Success and failure of decision support systems: Learning as we go

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Abstract

Much effort and money have been devoted to the development of decision support systems (DSS) to enhance the decision-making capabilities of primary producers and their advisers. These initiatives have been partly driven by the increased complexity of primary production brought on by market globalization, the need for sustainable production practices, and the increasing rate and volume of information exchange. Decision support systems can assist producers in making better decisions by integrating information into a more useable form, altering production systems, enhancing management skills, and reducing costs of production. Despite these benefits, the adoption of DSS by producers has been limited. Reasons include the lack of end user evaluation preceding and during DSS development, as well as the fact that the DSS output may not fit the producer's decision-making style or because the complexity needed to operate the DSS is great and requires considerable data input. Information systems-development methodologies are investigated as a way of increasing DSS adoption. These methodologies, including "hard" and "soft" systems approaches, are discussed as ways to provide greater concordance between developer and end user. A case study of "HotCross," a DSS under development to evaluate crossbreeding systems in northern Australia, was used to identify issues involved in DSS development and use. Issues highlighted include industry consultation, target audience focus, evaluation of DSS success, user participation, support and availability, and participatory learning processes. The case study provided evidence of a perceptible shift in the development process because greater emphasis was put on the learning process of breeding program design by end-users rather than emphasis on learning how to use the DSS itself. Greater end user involvement through participatory learning approaches (action learning, action research, and soft systems methodologies), iterative prototyping (evolving development processes), as well as keeping DSS development manageable and small in scope, will provide avenues for improving the rate of DSS adoption.

Key Words: Agriculture, Decision Analysis, Information Systems, Models, Livestock, Farming Systems Research

Introduction

Agricultural production decision-making is becoming more complex. This is due, in part, to the increased competition caused by the globalization of agriculture and the need to adopt more sustainable farming practices. This has greatly increased the need to manage the way information is combined and used when making decisions. In addition, the explosive growth of Internet use has influenced livestock industries by increasing the rate and volume of information exchange (e.g., Groves and Da Rin, 1999). Computer-based decision support systems (**DSS**) have the potential to be important tools in the decision-making process for primary producers and their advisers (Ritchie, 1995). An example is the use of computer modeling of animal production systems to evaluate the effects of tactical and strategic alternatives (Bourdon, 1998; Kinghorn, 1999). Despite the potential benefits, evidence from the literature suggests that the uptake of DSS technology by primary producers has been limited (Lynch et al., 2000). This article examines reasons why computerized decision-making within agriculture (livestock production, in particular) has not been as successful as anticipated. In addition, we have discussed approaches that may increase DSS use in animal agriculture by looking at participatory methods of information systems development. We have highlighted issues and challenges involved in increasing DSS adoption by presenting a case study of a specific DSS application as well as published examples.

Discussion

What are Decision Support Systems?

Decision support systems are computer systems that assist the user in complex problem solving or decision-making. They are an integrated approach to the age-old problem of helping people make better decisions. Decision support systems typically have quantitative output and place emphasis on the end user for final problem solving and decision-making. An expert system (**ES**) is another computer tool used for decision-making. Expert systems use qualitative rather than quantitative reasoning. They perform at a level generally recognized as equivalent to that of a human expert or specialist in a particular field. Often, ES are developed around very specific and highly detailed "domains" and thus tend to be narrow in their range of knowledge (Luconi et al., 1993). Overall, within the agricultural sector, DSS are more widely known and used than ES. Jenkins and Williams (1998) and MacNeil et al. (1998) summarize examples of DSS within the animal production. Even simple decision tools such as sire summaries can be categorized as DSS (Charteris and Newman, 1999). We will see that even though adoption of computerized DSS is a complex process, simple-to-use tools (like sire summaries) are much more readily adopted.

Benefits of DSS in Animal Agriculture

The use of DSS within animal production allows producers to integrate information into more useable forms and enhances management skills through improved decision-making and increased capacity for benefit:cost and risk analyses, and DSS allows comparisons of the cost-effectiveness of various production alternatives. They can reduce costs of production and improve productivity and sustainability by matching livestock requirements to feed inputs. As well, they can be used as education tools to increase the effectiveness of educating current and future generations of primary producers and service agents. In addition, DSS can be used to test alternative animal production strategies that would take years to determine using traditional experimental approaches. These systems allow producers to ask "what if" questions. For example, "How can I optimize pasture usage and labor availability if I draft animals into separate management groups at different ages?" Or, "If I institute a quality assurance scheme, how can I match the production outcomes to my objectives, costs constraints, prevailing pricing conditions, and contracts?"

