Software Tools for Supporting Crop Production Decisions

Murray J. Bentham
Project Manager
Parkland Agriculture Research Initiative
Decision Support System
Agriculture and Agri-Food Canada

Henry C. de Gooijer
Research Officer
Saskatchewan Centre for Soil Research
University of Saskatchewan

Abstract

Agriculture and Agri-Food Canada's Parkland Agriculture Research Initiative (PARI) under Canada's Green Plan, focuses on sustainable agriculture. The PAR1 Decision Support System (DSS) focuses on conservation farming systems. Producers need sound advice and accurate information on all aspects of their farm operations in order to make appropriate conservation farming decisions while also maintaining the economic viability of their operations. One of the PARI's programs is the development of a conservation production decision support system (DSS) to support farm managers (i.e. producers) and extension crop specialists. The PAR1 DSS infrastructure provides a "single window" to decision support by providing 3 different levels or types of expertise; basic decision support, advanced decision support and interrelated decision support. Interrelated decision support is the most sophisticated providing decision support for more complex problems with a broader focus. Record keeping plays a major role in the success of any decision support system and the PAR1 DSS is no different. A sophisticated record keeping system has been developed based on a "folder and tab" user interface and incorporates a database structure for management units. Six goals of the PARI DSS are discussed, with the integration of multiple experts for providing decision support for complex problems being the most important.

1. Introduction to the PARI DSS

Agriculture and Agri-Food Canada, Research Branch, under its Green Plan, initiated the Parkland Agriculture Research Initiative (PARI) in 1992 as a 5-year initiative consisting of 4 programs. At that time, and with equal importance today, soil degradation was and is one of the key points concerning the prairie agricultural industry. Consequently, the PARI focuses on the implementation of conservation production systems to ensure the long-term sustainability of the soil resource and in turn the sustainability of agriculture.

Although conventional farming practices are complicated, conservation farming practices are very complex, with more prevalent concerns, including crop rotations, herbicide residues, increased susceptibility of plant diseases, and especially residue management, as a result of minimum tillage. Producers need sound advice and accurate information on all aspects of their farm operations in order to make appropriate conservation farming decisions while also maintaining the economic viability of their operations. Furthermore, in order to deal with the many complex issues of conservation farming and numerous alternatives available, farm managers need access to multiple experts.

One of the PARI's programs is the development of a conservation production decision support system (DSS) to support farm managers (i.e. producers) and extension crop specialists. Although the PARI DSS is biased towards conservation farming systems, it has "value added" and supports the majority of conventional farming aspects as well.

1.1 Expert Systems and Decision Support Systems

An Expert *System* is a computer program that solves complicated problems that would otherwise require extensive human expertise. It does this by simulating the human reasoning process by applying specific knowledge and inferences (i.e. that which is inferred, a deduction or conclusion). Expert systems are a branch of artifieial intelligence, which is a science that attempts to develop thought tools by programming computers to mimic the kinds of human behavior that require intelligence, make judgments and consider experiences. The goal of an expert system is to mimic an expert's thought processes in solving a problem. By their very nature, expert systems address and solve knowledge-intensive problems; that is, those having large information sets, that can have multiple correct or acceptable answers.

A *decision support system* combines information, knowledge, and human expertise, by integrating expert systems, simulation models, and any other combination of software and/or information which can aid the management decision-making process through interaction with the end-user.

2. Types of PARI Decision Support

The PARI DSS is being collaboratively developed by Agriculture and Agri-Food Canada's Research Branch with several partners, including producers, provincial governments, universities, and private industry. Producers are involved in supplying ideas on the design, content and operation of the PAR1 DSS. With the PARI DSS being collaboratively developed, an infrastructure has been designed for its development which permits finished modules to be used on their own while providing natural growth for the overall PARI DSS. This infrastructure provides a "single window" to decision support by providing 3 different levels or types of expertise as illustrated in Figure 1.

