A qualitative case study of the adoption and use of an agricultural decision support system in the Australian cotton industry: the socio-technical view

Abstract

In response to the call for research that considers the human as well as the technical aspects of information systems implementation, the authors report on an interpretive case study which explores the adoption and use of an agricultural decision support system (DSS) *CottonLOGIC* in the Australian cotton industry. The study was informed through the innovation-decision model by Rogers and the technology-in-practice model by Orlikowski using a socio-technical approach. It was found that participants who achieved a high level of implementation success were reflexive and resourceful in adapting the technology to their changing needs, often in ways unanticipated by DSS builders.

Keywords

Decision support systems, Farm management, Cotton, Australia, Qualitative, Case study, Diffusion theory, Structurational model of technology, Socio-technical, Implementation

1. Introduction

Australian farmers are supplementing traditional practices with innovative management strategies in an effort to survive recent economic and environmental crises in the rural sector. Cotton has become Australia's fourth largest agricultural export despite only about 1,500 cotton farms in Australia. The area under cotton is estimated at around 500,000 hectares although this area has diminished in the past year due to the effects of a severe and prolonged drought in Australia [39]. These farms have diversified to grow other crops while many graze sheep and cattle [9]. Survival of the cotton industry is due in no small measure to the industry's commitment to research and practice. While innovative technologies such as the computer-based agricultural decision support system (DSS) *CottonLOGIC* are considered influences on the adoption of sustainable farming systems in the cotton industry, the continued low adoption rates of agricultural DSS have been a concern [8,10,11,15,16,17,19,21,22,23].

DSS research has been critically evaluated in a recent, ongoing project by Arnott and Pervan [2,3] who identified several key issues to be addressed. Some of the findings were: firstly, the relevance of DSS research would improve by increasing the number of case studies, especially interpretive case studies to help reduce the gap between research and practice; secondly, DSS empirical research is "overwhelmingly positivist, and more dominated by positivism than IS research in general" [2 (p.67)]; and finally, the academic rigour of DSS research would improve by broadening the reference theory foundation from its extant narrow base.

Furthermore, an alternative decision-making paradigm in DSS research to consider perspectives "beyond the technical" was proposed in a paper describing decision making in organisations by Courtney [7 (p.36)]. According to Courtney [7], the conventional view of DSS is both mechanistic and analytical in nature and "scarcely considers anything but the technical perspective" (p.30). Arnott and Pervan [2] extended the notion to allege that "a major omission in DSS scholarship is the poor identification of the clients and users of the various DSS applications that are the focus of investigation" (p.67). In response to the claims that social and personal views are neglected in DSS research, this paper takes a socio-technical approach to investigate the interaction of cotton growers on Australian family farms with the agricultural DSS *CottonLOGIC* by exploring both the societal and technical aspects of DSS implementation.

A multitude of definitions of computerised DSS exist. Turban, Aronson, Liang and Sharda [40] identified the functions of a DSS as an "adjunct to decision makers to extend their capabilities but not to replace their judgement" and to "support the solution of a certain problem or to evaluate an opportunity" (p.88). Arnott and Pervan [2] classified DSS as "the area of the information systems discipline focussed on supporting and improving managerial decision making" (p.67) while Hearn and Bange [16], in their paper reviewing the role of DSS in the Australian cotton industry, claimed that DSS assist the decision making of crop managers while raising "awareness of other dimensions" (p.53). All these definitions characterise the agricultural DSS in this paper.

This paper revisits the data from an interpretive single case study in the Australian cotton industry which informed a doctoral thesis by the first author [24]. Aspects of *CottonLOGIC* implementation, in particular adoption and use, are expanded in this paper and analysed through the conceptual lens provided by two theories of sociological origins, outlined as follows. The adoption process of *CottonLOGIC* as innovative technology is examined through the perspective of the innovation-decision model from Rogers' diffusion of innovations theory [35] with its deterministic and objective focus on technology. More subjective and informal insights are elicited by applying Orlikowski's technologies-in-practice model [30]. This model is an extension of the duality of technology from Orlikowski's structurational model of technology [29] which is based on Giddens' structuration theory [12]. Essentially, the technologies-in-practice model offers a more human perspective to the study of technology 'in use' as distinct from technology as an artefact, an object, or an innovation, as conceived by Rogers [35].

In brief, this paper highlights the value of considering both technical and social dimensions when investigating DSS implementation. The research objectives or problems of the study were formed through a critical review of the relevant literature, taking into account its ontological, methodological, theoretical, as well as practical goals. The problems to be addressed in this paper are summarised by the following research questions, with replies offered in the concluding section.

Question 1. *Does Rogers' innovation-decision model with its technical focus adequately represent the stages in the adoption of CottonLOGIC?* In other words, does Roger's model provide a full understanding of the adoption process of a technology? Are the roles of end-users accounted for in the adoption process?

Question 2. *Does Orlikowski's technologies-in-practice model explain the use of CottonLOGIC?* That is, does Orlikowski's model enable an in-depth exploration of a technology 'in use'? What are the outcomes when human agents (end-users) and technology (*CottonLOGIC*) interact with each other dynamically?

Question 3. *Does the use of CottonLOGIC influence farming practice and challenge end-users?* More specifically, does *CottonLOGIC* build on the way growers view decision problems and deal with them? Do *CottonLOGIC* users influence the design and development of future DSS with the potential to improve software uptake? Lastly, what is the impact on end-users?

The findings of this paper are expected to contribute to a greater appreciation of the issues facing cotton growers in their engagement with *CottonLOGIC*. While the contributions are outlined as follows, they are expanded more comprehensively in the relevant sections of this paper, and responded to in the concluding section. The ontological aim of the study is to provide a socio-technical view of cotton growing and to contribute to scholarly knowledge in the understudied research domain of Australian cotton growers, agricultural DSS, and cotton farm management [17,24]. The methodological significance stems from it interpretive nature since an inductive reading of the data provides in-depth insights into technology adoption and use, particularly from a client perspective. Moreover, studies suggest that relevance in DSS research increases through an empirical qualitative DSS case study [2,3,15,21]. The conceptual framework used to inform the study is novel for agricultural DSS research with both innovation-decision and technologies-in-practice theoretical models having sociological origins. These theories offer increased academic rigour from a wider reference theory foundation for DSS research, which, in the past, has over-relied on decision-making theory [2,3,7,33]. The practical implications of the study from the insights gained are expected to include the provisions of guiding principles for future agricultural DSS (11,39].

The paper has the following structure. Firstly, an overview of the background literature relevant to DSS particularly in the rural sector is followed by a brief description of the research site and the research strategy of the study. Next is a review of the two theories which comprise the conceptual framework; then an analysis of the interview data through the sensitising concepts from each of the theories along with a discussion of the findings. Finally, is the concluding section where the findings are interpreted, responses to the research questions are given, and the contributions of the paper are discussed.