Many DSS used in animal production are built around an underlying simulation model. Modeling has the capability of consolidating learning processes because models can rapidly identify parameters that drive or affect the system we either know little about or do not fully understand. Simulation modeling has received considerable attention in the last 25 yr from animal scientists. An extensive bibliography can be found in Harris and Newman (1994). Models are useful in research management and policy planning in livestock production. Models are often used as a way of learning how the components of a system interact and affect the outputs. As such they can be useful tools to model new farming practices. They can help farmers or decision-makers quantify the risk associated with a particular management strategy (Hammer et al., 1993).

Many studies have focused on the impact of genetic improvement programs on livestock production systems (Harris and Newman, 1994). Specific questions addressed by these simulation studies vary considerably, but most involve the interface between genetic improvement and production systems for livestock. One of the benefits of simulation modeling is that it offers the potential for more detailed and mechanistic understanding of the interface between breeding and production than is possible through experiments alone. Design of production systems that efficiently use genetically improved livestock performance is also another benefit (Bourdon, 1998). Farm-level models are necessary to not only better quantify the net benefits from genetic selection, but also to simultaneously quantify changes to farm management. Decision support systems driven by a dynamic production model would allow breeding decisions based on optimal production and processing pathways for prospective progeny. The result could account for animal merit, variance in merit, prevailing feed and marketing conditions, and options for multiple pathways to multiple product end points.

In recent years, there has been a move toward the development of more integrated models for beef systems. These systems integrate mating systems, feeding programs, genetic resource use, and marketing end points. For example, Naazie et al. (1997) developed a beef efficiency model that combines three submodels: herd structure, growth and feed intake, and enterprise efficiency. The Decision Evaluator for the Cattle Industry, or DECI (Jenkins and Williams, 1998), is a herd inventory model that has been developed as a DSS for industry use. The DECI tracks daily events for individual animals. It allows the user to evaluate management questions concerning the effect of culling strategy on herd output, the effect of genetic potential on feed resources, time of calving, age of weaning, marketing end point, postweaning growth response to alternative feeding programs, feed allocation, and feed usage. The models developed for DECI are based on the efforts of Sanders and Cartwright (1979a,b), Notter et al. (1979a,b,c), and Bourdon and Brinks (1987a,b,c). Enhancements to the general cattle production systems model have been made by Keele et al. (1992), Williams et al. (1992a,b; 1995), Bennett and Williams (1994), and Williams and Jenkins (1997, 1998).

Problems with DSS Development and Adoption

Although these systems seem to have many benefits to producers, they have not widely been taken up by them (Wilde, 1994; Lynch et al., 2000). Cox (1996), Campbell (1999), and Lynch et al. (2000) have examined reasons behind the low adoption of DSS and other intelligent support systems within agriculture. Some of the reasons they suggest are as follows:

Limited computer ownership among producers,

Lack of field testing,

No end user input preceding and during development of the DSS,

DSS complexity and possibly considerable data input,

No reason seen for changing current management methods,

Distrust for the output of a DSS because producers do not understand the underlying theories of the models,

Mismatch of the DSS output with the decision-making style of the producer because the producer's conceptual models are excluded, and

Unclear definition of the beneficiaries (e.g., scientists, primary producers, and technology transfer agents).

Some of these issues are discussed in the following sections.

Ease of Use. Features of the DSS will affect adoption (i.e., that DSS are not useful to the user and(or) are not easy to use). Perceived ease of use and perceived usefulness issues has been discussed by Keil et al. (1995) and are best described through Figure 1. Perceived usefulness is a measure of how well the DSS will enhance a user's decision-making capability, that is, the amount of time it might take to perform a certain task. Alternatively, perceived ease of use is a measure of the reduction (or increase) in physical or mental effort to use the DSS. It is important to balance emphasis and effort between ease of use and usefulness. Keil et al. (1995) suggested that software that rates low in ease-of-use and low in usefulness will be rejected. Software that is high in ease-of-use and low in usefulness they term "toys." Users may embrace this software initially but there is little chance of lasting acceptance. Software that is low in ease of use but high in usefulness will only be used by what they term "power users," very competent computer users. Most users will avoid this type of software because the time and effort required to learn how to use it outweighs the potential benefits. The aim is to develop software that rates high in ease of use and high in usefulness. They also suggest that designing for ease of use "must begin with some type of task analysis that goes beyond the typical considerations of ergonomics and user interface."

Beneficiaries of DSS Use. Often the beneficiary of the system is unclear at the development stage. This lack of clear definition of end users can result in the development of a system that does not meet the needs of any group. Indeed, many of the problems associated with the development of these systems can be traced to limited end user involvement from the start of the project. The development team must involve users from the conceptual beginnings of the DSS, and continual feedback must be established (Ludwig et al., 1993; Stuth et al., 1993). The key issues are that DSS must address significant problems identified by its users and that the DSS must target the primary audience in the short-term and adopt a longer-term strategy toward development of educational software for training in the next generation. Also, the development team should include a researcher who knows something about DSS, a programmer who knows something about the real-world problem being addressed by the DSS, and an end user focus group.