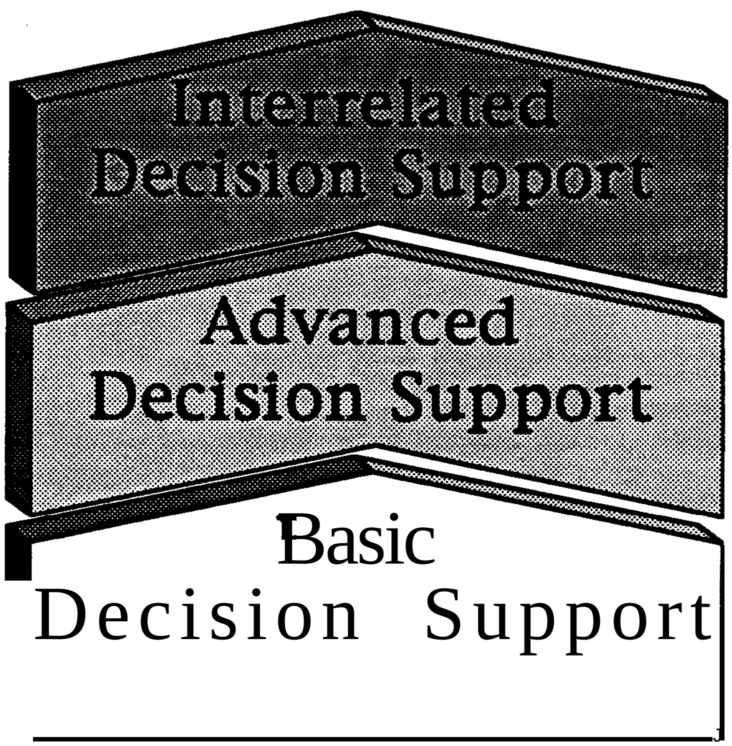

Figure 1: Types of PAR1 Decision Support

2.1 Basic Decision Support

Basic decision support is delivered via the PARI DSS Web site at URL Paridss.usask.ca. This Web site is continually being enhanced and maintained like all successful Web sites. The PAR1 DSS Web site contains various newsletters and articles as well as "new information". All the PAR1 Fact Sheets from the PAR1 '95 Workshop are available as well as a data dictionary defining data that is available in the PAR1 DSS Prairie-Wide Database(s). In addition, there is a "Who's Who" from which clients can gain access to human experts. For collaborative sites which do not have the resources to create their own Web sites, the PAR1 DSS provides services for incorporating their Web pages on the PARI DSS site. There are also links to other related Web sites from the PARI DSS Web pages. The site also incorporates an existing Gopher which was created when "Gophers" were first introduced on the Internet, although it is being phased out as its information becomes outdated.

2.2 Advanced Decision Support

The advanced decision support consists of standalone expert systems which provide support and expertise for specific areas of concern. Some of these expert systems have access to internal databases while others have no need for access. Some of the expert svstems available include:

- Crop Variety Select: An expert system for selecting Canadian prairie crops
- PARMS and RTDS: Expert systems for planting and residue management
- Weed Management Planner: An expert system consisting of 5 modules including a problem weed module, long term management module, weed identification, weed survey module, an economic threshold module and integrated with the Prairie Crop Protection Planner.
- AFFIRM: An expert system - Fertilizer Information and Recommendation Manager
- SoilCrop: An expert system for soil conservation crop productivity relationships
- ASK: An Agronomic Soil Conservation Knowledge Base
- STARRT: An expert system - Stepwise Technology Adoption Risk Reduction Tool
- ASSESS: An expert system to assess salinity problems
- DICTA: An expert system for diagnosing crop diseases
- CCS: An expert system for Climate Classification

2.3 Interrelated Decision Support

Present day problem-solving systems are large and complex reflecting rapid and constant changes to objectives in application domains. Often these systems require the expertise of multiple expert systems cooperating together to produce comprehensive solutions to complicated problems. These expert systems might be developed from scratch for each application system, a costly and timely process, or more recently, applications such as the PARI DSS are being built with heterogeneous and reusable agents [1].