2. Review of the literature

Early information systems (IS) research of design and development projects conceived IS to be technical with social consequences, implying an emphasis on IS problems and solutions as having technical complexity [13,14]. However, in the 1980s, Goldkuhl [13] and GoldKuhl and Lyytinen [14] identified that IS are actually "social systems only technically implemented" being "formal linguistic systems for communication between people" (p.3). In that era, Kling [18] determined that both technical and human factors should be considered in the IS design and development process while Mumford [26] recognised that technology in use had social implications. In 1983, Land and Hirschheim [20] declared that "technology is never more than a component of the information system" (p.91). These authors insisted that "the emphasis on social systems is of paramount importance" (p.91) therefore IS "design and implementation should be dealt with in some participative fashion" (p.93). That is to say, users should be able to influence the design process. More recently, Orlikowski and Barley [31], in emphasising the mutual reciprocity between technology and human agents, claimed that "technologies are simultaneously social and physical artefacts" although, during integration into everyday practice, "users shape the implications of technologies" and the properties of technologies "influence agency" (p.149). As Avison, Fitzgerald, and Powell [4] recently affirmed, the social and human factors are at least as important as the technological ones.

Australian research scientist, McCown [23] noted that several forces are driving innovation and change in Australian agriculture. One is the greater emphasis of public policy on issues of sustainable farming practices with less emphasis on problems of production. The other is the government initiative of reducing costs whereby many rural extension programs have ceased, to be replaced by participatory on-farm research [22]. Moreover, agricultural DSS as software tools to guide farmers and their advisors in the management of farming systems were predicted to fill the gap, traditionally occupied by rural extension services, between the scientific theory of the rural researcher and the real-world practice of the farmer [22,23]. McCown [23] identified agricultural DSS as a "socio-technical innovation" while recognising the existence of a "socio-technical relationship between scientific models built to guide practice and actual practice" (p.11). Likewise, McCown [22] cautioned on the "problem of implementation" and the challenges of bridging the gap between the theory of researchers and the practice of farmers (p.549).

Despite the recognised benefits to agriculture of cutting-edge knowledge integrated in the technology, the principles of science-based intervention, also termed the 'transfer-of-technology' push, have been criticised extensively with growing scepticism from potential DSS end-users [8,19,21,33]. Rural researchers, Vanclay and Lawrence [44] argued that the scientific knowledge transfer model is limiting, and that factors in the diffusion process such as the experience and intuition of farmers are neglected. Moreover, agricultural scientist, Cox [8] condemned the use of DSS in agriculture and argued vehemently that "the tendency for scientific knowledge to override practical knowledge impedes communication" (p.272).

Many studies reported the poor uptake of agricultural DSS, recognised as a worldwide phenomenon [8,10,11,15,17,19,21,22,23]. The numerous justifications for low adoption rates commonly criticised the DSS technology in a negative manner. The criticisms include: 1) the software is too complex; 2) the software expects too much prior knowledge of the farmer; 3) the software is not aligned with farming objectives; 4) the software updates are too infrequent; and 5) data capture and entry for the software are too tedious. Despite the persistent negativity, there remains a degree of optimism regarding agricultural DSS implementation, associated with client participation.

Studies of DSS users have determined that client involvement during the software design and development process are positively related to system outcomes [21,33]. In a comprehensive interpretive study of DSS adoption in the Australian rural sector, Lynch and Gregor [21] found that the degree of user influence is strongly associated with systems implementation. British researchers, Parker and Sinclair [33], provided an account of a survey study of DSS failure in crop production in Britain, finding that a user-centred approach during the design and development process is aligned with system implementation success. Parker and Sinclair [33] alleged that, while papers of successful DSS development and release with a focus on technical aspects have been published, there are few papers on the failure to adopt and use DSS (p.456).

A quantitative meta-analysis of DSS literature undertaken by Alavi and Joachimsthaler [1] examined user-related factors in DSS implementation. The researchers [1] found that user-situational variables such as involvement, training, and experience were significant factors in DSS implementation success. Kuhlmann and Brodersen [19] in a quantitative study of DSS and other technological farming decision models from Germany asserted that the requirements for DSS acceptance are changing and that farmers are more inclined to employ DSS as devices for crop input and yields and retrospective calculations rather than for forward farm planning (p.72). The authors [19] recommended reducing the credibility gap of farmers through greater engagement by training and education as well as using simpler decision models to match the expertise of farmers (p.76). These concerns are being acknowledged in the field of Australian agricultural DSS. Over the past 10 years, the Farmscape program for decision support with its Participatory Action Research (PAR) approach has resulted in improved outcomes for end-users of DSS technology in Australia [6]. Guerin and Guerin [15] also commended PAR for technology development and knowledge transfer, adding that it complements the traditional technology diffusion model by Rogers [35] by encouraging user participation.

The second author of this paper, Kerr [17], maintained that agricultural DSS are often funded for research and development, not appraisal. For example, in Australia many DSS projects are part of a three-year industry funded research grant. These grants are competitive and administered by research and development corporations with funding to cease at the end of the three year period. It is at the end of this critical period when the DSS project has been completed and the product needs to be marketed, that additional resources should be allocated to ensure adoption. However, these additional resources are rarely made available [17]. *CottonLOGIC* is an exception.

A lesson learnt from the demise of its precursor SIRATAC was the value of having stakeholder groups represented in all stages of design and development with on-going evaluations by end-users [16]. An assessment of the impact of *CottonLOGIC* on the Australian cotton industry was conducted in the early phases of software release by an independent consultant. Van Beek [41,42,43] was engaged by the Australian cotton industry to evaluate *CottonLOGIC* using both survey and interview data gathering techniques and to produce a series of reports. There were two other industry-funded *CottonLOGIC* assessments, both based predominantly on a positivist epistemology. One was a survey of 135 cotton growers by Deutscher and Bange [10] in 2002 and the other, interviews and surveys for a study of the cotton DSS program by cotton consultants, Doyle and Coleman [11] in 2005. Doyle and Coleman [11] found that growers who use consultants regularly to perform services are more likely than other growers to use *CottonLOGIC* software tools. While explanations are ambiguous, it appears that these growers are more conscientious in every aspect of production.

In brief, this paper contributes to existing literature due to: 1) the independent nature of scholarly inquiry as distinct from industry funded evaluations; 2) its focus on DSS users as well as technology through an interpretive view of stakeholder influences on technology adoption and use; and 3) the currency of the research. Furthermore, the study has a uniquely Australian context which is distinct from rural European DSS studies [19,33].