Measuring DSS Success. The discipline of information systems (**IS**) includes the study of both the social and technical aspects of the use of information technology for decision-making and problem solving (Lyytinen, 1987). Much of IS research has been devoted to the investigation and analysis of IS success: what is it and how do we measure it? In a seminal IS paper, DeLone and McLean (1992) believe that the ultimate dependent variable in IS research is "success." However, the concept of success itself has not been adequately defined or explained in the literature. Information systems research has focused on various aspects of success, making comparison and cumulation of results difficult. The authors introduce a taxonomy of the six major dimensions of system success: system quality, information quality, use, user satisfaction, individual impact, and organizational impact. Their work differs from other IS frameworks in its practicality and its recognition that the most important outcomes are those seen from the user's perspective. Therefore, the last two dimensions (individual impact and organizational impact) are identified as the most important areas for future research.

A major challenge with DSS adoption and use is determining when a system has been successful. The SIRATAC (Cotton Research Council, 1987) system was an ES developed for cotton farmers and is often cited in the literature when discussing ES (Hamilton et al., 1990; Macadam et al., 1990; Plant, 1993). The SIRATAC system was a pest management program developed in the early 1980s to reduce pesticide use in the cotton industry. Growers entered their data into a centralized computer via a modem, and the system responded with a recommendation to spray or not to spray. Although initially very successful, SIRATAC eventually failed despite intense efforts to maintain its relevance to the constituents (Macadam et al., 1990; Cox, 1996). Its failure might be attributed to a number of reasons. It failed to keep pace with users' needs, and, once users interacted and learned from the system, they no longer required its use for decision-making. There were also problems with the underlying model, and the opportunity to simplify the technology was not taken.

What makes a DSS successful within an agricultural context (Lynch et al., 1998)? Is a DSS successful when it matches the decisions made by experts? Is it successful when it has reached a certain percentage of the targeted market? Is it successful when it can be shown that it has changed farming practices or that through its use it has resulted in improved returns for farmers? Is it successful if it continues to exist and has some use among researchers, extension officers, and farmers? Alternatively, is the DSS successful when it becomes obsolete through use of the decisions it has made? Is it successful if farmers, through some other form, such as fax, newspapers, or other media, use the information generated from the DSS to make tactical or strategic decisions? Some or all of these attributes characterize successful DSS.

In light of this, the importance of the actual user's perspective of success, and the critical aspect of meaningful user participation, it becomes clear that DSS developers need to determine, before proceeding, what constitutes success in their context. In asking this one question, they may have a clearer understanding of whether to proceed with the development of the system or whether there are other ways of providing potential users with the tools required to aid the decision-making process.

Improving Development Methodologies and Adoption Rates

Despite optimistic plans and best intentions by developers, a high percentage of information systems still fail (Wilde, 1994), and this high rate of system failure has been consistent across all organizations and industries. About 40% of systems fail or are abandoned (OASIG, 1996). The OASIG study also found that 80 to 90% of systems do not meet their performance goals, 80% are delivered late and(or) over budget, and between 10 and 20% meet all their success criteria. Partly in response to this high rate of failure, information systems development (**ISD**) research has become a major research area within the discipline of information systems. Information systems development is the formal, usually documented, process of developing a computer system. Information systems development methodologies (**ISDM**) have been defined as the various ways and means, tools, techniques, and models that are available to the information systems developer (Hirschheim et al., 1995).

The first generation of ISDM tended to be rational and technical approaches that only gradually came to consider the social consequences of information systems implementation (Gregor, 1998). These rational, technical exercises have come to be known as "hard systems." Hard systems approaches focus more on the certain and the precise, looking at the problem from one viewpoint (Avison and Fitzgerald, 1997). In an agricultural context, hard systems methodologies often center on mathematical models of the systems of interest.

In general, soft systems approaches regard ISD as mostly social processes involving multiple perspectives, learning, and change. Specifically, the soft systems methodology (**SSM**) from Checkland (1981) focuses on problem formulation. Checkland (1981) proposes that the scientific approach to problem solving is too narrow and that problems are actually "user requirements" constructed from the various perspectives of the system's stakeholders. The SSM uses tools such as rich pictures, root definitions, and description techniques to construct more meaningful user requirements than by the structured methods of "problem" solving (Hirschheim et al., 1995). "It attempts to engage the various stakeholders in a dialogue about their perceptions and seeks a consensus view of the preferred problem formulation. . . . On the other hand, SSM does not consider technical implementation and leaves this to some conventional [rational] approach" (Hirschheim et al., 1995; p 141). The SSM of Checkland (1981) "acknowledges cultural, political and social perspective's and, through innovative and meaningful and structured and collaborative debate between accommodating stakeholders, seeks to create an environment where appropriate action can be taken" (Jackson and Sulaksono, 1998; p 41). Furthermore, SSM acknowledges that problems are often not well defined and builds this fuzziness about the problem into the methodology.

