# Advancements in computerized decision support for Australian cotton systems

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## ABSTRACT

*Decision support systems (DSS) are widely accepted in the Australian cotton industry for assisting with integrated pest management (IPM), crop nutrition and information transfer. CottonLOGIC, a suite of computer based DSS is one example. The development of CottonLOGIC is undertaken with the specific aim to integrate complex research information and assist growers with their decisions, utilizing desktop software, the Internet, and electronic handheld devices. This paper discusses some approaches taken in the development and delivery of computerized DSS in Australia, and introduces the use of CottonLOGIC developed specifically for electronic handheld devices to assist with pest management decisions.*

*Over the years a significant challenge has been to produce and deliver effective DSS that meet the needs of the many stakeholders in the Australian cotton industry. Confronting these challenges has relied on the experience gained from almost three decades of DSS development. To ensure continuing success, it has been fundamental to adopt a more formal business like approach to DSS development that explicitly identifies the need to allocate specific resources to a range of tasks.*

*One recent innovation in DSS development is CottonLOGIC for Palm OS® handhelds. Software has been developed to allow growers and advisors the ability to conduct in-field electronic recording of insect population data, and process this information using models of pest development to assist with decisions relating to pest management. Used in conjunction with the CottonLOGIC Palm manager software, the handheld tool can be adapted to support various scenarios where multiple handheld devices are used and different farms are managed. The CottonLOGIC Palm manager also manages the transfer of data between the handheld device and the CottonLOGIC desktop software. Extensive field validation and independent evaluation have shown CottonLOGIC for Palm OS handhelds are highly valued by people who use it. The system has helped with maintaining data integrity, consistency when there is more than one person collecting information, and considerable time savings in collating information for pest management decisions using an IPM approach.*


## Introduction

Managing sustainable cotton production is becoming more difficult with the ever-increasing demand on limited resources. In addition, cotton growers are facing increased pressures to manage resources more cost effectively and to be more accountable for the impact that their decisions make on the surrounding environment. Consequently, computer based decision support systems (DSS) are being developed in Australia to help cotton growers achieve this. *CottonLOGIC* (a suite of software tools) is one of these DSS with the specific aim to provide cotton growers and advisers information generated from research to assist with these complex management decisions, aspiring to achieve sustainable cotton production systems.

The Australian Cotton Industry has a strong reputation for accepting and adopting innovative computerized DSS to improve crop and pest management and have benefited from doing so (Hearn and Bange, 2002). A recent independent assessment of the cost benefits of the pest management component of *CottonLOGIC* adopted in the Australian cotton industry found a benefit: cost ratio of 18.5 (The Centre for International Economics, 2003). The demand for reliance on this technology is also increasing. The number of registered *CottonLOGIC* users has steadily increased from 200 in 1995 to over 1100 presently (Figure 1). In addition, a recent survey (August 2002) showed that *CottonLOGIC* had been used across 51% (207 208 ha) of the total area of cotton grown in Australia in the 2001/2002 cotton season (404 000 ha; Dowling, 2002). Of this area where *CottonLOGIC* was used, 93% of use was for record keeping (insect and operational data) elements of the software, while 69% was to assist with management decisions using research models embedded in *CottonLOGIC* (Table 1).

This paper discusses philosophies and principles that drive the development and implementation of DSS in Australia. It also presents some recent and future developments of computerized DSS especially the development of *CottonLOGIC* (for Palm OS handhelds).

## Development of DSS in Australia

The Australian cotton industry is rich with successes and failures in DSS, we can call on a number of approaches to assist acceptance, development and evaluation of its products and activities. Conflicting opinions may result in serious tension amongst stakeholders. Much of this can be avoided if appropriate mechanisms are put in place that remain adequately financed, remains flexible, and ensure that scientists and the developers of DSS are aware of the social dynamics and respond sensitively. In an endeavor to overcome many issues relating to DSS development, it has been important to define and widely promote a number of philosophical and ethical principles to meet the needs of all stakeholders in DSS development, which are:

1. Aim to develop effective, useful and user-friendly DSS backed by quality science.
2. Promote responsible crop management based on the best and most appropriate science that is accepted by industry (e.g. best management practice (BMP)).
3. Ensuring that the science used in the software is inherently shared by all researchers involved, and not entirely by developers of decision support.
4. Select development priorities based on appropriate constructive feedback and industry input.
5. No group or region within the industry will be favored nor ignored.
6. Approach each task pragmatically, and only after careful planning and responsible considerations commit to software development.
7. Make activities and decisions transparent to superiors, industry and funding bodies.
8. Produce quality outcomes, thoroughly tried and tested.
9. Promote the decision support systems as tools, they do not make the decisions, but provide information to assist in the decision-making processes. (e.g. promote IPM and *CottonLOGIC* helps achieve this).