Harmoniously joining diverse knowledge, from the viewpoints of cooperating human experts, provides an extremely important source of balance and robustness in many real-world situations. This is characterized by carefully selected human project teams and work groups. Teams and groups can solve problems which are normally beyond the comprehensiveness of individual experts, and in doing so, provide potentially creative and innovative solutions resulting from a rich and varied body of knowledge [Lander and Lesser, 1981).

The complexity of conservation farming is a result of the complicated interrelationships that exist among farming entities. For example, tillage operations with weed management, crop rotation with plant disease, and residue management with direct seeding. The knowledge of these interrelationships has been acquired from credible sources including human experts and published material, and developed into intricate rule sets that are requited to control the dynamic problem-solving and reasoning process within the PARI DSS.

1 Agents are expert systems that are integrated into decision support systems.

Interrelated decision support provides the most sophisticated decision support through the integration of multiple reusable expert systems utilizing a blackboard architecture to provide a cooperative problem-solving environment. As an analogy, envision that a group of human experts are gathered around a large blackboard to cooperatively work together to solve a problem. The problem-solving session begins when the initial data and problem are described on the blackboard which is a specialized database. A moderator examines the information on the blackboard and determines, using a dynamic reasoning process, which expert can or should apply their expertise next to the developing solution. When sufficient information is available for any of the experts to make a contribution, the moderator triggers the appropriate expert into action, who in turn makes their contribution on the blackboard, allowing other experts, via the moderator's reasoning capability, to apply their expertise. This process of adding contributions and information to the blackboard database continues until the problem is solved.

3. Record Keeping for Decision Support Systems

The farmer is normally bombarded with information, but discovers, after testing it against his particular situation, that much of the information is invalid. Thus the farmer has a feeling of uncertainty for data and information or becomes skeptical, not knowing what to believe and what to ignore. Consequently, a farm manager will seek out and validate, in their own mind, what sources of information and knowledge are credible (Bentham 94). These sources of credible information and knowledge might be, for example, persons, publications and/or the media. Whoever and/or whatever these sources are, the farm manager analyses them as being able to provide a certain level of knowledge or information within a specific domain as it pertains to their own farm. For a decision support system to obtain a high rating of credibility from the farm manager, its support and services must be accurate, convincing[1] and most importantly the decision support provided must be targeted to the specific farm manager's enterprise.

In order for an agricultural decision support system to accomplish this, on-farm databases must contain accurate and complete data. Hence, the most important requirement in developing a credible agricultural decision support system is implementing a sound record keeping system for collecting, validating, storing, retrieving and updating complete sets of on-farm data. Without a sound on-farm record keeping system, the agricultural decision support system will not be able to provide the required support, and will fail the farm manager's credibility test.

A successful decision support system must gain the confidence of the user. One of the downfalls of decision support systems, which has led to poor acceptance, is the inability of the decision support system to adequately explain and justify its recommendations and relate its reasoning process based on the farm manager's on-farm data and information [Barrett 92).

Establishing the necessary databases is necessary and very important to the development of an effective and credible decision support system. It is data and information which supports, services or "drives" the decision support system. The PARI DSS is similarly "data driven" and incorporates a very sophisticated production record keeping system with a very intuitive user interface built on a "folder and tab" concept which is extended throughout the PAR1 DSS for a consistent "look and feel". Within this interface, folders have been developed to summarize results that are focused at the producer's specific farming operations while additional folders have been created to describe the reasoning process used in arriving at the specific conclusions and recommendations.

4. The Goals of PARI DSS

There are numerous and various goals of the PARI DSS. Some being technical in nature, while others are end-user oriented and still others are targeted at development considerations. For this discussion, the goals emphasized will be of a general nature.

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[1] be able to substantiate why it is making a particular recommendation

4.1 Development of an Open System

The development of an open system is to facilitate technology transfer. The PAR1 DSS is a vehicle or mechanism with which to transfer technology and knowledge from the research laboratory to the end-user. The multi-agent design of the interrelated decision support component enables expert systems (i.e. new knowledge) to be added, deleted and/or updated without re-engineering the entire system. This goal has been accomplished through the development of a cooperative problem-solving environment.