Ultimately, the purpose of ISDM is to provide an approach to assist developers to build systems that meet their clients' needs. Traditional, formal ISDM are still favored by developers (Saarinen and Vepsalainen, 1993; Hirschheim et al., 1995). Clearly, there are problems with these hard systems approaches because a high percentage of information systems fail. It has been suggested that many developers currently do not even follow ISDM when developing software systems (Fitzgerald, 1998; Russo and Stolterman, 1998). Russo and Stolterman (1998) suggest that there is currently a lack of fit between formal methodologies and the actual subjective needs of developers and users. They believe that this is due to the fact that in recent years the types of systems that are developed have changed from technical systems, which were developed for a few specially trained users, to user-focused systems, which are developed for users with limited computer skills.

Although the adoption of DSS within the agricultural sector is low, the problem lies not only with these types of systems. Researchers are aware of the continual high failure rate across all software systems (OASIG, 1996). However, for reasons given in previous sections of this paper, the uptake of these systems is even more problematic than the uptake of computer systems within small business. The OASIG study suggested that part of the reason for the high failure of systems was the lack of user involvement from the early stages of development.

The low adoption rate of DSS in agriculture was discussed by Lynch et al. (2000) using diffusion theory (Rogers, 1995). They suggested that low rate of adoption is predictable and advocate greater user involvement in the development of these systems. They suggest a participatory approach to system development. This type of approach is familiar to many extension specialists and researchers and goes under several names, including participatory learning, action learning, action research, and soft systems methodologies, as mentioned above. Logically, these approaches, due to their focus on user involvement, provide a possible way to improve the adoption of information systems. Part of the challenge is that, although the value of participatory ISDM has been generally recognized, in practice they are very unstructured and subjective exercises. There is no generally recognized methodology to do this (Avison and Fitzgerald, 1997). More research and practical experience with these methods is required.

An example of combining hard and soft systems methodologies is that of McCown et al. (1998), who developed FARMSCAPE (Farmers', Advisers', and Researchers' Monitoring Simulation, Communication, and Performance Evaluation) to support farmers' management of dry-land crop production in Australia as an alternative to the development of DSS. The approach uses hard systems tools (simulation modeling) in interactions with farmers and advisers in ways that utilize soft systems thinking. One of their goals was to maximize the educational value of simulation rather than simply focusing on its role in making recommendations. A collaborative research approach is used for FARMSCAPE, with the farmer-client using simulation of crop growth and yield in "kitchen table sessions" and with farmers, researchers, and advisers posing questions that relate to one or more paddocks on neighboring farms. The simulator is employed to compare options for the forthcoming season. These interactions create great opportunities for learning about environmental and management factors affecting crop growth in different seasons (Foale et al., 1997).

Coutts et al. (1998) evaluated the participative methodologies developed in FARMSCAPE and concluded that the evaluation approach is augmenting the experience in the evolution of farming strategies. The evaluation process provided evidence that the project was having a positive impact on learning within each group, attitudes, decision-making, and practice. Importantly, the evaluation also showed that, when taken in context, simulation helped participants gain insight into production system function and augmented their farming experience in tactical decision-making.

In addition to adopting a participatory approach, an important aspect for improving system success is keeping the scope of the project manageable. Review of early work with DSS suggests that the development approach needs to be small in scope and iterative, so that the systems can evolve and change as the situation changes (Sprague, 1993; Plummer et al., 1999). One example of a participatory approach is that of Stuth et al.(1993), who describe an five-step DSS development protocol: 1) identify need for the DSS, 2) conduct a feasibility analysis (task, user, and organizational profiling, and resource requirements), 3) establish an action plan (user skills, software development, system design, documentation, etc.), 4) use iterative prototyping (allows the development process to evolve, based on evaluation from potential end users), and 5) release and train. Recently, Turban et al. (1996) describe a similar iterative process: 1) select an important subproblem; 2) develop a small but useable system to assist the decision maker; 3) evaluate the system and improve it; 4) then evaluate again; and 5) refine, expand, and modify the system in cycles. Both procedures highlight the need for identification of the need for DSS before the investment of research funds, and the need for user feedback and participation in the development process.

HotCross: A Case Study

This section is intended as an exploratory case study discussion of the on-going development and delivery process of the HotCross DSS. Case studies are often used within the discipline of IS to investigate how and why questions of systems phenomena that cannot be studied with traditional experimental approaches due to the complex interaction of people and technology. Case studies are appropriate in situations in which a contemporary issue is being investigated, the process being studied is dynamic, and the experiences of individuals and the context of actions are critical (Yin, 1994; Darke et al., 1998). The development of the HotCross DSS fit all of these criteria. Although a case study method is often used for theory building, this examination of HotCross is exploratory in nature and is intended as a discussion of the on-going configuration and delivery process of the DSS. This progression also forms the basis for describing issues discussed previously that are relevant to all DSS development practices.