Development of effective decision support tools requires the integration of many facets from the conception of an idea through to delivery and support. One principle approach is to use multifaceted skills and knowledge, coordinated effectively with expertise and input of others when available. A more formal approach to DSS development is needed which explicitly identifies the need to allocate resources to specific tasks. An important aspect is to recognize that DSS development is not just about software programming. Some of the important functions and activities of a decision support team are presented in Table 2. Each role requires resources and is critical to the overall success of DSS development and delivery.

The operation of the team strongly focuses on supporting the user with careful attention to attaining feedback from industry in order to develop the most effective decision support tools. A range of feedback mechanisms has been developed that have proven to be very valuable. User workshops conducted annually have been an effective way to receive user feedback and the decision support advisory committee made of representatives from all stakeholders in DSS has been essential to assist in strategically planning the direction of DSS development. In addition, there has also been significant interest from the cotton industry for independent and constructive assessment of the attitudes, development, delivery and contribution of DSS towards management of sustainable cotton production systems. Consequently the DSS team employs an independent consultant to conduct comprehensive evaluation studies. The primary aim being to assess the impact that decision support tools are having on the users decision-making processes, and to gather ideas to make these systems more effective. This also acts as an important mechanism for crucial feedback in order to focus and plan our efforts.

Another strategy that has been fundamental to the development of an effective DSS is field validation. Field experiments and user groups have been used to test the efficiency and functionality of DSS, and provide valuable feedback for continued development and improvement. Field experiments have been located in various cotton growing regions of Australia, and have demonstrated the robustness of the DSS in a range of climatic and management conditions (Deutscher *et al*., 2001; Deutscher and Plummer, 1998).

By embracing a range of flexible strategies to help manage the DSS development and delivery, we are ensuring the usefulness and future use of DSS for the industry. This approach is being applied to recent and ongoing development of DSS in Australia, which will now be discussed.

## *Recent advancements in DSS in Australia*

A major production issue which Australian cotton growers face each season is the protection of the crop against a range of insect pests. Cost of this protection can be as high as A$400-A$1000 ha and gives rise to ecological problems from pesticide resistance in key pests, and environmental concerns with pesticide movements off-farm (Wilson *et al*., 2003; Fitt, 2000). In order to address these issues, the Australian industry has embraced many components of an Integrated Pest Management (IPM) systems approach (Wilson *et al*., 2003). Consequently, cotton pest management has remained a key research and extension priority.

One of the key elements of an IPM approach is the regular monitoring of numbers of pest and beneficial insects and the use of economic thresholds to guide decisions on pest management. Traditionally the process of collecting insect population information in the field has been undertaken by counting pest and beneficial insect numbers from a number of representative areas and recorded using pencil and paper cards. This information was then provided to the decision maker directly or entered into the decision support system *EntomoLOGIC* (the pest management component of *CottonLOGIC*).

For many years, cotton pest managers have requested the use of a small-computerized device that can be taken into the field to assist with insect management decisions. Advances in handheld computing have made using devices for recording and processing data in the field more feasible. Consequently, this has resulted in expanding the development of *CottonLOGIC* for use with Palm OS® handhelds. This development is expected to increase the use of *CottonLOGIC* by consultants for decision support, as they will be able to enter the data and make a decision in the field.

A similar system 'Scout Link' has been developed for cotton systems in the US to assist pest information collection (Giles, 2002), but is not linked to models of pest development or handles the complexities of different approaches to collecting pest information from different farms and different fields with a number of users.

This paper will briefly describe the concepts behind the development of the new *CottonLOGIC* system for use with Palm OS® handhelds and its application in the Australian cotton industry.