3. Research site and research strategy

This section contains a description of the research site, the agricultural DSS *CottonLOGIC*, and the research methodology of the study. The management of sustainable cotton production is becoming more complex with the ever-increasing demand on limited resources such as soil and water, the need to utilise effective insect, weed, and chemical management, and to limit adverse environmental impacts. The cotton industry in Australia has endorsed best management practices (BMP) particularly integrated pest management (IPM) as initiatives to encourage growers to be more efficient producers, responsible neighbours, and to be in harmony with the environment. Furthermore, cotton growers and their advisors need to adjust to the growing of new insect resistant, transgenic (genetically modified) cotton seed varieties such as Ingard® and Bollgard II®, introduced as IPM initiatives to limit harmful spraying regimes [39].

Three generations of DSS have been developed for the management of cotton production in Australian over the past twenty-five years. These are SIRATAC, SIRATAC Plus, and more recently *CottonLOGIC*. The SIRATAC pest management system was used in Australia between 1980 and 1993. SIRATAC was a computer-based dial-up crop management system with a centralised database consisting of several simulation models and a decision model to help cotton growers make good tactical decisions in the use of pesticides. After SIRATAC's demise at the end of its useful lifespan, the development of SIRATAC's replacement, SIRATAC Plus, was abandoned in 1990 on the grounds of excessive complexity and cost [16].

CottonLOGIC is a farm management suite of software programs to assist cotton growers and their advisors in the management of cotton pests, soil nutrition, and farming operations. *CottonLOGIC* was developed in Australia in the late 1990s as an agricultural DSS by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and the Australian Cotton Cooperative Research Centre (CRC), with support from the Cotton Research and Development Corporation (CRDC). *CottonLOGIC* contains two modules, one for record-keeping and the other for decision support. The record-keeping modules of *CottonLOGIC* enable the recording and reporting of crop inputs and yields, insect populations (heliothis, mites, tipworm, mirids and so on), weather data, and field operations such as fertiliser and pesticide applications. The decision support modules of *CottonLOGIC* have models to simulate the prediction of insect densities and soil nutrition [16]. Although DSS use in the Australia cotton sector is voluntary, there is growing support for mandatory use associated with best management practices (BMP) and integrated pest management (IPM) compliance. *CottonLOGIC* training courses were run over five years from 1999 to 2003 in the form of interactive half-day workshops provided annually, gratis, to facilitate the use of the software by cotton growers and industry professionals, as well as to obtain feedback from end-users.

The research methodology of the study was qualitative thus letting the social world of cotton growing be understood contextually through the first-hand knowledge of participants, in a manner described by Walsham [45]. The rationale for a qualitative study was that an in-depth study of a situated experience would provide deeper understanding than gathering standardised quantitative data from a large sample of the population. The study was interpretive, meaning that constructs emerged from the interview data rather than being determined beforehand as questions for a survey would have been. Moreover, the phenomenon explored was understood through meanings assigned by participants rather than survey instruments [34].

The unit of analysis was at the individual level, namely, the Australian cotton grower and their activities associated with implementing farm management software. To enrich the data collection further and for the purposes of comparative analysis, a range of informed industry professionals were consulted for their perceptions of growers' roles in DSS usage and farm management. All participants were selected according to a purposeful sampling strategy as outlined. The cotton growers were selected based on the following criteria: 1) farmed in the Australian eastern states of Queensland or northern New South Wales; 2) were responsible for, that is, owned and /or managed family farms irrespective of size (as distinct from farms owned by large corporations); 3) indicated an awareness of environmentally sustainable and high-technology farming practices; and 4) were registered on a *CottonLOGIC* and / or Wincott (Women in Cotton Network) database. The industry professional were cotton agronomists and consultants, rural extension officers, researchers and educators, rural experimental scientists and *CottonLOGIC* developers who were located in Queensland or northern New South Wales. As professionals, all these participants had to have some knowledge of agricultural DSS either through development, usage, research or teaching, and, to some extent, were observers and/or advisors of cotton growers.

Data gathering took place during three field studies and one telephone study with 32 participants over three years (2002, 2003, 2004) by the first named author of this paper. An interview guide was prepared to steer the interviews which were semi-structured, conducted at locations selected by participants, with each interview lasting at least an hour, and recorded on audio tape with permission. Notes on each interview were written up that same night in an activity log and interviews were transcribed from audio tape into Microsoft Word as soon as possible. Analysis was manual rather than computer-assisted since the number of interview transcripts was workable and the obligation to stay closely connected with the data was fundamental. Codes used in analysis were based on concepts or themes drawn from both the literature and theoretical framework. In short, this study of cotton growers using farm management software in the Australian cotton industry was an interpretive single case using ideographic methods. It allowed a first-hand investigation, involving several field trips to study participants in their natural setting, taking place over an extended period of time, and producing a textual analysis of rich insights after a period of reflection.

The claim by Lynch and Gregor [21] that there is a predominance of quantitative studies using survey methods in the DSS domain and comparatively little qualitative research was corroborated by Arnott and Pervan [2,3]. Furthermore, Guerin and Guerin [15] maintained that the role of a survey for rural extension research is questionable and that more informal approaches are needed (p.566). While acknowledging the "… tension between academic rigour and professional relevance", Arnott and Pervan [2 (p.667)] advocated improving the relevance of DSS research by increasing the number of case studies, especially interpretive case studies, which "can illuminate areas of contemporary practice … and build lasting links between academics and senior professionals" (pp.667-668). For the reasons stated above, the authors consider that the qualitative and interpretive nature of this case study is a significant contribution to the scholarly DSS literature.

4. Theoretical foundations

The two sociological theories which comprise the conceptual framework of this paper are discussed in this section. The first theory, the innovation-decision model from diffusion of innovations theory by Rogers [35] is used to examine the adoption process of a technological innovation such as *CottonLOGIC*. The stages of the innovation-decision process conceptualised by Rogers [35] are knowledge acquisition, problem framing or persuasion, decision, implementation, and confirmation. Rogers developed diffusion theory during the 1960s from investigations conducted in peasant communities in developing countries. The influence of diffusion theory on research has been immense with Rogers' book on diffusion theory republished several times amidst thousands of citations.

