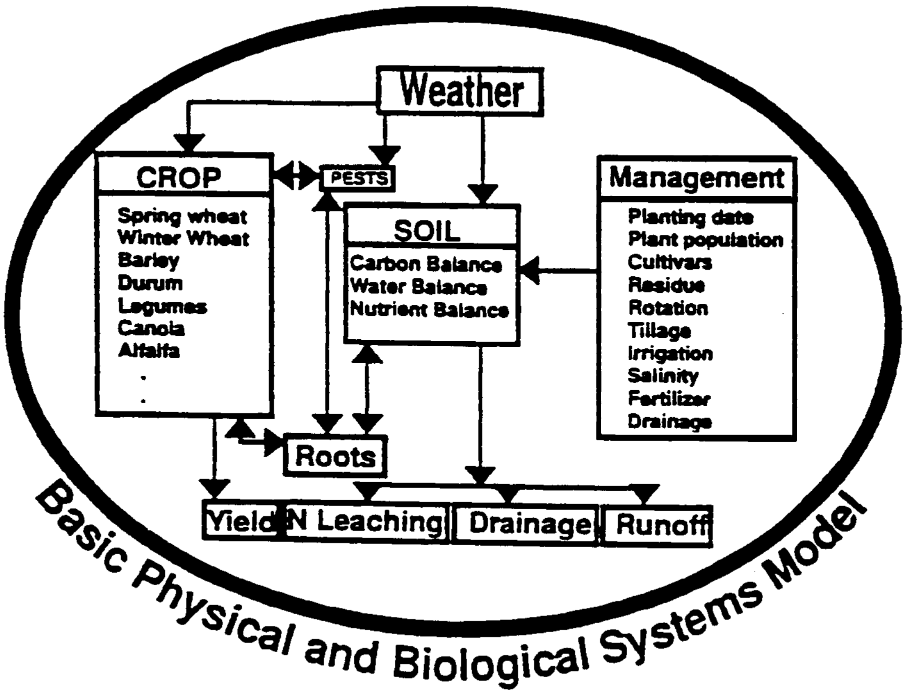

Figure 3. Components in crop growth models

Run 1 WATER STRESS:1992
INST_ID **:AC** SITE-ID: SC **EXPT_NO:** 01 YEAR : 1992 **TRT_NO:** 3
EXP. **:Water Stress:1992**
TRT. **:92-IRRIGATION**
WEATHER **:Swift** Current **Canada** 1992
SOIL :S.C. **Swinton Loam Silt** (Ortbk Brown **Chernozem)**
VARIETY **:NEEPAWA**

	PREDICTED	OBSERVED	STANDARD SAMPLE ERROR
SOWING DATE	**134**	**134**	
EMERGENCE DATE	**143**	142	
TERMINAL **SPIKELET** DATE	**169**	167	
HEADING COMPLET	200	**208**	
BEGIN GRAIN FILL DATE	**218**	224	
MATURITY DATE	25s	254	
GRAIN YIELD **(KG/IIA)**	**5276.**	5338.	**.00**
KERNEL **WT(MG)**	29.8	29.4	**.000**
TILLERS PER PLANT	4.27	3.88	**.0000**
GRAIN PER EAR	111.41	**20.88**	**.0000**
LAI AT STEM COMPLETE	4.2 l	4.65	**.0000**
BIOMASS **(KG/HA)**	**15411.**	15094.	**.00**
STRAW (KG/IIA)	**10135.**	**9756.**	**.00**
GRAIN **N%**	3.22	2.70	**.0000**
TOT N UPTAKE **(KG/HA)**	200.2	228.0	**.000**
STRAW N UPTAKE	30.4	m4.2	**.000**
GRAIN N UPTAKE	169.8	145.0	**.000**

Table 1. A summary out put file generated from the SPARC-wheat model for the 1992 irrigation experiment