## *CottonLOGIC/EntomoLOGIC*

The pest management component of *CottonLOGIC* is recognised as *EntomoLOGIC*. *EntomoLOGIC* was derived from the *SIRATAC* decision support system employed in the Australian cotton industry from 1976 to 1993 (Hearn and Bange, 2002). The package aims to optimise the use of inputs and resources, maintain productivity, whilst protecting the environment. This is achieved by assisting growers to make more informed pest management decisions based on the integration of their data (insect and operational) with a series of models for key pests of cotton. The system caters for a range of insect sampling techniques where insect numbers are converted to densities of the pest per square meter. Models of pest growth and development add value to pest population data collected, by predicting the future population development of *Helicoverpa* spp. (a key pest) with climate data or the potential consequences on yield from outbreaks of the two-spotted spider mite (*Tetranychus urticae* Koch.). When mites are recorded on the crop the rate of mite population increase and predicted percentage yield loss are shown. Reports generated from *EntomoLOGIC* present current and predicted information on insect densities compared with standard or user defined pest thresholds, as well as information about the last insecticide spray applied to the crop.

The ability to predict pest populations increases the accuracy of knowing when to control a pest population reducing the occurrence of unnecessary chemical control. In numerous and comprehensive field studies, the use of *EntomoLOGIC* has been shown to reduce insecticide use by an average of 16% compared with conventional approaches to pest management (Deutscher *et al.*, 2001).

## *CottonLOGIC for Palm OS® handhelds – An Overview*

The aim of developing *CottonLOGIC* for Palm OS handhelds was to develop software that could be used on reliable electronic devices to: streamline the data entry process; run models of pest development that access climate and historical data for insects and crop details; generate in-field reports; and most of all save time. To meet this, *CottonLOGIC* (for Palm OS handhelds) has been expanded with the addition of two other software components, *CottonLOGIC* Palm manger and the existing desktop version of the *CottonLOGIC* software (Figure 2). Palm OS handhelds were chosen because they are extremely popular organisers that are compact; inexpensive; user friendly; designed to be viewed in direct sunlight; have infrared capabilities; recognise hand writing; relatively easy to develop software for; and they host a range other useful tools for different applications. Current functions of *CottonLOGIC* for Palm OS handhelds (Version 1.0) include:

- Insect population data entry for pests and beneficials (Figure 3a);
- In field reporting of pest and beneficial status for remote printing; insect data from the last 16 days prior to the current check for use in the two-spotted spider mite model;
- The ability to edit crop information e.g. crop development and plant populations;
- Insect density reports including results from the *Helicoverpa* spp. development and prediction model (as shown in Figure 3b); and
- The capacity to enter temperature forecasts to enhance the *Helicoverpa* spp. population model.

This advancement now allows pest managers of cotton to access insect models that utilise the data collected in the field to assist with more informed in- field decisions.

One of the biggest challenges pertaining to the development of the handheld system was to accommodate necessary spatial, temporal, and multiple user elements. This was critical to the development of the system in order to allow flexibility and functionality when it involved: one or a number of people collecting insect data for crop management; a number of farms or fields; and a collection taken on different days of the week. To transfer information to and from the handheld device in these different scenarios is the main purpose of the *CottonLOGIC Palm Manager* (Figure 2), and the concept of 'Crop profiles' embedded in the software. The Palm Manager is software that operates on a desktop computer and is used to select the information to upload onto the handheld device and also transfers the latest data from the handheld to *CottonLOGIC*. Data is uploaded to your handheld on a crop basis, using the Palm Manager to select the crops. Selected crops are then saved as a 'crop profile' and uploaded to your handheld. You can create multiple crop profiles and upload them as required. All information can still be downloaded seamlessly onto desktop computers for a more comprehensive interpretation, or to compile in the case when more than one handheld is used for pest management decisions.

## Field validation and project evaluation

Rigorous in-field validation and project evaluation activities were conducted before the release of *CottonLOGIC* (for Palm OS® Handhelds) in August 2002. Field validation was carried out over a period of 18 months prior to release across the industry. The system was tested in a group which varied in terms of the size of the enterprises and they way they endeavored to use the software. The majority of ideas and concepts generated from this field validation were implemented for the formal release of the first version.

In addition to large-scale field evaluation, smaller trials were also conducted to address specific concerns. For example, a major benefit of using *CottonLOGIC* (for the Palm OS®) was thought to be its time saving ability. To confirm the potential time saving advantage, small time trials were conducted. The time taken by users was measured entering the same insect data into the handheld and then on the insect checking cards using a pencil. Time was also measured entering the insect data from the cards into *CottonLOGIC* on a desktop computer, compared with downloading automatically to the desktop with the handheld system. The results showed that on average, the time taken to enter insect data into the handheld was considerably more than the paper (card) system, although this depended on the level of skill of the person using the handheld. A skilled Palm handheld user could enter data as quickly as the traditional method. On average the time taken to synchronise the palm to the desktop was 45% less than the time taken to enter data from the cards into the desktop. The added benefit was that during this time other activities could be undertaken.