Diffusion theory is well established and widely used in information technology research [27]. Mustonen-Ollila and Lyytinen [27] asserted that diffusion of a technological innovation is often strongly influenced by several recurring factors although sometimes adoption fails to follow any discernible patterns. Vanclay and Lawrence [44] explained that rural extension was based traditionally on the diffusion model, yet the adoption of a technological innovation does not necessarily follow predetermined and ordered stages, while failure to adopt may actually have a sound basis. Nevertheless, Guerin and Guerin [15] found that the diffusion model was still applicable for rural extension in the Australian farming community although it needed to be "supplemented by participatory approaches" (p.566). Critics of diffusion theory contend that Rogers' view of technology adoption is misguided by being prescriptive, rational, and linear. In studies of adopter-centred technology adoption, Seligman [37] argued that adoption, being immensely complex, is often a highly politicised, unpredictable process driven by management support and reliant on user involvement. Moreover, Newell, Swan and Galliers [28] allege that the strength of diffusion theory is the diffusion of knowledge and ideas rather than the adoption of a technical artefact per se (p.253). Despite contradictory critiques, the authors of this paper decided that the innovation-decision model from diffusion theory provided a suitable lens for exploring the technical aspects of the adoption of *CottonLOGIC*, especially since the interpretive nature of the study would complement the deterministic character of diffusion theory.

The second theory, technologies-in-practice model by Orlikowski [30], was selected in order to elicit further subjective insights from the study. This model is based on the duality of structure from structuration theory, a social theory formulated by social theorist Giddens [12]. The duality of structure refers to the shaping of the institutional structures of social systems as the result of reciprocal and repetitious interactions by human agents, which in turn reshape human actions. The mutual dependence of human actions and social structures is implied.

Technology has received little attention in structuration theory, yet the impact of technology on modern society has led to the formulation of theories to enhance our understanding of technology in social research [29,30]. In her 1992 paper, Orlikowski [29] developed the structurational model of technology as an extension of Giddens' duality of structure [12] to reconceptualise the nature and role of technology in organisations and for analysing the interpretive flexibility of technology where technology is both a product and a medium of human action. Drawing on the structurational model of technology, Orlikowski [29] and Orlikowski and Robey [32] constructed a conceptual framework to illustrate the recursive nature of technology *design* and *use*. In this paper, the focus is on the *use* mode of the technology *CottonLOGIC*. According to Orlikowski [29], in the *use* mode:

> *Human agents appropriate technology by assigning shared meanings to it, which influence their appropriation of the interpretive schemes (rules which reflect knowledge of the work being automated), facilities (resources to accomplish that work), and norms (rules that define the organisationally sanctioned way of executing that work) designed into the technology, thus allowing those elements to influence their task execution* (p.410).

In her 1992 study, Orlikowski [29] claimed that technology is stable and not subject to the whims of users to change it. This comes about because, once the technology is developed and deployed, Orlikowski asserted that it loses connection with the human actors who constructed it. Hence, the link through technology between institution and human agent is lost. In a subsequent paper in 2000, Orlikowski [30] expanded her 1992 structurational model of technology as the technologies-in-practice model to address this conundrum. With the rapidly changing form and function of technology, it is inevitable that the earlier model by Orlikowski [29] would need to be revised. Orlikowski [30] admitted, "assumptions of technological stability, completeness and predictability … are inappropriate in the context of the dynamically reconfigurable, user-programmable, and highly inter-networked technologies being developed and used today" (p.406). According to Orlikowski [30], this comes about because people "draw on their skills, power, knowledge, assumptions, and expectations about the technology and its use, influenced typically by training, communication and previous experiences" (p.410). In her article in 2000, Orlikowski [30] focused on the "emergent rather than embodied structures" of technology as technologies-in-practice, that is, 'in use', to be distinguished from technology as a technological artefact.

Orlikowski's theory [30] regarding the practice perspective was extended in studies of an online health insurance company by Schultze and Orlikowski [36] who found that technical features were appropriated by end-users for both intended and unintended purposes (p.87). Boudreau and Robey [5], in their study of the implementation of an ERP (enterprise resource planning) system in a large government institution from a human agency perspective, found that improvised learning by end-users occurred when technology was in use, which they described as working "around system constraints in unintended ways (reinvention)" (p.3). In brief, social transformations are enacted in use rather than being features of the technology.

Both the innovation-decision model and the technologies-in-practice model have had limited, if any, application in qualitative empirical studies in the DSS domain. In their critical review of DSS research, Arnott and Pervan [2,3] claimed that many DSS papers fail to reference decision-making theory or else cite "relatively old theoretical foundations" (p.667). Consequently, there is a need to broaden the theoretical foundations of DSS studies to make DSS research more rigorous. Furthermore, there is an abundance of DSS studies of a technical nature but a dearth of in-depth sociological studies of DSS adoption and use [2,3,7,33]. Therefore, a theoretical contribution of the study is the novel application of the innovation-decision and technologies-in-practice theories, either singly or in combination, as an analytical lens in a qualitative case study.

5. Analysis and discussion of the implementation of *CottonLOGIC*

In this section, the interview transcripts of *CottonLOGIC* implementation (specifically adoption and use) are analysed within the theoretical concepts of the framework. Extracts of quotations from interviewees are provided as evidence. The remarks of study participants provide a rich and informative qualitative account of participants' experiences regarding the adoption and use of *CottonLOGIC* as a technological artefact. The data analysis section has been broken into two sub-sections (5.1 and 5.2), each informed by a theory from the conceptual framework. The first sub-section (5.1) uses the innovation-decision process from the diffusion of innovations theory by Rogers [35] and explores the adoption stages of *CottonLOGIC*. The second sub-section (5.2) investigates the interaction of users with *CottonLOGIC* through the technologies-in-practice model by Orlikowski [30]. The findings are explained at the end of each sub-section and interpreted in the conclusion.

5.1 Adoption: the innovation-decision process

As explained earlier, the stages of the innovation-decision process conceptualised by Rogers [35] are knowledge of the innovation, persuasion to adopt, decision, implementation, and confirmation. Aggregated data of the *CottonLOGIC* adoption stage attained by each participant, as interpreted by the researcher from the interview data, are displayed in Table 1 below. Column one illustrates each stage of the innovation-decision process in sequence. Column two lists the pseudonym of each participant against the final stage of adoption they have achieved based on self-reporting. Column three indicates the gender of participants in that stage of adoption. Column four identifies the participants as cotton growers or professionals. Column five classifies the participants as *CottonLOGIC* users or non-users. Finally, column six specifies in which field study the participants took part.

INSERT TABLE 1 HERE

Decision stage

The first two stages in Table 1, knowledge and persuasion, are represented by only two participants and are disregarded in this analysis. Stages 3 (decision), 4 (implementation), and 5 (confirmation) of the innovation-decision process framework remain to be discussed below. According to Rogers [35], *decision* occurs when an "individual (or decision-making unit) engages in activities that lead to a choice to adopt or reject the innovation" (p.171). Seven participants had reached this stage: two of the growers had evaluated *CottonLOGIC* and its implementation was under consideration, while five growers had rejected it outright. Participants who had actually implemented the software were not considered at this stage since they had progressed to a later category in the innovation-decision process such as implementation or confirmation.