Background

Given the myriad production environments, management systems, and marketing scenarios, within which beef is produced in Australia, least-cost producers are increasingly using crossbreeding as a management strategy. This is especially true in the northern areas of Australia, where a balance must be struck between improving economically important traits (e.g., reproduction, survival, and carcass and eating quality) and maintaining high levels of resistance to heat, poor nutrition, tick, and worm stresses.

Despite the enormous amount of research that has been carried out comparing breeds and crosses, there is no convenient way for a tropical cattle breeder to compare the expected performance of different breeds and crosses in a particular environment. Given the long generation interval in cattle, the development of decision support aids to provide predictive models for crossbreeding programs is worthwhile. In a tropical setting, it is important that predictions be adjusted for various stresses operating in the environment in which the animals are produced. The perceived benefits of such a package would include accurate prediction of performance of genotypes adjusted for environmental stress, the ability to utilize a wide array of genotypes, the ability to simulate a wide variety of crossing systems, and the ability to estimate performance generations into the future.

The development of this “Ready Reckoner” was undertaken as part of the Genetics Program of the Cooperative Research Centre for the Cattle and Beef Industry (Meat Quality), or CRC (CRC, 2000). This arrangement provided funding to develop a DSS for northern Australia (tropical and subtropical) beef producers to allow comparison of breeds of cattle in various combinations adjusted for the environment in which they lived.

Configuration and Delivery

The evolution of the DSS since its inception is described as a time line in Figure 2. Funding for the CRC (and hence the HotCross project) began in July 1993. A prototype was available for testing in mid-1995. Soon after, a computer programmer was hired to oversee the coding of the DSS. Simultaneously, databases were constructed containing performance data for the prediction equations from various literature sources around the world. The genetics database contained information from tropical crossbreeding studies. Temperate studies were added to allow comparisons between the two environments. A second database was also developed that incorporated data from a number of studies on components of environmental stress, including tick, worm, heat, and nutrition stress on productivity.

Potential industry-based end users became directly involved in development of the DSS about 18 mo after commencement of the project (Figure 2), although potential end users were queried about their needs prior to the start of the CRC. The focus group comprised five individuals (two seedstock and three commercial producers), who were deemed to be progressive producers by extension advisers. The role of the focus group was to help evaluate the software and indicate features they would like it to have as a finished product.

An alpha test version of HotCross was released to a limited number of evaluators (mostly producers and scientists) in October 1996. This version predicted only a limited number of growth traits. Evaluators' comments were collated, discussed, and prioritized, and the DSS was redesigned. Most of the changes were of a "look and feel" nature (e.g., placement of buttons and screen colors). HotCross was released to industry as a beta version in mid-1997 (Newman et al., 1997). This version contained equations for the prediction of carcass yield and quality in addition to growth traits.

Five options for marketing HotCross to industry were considered during 1998. They included the following: 1) distribute the DSS freely to industry, 2) establish a purchase price for the DSS, 3) distribute the DSS freely with users having the option of paying for database upgrades, 4) apply a "postage and handling fee" as the cost of the DSS software, and 5) provide a full-day course on breed utilization strategies including distribution of the software and lessons in its use. HotCross would be included as part of the course fee.

Option 5, providing a workshop with HotCross included in the price, was determined to be the best alternative for maximizing the technology transfer capability of the DSS. The first HotCross workshop was held in October 1998 and continues to be offered to industry. A team of three facilitates the workshops. The team includes a geneticist (the HotCross developer), a systems scientist, and a state extension genetics specialist. This specialist developed a computer-aided learning package (Thompson, 1994), devoted to teaching the concepts of genetics and animal breeding, that is an integral part of the workshops. Feedback from the focus group and data from the North Australia Beef Industry Survey (Bortolussi et al., 1999) stressed the need for beef producers to have an understanding of principles of genetics before moving on to understanding crossbreeding systems. Workshop structure and evaluation is detailed below.

HotCross will be completed in mid-2000. Release to industry will be through Australian state departments of agriculture. The facilitation team will develop "train the trainer" workshops and provide all teaching materials and HotCross to these organizations. It will then be up to the individual organizations to decide how they want to transfer the package to the wider beef industry.

Lessons Learned

A number of issues have been raised about the development process of HotCross that are in line with DSS development and adoption issues discussed in previous sections of this paper.