Another major concern was the durability of using the handheld devices in the field, particularly when the field was wet. To alleviate these concerns, a plastic water-resistant pouch was sourced that protected the device, and made it easier to carry and use.

In addition to in-field validation, the services of an independent consultant were employed to assess the value of the technology in assisting with cotton management decisions (Van Beek, 2002). The general expectation captured prior to the use of *CottonLOGIC* for Palm OS handhelds, mentioned by all interviewees, was that it would save time with data entry. Other expectations were that it would provide better quality data with fewer mistakes, provide a set format for data collection, and add value to the service that a consultant could provide. Following the season where the majority of the users had persisted in using the software, the evaluation showed that most had believed that it had met their expectations, and believed with improvements in some areas, the product would be successful. Some of the comments made by people who had used the system were: The Palm-top is only new and of course there are hick-ups and extra things we want. But it improves our lifestyle as much as it improves our business'.

A interviewee said that using the handheld 'had not affected decisions much this year but it will make them quicker next year, less guesstimating and sorting manually through files. It is quicker especially on the *CottonLOGIC* side for forecasting insect populations, and that will give better decisions. It will definitely be an improvement. And it gives more confidence'.

'You get the info in your pocket, the history, and you become able to make decisions in the field, and get the application quickly, rather than have to go home and go look for the info. It speeds up the process and that is important especially in sensitive areas.'

The concepts and ideas expressed from these evaluations set the foundation for promoting and developing future developments of *CottonLOGIC* for the Palm OS handheld.

## Ongoing developments in DSS in Australia

Advances in information technology through improvements in desktop software, handheld devices and the Internet have provided significant opportunities to enhance the development of DSS. Current and ongoing developments of DSS aim to utilise and integrate these technologies to improve cotton management with research outcomes. Some of these initiatives are:

- *HydroLOGIC*. A cotton irrigation scheduling and management tool, which allows users to explore the consequences of irrigation management on cotton development, yield and water use.
- Crop compensation. Incorporating knowledge of the ability of cotton crops to compensate for pest damage into DSS.
- Area wide management. Improving the ability of farmers and advisers to share knowledge to address regional issues relating to pest management.
- Farm water accounting. Providing irrigated cotton growers with software to track the movement of the water resource on their farm and calculate efficiencies (e.g. irrigation efficiency).
- *HEAPS*. Exploit the capabilities of the HEAPS (Helicoverpa Armigera and Punctigera simulation) model, which simulates *Helicoverpa* spp. population growth and dispersal over a region, to specifically support resistance management for transgenic cotton and conventional insecticides.
- 3rd Party software integration. Improve the ability of the *CottonLOGIC* software to share information with other software.
- Improved information delivery. Engage the use of multi-format software tools that allow rapid publication of Web, hardcopy and CD based information. This initiative has the ability to make information widely available, easier to access, navigate

and upgrade, and more cost effective as information changes.

## Conclusion

Maintaining the level of resources needed to develop and deliver effective DSS is the most significant challenge. The factors that determine how resources are allocated to a task is summarised by the need to maintain four key elements. They include:

1. Creating innovation (developing new solutions for decision support);
2. Software development to address strategic industry issues (e.g. water and environment);
3. Industry software support (addressing day to day needs and current issues); and
4. Maintaining a software development environment so that new and existing software can be developed and will function. (e.g. making sure that *CottonLOGIC* will run on different Microsoft windows operating systems).

An extremely important lesson that has been learnt from developing DSS or any software for that matter, is not to let one of these elements dominate. They must be considered equally for the success and future of the significant investment in DSS. To allow one to dominate is at the expense of another, but ultimately resources (sometimes more than originally required) are needed to bring the other elements in line. Although, the quandary is that in doing this, other elements again suffer.

We are in an enviable position working with the cotton industry in Australia, which has a rich record of success with computerized DSS. Research continues and new DSS need to be developed to provide the tools for sustainable cotton production systems. Progress in information technology (such as the handheld devices) offer new and exciting solutions for DSS development. With an agreed and coordinated approach, working close with industry we endeavor to maintain this success.