Two growers, Nicole and Julia, had decided to use *CottonLOGIC* but had not managed to implement it yet. For prospective users with lesser agronomic and computer skills, *CottonLOGIC* offered a challenge as they attempted to implement the program without adequate support. Julia explained the reason for her delayed progress.

> Julia (grower): *I started setting it up and I found it hard to be able to use it properly, to have each field listed with the correct acres, and everything to each field.*

As stated above, five growers declined to use *CottonLOGIC*. Below are typical comments justifying their rejection of the software.

Rachel (grower): *The thing is that Tim [farm partner] has so much accumulated knowledge and we have the agronomist here three days a week.*

Meg (grower): *The thing I found with CottonLOGIC is a bigger knowledge of agronomy than I had. To input the information, like the [insect pest heliothis] egg lays and the number of eggs ….*

Elle (grower): *The bug-checking information comes from the consultant. They give us more information about when things are watered etc. That probably alleviates the need for a CottonLOGIC. I guess like a lot of farmers, my husband's not very good with bookwork. Now he sees that [office work] as not productive time. They [male farm partners] have trouble and have to see it as 1. worthwhile and 2. productive.*

These statements represent several recurring themes influencing the decision not to implement *CottonLOGIC*. Firstly, the agronomist or consultant or crop scout (bug-checker) was already either using the software or recording the insect (or bug) count and crop spray data in some manner. This gave growers little incentive to use *CottonLOGIC* themselves since it would have been an unjustifiable duplication of time and effort. Secondly, the software was considered superfluous since male farm partners had accumulated knowledge and experience of cotton production. Thirdly, office work was perceived by male farm partners as unproductive compared with time spent outside in the fields. This meant that the men were often reluctant to cooperate with the women in collating, entering, and analysing the data from *CottonLOGIC*. Fourthly, this attitude was compounded by the fact that the women were not confident of their agronomic knowledge and hesitated to use the software without the support of their male farm partners.

Implementation stage

Eight participants had attained the implementation stage of the adoption process. *Implementation* [35] occurs when an "individual (or other decision-making unit) puts an innovation into use" (p.174). However, rather than use *CottonLOGIC* in its entirety, they had all imposed some degree of *re-invention* [35], thereby modifying their usage of the software to meet their own particular conditions. The concept of *re-invention*, defined by Rogers [35] as "the degree to which an innovation is changed or modified by a user in the process of its adoption and implementation" is an extension of the notion of implementation. Rogers [35] insists that, in general, designers of innovations regard re-invention as an undesirable quality since they lose quality control, while adopters view re-invention or adaptation in a more favourable and resourceful light. One reason for re-invention being attainable was due to *CottonLOGIC*'s design into modules for record-keeping and decision support, the latter facilitating the forecasting of insect (bug, pest) densities.

Toni, a grower, wanted to be able to compare the costs of conventional and transgenic cotton varieties such as Ingard® and Bollgard II® in each paddock. Having well-organised data recorded in standardised electronic format was more effective than paper-based data placed on various slips of paper from consultants, bug checkers, and spray operators.

> Toni (grower): *So that when we come to the end of the season, we can print up what sprays that paddock has had, how much it costs. Because with Ingard, we have to have costings of all the sprays we used. You have to compare it with conventional costs. We have Bollgard too this year. … that data is important because it saves reefing through all the agronomy sheets, there's about a hundred of them.*

The remarks below by Jodie, a cotton grower, were typical of statements by the interviewees.

> Jodie (grower): *I use CottonLOGIC for [recording] farming operations [fertilisers, sprays, cultivation]. I enter bug-checking data but do not check thresholds [of pest densities using decision support modules]. That is done by the agronomist.*

These statements attest to the value of the record-keeping functions of *CottonLOGIC*. By record-keeping, although definitions varied, the interviewees generally meant that they entered data related to farming operations such as fertilisers and seeds, as well as herbicide, pesticide, and insecticide applications. It was emphasised by several interviewees, mostly growers, that *CottonLOGIC* was not utilised for decision making. The interviewees were implying that, although they entered the insect counts into the records, they did not use the decision support modules. That is, *CottonLOGIC*'s heliothis pest thresholds models in the decision support modules were not engaged as a spraying guide to critically assess and determine spraying regimes.

Confirmation stage

The category with the most number of participants was confirmation. *Confirmation* [35] occurs when an "individual (or decision-making unit) seeks reinforcement of the innovation-decision already made, or reverses a previous decision to adopt or reject the innovation if exposed to conflicting messages about the innovation" (p.181). Eleven participants (four growers and seven professionals) had implemented *CottonLOGIC* and then had sought to confirm its use. The confirmation stage for *CottonLOGIC* usage appeared to have three distinct outcomes: 1) continue use without further modifications; 2) continue use but with some more re-invention; and 3) discontinue use entirely.

Confirm use with no re-invention

For the first outcome, five participants had re-evaluated their use of the software. Being satisfied, they had elected to continue usage without any further adaptations. All these participants in this category were very well versed with the agronomic side of cotton production and their computer literacy skills were excellent. *CottonLOGIC* was viewed by these participants as an established farm management tool, adaptable, relevant, and easy to use. All the same, it was more likely to be used for record-keeping and rarely as the basis of spray decisions. Uma, a grower, who had trained as an agronomist before starting a family, explained how she and her farm partner, Jason, used *CottonLOGIC*. They were continuing to use the record-keeping features of *CottonLOGIC* not the simulated pest pressure thresholds as a basis for insecticide spray decisions.

> Uma (grower / professional): *A day or two later or maybe a week later, Jason [farm partner] or myself will enter it [farming operation] into CottonLOGIC so it is there for us…put all the numbers into the insect management data system of it. …What we use it mostly for, we also put in what the sprays are, when they were applied, what the weather conditions were at the time, what the cost was of the chemical we have used. … At the end of the season, we might map out all the graphs of where the insect numbers have gone. And what we sprayed when and think maybe it would have been better if we'd used the chemical here because …. We don't really use it as a decision-making tool but more just for data storage.*

Reese, a cotton consultant with agronomic knowledge and computer skills, was looking to consolidate and extend her knowledge. For those reasons, she benefited from the *CottonLOGIC* training courses.

> Reese (professional): *Yes, I got a lot out of it [CottonLOGIC course]. Because I basically taught myself how to use it, like just going in and mucking around and figuring out what different types were. I really got a lot out of the workshops and just mainly seeing how things worked.*

Steve, a grower, claimed to use all aspects of *CottonLOGIC*.