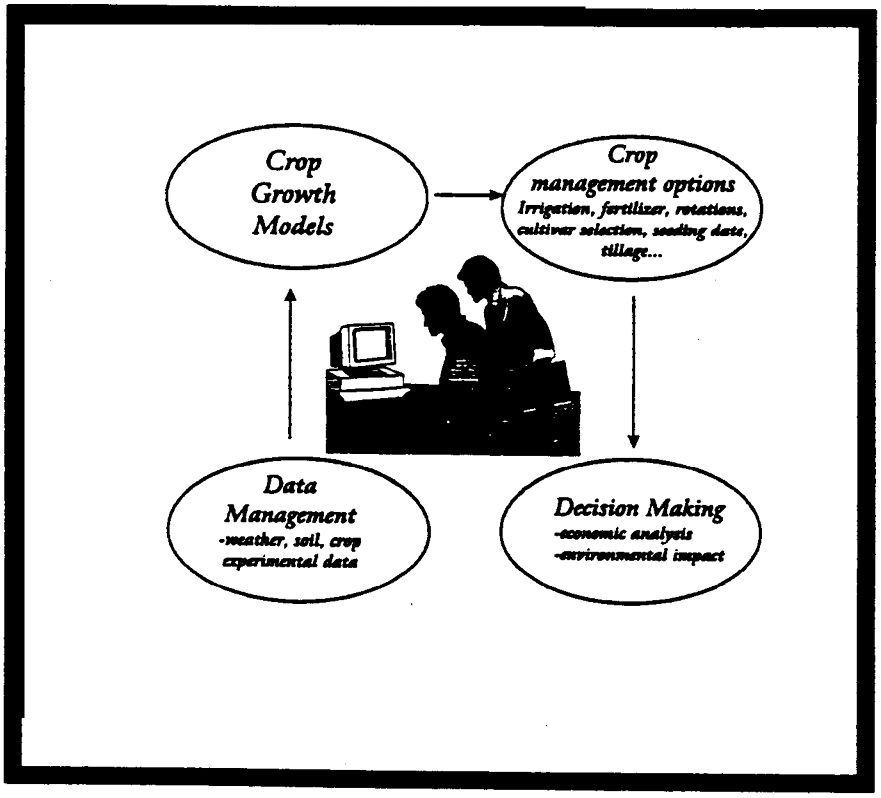

Figure 1. Crop management decision support system

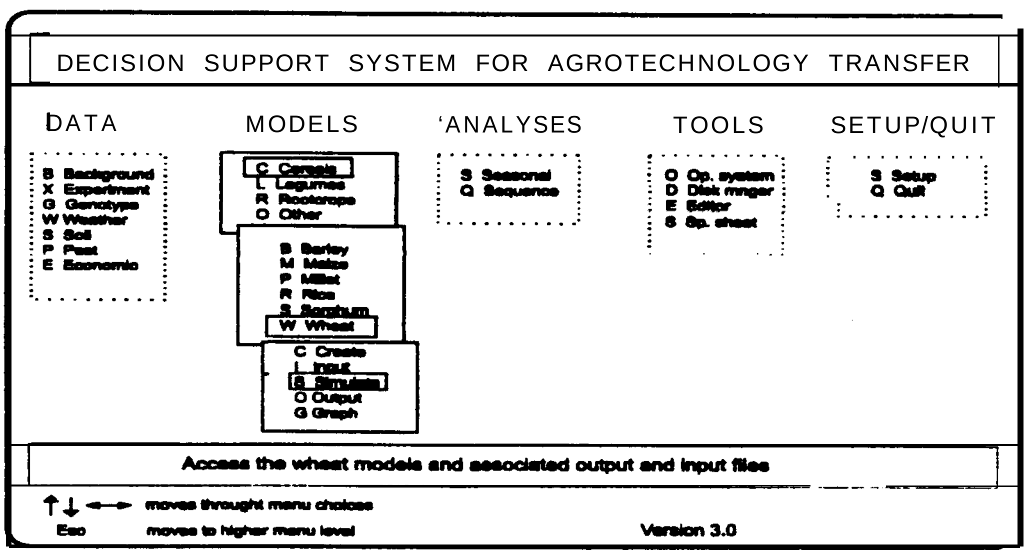

Figure 2. Pop-up menus on the shell program of DSSAT

Under the auspices of IBSNAT, an international team of scientists spent almost 10 years in developing the Decision Support System for Agrotechnology Transfer (DSSAT). DSSAT is essentially a set of computer programs designed to accommodate standardized crop models so that users can easily: (1) input, organize, and store crop, soil, and weather data; (2) calibrate and validate crop growth models; and (3) evaluate different crop management options for a particular site. The programs required to perform these functions are written in various computer languages. A shell program (Figure 2), using pop-up menus, facilitates easy access to perform each specific task. The mandate of the IBSNAT project was to develop crop models for the 12 most importnnt agronomic food crops used around the world. The recent release of DSSAT version 3 (Tsuji et al. 1994) includes models for the following crops: wheat, rice, maize, barley, sorghum, millet, soybean, drybean, peanut. potato. cassava and aroids. Since the introduction of DSSAT in 1992, several networks of international scientists have used the system for various agricultural applications.