Consultation. Potential end users of HotCross were not initially involved in the development phase but were queried for requirements of such software prior to the start of the CRC. Developers of DSS can improve their products if they firstly engage in a much closer relationship with the client. As well, the developer must understand how people learn. The developers can then apply this knowledge to DSS design (Campbell, 1999). The consultation process for HotCross involved several iterations of interactive meetings with the focus group, performing suggested revisions of the software (look and feel issues, breeds and traits to include), and releasing the revised beta version for further evaluation. Although the focus group was interested in the development of the software and provided a useful market focus, it was important that the development team set milestones for consultation and meeting with the focus group to advance the project.

Maintaining continuity of participation was also an issue: after a period of time, focus group members tended to drop out and thus reduce "critical mass." We suggest from our experience that a facilitator with adult education skills assist in the consultation process.

The DSS was also demonstrated to individual producers not associated with the focus group whenever possible. However, the focus group proved to be a more fruitful source of advice than the individual contacts. Although it was expected that the focus group was skilled in computer use, it turned out that the group possessed a range of computing experience from the not yet skilled to the highly competent. Although such diversity can be difficult to manage, it helped tailor the product to a market with variable skills and competencies with DSS.

Focus. There was an evolution of focus in defining the target audience over the development process. At first, the target audience for the DSS was unclear, that is, simply "beef producers." Widening contact with industry through field days, workshops, the focus group, and industry media sharpened the focus. A more specialized audience has been identified through the workshops.

As the focus of beneficiaries has evolved, so has the basic usage of HotCross as a decision aid and as a computer-aided learning tool. As pointed out by Ludwig et al. (1993), short-term target audiences for DSS should include producers, extension personnel, and agribusiness. In the long term, audience focus should also involve educating the next generation of producers and service providers.

Evaluation. Initially, a measure of DSS success was not considered, other than the meeting of project milestones. Prediction equations were validated from survey data (Bortolussi et al., 1999). There was also considerable evaluation in terms of look and feel issues from various groups. This yielded a spatial flow of buttons on-screen, so that the user is always working either down or across. The reduction in the number of requested and suggested changes to the package over time was also seen as a measure of acceptability.

Even though the workshops have been valuable in the evaluation phase for a variety of reasons, it is still difficult to quantify the immediate impacts of the DSS (i.e., to measure its success). For example, a participant might not use the DSS for decision-making per se. Perhaps the impact will be observed through knowledge gained in some other way (e.g., use of estimated breeding values to choose a future sire) to make changes to current practices. A survey is planned to elucidate these issues.

Participation. User participation is of paramount importance. However, potential users have typically been asked to concentrate more on "look and feel" issues of the DSS rather than the underlying principles or focus (Ludwig et al., 1993). As stated earlier, the fact that participation was requested in the development of HotCross was important and useful. Potential users were initially asked to concentrate on look and feel issues. However, workshops and field days allowed greater discussion of underlying issues in model development, data analysis, and presentation.

Support and Availability. Many DSS never get past the prototype (Wilde, 1994). Long-term commitment is very important when embarking on DSS development. Fortunately, funding for HotCross has been maintained. However, there are no plans to develop upgrades for the DSS once it is handed over to industry through the "train the trainer" workshops. The state departments of agriculture will have the opportunity to make enhancements to the package if necessary or desired. Systems will improve if others are able to take over where others have left off, rather than starting all over again. Furthermore, they must also become the "champions" of the system so that the benefits of the software can be demonstrated and used by industry. The workshops have contributed to this role.

Participatory Learning. The HotCross workshops are an excellent example of participatory learning (Hamilton, 1996; Coffey, 2000). Through the workshops, HotCross is shown to have the capability to act as a computer-aided learning device, rather than solely as a decision-making tool. This shifts the focus of the package's use. Indeed, the initial intention of the package was an aid in the development of crossbreeding systems. However, the DSS does serve a dual purpose by providing the added feature of helping producers to learn breeding program concepts.

The aim of the workshops is to equip participants who generally have a poor functional knowledge of genetics and animal breeding with sufficient knowledge to understand the underlying concepts involved in planning and evaluating breeding decisions. The process was designed to consolidate participant learning from an intensive training workshop. The workshops are 1 d in duration and provide training in basic genetics and animal breeding (e.g., Mendelian inheritance, variation, factors affecting selection, genetic evaluation), as well as an introduction to crossbreeding and composite breed development. Time is set aside for participants to relate their experiences with crossbreeding. It is the last 2 h of the day that are used for training in HotCross. Participants are provided with all reading material and copies of presentations as well as a copy of HotCross. The facilitators bring laptop computers and all other visual aids. Workshops are usually held on a host property. Each enterprise represented at the workshop pays a fee to cover workshop expenses; up to three individuals per property may attend under one fee.