4.2 Utilization of ALL Types of Information and Knowledge

The 3-tier structure of the PARI DSS does not limit the type of information or knowledge that can be utilized. Information and knowledge can be incorporated as basic, advanced or sophisticated interrelated decision support, depending on its characteristics.

4.3 Capture the Knowledge of Human Experts

Through the development of expert systems, the PAR1 DSS can capture the knowledge developed by human experts and preserve and enhance it over time. This is an important goal with the current trend of short-term research.

4.4 Support Independent Expert System Development

Although the PAR1 DSS has a set of expert system development guidelines, there are no stringent standards that must be followed. Hence, collaborators have the freedom to develop expert systems that fulfill there own needs first and then can be incorporated into the PARI DSS for transfer to the end-user with usually only a few modifications.

4.5 Provide Cooperative Multi-Agent Problem Solving

The complexity of problems that can be solved by cooperative multi-agent problem-solving systems far exceeds the problem-solving capabilities that could be obtained by developing one large knowledge system. A specialized multi-agent system which shares expertise has several advantages over a large monolithic system developed to solve the same problem(s). The multi-agent system approach provides the PAR1 DSS with a natural, flexible development framework in which to integrate heterogeneous reusable agents, as well as the capability to implement agents independently with minimal time and resource requirements. Agents developed for multiple uses are generally more reliable and their development cost can be amortized over many uses [Lander and Lesser, 1994). In addition, a modular system approach, comprised of heterogeneous multiple agents, provides the ease and simplicity associated with developing, debugging, testing and maintaining small systems. The interrelated decision support component of the PARI DSS is leading edge technology, not before attempted in an agricultural application.

4.6 Provide Decision Support Specific to Individual Farming Systems

This goal, although listed last, is certainly not least, but rather contributes greatly to the overall success of the PAR1 DSS. The fact that the PARI DSS is “data driven” and “goal driven” enables results to be calculated that are specific to the individual producer’s farming operation.

5. Status and Summary

The PAR1 DSS Web site continues to be enhanced and updated as is the case with most successful sites. The development of all the expert systems is complete. The development of the interrelated component is currently underway. University Technology International, Calgary, is conducting a pre-market analysis of the PAR1 DSS. It is anticipated that their analysis will determine a price and distribution options.

The PARI DSS avails of credible knowledge and information from human experts and published material. By adding value to the producer's data, the PAR1 DSS helps the producer make decisions or provides a choice that is specific to the producer's own farming operation. Through the integration of data, expert systems, and intelligent knowledge bases and databases, the PAR1 DSS provides interrelated decision support at the highest level.

References

1. J.R. Barrett, "Information Requirements and Critical Success Factors for Corn/Soybean Decision Support Systems," *Proc. 4th International Conference on Computers in Agricultural Extension Programs,* Orlando, FL, 1992, pp. 147-152.
2. M.J. Bentharn, "Parkland Agriculture Research Initiative Decision Support System/Expert Systems," *Proc. Moving to Sustainable Agriculture Conservation Workshop,* Edmonton, AB, 1994, pp. 181-187.
3. M.J. Bentham and J.E. Greer, "Conflict Resolution Among Heterogeneous Reusable Agents in the PARI DSS", *Proc. 1995 International Conference on Multiple Objective Decision Support Systems,* U of Hawaii, Honolulu, Hawaii, 1995, in press.
4. S.E. Lander and V.R. Lesser, "A Framework for Cooperative Problem-Solving Among Knowledge-Based Systems," *Proc. 1989 MIT-JSME Workshop on Cooperative Product Development,* 1989, pp. 1-14.
5. S.E. Lander and V.R. Lesser, "Sharing Meta-Information to Guide Cooperative Search among Heterogeneous Reusable Agents," Tech. Report CMPSCI 94-48, Department of Computer Science, University of Massachusetts, Amherst, MA, June 1994.