DSSAT is a powerful tool that can be used in making decisions regarding issues such as when and how to irrigate, apply fertilizer, seed a crop, what crop to plant and so on. These decisions can be made before or even during the growing season.

Once a user is convinced that the crop models in DSSAT can accurately simulate local behavior, he can use the strategical analysis program in DSSAT to defme various possible management options available to him and then simulate these conditions using historical weather data or weather data generated by a weather generator. After the simulations are completed, the program provides means and probabilities for each predicted variables, e.g., crop yield, crop quality, net return, water use, soil organic matter, nitrogen leached, etc. With the simulation outputs the user can decide on which option is the most desirable in terms of economics, risk, and environmental impacts. DSSAT can be used to analyze management options either within a growing season or sequentially operate models to simulate long-term crop rotations.

Recently, a new international consortium has been formed to replace IBSNAT. The main objective of the International Consortium for Agricultural System Application (ICASA) is to bring together expertise from various international research institutes for more effective and efficient development of system analytical tools for integrated research and analyses, and for practical applications of system approaches to agricultural production and resource management. Under ICASA, efforts are underway to develop the common model structure so that the building blocks in DSSAT, such as crop models, soil models, weather generator and analysis software can be readily adopted to different applications.

DSSAT, a registered computer software, can be purchased from the ICASA coordinator Dr. Gordon Tsuji, Department of Agronomy and Soils Science, the University of Aawaii, 2500 Dole St. Krauss 22, Honolulu, HI 96822. Because most agronomists do not fully understand the concept of system approach research and its application to crop management, training programs on crop modeling and decision support systems are offered by members of ICASA to research scientists, agricultural consultants, producers, extension personnel, and government policy makers. Presently, these training programs are given at several locations in United States, Netherlands, and Indian. In co-operation with ICASA, the training course will also be offered at SPARC for potential users on the Canadian prairies.

CROP MODELS FOR USE ON THE CANADIAN PRAIRIES

The reliability of DSSAT for decision making depends mainly on the accuracy of crop models it employs. The crop growth simulation models used in DSSAT mimic the development and responses of the crop as it grows in the field, by predicting the growth of its components (e.g., leaves, stems, roots, tillers, and grains) in a daily time step. Thus, the models will predict crop production under a set of defined conditions, as well provide quantitative information about processes involved in the crop growth and development.

Because there are many levels of detail to which a crop model can be developed (Jame and Cutforth 1996), a number of crop models are presently available. The crop models adopted for use in DSSAT, such as the CERES model for cereal crops and the CROPGRO model for grain legumes, normally include the following major processes governing the growth and development of a plant: phenologic development, canopy development, organ formation, photosynthesis, assimilate allocation, soil temperature, and carbon, water, and nitrogen dynamics in the soil and in the plant (Figure 3). A set of minimum information related to weather, soil properties, species or cultivar characteristics and management factors is needed to run the model.

It is not possible to dcvelnp a perfect crop model for universal use because the biological system is too complex and we still do not fully understand many processes involved in the system. Thus, all crop models developed for practical application employ some empirical functions and even the most advanced crop simulation models are still small imitations of reality (i.e., all models have their limitations). Consequently, adapting a crop model to a new environment requires that it be properly calibrated and validated.

At the Semiarid Prairie Agricultural Research Center (SPARC) in Swift Current, we has spent several years calibrating, validating and modifying the CERES-wheat model (Ritchie and Schulthes 1994) for use on the Canadian prairies. The model was tested against results obtained from well-defined experiments, in which the soil and climatic conditions were carefully monitored and details of crop growth recorded. This rcsnlted in the development of the SPARC-Wheat model (Jame et al. 1993). Now, we arc also engaged in calibrating and validating the SPARC-Barley model for use on the Canadian prairies.