The workshop format has remained fairly constant. However, there has been an attempt to develop each workshop around the competencies of the group by working with the local livestock adviser to ascertain knowledge and skill levels prior to the workshop. These change from group to group, as do the perceptions about genetic improvement and breeding programs. Based on feedback from this approach, the workshops have raised the level of competency of the participants through a better understanding of genetics and increased awareness of breeding strategies. The workshops have provided a reasonable platform for planning and evaluation of crossbreeding systems through HotCross, and provide participants an awareness of alternative systems. Most importantly, they have made the participants aware of what questions they need to ask to achieve their breeding objectives. Thus, the workshops have helped to shift emphasis toward learning, rather then simply concentrating on HotCross as a decision support tool.

Information Systems Development Methodologies. No systems development methodologies were used in the development of HotCross. A business plan for marketing the DSS should have been developed earlier in the process, and continued funding for upgrades (or availability of code) to the DSS still need to be reconciled. As shown previously, ISDM can provide a framework to encompass these issues, and some published examples are provided in the next section.

Learning as We Go

We believe those approaches to DSS development that focus on end user involvement will lead to more successful systems and improved products. However, few concise descriptions of methodologies used in the development of agricultural-based DSS can be found in the literature. We present five cases that exhibit this emphasis.

Rickert (1998) describes the development of FEEDMAN, a DSS developed to help farmers and farm advisers make strategic and tactical decisions about feeding options, animal performance, market options, and economics for growing cattle. This is an example of the use of the development protocol developed by Stuth et al. (1993). The developers of FEEDMAN were aware of the need to create a package that was user-friendly but at the same time accommodated complexity in the farming system. A feasibility study was completed prior to development in accordance and in negotiation with the industry body funding the work. A development team, consisting of a scientist, a farm adviser and a computer programmer, developed the package through four distinct stages: a spreadsheet version (Prototype 1), expansion and refinement (Prototype 2), validation and evaluation, and commercialization. An advisory panel of four potential users thoroughly tested a prototype version during four separate workshops and provided advice on its presentation and predictions. Despite the involvement of users in the development of this system it has not had wide uptake. Rickert (1998) believes the low uptake has been caused by two primary factors. First, experienced managers are reluctant to accept DSS (Cox, 1996) because they cannot see clear benefits from using it. Second, in the case of FEEDMAN, there was no long-term planning and maintenance of the software necessary to demonstrate its benefits to industry (e.g., a "product champion" as described above). We suggest that end users were involved in the process too late. The system may have been easy to use but it may not have been useful (Keil et al., 1995).

Hochman et al. (1994) evaluated X-breed, a knowledge-based DSS for crossbreeding beef cattle developed for agricultural advisers. They reported that the DSS benefited from end user involvement in establishing users' attitudes and needs, iterative modification and expansion of the system after observing user response, field evaluation in the users' work environment, and direct input of knowledge for use in the knowledge base. Of importance was their finding that development activity was in general driven by end user consultation. Substantive technical issues were still raised through field evaluation even after rigorous technical testing. Hochman et al. (1994; p 232) also reported a "paradox of acceptability" in their results. Even though the purpose of the system was to make available expertise beyond the that of the user, confidence in, and agreement with, the system were prerequisite for user acceptance. This paradox arose when users disagreed with a recommendation that was acceptable to the domain experts. X-breed has experienced limited use in the field (Newman and Stewart, 1997), likely due to long-term planning, organizational support ("product champion" within the organization supporting development), and maintenance issues.

User involvement was of primary importance in the development of DAIRYPRO (Kerr et al., 1999). Three farmers from each of three regions in southeast Queensland, Australia, provided input and feedback during iterative prototyping. The system was deemed to be successful if "the user interface were considered adequate, the 'rules of thumb' were technically accurate and dairy farmers thought the system was a useful aid for making decisions on their farm" (Kerr et al., 1999; p 258). Usefulness of the system was determined by feedback during demonstrations to farmers not involved in initial development. All farmers considered the concept a useful adjunct to advice given by extension advisers (Kerr et al., 1999). However, it is too early, to determine whether this system will be widely used.

Finally, two instances are provided in which the use of DSS has resulted in either improvement in economic returns or changing farming practices. These two DSS are GOSSYM/COMAX (McKinion et al., 1989; Ladewig, 1990) and the Penn State Apple Orchard Consultant, or PSAOC (Rajotte et al., 1992). The GOSSYM/COMAX system "represents information from a team of 16 scientists, 17 years of research, 4 years of on-farm testing, and continual updating" (Ladewig, 1990; p 1). The PSAOC development team involved "experts from plant pathology, entomology, horticulture, agricultural engineering, agricultural meteorology, agricultural economics, and rural sociology" (Travis et al., 1992; p 545). As an example, the budget for support and maintenance only, to ensure adoption of the PSAOC expert system, was $55,000 for the first year and $48,000 for the second year (McClure, 1993). Although neither of these systems appears to have used a participatory approach to development, the funding provided to ensuring adoption of PSAOC and the extensive period of on-farm testing for GOSSYM/COMAX may have had a similar effect.