> Steve (grower): *I don't use CottonLOGIC just to look at heliothis. I get them (bugs, beneficial insects) on the check-sheets from the consultant and transfer them into the system.*

The introduction of genetically modified cotton such as Bollgard® to reduce the heliothis menace and thus limit environmentally damaging pesticide spraying routines using endosulfan and others, had altered the pest dynamics to such an extent that some growers had adopted a wait-and-see approach. They were unsure what the next pestilence would be. This shift had little influence on how Steve used *CottonLOGIC* since he used it for more purposes than predicting heliothis density. In brief, many growers and consultants expected to base their spraying decisions on heuristics and instincts rather than structured programmed advice.

Confirm use with re-invention

Russell, an on-farm agronomist, was the sole representor of this category. He had reached the crossroads with *CottonLOGIC* and was seriously re-evaluating his options. His main concern was that the pest pressure forecasting models were developed predominantly for heliothis caterpillars and were unproven for other pests. Therefore, Russell expected to modify his use of *CottonLOGIC*.

> Russell (professional): *CottonLOGIC I have used. Historically I've used it for record-keeping and for insect checks and to check decisions. Presently I'm using it for insect checking and for insect decisions and probably in the future…don't know what I'll use it for…. Possibly not basing decisions on what CottonLOGIC says. At the moment, they don't have anything in CottonLOGIC to handle Bollgard® situations.*

In essence, the introduction of genetically modified cotton such as Bollgard® meant that *CottonLOGIC*'s models were now less relevant for Russell. Consequently, he displayed considerably less loyalty and enthusiasm than the previous group.

Discontinue use

Five women participants (two growers and three professionals) represented the third outcome of the confirmation stage. Each interviewee had opted to discontinue use of *CottonLOGIC*. Although the grounds for rejection varied, the following interview by Kirsten indicated that the cotton professionals had specific issues with the functionality of *CottonLOGIC*.

> Kirsten (professional): *CottonLOGIC currently has crashed computer – five year old PC – not enough memory to open files.*

Helena, a grower, complained that her agronomist was using *CottonLOGIC* and therefore she did not want to duplicate his effort. Hence, *CottonLOGIC* was no longer useful. Conversely, Selma, also a grower, complained that *CottonLOGIC* was no longer relevant since her agronomist was not using it and she had intended to collaborate with her agronomist.

Selma (grower): *I used to play with some reports [from CottonLOGIC] to work out what the thresholds were and maybe if we let it [spraying] go. My agronomist wasn't using it so it [CottonLOGIC] so it didn't seem relevant.*

These participants were knowledgeable about cotton production and computer literate, having achieved a high level of *CottonLOGIC* adoption.

Findings from the innovation-decision process

Evidence from the sample of 32 participants displayed in Table 1 indicated that 50% of interviewees claimed to be *CottonLOGIC* users while 50% had rejected the software at some stage. This confirmed the findings of a quantitative survey in Australia in the 2001/2002 season which found that *CottonLOGIC* was being used across 51% of the total area of cotton grown in Australia during the 2001/2002 season [10].

The aggregated data in Table 1 indicated that, even though slightly more growers than professionals were interviewed (seventeen versus fifteen), it was predominantly the growers who rejected *CottonLOGIC* in the early stages and it was predominantly the professionals who confirmed its use in the later stages of adoption. Qualitative evidence from the interviews suggested that *CottonLOGIC* was being rejected for reasons not necessarily anticipated by its builders. As discerned by Mustonen-Ollila and Lyytinen [27], several factors regarding adoption were recurring. While some problems were of a technical nature such as *CottonLOGIC*'s incompatibility with old hardware, the majority of factors were derived from less technical sources. They included the predicament for several women in obtaining input data from their farm partners, and the hesitancy of the women to use the agricultural software without guidance. Also identified was the reluctance of some male growers to spend time in the farm office and their reliance on accumulated 'real-world' knowledge and intuition for making heuristic decisions. Many of these issues were of a social origin rather than associated with technology alone. It is worth commenting that while gender was significant for the study, it is not emphasised in this paper due to the constraints of space. Topics from the study related to gender relations and gender differences are being written up for forthcoming papers.

Ostensibly, Roger's innovation-decision model characterised the adoption process of *CottonLOGIC*, such that adoption occurred in a deterministic and systematic manner. The first stage in Roger's innovation–decision process, *Persuasion*, was indicative of an unengaged, less mature relationship with the software and was poorly represented in the study. The most advanced stage of *Confirmation* suggested commitment and a more sophisticated knowledge. The participants in that category displayed efficacy with both computer technology as well as agronomy. In the main, these participants had achieved a high level of DSS success through a combination of user-related factors such as *CottonLOGIC* training and agronomy experience, thereby validating the findings of Alavi and Joachimsthaler [1] that user-situational variables such as involvement, training and experience were significant factors in DSS implementation success.

An intriguing stage of adoption was *Implementation* where, by *re-invention*, end-users improvised in both intended and unintended ways. This confirmed the findings of Mustonen-Ollila and Lyytinen [27] that for many innovations, there are no discernible adoption patterns.

The study revealed some confusion in the meaning of 'record keeping' and 'decision support'. Nevertheless, the evidence suggests that both growers and professionals utilised the record-keeping modules of *CottonLOGIC* for historical purposes thus enabling informed seasonal comparisons of the location and density of heliothis eggs and caterpillars (grubs) as well as beneficial insects. This application of *CottonLOGIC* confirmed the findings of Kuhlmann and Brodersen that farmers are more inclined to employ DSS retrospectively than for farm planning [19]. The findings also revealed that participants reported not using *CottonLOGIC*'s simulated models of pest pressure thresholds as the direct basis for insecticide spray decisions, especially with its outdated heliothis models.

5.2 Use: the technologies-in-practice model

While the previous section focussed on the adoption process of a technological artefact, this section has a less formal, more personal approach where *CottonLOGIC* 'in use' is investigated from a practice perspective using the technologies-in-practice model by Orlikowski [30] as the analytical lens. One of the findings from the previous section was that *reinvention* of the technology by end-users is a major factor in overcoming some of the constraints of the technology. The following transcripts confirm this as well as emerging end-user issues.

The following statements from consultants, Lucy and Reese, are simple examples where *CottonLOGIC* is customised in use to suit individual requirements. While Lucy entered data such as insect counts for grower clients when she had the time, Reese preferred to enter data at regular intervals.

> Lucy (professional): *With the way I use CottonLOGIC, I don't actually enter the information every day. I'll do it when I've got the time to put it in.*

> Reese (professional): *I think it's less tedious if you do it along the way rather in one big hit at the end of the season.*

Some suggestions for use were quite original. Reese had given some thought as to how she could adapt the use of *CottonLOGIC* so that more complete spray records could be kept for her clients, the cotton growers. Reese explained that, in the spray order form, she can record what is recommended to the grower such as which crops are due to be sprayed on a certain date, while in the spray application form, she can record which crops were actually sprayed, the chemical used, the cost, the quantity, and the method of spraying (aerial or ground). In this way, Reese could maintain more complete client records.