The software for the SPARC crop growth model is written in the FORTRAN computer language for case in integrating many variables and rubmodels. A special designed user-friendly interface, written in PASCAL computer language, is also included in the model to provide an easy method of operating the model, a simplified data entry format, and a graphical analysis of the model outputs. The model is user friendly. This is importont because it reduces the frustration often experienced by novice computer users, and will increase its usability and utility. In SPARC model, model predictions and experimental data of most soil and plant variables are graphically displayed for ease of comparison (Table 1 and Figures 4 and 5) so that hypotheses used to describe major processes of plant growth and development can be easily tested.

The SPARC model was designed to be an integral part of DSSAT for use by agricultural managers on the Canadian prairies in choosing appropriate crop management options and strategies to achieve the specified objectives. Although it was designed as a part of DSSAT, the SPARC model can be used independently. This aspect will be the theme of a future paper. DSSAT with the SPARC model version will be available at the training programs offered at SPARC. Members of DSSAT Network on the Canadian prairies will automatically receive the update versions of DSSAT and related computer software when they become available.

DIRECTIONS FOR FUTURE DEVELOPMENT

The limitations to DSSAT applications are mainly related to the limitations in the crop models. Simulation models for major crops are being developed, but they require careful calibration and validation for local use. Recently, International Crop Networks were organized by Focus 3 of GCTE (Global Change and Terrestrial Ecosystems), a core project of IGBP (International Geosphere-Biosphere Programme). The aim of the networks is to develop and validate fewer crop models that are more generic in performance. Generic models allow users to have more uniform procedures for calibrating and validation. The initial emphasis of this project has been on the establishment of worldwide research networks on wheat and rice. The network approach facilitates adequate cross comparison of different crop models and maximizes collaborative utilization of field data for testing the models.

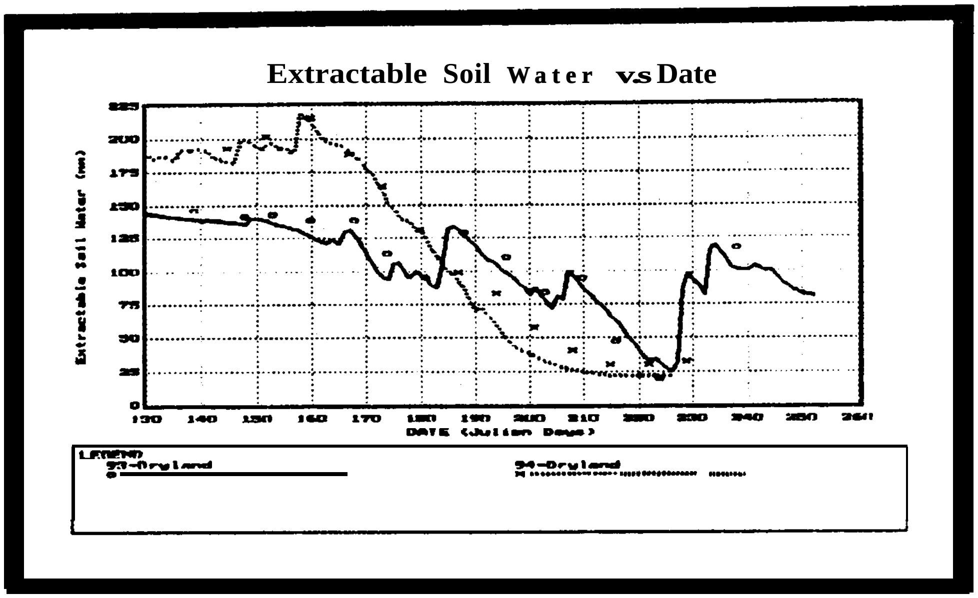

Figure 4. Predictions (lines) from SPARC-wheat model vs. observations (symbols) of extractable soil water in the 120-cm profile for wheat grown in 1993 and 1994