Closing Comments

There is still optimism about the future for DSS despite evidence for the potential lack of success. This optimism might be linked to the ability of researchers to continue to produce products and contributions to the literature (see below). Perhaps the greatest challenge to DSS development is how they are delivered to, and used by industry and policymakers. To achieve these goals, not only must we learn from experience, but we must also be ready to accommodate new technologies and research areas, which include the following:

Demonstrations that systems simulation can deal credibly with real agriculture,

Tactical approaches to decision-making using evolutionary computation that utilizes all prevailing information to develop action reports that dictate management decisions directly (e.g., Kinghorn, 1999),

Software delivery systems developed in line with the emerging influence of soft systems approaches,

Significant case studies demonstrating the contribution of systems simulation and DSS deployment to policy development,

Resolution to the debate on whether DSS have a place among the tools of systems managers,

Development of methods for executing simulation models via a WWW interface in an expedient manner, and

Greater reliance on data warehousing and data marts (Inmon et al., 1998) for mining information and increased access to large private databases.

Two important points concerning the development and deployment of DSS hold true today and will do so into the future: computing is prevalent in everyday life, and simulation provides a cost-effective and attractive means to quantitatively explain biological phenomena and predict outcomes under different environmental stimuli. Systems simulation and development of DSS are proving to be increasingly good investments by research, development, and extension agencies, even if for their own use. However, it is important to understand whether the feasibility for funding is due to research rewards (e.g., peer-reviewed papers or new products) or potential impact of the technology on industry. There is a perceived conflict between achieving a research career and achieving real impact in industry. Pertaining to the development of DSS, most successful impacts in industry have been achieved by those who chose to forgo an optimal scientific and(or) academic career path. Often, researchers get rewarded for new product development but not actually for delivering benefits to industry.

Implications

Decision support systems allow users to organize, set priorities, visualize potential management decisions and evaluate the outcomes of those decisions, and integrate research disciplines. The adoption of this technology can be greatly enhanced by structured approaches to development that emphasize user input and evaluation throughout the research and development process and increased emphasis on delivery of systems to industry through greater involvement and participation of potential end users. Developers of decision support systems must recognize the importance of learning processes in software development.

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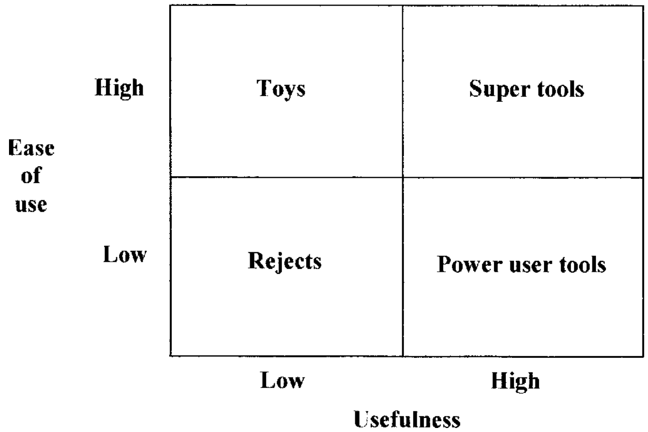

Figure 1. The usefulness vs the ease of use of decision support systems (DSS; after Keil et al., 1995). Usefulness is a measure of how well the DSS enhances decision-making. Ease of use is a measure of the physical or mental effort to use DSS. Systems defined as "toys" are initially accepted but have little chance of lasting acceptance. Software that is rated low for ease of use and low for usefulness will invariably be rejected by potential end users. "Power user tools" are those that will be of use for very competent computer users, and most will avoid their use due to the time and effort required to learn. Developers should aim to develop "Super tools," which possess high ease of use and high usefulness.

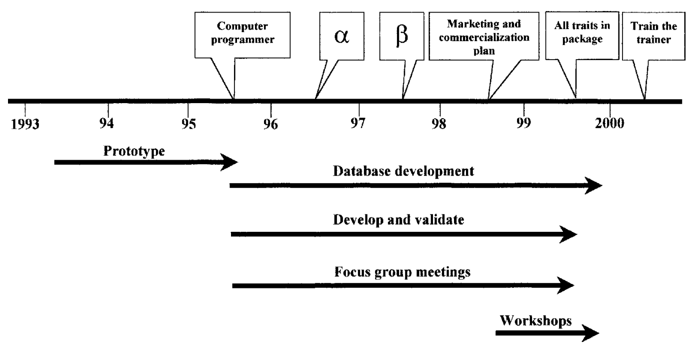

Figure 2. Evolution of HotCross, a decision support tool for crossbreeding beef cattle (see case study). On this time line, "α" corresponds to release of the alpha test version and "β," the beta test version of the software.