> Reese (professional): *There is a way we can use it [CottonLOGIC] to track what we recommend and what the grower actually applies… It's different, what we recommend and what they actually apply. It's for better record-keeping.*

Julia, a grower, was pleased to find that *CottonLOGIC* was not cotton-specific and that grain as well as cotton data could be recorded. This was indicative of several users who were initially unaware that *CottonLOGIC*'s record-keeping functions could be modified to diversify its usefulness.

> Julia (grower): *I just looked at CottonLOGIC. It's designed for cotton. You could put grain things in there.*

The analysis disclosed that attitudes to *CottonLOGIC* were shifting. Van Beek [41,42,43] in his assessments of *CottonLOGIC* had found that many growers valued highly the science embedded within *CottonLOGIC* while others trusted *CottonLOGIC* as a tool for learning about pest management, resource management, and other aspects of responsible crop management. However, now some doubts had surfaced. Russell, an on-farm agronomist for a large cotton company, had been using *CottonLOGIC* intensively and with confidence. He now considered its heliothis simulation models less relevant and reliable since the advent of genetically modified cotton seed varieties such as Bollgard® with its built-in resistance to the heliothis menace. Russell had depended on the integrated pest management (IPM) principles embodied within *CottonLOGIC*. Now he expressed uncertainty.

> Russell (professional): *We've practised IPM on conventional country. How does that relate to Bollgard® now? We'll have to learn IPM all over again with probably a little less record-keeping*

This was confirmed by Ben who insisted that accuracy, both in record-keeping and in modelling, was essential to achieve industry credibility.

> Ben (professional): *One of the key factors in IPM is accuracy of information. Without information, growers can't make perfect decisions.*

Growers are busy people and keen to avoid unnecessary actions. In the main, growers resisted re-keying insect data into *CottonLOGIC* when it had already been entered by advisors such as consultants or agronomists or bug checkers. Renee, a technically competent grower, devised a simple solution for how *CottonLOGIC* could be optimised. She clearly felt that collaboration between cotton growers and advisors was essential to avoid the replication of tasks.

> *Renee (grower): I'd be really interested in using it [CottonLOGIC] if I didn't have to put all the bug information in. To be able to import it into CottonLOGIC would be great. If they [consultants or agronomists] could send me their information each month and put it in.*

Steve was typical of the tech-savvy growers who sought some way of integrating into one package the various farm tasks such as soil and yield monitoring by global positioning systems (GPS), field mapping by geographic information systems (GIS), and insect pressure simulation by DSS. He predicted that the Web might be the architecture to accomplish a convergence of functions.

> *Steve (grower): I think that the Internet structure should be the structure we should be revolving around to make it widely more accessible … if we can find a system that ties all this research [GPS, GIS, DSS] together ….*

In brief, once *CottonLOGIC* was deployed, users identified its constraints, devised ways to overcome its limitations, and to build on its strengths.

Findings from the technologies-in-practice model

Agricultural software such as *CottonLOGIC*, when initially constructed, reflected the development team's view of the world, as, for example, in the integrated pest management (IPM) properties it embodied. After analysing the interview data, it was apparent that end-users of *CottonLOGIC* constantly modified their engagement with the software for farm management purposes, with skills acquired through use and training. Study participants who continued to use *CottonLOGIC* were adaptable and practical as they efficiently moulded the software to their farming objectives, in ways unforeseen by the software designers and developers. Furthermore, *CottonLOGIC* was used, often unintentionally, as an instrument for end-users to learn about resource management and sustainability through IPM. The emphasis on information accuracy, especially for IPM, demonstrated the importance of knowledge transference above artefact adoption, as argued by Newell et al [28].

Growers and professionals, alike, were aware of the complexity of the problems facing the industry and were mindful of industry endorsed schemes such as IPM embedded in the software. Many users criticised *CottonLOGIC's* heliothis models, claiming they were no longer relevant nor accurate in the altered industry pest management setting. End-users' expectations resulted in proposals for technological enhancements such as Web-enabled, multi-functional, and integrated farm management software with global positioning systems (GPS) and geographic information systems (GIS) which they considered to be synonymous with their revised farming objectives. Consequently, through recurrent use, the software has been enacted to better reflect users' requirements as technologies-in-practice. The findings suggest that technology (and the institution of farm management) are constructed and reconstructed by users, and that users are resourceful as they attempt to overcome technological constraints and adapt the technology to their changing needs. Consequently, the association between users and technology is dynamic not static.

The interplay between software and users is represented in Table 2 which is an adaptation of the Orlikowski [29] and Orlikowski and Robey [32] conceptual framework, based on structuration theory, for analysing technology (*CottonLOGIC*) use, mutually constituted human action (cotton growers and professionals) and institutional structures (farm management). A limitation of this model is that the table is a matrix and does not wholly represent the recursive, iterative, and ongoing nature of human agent-social institution interactions in the context of the agricultural DSS *CottonLOGIC*.

INSERT TABLE 2 HERE

6. Conclusion

The socio-technical approach of the paper has lent an alternative, more human perspective to the study of farm management using a technological artefact when, as McCown [23] asserted, nearly all DSS research in agriculture examines technological tools with little concern for the practicalities of decision support for farm management (p.20). Responses to the three research questions are given below.

Question 1. *Does Rogers' innovation-decision model with its technical focus adequately represent the stages in the adoption of CottonLOGIC*? The study found that *CottonLOGIC* was adopted by users in a relatively orderly and rational manner indicative of Roger's innovation-decision phases. However, on closer inspection made possible though interpretive readings of the interview transcripts, it was evident that human endeavours were of major consequence. The end-users of *CottonLOGIC* were adaptive and resourceful as they modified the technology, through re-invention, to their changing needs, often in ways unanticipated by the software development team. All the same, the attributes of the technology such as the design of *CottonLOGIC* into record-keeping and decision support modules contributed to adoption success. These findings confirmed those of Schultze and Orlikowski [36] and Boudreau and Robey [5] that the outcome of technology in practice was facilitated by both human agency and technological attributes with intended and unintended consequences. Furthermore, the participants who achieved a high level of adoption success were supported by a combination of user-related factors such as *CottonLOGIC* training and agronomy experience, thus reinforcing the findings of Alavi and Joachimsthaler [1].