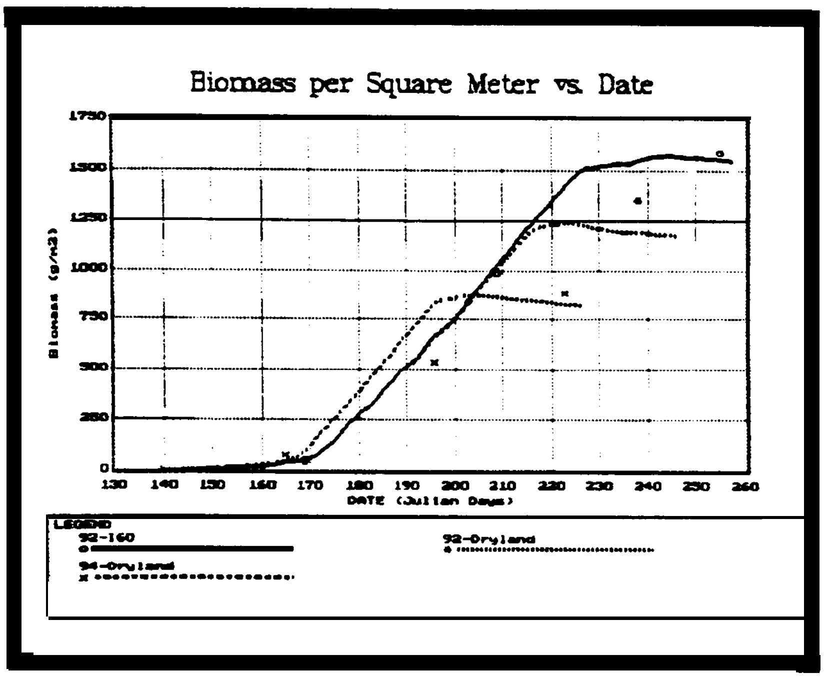

Figure 5. Predictions (lines) from SPARC-wheat model vs. observations (symbols) for total biomass (g/m*) produced in 1993 irrigation and dryland experiments and in 1994 dryland experiment.

Crop models in DSSAT are only in an early stage of development. In many cases, model predictions when compared to field observations are still not satisfactory, indicating that our understanding of the system is incomplete. Thus, an emphasis of agronomic research required to further our understanding so that improved functions can be incorporated into the crop models. Most models only simulate the major factors that affect crop performance, e.g., weather, water, and soil nitrogen availability. Components to simulate the effects of tillage, pests, weeds, salinity, excess water and other factors on crop performance have yet to be included in the crop models. In this context, crop models will become an important mechanism for synthesizing the existing knowledge about plants and resources and for updating this knowledge as we learn more about complex agricultural systems. The improved model will have increased precision, applicability, and explanatory power.

So far we have only concentrated our work on the development of crop models for wheat and barley on thr prairies. Crop models for other important crops grown on the Canadian prairies (c.g., oilseeds and pules crops) are needed so that the DSSAT can be used to sequentially operate models to simulate crop rotations and to properly analyze crop yields, net economic returns, risk, and long-term effects of cropping systems on soil and water quality.

Most crop models only predict yield for a uniform field. On a farm level. soil conditions differ. On a regional scale both weather and soil conditions vary. Thus, at both farm and regional levels, the decision support system will need to consider the additional uncertainties, such as spatial variability of soil and weather.

One computer tool that can assist in handling spatial variability is the Geographic Information System (GJS). GIS allows a user to digitize a map and store all the information of the map in digital form. Linking a GIS with DSSAT gives the user the capability to address both the spatial and temporal variations of environmental variables and the effect of such variation on crop production. A project to integrate DSSAT lo GIS, called Agricultural and Environmental Geographic Information System (AEGIS), is presently undertaken by ICASA. The system will allow users to map crop production for a region, or to optimize the fertilizer use on a spatially variable field. Technology advances in Global Positioning System (GPS) for grain yield monitoring has provided a new opportunity for characterizing variability of a crop field. Thus, in the near future, the GPS-GJS-DSSAT tool will be available on the Canadian prairies to lead us toward the goal of sustainable precision farming.

CONCLUSIONS

Agricultural systems are very complex, with many factors to consider in the decision making process. With the availability of the modem computer and advancements of modeling techniques, computer technology is the most logical solution to achieve the goal of increased efficiency in managing our scarce agricultural resources.

Model-based decision support systems are built based on the understanding of the natural processes and uses this understanding to describe the performance of agricultural systems through system analysis. The reliability of this decision support system depends on how well we understand the physical and physiological processes involved in the growth and development of a crop. This understanding is by no means complete. Thus, research project focusing on increasing our knowledge of soil-plant-atmosphere relationships is needed to be increased. The development and validation of crop models and decision support systems require an integrated research approach. Agricultural systems research teams working on well focused objectives are needed to produce usable, integrated and complete data sets so that decision makers can use them in deriving reasonable solutions for the many complex questions that producers and society face.

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