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***Table 1.*** *Results of a survey measuring CottonLOGIC use (in area) in the Australian cotton industry (August 2002; 135 survey respondents).*

| CottonLOGIC Function | Area used (ha) | Proportion of total |
|---|---|---|
| Insect identification tool | 84811 | 41 |
| Record keeping capabilities | 193348 | 93 |
| *Helicoverpa* spp. prediction model | 63452 | 31 |
| Two spotted spider mite model | 39210 | 19 |
| NutriLOGIC – Nitrogen model | 21950 | 11 |
| Spray ordering capabilities | 33756 | 16 |
| Decision Support (excluding record keeping and spray ordering) | 142072 | 69 |
| Total Area of Cotton Industry† | 404000 | |

† Source Dowling (2002)

*Table 2. Important functions of a team developing DSS.*

| Team Function | Example of activities |
|---|---|
| Scientific foundation | Compiling and integrating knowledge for developing DSS |
| Software development | Software coding, and testing |
| Software engineering and research | Investment in maintaining software development platform, exposure to new IT systems |
| Education and training | CottonLOGIC training workshops, field days, phone support, Internet support |
| Industry Feedback | Surveys, Industry Advisory Committee |
| Packaging and Distribution | CottonLOGIC packaging (professional appearance) |
| Promotion | Attendance at trade shows, important industry events |
| Scientific Review | Attendance at conferences, publications, peer review, scientific journals |
| Field Validation | Regional specific field trials, working closely with extension |
| Project Evaluation | Surveys, independent feedback from specialist DSS consultant |
| Administration | Personnel and project management, sourcing funding, strategic planning |

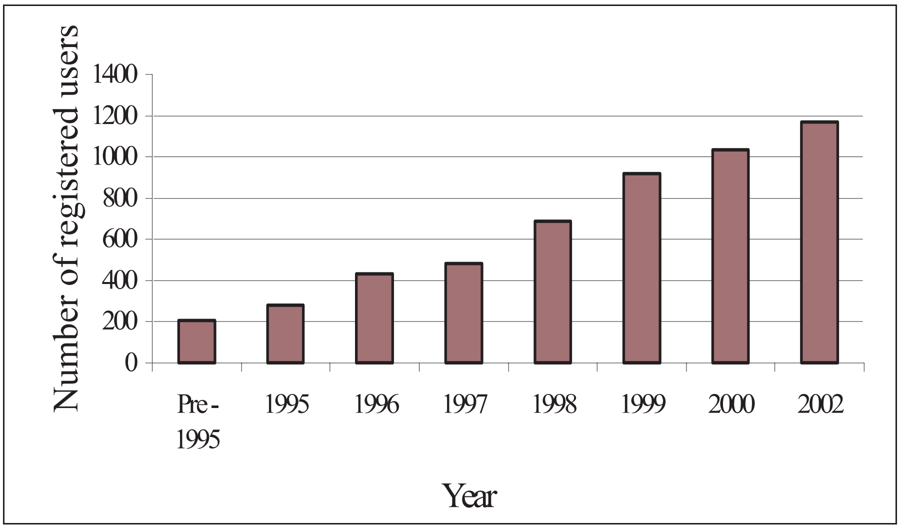


***Figure 1.*** *Increase in registered copies of CottonLOGIC distributed to the Australian cotton industry.*

*Figure 2.* Flow of information and software components of CottonLOGIC for Palm OS® handhelds.

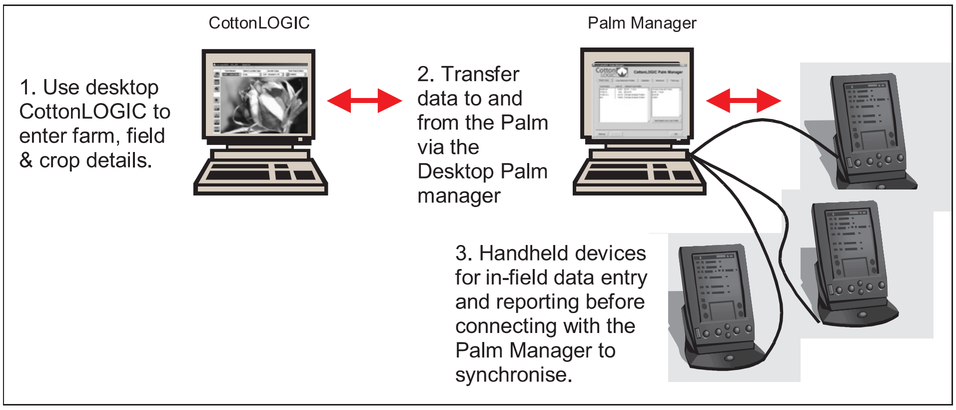


*Figure 3.* The CottonLOGIC for Palm OS® handhelds insect data entry screen (a) and the report screen (b).