Question 2. *How does Orlikowski's technologies-in-practice model explain the use of CottonLOGIC*? Orlikowski's technologies-in-practice model enabled an in-depth, more personal exploration of re-invention and other aspects of *CottonLOGIC* 'in use'. It was evident from the study that Orlikowski's technologies-in-practice model represented *CottonLOGIC* usage whereby the technology (and the institution of farm management) were dynamically constructed and reconstructed by users, just as the technology was shaping and reshaping the lives of users, thus reflecting the core principle of structuration theory that social life is recursive [12].

Question 3. *Does the use of CottonLOGIC influence farming practice and challenge end-users*? The integrated pest management (IPM) principles embedded within *CottonLOGIC* as an agricultural DSS have provided an industry benchmark for sustainable farming and resources managment. Growers and professionals alike were confused and disappointed with the advent of genetically modified cotton, meaning that the older reliable heliothis models applicable to conventional cotton seed are becoming obsolete. An additional benefit of DSS is the knowledge transfer factor [28,33] especially for the purposes of diffusing information on farm management and resource sustainability [15,44]. It was apparent that the environmental lessons learnt through the principles which *CottonLOGIC* embodies have flowed through to the cotton community [16]. As stated earlier, the use of *CottonLOGIC* is voluntary. Parker and Sinclair [33] noted that it is likely that DSS would have a greater uptake and impact if use was made mandatary by environmental legislation. All these issues are of paramount interest to DSS stakeholders, especially designers and developers, since user influence is aligned with implementation success [21,33].

The contributions of this case study were identified as ontological, methodological, theoretical and practical. The study was predominantly ontological with evidence from the study presented as rich insights. As explained by Walsham [45], rich insights are a category of generalisation and are the capturing of "insights from the reading of reports and results from case studies that are not easily categorised as concepts, theories or specific implications" (p.80). In a case study, generalisability is unavoidable since the findings of the case may be generalised to what can happen in the future and in other situations [46]. The insights into the adoption and use of *CottonLOGIC* acquired from this study can be synthesised with the existing body of knowledge of DSS, especially for agriculture.

The methodological significance of the study stemmed from it qualitative and interpretive nature since there is a paucity of qualitative DSS case studies [2,3,21]. Furthermore, the quality of DSS research is improved through a case study which has relevance to extant practice [2,3], particularly of the rural sector which suffers from a surfeit of surveys from the positivist paradigm [15].

The theoretical framework which informed the study is believed to be novel for agricultural DSS research with both innovation-decision and technologies-in-practice models having sociological origins [3 (p.666)]. This paper has taken a socio-technical approach. That is, technology adoption was examined through the objective perspective of the innovation-decision model from Rogers' diffusion of innovations theory [35] while more subjective insights emerged by applying Orlikowski's technologies-in-practice model [30] to *CottonLOGIC* 'in use'.

According to Arnott and Pervan [2,3], academic rigour in DSS research would improve by widening the reference theory base. As stated earlier, decision-making theory by Simon [38] with its systematic model of 'intelligence-design-choice' has dominated DSS theory and practice [2,3]. Moreover, Parker and Sinclair [33] claimed that the Simon's model is actually an "obstacle" (p.450). Courtney [7] proposed the use of an alternative decision-making paradigm in DSS research that is less technical and analytical, and incorporates social and individual views (p.30). Critics advocate a less orderly and more user-friendly theoretical foundation for the next generation of DSS tools. This study proposes alternative reference theories for DSS research from the sociological research domain.

The implications of the study for practitioners are both narrow and broad-based. Firstly, on a broader scale, since the Australian cotton industry is currently reviewing its investment in computer-based decision support [11], the findings of this study, while not exhaustive, offer some non-prescriptive guidelines for the future design, development, delivery, and continued use of agricultural

DSS. The findings suggest that *CottonLOGIC*, if re-developed, should concentrate on record-keeping for compliance with best management practices (BMP) including integrated pest management (IPM).

Secondly, and more specifically, the attainment of greater skills in the use of agricultural DSS may be a key to improving the self-confidence of cotton growers as decision makers, and that involving informed cotton growers in industry decision making may help in finding farming solutions outside those in existing practice.

Some limitations of the study are tendered as follows. Firstly, the innate gender issues in the study have been suppressed for lack of space but several research papers on gender are underway. Secondly, Patton [34] referred to issues associated with temporal sampling. The study took place over a three year period during which time, participant attitudes to *CottonLOGIC* evolved from optimism to a more realistic and critical outlook, as expected with the short life span of software. It is thought that the rigour of the research was enhanced with an opportunity to address inherent prejudices and design flaws using a longitudinal qualitative study. Finally, the cotton industry in Australia, along with agronomy tools and technologies, is changing rapidly and dramatically, thus justifying further research [39].

Overall, the study found that innovative practices and sustainable solutions are an imperative in cotton farm management for generating improved production and responsible environmental outcomes. Despite being somewhat outmoded, *CottonLOGIC* in the hands of inventive and capable end-users is still an industry benchmark for supporting IPM principles.

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Appendix A: Glossary of Acronyms and Definitions

The glossary is offered as a point of reference for some terms used in the paper. Some terms have references cited, however when references were not readily available from cotton industry resources, they were sourced from the free online encyclopaedia, wikipedia http://en.wikipedia.org/wiki/ downloaded 2008.

BMP: Best management practices is a recognised voluntary environmental program that requires specific standards of cotton growing. BMP includes integrated pest management.

Bollgard® and Ingard®: Cotton genetically modified by Monsanto to produce a natural pesticide to control the heliothis pest which is a scourge of conventional cotton. Also termed transgenic cotton.

Decision: A decision is a specific commitment to action while a decision process is a set of actions [25]. Types of decisions on farms are strategic or long term (capital purchases, property development), tactical or medium range (selecting crops, cattle options), and operational or short term (spray decisions, cattle mustering).

End-user: The descriptions user-centred, adopter-centred and user-situational are applied almost interchangeably in this paper as are the terms user, client, stakeholder and human agent. The terms reflect their sources.

GIS: A geographic information system is a computer system capable of integrating, storing, editing, analysing, and displaying geographically-referenced information.

GPS: A global positioning system is technology that uses the position of satellites to determine locations on earth.

Heliothis: Moth caterpillars that destroy cotton bolls. Also called boll worm or helicoverpa.

Implementation: The term is used in this paper to refer to both technology adoption and use as distinct from design and development. Implementation in this sense is less specific than the implementation stage of adoption in the innovation-decision model as classified by Rogers [35]

IPM: Integrated pest management is a sustainable resource management practice to reduce the amount of insecticide used on a crop while maintaining profitability, yield, and fibre quality.

Wincott: The Women's Industry Network Cotton was formed in 2000 to provide support, information and resources to encourage and empower women in the Australian cotton industry to have skills, confidence and an informed voice.